出國報告（出國類別：國際會議）

參加「第6屆智慧城市、系統、設備及技術國際會議」

服務機關：行政院環保署
姓名職稱：黃俊銘科長、陳信德分析師
派赴國家：義大利威尼斯
出國期間：106年6月24日~7月1日
報告日期：106年9月20日

摘　要

赴義大利威尼斯參加第6屆智慧城市、系統、設備及技術國際研討會，由IARIA 協會所主辦，提供各地的人員分享科學技術應用的心得，達合作關係以推動創新與進步。

1.我方針對我國環境物聯網感測應用，結合地理資訊應用成果，進行口頭簡報，並與會上參與者討論(From Crowdsourcing to Crowdsharing : The Smart Environmental Sensing Web of EPA)，各國的智慧城市建設重視資訊技術於城市的環境、生態、交通、醫療、智慧建築等方面，其中為實現節能減碳，以永續發展為目標、推動低碳智慧城市，以達便民利民之目的。

2.會議中，展現各類數據的各種複雜網路系統的工程中，結合物聯網、網路、大數據和移動雲服務中使用最先進的技術和解決方案。觀摩城市環境改善案例，獲知雲端、網路及大數據先驅的應用。

目　　錄

參加「第6屆智慧城市、系統、設備及技術國際會議」

出國報告

壹、會議源起與目的

「第 6 屆智慧城市、系統、設備及技術國際會議」(簡稱 SMART 2017 國際研討會）由 IARIA（International Academy, Research, and Industry Association）協會所主辦，提供來自世界各地的研究人員及學者分享科學認知和技術應用的心得，瞭解環境數據的各種複雜網路系統的工程中，結合物聯網、大數據和移動雲服務中使用最先進的技術和解決方案。參與本案會議，觀摩城市環境改善案例，獲知雲端、網路及大數據先驅的應用。將以人機、網路、系統融合強大的智能界面，促進使用者智慧生活。

主要係供學術單位、研究機構及民間部門等不同領域人員進行討論，依系統、社會、人機及智能等方式，進行調查及收集大量資料，尋求最佳解決方法。我們將“人與人之間的互動、人機系統和系統與系統間連結”，融合為可能促進社會積極的智慧。這些研究課題需要不同科學和工業界之間的緊密合作。然而，跨多學科有不同的想法、概念、方法，產生的各項數據如何分析、理解、介接，就成為重要課題。

第 6 屆智慧城市、系統、設備及技術國際會議於 106 年 6 月 24 日至 7 月 1 日於義大利威尼斯 Novotel Venezia Mestre Castellana 飯店舉行，來自世界各地的研究人員及學者分享科學認知和技術應用的心得，交流彼此經驗知識，會議網址為 https://www.iaria.org/conferences2017/SMART17.html。

今年討論之議題主要在於智慧城市面向、環境中的物聯網、移動性監控和控制、智能家居與智慧城市使用案例分享、城市與生態結合及其它與交互技術有關之議題。

貳、 會議過程

以下按日分別紀錄現場聆聽、參觀之會議活動項目：

一、6 月 24 日：抵達

當地時間 19:40 抵達義大利威尼斯。

二、6 月 25 日：辦理報到手續及參加專題研究發表會

在威尼斯 Novotel Venezia Mestre Castellana 飯店參加 SMART 2017 國際研討會。辦理報到手續後，第一天議程內容略術如下：

(一)由美國佛羅里達大學 Ian Flood 教授為現行及新興技術的運用潛力進行說明，如何建置有效模型，搭配智慧研究，以增加終端產品的開發的成功率。

(二)由葡萄牙 AntónioLuis Jesus Teixeira 博士說明光纖網路運用，來解決資料蒐集問題，讓建立模組化模型之可行性提高，後期讓應用者經分析、設計、優化而將模組結合成為成品可行性增高。

二、6 月 26 日：參加專題研究發表會

(一) 我方針對我國環境物聯網感測應用，並結合地理資訊應用成果，進行口頭簡報，並與會上參與者討論(From Crowdsourcing to Crowdsharing : The Smart Environmental Sensing Web of EPA)、參與 Panel discussion (Panel on SMART/ MOBILITY/ SPWID-主題: Mobile Services in Smart Cities, 主持人為 prof. Berntzen, University College of Southeast Norway)。

(二) 羅馬尼亞以“Proof of Concept”方式發展微型感測，大量透過低成本的微型感測器裝設於車輛上達移動式監測，隨著車輛行經不同空間位置做環境監測，儲存時空數據以助後續分析環境時空演變及特徵，進行分析。

(三) 由 Gerson Damanik, Denny Hendraningrat 主講印度尼西亞公共安全寬帶通信網路的發展模式，說明在未來 5G 無線發展時，在考慮物聯網傳輸通道時，應同時考慮安全機制的發展。

(四)「蜂蜜複製-通用蜜罐系統的概念和原型」及「駭客攻擊手法」等議題，主要是針對訊息傳輸之安全考量所研究新技術及以駭客角度審視傳輸資訊的漏洞。

三、6 月 27 日：參加專題研究發表會

(一) 英國倫敦大學學院 Alex Galis 教授 5G 智慧網路，說明現行無線網路不利於 IOT 的資訊蒐集，不只資訊收集量少，還有無法即時性、安全性缺乏、還有雙向互動不良等問題等待突破，需要有更新通訊協定及技術就是 5G 無線網路。對 5G 無線網路的研究方向各有不同，但各研究單位有共通方向，就是朝向 5G 智慧網路發展，以解決上述問題，會議中解釋在 5G 架構下之可行式設計、規劃，及未來管理之設想。

(二) 挪威東南挪威大學學院 Lasse Berntzen 教授主講兩個議題，摘述如下：

1.從商業角度看智慧城市：

(1)智慧城市是一個概念，大多數定義是使用資訊技術，主要目標是提高公民的生活質量，提供更好的服務，減少環境污染，期望能永續發展。

(2)智慧城市探討是關於發生在這個城市的一切，其商業行為包括通訊、文化、能量、 緊急服務、環境與氣候、健康、安全防範、旅遊、運輸、工作等。

(3)有價值的商業應用需要了解的智慧城市的價值鏈，以新的組合創造新的價值和分配方式。

(4)有關智慧城市中，環境與生態為不可或缺議題，包括監測環境、執行污染限制、更好的公共交通解決方案（減少汽車使用）、智慧路燈、使用可再生能源（太陽能，地球，電動汽車）等。

2.智慧城市移動服務：

(1)智慧城市重在掌握資訊的速度，現在關鍵是有延遲通信情形，未

來 5G 通訊協定要有良好獨立通道，要安全保護，能獨立自主運作及管理，現行智慧城市移動服務的行政面瓶頸，在於基礎設施資訊不即時開放共享。

(2)智慧醫療不只在醫院，還涵蓋整個社會，配合行動裝置及通訊，讓民眾健康四處活動，穿戴上包含心跳帶、智慧手錶、智慧手環，隨時可提供警示及遠距救護。行動醫療要考慮大數據、物聯網、數據頻率及品質，但須考慮醫療資訊是屬個人隱私資訊，須注意相關資訊安全及法律問題。

(3) 奧地利維也納大學透過系統監控每位用戶飲水習慣、再結合用戶個人病史及健康資訊，透過智能飲水系統體系發展、蒐集各個用戶使用者基本與使用者資料，以大數據進行健康分析研究。

四、6 月 28 日：參加專題研究發表會

(一)由 ESTIA 公司 Jean Esterle 主講 ESTIA 公司在智慧介面的作為，講述 ESTIA 公司曾以 SOFC 型燃料電池和微型渦輪組合，在低環境下達到最佳的電氣性能，孤立農村微電網的影響；亦結合城市開發，維持生態環境條件下維護城市運作；會中展示精緻畜牧業在智慧介面的運用的實際成果：透過裝置監控牲畜生活行為，適時的飼育作為、繁殖期環境周邊調控等，此外，再搭配適當的商業模式及應用服務以提高其生產力帶動整體經濟。

ESTIA 公司不斷支持研究活動，希望給出了一個關於復雜的綜合社會，環境和經濟系統模型，接下來的幾年技術和研究人員研發提出的智慧介接工程概念性挑戰。後續面臨全球化的挑戰，將對氣候變化和能源革命的影響的改變經濟範式緊急情況。

(二)環境變化常有季節性差異，尤其空氣品質有更顯著的變化。都市區空氣污染以汽車等行動工具排放最大，實施減少道路汽機車上路，以減緩汽機車排放廢氣所造成的空氣污染；或可依據汽機車車牌號碼加以限制使用，管制通行時段、不同時段開放僅給予特定車牌號碼數字通行。

五、6 月 29 日：參加專題研究發表會與結束會議

(一) Lasse Berntzen 擔任「智能信息處理會議」主席，其中有「智能移動和文化旅遊」議題，以卡西利諾電子博物館(Ecomusem Casilino)的成功案例進行分享：通過使用鐵路羅馬裝置感應及接收器，在所經過的地區微服務器和傳感器等 IOT 裝置，分佈式支持在該地區移動用戶，結合 GIS 圖資與網路結合，這些地理標記和鏈接到移動文化信息系統，可以通知乘客和公民，各觀光景點、文化特色可展示出來，亦可統計民眾對那些觀光景有興趣，人潮多少，相關配套措施，如公廁、電信設施、交通運輸等調整與規劃。

(二) Jean Esterle 擔任「賦予工程智慧界接會議」主席，其中有「建立通向住戶促進企業行為的途徑設計激勵同步模型的經驗分享」議題，內容摘述如下：強調特別關注住戶和消費者，在用戶同意下，以住戶體驗（UX）設計包括探索消費者的真實個人動機，需求和表示，將住戶納入未來系統設計的所有階段，通過監控界面監控他們的環境演進，使用 UX 工具和方法將集成在結合社會資訊，以技術將用戶方面資訊的表現在系統視圖中。後續工作是需要利用大量用戶行為分析，可依據區域、環境、人文特性等進行不同策略(如獎勵、活動、宣傳等)，達成減少污染、節能、環境優化等目標。

(三) 由 ESTIA 公司主講「情緒管之智慧管理」議題，摘述如下：研究表明員工他們的情緒狀態會使生產力受到很大的影響的。負面情緒，如壓力，沮喪和焦慮與適得其反工作行為。自動情感識別可能是智能行業的重要要求以確保和維護員工的福祉。然而，情緒識別在現實條件仍然是一項艱鉅的任務，因為現有傳感器可以提取與情緒相關的生理信號通常需要侵入性技術，因此可能會干擾用戶的生產，所以智慧設備介面可以從 IoT 設備中提供非侵入性僱員的情感認知和可穿戴設備（例如：影像、麥克風、智能手機等）等資訊進分析員工特定情緒相關的信號。一旦消極情緒得到承認，增加情境以緩和情緒以保持健康的工作環境。

(四)會議於當地下午 5 時結束

六、6 月 30 日～7 月 1 日：搭飛機於下午 2 時 45 分回台灣。

參、心得與建議

（一） 本次主要目的為赴義大利威尼斯參加SMART 2017國際研討會，由IARIA（International Academy, Research, and Industry Association）協會所主辦，提供來自世界各地的研究人員及學者分享科學認知和技術應用的心得，交流彼此經驗知識，達合作關係以推動創新與進步。

1. 各國的智慧城市建設重視資訊技術於城市的環境、生態、交通、醫療、智慧建築等方面，其中為實現節能減碳的目標，以永續發展為目標、推動低碳智慧城市，以達便民利民之目的，同時透過蒐集市民的意見回饋以助政策實施、法令修正；如挪威已針對環境領域調查市民對於空氣品質感受初步統計，可參考網站http://oslo.citi-sense.eu/browsedata.aspx。

2. 羅馬尼亞於推動空氣品質監測，以“Proof of Concept”方式發展微型感測，大量透過低成本的微型感測器裝設於車輛上達移動式監測，隨著車輛行經不同空間位置做環境監測，儲存時空數據以助後續分析環境時空演變及特徵，還原環境實際樣貌。

3. 環境變化常有季節性差異，尤其空氣品質有更顯著的變化。法國巴黎和挪威卑爾根採取因應措施，如實施減少道路汽機車上路，以減緩汽機車排放廢氣所造成的空氣污染；如每年冬季期間，依據汽機車車牌號碼加以限制使用，管制通行時段、不同時段開放僅給予特定車牌號碼數字通行。

4. 近年於歐盟推動物聯網發展下，讓精準畜牧業得到重大的進展，透過嵌入電子裝置逐漸小型化、方便裝設至牲畜身上，並透過感測裝置收集所在地理位置資訊或是用於辨別物種使用等多種用途，例如透過裝置監控牲畜生活行為，可以給予合宜、適時的飼育作為如飼料分配、繁殖期環境周邊調控。此外，再搭配適當的商業模式及應用服務帶給農民嶄新服務，以提升畜牧業經營效益，提高其生產力帶動整體經濟。

5. 比利時根特大學指出偵測心率穿戴式裝置多樣化發展，目前市場上包含心跳帶、智慧手錶、智慧手環以及智慧手機相機等。然而，攜帶於手腕式裝

置受限僅能偵測針對手腕部分進行心率偵測，但手腕心率偵測已有一定精確度可參考；另智慧手機相機心率偵測則受限每一手機相機使用元件，所偵測心率精準度需靠依靠軟體個別、個體化執行校準作業才能得到較為精準心率數據。

6. 奧地利維也納大學發展飲水系統，透過系統監控每位用戶飲水習慣、再結合用戶個人病史及健康資訊，以依據個人情況或需求的不同給予適當提醒。再者，藉由透過智能飲水系統體系發展、蒐集各個用戶使用者基本與使用者資料，進行大數據分析研究，於醫學研究之健康管理領域將有極大貢獻。

7. 近來互聯網運用越來越廣，會議中有多項探討互聯網安全性，針對資訊傳輸通道及平台上加密的安全、公共安全寬帶通信網路的資安發展模式等議題探討，並引進新的駭客手法及防護機制進行研究。

（二） 建議事項：

1. 為利後續環境監測及物聯網推動，建議持續蒐集民間對我國環境品質的建議或看法，透過本署開放資料平臺、首長信箱、應用系統網站及APP等民眾回饋意見內容，持續了解民眾需求，以適時反饋於精進環境監測及物聯網智慧環境相關應用發展，達成「以民為本」之資訊應用發展目標。

2. 因應行動裝置設備及行動應用技術迅速發展，建議後續環境物聯網相關應用服務發展，可廣納環境感測資訊，結合民眾生活應用，以持續強化本署資訊服務之多元性。

3. 因應資通訊科技快速發展，建議持續參與相關智慧環境應用、空間資訊發展國際會議，以期了解相關技術及發展趨勢，並參酌各國相關研究及應用經驗及案例，作為本署未來導入資訊發展參考及借鏡。

肆、活動照片

圖 1 於 Novotel Venezia Mestre Castellana 飯店辦理報到手續

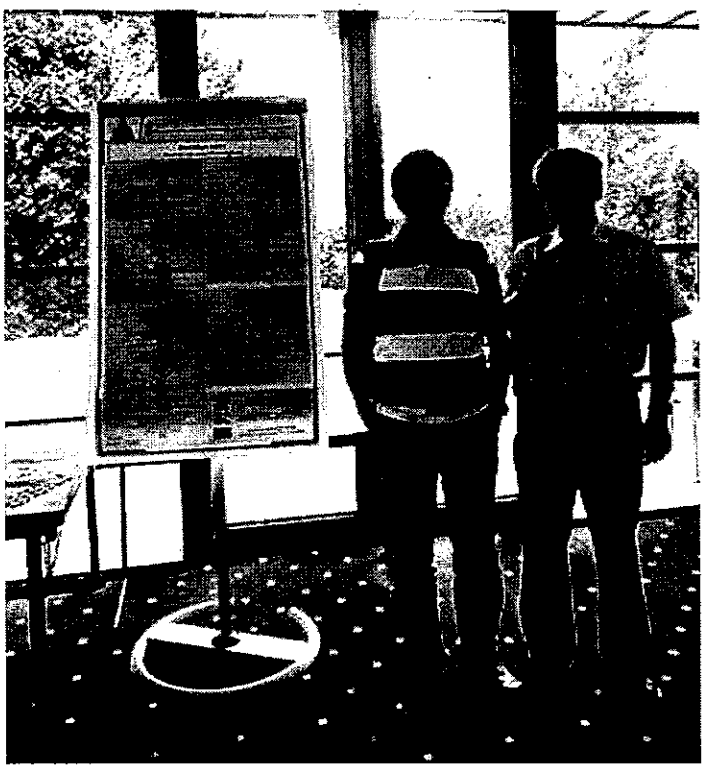

圖 2 與會議休息區合影

圖 3　我方進行口頭簡報 (From Crowdsourcing to　Crowdsharing : The Smart Environmental Sensing Web of EPA)

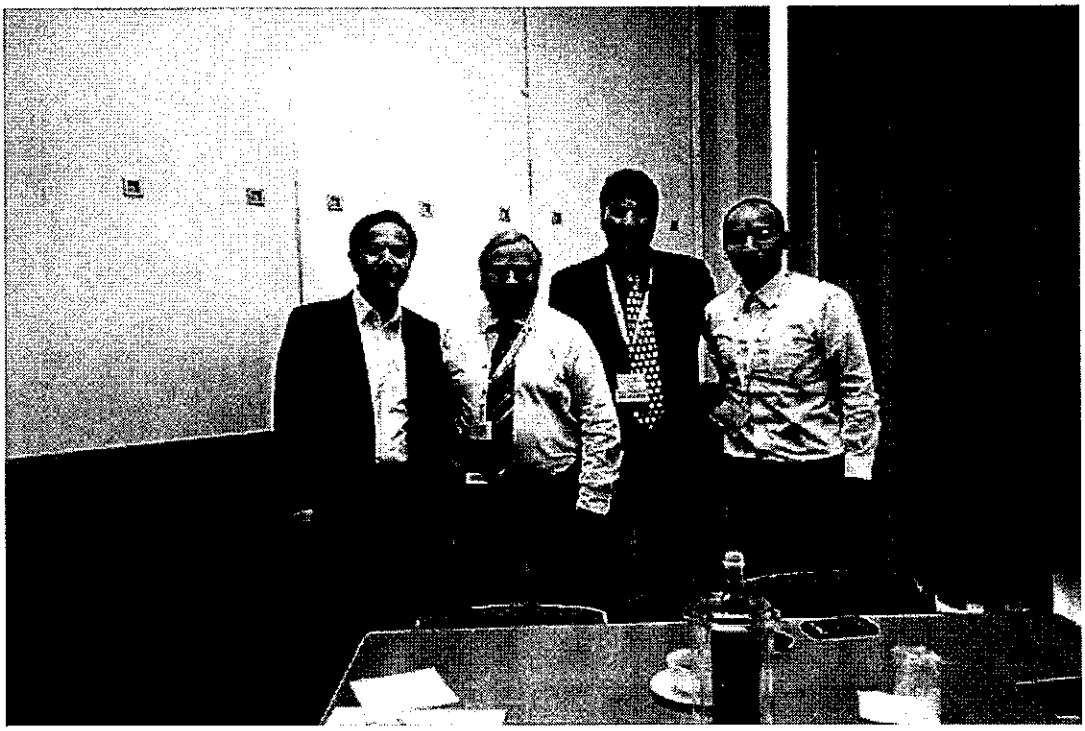

圖 4　與挪威挪威東南大學 Lasse Bermtzen 教授及羅馬尼亞錫比烏大學 Adrian Florea 教授合影

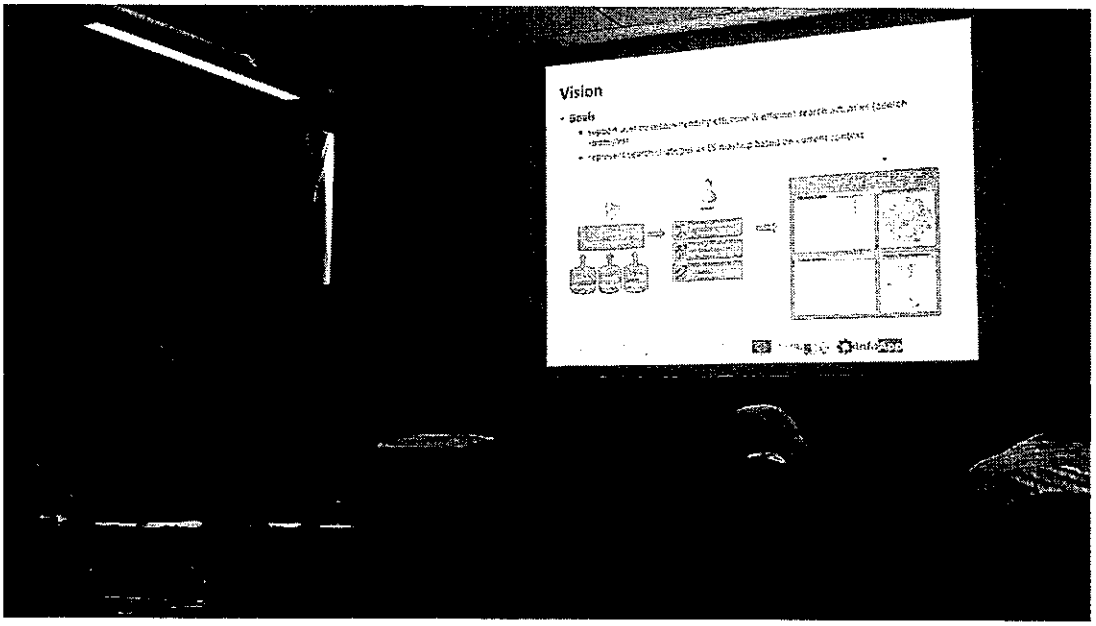

圖 5、物聯網與數據搜尋及分析

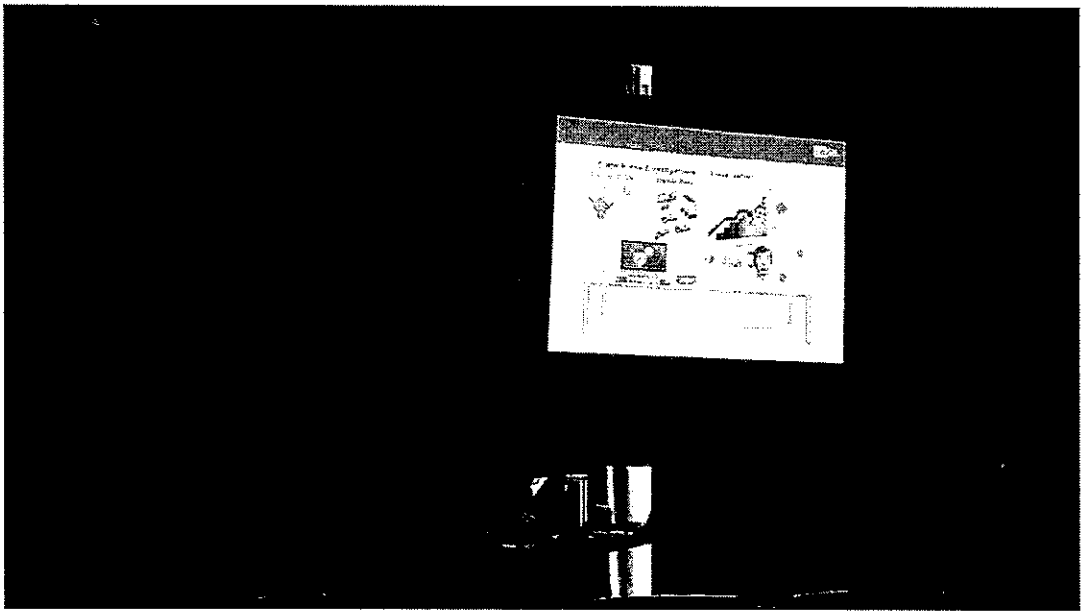

圖 6、大數據分析應用在社會網路犯罪之資料探勘

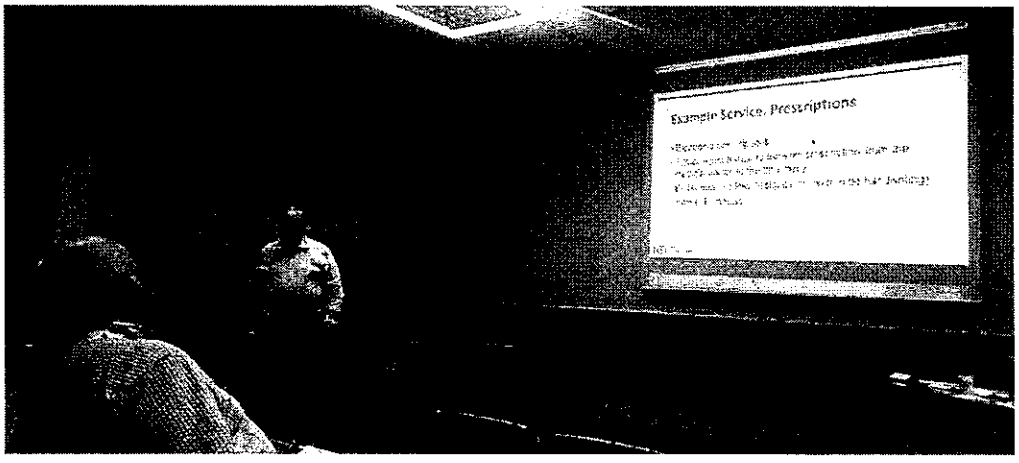

圖 7、智慧城市的商業應用

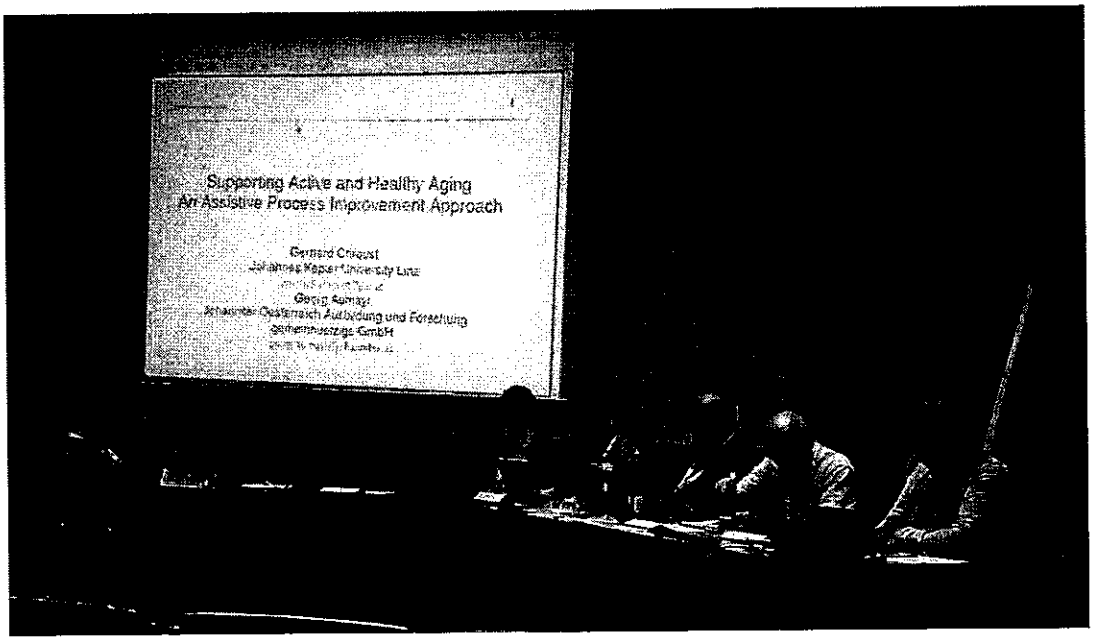

圖 8、智慧城市之移動服務探討

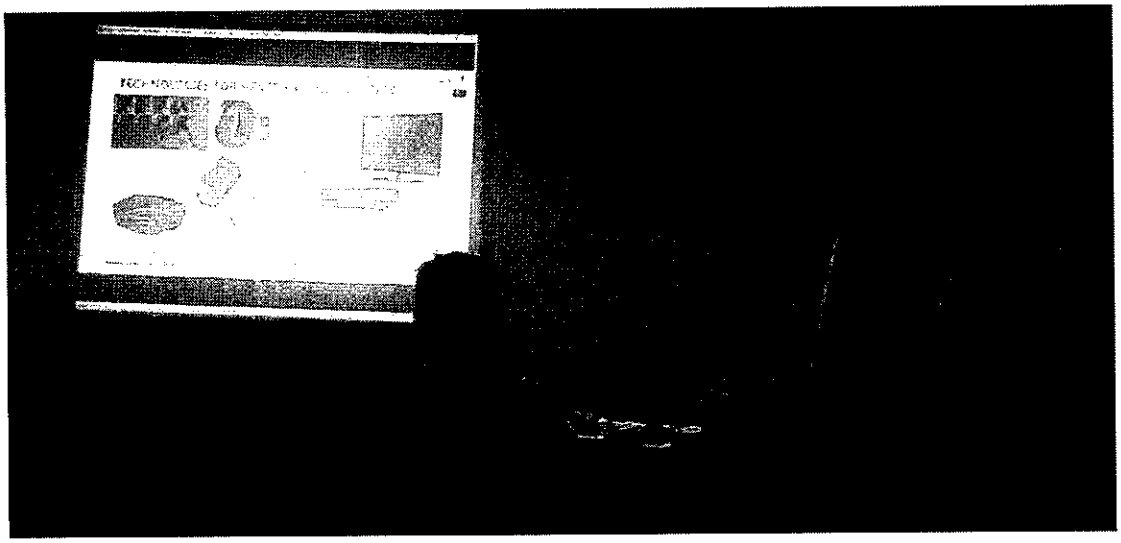

圖 9、物聯網應用於人體健康監控

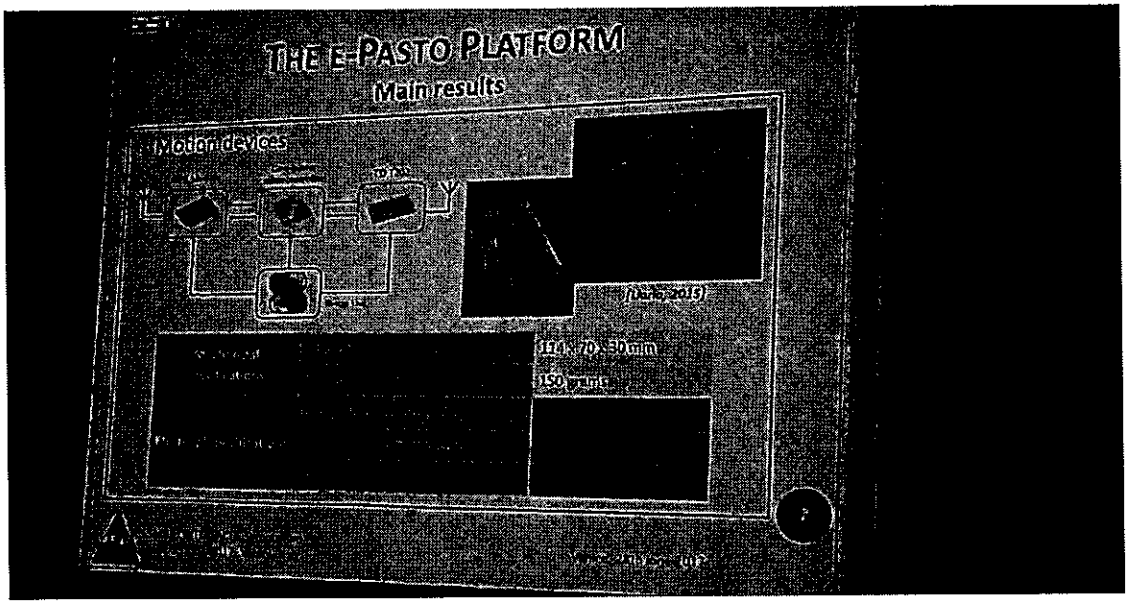

圖 10、畜牧業是使用物聯網分析，促進產業升級

附錄一　會議議程

The Sixth International Conference on Smart Cities, Systems, Devices and Technologies

SMART 2017
June 25 - 29, 2017- Venice, Italy

Preliminary Program

DataSys 2017

AICT 2017 / ICIW 2017 / ICIMP 2017 / SMART 2017 / IMMM 2017 / INFOCOMP 2017 / MOBILITY 2017 / SPWID 2017 / ACCSE 2017 / URBAN COMPUTING 2017 / DATASETS 2017 / MODOPT 2017

Conference Venue Location
NOVOTEL VENEZIA MESTRE CASTELLANA

Via Ceccherini 21
30174 Venezia Mestre
Italy

Note: *Sessions marked with /s are from special tracks. The final program might vary slightly according to the number of successful special tracks and the final registrations.*

Conference rooms Time slots	Room A	Room B	Room C	Room D

Sunday, June 25

12:00	**Registration starts** The registration desk is located in front of the conference rooms Operating during the entire conference
13:00 - 15:00	**Tutorial I** **Empirical Modeling: Current and Emerging Techniques** Prof. Dr. Ian Flood, University of Florida, USA
15:00 - 15:15	**Coffee**
15:15 - 17:15	**Tutorial II** **P(Security)=1-P(Crime) – Is Security the Absence of Crime?** Prof. Dr. Dirk Labudde , Bioinformatics group Mittweida (bigM)/Forensic Science Investigation Lab (FoSIL), University of Applied Sciences Mittweida, Germany

17:15 - 17:30	**Coffee**
17:30 - 19:30	**Tutorial III** **Photonic Integration for Access Networks** Prof. Dr. António Luis Jesus Teixeira, Instituto de Telecomunicações - Aveiro, Portugal
19:30 - 20:30	**Welcome Cocktail** You must have your badge to attend the cocktail

Monday, June 26

09:00 - 09:15	**OPENING SESSION**			
09:15 - 10:15	**Keynote Speaker** **Quality of information from an Evolutionary Perspective** Prof. Dr. Ir. J.J.M. (Jos) Trienekens, Open University	Eindhoven University of Technology (TU/e), The Netherlands		
10:15 - 10:30	**Coffee Break**			
10:30 - 12:00	AICT 1	INFOCOMP 1	IMMM1	ICIW 1
12:00 - 13:00	Lunch on your own			
13:00 - 14:30	AICT 2	ACCSE 1	IMMM2	ICIMP 1
14:30 - 14:45	**Coffee**			
14:45 - 16:15	MOBILITY 1	SMART 1		
16:15 - 16:25	**Coffee Break**			

16:25 - 18:00	**Panel on AICT/ICIMP/ MOBILITY** **Topic: Challenges for Long-Term Evolution and 5G for IoT Systems** **Moderator** Sergei Semenov, Huawei/HiSilicon, Sweden **Panelists** Josef Noll, Basic Internet Foundation #Basic4All | University of Oslo (UiO) / ITS, Norway Bernhard Tellenbach, Zurich University of Applied Sciences, Switzerland Gerson Damanik, Satya Wacana Christian University, Indonesia Sergei Semenov, Huawei/HiSilicon, Sweden

Tuesday, June 27

09:15 - 10:15	**Keynote Speaker** **Programmability, Softwarization and Management in 5G Smart Networking** Prof. Alex Galis, University College London, UK			
10:15 - 10:30	**Coffee Break**			
10:30 - 12:00	**Panel on INFOCOMP** **Topic: From Advanced Applications to Optimisation and Energy Efficiency: How Will Data Science Benefit to Communication and Computing in Science and Society?** **Moderator** Claus-Peter Rückemann, WWU Münster and DIMF, Germany **Panelists** Isabel Schwerdtfeger, IBM Deutschland GmbH, Hamburg, Germany Lutz Schubert, University of Ulm, Germany Zlatinka Kovacheva, Middle East College, Muscat, Oman Claus-Peter Rückemann, Leibniz Universität Hannover and WWU Münster and HLRN, Germany			
12:00 - 13:00	Lunch on your own			
13:00 - 14:30	AICT 3	INFOCOMP 3	MOBILITY 2	ICIW 2
14:30 - 14:45	**Coffee**			
14:45 - 16:15	INFOCOMP 7 / COPI I	IMMM 3	ACCSE 2	ICIW 3

16:15 - 16:25	**Coffee Break**			
16:25 - 17:00	**Keynote Speech** **Smart Cities from a Business Perspective** Prof. Dr. Lasse Berntzen, University College of Southeast Norway, Norway			
17:00 - 18:45	**Panel on SMART/MOBILITY/SPWID** **Topic: Mobile Services in Smart Cities** **Moderator** Lasse Berntzen, University College of Southeast Norway, Norway **Panelists** Adrian Florea, Lucian Blaga University of Sibiu, Romania, Khalil El-Khatib, University of Ontario, Canada Alex Galis, University College London, UK Gerhard Chroust, Johannes Kepler University Linz, Austria Peter Larkin, Swiss Re, Switzerland			
18:45 - 18:50	**Coffee**			
18:50 - 20:20	INFOCOMP 2 / LSEEDCC			

Wednesday, June 28

09:15 - 10:15	**Keynote Speaker** **5G and Sustainable Development** Prof. Dr. Josef Noll, Basic Internet Foundation #Basic4All and University of Oslo/ITS, Norway			
10:15 - 10:30	**Coffee Break**			
10:30 - 12:00	AICT 4	ACCSE 3	SMART 4 /SMART INTERFACES I	ICIW 4
12:00 - 13:00	Lunch on your own			
13:00 - 14:30	AICT 5	INFOCOMP 4	SMART 2 / A&MHealth	SPWID 1 / SPA I

14:30 - 14:45	Coffee			
14:45 - 16:15	AICT 6 / ESTDETDEC	INFOCOMP 5 / MODOPT I	IMMM 4	ICIW 5/ WFIS
16:15 - 16:25	Coffee Break			
16:25 - 17:00	**Keynote Speaker** **Allow Knowledge to Prevail: Advanced Computing, Data, Experience, and the Universal Decimal Classification** Prof. Dr. Claus-Peter Rückemann, Leibniz Universität Hannover / Westfälische Wilhelms-Universität Münster / North-German Supercomputing Alliance (HLRN), Germany			
17:00 - 18:30	**Panel on INFOCOMP/IMMM/ICIW** **Topic: Challenges on Web Semantic Mapping and Information Processing** **Moderator:** Claus-Peter Rückemann, WWU Münster and DIMF, Germany **Panelists** Marc Jansen, University of Applied Sciences Ruhr West, Deutschland Fahad Muhammad, CSTB, Sophia Antipolis, France Kiyoshi Nagata, Daito Bunka University, Japan Claus-Peter Rückemann, WWU Münster and DIMF, Germany			
18:30- 18:40	Coffee			
18:40 - 20:10				INFOCOMP 8/COPI II
20:30 : 23:30	CONFERENCE DINNER			

Thursday, June 29

09:15 - 10:15	**Keynote Speech** **Learning from the Human Immune System:** **Artificial T-cells as a Response to Cyber Attacks** **Speaker: Michael Spranger** **Contributors:** Prof. Dr. Dirk Labudde, Bioinformatics group Mittweida (bigM)/Forensic Science Investigation Lab (FoSIL), University of Applied Sciences Mittweida, Germany Michael Spranger, Bioinformatics group Mittweida (bigM)/Forensic Science Investigation Lab (FoSIL), University of Applied Sciences Mittweida, Germany			
10:15 - 10:30	**Coffee Break**			
10:30 - 12:00	SMART5 / SMART INTERFACES II	SMART 3	ICIMP 2	ACCSE 4 / AARB
12:00 - 13:00	Lunch on your own			
13:00 - 14:30	SMART6 / SMART INTERFACES III	INFOCOMP 6 / MODOPT II	SPWID 2/SPA II	
14:30 - 14:45	**Coffee**			
14:45 - 15:15	**Keynote Speaker** **Applications of Techno-social Systems in Economy and Governance** Dr. Alexander Troussov, Russian Academy of Science, Russia			
15:15 - 17:00	**Panel on ACCSE/INFOCOMP/MODOPT** **Topic: Achieving Full Potential for Information Modeling and Processing** **Moderator** Ian Flood, University of Florida, USA **Panelists** Dominique Thiebaut, Smith College, USA Alexander Troussov, Russian Academy of Science, Russia Ian Flood, University of Florida, USA			
17:00 - 17:10	**Coffee and Closing Session**			

附錄二

From Crowdsourcing to Crowdsharing: The Smart Environmental Sensing Web of EPA

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Abstract—**This article describes how the Environmental Protection Administration (EPA) under the Executive Yuan of Taiwan (R.O.C.) leverages its Smart Environmental Sensing Web comprising crowdsourcing and crowdsharing built on its existing Internet of Things (IoT) based environmental monitoring system to make the public care more about the quality of their living environment, and create positive feedback loops of information flows. Furthermore, we use data visualization technology and location-based services to design graphical dashboards and interactive maps to enable users to access real-time local environmental sensing information at any time. Taiwan EPA will also continue to maintain the concept of open, transparent and innovative applications to serve society with public, diversified, and convenient information services.**

Keywords- Citizen as Sensor; Crowdsourcing; Internet of Things; Location-Based Service; Social Networks; $PM_{2.5}$.

I. INTRODUCTION

This article describes how Taiwan EPA leverages its Smart Environmental Sensing Web comprising crowdsourcing and crowdsharing [1] built on its existing IoT-based environmental monitoring system. This Smart Environmental Sensing Web includes continually expanding Micro Environmental Sensors, an environmental quality sensor networking platform, an Environmental Info Push application for smart phones, and an i-Environment website. Combining environmental sensing data from different sources through common transmission protocols and Open Geospatial Consortium (OGC) Standards, we used data visualization technology and location-based services to design graphical dashboards and interactive maps enabling users to access real-time local environmental information at any time, while also adding a convenient notification function that sends alerts when needed.

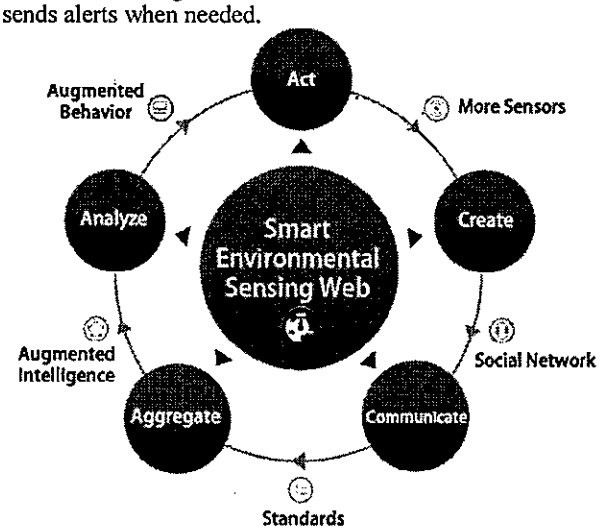

Figure 1. The Conceptual Cycle of Smart Environmental Sensing Web

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We also encourage the deployment of sensors, Open Data and crowdsharing to maximize the benefits of the Smart Environmental Sensing Web. Users can not only freely use these Open Data on environmental quality to design their own innovative value-added services and explore environmental issues, but also they can make use of the existing platform to share their personal feelings regarding the environment and publish these on the community website. Users may also use community links to stimulate other people's concern about the quality of living environment to create positive feedback cycle of data flows (in Figure 1).

II. METHODS

A. *Data enrichment— Crowdsourcing*

In addition to collecting and disseminating the various types of environmental monitoring information generated by Taiwan EPA, the Smart Environmental Sensing Network will also incorporate data from Micro Environmental Sensors operated by local governments, educational institutions, enterprises, and individuals. These Micro Environmental Sensors (list in TABLE I.), inspired by the Maker Movement, are designed to operate as a network of sensors managed by the public and experts. The sensors will continuously monitor air pollutants ($PM_{2.5}$), temperature, and humidity, and upload their real-time sensing data via wifi to an open or self-built IoT platforms. The platform provides Application Programming Interfaces (APIs) for Open Data to aid the development of display interfaces and application services for these types of environmental information. Currently, the number of micro-sensors has reached 2,100 units, which are mainly distributed in Taiwan's densely populated metropolitan areas, as well as at public primary schools in several counties and cities.

TABLE I. DIFFERENT SOURCES OF ENVIRONMENTAL SENSING NETWORK

Deployment	Number of Devices	Sensors	Trans-mission	Device Provider
Airbox Taipei City	155	$PM_{2.5}$, Temperature, Humidity	Wifi	Edimax
Airbox New Taipei City	298			
Airbox Taichung City	232			
Airbox Tainan City	214			
Airbox Kaohsiung City	242			
AirBox (other)	621			
LASS	97	$PM_{2.5}$, Temperature, Humidity	Wifi	Open Community
MAPS	83	$PM_{2.5}$, Temperature, Humidity	Wifi or LoRa	IIS-NRL of Academia SInica
EPA Monitoring Site	76	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2	ADSL	EPA or Local Goverment
EPA Industrial Parks	33	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO, NO_2, NO_X, THC	ADSL	
Local Government Monitoring Site	26	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2	ADSL	
EPA Large-scale Enterprises	70	O_3, $PM_{2.5}$, PM_{10}, SO_2, NO_2	ADSL	
EPA Mobile	20	$PM_{2.5}$, Temperature, Humidity	Bluetooth	
EPA Fix	200	$PM_{2.5}$, PM_1, O_3, NO_2, CO, Temperature, Humidity, Noise	Wifi	

Data from pm25.lass-net.org [2] and EPA

In order to increase the density of the environmental sensing network, Taiwan EPA encourages citizens to join the network by installing personal air sensors in their living environment, such as AirBox and Location Aware Sensing System (LASS), which monitors air quality that people actually breathe. Since 2016, Taiwan EPA has also continued to develop new sensors that can transmit real-time data to the Smart Environmental Sensing Web via other modes of transmission, such as Bluetooth, Wifi, or Long range (LoRa) [3]. Since LoRa technology has advantages of low power consumption and long range capability, Taiwan EPA has begun deploying these sensors in a certain industrial park.

The Environmental Info Push App provides the public with environmental information that is updated every minute. Internet access is all it takes for people to know the air quality near their home or the place they plan to visit, so they may take appropriate measures to protect their health.

B. *Technique of implementation*

Through the Open Platform for Environmental Resources [4], Taiwan EPA compiles real-time monitoring information to create i-Environment [5], a thematic interactive map browsing platform, and the Environmental Info Push app to serve the people's demand for this type of information.

 ISBN: 978-1-61208-565-4

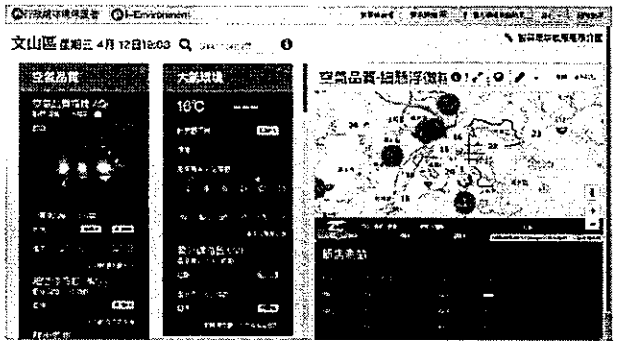

Figure 2. i-Environment Webpage (2016)

Based on governmental open data, "i-Environment" is the first government website designed for the Hybrid Web. It is developed using data visualization technology, which helps present reports, statistics, quantitative figures, and other information in a visual manner. An interface with dashboards and interactive maps provides location-based services that allow users to easily browse and search the environmental information they need (see Figure 2). In addition to these convenient information services, the sensor network also provides air quality alerts to the public, along with suggestions for appropriate activities under the various circumstances reminding users of immediately responding to discomfort and risks from environmental pollution, and to maintain their best health.

III. CURRENT PRACTICES—CROWDSHARING

To raise the public's environmental awareness and call attention for sources of air pollution in people's immediate living environment, Taiwan EPA has monitored the Mazu Goddess Tour, a month-long procession of a sea goddess touring Taiwan, greeted by the way by of celebrations involving massive fireworks that push up $PM_{2.5}$ values into the hundreds or even above 1,000 since 2016.

Firstly, in the spirit of crowdsourcing, EPA launched AirPhoto, a function of Environmental Info Push app through which people can share a photo stamping real-time air quality data on it, and share the photo on the map as well as on one's own Facebook Wall. Thus, through crowdsourcing and crowdsharing, the public is engaged as "citizen sensors" and made more aware of environmental issues.

Secondly, in response to the development era of Internet of Things, Taiwan EPA has developed Bluetooth transmission modules that can be deployed around temples and those places where celebrations were held to monitor the environmental conditions on the ground. After the dynamic data was measured and uploaded, it can be immediately seen on mobile phones with the app and also uploaded to the IoT cloud platform of Taiwan EPA (see Figure 3.).

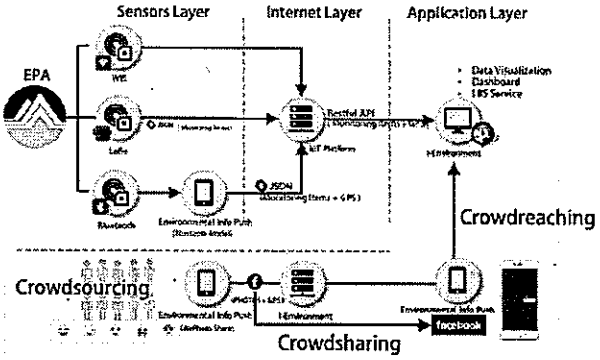

Figure 3. New Structure of Environmental Sensing Web of EPA (2017)

During events, people can view real-time information on the i-Environment website, including real-time air quality monitoring values, photos shared through the AirPhoto, as well as statistical charts and data. In addition, the public can use trend maps that compute spatial changes in combination with real-time sensor information and interactive features of maps on the i-Environment website (see Figure 4).

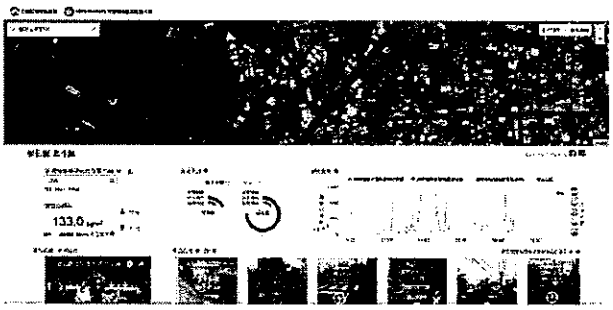

Figure 4. New Web design of Environmental Sensing Web of EPA (2017)

IV. CONCLUSION

In light of the worldwide positive acclaim of Open Data, Taiwan EPA will continue to maintain the concept of open, transparent and innovative applications [6] to serve society with public, diversified, and convenient information services to facilitate people's decision-making that involves environmental aspects. Taiwan EPA furthermore hopes that the Smart Environmental Sensing Web along with the relative apps will encourage crowdsourcing and crowdsharing to make the public more concerned about the quality of their living environment, and create positive feedback loops of information flows.

REFERENCES

[1] M. N. Kamel Boulos et al., "Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples,"

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International Journal of Health Geographics, vol. 10, no. 1, p. 67, 2011, http://dx.doi.org/10.1186/1476-072X-10-67

[2] IIS-NRL, PM2.5 Open Data Portal. [Online]. Available from:https://pm25.lass-net.org/zh_tw/ 2017.03.22.

[3] LoRa Alliance, LoRaWAN What is it. Technical Marketing Workgroup 1.0, Nov., 2015. Available from:
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[5] Environmental Protection Administration. *i-Environment.* [Online]. Available from: https://ienv.epa.gov.tw/ 2017.03.22.

[6[Environmental Protection Administration. *Opendata.epa*, http://opendata.epa.gov.tw/ 2017.03.22.

 ISBN: 978-1-61208-565-4

附錄三

Mobile Services in Smart Cities

- **Moderator**
  Lasse Berntzen, University College of Southeast Norway, Norway

Panelists
Adrian Florea, Lucian Blaga University of Sibiu, Romania,
Alex Galis, University College London, UK
Gerhard Chroust, Johannes Kepler University Linz, Austria
Khalil El-Khatib, University of Ontario, Canada
Peter Larkin, Swiss Re, Switzerland

Panel on SMART/MOBILITY/SPWID

Topic: Mobile Services in Smart Cities

The Sixth International Conference on Smart Cities, Systems, Devices and Technologies

Venice, June 25-29, 2017

Smart city challenges:
Modeling / monitoring crowds / traffic
in order to reduce gas emissions & noise volume

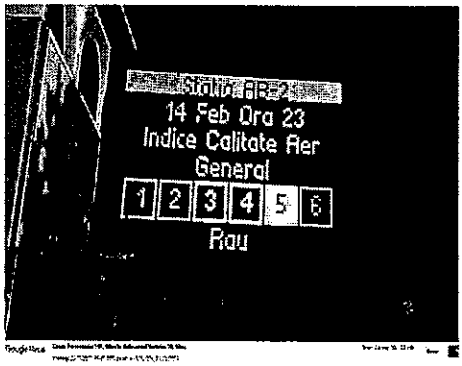
Adrian FLOREA

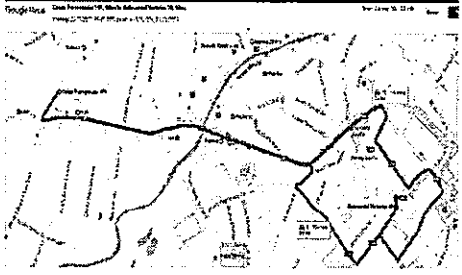
Moderators comments

- Panel had different approaches to the topic, ranging from virtual networks (slice networking) and sensor technology to human-centric solutions.
- Future panel debates could focus on integration of smart city solutions (big topic) to privacy concerns related to smart cities (another big topic).

