出國報告（出國類別：國際會議）

使用立體視覺系統實現輪形機器人之遠端控制

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摘要

2016 年「工程與應用科學國際研討會」(The International Conference on Engineering andApplied Sciences, TICEAS 2016)係由高等教育論壇(Higher Education Forum, HEF)舉辦，並於 105 年 2 月 18 日至 20 日在新加坡半島怡東酒店(Peninsula Excelsior Hotel)舉行，本人投稿該研討會論文乙篇，論文題目：使用立體視覺系統實現輪形機器人之遠端控制，因榮獲刊登及大會議程安排於 2 月 20 日上午 1030-1200 場次進行口頭發表，故於 2 月 17 日搭機前往與會。當日該場次會議中，計有來至台灣、日本、南韓、泰國、阿拉伯聯合大公國及新加坡等八篇論文發表，期間發表人均詳細報告其研究成果，報告完後，台下與台上學者討論熱絡，彼此交流受益良多。

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壹、目的：

2016 年「工程與應用科學國際研討會」」(The International Conference on Engineering andApplied Sciences, TICEAS 2016)，由主辦單位 HEF 於 105 年 2 月 17 日至 21 日假新加坡半島怡東酒店舉行，該研討會主要提供專家學者呈現其研究成果並互相交流未來發展技術與應用，其探討的主題分別為：生物醫學(Biomedical Engineering)、化學工程(Chemical Engineering)、與電機電子工程(Electrical & Electronic Engineering)等九大科技領域，其屬於探討現今新興科技於工程與應用之國際研討會，而本次參與發表之專家學者，計有來至日本、南韓、台灣、馬來西亞、泰國、印度、波蘭及新加坡等各國專家學者，合計發表論文達 100 餘篇。藉由參加本次國際研討會的互相討論，除了平日鑽研研究與查閱期刊論文所得知識，更能開闊自身眼界，瞭解國際研究趨勢與脈動，因而增進研究動力與方向。此外，本會議所投稿之論文均經由國際相關領域之學者、專家審查，因此一旦獲得大會收錄刊登，亦將大幅增加本院的能見度及學術地位。

貳、過程：

會議議程

Feb. 20, 2016, Lotus Room : 10:30 – 12:00

Session Chair: Prof. Seokho Yoon

本人發表之論文名稱：

The Mobile Robot Remote Control by Using Stereo Vision System

作者：

Chien-Wu Lan, Shih-Sung Lin, Hsiang-Yu Yang, Kuang-Hsiung Tan(談光雄) and Jo-Yen Nieh

(Chung Cheng Institute of Technology, National Defense University, ROC)

本次赴新加坡參加國際研討會，因國人赴新加坡免簽證及當地以華人居多之因素，故僅委託旅行社代訂來回機票，而相關住宿則自行決定住宿流浪酒店四晚，下榻飯店離研討會舉辦地點稍有距離，惟因新加坡地鐵四通八達具便利性，因而決定較市區偏僻的小印度區之飯店以節省開支。研討會舉行時間為 105 年 2 月 18 日至 20 日，故由旅行社代訂 2 月 17 日上午 09 時 55 分搭乘長榮航空班機赴新加坡樟宜機場，抵達樟宜機場時已逾當地時間 14 時 30 分(與台灣時間同)，辦好出關手續，即自行搭乘新加坡地鐵東西線抵達丹娜美拉站，再轉往與濱海市區線交會之武吉士站，接著步行約 10 分鐘後抵達下榻飯店，此時已逾 16 時 30 分，而晚上則在飯店稍作休息及準備。由於發表之場次為 20 日上午 10 時 30 分，且 18 日整日為大會安排研討會行政人員之教育訓練，當日除在飯店稍作休息外並外出瀏覽異國文化。2 月 19 日當日早上 09:30 到達會場新加坡半島怡東酒店並順利完成報到手續，當日並擇感興趣之場次聆聽相關論文發表。2 月 20 日發表當日早上 10:00 抵達會議地點，報告場次為上午 10 時 30 分，會議一開始，由會議主持人 Prof. Seokho Yoon 主持議程並由發表人逐一開始報告，本會議共發表八篇論文，分別由南韓 Sungkyunkwan University、日本 Wakayama University、泰國 Kasetsart University Sriracha Campus、阿拉伯聯合大公國 Telecom and Network Operations、及台灣大葉大學等教授及專機輪流發表，發表人均詳細報告其研究成果，報告完後，主持人亦提供時間給在場與會學者、專家提問，由於所研究之領域具相關性，因此台下與台上學者討論相當熱絡，導致會議主持人為控管時間而打斷討論，也因而會議延遲結束。本人發表之論文為第 2 順位，論文發表完後，主持人及台下學者亦提出見解及寶貴建議，對於本次參加國際研討會，使自身眼界更開闊及瞭解國際研究趨勢與脈動，因此對於未來研究與方向將產生更大的動力。

本人所發表之論文為「The Mobile Robot Remote Control by Using Stereo Vision System」，內容報告摘要如下：本研究提出了一個利用立體視覺系統實現輪型機器人遠端控制之系統架構，此系統架構包含遠端使用者端、網路服務伺服器端、以及機器人平台。透過此系統架構可實現以下功能：(1) 輪型機器人平台可透過網路攝影機於無線網路環境中將現場畫面即時傳遞至遠端使用者，(2) 使用者可透過肢體動作遙控機器人的行進方向及速度，(3) 建立各式網路服務提供資料傳遞服務，使遠端使用者的控制命令能傳

遞至輪型機器人平台，並接收輪型機器人平台所接收之相關環境資訊。本研究亦依此系統架構建立測試原型機來實現遠端控制之功能。相關收錄論文如附件。

2 月 18 日，當日為大會安排行政人員之教育訓練，本日無論文發表：

2 月 19 日，當日會議旁聽其他專家、學者發表議題，摘錄如下：

(1) Removal of Heavy Metals (Fe, Co and Ni) from Spent Electro-Decontamination Solution Using Organic Acids and Regeneration of Phosphoric Acid：

放射性廢水中的重金屬（如鐵，鎳和鈷）通常可使用磷酸和有機酸（草酸為主）來有效地移除，本研究執行模擬放射性廢水中重金屬之解離。本文提出三種不同方法，如(1)草酸，(2)有機酸，和(3)不同複合劑α，β，γ環糊精來處理放射性廢水，以得到最高的去除效率。此外，鐵有機酸沉澱物通過熱分解，來分析其特性在高溫下，FT-IR 和 XRF 的質量問題。本研究主要在探討用最經濟可行的方式使用磷酸結合有機酸來移除放射性廢水中重金屬的最佳去除率。

(2) Effect of Pressure, Temperature and Liquid to Solid Ratio on Aqueous Carbonation：

碳化是改變物質形成了碳酸鹽的過程，其主要使物質產生最終穩定狀態並可進一步提供使用的方法。碳化已經在被稱為替代性黏著劑(代替用於建築之波特蘭水泥或用於污染土壤中重金屬之固化)的煉鋼爐渣進行了測試。本項研究中，針對溫度，壓力和液體在水性碳化固比之影響進行研究與探討。

(3) Rice Bran Carbon/Styrene Butadiene Rubber Composites with Excellent Mechanical, Thermal and Tribological Performances：

在本文先前之研究，米糠碳（RBC）首次利用固體混合法（SCM）應用於橡膠之強化，然而，其強化之效果是不令人滿意，由於米糠碳的分散狀態差，導致聚集體之出現。材料聚集體不僅會干擾實驗結果的精確度，同時也降低材料強化能力。因此，本研究採用了一種新方法，以複合與合成 RBC / SBR 複合材料，來提高橡膠之強化性能。

(4) Some Properties of the (p,q) - Fibonacci Numbers and (p,q) - Lucas Numbers：

本研究中，作者探討廣義 Fibonacci 序列與 Lucas 序列為（P，Q），其中作者使用了比奈 Binet 公式證明（P，Q）的一些性質 Fibonacci 編碼和 Lucas 編碼。由本文的分析與研究，可得到的 Fibonacci 序列與 Lucas 序列廣義的特性。

(5) Study on Synthesis of Thermal Conductive Adhesive Using Alumina Modified with Silane Coupling Agent as Filler：