Main Goals

- **Develop a low-cost platform for smart city monitoring, display information and outdoor advertisement.**
- **The platform will be used to monitor air quality, temperature, humidity and noise, as well as counting the number of vehicles and people over time within a specific area.**





- **Determine the experiment accuracy by comparing collected data with well-known information from other sources about which route is heavy traffic (Beat the traffic, Waze, Google Traffic, etc).**
- **Impacted communities would benefit from accurate and timely localized knowledge of air pollution levels for immediate protection as well as for longer term mitigation of high pollution areas and traffic planning**

Adrian Florea

Main problem:

- **Heavy traffic, the speed of the traffic flow and inefficient modes of transport in urban areas are directly responsible for air pollution and noise ➔**
- **Negative impact on cardiovascular, respiratory and neuro-behavioural diseases**

Challenge:

- **Correlating real data about *air quality* & *noise volume* with *traffic measurements* and setting some limit thresholds.**
- **Real-Time Estimation of Pollution Emissions and Dispersion from (Heavy) Traffic**
- **Modeling real time traffic in order to reduce gas emissions & noise volume.**

Adrian Florea

Slice Networking in support of Mobile Services in Smart Cities

- Slices - Background and Context
- Key Challenges in support of Network Services
- Concluding Remarks & Acknowledgement

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Department of Electronic & Electrical Engineering
Torrington Place
London WC1E 7JE
United Kingdom

UCL

Solutions

- The municipality may improve the air quality by optimizing traffic
- Gamification (application for mobile phone) - using on large scale of common means of transportation or other alternatives
- Developing mobile phone Apps to provide in real-time air quality index, decongested routes, notifications for exceeding certain thresholds, rescue information
- Collecting enough data and store in databases in order to apply data analitycs tools to forecast further the environment conditions

Adrian Florea

Definitions of Network Slicing & References(II)

I - Slicing Resources:

Slice capabilities (2009) "Management and Service-aware Networking Architectures (MANA) for Future Internet" – A. Galis et all - Invited paper IEEE 2009 Fourth International Conference on Communications and Networking in China (ChinaCom09) 26-28 August 2009, Xi'an, China, http://www.chinacom.org/2009/index.html

3 Slices Capabilities

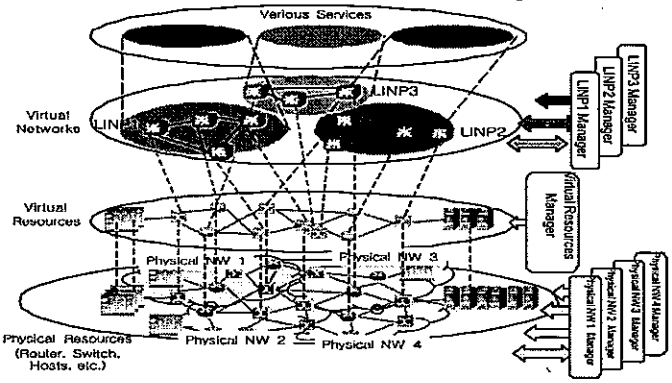
- "Resource allocation to virtual infrastructures or slices of virtual infrastructure."
- "Dynamic creation and management of virtual infrastructures/slices of virtual infrastructure across diverse resources."
- "Dynamic mapping and deployment of a service on a virtual infrastructure/slices of virtual infrastructure."

17 Orchestration capabilities

19 Self-functionality mechanisms

14 Self-functionality infrastructure capabilities

ITU-T Slicing (2011) as defined in [ITU-T Y.3011], [ITUTY.3012] is the basic concept of the Network Softwarization. Slicing allows logically isolated network partitions (LINP) with a slice being considered as a unit of programmable resources such as network, computation and storage.

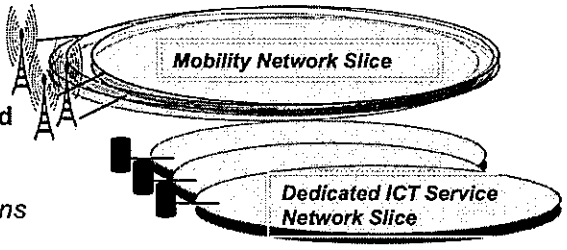


Smart Networks

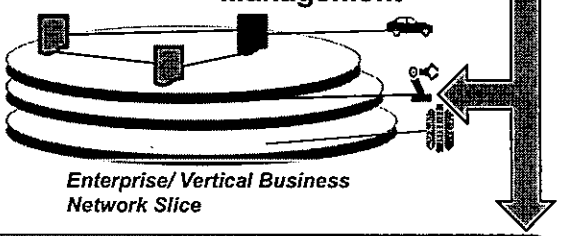
- **Transition from network devises to network functions and virtual network functions with inbound management**
- **Dynamically adapting the network to meet future demands requires**
- **Creating the dynamic, configurable, programmable, resilient, cost effective E2E network**
- **A programmable network operating system with simple interface to the network (smart network fabric)**

E2N Multi-Domain Orchestration
E2E coordination, conflict resolution, multi-domain information exchange

Service Adapted Network Slices *Enabled by Network Functions Including NFV*



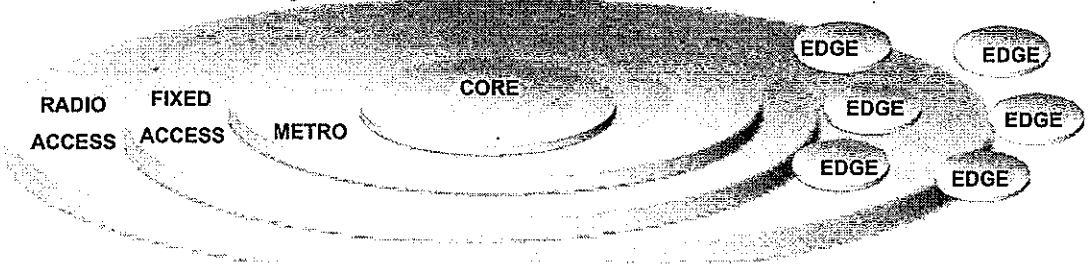
In-bound Cognitive Management



Enterprise/ Vertical Business Network Slice

Smart Network Fabric: E2E Multi-Domain Network Operating System Facilities
Network Abstraction, Allocate (virtual) network resources, Maintain network state, Ensure network Reliability in a multi-domain environment

Smart Cloud & Network Fabric *Enabled by Programmability Including SDN*



(Proposal) Unified Slice definition

Slice as a union of subsets of resources & NFVs at a given time

(1) The Service Instance component

- represents the end-user service or business services.
- an instance of an end-user service or a business service that is realized within or by a NS.
- would be provided by the network operator or by 3rd parties.

(2) A Network Slice Instance component

- represented by a set of network functions, and resources
- forms a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s).
- provides network characteristics which are required by a Service Instance.
- may also be shared across multiple Service Instances

(3) Resources component – it includes: *Physical, Logical & Virtual resources*

- *Physical & Logical resources* - An independently manageable partition of a physical resource, which inherits the same characteristics as the physical resource and whose capability is bound to the capability of the physical resource. It is dedicated to a Network Function or shared between a set of Network Functions;
- *Virtual resources* - An abstraction of a physical or logical resource, which may have different characteristics from that resource, and whose capability may not be bound to the capability of that resource.

(4) Slice Capability exposure component

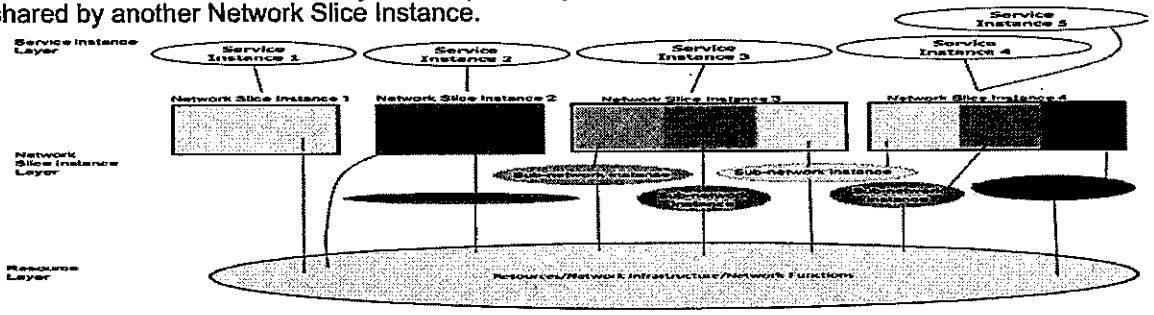
- allow 3rd parties to access via APIs information regarding services provided by the slice (e.g. connectivity information, QoS, mobility, autonomicity, etc.)
- allow to dynamically customize the network characteristics for different diverse use cases within the limits set of functions by the operator.
- it includes a description of the structure (and contained components) and configuration of the slice instance.

Definitions of Network Slicing & References(III)

II- Network Slicing :

NGMN Slice capabilities (2016) - consist of 3 layers: 1) Service Instance Layer, 2) Network Slice Instance Layer, and 3) Resource layer.

- The Service Instance Layer represents the services (end-user service or business services) which are to be supported. Each service is represented by a Service Instance. Typically services can be provided by the network operator or by 3rd parties.
- A Network Slice Instance provides the network characteristics which are required by a Service Instance. A Network Slice Instance may also be shared across multiple Service Instances provided by the network operator.
- The Network Slice Instance may be composed by none, one or more Sub-network Instances, which may be shared by another Network Slice Instance.



3GPP TR23.799 Study Item "Network Slicing' **2016**

ONF Recommendation TR-526 "Applying SDN architecture to Network Slicing" **2016**

IETF Draft draft-gdmb-netslices-intro-and-ps-02 2016- 2017

EU 5GPPP

- **15 Large Scale Research projects – all based on Network Slicing** (https://5g-ppp.eu) **(2015- 2018+)**
- **White Paper on 5G Architecture centered on network slicing** (https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-5G-Architecture-WP-July-2016.pdf) **(2016)**

Network Slice Usage Scenarios

- Mission-critical Ultra low latency communication
- Massive-connectivity machine communication (e.g. Smart metering, Smart grid and sensor networks)
- Extreme QoS
- Independent QoS isolation design
- Independent operations and management
- Independent autonomic management functionality
- Independent cost and/or energy optimisation
- Independent multi-topology routing
- Mobile Services in Smart Citie
- Sharing Infrastructure: Enablers for sharing infrastructure safely and efficiently (Multi-tenant)

NS Key Characteristics→ No1 Engineering Priority in 5G

- **A managed group of infrastructure resources, network functions and services** (e.g. Service Instance component, A Network Slice Instance component, Resources component , Slice Capability exposure component).
- **NS is programmable and has the ability to expose its capabilities**. The behaviour of the network slice realized via network slice instance(s).
- Concurrent deployment of **multiple logical, self-contained and independent, shared or partitioned networks on a common infrastructure platform**.
- Supports **dynamic multi-service support, multi-tenancy** and the integration means for vertical market players.
- **Service customized Network Slices (enabled by NFV principles) + Smart Network Fabric for coordinating/orchestration, control of network resource**
- **NSs** simplifies the provisioning of services, manageability of networks and integration and operational challenges especially for supporting communication services.
- **Network operators/ ISP can exploit network slicing** for
  - reducing significantly operations expenditures, allowing also programmability necessary to enrich the offered tailored services.
  - means for network programmability to OTT providers and other market players without changing the physical infrastructure.
- **Considerably transform the networking perspective** by
  - abstracting, isolating, orchestrating and separating logical network behaviors from the underlying physical network resources.

Summary & Concluding Remarks

- **Slice Networking** would considerably ***transform the networking perspective*** by
  - **abstracting,**
  - **Isolating at a sub-network level,**
  - **separating logical network behaviours from the underlying physical network resources.**
  - **dynamic management of network resources by managing resource-relevant slice configuration; simplification and reduction of operations expenditures**
  - **Support for rapid service provisioning including Mobile Services in Smart Cities**

Acknowledgement - 5GPPP EU Research Projects

- **5GEx – "5G Multi-Domain Exchange" https://5g-ppp.eu/5gex/**
- **5G SONATA – "Service Programming and Orchestration for Virtualized Software Networks in 5G" https://5gppp.eu/sonata/.**

Supporting Active and Healthy Aging (my-AHA)

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Thank you

Q&A

Vision

Curing ->	cAring ->	well-faring
diseases	compensating frailties	pro-active care
ex-post	ad-hoc	future-oriented
	observing, recognizing	checking, warning, reminding

Initiate healthy activities (personal and social)

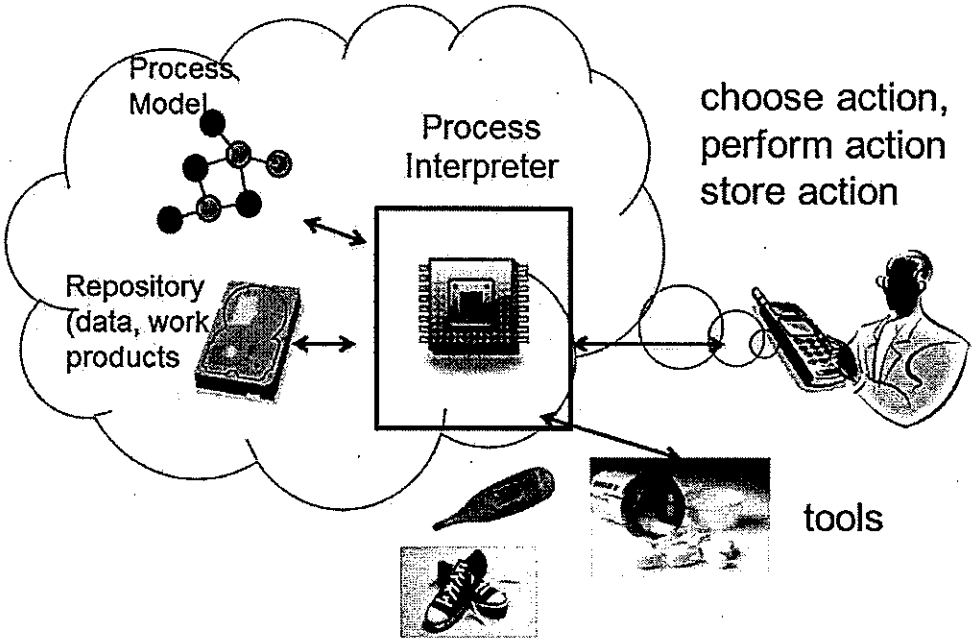
Objective of AHA

Active and Healthy Aging (AHA) :

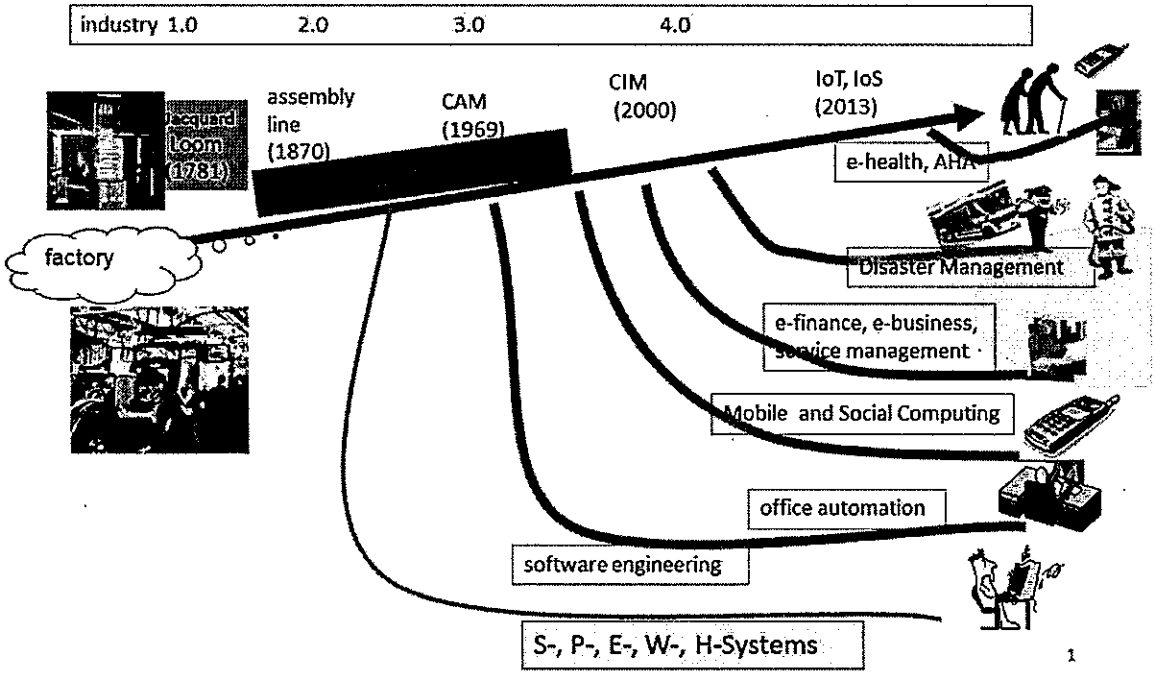
AHA: my-AHA - Europ. Union - Horizon-2020 Project No 689592, 2016-2019

- demographic changes (Western World)
- concern of a sustainable society
- Seniors actively and passively involved in AHA
- compensate physical and mental deficiencies of Seniors
- Automation + Technology for Process Support (like "Industry 4.0")

Interfaces for AHA



Evolution of Industry 4.0



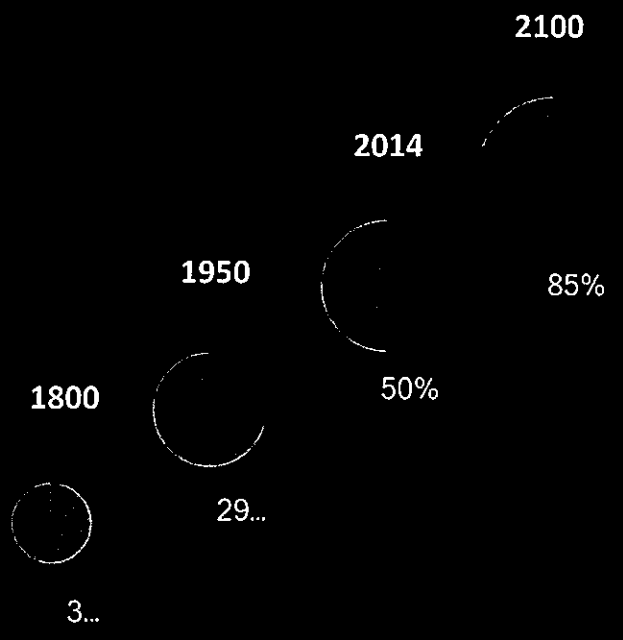
Conclusion and Further Work

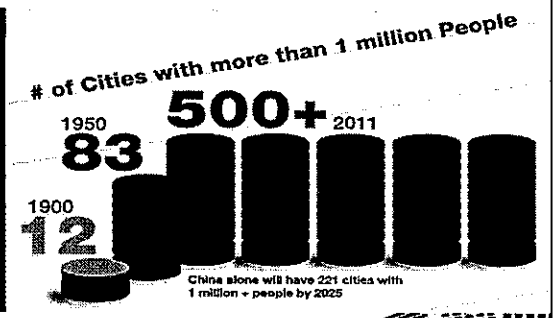
- Process view for AHA promising
- offers better and more effective control
- relieves support personnel
- allows comparison and assessment of AHA-processes (quality and capability)
- social, cultural, and economic difficulties
- 'look and feel' of interfaces crucial

Various Approaches

- **hData** : collect data and interpret them
- **Saluto-Genesis**: focus on HEALTH, not on disease
  on PREVENTION not cure!
- **Frailty Prevention**: physical and cognitive!

The World Is Urbanized

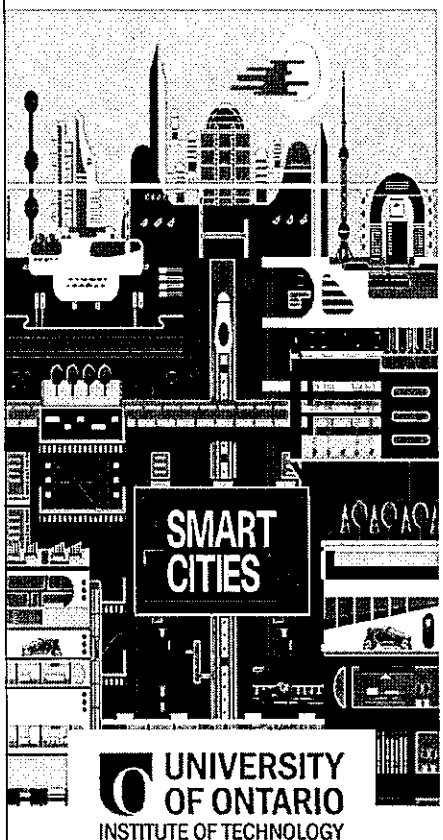




Pictures retrieved from: https://www.postscapes.com/anatomy-of-a-smart-city/

Challenges

- ✓ Air pollution
- ✓ Traffic congestion
- ✓ Housing requirement
- ✓ Health concern
- ✓ Energy and waste management



Communities and Mobility in Smart Cities

Dr. Khalil El-Khatib
(Roozbeh Jalali)

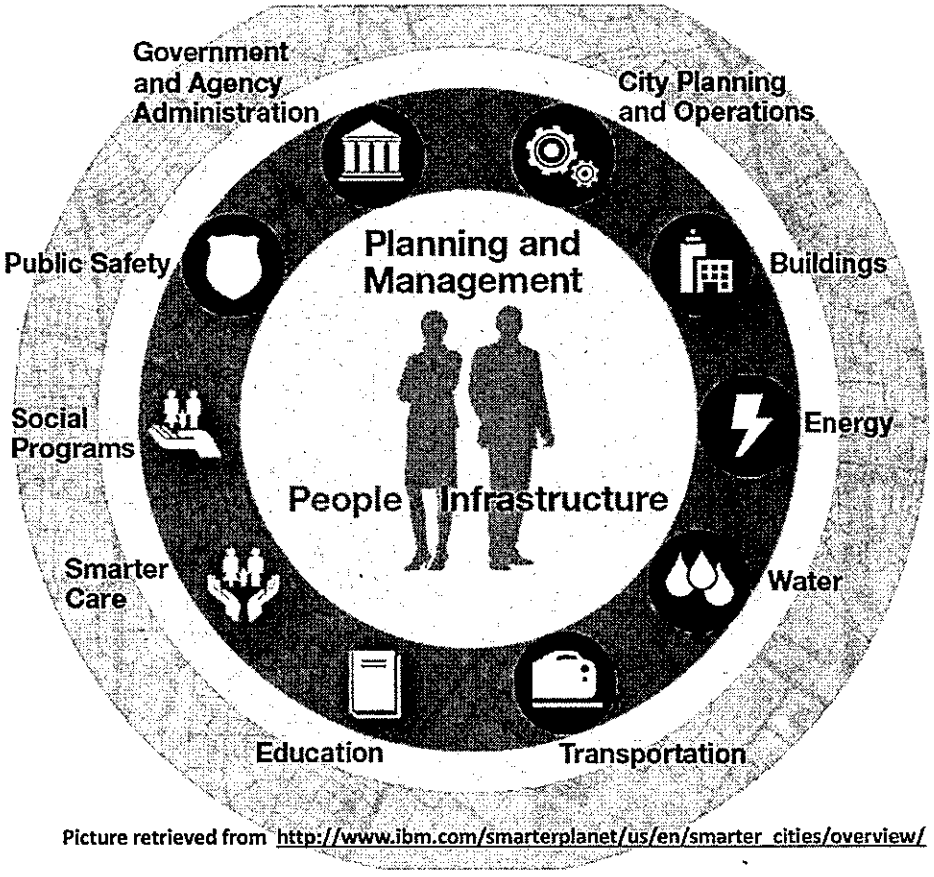
Faculty of Business and Information Technology (FBIT)
University of Ontario Institute of Technology, Canada

Research Challenges

- Architecture
- Data Delivery
- Heterogeneity
- Varied communities and human grouping
- Data quality and redundancy
- Incentive mechanism
- Information management and analysis
- Big data and scalability
- Predictive analysis
- Privacy

Smart City

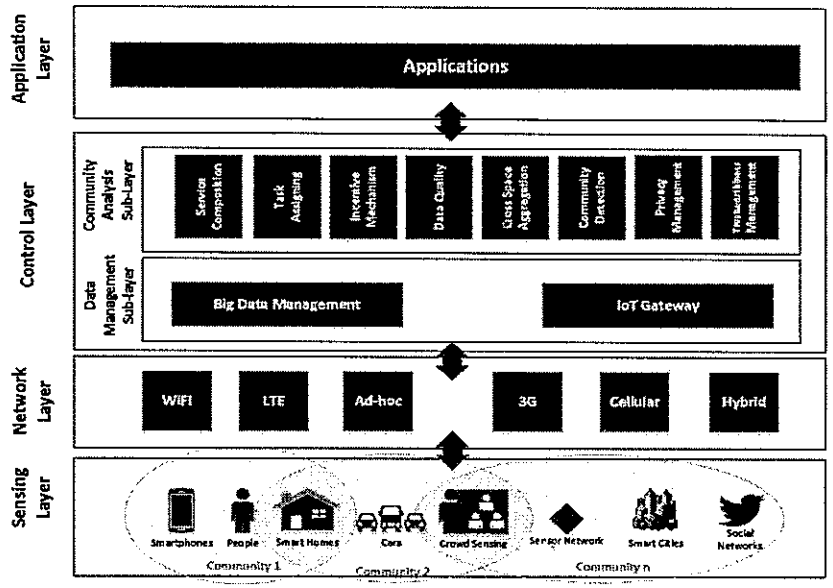
- ❖ Provide infrastructure for citizen to easily access many services
- ❖ Provide infrastructure for governing bodies to manage the resources in a city
- ❖ Use ICT to sense, analyze and integrate the information in running cities



Picture retrieved from http://www.ibm.com/smarterplanet/us/en/smarter_cities/overview/

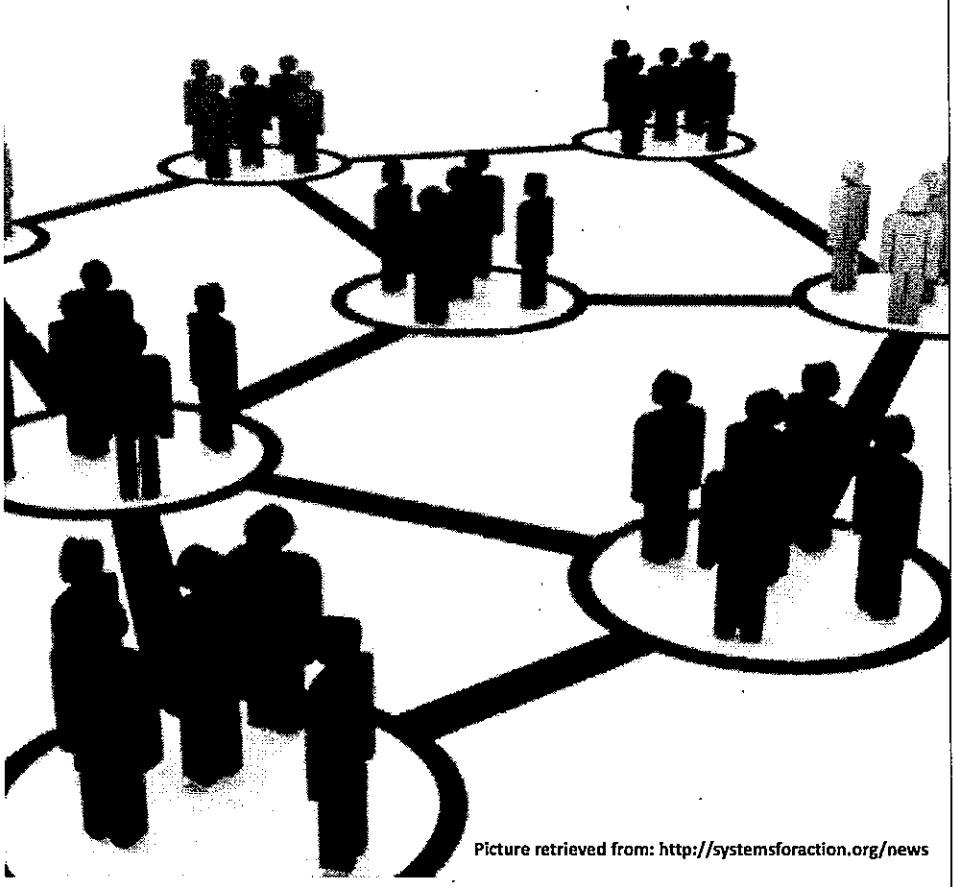
Framework for Community-Oriented Smart City

- ❖Big data management
- ❖IoT gateway
- ❖Service composition
- ❖Task assigning component
- ❖Incentive mechanism
- ❖Data quality
- ❖Cross space aggregation
- ❖Community detection
- ❖Privacy management
- ❖Trustworthiness management



Smart City as Communities

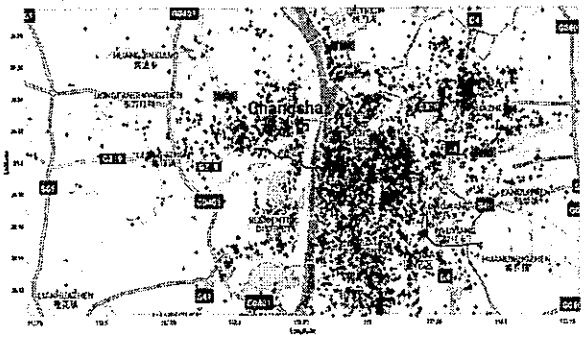
- A community is a group of people or objects that have common characteristics and are tightly connected via various social and physical processes.
- Smart city citizens and objects can be seen as multiple **communities**

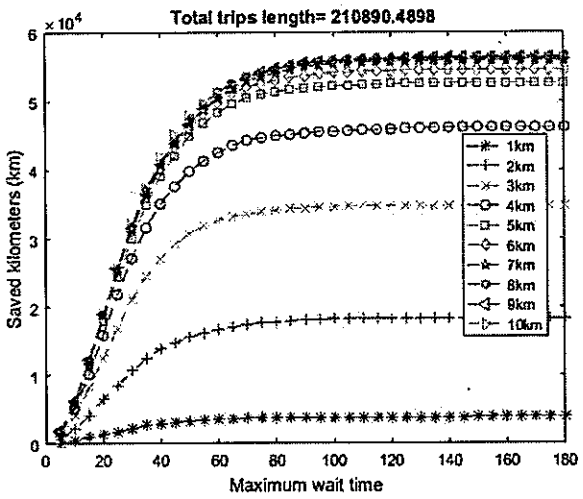


Picture retrieved from: http://systemsforaction.org/news

Investigating the Potential of Ridesharing to Reduce Vehicle Emissions

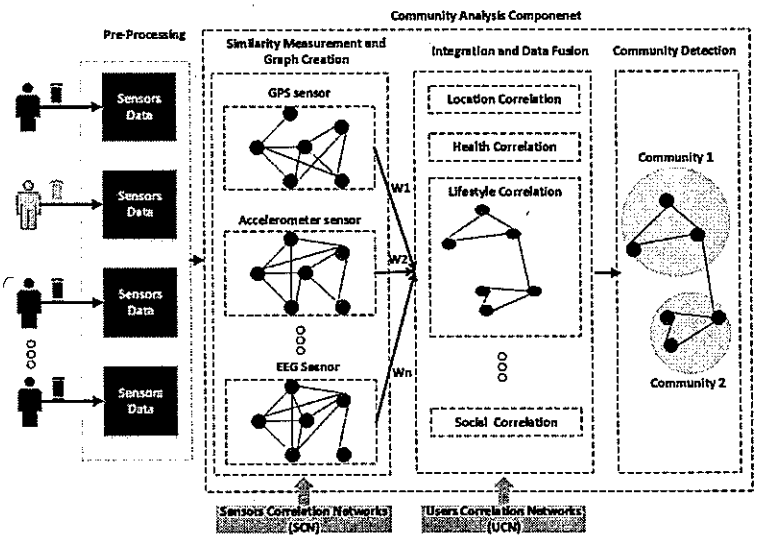
Similarity Function	Euclidean
Maximum distance between trips (Kilometers)	1–10
Number of clusters	11,000
Maximum schedule time (Minutes)	5–180
Total trip length (Kilometer)	210,890
Total number of trips	20,018
Total number of Vehicles	8900





8

Community Detection



- Preprocessing
- Similarity Measurement
- Graph Creation
- Integration
- Community Detection

7


THANK YOU
Picture retrieved from https://www.slideshare.net

Development Model of a Public Safety Broadband Communications Network in Indonesia

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Abstract — **The Public and Private Partnership (PPP) development model of a public safety broadband network between cellular operators and public safety agencies, such as the National Disaster Management Agency, is a challenge for the government of Indonesia to provide broadband access. Public safety agencies are local governments, police agency, health agency, fire brigades. Each agency built their networks independently. In this study, the public safety broadband network model in Indonesia is developed by using an investment budget to build a broadband network of each agency. The budget of each agency is a function of compensation for the public safety, because they do not build their own network separately, but they rather share it with the cellular network. Public safety users are included as cellular users who will be given priority access or Quality of Service (QoS), but they are not profitable users for cellular operators. So, a cellular operator only receives infrastructure compensation budget due to the addition of user traffic for public safety, because this is part of the responsibilities of the government. The feasibility of this model will be measured by Net Present Value (NPV) calculations. From a cellular operator perspective, it is concluded that operators choose the 2x25 MHz option, which must share bandwidth and network infrastructure with public safety agencies. It has a higher NPV than the 2x20 MHz option, which is only for commercial Long Term Evilution (LTE). From a government perspective, the NPV always has a positive value. So, it indicates that the government needs to consider implementing a development model of a public safety broadband network with a sharing scheme between cellular operators and public safety agencies.**

Keywords — public safety broadband network, sharing scheme, NPV, LTE

I. INTRODUCTION

Public safety is an activity comprised of prevention, treatment, and protection against things that harm other people who may be significantly affected or injured, or experience a loss or damage, such as a crime or disaster. It can be caused by human actions or a natural occurrence, which is why it is important to create a secure and comfortable condition in the community. By doing so, it can support national stability [1].

Today, communication systems supporting public safety agencies have different standards, such as using different frequency ranges of 300 MHz – 800 MHz and using different kinds of technology. The most widely used types of technology are the conventional systems, trunking systems, Public Switched Telephone Network (PSTN), and commercial cellular networks. In fact, the condition of public safety in Indonesia is still independent, which does not support interoperability among agencies. It causes coordination difficulties between agencies responding to disaster. In addition, the public safety network in Indonesia is still based on a narrowband system. The capital expenditures (capex) and operational expenditures (opex) will necessitate high investment costs when each of the public safety agencies build their own broadband networks independently. So, it will burden the government's budget while the public safety traffic is only used in emergency conditions based on operational statistic data [2] and traffic site summary information [3]. The average communication channel occupation during emergencies or disasters is 31.32 percent from the total capacity or 7.52 hours/day [4].

Consistent with the issue of broadband public safety, based on Ministerial Decree No. 22 of 2011, the Ministry of Communications and Information Technology of Indonesia has planned a migration of analog terrestrial television to digital television services, which is targeted by 2018 [5]. In Article 4 of Ministerial Decree No. 18 of 2005, it is declared that in the case where government entities desire to use a telecommunications network, they can lease it from the network provider. On the other hand, especially in Article 7 of Ministerial Decree No. 18 of 2005, it is declared that government entities networks are prohibited to collect payments [6].

Based on the explanation above, a public safety broadband network has the opportunity to integrate public safety networks, in which some portions of the Asia Pacific Telecommunity (APT) 700 MHz digital dividend bandwidth can be allocated for LTE based technology to serve public safety agencies [7]. In this study, public and private partnerships are developed to deploy a public safety broadband network in Indonesia based on the previous model [8] [9], and it has been changed according to Indonesia's condition, based on Ministerial Decree No. 22 of 2011 and Ministerial Decree No. 18 of 2005. The model is still being developed by using the existing public safety

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network. First, it will be deployed in the greater Jakarta area and its satellite area because Jakarta, as the capital city of Indonesia, serves the central government and economy with a high population density, so it needs to have a public safety broadband system.

II. METHODOLOGY

Based on previous experiences in other countries, the Federal Communications Commission-United States (FCC-US) adopted an order to create a nationwide broadband network with a 2x10 MHz bandwidth for the Frequency Division Duplex (FDD) that consists of 758-768 MHz for an uplink and 788-798 MHz for a downlink, which is called "D Block". In America, the public safety spectrum is allocated at 763-775 MHz for an uplink and 793-805 MHz for a downlink, which consists of 2x5 MHz (763-768 MHz and 793-798 MHz) for a public safety broadband network using a bandwidth shared with an LTE network and the other spectrum allocated for a public safety narrowband network. In March of 2008, the FCC attempted to auction the D Block with public safety encumbrances but failed to attract a winning commercial bidder [10]. This is caused by several reasons, some of which include [11] [12]:

a. The 2x10 MHz bandwidth allocation in the D Block was claimed to be too small to overcome the LTE user traffic.
b. The issue has been framed in such a way as to suggest that allocations to the public safety community are at the expense of commercial wireless providers.
c. Some of the business entities collapsed and the United States (US) needs more commercial broadband network capacity to remain competitive globally.
d. The inexact time of the auction which was followed by a flurry of waiver petitions, public comments, and much debate.

Ryan Hallahan [8] improved the broadband public safety wireless communication based on the US situation, in which public safety users were reputed as being profitable users or commercial cellular customers who must pay for the use of their traffic. He devised a handover scenario whereby a handset must connect (roam) to a cellular operator if the user moves to another location which does not have public safety network coverage in Block D. In addition, APT modified 2x10 MHz of digital dividend to be allocated only for public safety communications [13].

In this research, a different method from the USA is deployed. In Indonesia, it is developed from a public partnership model between cellular operators and public safety agencies, where the public safety users are cellular users that will be given priority access or quality of service (QoS), but they are not considered as profitable users for cellular operators. Public safety user traffic on a cellular network will be converted to the additional costs (capex and opex) of cellular network deployment. In a government perspective, the investment cost payments should be managed by the government, as the Ministry of Finance should provide the budget for the public safety broadband network agencies. In this study, those payments are defined as a function of the government costs. This model developed the investment cost utilization as a budget which is canceled for each of the public safety agencies to build a public safety broadband network independently. In this study, that canceled budget is defined as a function of the government value. The government should consider the expenditure efficiency when deploying a model of a public safety broadband network, so that the feasibility will be measured from the NPV of a government perspective. From a cellular operator perspective, the government cost is a portion of the contributions to the cellular network as an operator value function of the cellular operator NPV, besides the annual revenue per user (ARPU) of commercial users. In this model, the operator costs are calculated from the total investment sharing network costs and annual spectrum fees.

III. NPV MODEL DEVELOPMENT

This model is developed from the previous studies of Ryan Hallahan [8], John Ure [9], and Administrative Incentive Pricing (AIP) recommended by Australian Communication and Media Authority (ACMA) [14] with an adoption of the conditions of Indonesia. An illustration of this model can be viewed in Figure 1.

In this study, the NPV formula is based on a government and cellular operator perspective and developed as a measure of examining the feasibility of developing a public safety broadband network based on the model proposed in this study. The cellular operator NPV during the observation is defined by t = i, as follows:

$$NPV_{Op} = \sum_{i=0}^{n} \frac{(GV_i + 12.\ Sub_{COMM,i}.R_{COMM}) - (C_i.\ Capex + C_{TOT,i}.\ Opex)}{(1+D)^i} - SFi \quad (1)$$

Then, the government NPV is formulated as follows:

$$NPV_{Gov} = GV_i - GC_i \quad (2)$$

Where,

GV_i = total investment cost utilization as a budget, which is cancelled by the year-i for each of the public safety agencies to build a public safety broadband network independently. [USD/year]

GC_i = total payment of the investment costs by the i-year which should be prepared by the government, as a compensation for the public safety user traffic to the cellular operator. [USD/year]

$Sub_{COMM,i}$ = total number of commercial subscriptions by the year-i.

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RCOMM	=	monthly revenue from commercial subscriptions.	[USD/month]			network per element.	
Ci	=	amount of equipment per element developed in the i-year.		SFi	=	Annual Spectrum Fee (LTE 700 MHz) in the i-year.	[USD/year]
CTOT,i	=	total amount of equipment per element operating in the i year.		n	=	time horizon.	[Years]
Capex	=	upfront cost to develop the network per element.	[USD]	D	=	discount rate.	[%]
Opex	=	annual cost to operate the	[USD/year]				

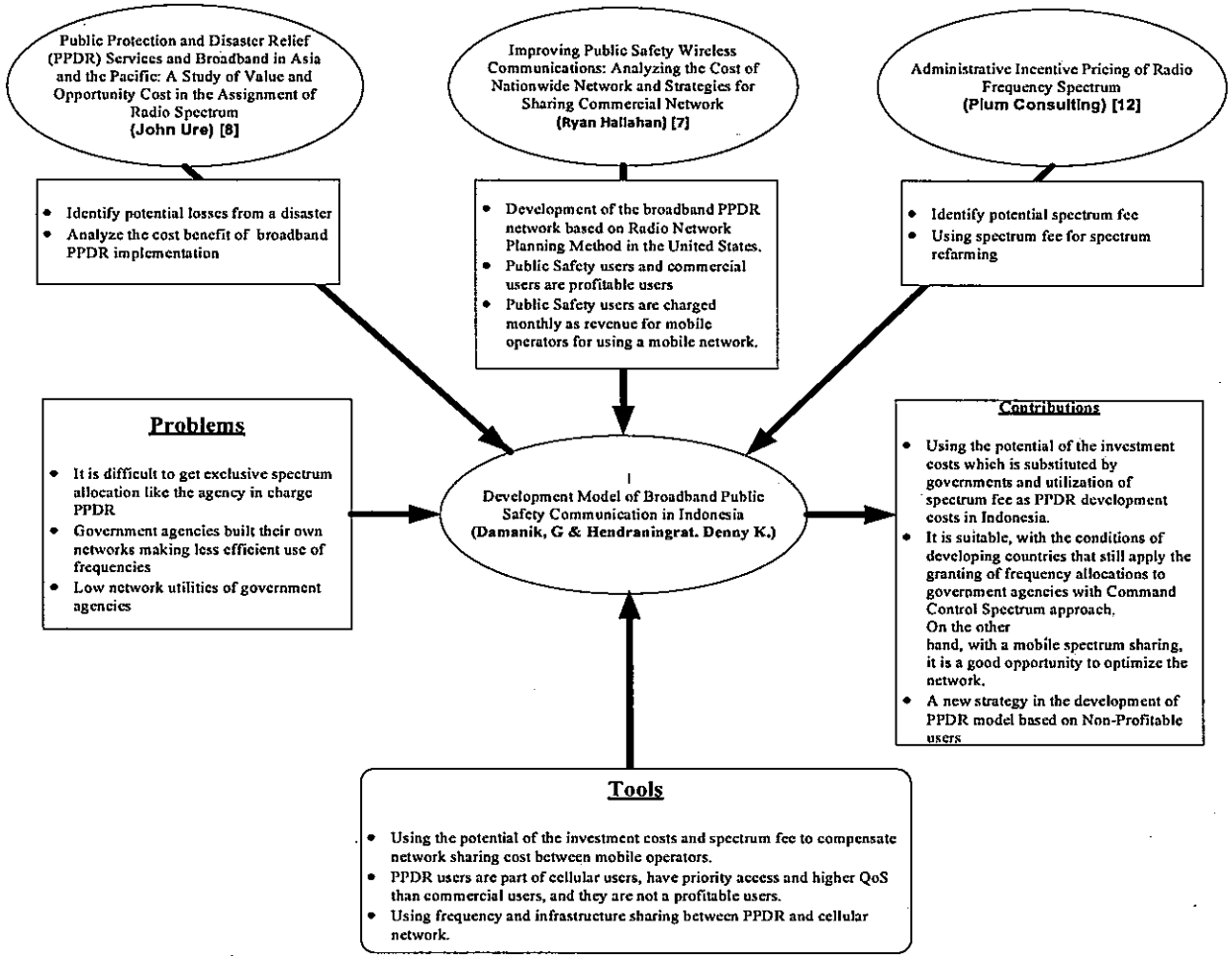

Figure 1. Development Model of a Public Safety Broadband Network

IV. Results and Feasibility Analysis of Public Safety Broadband Network Communications in Indonesia

The 3rd Generation Partnership Project (3GPP) has identified a 2x45 MHz bandwidth allocation for the Asia Pacific Region as a bandwidth allocation for Evolved Universal Terrestrial Radio Access (E-UTRA) technology, such as LTE technology [15]. In this study, the digital dividend ecosystem is divided into commercial LTE and public safety. LTE is more effective than Dual Carrier of High Speed Packet Access (DC-HSPA) when using a 2x20 MHz bandwidth system [16]. This simulation is designed by using 2 Mobile Network Operators (MNOs), where the MNO that is willing to share bandwidth and network infrastructure with the public safety agencies will be given a

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2x25 MHz bandwidth allocation and the other MNO will be allocated 2x20 MHz.

In this model, public safety users are cellular users who will be given priority access. The standard broadband QoS is described by 2 Mbps user throughput [17]. The services provided to the public safety broadband network include voice, two-way video, and data transfer.

In this study, the feasibility of broadband public safety communication is measured based on the NPV calculation, both from the government and cellular operator perspectives [18]. It consists of calculating the network (coverage and capacity) planning and then calculating the network cost deployment, so that the NPV can be determined.

A. *Defining Network Planning for Public Safety Communication*

1) Coverage Planning: This computation focused on performing a calculation of a maximum cell range of LTE 700 by QoS, which is outlined in Table I. In this study, it is assumed that the use of broadband LTE is in a fixed outdoor area. Based on the coverage planning method, the propagation conditions are one of the main factors to determine the cell size. In this study, link budget simulations are conducted to know the number of LTE e-Nodes B, which are needed to cover the planning area. The cell range prediction is calculated by adopting Okumura Hatta's [19] propagation model. An example of an LTE link budget calculation is shown in Table I.

TABLE I. LTE COVERAGE PLANNING

Freq Operation (MHz)	700			
RF PA power (Watt)	20			
Channel BW (MHz)	20			
Cell Edge Tput DL (Kbps)	2,048			
RF Load	80%			
BTS Antenna Height (m)	30	30	40	70
Cell Range (km)	1.62	1.95	4.89	6.80
Cell Area (km2)	1.71	2.47	15.55	30.05
Site Area (km2)	5.13	7.40	46.64	90.16
Inter Site Distance (km)	2.43	2.92	7.34	10.20

2) Capacity Planning: In a cellular network, capacity planning is required for the network optimization to meet the QoS requirements [20]. The calculation of capacity planning is started with an LTE rollout plan and the user prediction of the Indonesia cellular provider which has a 43% market share. So, the number of eNodes-B is calculated using the following formula [21]:

$$Number\ of\ eNodeB = \frac{Total\ Throughput\ Offered}{Site\ Throughput} \quad (3)$$

3) Defining Network Cost Deployment: Based on data from the vendor, the network infrastructure costs were calculated for the components, as shown in Table II.[22]

TABLE II. INFRASTRUCTURE COSTS

RAN	71,190	per unit
Core	12,000,000	per unit
Data Center and Application	714,695	per unit
RAN	35,171	per unit
Datacomm and Transport	16,268	per unit
Core	21,367	per unit
Data Center and Application	545	per unit

The total investment costs were calculated by multiplying the results of the network planning with the price list, which is shown in Table II. The total investment costs required to build the LTE network with a sharing system (first option) between a cellular operator and public safety is shown in Figure 2.

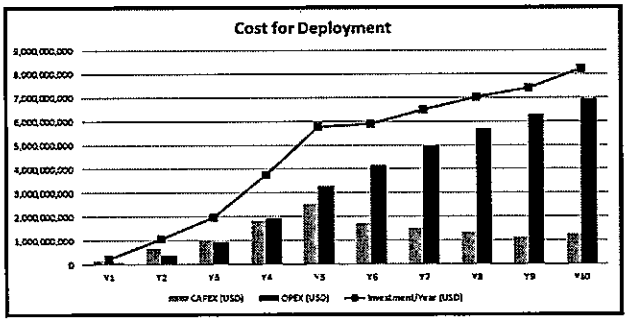

Figure 2. Total Investment Costs

B. *Defining NPV Calculation*

The NPV calculation is developed on the basis of revenues minus total expenses. From a government perspective, the revenue or government value is the total investment cost utilization as a budget which is cancelled by public safety agencies to build a public safety broadband network independently. On the other hand, the government cost is the total payment of the investment costs by the year-i which should be prepared by the government, as a compensation for public safety user traffic to the cellular operator. Figure 3 shows the calculation of government value and government costs.

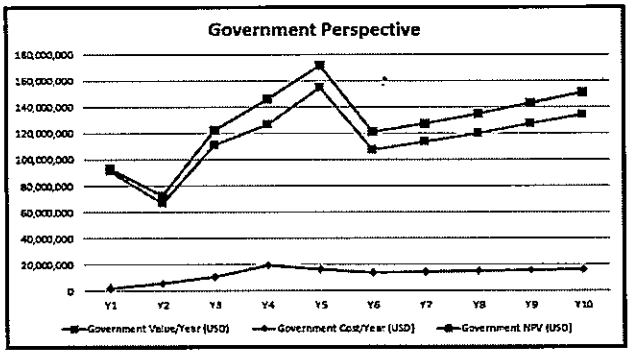

Figure 3. Government Perspective

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From the cellular operator perspective, the operator revenue (operator value) is the annual revenue per user (ARPU) of commercial users plus the compensation costs from the government (government costs). On the other hand, the operator costs are calculated from the total investment sharing network costs and annual spectrum fees. In the first year, the government value has a high value obtained from the capex (core networks) of public safety agencies to build a public safety broadband network independently. In the second year, the public safety network is not required to build core networks (only towers and e-NodeB). In the sixth year, the public safety network only requires maintenance fees (opex). So, if the Ministry of Finance diverts the costs of public safety agencies to build a public safety broadband network independently to become a sharing model, then it will be advantageous for the government. Figure 4 shows the calculation of operator value and operator cost.

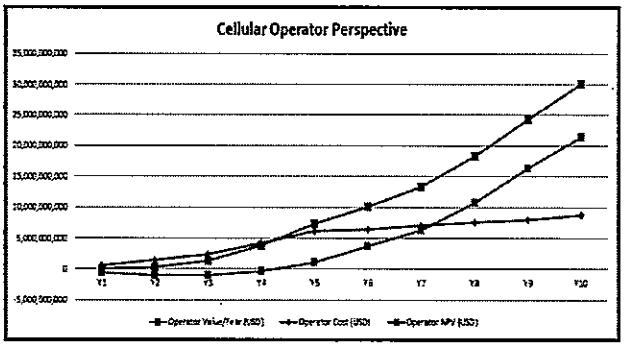

Fig 4. Cellular Operator Perspective

Figure 4 shows that the operator NPV has a positive value after the 5th year of LTE deployment. A cellular operator's revenue always increases after the 5th year of LTE deployment. It is concluded that cellular operators need to consider implementing the LTE technology.

C. Simulation Results of NPV Calculations

1) Cellular Operator Perspective: In this scenario, the cellular operator is only given two options of bandwidth allocation. This simulation will compare the results of the NPV calculation between these two options. In the first option, the operator using 2x25 MHz must share the bandwidth and network infrastructure with the public safety agencies. Based on the APT recommendation [16], public safety agencies will be given 2x10 MHz dedicated only for public safety communication. However, in this development model, it is designed with 2x10 MHz for sharing between public safety and commercial LTE and 2x15 MHz only for commercial LTE. In other words, the maximum bandwidth allocation is 2x25 MHz for commercial LTE and 2x10 MHz for public safety communication. In the second option, the operator only uses 2x20 MHz for commercial LTE. Figure 5 shows the NPV results for the first option (2x25 MHz) and second option (2x20 MHz) while setting a discount rate at 5% [18].

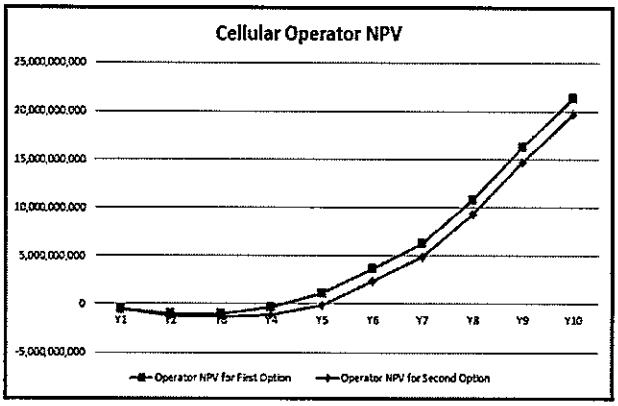

Figure 5. Cellular Operator NPV

Figure 5 shows that the NPV results for first option are higher than the second option. It is concluded that a cellular operator will obtain more benefits if the first option is taken rather than the second option.

2) Government Perspective: In this model, the Ministry of Communications and Information Technology acts as a grantor of the sharing policy between cellular operators and public safety agencies. On the other hand, the Finance Ministry acts as the owner of the budget for financing public safety broadband network implementation with a sharing concept between cellular operators and public safety agencies. Figure 6 shows the NPV results based on the government's perspective.

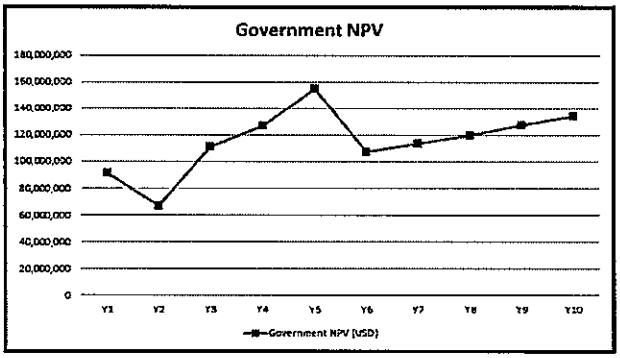

Figure 6. Government NPV

Figure 6 shows that the NPV results have a positive value with the implementation of this sharing model. This suggests that the government needs to consider implementing the development model of broadband public safety through a sharing scheme between cellular operators and public safety agencies.

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V. CONCLUSION

In this study, a public and private partnership model is developed to deploy the public safety network through a sharing model with commercial cellular operators. In this model, the investment cost utilization is a budget which is canceled for each of the public safety agencies to build a public safety broadband network independently. This study contributes to the cost savings of public safety network development.

The feasibility of this model is measured by net present value (NPV) calculations. From the cellular operator perspective, it is concluded that operators prefer the 2x25 MHz option, which must share bandwidth and network infrastructure with the public safety agencies. It has higher NPV than the 2x20 MHz option only for commercial LTE. From a government perspective, the NPV always has a positive value. So, it indicates that the government needs to consider implementing Development Model of a Public Safety Broadband Communications Network through a sharing scheme between cellular operators and public safety agencies.