本文探討，當包括 LED 在內之顯示器都不可避免會產生熱能。此熱能使顯示器電子元件的溫度上升，而造成功能降低和故障發生之機率提高。因此，為了防止顯示器電子元件的溫度上升，通常都會安裝散熱器和風扇。然而，由於電子元件小型化和電子設備的靈活性，也造沒有多餘空間來安裝散熱器和風扇。因此，本研究為了提高顯示器電子元件之散熱性，利用一種新型黏著劑強化熱輻射性能，以達到溫度不至於快速上升。

2 月 20 日，當日其他學者、專家發表議題，摘錄如下：

(1) Cuffless Estimation of Blood Pressure Using Photoplethysmographic Method：

血壓是與日常生活方式有密切關係。當測量血壓，通常需要利用箍的方式以施加壓力於血管。而近年來，有許多的研究指出測量血壓不使用箍的方法（O.R. cuffless 血壓方法）。而不使用箍的方法量測血壓通常需要心電圖(electrocardiography, ECG)和（photo-plethysmography, PPG）傳感器，以利用血壓校正。本文研究與分析該方法之實用性，並發現此方法是最不容易磨損 ECG 傳感器。

(2) A Method for Deciding the PID Parameters for an Energy-Saving Design：

近年來，全球氣候緩化已成為一個世界性的問題，因此有效地利用能源是極為迫切。在日本家庭中，消耗功率約有 60%來自於產生熱能之設備，例如烘衣機，烤箱等。而大多數工廠的功率損耗也幾乎來自產生熱能之設備。因此，針對此問題，對於產生熱能之設備其具有效控制功率的方法是必需的。由於，設備中因輸入和輸出間存在著非線性的特性，且無法以數學模式表示之，因此這種產熱之設備的控制是較為困難。因此一般的比例積分微分 PID 控制器通常是較常使用的。而在本文中，作者針對 PID 控制器與產熱能之設備進行了參數的設計與分析。

(3) Development of Compact Violin-Playing Robot：

目前，各種類型的小提琴演奏機器人已經被研究。然而，這些機器人體積過於龐大且機構太複雜，因此，會造成儀器或樂器上的不良影響。此外，龐大且複雜的機器人將造成花費龐大。有鑑於此，本文的目的是開發一個小提琴演奏機器人，結構緊湊、簡單且對小提琴不會有傷害的小型機器人，而作者所研發之小提琴演奏機器人，其所演奏之音樂將媲美人為演奏般動聽。此外，該論文的主要目的是對小提琴進行的聲譜之檢查，以驗證其效能與可靠性。

(4) Biomimetic Robot: Realization of the Mobility of Whirligig Beetle：

近年來，生物習性之研究已被提出與執行，例如仿生物機器人之開發。由目前研究可知，通過闡明這些生物的天生機制，例如鳥類利用翅膀的飛行原理與候鳥的氣後遷移等，均能夠應用於相關仿生物機器人的發展與研究。本文重點介紹豉蟲，它可以在高速游泳，並可以利用其體積小的優點快速迴轉。本文主要的目的是建構在豉蟲的生物特性上，發展一可快速在水面迴旋移動的機器人。

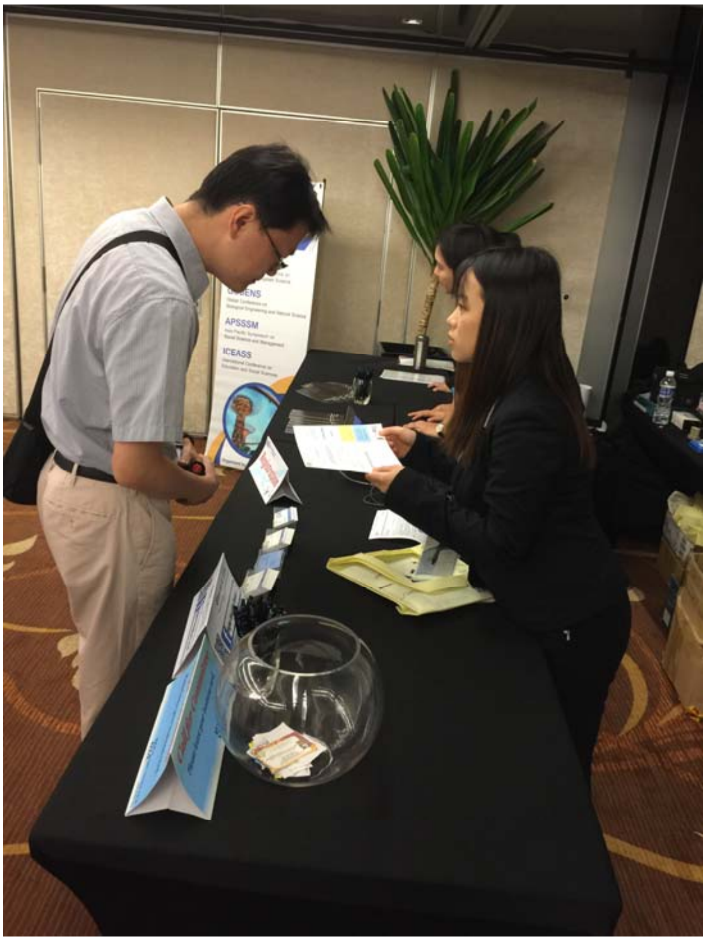
參、心得報告：

本次赴新加坡參加國際研討會，不僅是在學術方面，可以擴張自己研究知識，而在國際觀上，對當地生活習慣及科技發展也有新的見解與體認。在學術上藉由本次研討會，可以看到其他專家學者對於自己所專研領域具有一套特殊見解，也充分運用自身專業解決當今工程問題，例如:有學者提出仿生物機器人之開發，利用模仿生物天生能力來應用在日常生活等。另外，在國際觀上，因本次研討會在新加坡舉行，新加坡係由有華人、馬來西亞人、印度人等各國人種構成，可說是一個大熔爐的國家，街上到處可看到各種不同種族文化與商圈，而彼此也互相尊重和平生活在一個社會，這是一件相當不容易的事。此外，在新加坡超市看到自助結帳機的設備，完全採信任與自助方式，不僅可加快結帳腳步，也減少人力的派遣，這或許是我們可以多加學習採用。最後，參加國際研討會是一項很有意義的學術活動，也非常感謝科技部的經費提供，校院部各級長官的協助，使得此次研討會能順利成行。

肆、參考資料：

圖片為研討會內外場、海報展示區與會議現場等

研討會地點指示牌



註冊報到

研討會場外(1)

研討會場外(2)

海報展示區

研討會會議進行(1)

研討會會議進行(2)

研討會會議進行(3)

研討會會議進行(4)

研討會會議進行(5)

伍、建議事項：

對於參加國際研討會，將可增進學術交流亦可開闊自己國際觀，利用參加國際學術研討會，使各國瞭解我們的學術成就。所謂學術無國界，藉由各國的專家學者互相研討，彼此激勵出火花，對於學術而言也是一項寶貴收穫，因此，在經費有限的情況下，期許能鼓勵老師們能多出去走走，瞭解目前各國學術研究方向，增進學校能見度，以提升自己本職學能。最後，感謝科技部研的經費提供，校院部各級長官的協助，使得此研討會能順利成行。

陸、會議資料：

收錄論文光碟片(論文電子檔 100 餘篇)

TICEAS-1316
The Mobile Robot Remote Control by Using Stereo Vision System

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Abstract

The system architecture of stereo vision system remote control (SVSRC) is proposed to realize on a mobile robot. The system architecture includes remote user, web service server, and wheel robot platform. There are three functions are developed for this architecture. First, the moving speed and direction of mobile robot are controlled by the gesture of user. Then, the environment information, such as images of webcam, can be transmitted via wireless network. Moreover, several web services are developed to transmit control commands from remote user to the robot, and return environment information from the robot to remote user. According to the system architecture, the prototype is proposed to verify the functions.

Keywords: Remote Control, Stereo Vision System, Mobile Robot, Web Service

1. Introduction

With the popularity of the internet environment, the needs to use remote robot are gradually increasing. For example, a Sydney woman bought a new iPhone 6s by operating the robot at home. On the other hand, remote control robot can also replace human to finish the works in high-risk environments, such as the defense advanced research projects agency (DARPA) robotics challenge (DRC) held in 2012-2015, which's competition scene is build according to the Fukushima nuclear accident. The purpose of this challenge wishes to realize that robots work in worst disasters where humans can't work in.