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Honey-Copy - A Concept and Prototype of a Generic Honeypot System

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***Abstract*—In this paper, we present Honey-Copy, a concept and prototype for a honeypot system that can pinpoint modifications caused by attacks or intrusion for any honeypot. To achieve this, we track modifications without having to install any additional tools on them. We make use of cloning to identify whether or not a modification has been caused by the honeypot itself or an attacker or intruder. We briefly present our initial prototype and discuss the challenges to be solved toward a more complete and feature rich version of our prototype.**

Keywords–Honeypot; Detection; Security; Monitoring;

I. INTRODUCTION

Honeypots are decoy computer resources whose value lies in being probed, attacked or compromised [1]. The main difference between a normal computer resource and a honeypot is that the honeypot is not part of the production infrastructure [2]. One notable exception is the concept of Shadow Honeypots presented in [3]. As a consequence, attack detection methods do not have to cope with arbitrary production activity and the extraction of traces of attacks or intrusions is much simpler. After all, the traces do not submerge in production activities [2]. Honeypots are therefore a valuable tool to improve detection and reaction. However, since they do not protect a production infrastructure directly, they must be integrated with traditional security controls [4].

The lack of off-the-shelve products and solutions that allow automated and easy creation and monitoring of honeypots might be one of the reasons why the list of security controls used by a company does rarely contain one. Another reason might be that even though there exists many different kinds of honeypot systems and methodologies to analyze data produced by them, there is no system that satisfies all of the following four properties [2]: (1) the honeypots are not recognizable as such, (2) they are easy to configure and deploy, (3) the system reports activities related to attacks and intrusions only, (4) the core mechanisms (deployment, reporting of activities) work for any honeypot. Properties one and three are probably the most important ones. If these are not met, the system is of limited use since it would be easy to detect and it would be difficult to extract useful information from its reports. Properties two and four are relevant from an operational and business perspective. One of the major challenges is finding a solution to the problem of reporting activities related to attacks and intrusions without having to craft honeypot-specific algorithms or rules. At first glance, assuming that any activity on the honeypot is suspicious and should therefore be reported seems like a simple solution to this problem. After all, there is no production activity on a honeypot. While this often-made assumption might hold for activities like incoming network connections, it does not fit activities like the creation of a process or the modification of a file. Depending on the honeypot itself, we might see a significant amount of activity even on an "idle" system. This includes things like automated software updates, an application-specific timed or event-based tasks (e.g., sync or cleanup tasks) or log entries from arbitrary scheduled tasks. Furthermore, when considering property four, the assumption about incoming network connections might be wrong too - a honeypot might do updates using active FTP or it might run a distributed service that sees incoming connections from other parts of the service from time to time. It is therefore crucial to have a generic way to distinguish between activities of type *self* and *third party* with the former including any activity triggered (or expected) by the honeypot itself.

In this paper, we present the main idea and concept of Honey-Copy, a system that should overcome most of the limitations of today's honeypot systems. Our main contribution is a generic method to distinguish between activities of type *self* and *third party* and its integration in a general concept for a honeypot system. First, we provide an overview of Honey-Copy and discuss the basic idea of our generic approach to identify whether or not an activity is triggered by the honeypot itself or a third party (Section II) and we explain why an implementation of such a system is likely to be limited to high-interaction honeypots. Next, we introduce our prototype and discuss its implementation and evaluation (Section III). We then conclude our paper with a section on the challenges and next steps toward a more advanced version of our prototype (Section IV). A discussion of relevant related work can be found at the end of the paper (Section V).

II. HONEY-COPY - BASIC CONCEPT

The core idea of Honey-Copy is to make a clone of a honeypot and to put it behind a firewall that blocks incoming network connections. Since the clone cannot be accessed by third-parties, it exhibits activities of type *self* only. It should therefore be possible to identify and filter those activities from the reports of the honeypot system exposed to the attackers. Unfortunately, things like applications that create (temporary) files with random filenames or software updates that happen at different points in time make it difficult to implement an accurate and timely matching. This is why Honey-Copy can make up to n clones of a honeypot. By comparing them, patterns like random filenames can be identified and the chance that honeypot and clone(s) exhibit a certain activity of type *self* within a short time span can be increased. Hence, it should be possible to satisfy property (3).

Figure 1a shows the basic building blocks and setup of Honey-Copy. It consists of physical machines that make use of virtualization to run a host system and potentially many guest systems. The use of virtualization enables Honey-Copy to clone and deploy anything that can be provided in the form of a virtual machine image. This meets property (4) with respect to deployment. But this is not the only benefit of

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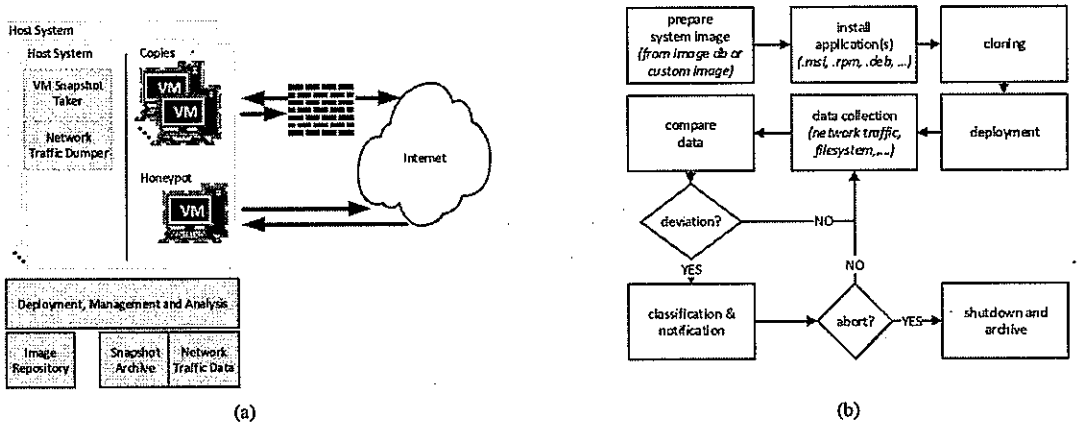

Figure 1. (a) Shows the basic setup of the Honey-Copy system and (b) the basic procedure it uses to deploy and manage a honeypot.

virtualization. Its use enables us to do the tracking of activities in the guest systems without installing any additional software and change to their configuration. In contrast to other honeypot systems, the honeypots deployed can be virtually identical to the production system they pose as. Hence, Honey-Copy can be said to satisfy property (1); the honeypot system itself does not make its honeypots more recognizable as such by itself.

The other two components running on the host system are the *VM Snapshot Taker* and the *Network Traffic Dumper*. The former can take snapshots of the guest systems, for example file-system or memory snapshots. The later can dump information about their network activity, for example full packet traces or flow level information only. This data can be captured and added to the *Snapshot Archive* or the *Network Traffic Data Archive*. It is then analyzed by the *Deployment, Management and Analysis* component, the heart of Honey-Copy. With the data available about the systems, different kinds of information like file or registry changes, running processes or network traffic can be checked for changes. From a data analysis point of view, the problem of identifying activities of type *self* by comparing this data from the firewalled clones and the honeypot itself is largely independent of the actual honeypot. The component has to learn or identify activities of type *self* from the clones and filter them from those reported by the honeypot. Hence, since the deployment mechanism as well as the activity-reporting works for any honeypot, Honey-Copy can be said to satisfy property (4).

In addition to the analysis task, it is also responsible for managing an Image Repository and for customizing and deploying images upon request. Unfortunately, it seems difficult to implement this in a generic and easy-to-use way for arbitrary honeypot types and configurations. One option to satisfy property (2) is to implement Honey-Copy for high-interaction honeypots only. In contrast to low- and medium interaction honeypots, these are real systems and not (partially) emulated or simulated ones. It seems, for example, practical to create a repository of images for many different operating systems and to use their software packaging and configuration mechanisms to quickly make and deploy a system that is a copy of a production web server or any other server or computer in a company network. In a corporate environment it would also be possible to use production server templates and mechanisms as a basis for this process.

Figure 1b illustrates the basic procedure to setup and manage an arbitrary high-interaction server honeypot in the Honey-Copy system. The first step is to choose an image from the *Image Repository* or to provide a custom image via an upload function. Next, additional applications and services can be installed and configured by providing them as package in the packaging format of the operating system, for example .msi for Windows or .deb for Debian Linux images or by using the configuration or packaging tool used by the organization. The packaging must allow for a fully automated installation of the application or service. Now that the image is ready, it can be cloned *n*-times and the honeypot and its clones can be deployed on the same or multiple physical hosts as outlined in Figure 1a. Data collection starts at the same time as the honeypot and its clones are turned on and does not stop until this honeypot is shutdown. In regular intervals, the data collected by the clones and the honeypot is compared and if deviations are found, they are classified and notifications are sent to those that subscribed to them. It is then checked whether the deviation found requires taking the honeypot offline, for example because it was hacked and the intruder started to attack 3rd parties in the Internet.

III. PROTOTYPE

In theory, the Honey-Copy concept meets all of the four desired properties. However, it is unclear whether or not it can be put into practice. To understand the related problems and challenges better, we built a an initial prototype of Honey-Copy.

A. Implementation

Our prototype consists of some Python scripts and a set of tools orchestrated by them. To manage and deploy the honeypots and their clones, we make use of Vagrant [5], a tool that is often used to create and configure lightweight, reproducible, and portable development environments. To deploy a honeypot, we first create a configuration file that specifies the type of machine to be used, the software that needs to be installed, and

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the way to access it. Based on this file, Vagrant can then create, deploy and launch an image for VirtualBox [6], a hypervisor that integrates well with Vagrant. When doing so, our prototype makes sure that the honeypot is cloned and that data capturing and the processes to detect activities other than *self* are in place and started.

For now, data capturing consists of recording full packet traces with tcpdump and snapshots of the file systems every *T=3600* seconds. This interval of one hour was chosen mainly to investigate the longer-term deviations between the clones and provide examples for activities of type *self*. For an actual detection setup, a much smaller interval is expected to be put in place. Whenever a new set of snapshots has been taken, the file systems of the honeypot and the clones are reconstructed, mounted and then scanned for differences using rsync. The reconstruction is required because we take differential snapshots to save storage space. In parallel to the file-system analysis, Pyshark with custom filters and rules (IP-Addresses, DNS-Names) is used to scan the network traffic dumps to extract communication partners that have not been seen by the clones. The result of the detection process is a report consisting of the differences in the file systems and the communication parters that are unique to the honeypot.

B. Evaluation

For an initial evaluation of our prototype, we deployed and tested the system with Linux and Windows based clones of typical web servers. For the evaluation, we compare the current status of the system to a perfect implementation of the Honey-Copy concept in terms of stealthiness, ease of deployment, attack detection and generic core mechanisms:

Stealthiness: The only two limitations of the prototype are that taking a file system snapshot of a virtual machine requires to suspended it and that the honeypots and clones are not physical but virtual machines. An attacker could detect the former using well-timed queries to the machine and the later might be achieved using fingerprinting methods like [7]. But the virtualization solution also supports snapshots of running machines, which could be implemented to mitigate the first limitation and as most organizations are using virtual machines at least in parts of their production infrastructure, this fact cannot be used as a sole indicator for a honeypot. Additionally, the only trace of Honey-Copy in the guest system is Puppet, an open-source software configuration management tool for Windows and Unix-like systems which is installed on them by Vagrants provisioning system. However, unlike honeypot specific logging and monitoring tools, its presence is not telling very much and it can be easily replaced with other tools. Other limitations exist but they are not introduced by the prototype itself but depend on how the system and its environment is configured and operated. For example, a public hostname like honeypot.company.com could be suspicious when used for a web server. And a system running a discussion forum with no activity in it might also look suspicious. As these factors are outside of the control of our solution and can be highly application specific, we consider them as out of scope for the prototype.

Ease of deployment: The prototype comes with the basic mechanisms and capabilities required to implement a user-friendly and easy-to-use interface to configure and deploy honeypots. However, for now it, the only interface is a command line interface. Furthermore, the *Image Repository* contains a few base images only.

Attack detection: The current mechanisms used for filtering activities of type *self* produces a significant number of false positives. One reason for this is that the prototype compares the file systems of the honeypot and its clones using the most recent snapshot only. For example, we observed many false positives because of automated software updates that did not happen or finish within the same snapshot interval. Another reason is that the comparison uses exact file matching. This turns files that are semantically the same but that have a different filename (e.g., temporary files with random filenames) or content (e.g., logfiles) into false positives. Another limitation is linked to the report generated from comparing the network traffic to the honeypot and the clones. This report lists communication partners seen by the honeypot but not its clones. Unfortunately, it contains a lot of entries that are not really interesting. This includes for example legitimate partners like search engine bots or Shodan [8] or illegitimate ones doing reconnaissance using known methods and tools. Furthermore, because the comparison of communication partners is done using exact matching, it cannot cope well with endpoints like content distribution networks.

Generic core mechanisms: Management and deployment works with any honeypot that is based on Windows or a Unix-like systems since these are the systems supported by Vagrant/VirtualBox. The same is true for the data capturing and comparison mechanisms since it does not depend on the actual system run in VirtualBox. Note that Unix-like includes most Linux distributions, Android and Mac OS.

IV. Challenges and Next Steps

In summary, we can identify two main challenges that the next version of our Honey-Copy must address. First, the system must provide a user-friendly and easy-to-use interface to configure and deploy honeypots. This can be done by writing an graphical user interface that compiles settings like the base images and the applications to be used by the honeypot into a suitable Vagrant file. The second challenge is more difficult to address. The mechanisms to identify files that are not modified by activities of the honeypot itself have to be able to detect files that are identical from a semantic point of view but that differ in content and/or have a different file name. To achieve this, generic heuristics that can detect patterns in file names or in the content of the files could be used. Another option would be to employ machine learning to search for such patterns. Furthermore, to cope for changes that might happen at different points in time on the honeypot and the clones, the mechanism must consider multiple snapshots from different points in time. What this means in terms of a delayed reporting and alerting is an important point of the evaluation of such an approach. While the focus is clearly on the file system part, there is also room for improvement with respect to the communication partners (attackers) reported by Honey-Copy. Endpoints like Windows update servers should not be reported as problematic because the honeypot and the clones use a different server for the update. The main challenge here is to make the matching mechanism aware of content distribution networks and similar behavior, for example by using third party tools, domain name resolution analysis or URL based heuristics to detect them.

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We plan to address these challenges in the next version of our prototype.

When these have been addressed, there are still many more ways that the Honey-Copy prototype could be improved. If we consider that activities of category *third party* can be subdivided further into *benign*, *attack* and *intrusion*, it becomes clear that depending on the purpose of the honeypot, it could be required that Honey-Copy can filter activities of type *benign* and maybe even *attack*. *benign* activities are triggered accidentally or without malicious intent. This includes scanning from legitimate sources like Shodan HQ [8] or search engine bots, connection attempts that are the result of someone mistyping an IP address or URL and backscatter [9] traffic. Activities of type *attack* are triggered by an attempt to compromise the honeypot, for example using the Metasploit framework [10] and those of type *intrusion* are triggered by a successful compromise of the honeypot. To identify them, it could be useful to correlate network and file system activities and to employ an intrusion detection systems like Snort or Bro to fingerprint known attacks. We plan to research whether and how this could be done without having to sacrifice the generic nature of Honey-Copy when moving toward the third version of our prototype. Any other improvements like for example the addition of memory snapshots to the sources of information, is left to prototypes beyond version three.

V. Related Work

High-interaction honeypot systems that have similar goals in terms of stealthiness, attack detection, ease of deployment and honeypot configurations (operating system, applications etc.) are HI-HAT [11], HoneyBow [12], and Sebek [13]. Like Honey-Copy, these systems are server honeypot systems. In addition, we review a number of projects in the client honeypot sphere that are interesting because of the way they approach the problem of differentiating between real attacks and other activities.

HI-HAT [11] implements a system which converts normal PHP web applications into usable server honeypots. Their solution mainly consist of two components: The first component converts an arbitrary PHP application into a honeypot by adding monitoring capabilities to functions that handle requests from the outside. The second component consists of a GUI which lets an operator analyze the data gathered by the honeypot. To decrease the amount of false positives (generated by web crawler or other legitimate requests) the system makes use of white- and blacklisting based on general attack patterns. Furthermore, it allows the creation of custom filters to take into account different behavior of applications. Similar to Honey-Copy, it implements a way to deal with false positives generated by generic PHP applications.

HoneyBow [12] on the other hand is a high-interaction server honeypot which is designed for generic applications. It makes use of virtual honeypots to automate the management and monitoring of the system. In order to collect the necessary data to detect an attack, it implements three different tools (MwWatcher, MwFetcher, MwHunter) that search for malware binaries in the virtual filesystem and the network flow. Similar to the methods used in Honey-Copy, the MwFetcher component compares the content of the honeypot filesystem to the one of a clean copy that was taken at the start of an operation. The files which were new or altered and are flagged as executables are then further processed as malware. MwWatcher on the other hand is installed on the honeypot itself and can detect changes to the filesystem in real time. MwHunter finally inspects the network traffic for packages that contain executable malware. Each of the tools used in Honeybow has its own advantages and limitations. The MwWatcher component for example can be easily detected and disabled by an attacker. While this approach increases the chance of detecting an attack it also decreases the number of attacks since the system can be easily identified as a honeypot. Furthermore, it cannot deal with updates on the honeypot since that would likely change a number of executables compared to the clean copy.

Sebek [13] is another popular high interaction server honeypot system. It provides a data capture tool which monitors all actions of an intruder by capturing all `sys_read` calls. Furthermore, it tries to capture and send the logged data as stealthy as possible. Nevertheless, there have been a number of publications, notably [14], which show a way to detect and even disable Sebek. Another limitation of the tool is that there is no filter for the captured data. A manual analysis is required to distinguish a real attack from a false positive caused by normal system activity.

In the area of client honeypots Capture-HPC [15] and Capture Bat [16] present similar ideas. Both systems are high-interaction honeypots that make use of exclusion and inclusion lists. The former specifies acceptable non-suspicious activities to be ignored by the detection mechanisms. The later contains activities that are considered to be malicious. Such lists can be created for resources like the Windows registry, the file system, or processes. Capture-HPC also supports regular expressions to group a number of exemptions together. Currently, these list have to be created by hand and both systems run on Windows only. Another limitation of the approach is that any change to the honeypot (software updates, different mix of applications, etc.) is likely to require a modification of the exclusion list. UW-Spycrawler [17] on the other hand, makes use of trigger conditions (blacklists) which are specific to the browser used in the client honeypot setup. These conditions define activities which cannot be caused by the browser itself. Similar to the use of whitelists, these lists have to be created manually for a specific application (browser). Shelia [18] on the other hand takes a different approach to the problem without white- or blacklisting. The researcher behind the project proposes a system where the focus is on a reduction of false positives. It gathers data of an attack by monitoring the registry changes and file system actions generated by a process. The detection of said attack is done by analyzing from which memory address an API call was invoked. Once this address is obtained, it is checked whether it points to an executable memory location. If this is not the case an alarm is generated. This method allows to detect buffer and heap overflows that are exploited by an attacker. The downside of such a system is that it produces a higher number of false negatives since there are ways to circumvent the detection [19]. Pwnypot [20] take this idea even further by implementing more methods to detect arbitrary shellcode. It can detect ROP-Exploits and ASLR/DEP-Bypasses used by attackers.

VI. Conclusion

The main contribution of this paper is a concept and an initial prototype of Honey-Copy, a system that uses cloning

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to address the problem of distinguishing activities of the honeypot itself from those of attackers. We explain why and how our concept could be used to build a honeypot system that comes close to a perfect one in terms of stealthiness, ease of deployment, reporting of activities triggered by attackers and independence of the core mechanisms from the actual honeypots to be deployed. Other systems violate at least one of these properties. Our evaluation of the prototype shows that the basic mechanisms of our concept work and allow for a stealthy and generic implementation of the system. However, to satisfy all of the properties, the current method to compare the state of the clones to the state of the honeypot has to be replaced by a more sophisticated one and an easy-to-use graphical interface to configure and deploy a honeypot has to be developed.

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Security Testing Over Encrypted Channels on the ARM Platform

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Abstract—**Security Testing has been applied for many years to detect vulnerabilities in applications. With the increasing demand for encryption to protect the confidentiality of network data, the requirements have changed. When proprietary, closed source software uses end-to-end encryption, security testing tools which are fuzzing the application layer over network with plaintext data will eventually fail. The Intrusion Detection Framework for Encrypted Network Data (iDeFEND) framework circumvents this problem without violating the security of the end-to-end encryption. Unfortunately, the framework cannot be used on the Advanced RISC Machines (ARM) platform, since it uses architecture depended features of x86. In this paper, we transfer iDeFEND to the ARM architecture and thereby, make it suitable for testing applications on embedded devices. In addition, we discuss the limitations of the current framework and improve it with novel methods to provide a more generic approach for security testing. We present a generic method for inspecting data on encrypted channels. Our approach does not require any knowledge of the structure of the wrapper function for receiving and decrypting like iDeFEND. Furthermore, we present a solution to test and inspect applications that are using packet queues. Finally, we evaluate our approach on popular mobile applications.**

Keywords–security testing; network security; reverse engineering; encrypted communication; embedded security.

I. INTRODUCTION

Nowadays, a wide variety of applications use encryption to protect their confidential data in network communications. Encrypting the network traffic prevents attackers from accessing sensitive data, but cannot stop them from exploiting security flaws in the implementation to achieve crashes, intrusion or code execution on the system. Security testing is responsible for detecting these vulnerabilities at an early stage. However, even powerful testing frameworks are blind when end-to-end encryption is applied and can only randomly generate or mutate packets. Additionally, the encryption layer makes it difficult for security testers to validate the remote program which increases the risk of missing faults. Solutions to this issue usually require a high amount of reverse engineering, since most of the target applications are closed source. Other solutions add an additional node to the encryption (e.g., a proxy server) and use it to access the plaintext data. This makes the communication more insecure. End-to-end encryption is designed to only terminate at the destination application to fulfil its required security. As a consequence, the plaintext can only be accessed by reverse engineering of the encryption algorithm and key, which is in general highly complex and time-consuming and thus, not feasible.

Another solution is presented by the generic framework iDeFEND [1]. The framework sustains the end-to-end encryption and leaves the communication channel untouched by extracting the plaintext data directly from process memory. It automates the reverse engineering process of applications by only relying on the detection and hooking of network and encryption functions. As a result, even closed source software can be handled at a much smaller effort. Although the framework has a generic design, it still has limitations. iDeFEND was implemented and evaluated for the x86 architecture, but nowadays most of the networking applications are running on mobile devices like smart phones or tablets whose processors are primarily designed by ARM. Since the framework uses hardware dependant features, its concept must be adapted to the specifics of the new platform.

Additionally, mobile applications tend to buffer network packets in a queue before sending them. This compensates bad connectivity, but results in a conflict with the current approach of iDeFEND. Furthermore, the framework relies on the presence of a specific wrapper function to inspect the received, unencrypted network data. In practice, this function can be more complex than expected by the framework and requires additional reverse engineering.

We overcome these shortcomings and extend the iDeFEND system. We provide a framework that allows to use common security testing tools for encrypted network applications. In summary, our contributions are the following.

- **Security testing over encrypted channels on ARM**
  We provide the same features of iDeFEND for ARM as it already does for x86. This means, we enable security testing on ARM devices when the target applications are communicating over an encrypted channel.
- **Improving iDeFEND to support applications with packet queues**
  We improve the current approach of iDeFEND with a new feature that makes it capable of handling applications with packet queues. Our new method allows to inject plaintext data into the packet queue and thus, into the encrypted communication channel.
- **Improving iDeFEND with a generic method for data inspection**
  We extend the concept of iDeFEND by a generic method for extracting received network data. We describe how this method enables the inspection of server responses without reverse engineering the function in detail.

The remainder of this paper is structured as follows. First, we present related work in Section II. In Section III, we summarize and describe the approach of the existing iDeFEND

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framework. How the framework is used for security testing is explained in Section IV. In Section V, we present the limitations of the current concept and introduce our design improvements. In Section VI, we discuss the conceptual transfer of iDeFEND from x86 to ARM. The implementation of iDeFEND on ARM follows in Section VII. In Section VIII, we evaluate our framework and summarize the paper in Section IX.

II. Related Work

Many different fuzzing frameworks exist that facilitate the security testing of network communicating applications. Gascon et al. [2] present a fuzzing framework for proprietary network protocols which uses inference to create a generative model for message formats. Their approach relies on unencrypted network traffic, similar to many other smart automated model-based [3][4][5] and grammar-based [6][7] fuzzing techniques. Nowadays, there is also a vast amount of powerful commercial fuzzing and vulnerability scanning frameworks like Defensics [8], Nessus [9], beSTORM [10], Peach Fuzzer [11], honggfuzz [12] and american fuzzy lop [13] on the market available. They provide very complex and sophisticated algorithms to cover many different areas of fuzzing and vulnerability testing, but overall also lack proper support of encrypted network communications.

Biyani et al. [14] address this issue and present a solution by extending the SPIKE fuzzing framework to support encrypted protocols. They add a SSL wrapper to the existing plaintext fuzzer which allows to communicate with the target test application over an encrypted tunnel. This way, the fuzzer can inject its plaintext test data into the encrypted channel and test the target application for vulnerabilities. This approach, however, is limited to Secure Sockets Layer (SSL) encryptions which only represent a small part of proprietary software products. Another drawback is that their implementation is customized and only applicable for the open source fuzzer SPIKE. Tsankov et al. [15] introduce a different solution that allows a more generic fuzzing of encrypted protocols. Their approach is based on the knowledge of the encryption key and algorithm which is problematic from a security point of view.

As of yet, there is no good solution to testing of applications with encrypted network traffic. Our approach is different. We use the iDeFEND framework [1] to have a layer between test program and test framework. This additional layer makes the encryption transparent without violating the security of end-to-end encrypted communications. This way, we reduce the problem of testing encrypted protocols to the testing plaintext protocols and thus, enable the usage of many already existing testing tools.

III. Design of iDeFEND

In this section, we summarize the iDeFEND [1] framework and describe how the framework enables inspection and injection of plaintext data in encrypted communications. We also show why the approach is well suited for security testing.

Usually, applications implement encrypted communication with the help of two wrapper functions. One takes plaintext data, encrypts it and sends it over the network. This function is labelled EnCrypt & Send (CaS). The other one, Receive & DeCrypt (RaD), is responsible for the reversed process. It receives ciphertext data from the network and decrypts it afterwards. Together, these functions form the transition between plaintext and encrypted network data in our target applications. The iDeFEND framework uses this property to get access to the unencrypted network data by detecting and hooking both wrapper functions. This way, the application itself serves as an abstraction of the encryption implementation and allows us to inspect the plaintext communication without knowing the encryption algorithm, key or even source code of the application.

Controlling the wrapper functions empowers us to inspect, intercept, modify and inject new plaintext messages into the encrypted channel. For security testing, especially fuzzing, the tester primarily wants to send test data to the remote application and thus, heavily relies on the injection of packets. Since the CaS wrapper function takes a plaintext data pointer as argument, encrypts it and sends it over the network, test data can be injected by passing its pointer to the CaS. This can be realized in two different ways. Either active by code injection to the target process and calling CaS directly or passive by hooking calls to CaS inside the application (e.g., with a debugger) and replacing the input plaintext pointer with a pointer to the test data. In both scenarious, the test data is sent to the remote application, the response is extracted at the RaD and the test case can be evaluated.

The functionality of iDeFEND is logically split into three modules: a detector, a collector and a monitor module. The detector module is responsible for locating the wrapper functions in memory. Afterwards, the collector module hooks the located wrapper functions and passes the plaintext data to the monitor module. The monitor module simply is an interface for external programs. The detector module is a debugger that is specifically geared towards the automated reverse engineering of the wrapper functions. In general, applications with encrypted network traffic implement the functions *crypt*, *send* and *receive*. Send and receive are public library functions of the operating system and thus, getting their addresses is simple. The crypt function, depending on the underlying algorithm, can either be one or two functions. In case it is part of a library, getting the addresses is simple. They can be extracted by looking at the export table. In case it is not, the paper for interactive function identification [16] introduces an approach that facilitates the identification. By definition, the wrapper functions successively call the pairs encrypt and send, and receive and decrypt, respectively. iDeFEND uses this property of CaS and RaD to identify the wrapper functions through backtracking with a debugger. The backtracking is realized with breakpoints on send, receive, enrypt and decrypt. When the debugger notices a break on one of the function pairs, it can determine the wrapper functions from the call stack. Sometimes data is only encrypted for internal purposes and never sent over the network. In order to filter those cases, iDeFEND compares the data pointers between the function calls and validates the data flow. Data for network communication is detected, for instance, if the output pointer of the encryption matches the input pointer of the send. Otherwise, the calls of encrypt and send were independent and did not originate from the wrapper function, but from an internal encryption.

The collector module hooks the detected wrapper functions and extracts the network data. It is either part of the debugger or a module that is injected into the target application.

- **Collector Module as a Debugger**

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Extracting the plain text with a debugger is simply achieved by inserting breakpoints on the wrapper functions CaS and RaD and extracting the data from their function arguments and return values, respectively. Since the debugging procedure is comparably slow, the target application is slowed down to a certain degree.

- **Collector Module as an Injected Module**
  A faster solution is to directly place code in the target application with a module injection. An assembly hook that is placed at the function prologue of the wrapper functions CaS and RaD redirects the execution to the injected code. The hook consists of a machine instruction like a jump or a call that substitutes the first few bytes of the function prologue and a function stub that is executed by the jump. The extracted plain text data then is passed via Inter Process Communication (IPC) to the monitor module.

IV. Security Testing with iDeFEND

In this section, we present an use case of the iDeFEND framework and explain how it enables security testing of encrypted network applications.

The iDeFEND framework is designed to support security testing of proprietary, closed source software. This type of testing is referred to as black box testing, since we examine the functionality of the programs under test without knowing details on the development, program internals or implementation. Even though the program is a blackbox, security analysts still can use powerful fuzzing tools to test for commonly known vulnerabilities. They can, for example, test a server against blind format string attacks [17]. In this scenario, a security analyst sends strings to the server application and afterwards validates the response and thereby, the outcome of the test case. For applications that use an encrypted communication channel, this approach of security testing inevitably fails. Since no information about implementation and design of the target application are available, also the internals of the encryption are unknown. As a result, there are only two possible responses of the target application to plaintext test messages from the security analyst. Either the test message does not fulfil the specification of the protocol and thus, the decryption fails and the test data is rejected. Or the decryption handles the test data, but changes it arbitrarily and is interpreted differently to the intentions of the tester. In both cases testing fails. Figure 1 illustrates this scenario with the orange arrow representing the test string data. The diverging arrow heads symbolize the misinterpreted test data after decryption that does not trigger the intended functionality any more.

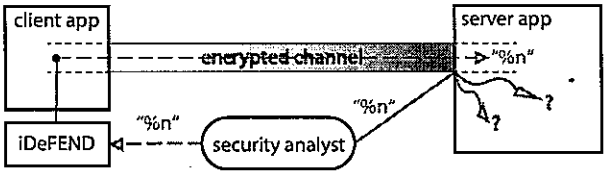

Figure 1. Security testing of encrypted communications.

If the security analyst wants to test the server application as intended, he can use the iDeFEND framework. Using the framework for testing circumvents the issue of encryption. It provides an interface for the security analyst to the client application and thus, access to the encrypted channel. This way, the security analyst can pass the plaintext test data to the framework interface which uses the client application to encrypt and send the data. The sent data then is decrypted correctly at the server application and eventually triggers the intended functionality. Figure 1 shows the flow of the plaintext test data with the dashed, green arrow. The security analyst passes the data to iDeFEND which injects it into the encrypted channel. The test data enters the server application and is decrypted correctly.

V. Improvements of iDeFEND

In this section, we discuss the limitations of the current iDeFEND approach for software testing and present our improvements. We put focus on the conceptual weaknesses of the framework and separately address the transfer to ARM in the following section VI.

Currently, iDeFEND implements the identification of the wrapper functions with backtracking. Therefore, the call stacks at successive calls to the logic function pairs are intersected. Knowing, for example, that wrapper CaS is responsible for calling encrypt and send, means that the call stacks of encrypt and send must have an intersection at the wrapper function. This approach introduces a weakness. The wrapper functions can only be detected when they successively call encrypt and send. For applications that use a message queue in network communication, this assumption is never met.

Additionally, iDeFEND defined the RaD wrapper function to return the decrypted plaintext packet. It inspects the plaintext data by hooking the function at its return instruction. This requires detailed knowledge about the structure of RaD and obviously the presence of a RaD.

In the following subsections we propose solutions to those two problems.

A. Test Data Injection into Packet Queues

Applications that use a packet queue construct the packet, encrypt it and then append it to the queue. At any other point in the program the encrypted packet is taken from the queue and sent over the network. As a result, the call graphs of encrypt and send do not intersect at the CaS, because there is no CaS any more. This introduces a weakness of the iDeFEND framework. Without the detection or presence of the wrapper function, the framework cannot inspect, intercept or inject data into the communication. This means, for applications that use packet queues it is not possible to use iDeFEND for security testing. We addressed this issue and analysed the program structure of such applications and came up with a solution. Even though the applications do not implement a CaS function, they still have a function that takes the plaintext data, encrypts it and appends it to the queue. This function can be used in the same manner as the CaS to inspect, intercept and inject data to the communication. The only difference is that the sending is delayed in time, which is irrelevant to our scenario of testing. Figure 2 illustrates the control flow graph for this new function type EnCrypt & EnQueue (CaQ). Identifying the address of this wrapper function requires a new approach. Usually, programs implement protocols that construct different packets for many different purposes. This means that for each packet the wrapper function is called from a different calling

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context, but their call stacks always intersect at the CaQ. For this reason, our solution to the issue of identifying the CaQ function is to record all call stacks at encrypt and intersect them to find the wrapper function. In order to validate network traffic in this scenario, it is also necessary to use a different procedure to the previous. Since the data is copied to the queue, the pointers at send and encrypt vary. We handle this problem by not saving the pointer itself, but the whole buffer. At the validation of the data flow we simply compare the contents.

The CaQ function can be identified as soon as at least two call stacks from different calling contexts are collected. The intersection of the collected call stacks identifies the wrapper.

This proposed method extends iDeFEND to support applications that implement packet queues.

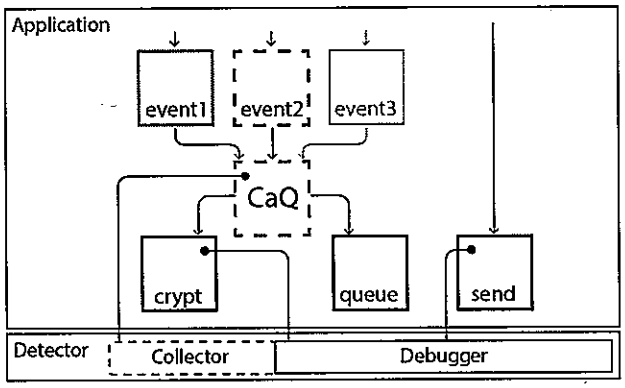

Figure 2. Control Flow Graph (CFG) for wrapper function CaQ.

B. Generic Approach for Data Inspection

The second problem of iDeFEND is that the current approach assumes the existence of a specially structured RaD function which in general is not the case. The RaD is assumed to return the decrypted plaintext data. iDeFEND hooks the RaD at the return and extracts the plaintext data. However, many applications do not implement this type of wrapper function. In general, the receiving wrapper function is a loop that never returns. It calls receive and passes the data to a parsing unit that finally decrypts the data. Furthermore, without knowing the structure of the RaD, the current iDeFEND cannot inspect the plaintext data. The correct offset and the information about the correct register or data pointer have to be known at this point.

We analysed this issue and came up with generic solution. Our approach is based on the assumption that data that is received over network is always decrypted at any later point in the program. Therefore, we store all incoming data at the function receive and wait for it to be decrypted. When the decryption function is accessing the data, we can extract the plaintext after the decryption has completed. This way, we do not need the presence of wrapper functions or knowledge about the function structure, but only require the presence of the the basic functions decrypt and receive. Additionally, our improved approach does not even rely on frame pointers.

Similar to the original approach, we also break on receive and decrypt. However, we identify data that is received from the network not by comparing the pointers of data, but by comparing the content of input and output buffer between receive and decrypt. The idea is the same as it was for validating data that is going to be send over the network for the CaQ. When the decrypt function returns and we validated that the encrypted data was received from the network previously, we extract the plaintext data from the returned buffer. The extracted data then can be passed to the tester for inspection.

With this method we extended iDeFEND to allow the inspection of unencrypted server responses, even though the application does not implement a wrapper function and use frame pointers.

VI. Transfer to the ARM Architecture

In this section, we discuss the transfer of iDeFEND to the ARM platform. We present the key differences between x86 and ARM with respect to debugging with hardware breakpoints, data extraction at function calls, call stack reconstruction from the stack and hooking of functions on machine code level.

A. Using Hardware Breakpoints for Debugging

Both architectures x86 and ARM implement both hardware and software breakpoints. Hardware breakpoints offer a better performance, do not require modification of the executable code and thus, are less obvious to detect. This makes them perfectly suited for implementing the detector module of iDeFEND.

In general, only a few hardware breakpoints are available per processor, but this is no limitation, since the specification of x86 offers up to four and ARM up to 16 hardware breakpoints. Implementing the detector requires at most four breakpoints. On x86, each debug register represents a breakpoint and holds the target address. A shared control register holds flags to enable, disable and configure each breakpoint. On ARM, hardware breakpoints consist of two registers: a control and a value register [18]. The value register stores the address of the breakpoint and the control register contains breakpoint options that allow, for example, to link different breakpoints, enable or disable them, specify the privilege and exception level the breakpoint debug event is generated on.

B. Extracting Data from Procedure Calls

The collector has to extract data from the function parameters on breaks. Since we break on function prologues, which means on the first instruction of the routine, we can access the passed parameters as specified by the underlying calling convention.

ARM, in contrast to x86, specified its own procedure call standard [19]. On ARM, the first four parameters are always passed in the first four registers `R0` to `R3`. Every additional parameter is pushed to the stack. Since the *Stack Pointer* register always holds the address of the top of the stack, the arguments five and higher can be accessed with help of the stack pointer register and the argument offset.

In case the output buffer is passed through the return value of a function, the *Link Register* can be used to access it. The *Link Register* is dedicated to hold the return address of the current function. The return value is passed through register *R0*.

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TABLE I. PRESENCE OF STACK POINTERS WITH DIFFERENT COMPILER SETTINGS

GCC Flag	Optimization				Offset to next frame pointer (FP)
	O0	O1	O2	O3	
no flags	✓				FP - 4
-mapcs-frame	✓	✓	✓	✓	FP - 12
-fno-omit-frame-pointer	✓	✓	✓	✓	FP - 4
-mapcs-frame fno-omit-frame-pointer	✓	✓	✓	✓	FP - 12

C. Call Stack Reconstruction

In order to identify the wrapper functions CaS and RaD, we want to intersect the call stacks and therefore, have to reconstruct them from the program stack. In a program every function call pushes a frame to the stack and pops it on return. The call stack can be reconstructed by unwinding the stack frame by frame. On ARM, unwinding the stack is complex. In general, the architecture does not provide a dedicated frame pointer register for the address of the first frame. Depending on the optimization level of the underlying compiler, frame pointers might not even be present on the stack. This is problematic, since it is highly complex to reconstruct stack frames without having frame pointers, as it requires a sophisticated analysis of the stack. Table I illustrates the effects of different settings on the generation of stack frames for the GCC compiler. The flags *mapcs-frame* and *fno-omit-frame-pointer* force the compiler to preserve stack pointers throughout all optimization levels. The only difference is that the pointer offsets vary. Without them, the compiler only generates stack pointers for optimization level O0, which means no optimization. In the default case, without any particular flag specified, frames are properly build by the compiler.

D. Hooking Functions

Injecting the collector module into the target process requires a redirection of the control flow from the original code to the injected module. Therefore, a hook is placed in the executable code at the prologue of the target function. Generally speaking, this means substituting the first bytes of the function prologue with a branch instruction. The replaced code must be backed up and executed later on, before jumping back to the original function.

On ARM, instructions have a fixed length of four bytes, which makes substitution of instructions simple. However, multiple types of prologues exist. This is problematic when the first instruction is program counter dependant and thus, cannot be moved. This happens on ARM, for example, when compilers use constant pools. Otherwise, when the instruction is independent of the program counter, the instruction can be moved and a hook is possible.

The actual branch can be implemented with a memory load that allows to target the full 32 bit address space. Since it modifies the program counter directly, the hook consists of only one instruction plus memory space that is holding the target address. Since compilers use multiple bytes of padding between two procedures in memory, this padding is a suitable location to place the address.

VII. IMPLEMENTATION

We implemented the improved iDeFEND framework on an ARM device that is running a Linux operating system. We chose Linux, as most of the target ARM devices like smart phones, tablets or embedded boards are either running Linux or Android, which is also based on the Linux Kernel. We used a Raspberry Pi 2 embedded board that is equipped with a 900MHz quad core ARM Cortex-A7 processor and 1GB RAM. It was running a Linux distribution Raspbian 4.1.13-v7 as operating system. For the sake of efficiency, portability to Windows and independence of other programs and their implementations, we decided to write our prototype as a stand alone C program.

The implementation consists of two parts. First we present the detector module, followed by the implementation of the collector module.

A. The Detector Module - a Debugger based on ptrace

We implemented the detector on top of the *ptrace* debugging API by setting four hardware breakpoints for each of the target functions.

1) Finding addresses of Send and Receive: Since Linux maps the whole binary object to memory, the virtual addresses of send and receive can be calculated by adding the offsets in the binary to the base address of the module process space. We retrieve the base address and path to the binary on disk from the directory */proc*. We then use the utility *nm* to find the offsets inside the binary.

2) Detecting Successive Calls to Function Pairs and Locating the Wrapper Functions: In order to locate the wrapper functions, we identify successive calls by extracting the function arguments at encrypt and at receive, and see if they match the input pointers at send and decrypt. For the special CaQ case, we copy the whole buffer instead of only pointers. We track the data per thread, together with a time stamp. A 15 seconds time out prevents internal encryptions to stay infinitely long in memory. We implemented stack unwinding for applications compiled with *-mapcs-frame*. As described in Table I, each frame pointer minus twelve then points to the previous pointer. After reconstruction, we intersect two call stacks by searching for the first frame that appears in both call stacks.

B. The Collector Module - Speed Up with Module Injection

We implemented the collector in both variants debugger and injected module. For injection, we implemented a call to *dlopen* that uses the dynamic loader of Linux to load objects at runtime. Finally, we placed the hooks at the wrapper functions and detoured the execution to the injected module.

VIII. EVALUATION

We have evaluated our improved iDeFEND framework for five applications. Beside the required criterion of encrypted network communication, we wanted to have at least one messenger, one file transfer and one secure shell application. These types implement different network protocols which handle text messages, binary files and customized commands. Furthermore, we wanted to have at least one test application that is single-threaded, multi-threaded, uses the console for user interaction and implements an own Graphical User Interface (GUI). In order to have ground-truth information of the wrapper functions, we used open source applications. Table II gives an overview of the selected applications telegram-cli (v1.4.1), uTox (v0.7.1), PLINK (v0.67), PSFTP (v0.67)

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TABLE II. DESCRIPTION OF THE OPEN SOURCE TEST APPLICATIONS THAT RUN ON A RASPBERRY PI 2

Name	Type	Data Category	UI	Threading
telegram-cli	Messenger	Text	Console	Multi
uTox	Messenger	Text	GUI	Multi
PLINK	Secure Shell	Commands	Console	Single
PSFTP	File Transfer	Files	Console	Single
PSCP	File Transfer	Files	Console	Single

TABLE III. EVALUATED APPLICATIONS

Name	Send	Receive	Wrapper Type
telegram-cli	Write	Read	CaQ
uTox	SendTo	RecvFrom	CaS
PLINK	Send	Recv	CaS
PSFTP	Send	Recv	CaS
PSCP	Send	Recv	CaS

and PSCP (v0.67). The second column states the type of the application. The third column shows the type of data that is primarily transferred by the protocol. The last two columns indicate whether the application implements a GUI or is multi or single threaded, respectively.

Table III summarizes the results of our evaluation. The first column contains the names of the applications. The columns send and receive state the system library functions the application used to communicate over the network. The column Wrapper-Type states whether a CaS or CaQ function is implemented. Briefly summarized, we were able to inspect, intercept and inject data for all five applications. Except for Telegram, all applications implement the CaS function. Telegram implements a message queue and therefore, uses the CaQ. With the improved approach we were able to detect it and use it for packet injection. We were also able to use code injection and hooking of the wrapper functions on all five applications.

IX. Conclusion

With the rising demand for confidentiality and thus, encryption in consumer level and commercial software, security testing faces new challenges. Currently, existing testing tools only have poor or no support at all for encrypted network communications. That is precisely the reason why we proposed a generic solution to this issue by using the iDeFEND framework. The framework makes the encryption transparent and thereby, does not violate the security of end-to-end encryption. Since iDeFEND cannot be used on the ARM platform and nowadays many network applications are from the mobile sector and thus, use ARM processors, we transferred it to the this architecture. Additionally, we pointed out the limitations of the current framework and introduced improvements to it. Our novel methods provide a more generic approach for security testing. We introduced a method that allows to inject test data into network applications that use message queues. Our solution detects and hooks the function that is responsible for encrypting and enqueuing packets.

Furthermore, we introduced a generic method to inspect the incoming unencrypted network data. Our method does not rely on the presence of a receive and decrypt wrapper function or even frame pointers.

With the extended iDeFEND framework we provide an interface to the encrypted channel of an application that allows already existing testing tools to work as intended, also on the ARM platform. Our improved framework decouples the testing of software from the actual encryption.

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Towards Exploratory Search Mashups based on Strategic Knowledge

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Abstract—**Exploratory search is a complex, long-lasting and highly iterative process. Users may have only a vague or an open-ended information need that is likely to change during the search process. Besides the insufficient domain knowledge, most users lack experience in efficient information search. Hence, they have to be guided during the search process by strategic recommendations. In this work, we present an overview of our strategy-oriented search platform that derives appropriate composite web applications from recommended and preferred search strategies with respect to the current user and search context. Moreover, we give a glimpse into our meta-model of search strategies, which represent best practices on how to solve search problems and are described using hierarchical task models.**

Keywords–Mashup; End-User Development; Exploratory Search; Search Strategy; Strategy Recommendation.

I. INTRODUCTION

Considering today's vast amount of digital information and it's increasing availability, information search is an omnipresent human activity [1]. Traditional Web search engines follow the same retrieval paradigm "query and response". Thereby, the user's information need is represented as a keyword-based query that is processed by the search engine. Corresponding results are returned as a ranked list of entities containing additional meta-data, e. g., title, content fragments and the data source. However, this lookup-oriented information seeking model does not fully represent the human search behavior in real life scenarios. Users may have a vague or open-ended information need, which furthermore is likely to change during the search process. Satisfying his/her information need is additionally hindered if the user's research or domain expertise are insufficient [2]. Consequently, *exploratory search* characterizes information seeking as a highly iterative, often long-lasting and complex process [3]. As pointed out by [4], assisting users during the search process is crucial. We argue the searcher has to be guided by *search strategies*, which are consolidated, verified and composable best practices on how to solve search problems. To this end, search strategies are recommended by the search environment and serve as foundation for generating dashboard-like search applications with respect to the current context (i. e., user's profile, search history, research task description and problem domain).

A promising approach for generating context-aware search dashboards are *composite web applications* (CWA) consisting of loosely coupled *mashup components*. The latter encapsulate arbitrary web-services and resources like domain-specific business logic as well as widgets. Moreover, each component is characterized by a semantically enriched interface providing information according to their data provision and capabilities [5]. It has the advantage that a component's interface as well as their capabilities can be matched more precisely on a semantic level with an abstract application description including required capabilities, e. g., a business process model, and allows to generate corresponding mashups.

In our vision, a *search strategy* is a formal description of the planned use of information gathering activities leading effectively and efficiently to relevant search results. An information gathering activity is performed by the user, e. g., providing an author's name, or by the search system, for instance, presenting the author's books or papers relevant to the user's information need. A search strategy is effective because the resulting entities (documents, terms, domains etc.) are highly relevant compared to the user's information need. It is efficient because it reduces the user's cognitive load by providing a predefined order of search activities and it reduces the amount of time in finding relevant information.

The idea is to utilize strategy models for assisting users throughout search processes. Thereby, strategies are recommended context-sensitively, giving advice on efficient search activities. Additionally, they serve as a foundation to derive adequate CWA, taking advantage of composition knowledge and the semantic description of component interfaces.

Typically, strategies are associated to a critical situation and should result in valuable information related to the initial search problem. Consider the following two strategy examples:

1) "Define the information need more precisely by selecting refined concepts of domain X using archive services $S_1, S_2, \ldots, S_n$ if precision level of current query is low."
2) "Reformulate a query more precisely by searching for concepts in top-10 relevant papers and slides of domain experts $E_1, E_2, \ldots, E_m$ if the user's search experience is low and the current result list is almost empty."

Such search strategies are defined explicitly by search experts or can be derived semi-automatically from usage and feedback data of experienced searchers.

Our vision of a guided exploratory search experience comes with various requirements. First, a sufficiently expressive *search strategy meta-model* for describing stepwise information gathering processes usable in a multitude of scenarios is needed. It should address the following aspects: (a) Specifying *information request and provision activities*, concrete domain concepts or placeholders, each referencing a domain concept, a document type or a human informant (e. g., the data analysis expert) are needed. (b) *Context criteria* to define valid usage situations of search strategies are required considering the temporal availability and validity of multidimensional context data. Secondly, the meta-model concepts are the basis for *strategy recommendation* and *mashup generation*, i. e., the concepts should largely support the component selection and

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composition process to reduce the configuration effort from the end-user perspective. Considering that there is a semantic gap between the abstract process-oriented strategy meta-model and the fine-grained, function-oriented model of mashup components, there is a need for an *efficient mapping algorithm* that should be executed transparently during the search process.

Regarding the previous requirements, the contributions of this work are the following: First, we propose a meta-model for search strategies that allows to specify arbitrarily complex information gathering activities and which features semantic annotations. Second, we present a novel reference architecture of an exploratory search platform. It supports unexperienced users in highly iterative information search with help of guidance mechanisms leveraging the strategy meta-model. Especially users are assisted by strategy recommendation and provision of adequate search mashups. The remainder of this paper is structured as follows. In Section II, we discuss related work. Then, Section III presents our search platform based on mashup concepts. Finally, Section IV concludes the paper.

II. Related Work

Approaches like query suggestion [4], [6] and facet recommendation [7], [8] try to compensate the limited domain and search expertise of users. Such techniques are assisting users in specifying an information need more precisely. However, users often have complex information needs requiring them to perform multiple search steps [9]. Such approaches fall short of expectations in supporting users on a strategic level.

Kangasrääsiö et al. [10] propose a search front-end showing estimates of the user's search action effects allowing the user to anticipate consequences and to direct his/her exploratory search. Thus, the user actively influences the information search. Musetti et al. [11] use topological knowledge patterns extracted from Wikipedia to deliver relevant and filtered search results. Each result is represented semantically and visualized based on concepts provided by DBpedia. Complementing meta-data are retrieved from additional sources such as Twitter. Anyway, for users without extensive domain knowledge, it is challenging to navigate to relevant information. We follow the motive of [10], but we argue that users without guidance explore information rather in a trial and error manner. Thus, information search still is time consuming and cumbersome. Compared to our solution, both approaches lack concepts for active user guidance.

Bates describes four levels of search activities [12], whereby higher levels build upon lower ones. *Moves* are the basic unit of her model. *Tactics* are composed of moves in order to improve search activities. *Stratagems* are larger complexes of several moves or tactics and they are typically domain-specific. A *strategy* can be considered as a plan for a whole search process, incorporating all other types of activities. Bates emphasizes the importance of supporting users on strategic levels, which is one of the main goals of our approach. In contrast to [12], we formally describe search activities of all levels. Belkin characterize *information seeking strategies* (ISS) [13] according to the dimensions: *method* of interaction, *goal* of interaction, *mode* of retrieval, and resource considered. They identify 16 relevant combinations and thus strategies. Our model is partly inspired by this work, as we describe user's situation and search activities. However, it lacks formalism and a detailed search process description. In [14] Belkin et al. propose script-based user guidance, whereby scripts represent effective interaction sequences for ISS. Such scripts serve as prototypical dialogs between system and user and can be combined to more complex ones. In the case of the *MERIT* platform [14], scripts guide users during the search process. Besides initially provided scripts, case-based reasoning is applied to derive scripts. Similarly, our approach allows to model circumstances when a strategy can be applied. However, we take the information need and user group into consideration. In addition, we describe search processes, yet in a semantically enriched and user-oriented way.

According to Sutcliffe and Ennis [15], strategies represent information searching skills and are determined by the type of information need. The latter is categorized according to aspects like the knowledge a user has about the information, whether the need is rather fix or likely to change, and if the target is precisely known or rather general. They propose a search process model that features strategy selection rules, which govern behavior within the process model. Such rules differ in their preconditions, incorporating information need types and other context parameters, as well as action clauses that, e. g., alter the query and invoke an action. Strategy rules are used to determine suitable strategies with respect to the information need type and current search process. Our approach is influenced by the work of Sutcliff and Ennis. For instance, we adopt their concepts for describing information needs and context-sensitively selecting suitable strategies in a rule-based manner. However, they provide no model of strategic process knowledge as we require it.

The *FIRE* system presented in [16] offers strategic help to users in form of suggestions, which partially correspond to Bates' classification. They apply reasoning on user actions and the search context to derive applicable suggestions. Selecting suggestions is based on rules describing necessary context conditions and the consequences as actions. Our approach not only allows to provide suggestions in context of a predefined search application, but also uses strategic knowledge to derive suitable applications, which is out of scope of FIRE. In addition, our strategy model can describe whole search processes and strategies can be composed. Kriewel et al. present *DAFFODIL* [9] that uses case-based reasoning techniques for determining appropriate strategic suggestions considering the current user's context based on the tactics and stratagems according to [12]. Tacke and Kriewel [2] extend DAFFODIL by providing tools enabling guided information search. They differentiate between macro and micro-level guidance. The former support unexperienced users in specifying his/her information need and explaining steps of a complex search task. A disadvantage is a fixed set of generic features and tools for the different search process phases. Domain-specific visualizations and user preferences are considered in a very limited fashion only. Our platform strives to provide strategic knowledge and a construction kit to reflect it in suitable CWA.

III. Strategy-oriented Search Platform

In this section, first we present an architectural overview of our CWA platform for exploratory search and its strategy-based functionalities. Afterwards, details on our proposed strategy model are discussed. Finally, we describe some of the novel features, which utilize strategy models.

A. Architectural Overview

We claim that assistance mechanisms based on formalized strategy descriptions, for instance, context-aware strategy recommendations, generation of appropriate applications and

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query suggestions, are supporting and substantially simplifying the user's overall search process. As result of our investigation of related solutions (see Section II) and to the best of our knowledge, there is a need for a novel information search platform providing such assistance, which we present afterwards.

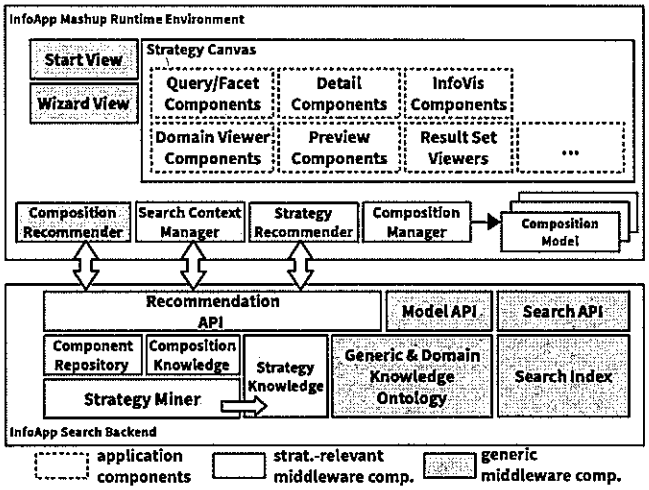

Figure 1. Architectural overview of our platform for exploratory search.

As illustrated in Figure 1, the search platform's front-end is based on a mashup runtime environment. The *composition manager* implements the life-cycle of CWA, which are represented by a *composition model*. Exploratory search mashups are rendered in the *strategy canvas* and build up on a set of components that provide capabilities to cover all phases of a search process, for instance, components for textual or graphical query construction, result lists and diagrams as well as charts for visual analytics. In order to provide several starting points into the research process, the front-end provides a *start view* and a *wizard*, c. f. Section III-C. The platform features a component-oriented recommender system (*composition recommender*) and assistance mechanisms for live development of CWA [5]. They allow to recommend, select and compose components as required. To this end, *composition knowledge*, that holds information about mashups and recurring composition patterns, and a *component repository*, that stores information about semantically annotated components, are utilized. Both are accessible via the *recommendation API*. In addition, the latter provides the following context-aware search-oriented recommendation functionalities: (a) suggest domain concepts and facets, (b) suggest query reformulations, (c) recommend related documents, domains and their inherent concepts, and (d) recommend search strategies each associated with at least one adequate CWA. These functions incorporate domain knowledge represented in *ontologies*. Furthermore, they pay attention to the current search context, which comprises a users' research task, queries, information need and skills. It is maintained by the *search context manager* and analyzed by the recommender in order to fulfill the above mentioned functionalities. *Strategy knowledge* serves as a further crucial data source for our recommendation and assistance features. Therein, formal models of search strategies according to our meta-model, see Section III-B, are stored and maintained. A *strategy miner* is responsible for semi-automatically detecting recurring work-flows in the *composition knowledge*. By comparing the current context with the purpose and use cases of a search strategy, the *strategy recommender* derives and presents suitable strategies, as detailed in Section III-C.

In order to answer user queries, search mashups leverage the *search API*, which grants access to our hybrid *search index*. The latter combines the efficiency of an inverted index together with the expressiveness of an ontology.

B. Strategy Model

As a prerequisite, we briefly outline our *user and search context model*. Therein, user profiles model skills that include search and domain expertise, and interests based on semantic concepts and quality levels. Users have certain *roles*, that additionally imply specific skills and can group users. Furthermore, the current search context describes the search task featuring a textual description, research goals (adopting [13]) associated with semantic domain concepts, a classification of the information need (based on [15]). Further, current research activities including a history of queries and gathered feedback of users in association to relevant documents, concepts or strategies is represented.

Search strategies describe effective, proven practices for fulfilling certain information needs, for instance, searching patents by navigating in a classification or by querying companies in a sector. According to our meta-model depicted in Figure 2, each *search strategy* is formally characterized by the following attributes.

- *core meta-data* like a name and description
- circumstances (*cases*) under which a strategy is useful. Such cases are basically tuples of *search task*, user *roles* and *rating*, reflecting the suitability of a strategy in a given context. To describe target groups of users for that a strategy is suitable, we utilize user *roles*, that group users with respect to their skills. Furthermore, a case is associated with a model of a CWA. There are two types of cases differing in their origin:
  - *reference purposes* are defined by search experts,
  - *community feedback* on the suitability of strategies.
- hierarchical task model (*search strategy* and subclasses) formally specifying a procedural description including
  - place holders carrying selection rules for dynamic expansion using other strategy models (see *isTemplate*),
  - composite and/or conditional activities (expressed in sequential or parallel order or as alternatives). Hierarchically defined *conditions* allow to further restrict when strategies are applicable. Therein, arbitrary context parameters are addressable using a selector language, like SPARQL property paths.
  - besides user actions, activities can model system actions and thus configure platform features similar to [15], like the recommender system and the component selection during CWA generation.

As can be seen, our model is influenced by cases and scripts [14], task models and capabilities [5]. With regard to Bates' categorization, our model covers all levels, i. e., it is capable of describing moves, tactics and arbitrarily complex stratagems and strategies.

C. Strategy-based Platform Features

As indicated in Figure 3, we distinguish two roles interacting with our platform. *Users* with little or no strategic

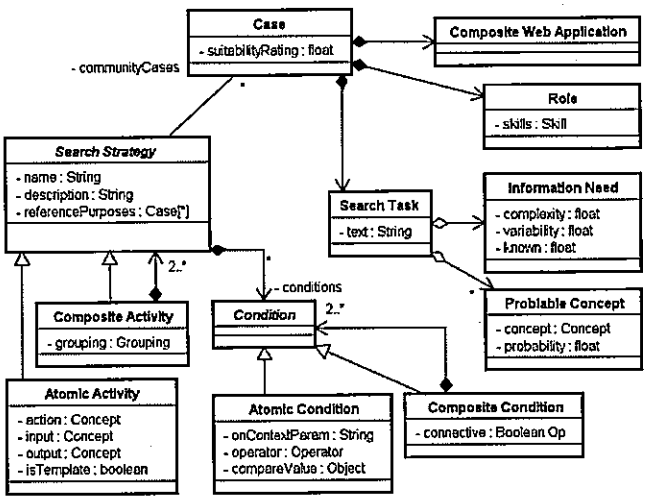

Figure 2. Overview of the search strategy meta-model.

expertise and with limited domain knowledge utilize our platform to fulfill their information need. *Search experts* are experienced information seekers with profound knowledge about efficient search strategies, which they apply as required. To this end, they create or modify CWA on demand. We assume, that experts are interested in sharing strategic knowledge by explicitly modeling their strategies and contributing them to the platform's strategy knowledge.

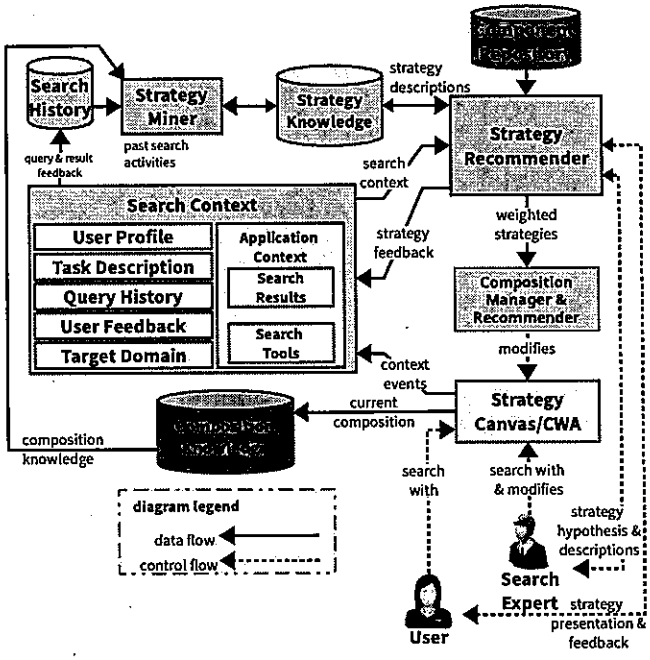

Figure 3. Strategy Recommendation Overview

In our approach the search platform provides following main features, which we explain in more detail afterwards:

Strategy assignment: Search strategies are assigned to matching CWA automatically by the *strategy miner* prior to the user's information search. Furthermore, the *search expert* can specify the association between a strategy and its representing application semi-automatically at runtime.

Strategy recommendation: Search strategies are recommended by the *strategy recommender* at the *beginning* or *during* the search process. For this, meta-data, e. g., the name and human readable description, are visualized by the *wizard* or as part of the *search canvas*.

Strategy usage: After strategies were recommended, the user activates the most appropriate strategy. At this point, the association between the selected strategy and its referenced CWA is resolved. Thereafter, we consider following integration cases: (a) Initial setup of the CWA, (b) extend or (c) replace the current composition.

Strategy feedback: From the user's perspective a strategy leads to more or less suitable search results. Reusing a valuable strategy or to filter out unsuitable ones the user can give feedback.

Next, we discuss these features considering the relations between actors and platform entities depicted in Figure 3.

Strategy assignment: We distinguish between *automatic* and *semi-automatic* strategy assignments. The latter is performed by *search experts*. In the first case, the *strategy miner* compares each registered strategy model with available CWAs managed by the *composition knowledge base* in association with historical context parameters provided by the *search history*, e. g., the research task or user profile. When comparing the strategy and CWA, the strategy's context condition are matched with context parameters associated to the current mashup. Moreover, the strategy's activities are compared with capability descriptions of each component referenced in the mashup's composition. Both values—the *context* and *activity* matching degree— result in the overall strategy-application similarity. After a strategy has been matched with available CWAs, the applications list is ranked with respect to the matching degree of every strategy-application pair. The top-k applications are associated with the current strategy using the *case* concept introduced in Section III-B and stored in the *strategy knowledge base*. In summary, each strategy is compared with available CWA and the best matching applications per strategy are assigned. The associated applications are considered as the strategy's manifestation on the application layer and are advertised during the user's search time.

In the case of *semi-automatic* strategy assignment, while the *search expert* is composing an information search mashup the *strategy miner* calculates probable strategies at runtime. At this, the expert's mashup as well as his/her search context are compared to each strategy model similarly to the algorithm described above. As result, probable strategies are calculated and visualized as *hypothetic candidates* to *search experts*. The latter evaluate strategy-application pairs and can modify strategy models and CWA, for instance, add domain and knowledge conditions as well as domain-specific mashup components. Thus, the validity and relevance of strategies is ensured by explicit feedback and the expertise of search professionals.

Strategy recommendation: Essentially, our platform provides two entry points into the search process: In the *start view* users can browse recommended strategies, which are filtered with respect to the user profile, or is guided by a *wizard*. The latter supports users in formulating research goals, captures relevant topics and assists users by recommending related search strategies. In addition, default search CWA for generic strategies can quickly be accessed. Initial strategy recommendations

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take into account the user context with skills, roles and history, and the search context including task description, information need and queries. The *strategy recommender* derives suitable strategies leveraging semantic filtering techniques. For this, context conditions of every strategy are evaluated and matched with current context parameters. For example, the strategy "find chemical patents by formular" includes following conditions: $((domain \simeq \text{chemistry}) \vee (userrole \simeq \text{patent officer}))$. As fallback solutions there are general purpose strategies and corresponding CWA featuring generic search tools.

Further, strategies are recommended at *runtime*. To enable guidance throughout search processes, the current context is continuously monitored. Upon relevant context changes, e. g., modified query, selected target domains and facets etc., new loops of the recommendation procedure are triggered. Consider the following example: After the user has selected several documents and topics from the chemistry domain, the platform offers matching strategies. One of them—strategy "precise chemical search queries"—suggests to use a chemistry-specific query formulation tool based on chemical formulas. As soon as the user accepts, assigned CWAs are presented as sorted list in the strategy canvas. The applications order depends on the similarity of each strategy-application pair and on the feedback of other users or search experts. The *case's suitability rating* introduced in Section III-B represents both aspects.

Strategy usage: After recommendation, a user can choose from several strategies and at least a CWA per selected strategy is generated. At this point, we differentiate between following integration cases. At the *beginning* of the search process, the *strategy canvas* only includes generic search tools such as a query editor, a facet browser and a search results viewer. Per selected strategy the user can activate most appropriate mashups and decides whether the current composition will be extended or a new mashup is created in the *strategy canvas*. After the user has chosen an option, components and communication relations between them are integrated as defined in the composition model associated to the activated strategy. The integration process is performed and monitored by the *composition manager*.

Moreover, strategies are recommended continuously throughout the search process. Hence, while using an activated strategy a recommended one can be *merged* into the existing application context. A sample strategy is presented in Figure 4. Activities and conditions of the search strategy "SUPER" are shown as UML state diagram. Context conditions are visualized as transition guards. For instance, the main strategy "SUPER" is suggested when there are less or equal than five search results and when the current query is overspecified. The strategy's purpose is to support users in finding appropriate hypernyms. For this, the main strategy contains two activities. First activity "Select" results in a hypernym that is automatically set as the current query (second "Modify" activity). As discussed in Section III-B our meta-model supports to define template activities, which could be replaced by more specific variants at runtime. In Figure 4 the first activity is replaced with a domain-specific one (green colored), which is activated after the user has selected the chemistry domain. The new strategy allows retrieving chemical formulas from several sources, e. g., a query from search history or a web-service, and to get an appropriate hypernym from a chosen chemical formula. The selected hypernym is used to solve the problem of overspecified queries and to broaden the search results. Modifications on the strategy's activity layer are synchronized with the mashup's composition layer. Considering the sample strategy in Figure 4, generic composition fragments are replaced with domain-specific components.

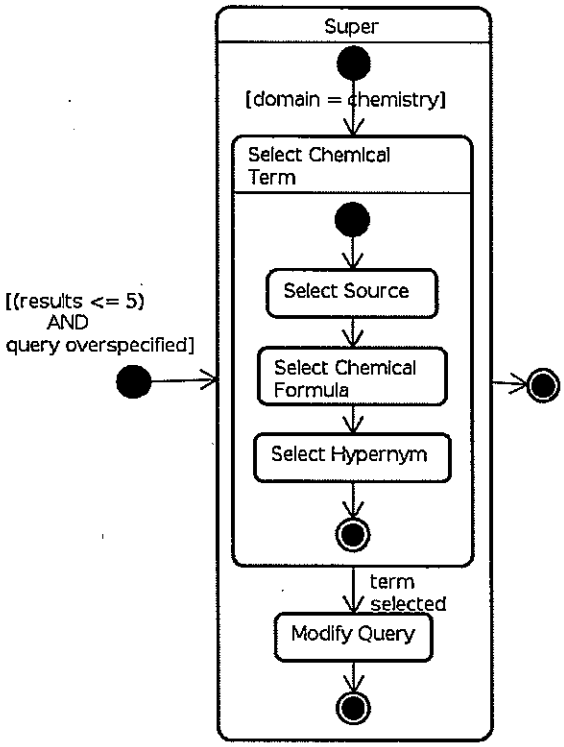

Figure 4. Sample strategy SUPER

Strategy feedback: At this point, we distinguish between *search expert* and *user* feedback on a strategy and its CWA. It is collected and managed by the *strategy recommender*. Feedback is created as a tuple of strategy, CWA, user and search context and represented as *case* stored by the *strategy knowledge base*. When more users give positive feedback according to the same case, the higher the corresponding strategy is weighted, i. e., its suitability rating increases. This in turn causes a higher ranking of the strategy during the recommendation process. Negatively rated strategies are degraded.

IV. Conclusions

In addition to the insufficient domain expertise, most users lack experience in efficient information search. Thus, there is a need for an intelligent search platform guiding the searcher by recommending appropriate search strategies. We support the user in his/her information seeking activities by continuously recommending collaboratively filtered search strategies depending on the current search context, so the user is able to design his/her CWA only by selecting a preferred strategy description. Further, search experts can teach valid search strategies to the platform. Users of the same community may profit from their expertise, because the platform is able to derive best matching compositions that the experts themselves can not anticipate during their search activities.

However, limitations of the presented approach are (a) the *cold start problem* and (b) the user's *cognitive overload* while using complex search strategies with deep activity hierarchies.

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The first limitation is characterized by the necessity to provide predefined strategy descriptions and composition models. Hence, we introduced the *search expert* as actor with sufficient information seeking and programming experience who can explicitly specify strategy models. In order to reduce the inherent cognitive load and time effort, sophisticated strategy development tools that allow designing strategies comfortably are required. For this, a visual editor based on UML activity diagram notations could be used to generate reusable strategy models. Another approach would be to extract strategies from existing CWA automatically. For this, tracking features to capture the expert's input and interaction events as entities of the application context are required. In addition, sufficient analyses and aggregation mechanisms to recognize strategic search decisions from user behavioral patterns are required. Considering black-box components that have app-like granularity, this is not feasible due to missing interaction details. Thus, we decided to rely on (semi-)automatic assignment of adequate CWA to strategies, but this implies that there are always corresponding mashups available. We assume there are several predefined compositions models, which are developed by domain experts without programming experience using EUD-tools [5]. Our platform supports the mashup EUD, but currently lacks the strategy assignment features described above. In the near future, we plan to develop the *strategy miner* and its strategy assignment features as part of the existing *composition and component repository* web-service of the platform's back-end.

The second limitation could be solved using automatically generated tutorials, which give an overview of integrated mashup components and are guiding users while interacting with them. For instance, in the chemistry domain they describe how a chemical formula editor is used in combination with the facet browser and a graph-like molecule viewer of the same application. Based on the assumption that such tutorials are generated from strategy knowledge and additional component interface annotations (e. g., capability descriptions) this solution complicates component development.

Finally, we plan to evaluate our approach with the help of a user study.

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Towards Validation of IFC Models with IfcDoc and SWRL

A Comparative Study

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Abstract—**Recent years have witnessed the need of automatic verification requirements to warn the non-conformities with the associated 3D visualization, or to provide access to the technical documentation for a given digital model based on its sophisticated contextual information. In this paper, we study two approaches for the validation of IFC Models, i.e., with IfcDoc and SWRL. The traditional approach is by using IfcDoc tool developed by buildingSMART International to improve the consistent and computer-interpretable definition of Model View Definitions. On the other hand, Semantic Web technologies, especially Semantic Web rule language, allow the semantic validation of IFC models to enable the compliance checking of IFC construction models with unmatchable query performance and flexibility. Therefore, we present and compare IfcDoc and Semantic Web rule language technologies for the model instance verification and conformance checking of IFC models, and demonstrate various important aspects and their limitations. We conclude that both technologies have their specific significances, but Semantic Web technologies provide a better hand over the traditional approach. The Semantic Web approach with the goal of combining the strengths of an ontology and IFC technologies makes information retrieval from an IFC model faster, flexible and also enables interoperability between IFC documents.**

Keywords-Validation of IFC models; SWRL; Ontology; BIM; Querying IFC models; MVDXML.

I. INTRODUCTION

To understand a building through the usage of a digital model which draws on a range of data assembled collaboratively before, during and after construction is referred to as Building Information Modeling (BIM) [1]. It brings together all the information about every component of a building, in one place. BIM with its interoperability properties is intended to facilitate exchanges and handovers between different stakeholders. While the visualization and geometric representation are intrinsic to the digital building model, the fields of quality requirements, evaluation and regulatory contextualization (destination, named areas, threshold values, certified data, evidence of compliance, etc.) need higher level of maturity [2]. Industry Foundation Classes (IFC) is the complete and fully stable open and international standard for exchanging BIM data [3]. Building SMART organization aims at publishing IFC and related buildingSMART data model standards. The buildingSMART data model standards are developed by the Model Support Group, and the implementation activities are coordinated by the Implementation Support Group [4]. Together, both groups organize the IFC software certification process. It aims to be a global standard for the BIM data exchange. The subset of the IFC schema needed to satisfy one or many Exchange Requirements of the Architecture, Engineering and Construction (AEC) industry is called Model View Definitions (MVD). The XML format used to publish the concepts and associated rules is MVDXML and it is regarded as an open standard [5]. MVDs provide additional rules for the IFC validation and focus on extracting integral model subsets for the IFC implementation purposes. There are many drawbacks of MVDXML for extracting building views such as: lack of logical formalisms, solely consideration of IFC schema and MVD-based view constructors are not very flexible and dynamic [6]. Although IFC is an open standard, its complex nature makes the information retrieval difficult from an IFC model, and thus affects the validation process by MVDXML rules. Many tasks for IFC model such as information retrieval, model validation, etc., do not achieve real-time performance in the real-world BIM scenarios.

Our enterprise, Centre Scientifique et Technique du Bâtiment (CSTB), through its research and development efforts, aims at automatic validation requirements to warn the non-conformities with the associated 3D visualization, or to provide access to the technical documentation for a given digital model based on its sophisticated contextual information. To achieve these goals, our research adopts a traditional approach using MVDXML [5] and, in addition, focuses on the Semantic Web rule language SWRL [7] for the validation of IFC construction and building models. The traditional approach by using IfcDoc tool developed by buildingSMART International is to improve the consistent and computer-interpretable definition of MVD as true subsets of the IFC Specification with the enhanced definition of concepts. Therefore, first, we present background knowledge about both these approaches and then compare IfcDoc and SWRL technologies for the model instance verification and conformance checking of IFC models. In addition, we demonstrate various important aspects and their limitation as well. We also performed experiments via queries by the traditional approach via IfcDoc and the ontology-based Resource Description Framework (RDF)

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approach IFC-to-RDF via SPARQL queries [8]. IFC-to-RDF is a set of reusable Java component that allows parsing IFC-SPF files and converts them into RDF graphs. Our approach uses IFC to RDF conversion and then stores RDF triples into Stardog [9] knowledge graph that gives unmatched query performance. We investigated that IFC; although is an open standard, it has a complex nature which makes information retrieval difficult from an IFC model. On the other hand, Semantic Web technologies, especially SWRL, allow for the semantic verification of IFC models to enable the compliance checking of IFC construction models with fast querying performance.

The rest of paper is organized as follows. Section 2 provides the background knowledge of the domain. Section 3 presents the related work. Section 4 presents two approaches for the validation of rules and conformance checking. Section 5 discusses our experimental findings via MVDXML validation rules on IfcDoc and SPARQL queries. Section 6 concludes this paper.

II. BACKGROUND

In this section, we provide some background about the two approaches that can be used for the validation of IFC models.

A. *IfcDoc Tool and MVDXML*

The subset of the IFC schema needed to satisfy one or many Exchange Requirements of the Architecture, Engineering and Construction (AEC) industry is called *Model View Definition* (MVD). The XML format used to publish the concepts and associated rules is MVDXML and it is regarded as an open standard [5]. MVDs provide additional rules for the IFC validation and focus on extracting integral model subsets for IFC implementation purposes. The buildingSMART is willing to support construction domain developers in reusing its leading openBIM standard IFC as a baseline to set up specific data exchange protocols to satisfy exchange requirements in the industry. The buildingSMART International has developed IfcDoc tool for creating Model View Definitions. Based on the newly developed mvdXML standard, just Model View Definitions can now be easily developed using the IfcDoc tool. The tool and methodology can be applied to all IFC releases (IFC2x3, IFC4, etc.). For the validation of an IFC file against a particular model view, IfcDoc tool user interface displays a pane on the right side containing object instances within the file matching definitions selected in the tree view. The end-user can generate a report in the HTML format indicating if the file is valid according to the specified model view, and detailing what passes or fails. However, it does not show the cause or provide mechanisms for reasoning the inconsistencies or anomalies.

B. *SWRL and SQWRL*

The Semantic Web technologies, SWRL and SQWRL, are widely being used for the inference of new knowledge, validation and querying ontologies [7]. Ontologies, although they are best for knowledge modeling, have limitations and may not suffice for all applications. There are statements that cannot be expressed in Ontology Web Language; therefore, Semantic Web Rule Language is designed on top of ontologies to be an alternative paradigm for the knowledge modeling that adds expressivity to the OWL. Besides this, SWRL rules infer new knowledge from the existing knowledge modeled in the ontologies. SQWRL is the query language of the Semantic Web for querying the RDF data [10]. Along with query language SQWRL, it has more access to characterize on RDF graphs. SWRL rule engine employed with an ontology-based on IFC specifications can be used for the information retrieval process from an IFC model and is the focus of our research.

III. RELATED WORK

To achieve the benefits of ontologies, there are many efforts to build an ontology for the IFC construction industry. One of the outcomes can be seen as an IFC-based Construction Industry Ontology and Semantic Web services framework [11]. With simple reasoning built over the ontology, their information retrieval system could query the IFC model in XML format directly. The BuildingSMART Linked Data Working Group has developed IfcOWL ontology to allow extensions towards other structured data sets that are made available using Semantic Web technologies [12]. There are many versions of IfcOWL ontology since the work has been started. We have been working on an ontology IFC4_ADD1.owl that was launched on 25 Sept. 2015. We have enriched this ontology with English-French and IFC vocabulary (synonyms, descriptions, etc.) from bSDD semantic data dictionary in our research project where we map regulatory text and certification rules over BIM [13]. In addition, we assigned concepts of IfcOWL ontology with Global Unique Identifier (GUID) to serve as a unique language-dependent serial number from the bSDD.

Data models formally define data objects and relationships among data objects for a domain of interest. EXPRESS is a standard data modeling language for product data [25]. There are some research projects that bring BIM to the Web, to overcome drawbacks due to several limitations of EXPRESS, by converting IFC models into RDF graphs. Then, the RDF models become accessible from the Web; they can be processed and queried in more flexible ways, and they can be interlinked using the Linked Data technologies. This way of bringing BIM to the Web allows to take advantage of the fast evolution of the Web and the emerging services and data sources. Hoang and Torma [14] developed an open-source Java based IFC2RDF tool that performs multilayer conversion from IFC schemas developed in EXPRESS into OWL2 ontologies [26] and IFC data from STEP physical file format (SPFF) into RDF graphs aligned with the ontologies. Through the multi-layer model, users can get three ontology layers according to the requirements of an application, where each ontology layer is compatible with essentially the same IFC-derived RDF data. There is another tool named IFC-to-RDF-converter developed by Internet & Data lab at Aalto University and Ghent University [15]. They provide with an EXPRESS-to-OWL and IFC-to-RDF conversion service. The converter can be accessed in a

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number of ways: using a command line tool (written in Java), using a RESTful Web interface, or using a Graphical User Interface (GUI).

Besides these projects that build an ontology for the IFC, recent years revealed some contributions based on Semantic Web technologies. SWOP-PMO project is one of recent contributions that use formal methodology based on the Semantic Web standards and technologies [16]. It uses OWL/RDF to represent the knowledge, and SPARQL queries and Rule Interchange Format (RIF) to represent the rules. The RDF/OWL representation is not derived from the written knowledge but has to be remodeled in accordance with the rules of OWL/RDF. There are some other works for the semantic enrichment of ontologies in the construction and building domain. Emani et al. proposed a framework for generating an OWL Description Logic (DL) expression of a given concept from its natural language definition automatically [17]. Their framework also takes into account IFC ontology and the resultant DL expression is built by using the existing IFC entities.

Pauwels and Zhang [18] listed three ways for the conformance checking of IFC models. First, we have the hard coded rule checking, which is similar to the approach adopted by Solibri Model Checker [19]. This tool loads a BIM model, considers rules stored natively in the application and performs rule checking against BIM for the architectural design validations. This approach is fast as rules are integrated inside the application, but there is no flexibility or customization possible as rules are not available outside the actual application. Another solution, the traditional approach of compliance checking is with the IfcDoc tool developed by buildingSMART International for generating MVDXML rules through a graphical interface [20]. It is based on the MVDXML specification to improve the consistent and computer-interpretable definition of Model View Definitions as true subsets of the IFC Specification with enhanced definition of concepts. This tool is widely used as AEC specific platform in the construction industry.

The second approach is 'rule checking' by querying the IFC model. In this approach, BIM is interrogated by rules, which are formalized directly into SPARQL queries. As an example, K. R. Bouzidi et al. [21] proposed this approach to ease regulation compliance checking in the construction industry. They reformulated the regulatory requirements written in the natural language via SBVR, and then, SPARQL queries perform the conformance checking of IFC models.

The third is a semantic rule checking approach with dedicated rule languages such as SWRL, Jess [27] or N3Logic [28]. There are few projects in AEC industries that use this approach for the formal rule-checking, job hazard analysis and regulation compliance checking. H. Wicaksono et al. [22] built an intelligent energy management system for the building domain by using RDF representation of a construction model. Then, they formulated SWRL rules to infer anomalies over the ontological model. Later, they also developed SPARQL interface to query the results of rules. Pauwels et al. [23] built acoustic regulation compliance checking for BIM models based on N3Logic rules. They use N3logic rules with an ontology to reason whether a construction model is compliant or not with the European acoustic regulations. Another project that was built on the ontological framework for the rule-based inspection of eeBIM-systems was developed by M. Kadolsky et al. [24]. They used rules to query an IfcOWL ontology that captured a building.

IV. VALIDATION OF CONSTRUCTION MODELS VIA IFCDOC AND SWRL

The validation of IFC building models is vital in the BIM-based collaboration processes. The aim of validating Models is to align several specialized indexations of building components at both sides, assuming that they deal with the same abstract concepts or physical objects, but according to their separate representation prisms. We have adopted two methods for the verification of rules. Firstly, we use IfcDoc tool (MVDXML checker) which performs three step automatic control sequence. The IfcDoc engine loads the IFC file and MVD files, and then executes the defined rules. Finally, it generates a report indicating compliance (compliant/non-compliant) of each item under the rule. It assigns each rule a green or red depending on whether the item is/is-not in compliance to the defined rules. Secondly, we have built a SWRL-based rule engine to verify our rules. For this, we have converted our IFC model into RDF which is the input of the rule engine by using IFC-to-RDF-Converter. Each method has its own pros and cons and should be used according to requirements of the research project. The following subsections present these two approaches of verification, and also present a comparison between two technologies MVDXML and SWRL side by side.

A. *Verify the presence of an Attribute Value*

When we need to access the name/label of an IfcSpace, we can simply access the name attribute of the IFC schema. Figure 1 shows the MVDXML template and Figure 2 illustrates how we can access it with the help of SQWRL. In addition, SQWRL provides a lot of built-in functions which we can apply on the name to get results more appropriate according to their order, size, etc. For example, Figure 2 also illustrates how the names of IfcSpaces are obtained with the help of built-in ordered function (sqwrl:orderBy).

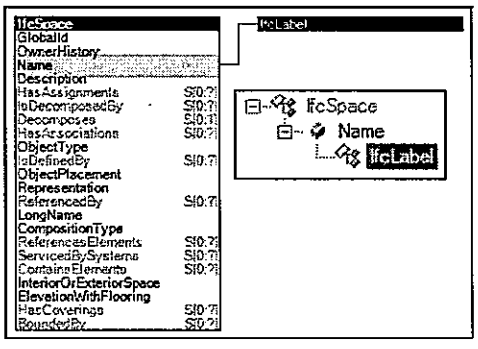


Figure 1. Accessing attribute of IfcSpace in IfcDoc .

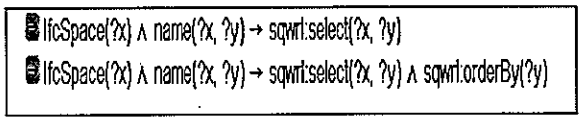


Figure 2. Accessing attribute of IfcSpace in SWRL

B. *Verify the presence of an Element*

When there is a need to restrict the relation between the elements of IFC, we can use the IfcRelAggregates relation in MVDXML to specify relating objects. For example, Figure 3 illustrates when we want to check IfcProject should contain an IfcBuilding as represented by the cardinality involved between IFC objects. On the other hand, in case of ontology, we can restrict IfcProject by a restriction: IfcProject contains some IfcBuilding, (i.e., IfcProject ⊃ ∃ contains.IfcBuilding) as illustrated in Figure 4. We can also check this with the help of SQWRL by counting the number of buildings related to IfcProject and verifying whether their number is greater than one.

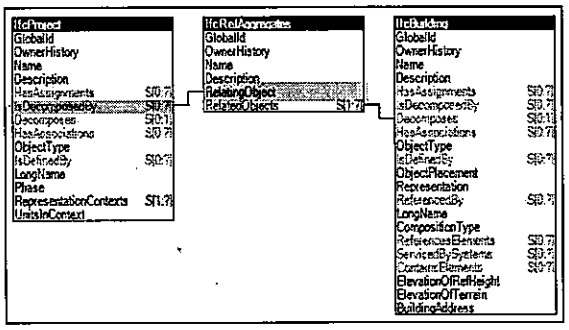


Figure 3. Verify the presence of an element in IfcDoc

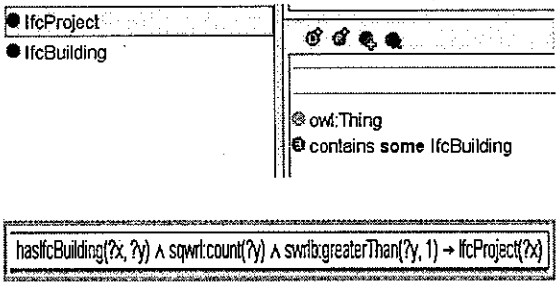


Figure 4. Verify the presence of an element in SWRL

C. *Verify the value of a Simple Attribute*

In MVDXML and SWRL, we can create various types of conformance checking conditions on the attributes of objects. For example, consider a case when we need to check the value of overAllWidth attribute of a door to be greater than 0.8. Figures 5 and 6 illustrate how we can verify this in these technologies. Both technologies support a lot of operators for the implementation of conditions (such as: $=, \neq, <, >, \leq, \geq$).

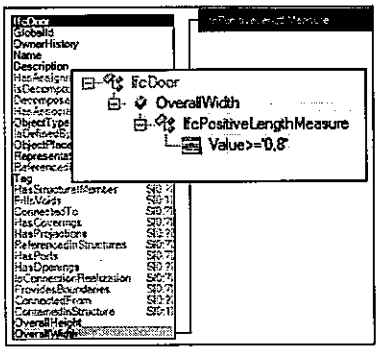


Figure 5. Condition on OverAllWidth attribute of an IfcDoor in IfcDoc

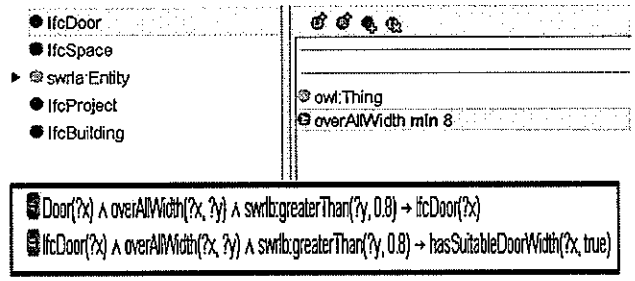
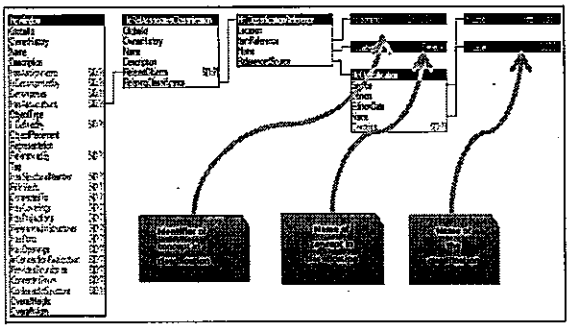


Figure 6. Condition on OverAllWidth attribute of an IfcDoor in SWRL

D. *Verify Attributes of Element relative to the Classification*

Both technologies allow us to verify attributes of elements relative to the classification. Figures 7a and 7b illustrate how MVDXML and SWRL support various representations of IFC objects with respect to the classifying element.



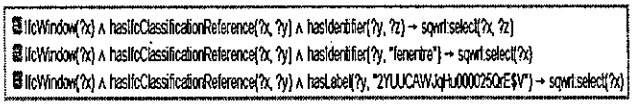


Figure 7. Selection of the concept by 'Fenêtre' in (a) IfcDoc (b) SWRL

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E. *Verify the cardinality of an Element*

Both MVDXML and OWL schema allow verifying the cardinality of an element. For an example, they allow to verify whether IfcGroup has two WCs. Figures 8 and 9 illustrate how these technologies support the verification of the cardinality of an element. There can be many ways to perform this semantically, as depicted in the Figure 9.

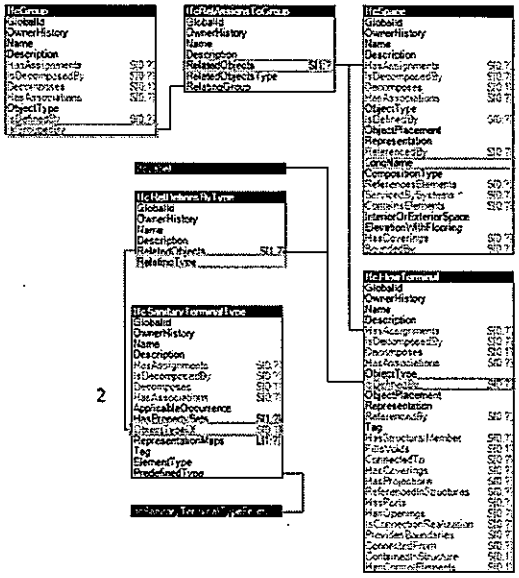

Figure 8. Verifying IfcGroup should have two WC in IfcDoc

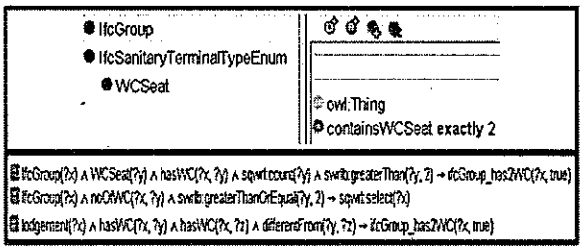

Figure 9. Verifying IfcGroup should have two WC in SWRL

F. *Composition of Simple Rule to build complex rules*

MVDXML and SWRL allow building complex rules which are formed from basic rules. We can concatenate simple rules with operators to form more complex rules. Figures 10 and 11 show an example of building complex rules with the composition of simple rules.

```
<Concept name="Nombre de WC dans le logement">
  <Template ref="1" /><!-- vers le Template : WC séparé-->
  <Template ref="2" /><!-- vers le Template : 2 WC-->
  <TemplateRules operator="and" />
</Concept>
```

Figure 10. Composition of complex rules based on simple rules in IfcDoc

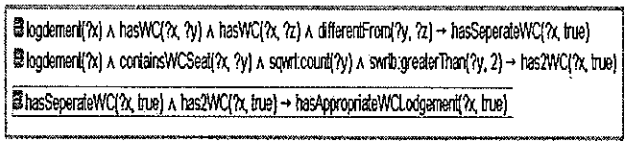

Figure 11. Composition of complex rules based on simple rules in SWRL

G. *Beyond MVDXML – More functionalities in SWRL*

As SWRL is a W3C [29] recommendation, a lot more functionality is added to meet the requirements of the real world scenarios. For example, one can perform calculations in SWRL, which we cannot do in MVDXML. For instance, volume of a door can be calculated given the length, width and height of a door. In SWRL, we use *multiply* function to get *LxWxH* to calculate and display the volume of a door. In addition to a mathematical library (e.g., add, subtract, multiply,..,sin, cos, tan), we have a large number of functions for the string manipulation (e.g., stringConcat, stringLength, substring, normalizeSpace, etc.), and for the DateTime, Duration, URIs and Lists as well. In addition, we can also define new attributes and elements and give them values based on the initial axioms in the repository and store them back in our repository for further processing. This is a very interesting feature of semantic technologies as we cannot define everything in the repository at the initial stage. Some information which is missing, evolving, or new, can be inserted in the repository during the later stages of design and processing. For example, if we want a new attribute isWheelChairAccessible associated with the water closet (WC) based on the dimensions of its door, then we can verify its width and height, and assign a value to the attribute *isWheelChairAccessible* and store its value back in the repository to judge the accessibility of a WC.

V. EXPERIMENTAL ANALYSIS ON IFCDOC AND SPARQL

We also performed experiments via different queries on different sizes of IFC models by the traditional approach via IFCDoc and the ontology-based approach via SPARQL. We have used IFC-to-RDF-Converter developed by Pauwels and Oraskari [15]. The IFC file needs to follow the IFC4_ADD1, IFC4, IFC2X3_TC1, or IFC2X3_Final schema. Once IFC document is converted into RDF, then we stored it into the Stardog triple store. Stardog is the enterprise knowledge graph used for querying, searching, and analyzing enterprise data, wherever it is, using scalable, cutting-edge knowledge graph technology. We found that SPARQL queries are flexible for retrieving data and do the validation in an optimized way giving better run-time as compared to the traditional approach. But conversion from IFC to RDF and then storage of triples into stardog takes time. But, once the stardog triple store is loaded with the data, it is much faster querying and validation of IFC document. SPARQL queries and SWRL rules can be modified easily with the new or customized conditions and constraints for the conformance checking against the stored triple store. Besides flexibility, reasoning is another advantage of Semantic Web technology, as the IfcDoc tool does not provide any justification. With

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queries and rules, we can identify the reason of inconsistency and anomalies. Therefore, each approach has its own pros and cons. The traditional approach is simpler as there are no conversion tasks. On the other hand, Semantic Web technologies require a conversion layer to be integrated for the validation tasks for IFC models. But, it can enable interoperability and fast information retrieval once the triple store is ready. Table 1 summarizes file and schema features of both approaches, where 1 represents the traditional approach via MVDXML and 2 represents the Semantic Web approach via SWRL.

TABLE I. FILE AND SCHEMA FEATURES OF BOTH APPROACHES

	Data File	*Rule File*	*Rule Schema*	*Data Schema*
1	IFC	.mvdXML	.XSD	.step
2	RDF (IFC converted)	.SWRL, .OWL	.OWL	IfcOnt

VI. CONCLUSION AND FUTURE WORK

This paper addresses the need of automatic verification requirements to warn the non-conformities with the associated 3D visualization as a hot challenge. We studied two approaches for the validation of IFC Models, i.e., with IfcDoc and SWRL. Each approach has its own pros and cons and should be used according to requirements of a research project. Some of major points are:

- IfcDoc tool and traditional conformance checking by MVDXML technology is a good candidate for the simple rules on small IFC models. Verification by SWRL requires a prior conversion of the IFC model in to the RDF, which is an extra task to achieve.
- Although IFC is an open standard; its complex nature makes information retrieval from an IFC model difficult as the size of IFC model grows. Querying semantic model is faster and gives a good run-time. One can customize queries easily and according to requirements.
- There is no intermediate state and IfcDoc tool gives no explanation for the reason of non-compliance. Whereas the Semantic Web technology is a good compromise between development efforts and opportunities. The graphical representation of RDF allows rules to be more intuitive and more efficient to reason and execute.

As a future direction, we are going to present a comprehensive quantitative comparison between the two approaches, and also investigate other triple stores which are competitors of stardog for the storage and querying of IFC models.

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The Infiltration Game: Artificial Immune System for the Exploitation of Crime Relevant Information in Social Networks

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Abstract—**Efficient and sensitive monitoring of social networks has become increasingly important for criminal investigations and crime prevention during the last years. However, with the growing amount of data and increasing complexity to be considered, monitoring tasks are difficult to handle, up to a point where manual observation is infeasible in most cases and, thus, automated systems are very much needed. In this paper, a system of adaptive agents is proposed, which aims at monitoring publicly accessible parts of a given social network for malign actions, such as propaganda, hate speeches or other malicious posts and comments made by groups or individuals. Subsequently, some of these agents try to gain access to crime relevant information exchanged in closed environments said individuals or groups are potentially part of. The presented monitoring and investigation processes are implemented by mimicking central aspects of the human immune system. The monitoring processes are realized by network-traversing informant units similar to pathogen-sensing macrophages, which initialize the human immune response. The subsequent investigation process is commenced by gathering information automatically about the targeted individual or group. Furthermore, based on the gathered information one can identify closed and usually inaccessible environments in the social network (e.g., private groups). Using so-called endoceptor units—automatically generated social bots imitating environment-typical appearance and communication—closed environments are accessed through individuals susceptible to the bot's strategy. Once being part of the closed network, an endoceptor aims to intercept and report back crime relevant communications and information to the investigators.**

Keywords–social network; prevention; predictive policing; text mining; autonomous agents; artificial immune system

I. Introduction

Over the last ten years, social networks have grown to become an essential part in our communication. Despite their success and advances made, social networks have also produced central hubs for criminal energy by providing the possibility/means to network as well as interchange and communicate ideas quickly, while remaining private in an environment difficult to control and monitor by investigators. Thus, for extreme political groups, criminal gangs and terrorist organizations, social networks are ideal platforms for planning and appointing the execution of criminal actions. Therefore, targeted monitoring of social networks can help to improve strategic security planning and prevention processes by authorities, as well as, help to increase the users' sense of security. Homeland security and secret services are aware of the importance of crucial information hidden in these networks and therefore more and more focus on social network surveillance. Looking at the increasing number of users worldwide – currently every third person uses social networks – there is a huge number of potential profiles and communication traffic to be monitored. This shows the need for an automated and sensitive solution that is able to cope with the vast amount of data and computational complexity yielding from it. Yet, besides these theoretical hurdles, the implementation of such monitoring procedures is further impaired due to the simple fact that in most cases crime-specific information is not discussed in the publicly accessible environment of social networks. Such relevant exchanges and discourses are rather made in closed inaccessible groups.

With respect to the legal limitations, in this work a multi-agent-based system is proposed, which aims at monitoring social networks and targeting potential offenders and (mostly) inaccessible subnetworks of their associates. The presented strategy utilizes a cascaded system of multi-role agent units, whose implementation and tasks are inspired by the human immune system. Similar to the cells involved in the human immune response (e.g., macrophages, killer cells and T-helper cells), the framework employs agents capable of sensing malicious actions, such as malign or offensive posts, analysing the profiles of the (potential) offenders, identifying the (mostly private and inaccessible) subnetworks of associates, entering these subnetworks as social bots that are automatically adapted to the appearances, ductus, and characteristic styles of these associates, and relaying explosive information exchanged in these subnetworks to the investigators.

In Section 2, we discuss related work presenting implementations of social network monitoring processes, as well as *in silico* realizations of the human response system and their applicability in this respect. Details about the proposed framework are presented in Section 3.

II. Related Work

Research conducted towards monitoring social media in the context of forensics has given rise to a large body of literature. In this section, a brief overview on works addressing this issue is given. Further, in order to put the proposed framework into context, some of the landmark papers discussing computational implementations of the human immune response system for data analyses are summarized. For a more in depth view, please refer to the notable review paper from Benkhelifa et al. [1] in which the authors outline some of the recent high-impact advancements and also propose a digital forensics incidents prediction framework tailored towards being utilized in cloud environments.

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Complementing the idea of predicting future criminal incidents, in one of the most recent papers Soundarya et al. [2] elucidated the utilization of so-called genetic weighted k-means cluster analyses combined with negative selection schemes in an effort to make predictions based on social media profiling. Although the predictive power looks promising, implementing the presented prediction scheme successfully in real life applications is questionable, as underlying features used in their method are derived from information difficult to obtain in practice (e. g. the number of logins/sessions per day and the time duration of individual sessions). Another interesting idea was presented by Huber et al. [3]. Using their so-called Social Snapshot method, data can be efficiently acquired from social network websites that are of special interest for law enforcement agencies. This method is based on custom-made add-ons for crawling social networks and underlying web components. The Social Snapshots method further allows the extraction of profile information such as user data, private messages and images, and associated meta-data like internal timestamps and unique identifier. A prototype for Facebook was developed by the group and evaluated based on a volunteer survey.

Computational modelling of human immune response mechanisms and applying such models to various problems in data mining has been an ongoing research process for over two decades. In 2000, Timmis et al. [4] published an immune response-mimicking framework specifically designed for data analysis. Furthermore, the group presented a minimalistic formulation of an artificial immune system and elucidated its action/response mechanisms. As another example for application, Wu & Banzhaf [5] and West et al. [6] independently developed artificial immune systems for the detection of transactional frauds in automated bank machines. Both works employ binary matching rules paired with fuzzy logic in order to detect transaction anomalies. Chen et al. [7] discussed a classification technique, which considers some general aspects of immune response mechanisms. In combination with a population-based incremental adaptive learning scheme and collaborative filtering, their method aims at detecting invasive actions targeting computer networks. Finally, the research group of Karimi-Majd et al. [8] developed a novel hybrid artificial immune network for detecting sub-structures, so-called communities, in complex networks using statistical measures of structural network properties.

III. The Proposed Framework

The proposed multi-agent monitoring system, as illustrated in Figure 1, is inspired by the cellular mechanisms implemented by the human immune system. Although there are multiple immune response mechanisms and cell types with roles highly adapted to these individual mechanisms, the general concept of immune response can be summarized as follows: mobile recognition cells freely traversing the human body (e.g., macrophages) are able to recognize and absorb pathogens, such as viruses or infectious bacteria, and to report back pathogen-specific information upon which an adaptive immune response is triggered. Subsequently, mobile cells are synthesized that use the reported cellular information to specifically target and destroy invaded pathogens by means of a pathogen-specific molecular lock-and-key binding mechanism. Multiple aspects are implemented in the proposed framework that aim at mimicking this response concept in the context of recognizing hostile and malicious activities in the publicly accessible parts of the environment under investigation (e.g., selected profiles in (sub-) social networks, blogs or internet forums), and targeting groups of malign entities usually inaccessible to the public (e.g. closed groups in social networks).

The agent units implemented by the proposed framework are presented in more detail in the following subsections.

A. Informants

Similar to the biological role of pathogen-sensing macrophages, the task of informant units is to recognize potentially dangerous profiles within the social network. There are two basic types of informants, observers I^o and classifiers I^c. The objective of the observers is to read along public discussions, so called feeds. If a post or comment with potentially dangerous content is detected, the corresponding profile is reported as a candidate profile p^c to a central control unit, the agency Ψ (Implementation details about the agency are given later). The algorithmic layout of informants has to be manifold due to profile appearance variability of potential offenders. For example, to recognize the profile of a right-wing individual or organization, an analysis of the images on the profile or the members or friend lists can be helpful. In this respect, a binary classifier is trained for each feature, which is suitable to identify a particular type of potential offender. The training takes place in the form of semi-supervised learning. Candidate profiles whose membership to a certain potential offender type are considered to be secured serve as seeds. In order to minimize the likelihood of a misclassification, all classifiers of a certain type of potential offender form an ensemble which reports a profile as a candidate p^c to the agency by majority vote.

B. Analysts

The analysts A are specifically tailored towards certain groups of potential offenders. Their task is to gather information about candidate profiles. Such information could be, for example, the mood in the network determined by sentiment analyses, the development of its structural properties, or planned activities. As a special task, the analysts have to adapt to the language specificities of the respective group. In this way, on the one hand, the ability of the informants to discriminate profiles can be further improved. On the other hand, such specificities form the basis for the synthesis of adapted endoceptors. In the case of a group profile or the profile of an organization, the opinion-makers are detected by analysing the communication and subsequently reported to the agency. The detection of opinion-makers or multipliers can be conducted by considering the Page Rank algorithm [9] [10] or Hyperlink-Induced Topic Search (HITS) algorithm [11] developed to detect hubs and authorities on websites. Further informative features, such as hashtags, '@' references or information deduced from discourse analysis, need to be considered and are readily available in social network environments.

C. Endoceptors

The most subtle type of agents in the framework are endoceptors E. They are used when certain circumstances in the analysis justify the assumption that further explosive information is distributed in closed groups. Endoceptors are a

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kind of chat bot that adapts to the language behaviour of a potential offender group and tries to contact the leading members in order to become a member of the group. Once included, endoceptors remain passive and relay distributed information to the agency. In this way, they imitate the behaviour of a confidential informant.

D. Agency

In line with the human lymphatic system, a technical agency Ψ forms both the infrastructural basis of this framework and its bilateral interface to investigators. Such agencies include, in addition to the set of so-called candidate profiles P^c, a set of activation functions $\alpha_1, ..., \alpha_n$ as triggers for synthesizing different types of agents. A candidate profile in this respect can be the public profile of a group or organization but also the non-public one of an individual. A ranking $r(P^c)$ is assigned to each candidate, which determines whether and with which priority it is observed and which concrete actions, i. e., which concrete agent synthesis are triggered by the agency. Equation (1) shows that the ranking is mainly driven by two parts. The first part takes the frequency of notifications by observers into account. The second refers to the mean voting of all classifiers, whereat the individual influence can be adjusted by a weight w_i with $\sum w_i = 1$. For example, the classification of the profile of an organization as right-wing extremist might depend more on the estimation of the image classifier than the one who makes the same assessment by means of the list of friends. The influence of each part of the ranking function can be controlled by parameter λ with $\lambda = [0, 1]$, which needs to be estimated empirically.

$$r(p_i^c) = \lambda \frac{count(I^o, p_i^c)}{\sum_{P^c} count(I^o, p_j^c)} + (1 - \lambda) \sum_{j=1}^{|I^{c_j}|} \frac{w_j I^{c_j}(p_i^c)}{|I^{c_i}|} \quad (1)$$

The synthesis of an instance of a specific agent type is triggered by an activation function α. Equation (2) shows such a function for the activation of the analysts. The function decides on the basis of the rank of a candidate whether or not a threshold is exceeded and the synthesis is triggered. The threshold value can be regarded as a kind of intervention threshold. Thus, it represents a parameter for the implementation of safeguards against arbitrary surveillance.

$$\alpha_A(p_i^c) = \begin{cases} 1, & \text{if } r(p_i^c) > \epsilon \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

E. Workflow

An illustration of the recognition and response mechanism is given in Figure 2. Individual monitoring steps are labelled A through E. The 'informant synthesis'—the *ad hoc* generation of informant units—is based on *a priori* expert knowledge provided by the investigators. The number of informants of a certain type of concept or topic to be monitored (illustrated by circle, square and triangle symbols) depends on the structural properties of the network and the amount of information exchanged by the users. Again, informants can only access publicly available information. Once public malicious activity is detected by an informant (see step A in Figure 2), entity-specific information is reported back to the agency (step B in Figure 2). In the illustration in A, an informant of type

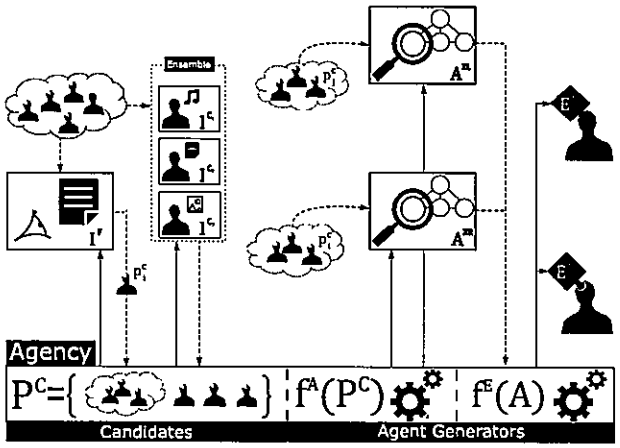

Figure 1. Schematic structure of the proposed framework. The informants I supply candidate profiles p^c to the agency where they are registered and evaluated by means of a ranking function. If a critical value is exceeded, analysts A are synthesized by a function f^A and sent out to collect information about these profiles. This information is the basis for endoceptors synthesized later by the function f^E attempt to infiltrate the protected areas of potentially dangerous profiles by contacting them in the manner of a chatbot by sending friendship requests. Once accepted, they remain passive and forward information to the investigating authorities.