In the past decades, there are several researches [1-9] have been proposed for the remote robot, which can be divided roughly into the transmitting methods for control commands and the remote control methods. For the transmitting methods, a prototype of remote batter swapping and charging for home robot has been developed in [1], which uses home server to transmit image information to the user through the Wi-Fi environment.

Several researches propose control robot through wireless network [2-4]. One develops a didactic robotic platform [2], which users can upload their programs through browser, and control robots which is linked by Wi-Fi. The robot which controlled through wireless network can also be used to track from camera images [3]. In [4], a robot platform which can be controlled by the computer only with keyboard and mouse on network is proposed. However, how to connect robot with users through Wi-Fi network is complex. Richtr et al. propose a simple way to connect robot by web service, and develop a Silverlight web page for users to control the robot [5]. In [6], ZHU et al. also develop a system which can control robot by speech web service. Therefore, according to the literatures, Wi-Fi with web service connection is a suitable solution for remote robot control.

On the other hand, the traditional control methods for remote control are not intuitive. Several new control methods are proposed in [7-9]. A robotic arm is developed to be controlled remotely by feedback of arm signal [7]. The other robot is controlled remotely by charge coupled device image, which the user should wear the marked gloves for image detection of control [8]. Different from the above researches which the users should wear some devices, Cheng et al. develop the system which control the robot by using stereo vision system [9]. While the skeleton of user is detected, the robot can be controlled just by the motion of the human. Therefore, the stereo vision system is chosen for the remote control method of robot.
In this study, the remote robot controlled by stereo vision system through Wi-Fi is realized. Moreover, the web service server is build to exchange data from robot to remote user each other, and users can monitor the robot information through the browser. The architecture of system and control method will be depicted in the following sections. The system architecture of SVSRC will be introduced in Section 2. Then, the motion analysis and the control command creation will be described in Section 3. Finally, some illustrated experimental results will be presented in Section 4.

2. System Architecture

The system architecture of SVSRC on mobile robot is illustrated in Fig. 1 [10]. The system is composed of three blocks: 1) server; 2) client and 3) robot module. The sever block provides web services for data transmission and information web page, which is communicated with robot and users through the internet. There are three web services, motion command transmission service, real time image transmission service, and real time sensor data transmission service in the proposed SVSRC. For the motion command transmission service, robot can receive the control commands form the remote user through this service. The environment information which is detected by web cam or sensors of robot can be transmitted to remote user or shown on web page through real time image and sensor data transmission services. The web page is used to provide the real time images and sensor data information for remote viewers.

The robot block consists of one wheel robot with several sensors, such as collision detecting sensor, laptop and web cam. It queries the server through Wi-Fi whether there is new control command or not. While the server obtains new control commands, it will be transmitted to the wheel robot and executed. During the process of action, the robot module also detects the environment information by web cam and sensors at the same time. The images and data of sensors will be transmitted by calling real time image and data transmission respectively. All these process are operated by the laptop of the robot module.

The client can be divided into two categories. One is the viewer, and the other is the operator. The viewer can just monitor the images and sensor data of robot by viewing the web page of the browser. On the other hand, the operator can remotely control the robot by using human machine interface (HMI) and stereo vision system. The HMI analyzes the image of stereo vision system, transforms the motion information to commands and transmit commands to robot by calling command transmission service through internet. How to transform the stereo images into motion commands will be depicted in next section. The HMI can also show the images and sensor data of robot to assist the operator.