'triangle' detects malicious activity in a subnetwork of users. Similarly, in B an informant of type 'cycle' reports an incident back to the agency. Subsequently, analyst unit synthesis is triggered according to an activation function (see Section III-D for formal details). The set of activation functions and their importance weighting relative to the number of detected incidents over time can be interpreted, in a biological sense, as the number of specific receptors for the different types of informants. The more 'alerted' informants are reporting back to the agency and are 'bound' to the agency, the more specific informants and receptors are subsequently synthesized. The ratio of synthesized receptors and informants bound to them illustrates the weight of the individual activation function. The role of the analyst unit is to use information retrieved from the publicly active malign entity to locate the network of associated malign entities and possible entry points to the subnetwork (step C in Figure 2). In a next step, this information is used to synthesize an endoceptor unit (step D in Figure 2). By mimicking the behaviour and appearance of target entities, the endoceptor aims at penetrating the closed environment, thus becoming a part of the network. Information exchanged by malign entities is now intercepted and communicated back to the agency module (step E in Figure 2).

IV. Conclusion and Future Work

In this work, we outlined a framework that allows investigators from law enforcement agencies and intelligence services to automatically monitor social networks and collect information about potentially dangerous activities. The framework is based on autonomous agents and inspired by the processes in the human immune system. However, no attention was paid to an exact replica of the biological processes. For the proposed framework, it is more important that the system is able to adapt itself to various disturbances. Therefore, it has to be able to adjust to the form of profiles of potential offenders, infiltrate

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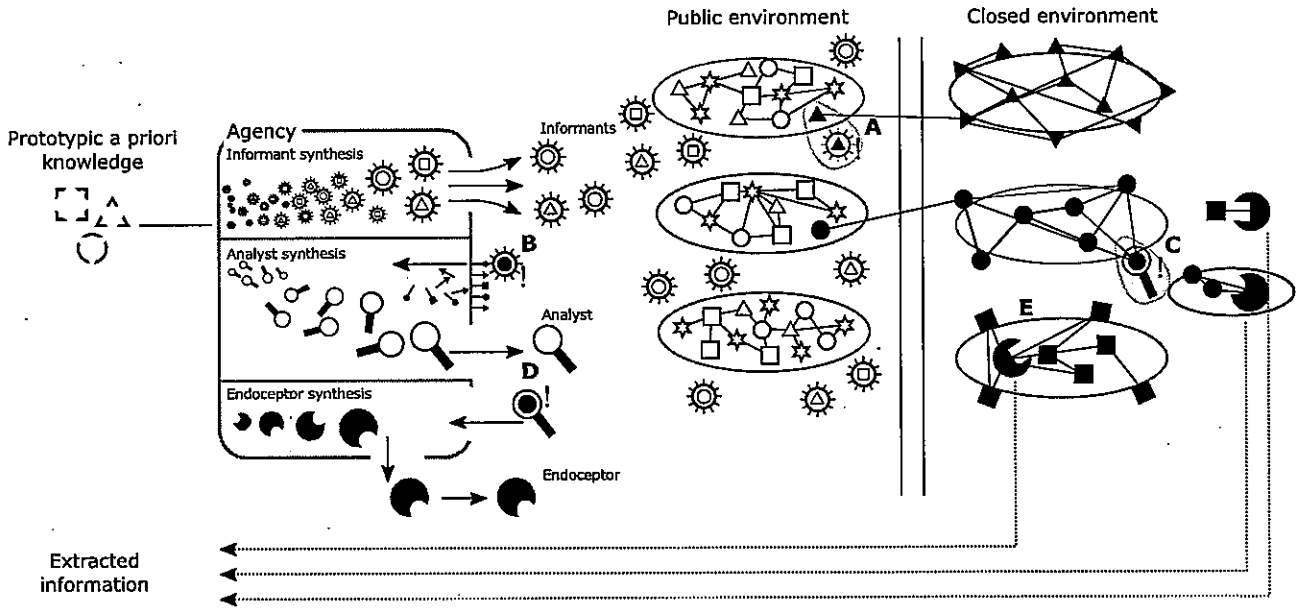

Figure 2. Schematic of the proposed workflow. Please refer to Section III-E for implementation details.

them and forward important information to the investigators. In this way, risks can be detected early and, at best, damage can be prevented.

Current and future work is mainly concerned with the design of the analysts, whereat the focus is on the detection of opinion-makers and the analysis of language style and writing behaviour in the group as a prerequisite for the synthesis of chat bots (Endoceptors) that are recognized by that group as their peers. As a by-product, we can learn how chat bots can be detected in networks. In parallel, independent sets of social features have to be found, which are suitable to classify candidates with the necessary accuracy to address privacy concerns.

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Understanding the Food Supply Chain using Social Media Data Analysis

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Abstract— **This paper proposes a big data analytics based approach, which considers social media (Twitter) data for identifying supply chain management issues in food industries. In particular, the proposed approach includes: (i) capturing of relevant tweets based on keywords; (ii) pre-processing of the raw tweets; and, (iii) text analysis using support vector machine (SVM) and hierarchical clustering with multiscale bootstrap resampling. The result of this approach included cluster of words, which can inform supply chain (SC) decision makers about the customer feedback and issues in the flow/quality of the food products. A case study of the beef supply chain was analysed using the proposed approach where three weeks of data from Twitter was used. The results indicated that the proposed text analytic approach can be helpful to efficiently identify and summarise crucial customer feedback for supply chain management.**

Keywords- Twitter data; social media; data mining; clustering.

I. INTRODUCTION

With the advent of online social media, there is lot of consumer information available on Twitter, which reflects the true opinion of customers [9]. Effective analysis of this information can give interesting insight into consumer sentiments and behaviors with respect to one or more specific issues. Using social media data, a retailer can capture a real-time overview of consumer reactions about an episodic event. Social media data is relatively cheap and can be very effective in gathering opinion of large and diverse audiences. Using different information techniques, business organisations can collect social media data in real time and can use it for developing future strategies. However, social media data is qualitative and unstructured in nature and often large in volume, variety and velocity [6]. At times, it is difficult to handle it using traditional operation and management tools and techniques for business purposes. In the past, social media analytics have been implemented in various supply chain problems predominantly in manufacturing supply chains. The research on application of social media analytics in domain of food supply chain is in its primitive stage. In this article, an attempt has been made to use social media data in domain of food supply chain to make it consumer centric. The results from the analysis have been linked with all the segments of supply chain to improve customer satisfaction.

Firstly, data was extracted from Twitter (via Twitter streaming API) using relevant keywords related to consumer's opinion about different food products. Thereafter, pre-processing and text mining was performed to investigate the positive and negative sentiments of tweets using Support Vector Machine (SVM). Hierarchical clustering of tweets from different geographical locations (World, UK, Australia and USA) using multiscale bootstrap resampling was performed. Further, root causes of issues affecting consumer satisfaction were identified and linked with various segments of supply chain to make it more efficient. Finally, the recommendations for consumer centric supply chain were described.

This paper is organized as follows. Section II, presents the literature review related to food products supply chain and state-of-the-art methods used in the area. In Section III, the proposed methodology is discussed in detail. Section IV presents the results obtained by applying proposed twitter based analytics for beef supply chain. Section V details the managerial implications of the proposed analysis method in food products supply chain. Finally, Section VI concludes this research with some guidelines for future research.

II. LITERATURE REVIEW

Food products supply chain, such as for beef products consists of various stakeholders, which are farmer, abattoir and processor, retailer and consumer. Literature consists of research publications on diverse characteristics of beef supply chain such as waste minimisation, vertical coordination in supply chain, traceability, greenhouse gas emission, meat quality, meat safety. For instance, Francis et al. [4] have applied value chain analysis for examination of beef sector in UK. The opportunities for waste minimisation at producer and processor level have been identified in the UK by comparing them to practices followed in Argentina. Consequently, good management practices have been suggested to mitigate the waste generated in UK beef industry. Wang et al. [16] have utilised the standardized performance analysis data to examine the beef farms in Texas Rolling plants.

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In literature, several types of framework have been proposed to investigate problems and issues associated with supply chain through big data analysis. Chae [1] has developed a Twitter analytics framework for evaluation of Twitter information in the field of supply chain management. An attempt has been made by them to fathom the potential engagement of Twitter in the application of supply chain management and further research and development. Tan et al. [14] have suggested an analytic mechanism for capturing and processing of big data generated in the corporate world. It employed deduction graph technique. Hazen et al. [7] have determined the problems associated with quality of data in the field of supply chain management and a novel procedure for monitoring and managing of data quality was suggested. Vera-Baquero et al. [15] have recommended a cloud-based mechanism utilising big data procedures to efficiently improve the performance analysis of corporations. Frizzo et al. [5] have done a thorough analysis of literature on big data available in reputed business journals. A very limited work is being done to explore the characteristics of food supply chain by utilising social media data.

Twitter, Facebook and Youtube denote the swift expansion of Web2.0 and applications on social media lately. Twitter is the most rapidly growing social media platform since its outset in 2006. More than 75% of corporate firms enlisted in Fortune Global 100 have one or more Twitter account for the entire firm and for their distinct brands [10]. This research study will use Twitter data for the identifying issues in supply chain management (SCM) in food industries. The next section describes the research study conducted in this paper.

III. ANALYTICS APPROACH

In case of social media data analysis, three major issues are to be considered, namely, data harvesting/capturing, data storage, and data analysis. Data capturing in case of twitter starts with finding the topic of interest by using appropriate keywords list (including texts and hashtags). This keywords list is used together with the twitter streaming APIs to gather publicly available datasets from the twitter postings. Twitter streaming APIs allows data analysts to collect 1% of available Twitter datasets. There are other third party commercial data providers like Firehose with full historical twitter datasets.

The Twitter streaming API allowed us to store/append twitter data in a text file. The analysis of the gathered Twitter data is generally complex due to the presence of unstructured textual information, which typically requires Natural Language Processing (NLP) algorithms. We proposed two main types of content analysis techniques – sentiment mining and clustering analysis for investigating the extracted Twitter data; see Figure 1. More information about the proposed sentiment mining method and hierarchical clustering method is detailed in the following subsections.

A. Data Analysis

The information available on social media is predominantly in the unstructured textual format. Therefore, it is essential to employ Content Analysis (CA) approaches, which includes a wide array of text mining and NLP methods to accumulate knowledge from Web 2.0 [2]. An appropriate cleaning of text and further processing is required for effective knowledge gathering. There is no best way to perform data cleaning and several applications have used their own heuristics to clean the data. A text cleaning exercise, which included removal of extra spaces, punctuation, numbers, symbols, and html links were used. Then, a list of major food retailers in the world (including their names and Twitter handles) was used to filter and select a subset of tweets, which are used for analysis.

1) Sentiment analysis based on SVM

Tweets contain sentiments as well as information about the topic. Thus, sophisticated text mining procedures like sentiment analysis are vital for extracting true customer opinion. The objective here is to categorise each tweet with positive and negative sentiment. Sentiment analysis, which is also widely known as opinion mining is defined as the domain of research that evaluates public's sentiments, appraisals, attitudes, emotions, evaluations, opinions towards various commodities like services, corporations, products, problems, situations, subjects and their characteristics.

The identification of polarity mentioned in opinion is a crucial for transforming the format of opinion from text to numeric value. The performance of data mining methods such as SVM is excellent for sentiment classification. SVM model is employed in this approach for the division of polarity of opinions. Initially, a set of features from the data must be chosen. In this case, we have used Unigrams and Bigrams, which are the tokens of one-word and two-word, respectively, identified from the tweets. In this study, we used binary value {0,1} to represent the presence of these features in the microblog.

SVM is a technique for supervised machine learning, which requires a training data set to identify best Maximum Margin Hyperplane (MMH). In the past, researchers have used approach where they have manually analysed and marked data prior to their use as training data set. In this case, we have examined the use of emoticons to identify sentiment of opinions. In this paper, Twitter data was pre-processed based on emoticons to create training dataset for SVM. Microblogs with ":)" were marked as "+1" representing positive polarity, whereas messages with ":(" were marked as "-1" representing negative polarity. It was observed that more than 89% messages were marked precisely by following this procedure. Thus, the training data set was captured using this approach for SVM analysis. Then, a grid search (Hsu et al., 2003) was employed to train SVM. The polarity (Pol_m={+1,-1}) representing positive and negative sentiment respectively of microblog m can be predicted using trained SVM. In real life, when consumers buy beef products, they leave their true opinion (feedback) on Twitter. In this article, the SVM classifier has been utilised to classify these sentiments into positive and negative and consequently gather intelligence from these tweets.

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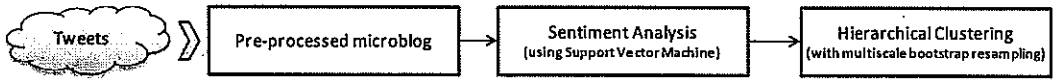

Figure 1. Overall approach for social media data analysis

2) Hierarchical clustering with p-values using multiscale bootstrap resampling

In this research, we also employed a hierarchical clustering with *p*-values via multiscale bootstrap resampling method to analyse the content of tweets with positive and negative sentiments [13]. The clustering method creates hierarchical clusters of words and also computes their significance using *p*-values (obtained after multiscale bootstrap resampling). This helps in easily identifying significant clusters in the datasets and their hierarchy. The agglomerative method used is ward.D2 [11]

In a typical data clustering approach, data support for the identified clusters is not present. The support of data for these clusters can be obtained by adopting multiscale bootstrap resampling. In this approach, the dataset is replicated by resampling for large number of times and the hierarchical clustering is applied. During resampling, replicating sample sizes was changed to multiple values including smaller, larger and equal to the original sample size. Then, bootstrap probabilities are determined by counting the number of dendrograms, which contained a particular cluster and dividing it by the number of bootstrap samples. This is done for all the clusters and sample sizes. Then, these bootstrap probabilities are used to estimate *p*-value, which is also known as Approximately Unbiased (AU) value.

The result of hierarchical clustering with multiscale bootstrap resampling is a cluster dendrogram. At every stage, the two clusters, which have the highest resemblance are combined to form one new cluster. The distance or dissimilarity between the clusters is denoted by the vertical axis of dendrogram. The various items and clusters are represented on horizontal axis. It also illustrates several values at branches, such as AU *p*-values (left), Bootstrap Probability (BP) values (right), and cluster labels (bottom). Clusters with AU >= 95% are usually shown by the red rectangles, which represents significant clusters.

IV. RESULTS AND DISCUSSION

The proposed Twitter data analysis approach is used to understand issues related to the beef/steak supply chain based on consumer feedback on Twitter. This analysis can help to analyse reasons for positive and negative sentiments, identify communication patterns, prevalent topics and content, and characteristics of Twitter users discussing about beef and steak. Based on the result of the proposed analysis, a set of recommendations have been prescribed for developing customer centric supply chain. The total number of tweets extracted for this research was 1,338,638 (as per the procedure discussed in Section 3). They were captured from 23/03/2016 to 13/04/2016 using the keywords beef and steak. Only tweets in English language were considered with no geographic constraint. Figure 2 shows the geo-located tweets in the collected dataset. Then, keywords were selected to capture the tweets relevant to this study. The overall tweets were then filtered using this list of keywords so that only the relevant tweets (26,269) are retrieved. Then, country wise classification of tweets was performed by using the name of supermarket corresponding to each country. It was observed that tweets from USA, UK and Australia and World were 1605, 822, 338 and 15214 respectively. There were many hashtags observed in the collected tweets. The most frequently used hashtags (more than 1000) were highlighted in Table 1.

As described in the previous subsection, the collection of training data for SVM was done automatically based on emoticons. The training data was developed by collecting 10,664 messages from the Twitter data captured with emoticons ":)" and ":(". The automatic marking process concluded by generating 8560 positive, 2104 negative and 143 discarded messages. Positive and negative messages were then randomly classified into five categories. The 8531 messages in first four categories were utilised as training data set and the rest of the 2133 messages were utilised as the test data set.

Numerous pre-processing steps were employed to minimise the number of features prior to implementing SVM training. Initially, the target query and terms related to topic (beef/steak related words) were deleted to prevent the classifier from categorising sentiment based on certain queries or topics. Various feature sets were collected and their accuracy level was examined. In terms of performance of the classifier, we have used two types of indicators: (i) 5-fold cross validation (CV) accuracy, and (ii) the accuracy level obtained when trained SVM is used to predict sentiment of test data set.

Table 2 reports the performance of SVM based classifiers on the collected microblogs. The best performance is provided when using unigram feature set in both SVM and Naïve Bayes classifiers. The unigram feature set gives better result than the other feature sets. This is due to the fact that additional casual and new terms are utilised to express the emotions. It negatively affects the precision of subjective word set characteristic as it is based on a dictionary. Also, the binary representation scheme produced comparable results, except for unigrams, with those produced by term frequency (TF) based representation schemes. As the length of micro blogging posts are quite short, binary representation scheme and TF representation scheme are similar and have almost matching performance levels. Therefore, the SVM based classifier with unigrams as feature set represented in binary scheme is used for estimating the sentiment score of the microblog.

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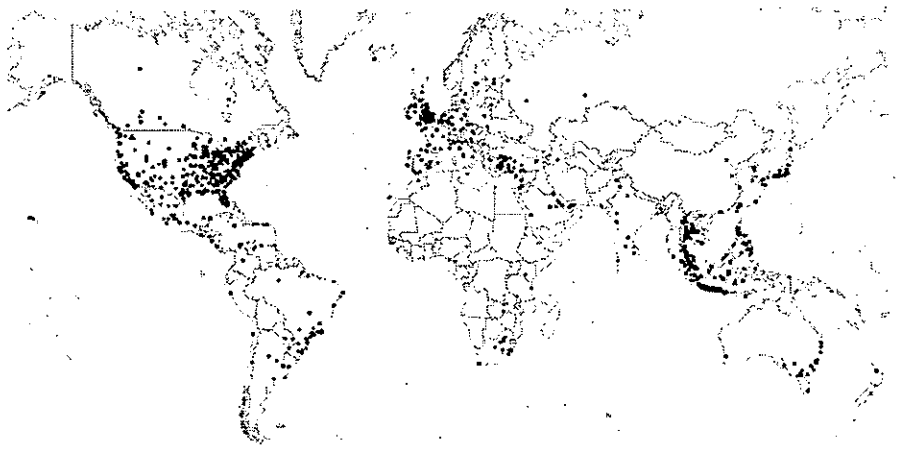

Figure 2. Visualisation of tweets with geolocation data

TABLE 1. TOP HASHTAGS USED

Hashtag	Freq (>1000)	Freq (%)	Hashtag	Freq (>1000)	Freq (%)
#beef	17708	16.24%	#aodafail	1908	1.75%
#steak	14496	13.29%	#earls	1859	1.70%
#food	7418	6.80%	#votemainefpp	1795	1.65%
#foodporn	5028	4.61%	#win	1761	1.62%
#whcd	5001	4.59%	#ad	1754	1.61%
#foodie	4219	3.87%	#cooking	1688	1.55%
#recipe	4106	3.77%	#mplusplaces	1686	1.55%
#boycottearls	3356	3.08%	#meat	1607	1.47%
#gbbw	3354	3.08%	#lunch	1577	1.45%
#kca	2898	2.66%	#bbq	1557	1.43%
#dinner	2724	2.50%	#yum	1424	1.31%
#recipes	2159	1.98%	#yummy	1257	1.15%
#accessibility	1999	1.83%	#bdg	1255	1.15%

TABLE 2. PERFORMANCE OF SVM BASED CLASSIFIER ON SELECTED FEATURE SETS

Representation scheme	Feature Type	Number of Features	SVM	
			CV (%)	Test data (%)
Binary	Unigram	12,257	91.75	90.80
	Bigram	44,485	76.80	74.46
	Unigram + bigram	56,438	87.12	83.28
Term Frequency	Unigram	12,257	88.78	86.27
	Bigram	44,485	77.49	71.68
	Unigram + bigram	56,438	84.81	80.97

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To identify meaningful content in the collected tweets, initially, we performed sentiment analysis to identify sentiments of each of the tweets followed by HCA. Following section provides the results of the analysis performed on the tweets (by sentiment) collected worldwide and UK.

a) Analysis of negative tweets from the world

The collected tweets were divided into positive and negative sentiment tweets. In negative sentiment tweets, the most frequently used words associated with 'beef' and 'steak', were 'smell', 'recipe', 'deal', 'colour', 'spicy', 'taste' and 'bone.' Cluster analysis is performed on the negative tweets from the world to divide them into clusters in terms of resemblance among their tweets. The three predominant clusters identified (with significance >0.95 level) are represented in Figure 3 as red coloured rectangles. The first cluster consists of bone and broth, which highlights the excess of bone fragments in broth. The second cluster is composed of jerky and smell. The customers have expressed their annoyance with the bad smell associated with jerky. The third cluster consists of tweets comprising of taste and deal. Customers have often complained to the supermarket about the bad flavour of the beef products bought within the promotion (deal). The rest of the words highlighted in Figure 3 does not lead to any conclusive remarks.

This cluster analysis will help global supermarkets to identify the major issues faced by customers. It will provide them the opportunity to mitigate these problems and raise customer satisfaction and their consequent revenue.

TABLE 3. RAW TWEETS WITH SENTIMENT POLARITY

Sentiment	Raw Tweets
Negative	*@Morrisons so you have no comment about the lack of meat in your Family Steak Pie? #morrisons*
Negative	*@AsdaServiceTeam why does my rump steak from asda Kingswood taste distinctly of bleach please?*
Positive	*Wonderful @marksandspencer are now selling #glutenfree steak pies and they are delicious and perfect! Superb stuff.*
Positive	*Ive got one of your tesco finest* beef Chianti's in the microwave oven right now and im pretty pleased about it if im honest*

b) Analysis of negative tweets from UK

The most widely used words after 'beef' and 'steak' were 'tesco', 'coffee', 'asda', 'aldi'. The association rule mining indicated that the word 'beef' was most closely associated with terms like 'brisket', 'rosemary', and 'cooker', etc. It was least used with terms like 'tesco', 'stock', 'bit'. The word 'steak' was highly associated with 'absolute', 'back', 'flat'. and rarely associated with words like 'stealing', 'locked', 'drug'.

The four predominant clusters are identified (with significance >0.95 level). The first cluster contains the words – man, coffee, dunfermline, stealing, locked, addict, drug. When this cluster was analysed together with raw tweets, it was found that this cluster represents an event where a man was caught stealing coffee and steak from a major food store in 'Dunfermline'. The finding from this cluster is not linked to our study. However, it could assist retailers for various purposes such as developing strategy for an efficient security system in stores to address shoplifting. Cluster 2 is related to the tweets discussing high prices of steak meal deals. Cluster 3 represents the concerns of users on the use of horsemeat in many beef products offered by major superstores. It reveals that consumer are concerned about the traceability of beef products. Cluster 4 groups tweets, which discuss the lack of locally produced British sliced beef in the major stores (with #BackBritishFarming). It reflects that consumers prefer the beef derived from British cattle instead of imported beef. Rest of the clusters, when analysed together with raw tweets, did not highlight any conclusive remarks and users were discussing mainly one-off problems with cooking and cutting slices of beef.

The proposed HCA can help to identify (in an automated manner) root causes of the issues with the currently sold beef and steak products. This can help major superstores to monitor and respond quickly to the customer issues raised in the social media platforms.

V. MANAGERIAL IMPLICATIONS

The finding of this study can assist the beef retailers to develop a consumer centric supply chain. During the analysis, it was found that sometimes, consumers were unhappy because of high price of steak products, lack of local meat, bad smell, presence of bone fragments, lack of tenderness, cooking time and overall quality. In a study, Wrap (2008) estimated that 161,000 tones of meat waste occurred because of customer dissatisfaction. The majority of food waste is because of discoloration, bad flavor, smell, packaging issues, and presence of foreign body. Discoloration can be solved by using new packaging technologies and by utilising natural antioxidants in the diet of cattle. If the cattle consumes fresh grass before slaughtering, it can help to increase the Vitamin E in the meat and have a huge impact on delaying the oxidation of color and lipid. The issues related to bad smell and flavor can be caused due to temperature abuse of beef products. The efficient cold chain management throughout the supply chain, raising awareness and proper coordination among different stakeholders can assist retailers to overcome this issue. The packaging of beef products can be affected by mishandling during the product flow in the supply chain or by following inefficient packaging techniques by abattoir and processor, which can also lead to presence of foreign body within beef products. Inefficient packaging affects the quality, color, taste and smell. Periodic maintenance of packaging machines and using more advanced packaging techniques like modified atmosphere packaging and vacuum skin packaging will assist retailers in addressing above mentioned issues.

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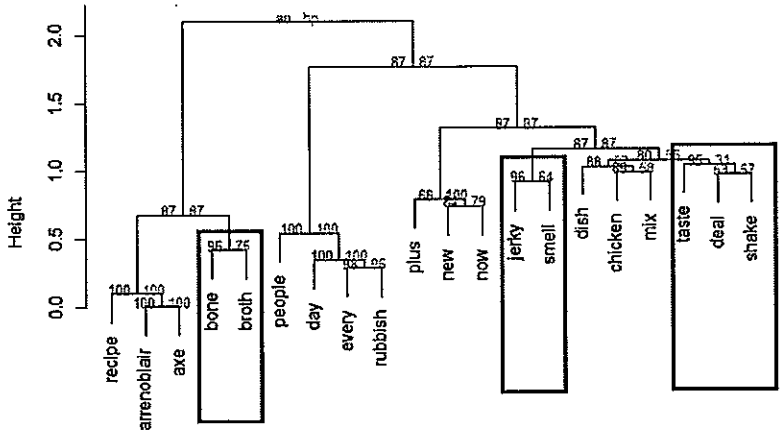

Figure 3. Hierarchical cluster analysis of the negative tweets originating in the World

The high price of beef products can be mitigated by improving the vertical coordination within the beef supply chain. The lack of coordination in the supply chain leads to waste, which results in high price of beef products. Therefore, a strategic planning and its implementation can assist the food retailers to reduce price of their beef products more efficiently than their rivals.

During the analysis, it was found that products made from forequarter and hindquarter of cattle have different patterns of demand in the market, which leads to carcass imbalance [3][12]. It leads to huge loss to retailers and contribute to food waste. Sometimes, consumers think that meat derived from different cuts such as forequarter and hindquarter have different attributes like flavor, tenderness, and cooking time as well as price. The hindquarter products like steak and joint are tenderer, takes less time for cooking and are more expensive whereas forequarter products like mince and burger have less tenderness, takes more time for cooking and are relatively cheaper. Consumers think that beef products derived from the forequarter and hindquarter have different taste and it affects their buying behavior. In this study, it was found that slow cooking methods like casseroling, stewing, pot- roasting and braising can improve the flavor and tenderness of forequarter products. With the help of proper marketing, advertisement, retailers can raise awareness between the consumers and can increase the demand of less favorable beef products, which will further assist in waste minimization and making the supply chain more customer centric.

The analysis of consumer tweets reveal that consumers especially from the UK, were interested in consuming local beef products. Their main concern was quality and food safety. Specially, after horsemeat scandal, customers are prone towards traceability information, i.e., information related to animal breed, slaughtering method, animal welfare, use of pesticides, hormones and other veterinary drugs in beef farms. Retailers can gain the consumer confidence by following the strict traceability regime within the supply chain.

VI. Conclusions and Future Work

Consumers have started to express their views on social media. Using social media data, a company can know the perception of their existing or potential consumers about them and their business rivals. In this study, Twitter data has been used to investigate the consumer sentiments. More than one million tweets related to beef products has been collected using different keywords. Text mining has been performed to investigate positive and negative sentiments of the consumers. During the analysis, it was found that the main concern related to beef products among consumers were color, food safety, smell, flavor and presence of foreign body in beef products. These issues generate huge disappointment among consumers. There were a lot of tweets related to positive sentiments where consumers had discovered and share their experience about promotion, deal and a particular combination of food and drinks with beef products. Based on the findings, some recommendations has been prescribed to develop consumer centric supply chain. In future, extensive list of keywords can be used for further analysis. Future work may include standardizing the data preprocessing steps for better model training and prediction. For instance, positive and negative words can be included in the analysis for better sentiment prediction. Network analysis tools can be also employed to understand the social network communities and identifying marketing opportunities.

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Low Cost Mobile Embedded System for Air Quality Monitoring

Air quality real-time monitoring in order to preserve citizens' health

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Abstract - **This paper reports on a case study using a mobile platform for air-quality monitoring. This case study was done in Sibiu, Romania, and includes a description of related work, a survey, a summary of existing results regarding air quality, a description of the mobile air quality monitoring platform, and the results of trials done in February 2017. The aim of the case study is to pave the road for further studies of using mobile low-cost units for air quality monitoring.**

Keywords-air quality monitoring; environmental monitoring; sensor platform; traffic optimization; crowdsensing.

I. INTRODUCTION

This paper reports on a case study using a mobile platform for air-quality monitoring as part of a research project jointly conducted by the "Lucian Blaga" University of Sibiu, Romania and University College of Southeast Norway. The case study was done in Sibiu, Romania. Sibiu experience air quality problems caused by traffic. The design and development of the platform has been described in an earlier paper [1], and will only be briefly described here. The aim is to show how the platform is used, and to compare with other studies. The case study includes a survey among university students and employees to investigate their concerns about air quality.

A. Background

Europe and the rest of the world face severe societal challenges, especially related to energy consumption, environment and security. Air quality has become an important issue in most industrialized and urban areas. The use of fuels for cars, ships and production of energy, heavy traffic and inefficient modes of transport, waste burning, and industrial activities degrade air quality [2][3]. Information and communication technologies contribute around 2% of the global CO_2 emissions and approximately 8% of the European Union's use of electricity [4]. Contamination of the air is both a global and a local problem. On a global level the emissions of CO_2 and NO_X influences climate and global warming. On local level air pollution (detectable particles from smoke, ash, dust, spore, pollen and mildew) has an important impact on human health, causing health issues like asthma, allergies and bronchitis. According to World Health Organization (WHO) report from September 2016, 3 million deaths a year are linked with exposure to outdoor air pollution [5]. Air pollution may also reduce the value of properties in exposed areas.

Many cities, including London, Madrid and Paris, experience severe problems with air quality, especially during the winter season. Air pollution on cold days affects many citizens, and forces them to make quick decisions to avoid exposure, either to stay inside or choose an alternative route.

Even Norwegian cities such as Oslo and Bergen suffer due to climatic conditions, as the polluted air doesn't get warm enough to escape the cities surrounded by hills or mountains. When pollution levels are high, the cities of Bergen and Paris restrict the use of cars based on the last digit of the number plates. In January 2017, Oslo was closed for diesel cars for a short period. The city council considers raising traffic tolls on days with high pollution levels. Air pollution is a top priority for citizens especially in megacities from all around the globe [6]. More than that, each flight Paris-New York is melting 3 cube meter of icecap. If the trend continues, the Arctic ice cap will disappear in 30 years [7].

According to information presented by Dr. L. Roman from Autohaus Huber SRL (Sibiu), in a workshop[1] organized as part of the project, the pollution levels caused by automobiles change (to the worse) depending on several factors such as:

- Road traffic contributing to particle pollution both because of car tires wearing down the asphalt surface, and due to incomplete combustion.
- Quality of the fuels and lubricants.
- State of wear of the mechanical components of the engine and its auxiliary installations.

1 http://www.ulbsibiu.ro/myaccount/src/file.php?file=file1&news=true&id=2816

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- State of wear of electrical and electronic components.
- Running distance on which the vehicle is used daily.
- Quality of car maintenance.
- Driving quality (skill) of the vehicle users.
- Political decisions of reducing taxes on importing second hand cars.

In most cases, it is no quick fix for air pollution. Shutting down power stations or industries polluting the air are normally long-term projects. The use of filters and catalyzers may reduce the output of pollution. However, small projects may help reduce local pollution. One example is to provide passages for pedestrians under or above heavily trafficked roads [8], and building viaducts over railroads. This can increase the flow of vehicles and reduce the pollution caused by still-standing cars.

To combat air pollution, it is necessary to have objective air-quality measurements. Today, most of the air quality monitoring is done by a relatively small number of expensive stationary units. This causes a problem with granularity. A stationary unit collects data from a single geographical point and the data may not be representative for a larger area.

One strategy to improve air quality is to reduce traffic, and optimize the remaining traffic. This can be done in a multitude of ways: increasing traffic tolls, improving public transport, introducing smart parking systems that direct the driver to an available parking spot, and by disallowing certain types of cars to be used. In Oslo, cars need to pay a special tax if the car uses winter tires with spikes, to encourage car owners to choose more environmentally-friendly tires. (The spikes wear down the asphalt and create dust particles.)

The cities may implement different regulatory measures to reduce the emission of pollutants. For example, the mayors of Paris, Madrid, Athens and Mexico City have announced that trucks will not be allowed to enter their city centers from 2025. Also, diesel cars will be banned and the city councils are considering raising tolls on days with high pollution levels [9]. Walking and cycling will be encouraged and citizens will be provided incentives for the use of electric or hybrid vehicles [10].

The aim of this paper is to present a project to measure air quality by using a mobile platform for monitoring. This platform can provide more accurate information on air quality issues. Such monitoring can help raise awareness of air quality problems, their causes, and their impact, and thereby contribute to better decision making.

The project goals are:

- Give citizens a real image of the air quality in cities by making the mobile monitoring platform collect information from sensors, and send the data to a server for further analysis and visualization.
- Improve the quality of environmental monitoring by designing and developing a low cost "proof of concept" prototype for use in cars.
- Cars host the mobile environmental monitoring platform. Whenever the car is parked, the platform will start monitoring the environment around itself, and forward this information to the server. (The platform can also be used when the car is moving).
- The platform may perform some preprocessing of data to reduce the data traffic generated. Instead of sending data at fixed intervals, the platform can send alerts when changes happen. This can improve the scalability of the solution.

The rest of the paper is organized into four sections, where Section II briefly reviews some state of the art papers related to this study. Section III presents the Sibiu case study, including the survey, some existing studies from the Romanian National Network of Air Quality Monitoring, and information from traffic and roads administration. Section IV describes the research design - the mobile platform for environmental monitoring - both from hardware and software point of view, including some obtained results. Finally, in Section V, we provide implications and conclusions.

II. Related Work

Air quality monitoring has been around for many years, but has mostly been done by public authorities responsible for environmental monitoring. In most cases, the monitoring is done by expensive monitoring platforms in fixed locations. The aim of our project was to investigate alternative ways of obtaining measurement results to improve the granularity of measurements.

A. Hand-held units connected to smartphones

One approach is to use hand-held units to be carried around by citizens. Such units normally connect to a smart phone, and use the smartphone to obtain access to the internet.

Leonardi, Cappellotto, Caraviello, Lepri and Antonelli [11] developed an air quality monitoring unit to be carried around by citizens. An important reason for developing the mobile unit was: "*Official authorities use to monitor and publish air quality data collected by networks of static measurement stations. However, this approach is often costly, hard to maintain and not scalable in the long term*". They also argue that fixed station provides "*a lack of accuracy in the intra-urban air pollution maps*". The authors collected data from 80 persons in Trento, Italy. The unit, called "*SecondNose*", measures temperature, light, humidity, altitude, pressure and two air pollution parameters: carbon-monoxide (CO) and nitrogen-dioxide (NO_2). The unit communicates with an app installed in an Android smartphone through Bluetooth. The unit weighs only 28 grams, and has a battery capacity of five days.

Dutta, Chowdhury, Roy, Middya and Gazi [12] developed "AirSense", a monitoring platform based on Arduino Nano equipped with two sensors, one for air quality (MQ135) and one for carbon-monoxide (MQ7). The platform connects to an Android smartphone through Bluetooth, and weighs around 60 grams. The authors cited inadequate number of fixed monitoring stations as the reason for developing "AirSense".

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CITI-SENSE, an EU-funded project, developed a hand-held sensory unit to be carried around [13]. The "*Little Environmental Observatory*" (LEO) is a portable sensor pack. It measures NO, NO_2 and O_3 using electrochemical sensors. It also provides information about the current temperature and relative humidity. LEO connects to an Android smartphone through Bluetooth. CITI-SENSE also developed an app to let citizens report their own perception of air quality. CITI-SENSE ran from 2012 to 2016.

AIRALERT [14] is a service recently launched by the Romanian NGO CivicAlert. The service obtains data from a handheld sensor platform "*AirBeam*" with Bluetooth connection to an Android smartphone. Their idea is to collect data by issuing units to volunteer bicyclists. AIRALERT is using an existing visualization package to display results.

Z. Pan, H. Yu, C. Miao and C. Leung [15] used a somewhat different approach, by using smartphone cameras to detect air pollution through artificial intelligence techniques to determine particle pollution. This solution requires humans to actively do measurements.

B. Units equiped with GSM communication

Another approach is to equip the monitoring platform with built-in Global System for Mobile Communications (GSM) communication capabilities.

C. Migliore [16] developed a platform mounted on a bike, "*SwarmBike*", to measure air pollution. The unit has a Global Positioning System (GPS) receiver, a GSM module to handle communication, and sensors for barometric pressure, temperature, humidity and a CO sensor. His thesis describes other types of sensors for measuring air quality.

The projects OpenSense and OpenSense II [17] installed air quality measurement units on trams in Zurich and buses in Lausanne, Switzerland. The sensor platform measures ozone (O_3), nitrogen-dioxide (NO_2), carbon-monoxide (CO) and ultra-fine particles (UFP). The platform has a GPS-receiver, and transmits data to a server using GSM. A sensor was also installed in a Citroen C-Zero.

C. Related work compared to our platform

The problem with hand-held units is that someone must carry them around. Several solutions require Android smartphones. This excludes the large number of Apple iPhone users. Users may also be reluctant to provide access through their own phones. It seems that most of the projects described above lasted for a limited period.

Leonardi, Cappellotto, Caraviello, Lepri and Antonelli [11] reported that usage of "*SecondNose*" declined over time. Users said they were curious in the beginning, but soon learnt the characteristics of the places they measured. This may partially explain the non-sustainability of the projects using hand-held sensors.

Our unit is autonomous. No human is needed to carry it or turn it on or off. It uses a GSM module, and does not need smart phone for communication. It also has a built-in GPS. Insert a SIM-card and connect to car battery, and it is operating (plug-and-play).

The hand-held units described above seem to be more expensive. The sensor used by Leonardi, Cappellotto, Caraviello, Lepri and Antonelli [11] (SensorDrone) costs around USD 200. It only contains sensors and Bluetooth.

The components for our unit cost around 130 Euro, including sensors and GSM/GPS-module.

The OpenSense platform [17] closely resembles our platform, but collects data from trams and buses on the move. This brings some uncertainty caused by trucks being close to the measurement platform.

Our novel approach is to use parked cars. Parked cars provide the possibility to measure from one location over time. It is not dependent on human intervention to make the measurements. A city always owns cars used to provide services. But it is also possible to call on volunteers to host the platform in their cars.

D. Shared characteristics of monitoring platforms

Environmental monitoring platforms might be used by the municipality to create another layer in the city map (transparent for citizens), like layers showing networks of water, gas and electric cables, the sewer network, telephone and cable TV networks etc. Such layers may easily be implemented in a GIS system and can be used for increased transparency, sustainable regional development and innovative applications visualizing the pollution levels.

By collecting data from city and surroundings areas, platforms can identify the city's pollution hotspots (from air quality viewpoint), suggesting alternative positions for fixed stations or the need to introduce new ones. Such data will be valuable for the authorities responsible for air quality monitoring (National Environmental Protection Agency).

Platforms, like the ones described above, may provide real-time monitoring to preserve citizens' health and warn them when permissible level of pollution are exceeded. Platforms equipped with particle detectors may warn citizens about increasing levels of pollen or dust (producing allergies). In such situations, it may advise people to avoid areas that could be dangerous for health conditions and choose another detour and locate the closest pharmacies where antihistamine pills can be bought.

III. SIBIU CASE STUDY

This section presents the case study done as part of a research project conducted jointly by the "Lucian Blaga" University of Sibiu and University College of Southeast Norway and financed by European Economic Area (EEA) grants [18]. The focus is on a specific case for air quality monitoring: the city of Sibiu, Romania. The city is in Transylvania, and has a permanent population of approximately 155.000, and up to 25.000 students and temporary inhabitants. The traffic is high since two national roads, one south-north and one west-east, are meeting in the city. According to technical data obtained from Romanian National Company of Road Infrastructure Management, more than 70,000 cars are crossing Sibiu city every day.

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TABLE I. SURVEY QUESTIONS AND RESULTS

Q1:	How interested are you in air quality in general?
A1:	The citizens of Sibiu have high interest (>85%) in air quality and pollution level
Q2:	How would you describe the air quality in Sibiu in general?
A21:	The air quality in Sibiu is rather good (70%)
A22:	The air quality in Sibiu is poor (21%).
A23:	Uncertain: 9%.
	Arguments of respondents for "good air quality" consist in: • The air is clean and fresh due to relatively small distance to Carpathians mountains (Păltiniș). • There are enough green spaces in and outside the city ("Sub Arini" large park and "Dumbrava" forest – as known as "the city lung"). • The industrial areas are placed outside, rather to isolate the city by generated pollution. • Sibiu is a small town with relatively small number of inhabitants. • The Sibiu ring road reduced the traffic and contributed to diminish the noxious cars' emissions, even on highly travelled boulevards. Arguments for "poor air quality" are the followings: • The transformation of green spaces in residential districts. • The inefficient modes of transport and traffic. • There are many cars that pollute the air. • 31% of persons over 18 from Sibiu County have own cars (117.663 of 378.382), according to the Public Community Service for Driving License and Vehicle Registration Sibiu. • The number of cars increased in recent years: 6.14% from 2015 to 2016.
Q3:	To what extent do you think that the air quality in Sibiu affects your health?
A3:	Most subjects (76%) believe that air quality in Sibiu might be an important factor that can influence their health.
Q4:	Do you consider air quality when moving around in Sibiu (e.g. avoid cycling in busy roads or exercising outdoors if air quality is bad)?
A4:	About one third (35%) think they should avoid activities when pollution levels are high.
Q5:	What do you think about accessibility to air quality information in Sibiu? Or 'How often do you consciously look at air quality information (e.g. via television, newspapers, Internet)"?
A5:	Consciously, people are rarely seeking information on air quality (About once a month 18%). Although interest in environmental quality exists and usefulness of such information is obvious, the biggest problem lies in finding it.
Q6:	Who can improve air quality in Sibiu? And How?
A6:	The top three groups which can contribute to air quality improvement are: The municipality (e.g., city council): • By not allowing deforestation in the whole county, except dry/sick wood, which should be replaced by other freshly planted trees. • Protecting parks and forests, and developing new green spaces. • Introduction of electric public transport. • Optimize traffic in order to avoid congestion and useless fuel consumption. Industry and commerce: • Industry and commerce can find ways to pollute less by controlling their activities (dematerialization of economy). • Proper management of waste. People who spend most of their time in the city (e.g., residents, workers, students): • Students could participate as volunteers to plant trees in deforested areas. • Large scale use of public transportation or other alternatives (e.g. bicycle) Other groups were regional agencies or research scientists: • Regional and central government agencies must take responsibility to respect the law regarding the maximum level of air pollution, and if this level is overrun by any industrial company take appropriate measures. • Proposing legislation to reduce urban pollution. • Research scientists can contribute by finding new ways to stop air pollution.
Q7:	What steps do you think you would personally take to help improve air quality in Sibiu?
A7:	The large majority of the respondents are willing to: • use more environmentally-friendly means of transportation (electric bus, bicycle, etc). • involvement in public policy making, of social polls and participating to citizen advisory committees. • use greener systems at home such as renewables energy and electric heating to the detriment of burning wood.
Q8:	In which format would you prefer to receive air quality information?
A8:	Subjects suggested that an application for mobile phone would be most appropriate since they live in the "Internet of Things" and, nowadays over half of them use such easy accessible technology. Smartphones have excellent processing and storage capabilities and people carry them in their daily lives. Alternatively, information might be exhibited on panels in main public places, in public transport but also using social networks where information dissemination can be done very easily. Websites, TV and radio were also mentioned as alternatives.
Q9:	If you could have an application mobile phone app to inform you about air quality, how important would it be to have the following features?
A9:	See table II.
Q10:	In relation with the previous question, are there any other features you would like to have in a mobile app to be informed about air quality?
A10:	In addition to the numerical information about concentrations of air pollutants it would be useful that each pollutant to be accompanied by immediate and long-term effects on health. Possibility to select decongested routes to move in the city

A. Survey about air quality perception of people

Before starting our project implementation, we developed a survey regarding air quality perception by people, to see the relevance of air quality monitoring in Sibiu and its surroundings. We requested feedback from people working / studying / living in Sibiu (66% being in their twenties, 10% being between 30 and 45, and 24% being older than 45), most of them being students at the Faculty of Engineering. 200 participants were surveyed, 54% men, 46% women. 81% of respondents have secondary level education, 19% have higher education (Bachelor, Master, PhD). In the following we present the most important questions and the answers we received.

Table II lists the possible features of a mobile app to inform about air quality. The most important feature sought was information on how to protect own health. The second important feature sought was information about current air quality, followed by an air quality index to show how air quality improves or degrades.

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TABLE II. SURVEY RESULTS (Q9)

No.	Feature	Priority			
		High	Med.	Low	Not a priority
1.	Air quality in your immediate vicinity	58.9	29.3	11	1.2
2.	Numeric information on pollutant	39.2	41.5	14.6	3.7
3.	An *air quality index* indicating if the air quality is poor or good	72	23.2	3.7	1.2
4.	Ability to report what you think the air quality is like	28	45.1	22	4.9
5.	Ability to see what other users have reported	18.3	42.7	26.8	12.2
6.	Information on past air quality	36.6	34.1	22	7.3
7.	Information on *current* air *quality*	75.6	20.7	3.7	0
8.	Information on *forecasted* air quality	43.9	42.7	11	2.4
9.	Information on what to do to protect your health	84	14.8	1.2	0
10.	Notifications in case of increased air pollution	65.9	29.3	4.9	0
11.	Possibility to see the air quality levels in the routes you move around the city	59.8	26.8	12.2	1.2
12.	Possibility to select cleaner routes to move in the city	59.8	25.6	11	3.7

B. Earlier Studies

In Romania, air quality from ambient environment is legislated in accordance with European laws by the Air Act (no. 104/2011) [19], which establishes that the responsibility for air quality monitoring is undertaken by the National Environmental Protection Agency, through the National Network for Monitoring Air Quality [3]. Unfortunately, the number of air quality monitoring stations in Romania is rather small (142 fixed & 17 mobile units). This network includes four fixed stations in Sibiu County, which continuously monitor the air quality (Two are located in Sibiu, one in Mediaş and one in Copşa Mică).

The results presented in Figure 1 and Figure 2 were obtained from the two stationary units located in Sibiu city: SB1 – urban residential station and SB2 – industrial-type station.

The figures show CO and NO_2 concentration levels, for 2016. The agency has also on occasions used mobile units. The monitored parameters are: Sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), ozone (O_3), particles (PM 10 and PM 2.5), benzene (C_6H_6) and lead (Pb).

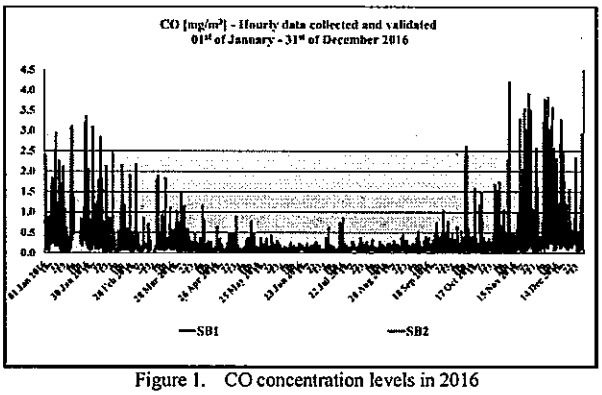

Figure 1. CO concentration levels in 2016

The evolution of values for CO concentration between 1st of January to 31st of December 2016 show that there were no exceedances of the daily limit value for health, taking into account that the daily maximum of averages at each 8 hours is 10 mg/m³, according to the Air Act 104/2011.

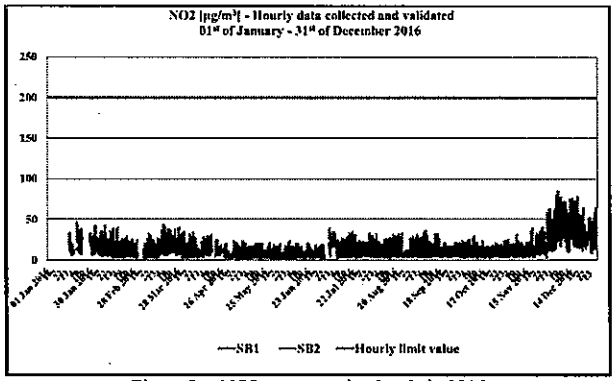

Figure 2. NO2 concentration levels in 2016

The NO_2 pollution indicator has not revealed breaches of the hourly limit of 200 µg/m³ (the maximum number of

exceeding's allowed by Air Act 104/2011 is 18 times yearly / station).

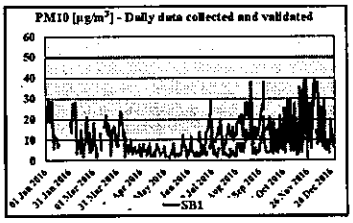

Figure 3. Particle concentration levels (PM10) in 2016

Particles are measured by size. PM 10 is the unit used to measure particles with a diameter between 2.5 and 10 µm. The particles (PM 10) pollution indicator is measured at SB1 station both automatically and manually. Figure 3 shows the daily limit values from SB1 and SB2 obtained in 2016. In 2016, the SB1 station reported 8 overruns of daily limit (50 µg/m^3) but which is still acceptable considering that the limit set by Air Act is 35 times yearly / station. (Single overruns cannot be seen in Figure 3, due to low resolution in the X-axis). Measurement results indicate that particle pollution is mainly caused by heavy traffic. The maximum (60.28 µg/m^3) was recorded in a heavily transited location at the entrance to the city where several hypermarkets are in the same area, while in Sub Arini Park (the largest park in the city) the recorded value of 13.93 µg/m3 was far below the daily limit value.

Explanations for this situation are: Apparently, in Sibiu the air quality is rather good, but the results might be pseudo true. The two fixed stations are situated as follows: SB1 is placed in an area where the traffic is relatively low and, SB2 is placed in an area which, on its deployment, in 2007, was heavily industrialized. Today, most industry has relocated (outside the city). Air pollution contributes to climate changes and to the emergence of *urban heat islands* (higher temperatures concentrated in urban areas densely populated and built), which cause temperature increases by up to 5 degrees compared with unaffected areas.

IV. PROJECT DESCRIPTION

The main objectives of the mobile air quality monitoring platform project were to:

- Develop a low-cost mobile platform for air quality monitoring where data are collected through crowdsensing.
- Test the platform in the City of Sibiu, Romania (and other locations) and compare collected data with already existing data, to verify results and extend the number of measurements being made.
- Make the necessary groundwork for establishing a larger project on air quality monitoring, this time with focus on analysis, prediction and visualization.

A. The Platform

The platform has been described in an earlier paper [1]. Shortly summarized the platform consists of a processor unit (LinkedIt Smart Duo 7688 - an open development board with two processors, one running Linux, the other compatible with Arduino), a combined GPS/GSM unit for location and communication, a gas sensor for measuring CO_2 and NO_X (SainSmart MQ135 Sensor Air Quality Sensor and Hazardous Gas Detection Module), a particle sensor measuring PM 10 (Grove Dust Particle Concentration Detection Sensor), and sensors for temperature (DS18B20 Temperature Sensor) and barometric pressure (BMP085 Digital Barometric Pressure Measurement Sensor). The technologies used are: Eagle (for printing the PCB) and Custom Electronic Shields, ASP.NET and Microsoft Azure (for database and cloud), C/C++ (for LinkedIt 8266 programming). 16 prototypes were built for experiments.

B. Hardware and Software Architecture

On the client side, the software will detect when the car is parked, and then start data collection from the sensors at regular intervals. The data are stamped with time and location (both retrieved from the GPS receiver) and sent to a server using a GSM data connection. Figures 4 and 5 show the hardware design of printed circuit board holding the sensors (except the particle sensor which is connected by a wire).

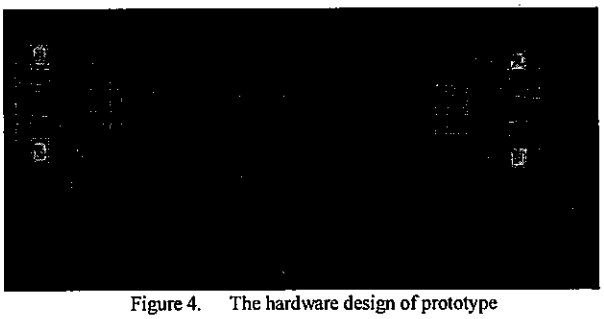

Figure 4. The hardware design of prototype

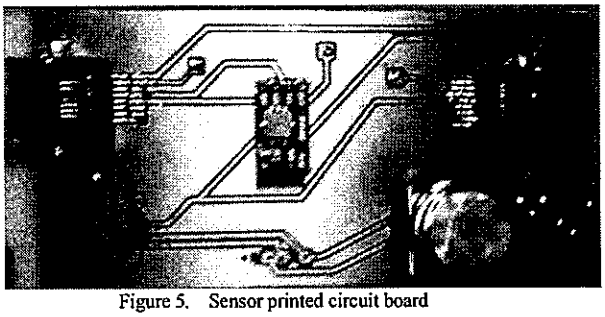

Figure 5. Sensor printed circuit board

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On the server side, the data are stored in a database for further analysis. The location of active cars is shown on a map (Google maps) with the possibility to click on one specific car to see the latest data.

C. Visualizing data

By clicking on each point from the map, information from each sensor is disclosed. The map is shown in Figure 6.

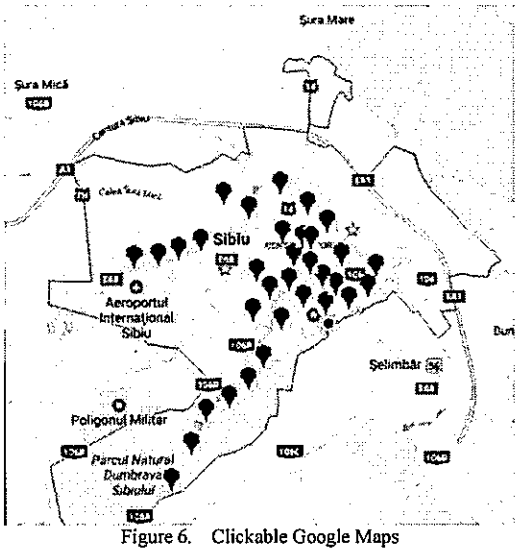

Figure 6. Clickable Google Maps

D. The Test

The platform was used for air-quality monitoring in Sibiu first weeks of February 2017. Data were collected from four units, each installed within a car. The data collected generally corresponds to earlier data collected by the National Environmental Protection Agency. At the same time, we showed that granularity has been improved since we could measure from many more locations. Some data were collected from cars driving the same route at different times.

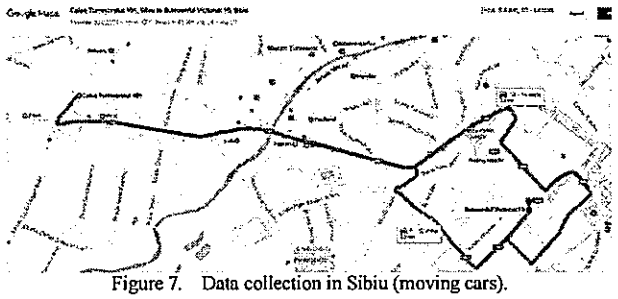

Figure 7. Data collection in Sibiu (moving cars).

Figure 7 illustrates a Google Maps snapshot with the route on which the data were collected at 5 pm when many people return from work. The red color shows heavy traffic because this road is connecting the airport with the city center and represents the single entrance in the city from the west side. In Figure 8, we present the chart with CO_2 variation during the route that takes around 16 minutes. The measurements were done with MQ135 gas sensor set up for CO_2 and the results are exhibited in parts per million (PPM). Regarding the MQ135 sensor and its detection capability, the researchers consider that the general sensitivity is roughly the same for all the gases sensed [14]. Since CO_2 is the fourth most abundant trace gas in the earth's atmosphere they recommend that it is safe to assume that in a normal atmosphere the MQ 135 sensor mostly detects CO_2. The values from Figure 8 somewhat faithfully follows the route from Figure 7, namely, where there is heavy traffic, CO_2 values are higher than 230 PPM. However, the maximum value obtained (277 PPM) is under the highest-ever daily average[2] at planet level (409.44 PPM) reached in 9 of April 2016.

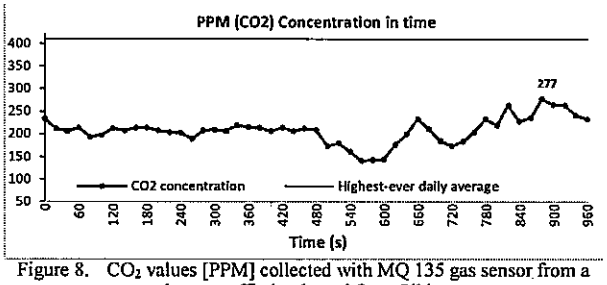

Figure 8. CO_2 values [PPM] collected with MQ 135 gas sensor from a heavy traffic boulevard from Sibiu

Table III presents the range where are situated the measured parameters (gas, temperature, dust and humidity). From a temperature point of view is observed how the heavy traffic produces higher temperature by approximately 2 degrees compared with unaffected areas (urban heat islands effect).

TABLE III. PARAMETERS VARIATION

	CO_2 [PPM]	Temperature [Celsius degree]	Dust [mg/m^3]	Humidity [%]
Maximum	277	2	0.35	87
Average	207.92	1	0.33	87
Minimum	141	0	0.32	87

Measurements were also made from parked cars in an densely populated area close to a major road, and here CO_2 values varied between 200 to 500, depending on the time of the day.

E. Making Groundwork for a New Project

EU Research & Innovation program H2020 [3] has allocated 80 billion Euros funding for initiatives related to environmental sustainability and energy efficiency. In a follow-up project, we intend to focus on further developing analytics, prediction algorithms and visualization. By collecting data over a longer period, we will be able to predict when pollution levels reach certain levels. Such information will be useful for decision-making.

[2] https://www.co2.earth/daily-co2

[3] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/

V. CONCLUSIONS

As mentioned earlier, several cities around the world are restricting car use when air pollution levels are too high. The use of stationary units provides low granularity of measurements, and are expensive. This project has shown that data can be collected by means of crowdsensing, either by using cars of the municipality or calling upon volunteers to accommodate units in their cars.

Largely, the obtained results are consistent with measurements from fixed stations. However, our solution provides much higher granularity of the measurements.

In a longer perspective, our aim is to further develop our platform as part of a system for smart-cities with the purpose of providing insights about people and environmental conditions, and disseminate such information to the public through multiple channels. Such a system will be important for decision making related to environmental issues, and be a measure to increase the transparency of the cities.

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Online Physical Activity Monitoring From Head Kinematics

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Abstract—**With older age, people experience increasing hearing loss. With the use of assistive technology systems it is possible to preserve and improve the quality of life of elderly people with hearing losses. The Augmented Hearing Experience and Assistance for Daily life (AHEAD) system, composed of hearing glasses (augmented with Bluetooth audio communication, and physiological sensors) wirelessly connected to a mobile phone also connected to a smart home environment platform, allows to provide services on top of the hearing enhancement provided by the hearing glasses. Beside the health related services that the AHEAD system offers (heart rate monitoring, emergency alarms), a physical activity assistant has been identified to be relevant in order to reduce sedentary behaviours. In this paper, we investigated how accurate fitness algorithms (walking time, step counter, physically active/inactive periods) based on head kinematic data would be. For that purpose we have adapted state-of-the art algorithms. A total of 10 healthy users performed activities of daily living and walking sessions. The results show that the head location is suitable to detect fitness indicators but some personalization of some parameters would be needed to improve the performance of the detection methods.**

Keywords–Active Ageing; Head Kinematics; Walking Detection; Hearing Instrument; mHealth.

I. INTRODUCTION

With older age, people experience increasing hearing loss. With the use of assistive technology systems it is possible to preserve and improve the quality of life of elderly people with hearing loss. Currently few hearing aids have a wireless connectivity and for those which support it, it is done through a dedicated physical device which works as a gateway between the hearing aid and the smartphone (Starkey SurfLink Mobile 2 (Starkey, 2015), Phonak ComPilot (Phonak, 2015)). The low usability of such wireless solutions limits the services that can be delivered to the hearing impaired person. The European project Augmented Hearing Experience and Assistance for Daily life (AHEAD) aims to provide a speech-controlled assistive system that supports elderly people in their everyday life as communication tool and healthcare manager, e.g., initiating phone calls, recording vital parameters, performing a audio verification test from home and providing environmental information. The AHEAD system is integrated into hearing glasses that are a combination of traditional hearing aids and eye glasses: two devices elderly people are used to and have accepted already. As health management is especially important for elderly people, the modified hearing aid is able to measure vital signs such as heart rate and body core temperature through sensors that are in contact with the skin of the inner ear and transmit these data for further analysis helping elderly people in self-managing their health. Finally, a 3D inertial sensor embedded into the hearing glasses records the user's physical activity in order to reduce sedentary behaviours. The AHEAD assistant is wirelessly connected to a smart phone which is the gateway to the smart living environment and third party services.

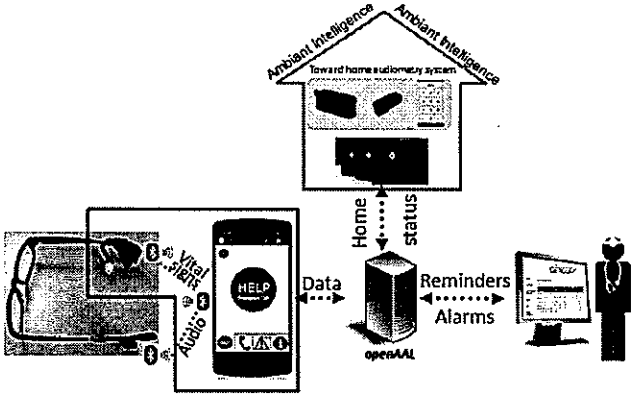

Figure 1. Overall AHEAD components

Figure 1, depicts the AHEAD system composed by the openAAL platform (back-end and ontology platform), a smartphone, a hearing instrument (either eyeglasses or behind the hear system), hearing verification tools, and embedded physiological and kinematic sensors. For more details regarding the hardware and the services offered, please refer to Barralon [1].

In this paper, we are focusing on a sub part of the AHEAD which is the smartphone and the head mounted physiological and kinematic sensor (red polygon on Figure 1), which are the key components supporting the AHEAD fitness service. This service monitors and provides feedback/recommendation to the user about his/her daily walking time, number of steps and also the duration of physically active and inactive periods with the final goal to reduce the amount of inactivity. This service was considered important within the AHEAD system because the relationship between greater time spent in sedentary behavior and the presence of Activity of Daily Living (ADL) disability has been reported for older adults [2].

Even though they are commercial activity monitors (FitBit, Polar, ActiGraph, Tritrac RT3, Actical, the Actiheart, Activ8) [3] available on the market the AHEAD consortium decided, based on collected user requirements [4], not to add any another body sensor (e.g., watch) to promote physical activities but rather investigate and use the sensor embedded into the hearing glasses. In this case a 3D accelerometer already integrated into the Cosinuss device [5]. The question was, however to investigate whether the head was a suitable location for detecting walking events. It is known that the head vertical position is very well regulated during walking in order to maximise the visual input quality [6]. Brajick [7] investigated

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different smartphone locations (hand held, backpack, handbag, trousers back pocket, trouser front pocket, and handheld using). They, obviously, did not study the head location.

Since the AHEAD smartphone is the gateway between the hearing glasses (microphone, speaker, physiological sensors) and the back-end platform (openAAL) we have investigated which are the available algorithms supporting the detection of walking events, the calculation of the daily number of step and the duration of physically active and inactive periods with low computation power. We have found the Jigsaw Continuous Sensing Engine for Mobile Phone Applications [8] from which we adapted the method to track the amount of physically active and inactive events. We have used the frequential Short Time Fourier Transform (STFT) method proposed by Barralon [9] and confirmed by Brajick [7] to be better than other alternatives such as thresholding time series (acceleration magnitude, acceleration energy, mean crossing counts, etc.). For reference, the following papers estimate walking detection event but also gait authentication and identification [10] [11], stride and heading determination for pedestrian navigation system [12], and gait event detection for Functional Electrical Stimulation (FES) actuation [13]. Recently, a novel confidence-based multiclass boosting algorithm for mobile physical activity monitoring has been proposed by Reiss [14] to improve the classification performance on most of the evaluated datasets, especially for larger and more complex classification tasks.

Since the AHEAD system includes a smartphone anyway, we have selected four mobile applications (Pedometer, WalkLogger, Pacer, Google Fit) to compare our results with.

The rest of the paper is structured as follows. Section 2 describes the materials and methods offering the aforementioned services. Section 3 reports on the performance achieved by the system in comparison with other applications. Conclusions are drawn in the Section 4.

II. Measurements and Methods

A user experiment was performed in Tecnalia HomeLab, to test the accuracy of the AHEAD fitness algorithm (including walking time, number of steps and active/inactive duration), and compare with other commercially available Android apps.

A. Subjects

10 Healthy subjects were involved in the test, all Tecnalia employees (5 males, 5 females; 25-64 years old, mean 35.8 years, standard deviation 11.3 years).

B. Experimental protocol

In order to test the sensitivity (Se) and specificity (Sp) of both the Active/inactive and Walking/non Walking detection methods the users were asked to perform the following activities during the test:

1) Spending 2 minutes in sitting position reading the newspaper (in this situation the user should be detected as "inactive" and "non walking").
2) Standing up and arranging the kitchen during 3 minutes (should be detected as "active". The evaluation of the performance (e.g Se, Sp) of the walking detection algorithm was never performed on this part of the recording since some few and sporadic steps happened and were not counted by the experimenters because of the complexity to define what is a step in this context).
3) Standing up and still standing for 2 minutes watching a video on TV (should be detected as "inactive" and "non walking").
4) Sitting down and remaining sited for 4 minutes watching a video on TV (should be detected as "inactive" and "non walking").
5) Initiating gait and walking for 5 minutes (should be detected as "active" and "walking"). In this phase the number of steps performed by the users was counted and reported by two observers.

C. Materials

1) Hardware: For this experimentation we used a Nexus 5 smartphone [15] running an Android operating system (version 5.1, released on December 2014. API 22). The Nexus 5 is powered by a 2.26 GHz quad-core Snapdragon 800 processor with 2 GB of RAM. The smartphone was connected to a Cosinuss One device [5] in charge of measuring physiological parameters (e.g., heart rate, oxygen saturation, body surface temperature) but also the head motion using a 3-axis accelerometer. The component is an integrated circuit which records an analog accelerometric input and returns a digital signal with 12 bits resolution. The sampling rate was set to $100Hz$. The accelerometer data (packet of the five last measurements) was sent by Bluetooth Low Energy (BLE), RAW Data Service (UUID 0xA000), RAW Data characteristic (UUID 0xA001), every 50ms to the Nexus 5.

2) Software: During all the trials, five mobile applications were running in parallel and recoding the tasks.

- AHEAD app: This app has been developed by Tecnalia within AHEAD project. It provides different services as already explained above. One of the services provided by AHEAD app is the Fitness service, that is being analysed in this publication. It monitors and provides feedback to the user about his/her daily walking time, number of steps and also the duration of physically active and inactive periods. The algorithms estimating these variables are analysed in the next section. The Fitness service is connected by BLE to Cosinuss One device, and receives x and y axes accelerometer data in the RAW Data Service every 50ms, including 5 x and 5 y axis data per package. This data is buffered, and then analysed in a period of 1 second. So, updated information about active/inactive time, walking time and number of steps is provided every 1 second.
- Pedometer (tayutau) [16]
- WalkLogger pedometer [17]
- Pacer [18]
- Google Fit [19]

D. Detection and classification methods

The first version of fitness algorithms have been developed in Matlab. This first development was validated in [9]. To implement these algorithms in AHEAD, we translated them into Java. Due to the processing limitation of a smartphone compared with a computer, and the fact that other AHEAD services are concurrently running in parallel in the smart phone, a loss in the algorithm performance could be considered. We therefore compared on pre-trial data the Matlab and Android outputs (Figure 3 and Figure 4).

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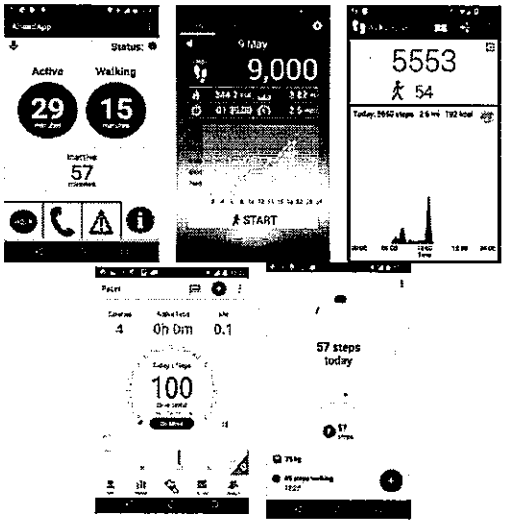

Figure 2. AHEAD app (top left) ; Pedometer (top center) ; WalkLogger (top right) ; Pacer (bottom left) ; Google fit (bottom right)

In a second step we have compared the AHEAD app methods with other Android apps. However, some of the selected apps (Google Fit, Pacer) do not detect (at least display) the physically active (or inactive) periods. For example when the user is not walking but still performing an activity of daily living (e.g., cleaning the dishes) no information is shown. In AHEAD these active periods are also detected and counted, with the aim to reduce the amount of inactivity of the user.

1) Physically active or inactive: In order to detect whether the user is physically active or not we have followed the approach of Lu and collaborators [8]. A stationary state detector is used to select qualified $\overrightarrow{a_i} = (a_{x,i}, a_{y,i}, a_{z,i})$ (i.e.,stationary accelerometer readings). Our stationary detector begins by dividing raw data into candidate frames each contain M successive samples. For each frame, the mean and standard deviation are calculated for the three axes. If all three standard deviations fall below a percentage threshold σ of the mean, we assume the device is stationary. In the AHEAD case and in order to alleviate the communication bandwidth between the mobile and the hearing glasses, we stream only two dimensions of the accelerometric components (vertical (a_v) and antero-posterior (a_{AP})). Instead of applying a threshold on each standard deviation of each component [8], we rather calculate the acceleration magnitude (AM) $AM_i = \sqrt{(a_{AP,i}^2 + a_{v,i}^2)}$ of the candidate frame and apply a threshold (named *minVariation*) on the standard deviation of the AM. The length of the candidate frame was set to one second (100 samples).

2) Walking duration and number of steps: Recently Brajdic has reported a comparison of different walking detection algorithms (MAGN_TH, ENER_TH, STD_TH, NASC+STD_TH, STFT, CWT, DWT, HMM) [7]. His conclusion was that the best performing algorithms for walk detection were the two thresholds based on the standard deviation (STD_TH) and the signal energy (ENER_TH), STFT and NASC, all of which exhibited similar error medians and spreads.

As explained in Barralon [9] and Brajdic [7], the walking detection is performed as follows: signal was split into successive time windows using SFTF of size *DFTwin* and labelled as walking if it contained significant (greater than a threshold: *DFTthresh*) spectral energy at typical walking frequencies *freqwalk*.

For the *DFTthresh* threshold, we used what was proposed by Barralon [9]:

$$DFTthresh = \frac{1}{pFactor}\left[\frac{b.DFTwin}{2}\right]^2 \quad (1)$$

where $pFactor$ is an attenuation coefficient, b the amplitude of the input signal (a_V or a_{AP}).

However, since the value of *DFTthresh* is adapted according to the amplitude b of the input signal, a noise with a small amplitude can be classified as walk if its frequency content is included within the frequency range of interest. To overcome this problem, Barralon [9] defined a constant threshold (T_b, named *minAmp* in this paper) to test b. If the amplitude of the input acceleration is too low then the algorithm will never classified the candidate frame as "walking".

The step counting is then only computed when walking has been detected and we compute a fractional number of strides for each window by dividing the window width by the dominant walking period it detected. These fractional values were then summed to estimate the total number of step taken.

During daily life activities, the fastest body movements occur when walking which corresponds to accelerometric signal ranging from 0.6 Hz to 2.5 Hz [20]. However Brajdic [7] has extended it to [0.01-7] Hz for the Short Term Fourier Transform (STFT) method.

For the walking and active/inactive detections we used the following parameters (see section III-B):

- $pFactor = 0.03$
- $freqwalk = [0.8 - 5]Hz$
- input accelerometer axis: vertical
- $minAmp = 0.1g$
- $minVariation = 0.13g$

III. Results

A. AHEAD algorithm - Comparison between Matlab and Smartphone

In figures 3 and 4 the results of the comparison between fitness algorithms running in Matlab and in AHEAD app are shown. Figure 3 shows the results during activities of daily living (e.g., cleaning up the kitchen table) and inactive episodes (reading and watching TV). Minor differences can be identified between the two implementations, surely due to the mislaid of some accelerometer data packages. Figure 4 shows the results of a walking sequence, where the results are the same for both Matlab and Android algorithms of walking detection and active/inactive detection. Step counting has not been included in this Matlab vs smartphone comparison, because it requires very few processing resources; the key point to correctly count the steps is the correct detection of walking episodes.

B. Thresholds identification

As presented in section II-D, several parameters have to be defined to detect the user activity. Even if values of these parameters have been reported for trunk mounted devices in various publications [9][7], we investigated how the change of some of them impact the performance for head mounted device which is the case of the AHEAD solution.

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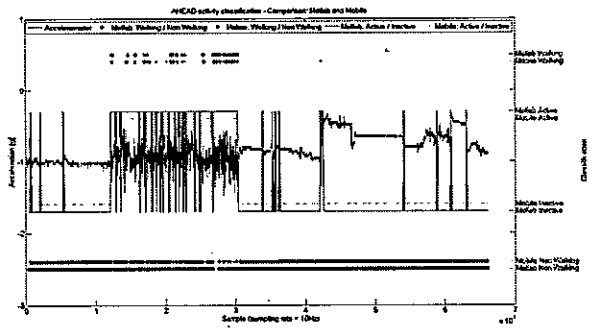

Figure 3. Illustration of AHEAD classification (walking/non walking, active/inactive) durind daily life activities

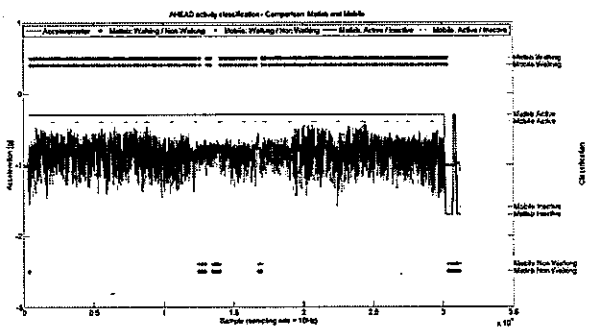

Figure 4. Illustration of AHEAD classification (walking/non walking, active/inactive) durind a walking sequence

In total, 10 subjects have performed the trial. Data from the first 3 subjects has been used to study and select the inner thresholds/values of the algorithms. The other 7 subjects' data has been used to validate the algorithm. The first three users have been selected to be representative of the whole set of subjects, and so we tried to include variation in gender and age: 2 males, 1 female; mean age 42.7 years, standard deviation of age 19.8 years.

1) Active/Inactive: The threshold to identify in the active/inactive detection algorithm is the threshold *minVariation* to which the standard deviations are compared with. Figures 5 and 6 show the results of this identification, with the Receiver operating characteristic (ROC) curve and the maximum accuracy with different threshold *minVariation* values. The best accuracy of 89% was obtained for $minVariation = 0.13$.

In the threshold identification process, data from tasks 1, 3 and 4 (sitting or still reading or watching TV) were tagged as inactive, and data from tasks 2 and 5 (arranging the kitchen and walking) were tagged as active.

2) Walking: Walking detection algorithm has three parameters that can be adjusted (and will affect the sensitivity and specificity). We therefore tested several combinations of those three parameters and analysed how they affect the performance of the walking detection algorithm:

- Walking detection algorithm is based on acc data from only one axis. So, the best axis (V or AP) to be used should be defined. V is the vertical axis, and AP is the anteroposterior axis.
- The highest peak on frequencies between 0.8Hz and 5.0Hz should be bigger than a percentage of the theoretical maximum frequency. This attenuation coefficient *pfactor* (1) should be defined.
- The amplitude of the acc signal above the mean should be bigger than a threshold *minAmp* to be defined (see section II-D2).

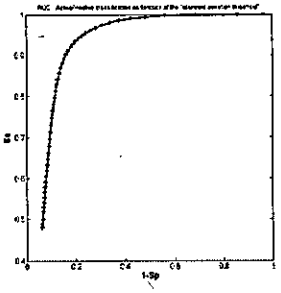

Figure 5. Active/inactive ROC curve as a function of the $minVariation$ parameter .

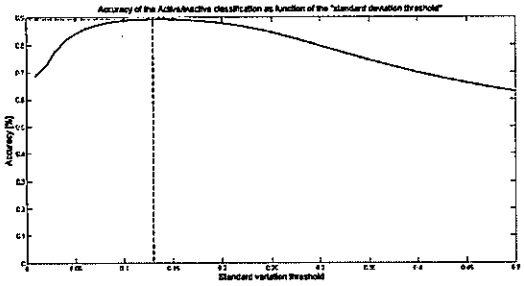

Figure 6. Active/inactive accuracy as a function of the $minVariation$ parameter

Figures 7 and 8 show the results of the identification of these 3 parameters. When selecting these values, a better sensitivity has been prioritized at the expense of poorer specificity. The best results were obtained for the vertical axis. We selected an attenuation coefficient $pFactor = 0.03$ and the minimum amplitude of the acc signal above the mean $minAmp = 0.1$.

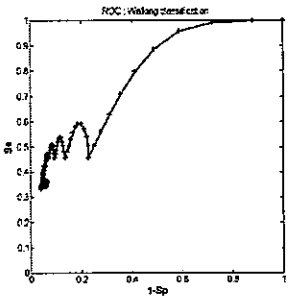

Figure 7. Learning: Walking - ROC as function of $pFactor$, $minAmp$ and acceleration axis (V or AP).

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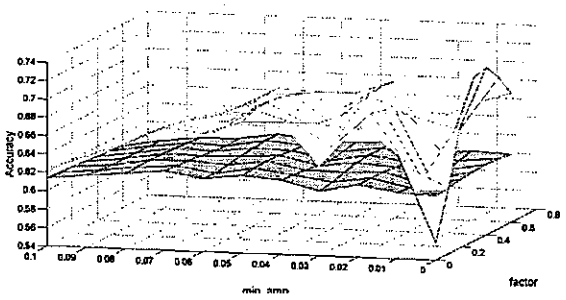

Figure 8. Learning: Walking Accuracy as function of $pFactor$, $minAmp$, and $axis$. The blue plot represents the AP axis and the white one the V axis

For this threshold identification process, data from tasks 1, 3 and 4 (sitting or still reading or watching TV) were tagged as non walking, and data from task 5 (walking) was tagged as walking. Data from task 2 was excluded from this section, because some few and sporadic steps happened and were not counted by the experimenters because of the complexity to define what is a step in this context.

C. Results on seven subjects

After setting the required parameters (see previous section), the configured algorithms were validated with the remaining 7 users: 3 males, 4 females; mean age 32.9 years (standard deviation 5.3 years).

Table I shows the overall results of the test, comparing AHEAD fitness service with the true values and the results obtained with other Android apps available in Google Play.

- Active/Inactive time detection algorithm has a sensitivity of 89 percent.
- Walking time algorithm has a sensitivity of 86 percent for all 7 users. For the 4 users where the algorithm has a better performance, the sensitivity is 96 percent, while it is of 72 percent for the other 3 users.
- Step counter has also a sensitivity of 86 percent for all 7 users. For the 4 users where the algorithm has a better performance, the sensitivity is 93 percent, while it is of 77 percent for the other 3 users.

In Figures 9 and 10, the walking time and number of steps information is shown. Numbers correspond to average values of the 7 users, and associated standard deviation in brackets.

AHEAD walking detection and step counting algorithms clearly had much worse performance with 3 of these 7 users. In Table I and in Figures 9 and 10, new columns were added to distinguish the algorithms good performance in 4 users and bad performance in 3 users.

IV. Conclusion

A new approach for fitness activity detection has been presented in this paper. The main novelties presented here are 1) the head location of the accelerometer sensor embedded into a pair of hearing glasses, and 2) the detection of physically active episodes that do not necessary imply a walking event. The integration of additional sensors into the hearing instruments will facilitate the user acceptance while offering additional services with the aim to increase the autonomy level of the users and reduce the amount of sedentary behaviours.

The results presented support that the head kinematics is a suitable location for physical activity monitoring. The results are promising, with a sensitivity higher than 85% for all 3 algorithms (active detection, walking detection and step counter). Even though the user trial was designed to cover sequentially inactive, active, and walking phases, the test was performed in a Homelab and the users executed those tasks in a very natural manner. As a consequence, sequences that were supposed to be "inactive" sometimes include "active" events (postural re-adjustment on a chair, head and trunk motion to scratch a leg, ...). Similarly, during walking we observed large head movements to either look around or talk to the experimenter. Besides, the Cosinuss sensor was placed by the user him/herself on the hear, and therefore the sensor placement was not identical for all users. All these elements contributed to reduce the performance of the implemented algorithms. The raw acc data of the 3 users with worse walking detection performance show some similarities, e.g., changes in the Cosinuss sensor orientation during the trial. Finally, the three users selected for the learning stage of the algorithm were chosen based on general characteristics (gender and age), but we did not take into account other gait related features such as body mass, leg or step length.

The promising results presented in this publication may require some more research so that the algorithm could be more independent of various gait patterns or gait styles.

The AHEAD subsystem presented in this paper is a potential candidate to be used in the ACTIVAGE project (European Large Scale Pilot on Smart Living Environments) where the main objective is to build the first European Internet of Thing (IoT) ecosystem across 9 Deployment Sites (DS) in seven European countries.

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TABLE I. RESULTS OF THE TRIALS PERFORMED BY HEIGHT HEALTHY SUBJECTS

Feature	Truth	Pacer	Pedometer	Walklogger	Google fit	AHEAD	AHEAD 4 best users	AHEAD 3 worst users
Walking time (s)	299 (2.2)	240 (34.6)	298.4 (5.7)	299.9 (5.6)	300 (60.0)	257.0 (39.9)	287.75 (11.9)	216 (12.5)
Number of steps	490.1 (33.8)	506.9 (46.0)	493.3 (33.5)	506.6 (45.6)	471.7 (78.7)	422.1 (51.7)	456 (35.5)	377 (28.2)
Active time	481 (2.8)	NA	NA	NA	NA	429.2 (23.6)	NA	NA
Inactive time	480.8 (1.0)	NA	NA	NA	NA	542.2 (31.8)	NA	NA

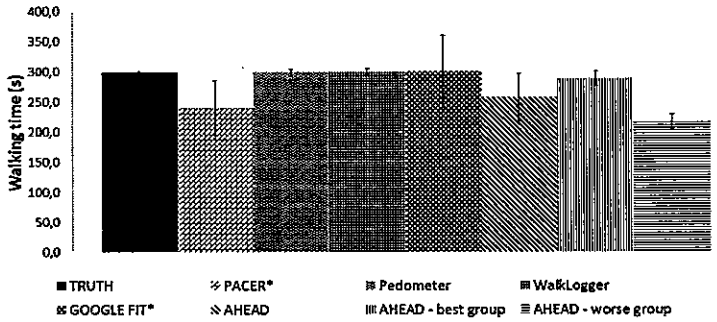

Figure 9. Testing Walking Time

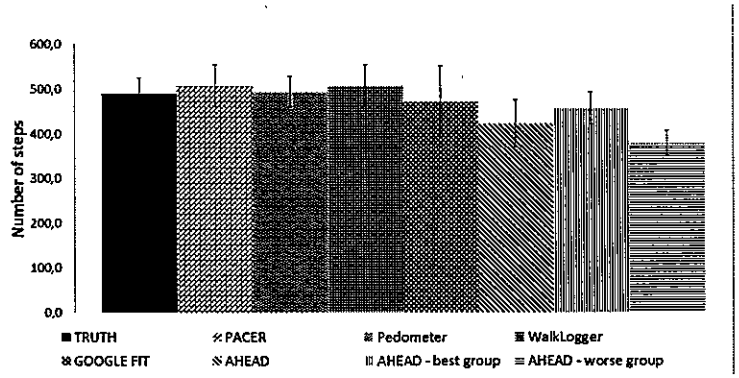

Figure 10. Testing Walking number of steps

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Real-Time Monitoring of Heart Rate by Processing of Near Infrared Generated Streams

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Abstract—**This paper presents a novel solution for non-invasive real-time heart rate monitoring by processing of Near Infrared (NIR) generated streams, provided by a low-cost, easy-to-use sensor, such as Microsoft Kinect™. The standard method to monitor physiological information exploits photoplethysmographic images. In fact, the changes in blood volume can be determined from the spectra of radiation reflected from (or transmitted through) body tissues. Using a mathematical processing, the study shows how it is possible to real-time estimate the heart rate of people sitting for 1 minute in front of the sensor at distance 1 meter by analysing the NIR stream and without wearing any other sensors. In order to prove the correctness of the method proposed, 35 different subjects are involved in the test phase. During the tests, each subject wears also a pulse oximeter for comparing the values calculated by our method.**

Keywords: Heart rate; Near Infrared channel; real-time; Kinect™ 2.0.

I. INTRODUCTION

The scope of this work is to present a new solution for non-invasive remote monitoring of vital signs (in particular heart rate), using an algorithm that processes the data acquired by the NIR channel of the Kinect™ sensor at medium distance (1 m). By analysing the raw signals with an appropriate mathematical elaboration, the cardiac pulse is extrapolated in "real-time" mode. In this way, it is possible to monitor the heart activity during playing games or during the execution of training programs (e.g., rehabilitation programs), even when light conditions are not optimal, without having to combine additional medical devices that are often invasive.

The Kinect™ 2.0 sensor, by combining a HD camera and an infrared camera (to estimate the depth), uses a human morphological model to match the silhouette seen through the infrared camera and to provide the position (X,Y,Z) for each one of 25 joints. In addition, each data stream (RGB, infrared) could be autonomously gathered for more accurate data analysis [1][2].

By thoroughly analyzing the work and the criticalities that have emerged in the previous tests on real-time heart rate determination via RGB channels [3], one of the key requirements for proper setup is the right lighting (natural or artificial). For this reason, it has been decided to take advantage of the supplied sensor at Kinect™ to use the near-infrared imaging technique (NIR) [4]. NIR is a source of electromagnetic radiation at the beginning of the infrared spectrum range and borders on the spectrum of visible light. Its benefits include the ability to be reflected from objects, penetrating glass and serving as an active source of illumination [5]. While most face sensors use color images as inputs, lighting variance remains a challenge because lighting can alter the color intensity in an image.

Especially in low light conditions, some faces may have a minimum contrast of intensity with the dark background, resulting in facial detection. IR images, on the contrary, remain the same despite the changes in lighting. Even in the dark, IR images can capture distinct details of the face [6].

The paper is organized as follows. The study begins in Section II with a general overview of the devices available on the market and referring to the telemedicine and various sensors for cardiac monitoring. In Section III, the analysis of the state of the art of the already implemented methods for remote monitoring of vital signs is presented. The core of this work is descripted in Section IV and the developed algorithms with the procedures adopted for their validations and tests are presented in Section V. In Section VII, the discussion of the results of the entire work and the conclusions are proposed in Section VIII.

II. BACKGROUND

The topic of non-invasively detection of vital parameters has been successful increased in the last few years, in part due to the use of new technologies in hospital wards and surroundings, in part because the majority of patients is in favour of personalized assistance instead of health care services provided up to now [7][8].

The market is witnessing the continuous spread of new devices and software systems that allow monitoring the vital parameters (e.g., heart rate, oxygen saturation, respiratory rate) or setting personalized triggered alerts. In this perspective, in order to enhance the daily management of diseases by facilitating self-care, e-Health and related personalized health services are steadily growing [9][10].

A further step towards non-invasive systems has been taken with the introduction of the pulse oximeter, an instrument that, thanks to the principles of photoplethysmography, is able to detect the oxygen saturation of the blood and the heart rate simply by exploiting the changes in blood volume in the microcirculation of the human tissues [11].

Considering the Physiology, the impulse of cardio-vascular wave that flows through the body periodically,

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causes stretch in the vessel walls. The volumetric changes due to fluctuations in the amount of blood or air contained within the human body can be measured by photoplethysmography (PPG) [12].

These fluctuations modulate the absorbance of light passing through a given volume of tissue, so it is possible to evaluate the variation of light during a normal cardiac cycle. If these changes are recorded, they originate a waveform that corresponds to the changes in the pulsatile arterial blood in the tissue [13].

It is worth noting that the PPG is usually performed with a dedicated light's source and it considers environmental light as a source of noise. Then, applying the PPG at medium/long distance (2.5m - 3m) implicates that the environmental noise becomes more relevant.

The absorbed light of a human in NIR consists of two components [14]: one static absorption constant from muscles, fat, bones and venous blood (de-oxyhemoglobin) and one varying component from arterial blood (oxyhemoglobin). As the heart beats, the concentration of oxyhemoglobin will fluctuate in the body and effect the light absorption subsequently [15]. The red color of the blood is caused by the fact that absorption coefficient is low for the red wavelengths (620 - 700nm) and high for the other wavelengths of visible light, meaning that only the red light is reflected. The light absorption coefficient in NIR (700 - 1400nm) is very low: 5.7 cm^{-1} in 850nm. The wavelength of 540nm (green light) has around a 50 times higher absorption coefficient than what NIR has [16]. Another difference between RGB-videos and NIR-videos are the number of wavelengths captured. An RGB-camera records three wavelengths simultaneously while a monochrome NIR-camera only records one. The benefit of having more than one frequency is to use the other wavelengths that have a lower oxyhemoglobin absorption as reference to cancel out ambient light and noise as Verkruysse et al [17].

III. STATE OF THE ART

In recent years, there has been a growing interest in the study of remote monitoring of vital signs using webcam and algorithms with computational software.

One of the first experiments to extract heartbeat from video (with a webcam) was conducted by Poh at al. [18] in 2010 at MIT in Boston: they have recorded videos of a minute and then completed processing of signals from the RGB channels by computer's webcam. The results obtained from MIT are based on studies conducted few years before: Verkruysse et al. [17] had demonstrated that the blood absorbs light more than the surrounding tissues and this application can also be used to evaluate the heart rate and breathing (photoplethysmography).

Moreover, the studies conducted by Takano et al. [19] considered the use of a charge coupled device (CCD) camera for the acquisition of the person's face every 30 seconds: from these studies, it was possible to extract the heart rate and respiratory rate.

Another webcam-based heart rate measurement method, was studied in 2013 using Laplacian Eigenmap (LE) [20]: this technique is used to extract the volume of blood pressure (BVP) from subjects' videos acquired.

In recent publications [21], different tests has been conducted in order to change the technology used, by adopting a camera with five channels and demonstrating that the alternation of the frequency bands, in particular the orange band, allows a physiological measurements much more correlated to the values obtainable with a classic pulse oximeter. However, this type of camera is not included in most of the commercial devices.

The use of the Microsoft Kinect™ device is certainly linked to gaming platforms, rather than to other areas [22]. Recently, the Polytechnic University of Marche has presented a method for measuring heart and respiratory rate [23] by using the Kinect™ 1.0 sensor. The study has been based on the detection of micro-movements of the neck, abdomen and chest of supine subjects, placed a short distance (<1m) from the sensor.

In the Healthcare Innovation Conference (HIC) [24] it has been presented a study that uses a Kinect™ camera mounted on the car's dashboard in order to collect video and to calculate the driver's heart rate in real time.

Finally, our paper presented at SpliTech 2016 [3] described the implementation and the tests of a novel methodology for evaluating the heart rhythm by a non-invasive monitoring system based on Kinect™ 2.0 sensor, acting at medium/long distance (2.5 m). Furthermore, this work highlights the capability to monitor the cardiac pulse rate during the performance of physical exercises.

About Infrared system, in 2015 Zeng presented in a paper a non-invasive heart rate detection process using Kinect™ to measure the heart rate via the obtained near-infrared video, in order to decrease the interference from light and establish a non-invasive system via near-infrared camera [25].

Procházka [26] detect possible medical and neurological disorders using Microsoft Kinect™ sensors for non-contact monitoring of breathing and heart rate estimation: video sequences of facial features and thorax movements are recorded by device image, depth and infrared sensors to enable their time analysis in selected regions of interest. Spectral analysis of the time evolution of the mouth area video frames (infrared data) was also used for heart rate estimation.

IV. METHODS

The combination of the Depth camera of the Kinect™ sensor and the information contained in the signal emitted by the major surface vessels is the base of the real-time method developed for monitoring the heart rate without the direct contact between the instrument and the patient. The solution proposed is able to solve some of the problems related to an invasive monitoring system, ambient light conditions and, at the same time, to ensure the reliability of the results from a physiological point of view. In these terms, the Kinect™ camera detects the changes of blood flow (and thus the work done by the heart) by collecting the mixture of the reflected photoplethysmographic signal (with the fluctuations based on the amount of reflected light) and the volumetric changes of the blood vessels.

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In order to choose the region of interest (ROI), the most suitable areas for the detection of heart rate are the forehead and cheeks [27][28]. A rectangle (size 100x140 pixels) that includes the person's face and tracks it during movements is designed from the neck joint. The sizes of the ROI are the best compromise in order to reduce the background noise and analyse the most significant pixels. Furthermore, it is decided to use the neck joint because the Kinect™ has encountered problems in identifying and tracking the face of people wearing glasses with anti-reflective lenses.

The software developed for this study, integrates a C# code able to activate the Kinect™ sensor, to detect the person's face and to proceed with the acquisition of the raw signals from the NIR channel and a Python code used for the data processing and the analysis of the signals. In this way, the Kinect™ sensor is able to maintain the 30 fps real-time images acquisition and to implement the mathematical algorithm processing, without creating duplication or data loss. Indeed, the raw IR data, i.e., the intensity average of the pixels of the ROI, are sent to the Python processes, while the Kinect™ sensor continues the real time acquisition of the frames. In order to mitigate the background noise, a bandpass Butterworth filter with infinite impulse response, double-pass, 7th order, and bandpass [0.85 ÷ 3.5 Hz] is applied.

Then, the spectral analysis (by Fast Fourier Transform) of the average of the filtered IR pixels is applied in order to represent the distribution of the power of the signal itself.

The FFT of the IR signal allows deciding the frequency corresponding to the maximum peak's intensity in the same band of the filter [0.85 ÷ 3.5 Hz], that corresponds to the range [51 to 210 bpm] of the heart rate: in this interval it is surely contained the normal range of physiological heart rate values for healthy people [60÷100 bpm] [29]. The average beats per minutes are obtained by the multiplication by 60 of this value of frequency. Every new 60 frames acquired, this analysis is re-performed. In this way, a new heart rate value is generated every two seconds. In Figure 1, the block diagram of the whole implemented algorithm is reported.

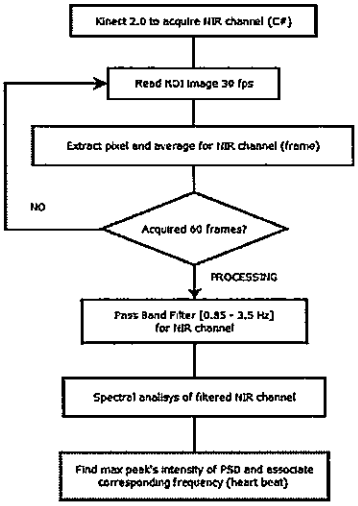

Figure. 1. Block diagram real-time processing NIR channel.

V. EXPERIMENTAL SETUP

The technical equipment used for performing the test is based on the Microsoft Kinect™ 2.0 sensor. All the videos are acquired in NIR (8-bit IR) at maximum frame rate available (30 fps - sufficient to generate a valid real time value for the heart rate) and with a resolution of 512x424 pixels.

A test is performed by 35 participants (18 men and 17 women), between the ages of 24-60 years, in good health (some of which are also well-trained) and with different features (beard, moustache, glasses, foundation creams). During tests, they wear a GIMA OXI-10 pulse-oximeter (in order to make a later comparison of the obtained values) [30].

The distance between the subject and the sensor is approximately set to 1 meter. The choice of the distance is given after a pre-test where the subjects are placed to different distances: 1m, 2m and 3m. It is worth noting that there are not any relevant deviations of the heart rate values calculated from the Kinect™ sensor due to the distances [31].

Figure 2 well represents the experimental setup created during tests in laboratory environment.

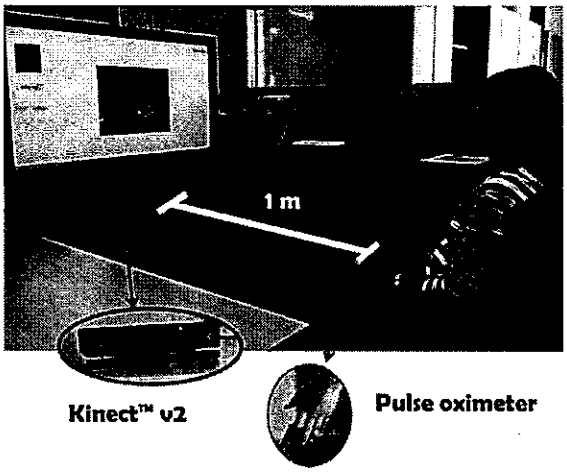

Figure. 2. Experimental Setup.

During the different tests to find the right setup of Microsoft Kinect™, is used a dual data acquisition that involves real-time heart rate detection using the RGB channels and infrared channel available to device.

By analyzing the Microsoft device used, Figure 3 compares the infrared sensor with the RGB channels of Kinect™ [32].

As shown in Figure 4, the two cameras are placed few centimetres far. This implicates that also the sensor area of coverage is slightly different: for this reason it is necessary to proceed with a pre-calibration to align as much as possible the size of the ROI gained through RGB and the ROI gained through NIR, especially if the facial rectangle is constructed following the skeleton joint's trend.

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Camera Name				
	Kinect 2.0 RGB Camera		Kinect 2.0 IR Camera	
Imaging Sensor				
Type	-		-	
Resolution (pixels)	1920 × 1080		512 × 424	
Pixel size (μm)	3.1		10	
Interior Parameters				
	Value	St. Dev	Value	St. Dev
Focal length (mm)	3.291	1.0e−3	3.657	5.2e−4
Format width (mm)	6.00		5.12	
Format height (mm)	3.38		4.24	
Image width (pixels)	1920		512	
Image height (pixels)	1080		424	
Principal Point x (mm)	−0.005	5.6e−4	0.032	3.5e−4
Principal Point y(mm)	−0.016	6.9e−04	0.033	3.9e−4

Figure 3. Sensors and IO parameters of RGB and IR cameras estimated during the camera calibration procedure for Kinect 2.0.

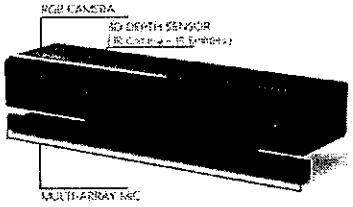

Figure. 4. Kinect™ features.

After all these considerations, to choose the best setup, the participants are standing and sitting in front of the Kinect™ sensor, at approximately 1 meter far from the built-in camera, while the system calculates the heart rate in real time mode using the NIR channel.

VI. RESULTS

For each subject, the graph comparing the timely progression of the heartbeat detected both by Kinect™ sensor and the pulse oximeter has been plotted. Then, it has been decided to calculate the heartbeat's average in the time interval considered.

The percentage error of the mean of heart rhythm detected by the Kinect™ sensor and the one obtained by averaging the incoming values from the pulse oximeter are also calculated.

Plots in Figure 5 show the graphs of heart rate value acquired by the Kinect™ based system (red line) and gathered by pulse oximeter (blue line) during the test.

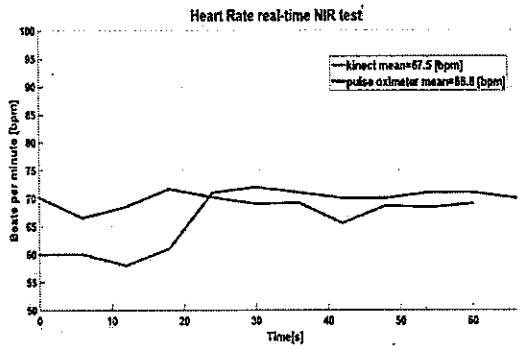

Figure. 5. Representation of heart rate-time during two different tests.

In Figure 6, the scatter graphs of mean value between Kinect™ and pulse oximeter are plotted for each test conducted: a linear trend line has been added for better understanding the graphs and the correlation coefficient (R) and the level of significance (p) are also calculated.

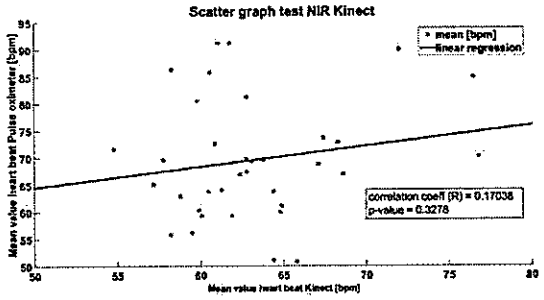

Figure. 6. Representation of scatter plot Kinect™/pulse oximeter.

The correlation coefficient (R) is a number between −1 and 1 that determines whether two paired sets of data are related: the weakest linear relationship is indicated by a correlation coefficient equal to 0. So the coefficient for the test shows a moderate positive correlation between data of heartbeat from Kinect™ and from the pulse oximeter. The p-value is a number between 0 and 1 that determines whether the correlation between variables is significant. A p-value (as calculated for the still test) of 0.30 indicates that the risk of concluding that a correlation exists—when, actually, no correlation exists—is about 30%. [33].

For each tester the average heart rate (HR) calculated is also reported in Figure 7, considering the device used and the type of the test performed. The table well summarize the comparison of the mean heart rate values obtained from Kinect™ and from pulse oximeter, according with the relative percentage error calculation.

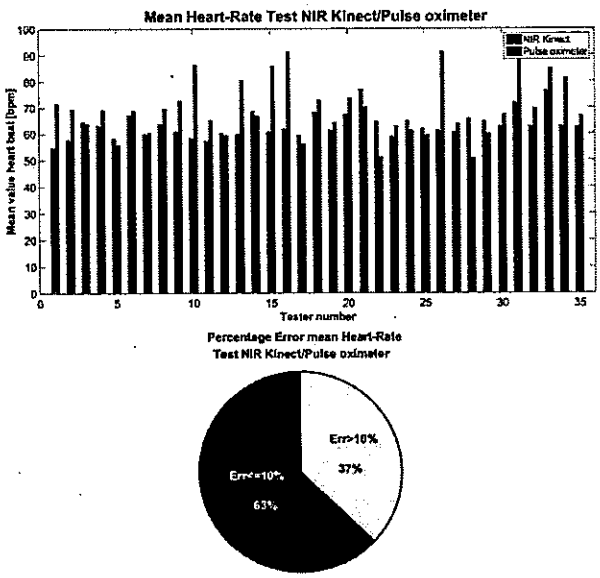

Figure. 7. Results of (HR) average of different tests and relative error.

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By considering these three factors, i.e., value of correlation coefficient (R), the p-value and the relative errors (acceptable within 10%), it is possible to say that, the values of the heart rate calculated with this novel solution are comparable with the values gathered by the medical device only during the still tests. Moreover, the obtained values are also comparable with the previously acquired data and analyzed through RGB channels of the Kinect™.

VII. Discussion

As discussed above, it is possible to consider the system implemented as a valid system for gathering the real-time heart rate values in static position, even when light conditions are not optimal. While considering the pulse oximeter as a reliable system, the device used has inherent accuracy ±2%. For these reasons, part of the deviation between the values gathered by the Kinect™ sensor and the GIMA oximeter should be related to a non-correct use of the oximeter.

Finally, not significant variations of the results are due to gender, age and fitness status of the testers.

VIII. Conclusion

This work describes the implementation and the tests of a novel methodology for evaluating the heart rhythm acting at medium distance (1 m), by analysing the NIR stream. The performance of the proposed method (applied in real-time) is tested in adverse situations, such as in the dim light condition. The study starts showing the real-time processing of the video acquired by the Kinect™ built-in NIR camera. The procedure begins with the automatically choice of the ROI with a strong passage of blood modulation and with the reduction of the background noise with a band-pass filter. Then, it continues with the analysis the signals coming from the IR channel of camera and it finishes by creating an ad-hoc algorithm for accurate heart rate detection using FFT.

The system and the algorithm implemented are validated by 35 participants sitting in front of the sensor at approximately 1 meter.

As described in the results, the study has shown a quite good reliability in detection of heartbeat at distance and in real-time, when the subject is in a static position in front of the sensor.

As a future development, it could be considered the possibility of applying this heart rate detection solution using infrared sensor, in situations where it is difficult to wear sensors for a long period of time (e.g., driving, neonatal department, etc.). Generally this type of monitoring can be useful in all the situations in which acquiring remote vital parameters is easier than wearing medical devices.

After the results obtained with a sufficiently reasonable number of testers, as a future work, it is designed to continue the study with large-scale testing to validate and perform the entire algorithm in a robust manner.

Acknowledgment

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Supporting Active and Healthy Aging - An Assistive Process Improvement Approach

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Abstract—**Active and Healthy Aging (AHA) is one of the growing concerns and aims of a sustainable society and of the European Union. In many business and industrial enterprises, the adoption of a process view and the analysis of the processes to be performed has brought about numerous advantages, ranging from clarity and understandability to increased efficiency due to assessment and measurements of quality and capability. In this paper, we apply the process view concepts to the processes needed for Assisted Healthy Aging. The necessary activities are described on an abstract level (i.e., as activity types) and organized in a Process Model. Individual processes are derived (instantiated) from the AHA-model to be enacted by the aging persons, the Seniors, utilizing the human and technical support structure. We discuss the application of the concept of process view in the AHA-environment, especially pointing out the difference from classical business/industrial processes. A discussion about the possibilities to assess the quality of AHA-processes and their support by a Model Interpreter closes the paper.**

Keywords–Seniors; Process View; Process management; Maturity; Capability; Assessment

I. INTRODUCTION

Active and Healthy Aging (AHA) is one of the growing concerns and aims of a sustainable society and the central theme of the EU Project My-AHA [1]. Supporting Active and Healthy Aging is an ethical, an economic and finally also an organizational issue, especially due to the demographic changes in the Western World. Most Seniors will become involved in active and/or passive roles in activities related to AHA, if they like it or not. Usually, support is needed to compensate for lack of Seniors' sufficient capability to perform simple or complex necessary processes on one's own. This deficit in capability has to be overcome by a human support environment (consisting of persons from many different disciplines: family, doctors, nurses, service personal, helpers, etc.) and the technological support system (consisting of gadgets, tools, computers, robots, etc.). Automation will be a key factor in providing an effective and also economic support.