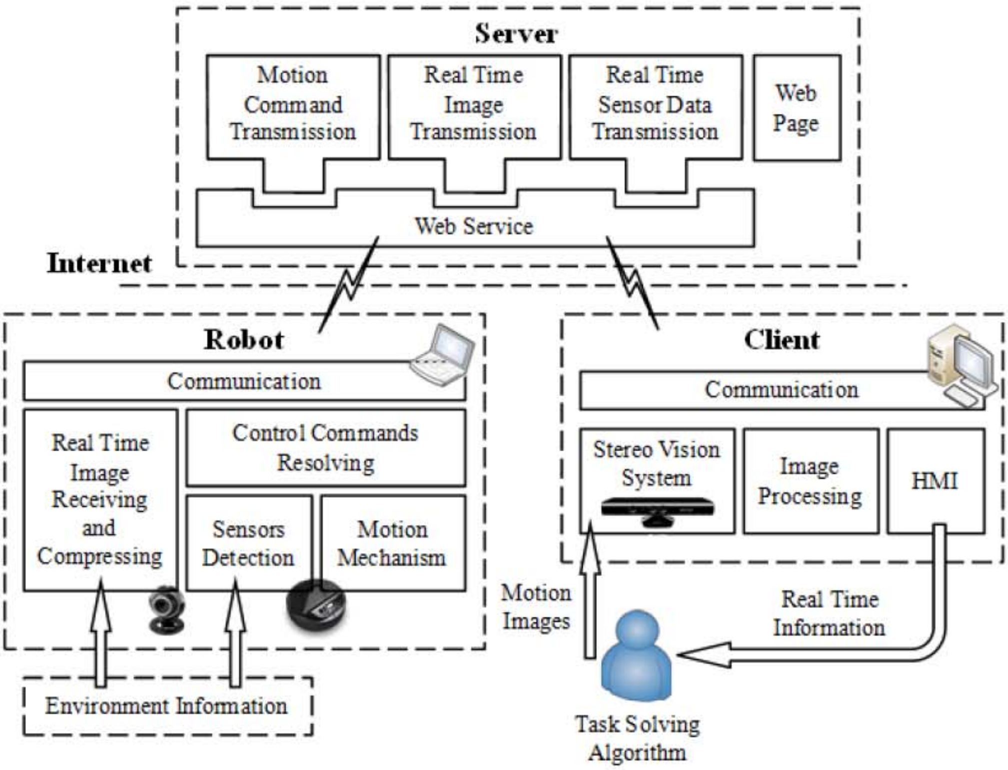

Fig. 1: System architecture of SVSRC on mobile robot [10].

3. Motion Analysis and Control Command Creation

In order to define the motion control commands, the Kinect software development kit (SDK) is used to analyze the motion of the operator [11]. Moreover, since the actions of upper body are distinguished easily, the control commands are calculated based on the motions of arms. The skeleton of operator can be detected from stereo images at first by using Kinect SDK. The detected skeleton is composed of several joints, such as left, right and center of shoulder, j_{sl}, j_{sr} and j_{sc}, left and right elbow, j_{el} and j_{er}, and joint of spin, j_{sp}, as depicted in Fig. 2 (a). The origin of the coordinate is on the camera of stereo vision system. After detecting the skeleton of operator, there are several vectors can be selected to define the motions of arm, such as the vector form the center of shoulder to the spin, the vector from the center of shoulder to the shoulder, and the vector from the shoulder to the elbow in the proposed SVSRC system. Based on these vectors, there are four variables are calculated, θ_l, θ_r, ψ_l, and ψ_r. Assume $\mathbf{h}_{cp}$ is the vector from j_{sc} to j_{sp}, $\mathbf{h}_{sr}$ is the vector from j_{sc} to j_{sr}, $\mathbf{h}_{er}$ is the vector from j_{sr} to j_{er}, and $\mathbf{n}_r$ is the cross product of $\mathbf{h}_{cp}$ and $\mathbf{h}_{sr}$. The θ_r is the angle between $\mathbf{h}_{cp}$ and $\mathbf{h}_{er}$, and the ψ_r is the angle between $\mathbf{n}_r$ and $\mathbf{h}_{er}$, as shown in Fig. 2 (b). Hence, the θ_r can be solved by (1), and the ψ_r can be solved by (2):

$$\theta_r = \cos^{-1}\left(\mathbf{h}_{cp} \cdot \mathbf{h}_{er},\right) \tag{1}$$

$$\psi_r = \cos^{-1}\left[\left(\mathbf{h}_{cp} \times \mathbf{h}_{sr}\right) \cdot \mathbf{h}_{er}\right] \tag{2}$$

Furthermore, the θ_l and ψ_l can be calculated similarly.