Based on the advantages and the success of the process view in industry ("Industry 4.0"), i.e., an increased autonomous intercommunication behavior of multiple machines, we suggest adopting a process view of supporting AHA. This will be a good basis for including technological means and tools. We believe that applying a process management approach can help to improve the quality, efficiency and understandability of AHA-projects. We will use the terminology and concepts of system development processes (e.g., ISO/IEC (International Organization for Standardization / International Electrotechnical Commission) 12207 [2] and ISO/IEC 15288 [3]) for describing the AHA-support processes, their interfaces and the necessary requirements. Quality assessment will be based on the ISO/IEC 33000 family of standards [4].

In this adoption process, we have to be aware that an obvious key difference is that the 'objects' of software processes are innate artefacts and not living beings, human Seniors. This will impose strong implications and limits with respect to aspects of humanity, morality, ethics, and risks.

The paper will be structured as follows: In Section II, we will describe the basic concepts and terminology of a process view, i.e., the structure of processes with activities and tasks and their interrelations and the Process Models. While this discussion is applicable essentially to all processes we will specifically discuss the requirements, challenges, and differences introduced by considerations of AHA, especially in comparison with 'pure' technical processes in Section III. In Section IV, we will again be inspired by software engineering with respect to discussing means to measure, control and even improve the quality of AHA-processes. At last, Section V will be devoted to the technological support to enact, assess, control, and measure the maturity of the AHA-processes leading to concepts for an AHA-Process Interpreter.

Statements and observations specific to AHA will be emphasized by printing them in italic and preceding them by "AHA:".

II. THE PROCESS VIEW

A. Activities and Tasks

The process view decomposes a complex undertaking into a set of processes, activities and tasks, which interact and exchange information and work products ("inputs" and "outputs"). The Software Engineering Standard ISO/IEC 12207:2017 [2] defines:

- process : set of interrelated or interacting activities that transforms inputs into outputs
- task : a requirement, recommendation, or permissible action, intended to contribute to the achievement of one

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or more outcomes of a process. (In the management literature a task is often considered an uninterruptible unit of doing to be performed in one go.)

- activity : a set of cohesive tasks of a process. Despite the fact that the above distinctions are important for the structuring of Process Models, we will in most cases simply speak of 'activities', encompassing also tasks and sometimes also processes.

The division of an activity into different tasks (the granularity) will depend on the nature of a task and also on the capability/knowledge of the performing person [5][6]. A Process Model designer must strike a good balance between too coarse a granularity (leaving to much open and some users helpless) and too fine a granularity (boring some users with unnecessary and/or' obvious' details of tasks).

AHA: *This issue will receive special attention in this paper (see Section III). Activities can be assigned to be performed by the Senior himself/herself, by various helpers from different professions and machines (computers) of diverse capability and diversity. One consequence is that the same support activity task has to be divided differently depending on the capability of the individual Senior.*

B. What is a Process Model?

A Process Model defines and documents the activities, their contents, their meaning, and their interaction (input and output) with other activities. For Software Engineering, the key documents are ISO/IEC 12207 [2] and ISO/IEC 15288 [3].

The Process Model abstracts from idiosyncrasies of a single process and describes the process 'in general', independent of the enacting person or the object of the activity. It describes in an abstracted form all necessary activities (e.g., 'evaluate health status' or 'perform operation') and their logical dependencies (e.g., 'measure blood pressure' before 'perform operation') and the necessary work products (e.g., 'blood pressure values', 'description of previous treatments') to be produced and used by these activities. When modelling a process, all semantically equivalent activities are abstracted into one "activity type" [7], e.g., measuring blood pressure in the morning, the afternoon and the next day are abstracted to one activity type 'measure blood pressure' (Figure 1). Similarly, the work products are abstracted into "work product types", e.g., to a work product type "blood pressure".

The logical dependencies between activities are also expressed on the 'type'-level and have to be applied for the individual activities (instances). This leaves still considerable freedom to "navigate", i.e., to choose the next task [9], see Figure 2. A Process Model contains in abstracted form the experiences of many preceding processes combined with theoretical considerations and desirable improvements. By updating the Process Model, newer experiences and best practices can also be added to it. Different methods and strategies will distinguish themselves, both in the activities and work products, but especially in the sequence the various activities are to be performed in.

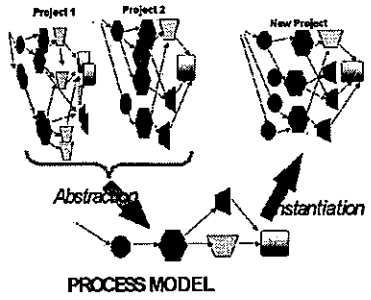

Figure 1. Process Abstraction and Instantiation [8].

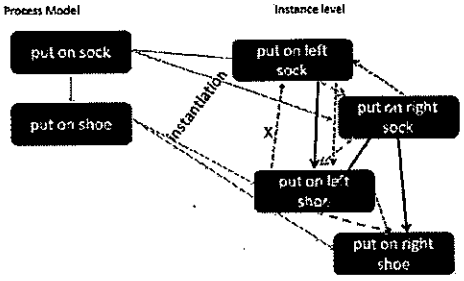

Figure 2. Instances of activity-types and work-product-types for AHA.

Figure 3 shows the extended meta-model of a software Process Model, also showing additional components: tools, roles, input/output relations, and structural information [9].

C. Advantages of the Process View

Key advantages of a formal Process Model are [9][10] :

- from implicit to explicit definition : A formally described Process Model can be recorded, standardized, transmitted to others, stored and taught, thus converting implicit knowledge into explicit knowledge [11].
- Storing Best Practices : It also acts as a repository for new best practices, thus preserving experience, but also allows audits and recording of inadequacies. One can also identify essential or usefully subprocess ex-post [6].
- Standardization : It provides standardization across different persons, projects and applications. This is of special value for the cooperation of heterogeneous teams.
- Quality assessment : The process can ex-post be evaluated, improved [12], its capability and maturity assessed (e.g., by the ISO/IEC 33000 family [4]. For details see Section IV.
- Audits, Tracing and Recording of Resources : Computer support allows the automatic recording of enacted activities and accounting of used resource (personnel, volunteers, operational material, etc.)
- Computer Support : A formally described Process Model can be supported by a Process Interpreter, see Section V.

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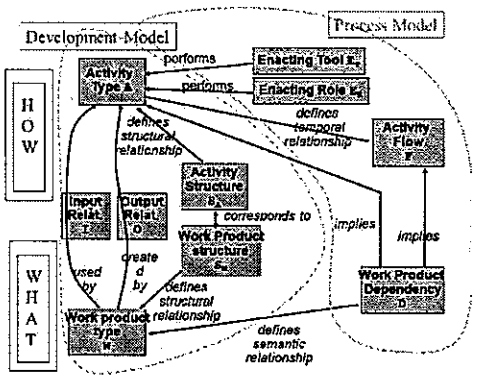

Figure 3. A Process meta-model.

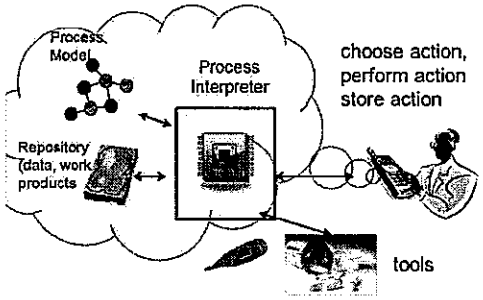

Figure 4. Interfaces for AHA.

D. Enacting a Process Model

When performing a project (or actually any activity based on the Process Model (Figure 3)) the model has to be 'enacted'. An appropriate 'Interpreter' of the Process Model (Figure 4), be it a human or a computer programs has numerous different activities to perform.

- Instantiation and administration of activity types : Instances of activity types must be created, shown to the user, worked on by the user, and their status remembered (planned, started, finished, under rework, etc.). Access to the needed inputs must be provided, outputs identified.
  AHA: *In many cases a Senior has to initiate and/or perform specific activities. The Process Interpreter can ask the Senior to do so. It is difficult to check whether the actions have been performed, see Section III-B.*
- Instantiation and administration of work products : All work products (documents or pointers to external artefacts) must be created (are 'replicated'), i.e., instantiated as often as necessary (Figure 2)), administered and related to the appropriate activities.
- Navigation : The enactment of an activity (an instance) must honour restrictions and dependencies within and between all other activities (e.g., sequence constraints between activities, common start or end of activities, exclusion of parallelism between them, etc.).
  The sequence in which activities are to be performed (the 'navigation information') is partially defined in the Process Model. The Model (as a construct on the 'type' level) leaves considerable freedom.
  AHA: *For example, a Process Model for a Senior might contain two activity types "put on socks" and "put on shoes" (see Figure 2). Actually, each of these two activity types identifies two activities (one for the right and one for the left foot) and thus would result in 8 different activity sequences.*
- Pre-emption and Resumption : Sometimes processes have to be urgently interrupted in order to assign resources to other activities, typically for emergencies.
  AHA: *An unexpected heavy bleeding has to be handled immediately, probably pre-empting another activity. After the emergency has been taken care of it is often difficult to decide how to handle the interrupted activity (start anew, continue at point of interrupt, abandon the rest of the activity). In all cases the Process Model Interpreter has to be informed and the necessary status set.*

III. System Development and Supporting AHA

In this section, we will expand on the use of the Process View in AHA and use the experience and know-how from Software Engineering. See also a similar comparison between Software Engineering and Disaster-Management in [13].

A. AHA as a Collection of Processes

The processes performed in AHA are in many aspects similar to systems engineering. A Senior himself/herself is a very complex system. The processes, which try to improve his/her status and/or situation must - as consequence - also be very complex, as the Law of Requisite Variety postulates [14]. Support for Seniors by humans and machines (including computers) must enact a large variety of support processes.

Health care processes diverge in their properties in several ways from the classical systems engineering processes. The reason lies in the different focus of these two types of processes: the 'objects' of AHA are living humans with their will, personality and idiosyncrasies while the objects of systems engineering processes are usually inert software objects. Humans are flexible, variable, sometime irrational, and provided with a free will, with moods and variations. This has to be considered when discussing the various components of the AHA-process. We restrict ourselves to My-AHA, i.e., supporting individuals in living through their aging process in an acceptable and healthy status.

All activities must be designed with strong consideration of human factors with respect to all involved persons [15][16]. This includes observation of cultural differences between ethnic groups [15] with respect to contents, form and differences as far as believing in and interpretation of warnings and instructions and the willingness to obey them [17].

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B. Challenges in AHA

Considerable differences exist between the situation in a system engineering situation as compared to a AHA-situation (see also [13]) . Many of them challenge our creativity.

- Completion Control : In a 'regular' system development project guided by a Process Model each task or activity has at least one outcome in tangible form (a piece of document, finished intermediate product etc.), which is expected (and needed) by a successive task. In most cases a different person will be in charge of the successive task and therefore will 'ask for' the result - quality might be lacking, but a document is expected.
  AHA: *In most cases this is not true. Most 'outputs' of an AHA-process are triggers for another activity or acknowledgements ('take medicine XYZ' , 'morning gymnastics done', ...). In the Process Model only surrogates for these 'outputs' are created. Whether the Senior has cleaned his/her teeth, or drank enough liquid is very difficult to control. The simple solution that the Senior has to acknowledge the completion of the task is of little use since a Senior can (and often will) easily fake the acknowledgement.*
  Two approaches are promising:
  Internet of Things: Utilizing the concept of the Internet of Things one can equip essential gadgets (e.g., the tooth brush or the jug) with active sensors and thus recognize the completion of an activity (at least to a certain extent). However, experience also tells us, that many Seniors dislike this type of control and will be very creative in circumventing and faking completion (e.g., watering the flowers instead of drinking, etc.)
  Gamification: A more promising approach seems to be the concept of Gamification [18]: the recognized successful completion of an activity will produce of visible 'achievement mark' on a prominently visible display. Psychologically this is more promising, but can only be used in certain environments.
- Misplacing and Searching : In a Software Engineering Environment the Process Interpreter stores, administrates and makes available the work product.
  AHA: *Seniors are generally plagued by misplacing things and having problems finding them later. To a certain extent an Internet of Things approach could help, one would need to equip all important object with sensors. In this case the system could indicate where to find the necessary objects or documents*
- Forgetfulness : Depending on the specifics of the chosen Project Interpreter, users will be reminded of pending activities and deadlines
  AHA: *Seniors tend to become forgetful. A Process Interpreter can bridge and alleviate much of this forgetfulness by registering activities and dates to remind the Senior.*
- Time variability : While mechanical systems show a reasonable predictability and stability this is not true especially of Seniors.
  AHA: *This means that one cannot make reliable assumptions about the physical or mental status of a Senior. It can change any time. Therefor the AHA-processes must be carefully double checking the situation etc.*
- Lack of full knowledge of the history : In Software Engineering lots of the information is not provided explicitly but hidden in the code and documentation (as far as trustworthy).
  AHA: *Similarly historical data documented about a Senior is full of hidden facts, omissions, mistakes, misunderstanding and unknowns - often due to privacy considerations. Treatment has to take this into account, especially if certain activities are performed by computers.*
- Pre-emption of activities : One often has to interrupt an activity in favour of performing another one.
  AHA: *A well-ordered enactment of a Process Model is often not possible. Activities have to be started suddenly due to an emergency (e.g., "severe coughs"). Other activities have to be interrupted and later taken up at the point of interrupt, or repeated.*
- Pressure of Time and Success : The production of software seems to be notoriously under performance pressure.
  AHA: *For Seniors the time very often 'runs away'. Hazards appear suddenly and have to be taken care of immediately. Life-saving activities often have a very narrow time window to be successful.*
- Stress and psychological pressure : Helpers are often under stress due to the responsibility in view of unclear situations [19][20].
  AHA: *This problem often is more pronounced due to the close relations between Seniors and personnel.*
- Systemic problems : Health problems are usually the result of several interacting causes.
  AHA: *Illnesses and hazards often have highly interrelated causes and reciprocal influences, often showing new symptoms (emergence [21]) like allergic reactions against some medicine. Domino-effects of existing illnesses, side effects of medication need to be considered*
- Cultural "blockages" and taboos : When treating Seniors, social taboos and conventions have to be kept in mind (no blood transfusion for Jehovah's Witnesses, no male personal for Muslim women, etc.).
  AHA: *Seniors often have their own mind, long established peculiarities and often no understanding for the necessities of treatment. They also often object to being 'led' by a 'machine' despite the lack the capability to manage themselves.*

IV. Capability assessment of the AHA-processes

One of the key advantages of defining and following a Process Model is the possibility to assess the capability of the performing organization: to what extent can the organization provide the services and products intended to be provided based on a standardized and accepted Process Model (cf. [4])?

In the 1980s, the Software Process Program was founded at the Software Engineering Institute (SEI) at Carnegie Mellon

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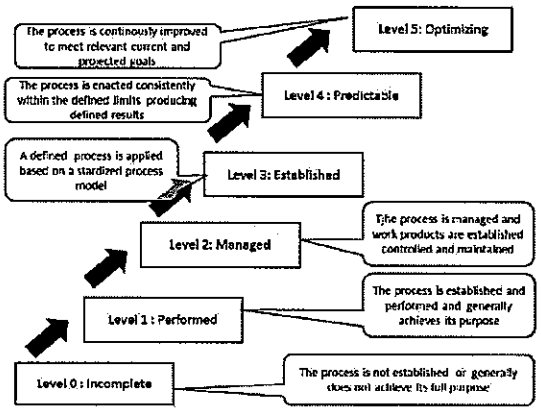

Figure 5. Levels of Process Capability (ISO/IEC 33000 [4]).

University under the leadership of Watts Humphrey. This program resulted in the development of the Capability Maturity Model [22][23][24]. A prerequisite is a comprehensive, generally agreed-upon Process Model containing all the key processes needed for software engineering. [2] identifies some 40 individual processes. These processes are rather comprehensive with many individual tasks. Each process is evaluated to what extent it is performed by the organization (N..not performed, P..partially performed, L..largely performed, F..fully performed). This yields a profile as shown in Figure 6. This profile can be compared to other Process Models, to an industry average and also compared with the profile needed for the specific project.

AHA: *A Senior who is able to walk alone, does not need certain processes irrespective of their performance level.*

In order to characterise a complete enterprise (be it a software house or - in our case - a senior home) its overall maturity is of high relevance for future planning and can be measured. Figure 5 is the basis for assessing an enterprise. In software engineering the levels (see Figure 5) run from incomplete (where the process is mostly unsuccessful) up to 'improving' (where the process is continually adapted to new needs and challenges). In a nutshell the maturity of an enterprise to produce good software can be assessed and measured using a two dimensional graph (capability versus individual relevant processes), see Figure 6. The Assessment can also be used for the improvement of the processes [10][12].

AHA: *One needs a comprehensive, agreed-upon Project Model and historical records of what has worked in the past. Then one can identify deficiencies in the Process Model, compatibilities and differences of various processes (since not all Seniors need all processes), and identify the improvement potential.*

V. A Process Interpreter

Computer support is the key for efficiency and effectiveness of the AHA-processes. It has to show two different faces:

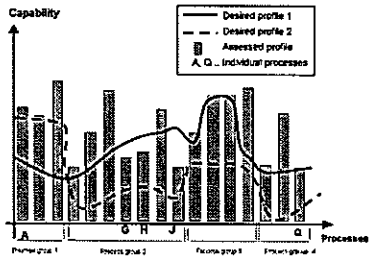

Figure 6. Comparing different profiles.

One is directed to the Senior, the aging person. It has to be empathic, helpful and tries to explain/show the situation in a way a Senior can understand. The other one is technological and effective and provides a stable, effective infrastructure for the other interface.

A. User Interface

The system helps the user to enact the processes he/she is supposed or intended to perform. It also allows the user enter processes of his/her own (things to do, things not to forget and be reminded, deadlines...) Considering the challenges listed in Section III-B a Process Interpreter for AHA-purposes must fulfil several somewhat contradicting properties:

- strict : Certain activities must be performed exactly as prescribed, often even within a very narrow time window.
- tolerant/flexible : Some activities may be performed not at all or very loosely, depending on the specific situation, especially in view of the varying psychical and mental situation of a Senior.
- robust : The system must be robust against disturbances of various kinds (be it changes in the well-being of the Senior, computer failures, cultural differences, sudden unexpected changes in the behavior or the situation, ...)
- agile : Handling of Seniors must be highly flexible (especially due to inflexibilities, which come with old age.)
- user-friendly : The interfaces must be easy to understand and show "good behavior with the sensitivity of an intuitive, courteous butler" [25]. They should take into account the personal and cultural differences as defined in [26]
- unobtrusive and non-stigmatic : The Senior must feel confident, that his/her use of the assisting system is accepted by his/her peers and neighbours without negative feelings.

B. The Role of Tools, Machines and Robots

In many ways, robots can even replace humans. For this to happen, it is necessary to have a clear, unambiguous and formal

description of the processes to be performed (the Process Model), plus a characteristic of machine environments. Thus it is possible to allocate processes to persons or machine, whatever is the better choice, also for the Senior. Robots can relieve helpers from chores, which do not really require human understanding and human empathy versus the Seniors. A Process Interpreter (Figure 3) is an ideal tool and infrastructure to automatically include the access to tools into the AHA-processes.

VI. Conclusion and Future Work

Adopting a process view for supporting Assisted Healthy Aging (AHA), like in other business and industrial areas, promises an improvement in clarity, understanding, and efficiency: The necessary processes are defined and documented in a Process Model, which is the basis for automatically guiding the execution of the individual processes by a so-called Process Interpreter. It helps all stakeholders, Seniors, human support personnel to follow the processes and use technical support. This approach also allows a better control of the execution of these processes and assess the quality and capability of the defined processes. Implementing such a scenario requires a deep understanding of the behavior, the limitations and idiosyncrasies of Seniors.

Obviously, the work described here is only a beginning. More work has to be done to understand the requirements of Seniors with different social, cultural and economic background. This strongly affects the 'look and feel' of interfaces, especially with respect to ease of use and empathy. We hope that our contribution will trigger further research and useful result for Assisted Healthy Aging of Seniors.

Acknowledgment

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Development of an Intelligent Drinking System for the Prevention of Dehydration in Old Age

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Abstract— **This paper describes the user needs analysis for a system that supports the professional management of fluid balance in older people to prevent dehydration. Dehydration is a frequent age related issue that typically leads to a steep decrease in physical and / or mental performance. Severe cases are life threatening due to risks of circulatory collapse or loss of consciousness. Hence, the prevention of dehydration is of particular importance. For data gathering, social-scientific methods (individual interview, focus group interview, cultural probes and documentary research) were implemented. The survey involved primary end users (elderly, dependent people), secondary end users (informal and formal caregivers), experts from ethics and the analysis of care documentation from older users. The main results were derived from the data by using a thematic analysis and subsequent data fusion as well as consolidation concepts on result level. As a conclusion, aside of valuable system-specific recommendations, a concept for reminding and motivating could be designed and will be implemented.**

Keywords: Active and Assisting Living; health care and nursing; dehydration prevention; interdisciplinary research

I. INTRODUCTION

Ensuring a sufficient supply of fluids to the body is a major challenge for the elderly, or the caregiving family members or nursing staff in a mobile care setting. With increasing age, the water content of the body, as well as the feeling of thirst decreases significantly [1-3]. This makes elderly people particularly vulnerable to dehydration. The effects of dehydration are extremely serious. Impairment of consciousness, fatigue and weakness, dizziness, muscle cramps and headaches are possible symptoms. With old people even a minor water deficiency leads not only to a drop in salvia production with mouth dryness, but also to reduced urine production and dry skin, which, in turn, can easily break up or develop pressure sores. In case of an even greater water deficiency, an accelerated pulse, an increase in body temperature, dizziness, weakness, impairment of consciousness and a decrease in physical and mental performance occurs. The onset of disorientation, states of confusion, apathy and a life-threatening circulatory collapse with loss of consciousness are possible consequences [1]. In elderly people, other causes such as heart disease or dementia are erroneously suspected without considering an insufficient supply of fluid as a possible cause. The consequences can also be life-threatening in the case of unconsciousness, circulatory or renal failure. Frequently, hospital admission is required. According to a study conducted in two English hospitals, 6.5 and 22.5 of 1,000 hospitalizations are based on dehydration. The mortality rate of hospitalized elderly people with dehydration symptoms is 45-46% [2].

The prevention of dehydration is therefore particularly important in mobile as well as in stationary care. Particularly in mobile care, the estimation of the quantity of liquid intake can only be carried out inaccurately, as the often very dependent clients live alone at home and are not supervised continuously. This means that elderly people cannot be cared for adequately in mobile care.

The presented research was conducted within the experimental research project "DrinkSmart" (2016-2018), which has the main aim to support the autonomy of elderly people with and without chronic diseases in order to facilitate their living in their own environment. The project led by the University of Applied Sciences "FH Campus

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Wien" was funded by the Austrian research promotion agency (FFG) and carried out in interdisciplinary cooperation with the software company "akquinet ristec", the plastic mug manufacturer "Schorm" and the home care provider "MIK-OG".

II. STATE OF THE ART

Technical solutions for adequate hydration are already being developed in this field. They are mainly advertised as lifestyle products and are aimed at a young IT-savvy user group. These include the "Pryme Vessyl [1] " and "hidratespark[2]" systems. Apart from the pure analysis of the drinking quantity, these systems also offer the analysis of the liquid inside the drinking cup. Further they provide an optical warning function when too little liquid was drunk. In addition, a connection with a smartphone app for iOS or Android is to be made via "Bluetooth low energy", which should enable the future entry of individual data of consumed fluid quantities and body data like weight and size combined with GPS function. Alternatively, a lid cap has been designed for a cup, which measures the amount of fluid drunk with different sensors. This information should be transferred to a PC.

All described products focus on the needs of a young target group, not on older, dependent people and care contexts. Specifically those systems were not designed to transfer data to an electronic care documentation system. Such systems are important to assure the quality of care and are typically used to document the health status of the patient and the activity of nurses. Both aspects are core concepts of the here presented approach.

III. METHOD

For the survey of user needs and the development of the intelligent drinking system with appropriate sensors in the drinking vessel, which is used to measure the daily liquid consumption, qualitative scientific methods were used. The needs assessment in the primary and secondary target group was conducted using different socio-scientific survey and evaluation methods: guideline-specific individual [4] and focus group interviews [4][5]. For all interviews and focus group interviews guides including the structure, timing and detailed open and closed questions were developed. The data was analysed according to Mayring [5]. Furthermore, the ethnographic method of "Cultural Probes" [6] was used to obtain detailed insight into the existing drinking habits of the target group. A documentation analysis [7] of the existing care documentation completed the survey. The methods were chosen based on the individual research questions. Focus groups and individual interviews were chosen based on the individual timing possibilities of the recruited participants. A wide mix of methods was chosen to become able to conduct cross-method triangulation [12] of results. Researcher triangulation was undertaken for further quality assurance. The data gathered showed clear signs of saturation, which was to be expected considering the large user base.

TABLE I. OVERVIEW ON DATA COLLECTION METHODS

Data collection methods implemented		
Data collection method	***User group***	***Number of users involved***
Literature research	-	-
Discussion and interviews with experts from ethics [4]	Ethics experts	2
Cultural probe studies [6]	Primary users	6
Single-user, semi-structured interviews [4]	All user groups	40
Focus-group interviews [4][5]	Secondary users	22 (in 4 groups)
Analysis of care documentation [7]	Older dependent users and formal caregivers	5 documentations

The development of the intelligent drinking system, which is based on the summarized user requirements and follows the product specifications, adheres to the user-centered design approach [8] combined with the phase model on product development according to Glende [9]. The implementation of the user studies with selected participants was accompanied by a process- and result-oriented evaluation approach [10][11] with regard to the technical and social-scientific aspect.

IV. RESULTS

The summary from interviews and cultural probes shows the following common aspects despite the heterogeneous user groups involved.

The material should be comfortable to touch and not breakable. A modular design is desirable, that is, the drinking cup should be adaptable to different end user requirements. Care dependency may be a fluctuating phenomenon, which means that in the case of an acute disease, independent drinking might only be ensured with devices on the cup itself, such as the handle, or the spout, which might not be necessary in the further course of the disease.

An important additional component is the design of reporting functions. With the help of acoustic and optical signals, reminder functions should be realized, which remind the user of drinking. At the same time, the cups should facilitate a motivating design or component for motivation as users often knowingly object drinking.

The system should provide an overview of the quantity of liquid that has been drunk. It is important that the signals issued by the system (e.g. to remind or motivate drinking) should not be irritating and the optical and functional design of the system should appeal to different senses. This was considered in particular regarding used colours, materials and the design of the user-system interaction.

The results of the cultural probes studies with a duration of one week each and involving a subset of the primary user group (n = 6), underline the complexity of existing drinking

[1] https://myvessyl.com/prymevessyl, last checked on 2017.5.10
[2] https://hidratespark.com, last checked on 2017.5.10

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habits. For example, drinks were consumed in parallel from several vessels; several differently shaped vessels were preferred in the course of the day or "favourite cups" were used which cannot easily be replaced by a single new system. As a consequence, the planned drinking system is limited in practice regarding the accuracy of the measurement of the total amount of liquid intake during a day, due to the users' habits. Further due to ethical concerns we found a need for a system that does not force users to change previous habits through alarms.

The analysis of nursing documentation shows that with many clients the focus is on the description of the risk of dehydration in terms of symptoms and causes. On this basis nursing measures and resources are formulated for the nurses to carry out. The objective of this standardized approach is to mitigate the symptoms of dehydration, to eliminate the causes, if possible, and to strengthen the resources of the clients by direct and indirect measures.

Based on the results of the conducted user need analysis a non-functional mock-up was created within a rapid prototyping process using the generative production method of Selective Laser Sintering (SLS). Due to the consistent consideration of the user needs, a simple and handy mug with clearly visible and intuitive visual and acoustic signals could be developed and is depicted in figure 1.

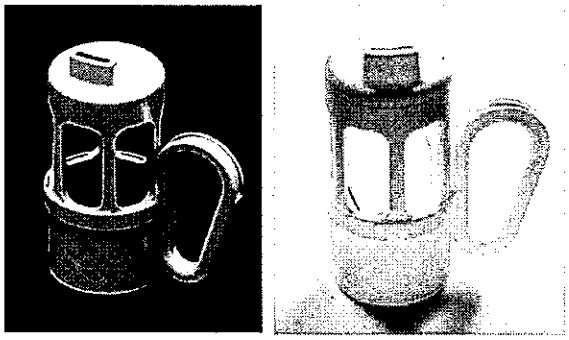

Figure 1. Mock-up of the modular system based on the user needs analysis. Comprised of a cup (inside), a plastic cup holder with electronics compartment and a grip. Acoustic and optical motivational and reminder functions are not yet visible. (left design-study showing the motivational component, right 3D printed system).

The optical components were realized as a dynamically growing seedling with seven leaves. Depending on the daily volume drunk, the leafs light up simulating a growing plant. This gives users a definitive feedback on the drinking volume reached up to the time X. By holding the system, the current drinking quantity status is displayed; otherwise the cup does not produce any acoustic or optical output to minimize potential irritations during night-time. The liquid within the cup forms a second optical component. It can be illuminated with an LED and in this way acts as a reminder for the users. This visual reminder is displayed when, within a predetermined interval, no liquids have been consumed.

At the end of the research project in 2018, the crucial result will be a market-oriented prototype (hardware and server / application software) for a smart drinking system. For the design of the corresponding sensors in the drinking cup, the liquid intake is measured via the Drink Smart Mug and controlled by means of reminder signals (visual and acoustic) and notification functions (e.g. SMS / E-mail). By connecting to a computer-aided care documentation already used in nursing care companies, the collected data can be recorded and documented. The caregivers are thus informed promptly and can react accordingly in acute cases.

The system is going to be evaluated within a home care setting including around 20 users for the duration of 4 weeks. Data gathering will be undertaken by implementing questionnaires, diaries, individual interviews and participatory observation. This qualitative research approach is important taking the complexity of the system and early prototype phase into account. The used social-scientific methods focus on the users' perspective and the nursing result quality, including also a risk-assessment for technology aversion. Technical evaluation methods test the efficiency, ease of use and technical practicability.

V. CONCLUSION

The consistent user-oriented approach ensures that the needs of the users and their relatives, as well as their caregivers, are largely covered in the development of the intelligent drinking system. The use of the documentation analysis method, as well as several different survey methods for the primary and secondary target groups, and the Cultural Probes method form a comprehensive data material, which clearly identifies the needs of the user groups by data fusion and structuring and greatly facilitated the design of the drinking system.

In the current technical implementation phase, the requirements generated from the results have been implemented as far as technically possible, and the resulting first prototypes (mock ups) have been subjected to further testing by the clients.

Thus the drinking system can be used as a supplementary aid in the future to prevent dehydration in old age and thereby it can be used in a low-threshold manner as a contribution to the management of chronic diseases. Consequently, elderly people are supported to live autonomously in their own homes, and help by caregivers can be targeted.

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Smart Mobility and Cultural Tourism: The Termini-Centocelle Train Museum, an Example of "Smartourism" Project in Rome

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Abstract—**Many recent trends in mobile Web and context aware applications are leading to consider new applicative scenarios including the so called smart services which are characterized by the use of autonomous devices connected to the Internet (sensors, beacons, etc.) and cooperating with user personal mobile devices (tablet, smartphone, etc.). In the case of urban mobility management, several issues are related to local mobility especially for tourism and cultural cases. We consider one of this related to old train re-using in Rome which has been selected as a pilot test for future sustainable transportation systems. We are able to show that, in this case, an effective system with mobile applications could leverage a real contribution both for mobile museums and for geo annotation of peripherical urban lands.**

Keywords—Internet of Cultural Things, Internet of Things, Mobile First, Mobile Web, Smart City, Smart Mobility.

I. Introduction

With the continuous development of Information and Communication technologies and Smart City for Cultural heritage, it is possible, thanks to the Internet of Things (IoT) implementation, to have smart systems connected to Wi-Fi, to revolutionize the management of tourism, promoting sustainable economic development, engaging the citizens effectively, as well as reducing mobility costs and resource consumption. To this purpose, we proposed the first applicative framework for Smart City named STREET WEB [1]. STREET WEB is a platform to distribute tourist information "on the road" without Internet connection. The physical architecture of STREET WEB is composed of a network of different nodes called Smart Box (SB), each representing a complete working station linked to a node sensor station to improve locality visibility. It is based on the Mobile First paradigm for adapting graphical user interface to multiple browsers and device sizes. In this paper, the purpose is to extend STREET WEB functionality to provide cultural contents and services to all visitors in the context of Smart Mobility (an important field belonging to the ecosystem of the Smart Cities). The fundamental issues of this approach, based on the integration of tourism, cultural heritage and mobility, are not only to enhance the cultural heritage present in the territory, but also to increase the tourists flow (cultural, scenic, artistic, gastronomic, etc.) and finally, to create new conditions for sustainable territorial socio-economic development. The paper is organised as follows: Section II introduces the Smart Mobility Context of the Mobility Project and the main issues of the Architectural Design. Section III gives the detailed description of the Platform used to distribute tourist information "on the road", based on Digital Niches Model and Microservers System. Section IV concludes the paper introducing implications and potential results yielding in the field of Sustainable Transport and Smartourism for obtaining information related to touristic Point of Interests in the land.

II. Scenario Overview

The use case scenario is related to a mobile system for exploring the "Ecomuseo Casilino", a type of museum [3] managed by the "Association Ecomuseum Casilino - Ad Duas Lauros" which aims to show and protect the cultural area [2] named "Comprensorio Casilino - Ad Duas Lauros"." The Ecomuseo Casilino hosts many archaeological resources, such as: Mausoleum of Elena (the mother of Emperor Constantine), the Catacombs of Marcellinus and Peter, the Roman villas in the Park of Centocelle, the Park of Villa dei Gordiani, and various Roman tombs. The archaeological and green area of the Ecomuseo Casilino includes two ancient Roman roads: via Casilina and via Prenestina and is traversed by the railway Roma-Giardinetti. Since 2012, the Association "Ecomuseum Casilino Ad Duas Lauros" promoted the use of the train as a cultural and tourist discovery tool. To enhance the public transport infrastructure and at the same time to enhance the area in which it travels, it was necessary to equip the train with a technological tool that can "augment" the features as a comprehensive virtual guide.

These reasons motivate the use of an ad hoc mobile system designed for such cultural train. To this purpose, we combined STREET WEB architecture with Digital Niches Model to implement a mobile cultural info-system. As shown in Figure 1, each train stop is represented by a sensor included in a Digital Niche and managed by a devoted Web-gis (Microserver Niche). Through a set of train stops and urban surroundings,

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which are geo tagged and linked to a mobile cultural info-system, it is possible to notify passengers and citizen in Ecomuseo Casilino while walking close to train stops. As referred in [9], a Digital Niche includes a set of sensors managed by a devoted Web-gis microserver.

To our knowledge, our proposed solution is a new wireless mobile system which differs from others due to the following reasons:

- It is the first mobile Web gis which is configurable and tailored to the scenario
- It will integrate map based on the wi-fi location system working on the train
- It is a complete Web based app connected to a local server providing up to date information

III. The Mobile Cultural Transport Digital System Overview

This section gives the detailed description of the platform used to distribute tourist information useful for exploring the "Ecomusem Casilino" by using the the railway Roma-Giardinetti [6], called Train-Ecomuseum in Figure 1. The platform used consists of some microserver and sensors, distributed on the area to support mobile users moving in smart scenarios with the aim to combine context aware information and high quality geo marketing services. Our App works on the same web infrastructure enhanced with sensor and it is composed by two front-ends. The first one for interfacing the train, and showing the various stops of the route by highlighting that to which we are closer. The other one serves to locate on the map georeferenced the touristic points of interest (t-PoIs). To this purpose, a platform is used, which is able to manage the set of train stops and the urban surroundings which are geo-tagged and linked to a mobile cultural info-system able to notify passengers and citizen in Rome while walking close to train stops. Generally speaking, Info Urban Mobility systems are well known systems, often implemented through Internet connected geo-referenced apps. Unfortunately, it also happens that these applications are not well designed and synchronized with peripheral areas where there is a great amount of cultural elements distributed at different levels and that are hard to explain without being close to them. Moreover, there are technical problems to keep the user connected while using the train due historical problems and consequently connecting technology must be adapted to be used through IoT (Internet of Things) paradigm in which it occurs to sense mobile users in proximity and trying to push as much as possible the information close to them without using an external Internet provider. These reasons motivate the use of STREET WEB as an ad hoc mobile system designed for such cultural train museum. We adopt a paradigm defined in accord to Digital Niches Models in which each train stop is represented as a set of points included in a Digital Niche and managed by a devoted Web-gis (Microserver Niche).

A. STREET WEB and Digital Niches

STREET (*S*ensor network "on *T*he *R*oad " for *E*nhanc*E*d Internet of *T*ouristic things) Web, as described in [1] is a conceptual framework, useful to support mobile users moving in smart scenarios with the aim to combine context aware information and high quality geo marketing services in the same Web infrastructure enhanced with sensors. STREET Web makes possible to implement smart services in an easy way by integrating microservers, distributed in the scenario (servers on the road), called smart boxes, working as a geo based Cloud system in an autonomous way, as a Distributed Local Storage system, without remote Internet access, working as a geo based Distributed Local Storage system. The physical architecture of the system is based on a network of microservers (called Smart Box -SB), each representing a complete working station linked with a node sensor station composed of a localization device BLE (Bluetooth Low Energy) Beacon, eventually enriched with QR (Quick Response) code or NFC (Ner Field Communication) tag to improve locality visibility and based on the Mobile First paradigm. Each microserver is devoted to three main tasks:

1) to allow mobile users to access stored data;
2) to listen to data sent by the connected sensor;
3) to store data in database MySQL or NoSQL(InfluxDB);

The proposed microserver is realized by Raspberry Pi 2 - Model B. Raspberry Pi is a fully-functional single-board computer with a Broadcom processor. It has programmable I/O pins where you can attach physical devices and sensors.

Main Features:

- RAM:1GB LPDDR2 SDRAM
- CPU: 900 MHz quad-core ARM Cortex-A7;
- Raspberry Pi 2 can run as Operating System the full range of ARM GNU/Linux distributions.

Through STREET Web platform, the users fit together all necessary activities concerning communications, mobility, environment, energetic efficiency, shopping (digital business) and social networking. The icon depicted in Figure 2 shows the logical architecture of STREET Web model, based on a generic mobile device, equipped with a Mobile-First application front-end working in accord to three types of interactions: event-alerting, local content interaction, dynamic map navigation. The logical architecture of Street Web assumes that a Wi-Fi zone is offering local service without connection to a global Internet provider.

If we consider that a Wi-Fi zone is defined as a logical zone useful to be considered equivalent to a niche of tourism or set of touristic Point of Interests (t-PoIs), we can merge different niches contiguous or close to each other in a cloud of niches (Figure 3).

B. Microservers and APP Definition

As mentioned before, thanks to the microservers platform, it is possible to acquire information about cultural points of interest that are the one for which the user interested to reach from the selected stop without the need to connect to remote servers. To furnish the access to this cultural content to all visitors walking in such place, we consider two app layers:

- APP on TRAIN (TRAIN APP)
- APP niche (STOP APP e other t-PoIs APPs)

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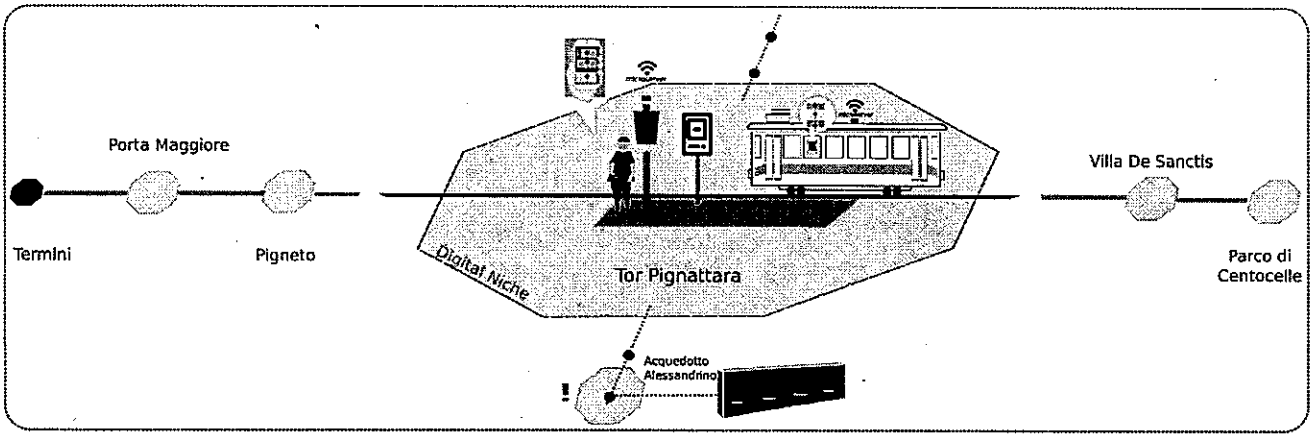

Fig. 1: TRAIN-ECOMUSEO Working Scenario

Fig. 2: The STREET WEB Model for Web 4.0

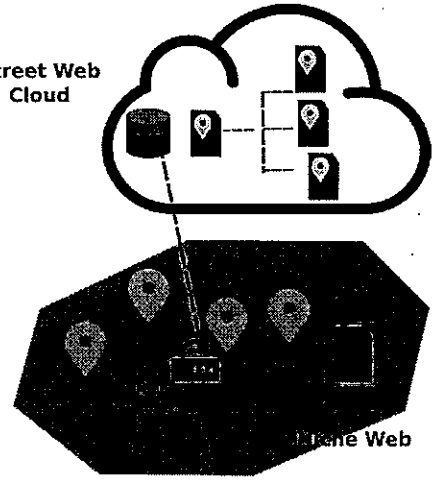

Fig. 3: The Application Architecture of Digital Niches.

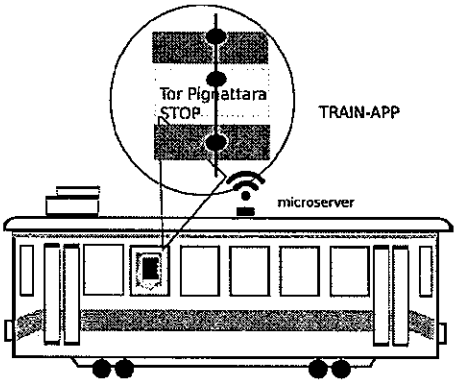

Fig. 4: Screen Train APP -Microserver

The former one (TRAIN Mobile APP) at each train stop shows the name of the train-stop place. Then, once a passenger gets off the train area, he can adopt the STOP APP front-end to see what's interesting in the neighbourhood. Figure 4 shows the front end of the STOP APP that is useful to display the digital niches on the map.

When being near a niche, the user can access digital content using 2 buttons: the button that indicates the global access makes use of the Web Internet. The button that refers to the t-PoIs is coupled to the local Cloud (represented by Street Web microserver). It is linked through the Wi-Fi address. If the user clicks the t-PoIs button, he goes to the microserver home where the local content can be found. The working scenario depicted in Figure 1 shows the pathway executed by a generic mobile visitor, equipped with a Mobile-First application front end. Through a localization/alerting system (based on BLE Beacon) the user, while walking, is notified of all application steps. These steps are organized in accord to three types of interaction: event-alerting, local content interaction, dynamic map navigation. Figure 3 describes the type of application used

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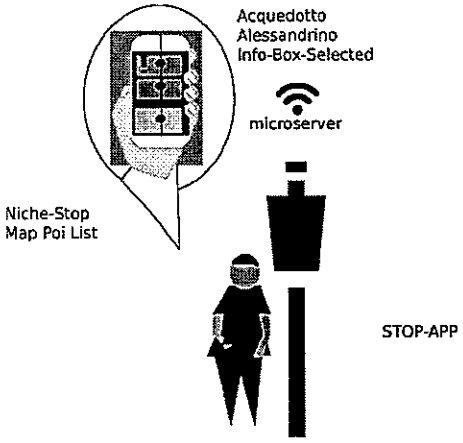

Fig. 5: Screen STOP APP –Microserver

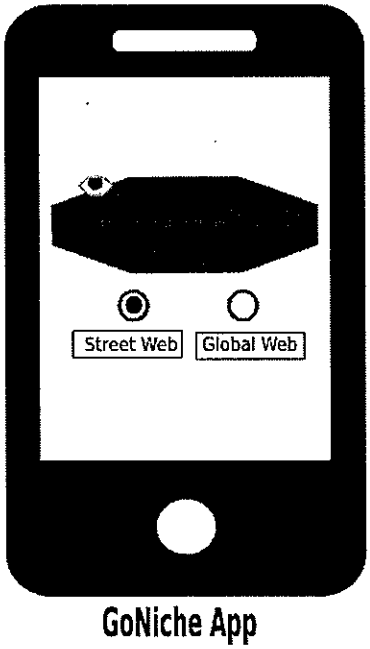

Fig. 6: Home Screen of the APP–Microserver

in the TRAIN while moving and before arriving to the next stop. In this case the user is notified of the next stop and could be alerted for any message related to that niche before to leave the train. After niche-stop notification from the microserver, the user automatically is guided to selected an area in which further details on the selected monuments will be provide by the corresponding microserver of the niche (5).

In every case, the user is alerted without any external beacon or another means but just through well known alerting system prompting a pop up window for selecting current wifi network address (see Figure 6).

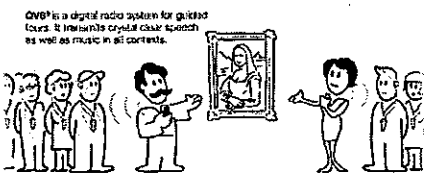

Fig. 7: Wireless Audio systems scenario

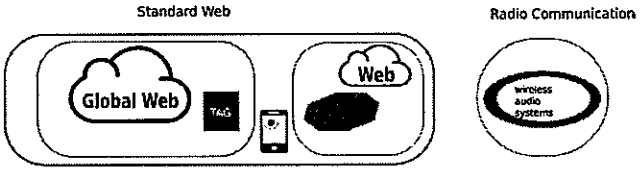

Fig. 8: TRAIN-ECOMUSEUM by STREET WEB comparison with global Web and local audio wireless systems

IV. Discussion and Conclusion

The Microserver based TRAIN – Mobile System (Figure 1) allows an effective way to mobile users for obtaining information related to touristic Points of Interest on land. To our knowledge this might be considered a first Web 4.0 solution in the sense that the host provider is no long external to the current niche but it is implemented inside the niche through a complete local Wi-Fi. The only comparable solutions come from a different technological point of view, that is wireless audio system. For instance, Quietvox [8] is a wireless audio communication system. As shown in Figure 7, the system is related to wireless audio communication designed primarily for museum with a large nuber of people. In the case of TRAIN ECOMUSEUM, however, the problem is due to the fact that such systems are not adequate. On the contrary, Digital Niches and Street Web Model gives the access through a generic smartphone (hence alwais connected system principle) following a mobile first interface paradigm.

Our solution hence goes a step further with respect to voice systems thus providing a true and effective mobile system without any non standard device and by following Web application paradigms (see Figure 8).

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Smart Interfaces at ESTIA, zer da hori?

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Abstract—**Smart Interfaces at ESTIA, what is that (zer da hori in the local basque language) ? Smart Interfaces for Engineering is one of the topics of the iaria conference at Venice. This notion emerged as a unifying research theme at the engineering school ESTIA at the end of the year 2014, after several years of common work between researchers in Sciences and Technology and researchers in Management Sciences. There is a good flow of papers on various aspects of smart interfaces, but it is not easy to find in the literature a global approach to this notion. The purpose of this paper is to contribute tio fill this gap. In section 2 we give some historical background, going back to the Macy Conferences and the Palo Alto group, to Levins equation and Action Research, and to Edgar Morins approach to complexity. In section 3 we analyze several recent thesis at ESTIA and show how the notion of smart interfaces for engineering appears on topics as different as, for example, flight critical systems, isolated rural microgrids and the Lean approaches in corporate management. We hope that this survey will contribute to the stucturation of Smart Interfaces for Engineering as a branch of modern research.**

Index Terms—**smart interfaces for engineering, complex systems, microgrids**

I. Introduction

ESTIA-Recherche started as a research team in 2008, when GRAPHOS (Groupe de Recherches Appliquées Pluridisciplinaire sur l'Hôpital et les Organisations de Santé) and LIPSI (Laboratoire en Ingénierie des Processus et des Services Industriels) decided to merge in order to work together to develop research activities in both Management Sciences and Sciences and Technology, and at the crossroads of these domains.

Research at ESTIA is aimed at:

Giving ESTIA engineering students an opportunity to work with established researchers who belong to both national and international scientific networks.

Developing a synergy between research works and evolution of academic programs.

Proposing innovative answers to technological, economic and societal questions.

Raising awareness among students and companies about the practice of research.

Contributing to the influence of ESTIA and to the attractivity of the territory.

The research project concerns engineering and technology; hence complex systems, open and self-organizing, in which there are also (and mainly) human beings, users, managers, etc. The dynamics of ESTIA-Recherche follows from the action of constraints, goals and objectives which may appear as contradictory: there is a need to obtain applications while producing theoretical contributions, and to contribute to transfert of technology while insuring academic valorization of research results through publications in internationnally recognized journals; also the researchers at ESTIA need to develop scientific links with Bordeaux University, but they are employed by ESTIA, a private entity linked to the Chamber of Commerce and Industry of Bayonne-Pays Basque and their research is partially supported from answers to calls for projects. They have to combinate in investigations about corporate management individual initiative and top-down approach, and to provide a continuous flow of electricity from intermittent sources, etc.

Generally speaking, scientific activity at ESTIA consists in studying interactions inside systems which are often complex.

Hence, researchers at ESTIA try to address simultaneously the need for academic recognition and the need for concrete benefits for firms. This double need lies at the heart of the research strategy of ESTIA. This explains why part of the research, especially the part which involves Creativity, Innovation and Management Sciences is performed through Action-Research, as explained below.

ESTIA-Recherche relies on an interdisciplinary team of researchers working on scientific, technological and societal topics in order to adress transversal projects. Innovation requires common work between specialists in sciences and technologies, but also between specialists in sciences and technologies and researchers in human sciences. Hybridation of ideas, concepts, methods and scientific domains is there a powerful fertilizer.

The prospective discussions within ESTIA-Recherche to prepare the external evaluation performed in January 2015 by ANR (Agence Nationale de la Recherche) led to the elaboration of the concept of Smart Interfaces for Engineering. Before illustrating this concept through examples we will go through a little amount of historical background.

II. Some historical background

A. Interaction: Macy Conferences and the Palo Alto group

The objective of Macy Conferences, organised from 1942 to 1953 (at Hotel Beekman, 575, Park Avenue, New-York, except

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for the last one, organized at auberge Nassau, Princeton, New-Jersey), was nothing less than building a general science of the way thinking works. These conferences were organized by a pluridisciplinary group of mathematicians, logicians, anthropologists, psychologists and economists. A description of these ten conferences can be found on Wikipedia [30]. There were two main participating groups, the first wished to establish an interaction between mathematics, physics and well-established psychological sciences, and the second, a group of "cybemeticians", including the famous mathematician Norbert Wiener, that wanted to fight well-established psychological sciences on behalf of mathematical and physical sciences. The group also included John Von Neumann, another prominent mathematician who played an important role at the beginning of computer science. This cycle of conferences played a seminal role in the emergence of Information Theory, Cybernetics and Cognitive Science, and led one of the participants, the anthropologist Gregory Bateson, to form a group, known as the Palo Alto group. The object of this group was to study the "paradox of abstraction in communication". We refer to [35] for more information about this group, whose work led to a deep change in the diagnostic of mental illness. Analyzing a "personnality" is impossible without taking into account the complex network of interpersonal relationships. Schizophrenia can be understood as a way for the patient to adapt to the pathological structure of his relations with his family [9]. They also thought that the best moment for a therapist to intervene was during a crisis, when the patient would be ready to do something to find a new equilibrium, unlike the traditional method of waiting for the patient to "cool down". Of course ESTIA Recherche does not intend to perform mental therapy, but the idea of taking into consideration the interactions of a person or a system with external environment plays an important role in the scientific approach developed at ESTIA.

B. $B = f(P, E)$, Lewin's equation and Action-Research

Action-Research did not arise all of a sudden from nowhere. In the XIX-th century, Karl Marx encouraged workers in industry to think about their living conditions by answering questionnaires (used as militant tools). This tradition of "inquiries" about peasant and/or worker situations and movements was followed more recently by Robert Linhart in his study of the struggle of workers in northeastern sugar areas of Brasil [24]. Of course ESTIA, which was created by the Chamber of Commerce and Industry of Bayonne-Pays Basque, does not have any revolutionnary goal in its research objectives, but Lewin's equation $B = f(P, E)$[23], which states that the behavior B is a function f of the person P and her or his environment E, describes heuristically various aspects of Estia-Recherche investigations. Kurt Lewin was a professor at Berlin University, specialized in Gelstat psychology. At the beginning, he was mostly interested in child psychology, and after moving to the United States he played a crucial role in the development of Action-Research, a research method where the researcher intervenes during the research and in the research, in order to bring positive changes and also to produce knowledge and theory. (He became very influential, and the U.S. government asked him during World War 2 to help dealing with food scarcity by helping customers to learn how to use and cook cheap cuts of cattle, like heart, tongue, tripe and kidneys). These ideas had been introduced by the "Chicago group," which asked sociologists to rely on leaders of communities under consideration (population of poor neighborhoods, ethnic minorities, professional groups) in order to elaborate knowledge which comes from the bottom and goes back to the bottom. Thus, the academic researcher and community leaders become "co-researchers" who produce new knowledge and act together in various domains. We refer to [8] and [19] for modern developments of Action-Research. This approach, which sometimes relies on a thorough investigation of a single case, inspired a lot of the research performed at ESTIA on innovation and on change in corporate management and organization.