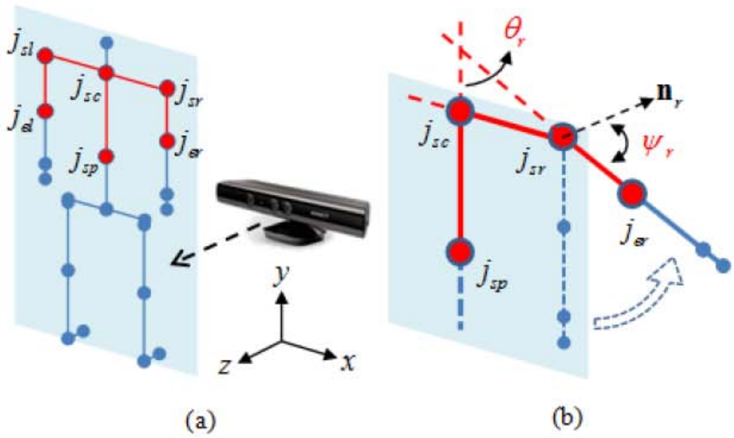

Fig. 2: (a) Detected skeleton with joints, and (b) location of θ_r and ψ_r.

The control commands can be given by the angles of θ_l, θ_r, ψ_l, and ψ_r. The commands can be divided into five categories: forward, backward, turn left and right, and stop commands. First, the θ_l and θ_r will be determined. The stop command is obtained while θ_l and θ_r are both less than 70 degrees (with hands down). Moreover, while the θ_l and the ψ_l are both larger than 70 degrees, the robot will be controlled to turn left. While the θ_l is larger than 70 degrees and the ψ_l is less than 20 degrees, the robot will be controlled to go forward. If the ψ_l is larger than 20 degrees and less than 70degrees, even the θ_l is larger than 70 degrees, the robot will do nothing. On the other hand, the θ_r and ψ_r will be used to determined the commands of turn left and go backward. Similarly, if ψ_r is larger than 20 degrees and less than 70degrees, the robot will be stopped, too. The command determination flowchart is depicted in Fig. 3.

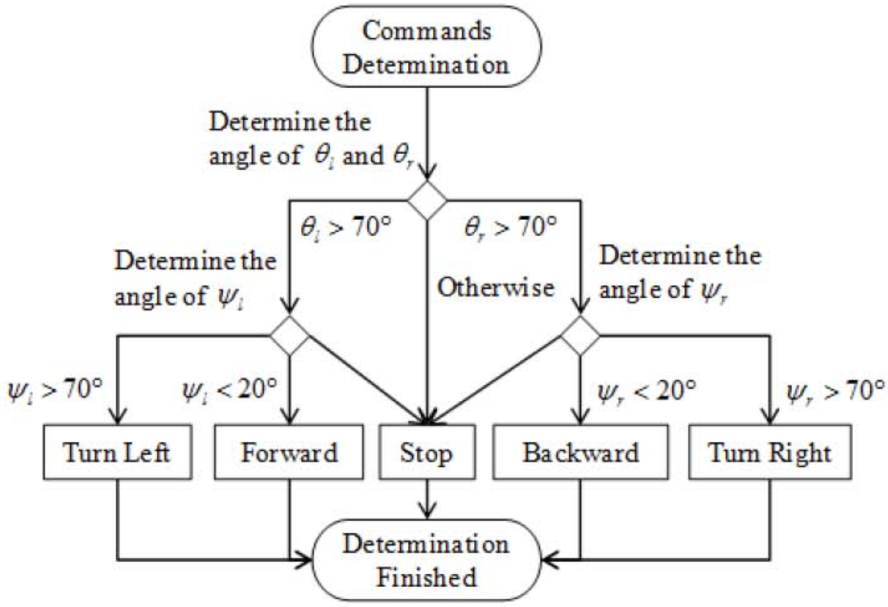

Fig. 3: Control commands determination flowchart.

4. Results

The prototype of the remote control robot is implemented in the Wi-Fi environment. The control commands are transmitted from the personal computer with stereo vision system and HMI, which is used to transform the motions of operator into commands. The server installed web services is used to transmit data from operator and robot to each other. The viewers can also watch the operation process on the web page. Finally, the feasibility and effectiveness of the proposed SVSRC system are verified with experimental results.

4.1 The Robot Module

The robot module shown in Fig. 4 consists of wheel robot, laptop (Acer Aspire 4930G with Windows XP OS) and webcam (Microsoft HD-5000). The Kobuki robot with three bumpers and cliff sensor, gyroscope and two wheel drop sensor is adopted as wheel robot [12]. These sensors can be used to provide the environment information to the remote operator.

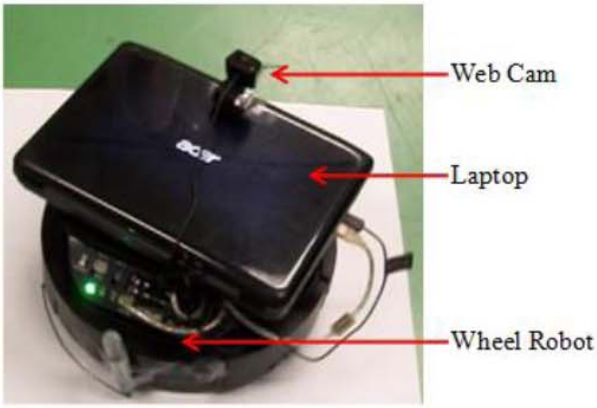

Fig. 4: Structure of robot module.

4.2 Remote Control and Monitor

The Microsoft Kinect is used as the stereo vision system of ore research. The location of operator is shown in Fig. 5 (a), and the computer which is connected with stereo vision system is depicted in Fig. 5 (b). In Fig. 5 (c), while the stereo vision is linked to HMI, the image of operator and the detected skeleton will be shown in the HMI. The left image of HMI is the real motion of the operation, and the right image is the skeleton image of operator. According to the rules of commands determination, it can be found that the operator is doing the "forward" command motion. The executed result of robot is shown in Fig. 5 (c). Moreover, the image shows the skeleton which only related to the vectors of $\mathbf{h}_{cp}$, $\mathbf{h}_{sl}$, $\mathbf{h}_{el}$, $\mathbf{h}_{sr}$, and $\mathbf{h}_{er}$. In Fig. 6, the operating images of web cam on the robot are monitored by Google Chrome browser. Finally, the mobile robot is operated by the proposed SVSRC system successfully.

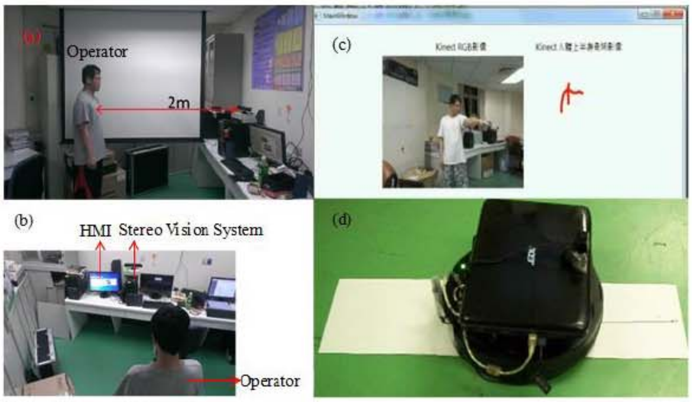

Fig. 5: (a) Operator, (b) Computer with stereo vision system and HMI, (c) HMI, and (d) operation result.

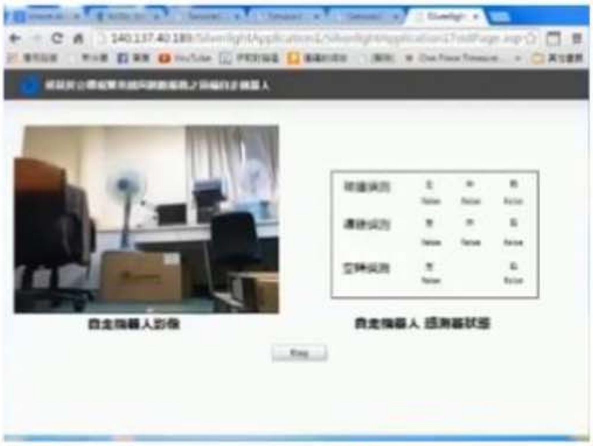

Fig. 6: Image of web cam on remote robot monitored by browser.

4.3 Acknowledgments and Legal Responsibility

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