C. Complex systems and the principle of dialogy

The dialogy principle is a concept introduced by Edgar Morin to understand complex systems. "The dialogy principle means that two or several different "logics" are linked in a single entity, in a complex way (complementary, concurrently and antagonistically) without the duality getting lost in unity. Hence the unity of european culture is not a judeo-christian-greek-roman synthesis, it is the game not only complementary, but also concurrent and antagonistic, between these cultures which have their own logic: this is their dialogy" [28], p. 28. " "The number and depth of interactions increase when one goes to the level of interactions, not only between particles, but between organized systems, atoms, stars, molecules, and over all living being, societies ..., and the diversity and complexity of effects and transformations produced by these interactions increases as well. Once the organisations that are the atoms and the stars are in place, the rules of the game of interactions may appear as Laws of Nature. Hence interaction is a hub between disorder, order and organization. This means in turn that order, disorder and organization are now tied, via interactions, in a single interdependent loop, where none of them can be conceived without refereeing to the others, and there they have complex (dialogic) relations, that is to say complementary, concurrent and antagonistic [27].

We refer, for example, to [3] for a survey of Edgar Morin's contributions to complexity theory. It is not necessary to perform research at ESTIA to have read the six volumes of La Méthode, or to understand deeply the filiation between the principle of dialogy and the idea of dialectics (Heraclite, de Cruse, Hegel, Marx), but the fact that ESTIA Recherche arose from the union of research groups from Engineering Sciences and Management Sciences which have been working together since 2008 allows all these researchers to have a systemic approach in their various research directions, and one could say that the concept of Smart Interfaces for Industry comes from a sucessful dialogy between these two groups.

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The module "Transformées" for second year students, which is taught at ESTIA by the author of the present paper, culminates with the celebrated Shannon sampling theorem, which reconstructs all the values of a square integrable function having a compactly supported Fourier transform from the values it takes on the integers, [22] (théorème 9.5.1 p. 131). Claude Shannon was working as an engineer for Bell Telephone company, and attended the 7th, 8th and 10th Macy Conference, where he presented his Information Theory in which signification was deliberately not taken into account. Reading Edgar Morin during the preparation of this paper, I realized that the approach to noise which was presented during some conferences on signal that I attended rather recently were based on Shannon's approach - where noise is a form of disorder which should be eliminated from the signal, while other appoaches could rely on finding some order in the disorder related to the dialogy order/disorder. Of course experts in signal theory are aware of this.

III. Working on Smart Interfaces for Engineering

We now briefly describe the eight theses completed at ESTIA during the years 2015 and 2016. At first glance the topics look different:

Augmented Reality applied to conception, gestion and maintenance of urban structures and furnitures; use of model reduction algorithms to optimize placement of robotized fibers, reduced model of scavenging to optimize cylinder for a 2-stroke diesel engine; design of an architecture for measurement and diagnosis of physical parameters in critical airborne systems, algorithms and architectures for control and diagnosis of flight critical systems; study of a hybrid fuel cell/turbine system in the context of an isolated rural microgrid; visualization for an informed decision to design space exploration by shopping, accompanying maturation of concepts in eco-innovation, taking in account human factors to overcome the limitations of the Lean approaches.

But, in all situations the researchers dealt with complex systems, for which a smart approach is proposed:

Combining a monocular georeferenced tactile device with a topography laser in order to diminish the edition and interpretation errors of cartography of urban structures;

Using model reduction algorithms to reduce the number of parameters in optimization of placement of robotized fibers, and introducing a cognitive dimension in reduced and separated meta-models of the scavenging by ports in 2-stroke Diesel engines;

Relaxing tolerance to the defects of the processing chain of signal obtained from the captor by improving the mathematical model of the processing chain and introducing dynamical models in measurement, diagnosis and control of flight critical systems;

Combining a fuel cell of type SOFC and a microturbine to reach the best electrical performance with a low environment impact for isolated rural microgrids;

Finding efficient graphs for information visualization in design space exploration according to the paradigm design by shopping, supporting the maturation of eco-innovative concepts to overcome the so-called collective fixations during the development of eco-innovations, defining a performance model supporting an actor vision of man at work to overcome the limitations of the Lean approaches.

From these eight theses, which we now describe briefly, we see why the notion of Smart Interfaces for Engineering emerged at ESTIA.

Environment of Augmented Reality for conception, gestion and maintenance of urban structures and furnitures is the topic of the University of Bordeaux thesis of Emeric Baldisser in computer science, prepared at ESTIA (2013-2016) under a CIFRE contract [18] with SIG-IMAGE, a company located at Technopole Izarbel at Bidart [7]. This work points out the relevance of Augmented Reality in order to diminish the edition and interpretation errors in cartography of structures. A prototype is proposed, evaluated and discussed. It combines a monocular georeferenced tactile device with a topography laser. It allows to draw and consult technical plans on a 2D representation of the site in real-time. The validity of this approach with respect to french reglementation remains limited. Another approach is proposed, which consists in fitting/matching the clouds of dense points obtained from topography scanners with the orthoscopic 2D representation of the site. The interactions in the augmented environment of the site then depend on its cloud of points. They are geolocalized and follow the paradgim of Picking-Outlining-Annotating. These interactions are described in [6].

Development of model reduction algorithms to optimize the PFR process is the topic of the UTC (Université Technologique de Compiègne) thesis of Nicolas Bur, prepared at ESTIA (2012-2015) [15]. The realization by robotized processes of composites parts intends to improve productivity. Nevertheless the "Placement de Fibres Robotisées" (PFR) is still at a stage of maturation and requires numerous developments, in particular in the case of composites with thermoplastic matrix or with dry fibers. The thesis proposes different tools in order to determine in advance the best heating power to implement these composites. The difficulty arises from the fact that this power depends on many parameters, arising not only from the components (density, etc.) but also from the process itself (moving speed, number and orientation of the folds). The technique called Proper Generalized Decomposition (PGD) has been used to construct a reduced multi-parametric model and thus overcome the complexity of the system. The results were compared to those obtained by more conventional methods and also to experimental data, [14].

Reduced and separated meta-models of the scavenging by ports in 2-stroke Diesel engines to use evolutionary algorithms in search space is the topic of the thesis prepared at ESTIA by Stéphanie Cagin [16], [17]. The use of numerical methods to design a product became more and more common over the past 30 years. However, numerical models are still

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specialized and they do not run fast which makes their use problematic. So, some reduced models of scavenging have been developed. These models are analytical and generic; they run quickly and avoid the numerical treatment problems. They are also efficient tools in the search of design solutions. The work carried out has led to a new methodology based on a behavioral meta-model called neuro-separated including a neuronal model of state, a pseudo-dynamic neuronal model and a model with separated variables. Then, exploiting the models previously developed, a process of decision with evolutionary algorithms (genetic algorithms) is used to determine optimal designs and the fast behavioral simulation of the optimal designs solutions is done, thanks to the kriging approach. This design approach is multi-viewpoints, multi-criteria and multi-physics. It also includes a cognitive dimension: both free and controlled evolutionary explorations of solution spaces have been done. To validate the method, some qualification criteria have been evaluated for each model. They allow to understand and to assume the gap between the reduced models and the initial CFD base (where the model are coming from). This approach has led to the development of a tool of model and decision aids using Python and Matlab software programs

Study of an hybrid system fuel cell/turbine in the context of an isolated rural microgrid is the topic of the Bordeaux University thesis of Sylvain Baudouin (2012-2015) [11]. Rural areas, often located far away from the main electrical network, are particularly suitable for deploying microgrids (MG), which allow to use efficiently a large number of renewable energy sources. Biogaz, obtained from methanation of agricultural waste, is a renewable energy source available in rural areas which is esay to store in large quantities, and more reliable and less dependent from random phenomena than solar or wind turbine energy.

A study of the state of the art leads to the conclusion that an hybrid system combining a fuel cell of type SOFC and a microturbine (MT) allows to reach the best electrical performance with a low environmenral impact. A unique multilevel converter of type SLNPC has been used to integrate the microgrid to the main electrical network. The first objective of the command strategy applied to the SLNPC converter was to regulate the power of the SOFC fuel cell to its nominal value, and the second objective was to fix the tension and the frequency of the microgrid when it is disconnected from the main electrical network. This system has been tested and validated through simulation and then experimentally on the EnerGea platform [21] of ESTIA.

Design of an architecture for measurement and diagnosis of physical parameters in critical airborne systems is the topic of the University of Bordeaux thesis of Romain Martin (2012-2015) [26]. The objective of this work was to propose a new architecture for measurement of physical parameters as temperature, pression and speed in airborne systems in critical situations. The goal for this architecture is to improve the integrity of the measured data while keeping their level of disponibility and fiability in highly critical airborne systems. The solution consits in relaxing tolerance to the defects of the processing chain of signal obtained from the captor. In order to do this more functions are introduced, including the mathematical model of the processing chain, to make the system smarter. The thesis was supported by a CIFRE contract [18] with the Thales company [34].

Algorithms and architectures for control and diagnosis of flight critical system is the topic of the Bordeaux thesis prepared at the same time by Alexandre Bobrinskoy [12],[13]. Flight-Critical Systems such as Electromechanical Actuators driven by Engine Control Units (ECU) or Flight Control Units (FCU) are designed and developed regarding drastic safety requirements. In this study, an actuator control and monitoring ECU architecture based on analytic redundancy is proposed. In case of fault occurrences, material redundancies in avionic equipment allow certain critical systems to reconfigure or to switch into a safe mode. However, material redundancies increase aircraft equipment size, weight and power (SWaP). Monitoring based on dynamical models is an interesting way to further enhance safetyand availability without increasing the number of redundant items. Model-base default detection and isolation such as observers and parity space are recalled in this study. The properties of differential flatness for nonlinear systems and endogenous feedback linearisation are used with nonlinear diagnosis models. Linear and nonlinear observers are then compared with an application on hybrid stepper motor (HSM). A testing bench was specially designed to observe in real-time the behaviour of the diagnosis models when faults occur on the stator windings of a HSM. The thesis was also supported by a CIFRE contract with the Thales company.

Information Vizualization for an informed decision to design space exploration by shopping is the topic of the Centrale-Supelec thesis prepared by Audrey Abi Akle at ESTIA (2012-2015) [2]. In Design space exploration, the resulting data, from simulation of large amount of new design alternatives, can lead to information overload when one good design solution must be chosen. The design space exploration relates to a multi-criteria optimization method in design but in manual mode, for which appropriate tools to support multi-dimensional data visualization are employed. For the designer, a three-phase process - discovery, optimization, selection - is followed according to a paradigm called Design by Shopping. Exploring the design space helps to gain insight into both feasible and infeasible solutions subspaces, and into solutions presenting good trade-offs. Designers learn during these graphical data manipulations and the selection of an optimal solution is based on a so-called informed decision. The objective of this research is the performance of graphs for design space exploration according to the three phases of the Design by Shopping process.

The results reveal three efficient graphs for the design space exploration: the Scatter Plot Matrix for the discovery phase and for informed decision-making, the Simple Scatter Plot for the optimization phase and the Parallel Coordinate Plot for the selection phase in a multi-attribute as well as multi-objective

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situation. In consequence, five graphs, identified as potentially efficient, are tested through two experiments. In the first, thirty participants tested three graphs, in three design scenarios where one car must be chosen out of a total of forty, for the selection phase in a multi-attribute situation where preferences are enounced. A response quality index is proposed to compute the choice quality for each of the three given scenarios, the optimal solutions being compared to the ones resulting from the graphical manipulations. In the second experiment, forty-two novice designers solved two design problems with three graphs. In this case, the performance of graphs is tested for informed decision-making and for the three phases of the process in a multi-objective situation. Part of this work was presented in [1].

How to support the maturation of eco-innovative concepts?: proposition of the method MIRAS to overcome collective lock-ins and explore stakeholder networks is the topic of the thesis prepared at ESTIA by Marion Real [31], [32], using a Research-Action approach inside the support group APESA. During the development of eco-innovations, companies are looking to implement a new activity that can create ruptures with its existing practices and cause many changes in their business model. In such complex situations, the stakeholders of emerging projects have some difficulties to consciously deviate from existing cognitive frameworks to explore alternatives in line with the initial goals of the project. Thus, they take trajectories that may lead to a dilution of the environmental and social values or cause the abandonment of projects. The work presented in the thesis focuses on the maturation of eco-innovative concepts and seeks to develop tools and methods to avoid and overcome such situations called collective fixations. The methodological approach is structured in two steps:- The analysis of three case-studies of eco-innovative projects allowed to characterize supporting practices and deepen the knowledge on the collective fixation present during the maturation of concepts. This first study has fueled the design process of the MIRAS method, the main contribution of this research. The MIRAS method offers a toolkit designed for eco-innovation intermediaries in order to help them to structure their intervention during the stage of concept maturation. Specifically the tools help to improve the sustainability potential of concepts, to analyze project group behaviors during sessions and to revisit stakeholder networks so as to anticipate future mutations and news ways of incubation.

Taking into account the human factor to overcome the limitations of the Lean approaches: proposal for a performance model and an accompanying methodology is the topic of the thesis prepared by Patrick Badets at ESTIA [4], [5]. Lean is an approach aiming at eliminating non-value added operations, used by companies to improve the performance of their production activities. Companies applying this approach are observing rapid gains in operational terms but gradually some observe a fall in operating results or a degradation of the health of work force. The objective of the thesis was to overcome these limits and improve the ability of those of the company to anticipate and to take corrective actions. The performance model and the decision adopted by corporate actors to deploy Lean was questioned. It is proposed that corporate actors evaluate the efficiency of production, processed by the Lean approaches, taking into account not only the operational level of performance, but also the human dimension integrating realwork activity. A performance model that supports a kind of actor vision of man at work is defined. To help corporate actors to change their existing model of Lean performance, a support methodology based on a reengineering approach integrating coaching aimed at changing there presentations of the actors by a sociocognitive learning is offered. This methodology is based on modeling tools to represent the impact of this new performance model on the decision and on the sustainability of the lean benefits.

IV. Conclusion

We hope that this survey will help the researchers in the field of Smart Interfaces to Industry to have a more global vision of scientific activities in this direction and understand how science and technology and management sciences can help each other. We also hope that this paper will help other scientists to discover this emerging subject, and, more generally, to get interested in a systemic approach to complex systems.

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Precision Livestock Farming: A Multidisciplinary Paradigm

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Abstract—**Since several years, Precision Livestock Farming (PLF) has experienced a significant progress mainly due to the electronics and embedded systems miniaturization, along with the Internet of Things expansion. Geolocation and animal behavior identification are common research subjects in PLF, and several solutions have been proposed in this frame. Nevertheless, the development and generalization of this kind of tools must still face up several technical and societal challenges and, in order to overcome these difficulties, a multidisciplinary work is necessary. In this context, this paper presents the e-Pasto experimental platform, which employs different smart interfaces, as a case-study to analyze the main issues related to the implementation of PLF solutions. Along with this analysis, some relevant aspects of current systems are studied and discussed from different points of view, from technological to human ones, with the aim of offering a new vision, which tries to take into account, as far as possible, the final user needs.**

Keywords-Smart Interfaces for Engineering; Data Processing; Decision-making; Systemic Approach; Precision Livestock Farming.

I. INTRODUCTION

The evolution of electronic devices, the improvement of wireless communication networks and the Internet access availability during the last years are the main reasons of the Internet of Things (IoT) expansion. Nowadays, IoT based solutions are considered a promising way to collect data that can be processed and analyzed by final users in order, for example, to supervise a manufacturing process or to monitor the health of home-based patient.

In this frame, solutions based on aggregation of technologies, such as interconnected ubiquitous objects, represent an interesting option to offer new tools that may improve livestock productivity and product quality, reducing at the same time the work hardness. Moreover, other information about animals and the whole cattle, such as physiological conditions combined with environmental data, is necessary to correctly monitor the livestock: survey of animal activity and location in large pastures and small areas, diseases prediction or detection, improvement of livestock nutrition effectiveness, productivity and quality optimization, ensuring at the same time the animal well-being. However, nowadays, the development of this kind of tools stays in a research phase because of a number of challenges that must be still faced up, from both technical and societal points of view without forgetting final user needs. In this context, the aim of this paper is to identify and analyze, using the e-Pasto platform as case-study, the different difficulties to be overcome. The need for a multidisciplinary approach to provide useful smart interfaces that allows the interaction among livestock, farmers and also the environment, based on suitable technical solutions, is also proved.

This document is structured as follows. In Section II, after a brief review of the existing research work concerning Precision Livestock Farming (PLF), the e-Pasto platform is presented together with the obtained results. Section III illustrates, considering the e-Pasto case-study, that a multidisciplinary approach, covering from technical knowledge to human sciences, is needed to face up the different found problematics. Finally, Section V concludes this paper.

II. CASE-STUDY: THE E-PASTO PLATFORM

A. State of the Art of Precision Livestock Farming

PLF consists essentially in acquisition, collection and analysis of data from each animal and its environment employing, as illustrated by Figure 1, different Information and Communications Technologies (ICTs) such as sensors, communication networks, decision-making algorithms and human-to-machine interfaces (HMIs) [1]. PLF allows farmers to access new services such as individual feeding, health monitoring, animal localization and, consequently, to conduct in a more effective way their livestock ensuring at the same time productivity, animal well-being and economic benefits.

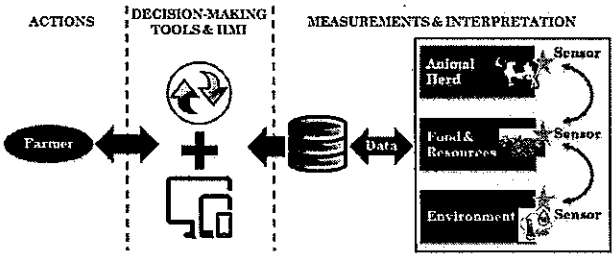

Figure 1. General architecture of a PLF solution [1].

There is a number of research works and solutions concerning PLF that can be found in the scientific literature [2]. A frequently employed solution is Radio Frequency Identification Technology (RFID), which is used to identify animals. From a regulatory point of view, RFID animal identification guarantees the traceability through the feed-animal-food chain. However, some current works and

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commercial solutions use also this technology in order to manage and automatize animal feeding regime or to allow the heat detection [1].

Moreover, ICT for domotics applications can be also applied to monitor the animal and to control cattle environment [3]. In barns, this kind of technology is useful to guarantee the animal well-being and health by regulating temperature, humidity and concentration of ammonia, among others. In the case of extensive farming exploitations, meteorological sensors help to predict the displacement of the cattle and, consequently, to improve their management.

In addition, accelerometer and other sensors (temperature, geolocation) are commonly used for animal's health and behavior monitoring. In the scientific literature, accelerometers and dataloggers have been largely applied to identify the animal behavior and principal activities [4]: grazing, resting, walking. This information, provided by accelerometers and coupled with a decision-making software, allows farmers to determine the welfare and health of their animals, optimizing the veterinary intervention.

Virtual fencing technologies are also a classical example of PLF solutions [5]. In extensive farming, virtual fencing combining Global Positioning System (GPS) and Geographic Information System (GIS) contributes to understand the cattle's displacements and also to enhance herd and grazing resources management. This capacity of remote monitoring allows farmers to optimize the time needed to accomplish their daily tasks, resulting in a better productivity, with a positive impact on the environment too.

B. e-Pasto Platform: Description and Main Results

In order to better illustrate what a PLF solution is, the e-Pasto platform [6] will be thereafter presented as a case-study. This solution, developed in the context of a European research project and dedicated to cattle supervision in extensive farming environments, is composed of four main parts: the motion devices, a communication infrastructure, an information system and a human-machine interface, as it can be seen in Figure 2.

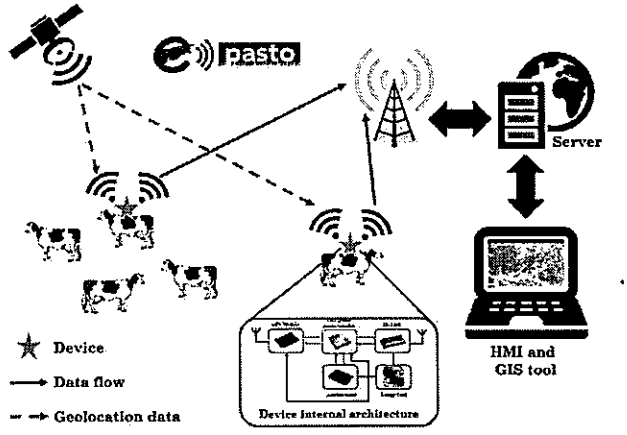

Figure 2. Global architecture of the e-Pasto platform.

The motion devices, which are directly embedded onto the animal collar, include a GPS and an accelerometer, and collect position and behavior data from animals. These data are transmitted to a remote server through the wireless communication network provided by SIGFOX©. The aggregated data can be remotely exploited by the farmer in two different ways:

- To locate animals in mountain pastures during the summer period, allowing at the same time a better management of the cattle and the grazing resources using a virtual fencing solution.
- To measure and supervise animal behavior with the aim to warn the farmer in case of eventual disease or predation activity against their cattle.

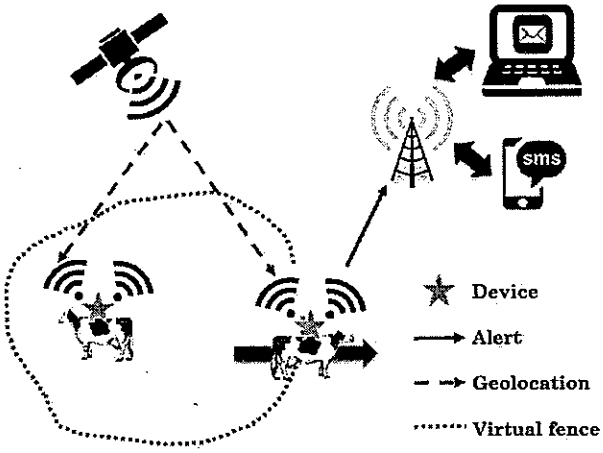

Figure 3. e-Pasto virtual fencing principle.

Real field tests were conducted in two experimental zones, one located in Ariège (France) and the other one located in Gipuzkoa (Spain), to validate the architecture of the platform and their global performances. During these field tests, the correct performance of the motion devices in terms of size, weight and autonomy was validated. More precisely, the motion devices employed in the e-Pasto platform offered a size and weight adapted to different animal species such as bovines, ovine and horses, along with an autonomy in energy generally equal or higher to 7 months, which was assured taking one location position per hour. These position data were sent afterwards through the long-range low-power consumption network developed by SIGFOX©.

As it has been said before, motion devices include an accelerometer. It has been proved that the data issued from the accelerometer can be processed in order to detect several behavior patterns (resting, walking and running), functionality which ameliorates the animal geolocation precision [7]. By the moment, this behavior identification has been only tested on humans.

To conclude, it is important to highlight that one of the most remarkable results of the e-Pasto platform was the validation of an innovative virtual fencing solution, whose principle of operation is depicted in Figure 3. This solution

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allows the farmer to draw and define the size and shape of their virtual fences, using the point-in-polygon geometric computation principle, by means of the HMI developed for the platform. If an animal equipped with the motion device goes out of the limits of its authorized virtual fence, an alert message is generated at the server level and transmitted to the farmer by SMS or e-mail. Consequently, contrary to other solutions proposed in the scientific literature [5], the e-Pasto virtual fencing solution is not based on a remotely application of negative cues (vibration, electrical stimulation) to induce a movement when the animal is detected out of the limits of a virtual fence. Instead, once the farmer is warned, he has the liberty to take a decision about how to solve the problem with the concerned animal.

III. DISCUSSION OF MAIN ISSUES

As it has been seen in previous sections, the application of PLF solutions based on ICTs seems to be an attractive way to motivate people to work in agriculture and livestock domains, by offering tools that improve productivity and product quality, reducing at the same time the work hardness and ensuring the animal well-being. In addition, the current changing context about intensive farming methods, implying a constant evolution of legislation, ethical issues and economic challenges, together with global warming, makes PLF solutions an interesting support to assist farmers in their decision-making process.

This section, always with the e-Pasto platform case-study, the state of the art and the current context in perspective, will highlight the main challenges and issues that PLF solution providers have to face up to generalize these solutions, applying a multidisciplinary approach.

A. Technical Challenges

From a technical point of view, several issues at different levels of a PLF solution can be identified.

1) Data collection and transmission

As illustrated by Figure 1, PLF solutions are based on the automation of data aggregation and transmission, not only at the animal level but also at the environment level [1] [3]. This way, technologies involving embedded electronics and sensors are very often used to capture the information needed for PLF applications.

First of all, accuracy and reliability of the collected data are major issues that directly impact the design of embedded electronics devices. In the frame of the e-Pasto platform, where animals have to be located in an outdoor wide area of 2000 hectares, it can be acceptable for end users a precision around 10 meter using GPS technology. On the other hand, when animals are located in an indoor environment such as barns, the employ of GPS is not reliable and, in addition, the technology to be used for animal geolocation should assure a more accurate position measurement, in the order of centimeters. Consequently, as shown by these simple examples, the election of the location measurement technology depends on several parameters like the environment, the sort of animal or even the application.

Data transmission in outdoor or indoor real environments is also a complex task due to eventual multipath propagation, shadowing, or signal attenuation [2]. Therefore, the choice among current communication technologies, such as Wifi, cellular telephony or ZigBee, in example, must take into account many aspects like data range, quantity of data to be transmitted, indoor or outdoor environment, always with the goal of minimizing any loss of data, which could perturb the overall reliability of the PLF solution.

Finally, it must be pointed up that the main challenge concerning data collection and transmission is to achieve an optimal trade-off among different aspects: accuracy, reliability of data collection and transmission, together with acceptable size and weight of embedded devices carried by animals in harsh environments, offering at the same time enough energetic autonomy to assure the correct operation during long periods of time [6].

2) Processing and exploitation of the data

The processing and the exploitation of the collected data within the framework of the e-Pasto platform are intended to help breeders in their decision-making process in order to improve their management of livestock placed in mountain pastures.

In addition to data issued from sensors placed on animals (geolocation, accelerometer, physiology, etc.) and mapping of the pastures area, the decision support mechanisms can use numerous additional data such as:

- Topographic data to qualify areas suitable for feeding livestock but also risky areas (cliffs, rocks, etc.).
- Data derived from the expert knowledge (breeders, scientists, mountain guides, etc.) to identify hazardous or accident-proning areas, protected areas for environmental reasons, as well as information about predators (attack locations, predator identification...). It is also possible to integrate collaborative aspects into the e-Pasto platform to allow an exchange of information between breeders and thus have expert knowledge updated more regularly and about wider areas.

Consequently, the data capitalized by this kind of PLF platform are diverse and can represent a large volume of information. The heterogeneity and the amount of data collected highlight several challenges that will need to be addressed to develop a powerful decision support tool.

Firstly, the diversity of capitalized data and their potentially random reliability [3] (failure of sensors, human errors, etc.) implies to choose a formalism adapted to the modeling of uncertain and heterogeneous knowledge. There are many tools relevant to this problem. For example, Case-Based Reasoning (CBR) [8], Constraint Satisfaction Problems (CSP) [9] or Bayesian networks [10] allow to cover part of the needs. Many methodologies linking several of these approaches to address the problem in its entirety are available in the literature [11].

Secondly, capitalized data can be used in several ways. The first possibility is to visualize the raw information on the map, such as the location of the last predator attacks, the protected areas or the current position of the livestock. These data alone help the user to decide. For example, when

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positioning a virtual fence, it may be useful to know if there has been a predator attack in the area. Another use may be to pre-process the data to obtain additional information [3]. For example, it would be possible, with time-based geolocation data, to identify overexploited areas to allow the farmer to act accordingly. A last way of using this data could be a virtual assistant, which, depending on the choices made by the breeder when using the platform, would offer additional information enabling him to refine his decision. For example, if the user defines a virtual fence too close to a risk area, the software would suggest an alternative positioning.

Finally, a major issue in decision-making is the level of autonomy of the tool. It is possible to propose a solution which, based on the capitalized data, calculates and decides alone the procedure to be followed (for example, define automatically virtual fences). An alternative to this kind of tool lies in the suggestion by the tool of possible choices for the user (based on the capitalized data) but leaving him the final decision. This major design choice is a very important criterion for the acceptance and therefore the use of the tool by the breeders [12].

B. *Challenges for Users*

If a closer look at the challenges induced by technological innovations in the agricultural sector is token, the e-Pasto platform finds its place. Indeed, looking at the evolution of the agricultural sector since the 1950s, there is little in common with practices applied today. The agricultural sector is constantly evolving (decrease of agricultural occupation for 50 years, evolution of agricultural policy, etc.). Being a breeder 50 years ago is no longer the same thing today. The evolution of farmers' practices is accompanied by a change in their needs. This aspect refers to a broader issue: what are the users' needs? Identifying the needs of users is inherent to technological developments. One of the reasons for this importance is that if the system does not satisfy a need, it will not be used by the user [2].

In addition, behind all these elements, for the farmer the question is: what is the impact of the technology on his daily tasks? In order to define the daily tasks, researchers and designers must precisely list different work situations of farmer and see with the farmer which of them are easy or difficult to do. Researchers must also understand what the work of the farmer is. A farmer cannot be forced to use a system that involves more constraints in his work than facilities. It is the system that must be adapted to the user, not the opposite.

Furthermore, many other important aspects should be considered: to be farmer in a country A is not the same thing that be farmer in a country B, and the needs of young farmers are different from those of very experienced ones. In addition, the farmer is not the only one user: animals must be also taken into account. For example, behaviors of cows in a cattle are different from one animal to another. All these aspects lead to define plenty of different work situations [13] [14]. Once these work situations defined, researchers and farmers will be able to dialogue and find solutions adapted both to the farmer and the animal. The found solutions must be always a trade-off between possibilities, constraints of daily work and technology.

Finally, it should not be forgotten that the agricultural sector is in continuous evolution. Thus, it is necessary to think about changes and the technological system could take into account these changes, creating a virtuous circle. To make a change, it is crucial to identify users in the earliest phases of the project and also integrate them into the development process.

IV. Conclusions and Perspectives

The work presented in this paper has presented some basic characteristics of PLF systems, showing at the same time the main contributions of the e-Pasto platform to these area, but not only: this article tries to initiate an exhaustive reflection concerning smart interfaces and their empowerment capacity, described in Figure 4.

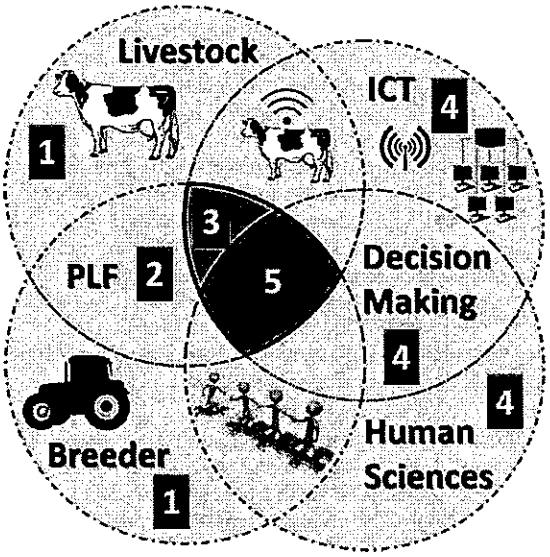

Figure 4. Smart Interfaces in a transdisciplinary project.

Contrary to classical thinking and as it has been said before, users (Label 1 in Figure 4) must be integrated the earliest as possible in the innovation project (Label 2 in Figure 4). This is the starting point.

Smart interfaces can be defined from two complementary and inseparable points of view. Firstly, the interface considered as the main contribution of the project: technological product or system (Label 3 in the Figure 4). Secondly, the interface considered as the transdisciplinary innovating process (Labels 4 and 5 in the Figure 4) [15]. In other words, to overcome the different issues analyzed in this paper, it is necessary that researchers and designers work together along with an integration of users in their reflections. Working together is not easy for people who are specialists in a precise field because everyone has his own

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logic. To work together, a decompartmentalization of scientific disciplines is mandatory, as well as an open-mindedness of researchers and the respect for different thinking. Consequently, it is imperative to exchange throughout the project to better understand each other. The result of this work is a trade-off between the expectations of the different stakeholders [16].

ACKNOWLEDGMENT

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Building Pathways for Empowering User Toward Prosumer Behaviour

The Design for Experience with the Prosumer Empowerment Concentric Model

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Abstract— **Acting as prosumers can help the transition toward low carbon and circular economies. This paper discusses what can be defined as "prosumer behaviours" and proposes an innovative approach that fosters users in adopting daily virtuous experiences about energy production and consumption. Such experiences are based on smart interfaces as they emerge from complex socio-technical systems that combined ICT devices, smart grids and user-centred tools created to empower users and facilitate the emergence of a positive intelligence. The Prosumer Empowerment Concentric (PEC) Model is presented here as an integrative vision to support the emergence of prosumer behaviours and perspectives are outlined via an interregional project that proposes to experiment the PEC model in households and citizen energy cooperatives.**

Keywords - smart interface; smart grid; energy consumption; user-centred approach.

I. *INTRODUCTION*

At individual and community level, low carbon economies rely on decreasing the energy consumption of households and improving the local production of renewable energy. Empowering consumers and encouraging them to act and become prosumers remains a key challenge to provoke effective impacts on sustainability. The term "prosumer" has different meanings in academic works [1] [2] and recent reports from European Parliament [3] [4]. It is used here in line with Greenpeace [5] definition of active customer: "*a customer who performs any of the functions of generation, storage and/or supply of energy from renewable sources, or energy efficiency/demand-side management, either individually or through a community energy*". Acting as a prosumer is adopting virtuous behaviours that create energy savings, reinforce the good understanding of energy bills and participate, in a direct or indirect way, in the production of local and renewable energy.

For designers, new systems, environments, experiences, products or/and solutions need to be imagined and developed so as to facilitate the adoption of prosumer behaviours.

In a technological viewpoint, different types of solutions are developed:

- Information and communication technology (ICT) solutions are the most widespread, mainly composed by sensors and connected objects. Visualization interfaces and serious games are also created for improving the awareness on energy bills and encouraging energy savings.
- Small renewable energy like solar and wind turbines and home energy storage can be interfaced to the main grid through a local scale grid. The microgrid concept allows a local grid to operate independently from the national grid and thus enable a decentralized and cooperative energy distribution system.

Recent works underline new business models who involve changes in the relation between consumers and energy Service Company and communities [6]. In this line, citizen energy cooperatives are emerging models that participate to the production of renewable energy in territories through the involvement of consumers/citizens by financing new installations and diffusing awareness. Besides, small renewable producers and energy storage holders along with consumers can be aggregated using the Virtual Power Plants (VPP) framework [7]. It allows local producer/consumers to exchange their production (renewable energy, heat, etc.) locally and buy/sell from other VPPs. The European FENIX project [8] currently investigates the practical implementation of such concept.

However, there are some barriers and limits in the adoption of such solutions that prevent behavioural changes. Indeed, currently there are solutions that do not have long-term benefits. It is pointed out in [9] that the gamified solutions offer only a gain of 0.2% of long-term energy saving. Moreover, a key determinant of energy performance is the behaviour of occupants. Occupants use energy to perform various activities of daily life and most of the complex processes that occur in dwellings energy consumption result from human behaviour. The activities they undertake are stochastic in nature and difficult to predict [10].

We think that the new solutions have to be in line with the needs and habits of consumers while proposing feedbacks and stimulations that help them to pursue their paths toward the adoption of new eco-efficient and sufficient behaviours.

This is why in our work, we propose a holistic human-centred approach that goes beyond classic product/service design, and give a particular focus on designing experiences for consumers, users and prosumers. User experience (UX) design consist in (i) exploring the real personal motivations,

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needs and representations of consumers [11], (ii) involving them in all stages of the design of future systems [12], (iii) monitoring the evolution of their environment through responsive interfaces [13] [14]. In our approach, UX tools and methodologies will be integrated in a systemic view combining both social, technical and user aspects.

Theoretical background on change and transition management is also investigated in this work to reach the design of coherent and adaptive experiences. Ethically, behavioural changes could not be managed externally without the consent and the intent of users. It exists a challenge for designers, and intermediary organisations, in persuading consumers through interfaces with the objective to inspire emergence of prosumers behaviours while reducing the diffusion of constraint feelings. Supports need to integrate the evolution of consumers and to guarantee solutions which will gradually influence the adoption of prosumer behaviours.

This paper proposes to describe a Prosumer Empowerment Concentric (PEC) model that fits the necessity to build pathways toward prosumer behaviours (presented in Section 2) and explain how it will be used, integrated and experimented in households through a further European projects (see Section 3).

II. *PROSUMER EMPOWERMENT CONCENTRIC MODEL*

The model represents a set of user-experiences containing socio-technological solutions to move from standard consumer toward prosumer behaviour. Each individual can build his/her own paths to become a prosumer by releasing different actions which includes different types of solutions. Structures and institutions like cooperatives or change managers can also use the model as an interface to fit consumers' needs with solutions providers and stimulating changes.

A. *Structures of the PEC model*

The model is built through concentric layers representing levels of empowerment toward prosumer behaviours. Based on Carvallo and Cooper's work [15], four layers have been identified. They represent different levels in which consumers can move: from "standard consumer", "consumer awareness", "active consumer" to "prosumer" (see Figure 1).

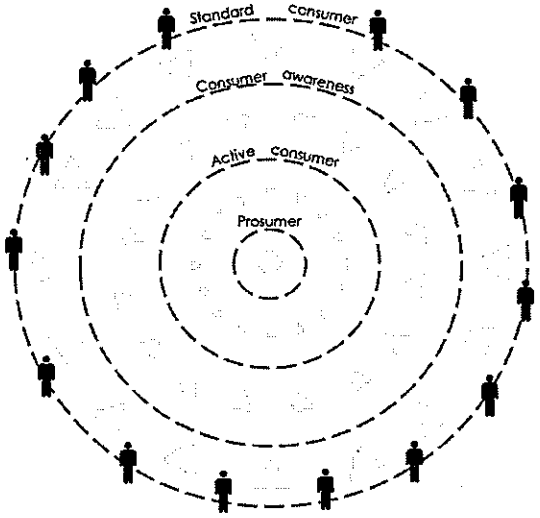

Figure 1. Concentric layers: going deeper in the engagement.

On each circle/layer of the model, we position "states" and in connection with these states we relate existing solutions (see Figure 2).

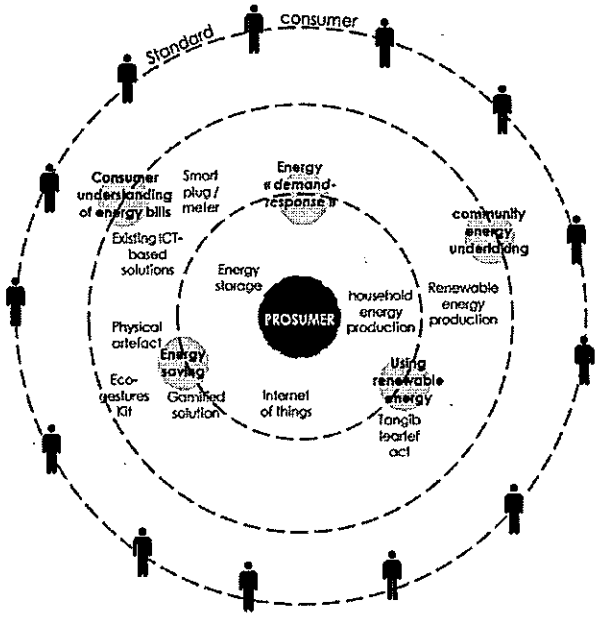

Figure 2. Model with statutes connected to existing solutions.

On the first circle so called "consumer awareness" there are two statutes possible: (i) "Consumer understanding of energy bills" where the objective is to facilitate understanding of energy bills and encourage the identification of equipment in the household that consumes a lot and possible energy losses within the home and (ii) "Community energy undertaking" which correspond to the involvement of consumers in citizen organisations, like

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cooperative. They can participate in financing parts of renewable infrastructures.

On the second circle "active consumer", three states are possible: (i) "Energy saving", people will be encouraged to reduce their energy consumption within their homes; (ii) "Energy demand-response" where the objective is to encourage consumers to consume differently i.e. change / move consumption behaviours to avoid periods of significant demand in energy. One of the first actions (for example) is to inform consumers about energy cost and efficiency; and (iii) "Using renewable energy", here, we have the ambition to motivate people (according to their location) to consume only when their region / territory produces renewable energy. This state is close to the previous one but it is much more stochastic in the behaviour because directly related to the production of "green" energy.

On the third circle, only "prosumer" status is possible, this is the last status available in this model. It consists in the production of energy directly produced by the consumer. It is encouraged on the one hand by all other states but also supported by existing solutions.

B. Pathways and evolution in the PEC Model

The model is built in order to adapt the path toward the consumer profile. Indeed, with this approach, the consumer chooses his/her own path towards "Prosumer" typology. In this way, the consumer chooses the «gateway» according to his/her profile (and his/her motivation) and defines step by step the objectives. In order to illustrate this adaptive pathway, the Figure 1, 2 and 3 present scenarios of various possible paths towards the status "prosumer".

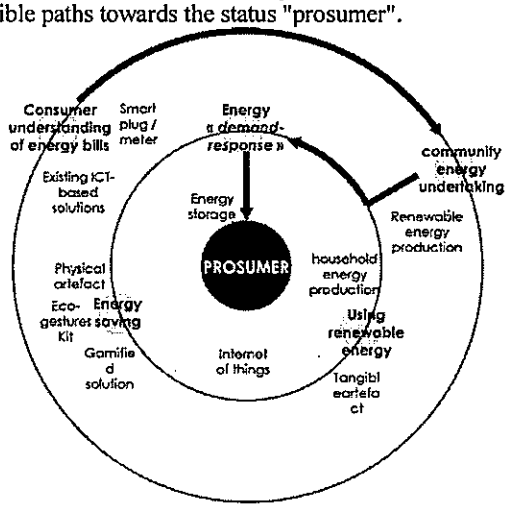

Figure 3. Example of path 1.

In the first scenario (Figure 3), the consumer initiates consciously his/her path toward prosumer typology by improving the awareness of his/her energy consumption. To do so, s/he starts to use an appropriate smart-meter and a visualisation tool to read its own energy bill and after one month choose to become a member of an energy cooperative. After an important reduction of consumption, s/he decides to test new ICT devices which help him/her to better know when s/he has to consume (e.g.,when to use a washing machine) to be in line with the energy production peaks. Finally, s/he decides to adopt renewable energy systems at home so as to gain in autonomy and participate in local electricity production. The scenario 2, depicted in Figure 4, insists on the role of energy communities as catalysers that motivate and advise consumers in adopting new habits and eco-efficient devices while the scenario 3 illustrates, in Figure 5, the case where people have already environmental awareness and start by actions that have a higher level of engagement (situated in both active consumer and prosumer).

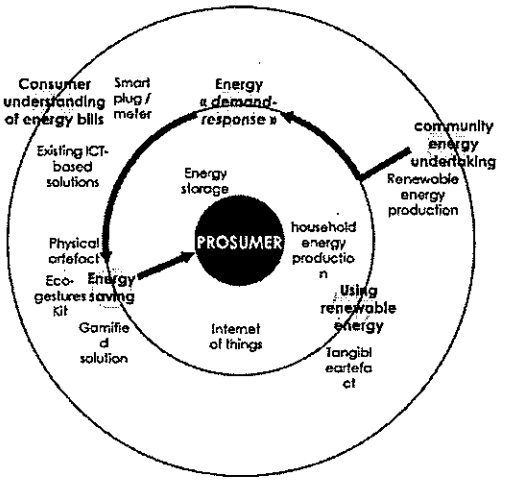

Figure 4. Example of path 2.

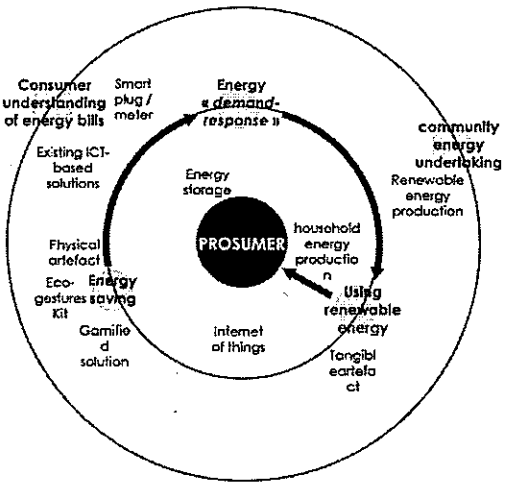

Figure 5. Example of path 3.

C. *The PEC Model integrated in Smart Interface*

"Smart and empowering interfaces" is coined as "the design and implementation of human-human interaction, human-system and system-system that may foster the emergence of a positive intelligence for users". For several

reasons, we are convinced that the PEC model is part of this area. First, it includes the study of behavioral changes and the interaction between solution kits and consumers in order to identify the potentials of deconsumption within each status (human-system interface). Then, it proposes the study of the interactions between the consumers within cooperatives to extract vectors of motivations towards a more virtuous behavior (human-human interface). Moreover, this work focuses on the exchange of energy between the VPPs (system-system interface). These interactions are also embedded in a systemic conceptual interface that connects different layers of environmental awareness within society.

III. *CONCLUSION AND FUTURE WORK*

The PEC model has already gained the confidence of two cooperatives (from Spain and France) and will be implemented and tested through a future European project, in three different regions of France, Spain and Portugal. In each region, cooperatives, energy service providers, intermediary organisations and households will be involved. The project will pursue the state-of-art of existing solutions helping in completing the PEC model. Then, the project will consist in defining the experiences offered to consumers whatever their profiles are. Each experience will be materialized by solution kits composed by a mix of ICT, renewable energy products, energy storage devices and pedagogical or gamified solutions. The first kit will be the installation box (i.e., the smart meters) and the other kits will be boxes sent monthly. The content of these boxes will obviously be adapted to the profiles and desires of consumers. A recruitment phase will select a panel of two types of consumers: members of cooperatives and aleatory households. A pre-analysis of consumers' needs and motivations will be realized. Once the solution kits and consumers will ready, the experimentation will begin. It will consist in four series of solution kits implemented in each household. The 4 phases of planned tests correspond to 3 states (on the "awareness" and "active consumer" layers) and a final test phase for the status "prosumer". For each series, different tasks will be reached: installation, learning stage, use phase with stimulations, feedbacks, behaviour changes and energy saving and production assessments. An approach to analyse human behaviour, behaviour change and their barriers will be deployed. The objective is to understand on the one hand the transition from one layer to the other (of the model) and on the other hand the transition from one status to another. Testing these experiences in real households will lead us to have direct feedbacks, to define new strategies of business models, especially for cooperatives and to draw conclusions for consumer empowerment. The experimentation will end by a capitalization and realization of a deep analysis on effective behavioural changes. Actions will also be engaged to transform citizen cooperatives in an interface organization for energy behavioural changes supported by the PEC model: a practical tool will be developed to help them in supporting the involvement and engagement of their members toward pro-active behaviours.

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Toward Emotional Internet of Things for Smart Industry

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Abstract—**In this paper, an approach to design and implement non-invasive and wearable emotion recognition technologies in smart industries is proposed. The proposed approach benefits from the interconnectivity of Internet of Things (IoT) to recognize and adapt to complex negative emotional states of employees (e.g., stress, frustration, etc.). Two types of connected objects are proposed: *emotional detectors* and *emotional actors*. The steps to design and implement these connected objects are described. The proposed approach is expected to ensure and maintain a healthy work environment in smart industries.**

Keywords–Emotion recognition; Internet of Things; Smart Industry.

I. INTRODUCTION

The proposed approach contributes to the development of new smart interfaces capable of adapting efficiently to users' emotions in the context of smart industries. Smart industry (also called Industry 4.0) is the current trend in which the industrial production, computing and communication technologies converge [1]. Smart industries are expected to increase operational effectiveness of employees as well as provide new services, new types of products, business models and reduction of pollution [2]. In order to work efficiently, smart industries must support interconnection of wireless devices, sensors, and people through the Internet of Things (IoT) [3]. Interconnected objects will provide new ways of collaboration between humans and machines in order to reach common goals in the manufacturing process. Studies have shown that the productiveness of employees are heavily influenced by their emotional states [4]. Negative emotions, such as stress, frustration and anxiety are strongly correlated with counterproductive work behavior [5]. Automatic emotion recognition could be an important requirement in smart industries in order to ensure and maintain the well-being of employees during the manufacturing process. However, despite recent advances in affective computing, emotion recognition in real-world conditions remains a challenging task. Existing sensors that can extract physiological signals associated to emotions (e.g., hearth rate (HR) [6], skin conductance [7], blood volume pressure [8], etc.) often require invasive technologies (e.g., electrodes), and hence may interfere with the users' production tasks. Smart interfaces could benefit from IoT devices in order to provide emotion recognition from employees using non-invasive and wearable devices (e.g., cameras, microphones, wearable hearth rate monitors, smartphones, etc.). These interconnected devices could be able to collect and exchange multimodal signals associated with specific emotions of employees. Once a negative emotion is recognized, the interconnected objects can control actions to respond and adapt to this emotion in order to maintain a healthy working environment.

In this paper, a proposed approach to design and implement emotional IoT devices in smart industry is described. Section 2 reviews the state of the art regarding emotion recognition from non-invasive and wearable technologies. Section 3 describes the proposed approach. Conclusions and perspectives are discussed in Section 4.

II. EMOTION RECOGNITION FROM NON-INVASIVE AND WEARABLE TECHNOLOGIES

A number of researchers in affective computing seek to recognize emotional states through the use of wearable and/or non-invasive technologies. Many of these technologies could be used in the context of industries or manufacturing tasks since they do not interfere with the user behavior. Recent advances in computer vision and speech recognition have led to the design of non-invasive systems capable of inferring user's emotions from voice [9], facial expressions [10], gestures [11], and body movements [12]. The advantage of these systems is that they do not require users to wear any sensors on their bodies since only cameras or microphones are needed. However, these techniques could not be precise under certain manufacturing tasks as they require users to face a camera (or a kinect) to recognize the emotion correctly. In addition, speech recognition systems require to isolate the user's voice from backgroung noise. The recent development of wearable computing devices has prompted a growing interest in using them for emotion recognition. Recent works [13] [14] have proposed intelligent wristbands including multiple sensors capable of acquiring physiological signals related to different emotions. Gao et al. [15] used wearable EEG headset technology to detect the brain's activity in response to different emotional states. Olsen et al. [16] showed that the accelerometer data recorded from a smartphone can be used to infer the user's emotional state. Despite many advances in emotion recogntion through wearable and/or non-invasive technologies, few works have been interested in detecting more complex emotional states such as stress, frustration, depression, pain etc. In addition, most of the proposed approaches do not beneffit of the interconnectivity of these devices to improve the recognition accuracy. Finally, using emotion recognition technologies in the context of industries or real-world manufacturing tasks is still unexplored.

III. PROPOSED APPROACH

The proposed approach consists in harnessing the interconnectivity of the Internet of Things to detect and respond to negative complex emotions of employees performing manufacturing tasks, thus ensuring a healthy working environment. In order to implement this approach, two types of connected objects

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are proposed: *emotional detectors* and *emotional actors*. *Emotional detectors* are wearable and/or non-invasive devices (e.g., cameras, microphones, wristbands, smartphones, etc.) capable of recognizing, in real-time, complex negative emotions (e.g., stress, frustration, anxiety, etc.) during the realization of several tasks involved in manufacturing processes. *Emotional actors* are smart systems or devices capable to respond properly to negative emotions of the employees. For example: adapting the difficulty of the task with respect to frustration levels of employees or activating stress management training systems installed in smartphones of employees. In order to design and implement *emotional detectors* and *emotional actors*, the following steps are proposed:

1) **Task identification:** manufacturing tasks inducing negative emotions will be identified. This identification can be achieved by applying psychological questionnaires to employees (e.g., anxiety scores [17]) before and after each task.
2) **Emotion induction protocols:** protocols capable of inducing identified negative emotions will be designed based on identified tasks. In these protocols, negative emotion-induction tasks will be similar to real-world manufacturing tasks.
3) **Multimodal data collection:** emotional induction protocols will be tested with a large population of employees. During these protocols, wearable and non-invasive devices will be used to collect multimodal data (e.g., physiological signals, video, audio, psychological questionnaires) from these employees.
4) **Analysis of emotional features:** multimodal data collected in the previous step will be processed and analyzed in order to find the most relevant features (e.g., facial expressions, body movements, hearth rate variability, etc.) associated with different negative emotions.
5) **Recognition of negative emotions:** the relevant features found in the previous step will be used to train machine learning models capable of reconizing negative emotions from different wearable and/or non-invasive devices.
6) **Emotional detectors:** wearable and non-invasive devices will be integrated into real-world manufacturing tasks. Wearable devices wil be used by employees while non-invasive devices will be located in specific positions where they will capture data from employees. Each device will integrate a computer system capable of extracting relevant features associated to negative emotions as well as providing syncrhonization (interconnectivity) with other devices. Each relevant feature extracted will be sent to a central computer system capable of recognizing negative emotional states using trained machine learning models.
7) **Emotional actors:** IoT systems capable of decreasing levels of negative emotions wil be designed and integrated into manufacturing tasks or wearable devices of employees (e.g., applications installed on smarthphones of employees).

IV. Conclusions and Perspectives

A novel approach to integrate emotion recognition IoT devices in smart industries is presented and described. The main objective of the proposed approach is to increase the productiveness of employees by maintaining a healthy work environment. Two types of IoT devices are proposed: *Emotional detectors* and *Emotional actors*. *Emotional detectors* will be used to recognize negative emotions from employees, while *emotional actors* will be used to decrease levels of negative emotions. Before implementing the proposed approach in real industries, a more detailed study of different IoT devices and manufacturing tasks will be required. In this study, several characteristics will be considered, such as perceived comfort of wearable devices, possibility of integration in different manufacturing tasks, etc. Finally, the social acceptability of using emotional IoT devices in industries must be considered.

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