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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出國期間：105/02/17-105/02/21
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摘要

本次公務出國之目的爲參加由高等教育論壇(Higher Education Forum, HEF) 於新加坡半島怡東酒店(Peninsula Excelsior Hotel)所舉辦的 2016 年「工程與應用科學國際研討會」(The International Conference on Engineering andApplied Sciences, TICEAS 2016)並發表論文，論文題目爲「使用立體視覺系統實現輪形機器人之遠端控制」(The Mobile Robot Remote Control by Using Stereo Vision System)，論文內容主要說明如何利用立體視覺系統解析人類肢體動作，並實現對遠端之輪型機器人進行控制。該篇論文於日前投稿本次研討會時榮獲刊登，並安排於 105 年 2 月 20 日上午 10:30 至 12:00 之場次進行口頭報告。本次研討會發表行程於 105 年 2 月 17 日出發，並於 105 年 2 月 21 日完成任務順利返國。

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壹、目的：

參與國際型研討會爲維持教育單位之學術地位與提升國際可見度之重要活動，同時也代表著我國軍事院校具有發表國際型論文之能力與水準，因此，維持發表國際型著作係爲軍事院校教師重要之任務之一，亦爲教師升等時之重要參考指標。而本次發表之著作爲日前與文化大學資工系合作所共同完成的研究內容，由於本研究在實作的內容上相當完整，因此在經過數月的整理、文章撰寫及潤飾後便進行發表。而在選擇發表的研討會方面，由於研究之餘仍須兼顧擔任大專院校教師之教學本務，因此在考量不影響學期授課進度、以及符合科技部計畫執行與經費運用期程的限制下，選擇投稿於農曆年後（105年2月18日至20日）所舉辦的工程與應用科學國際研討會。藉由本次國際型研討會的發表，除了希望能逐漸累積自身之學術成果外，亦希望能爲提升國軍國防科技之學術地位略盡棉薄之力。

貳、過程：

本次參加研討會行程自 105 年 2 月 17 日至 21 日，共計五天，依日行程分述如下：

一、2 月 17 日

出發當日搭乘 09:55 自桃園機場二航廈出發之長榮航空，預計 14:30 抵達新加坡樟宜機場三航廈，惟因樟宜機場班機壅塞須盤旋飛行延遲降落時間；以及降落後機上廣播貨艙連結問題等狀況，出境時已是當地下午約 15:30 左右。在趕往各服務櫃台購買當地所需之交通票券後，抵達下榻飯店（流浪酒店，Wanderlust）已接近傍晚 17:00 時，在完成入住登記手續並置放完行李後，於週邊地區簡單用完晚餐，當晚便於飯店內休息。

二、2 月 18 日

由於本日研討會表定爲行政人員教育訓練之行程，因此便利用今日了解由飯店抵達研討會會場之交通方式，所居住之飯店位於小印度區，步行約 10 分鐘可抵達鄰近之武吉士(Bugis)地鐵站，而研討會會場位於新加坡半島怡東酒店(Peninsula Excelsior Hotel)，鄰近同樣約步行 10 分鐘距離即可抵達政府大廈(City Hall)地鐵站，因此於武吉士地鐵站搭乘地鐵東西線(East-West Line)乙站即可抵達。在了解抵達會場的交通方式後，便利用剩餘時間了解當地文化與飲食，即返回飯店著手準備論文發表之練習。

三、2 月 19 日

在了解抵達研討會會場之交通方式後，本日上午約於 09:30 時許抵達新加坡半島怡東酒店並完成報到手續，接著便參與研討會相關議程；以及了解其他專家學者所發表之研究成果，摘述部分研究內容如下：

(1) Evaluation of Long-Term Catalysts, Performance Regarding to Using FeCrAl Metal Foam in Diesel auto-Thermal Reaction

本研究成果由韓國嶺南大學 Won Young Choi 等人所發表，主要利用柴油齊高能量密度的特性，來嘗試應用於產生燃料電池所需之氫源。然而，柴油反應過程所產生的焦炭化是希望被避免的，因此本研究提出相關實驗步驟來減少焦炭化的產生，主要分爲啓動條件和工作條件等兩部分，在啓動條件方面，將液流與炭的比例調整爲 1.3；氧氣與炭的比例調整爲 0.3。而在操作條件下，則將液流與炭的比例調整爲 2.5；氧氣與炭的比例調整爲 0.25。反應物在此條件執行實驗約 500 小時，並加入每單位 8800 毫升的的催化劑。經反應後，成功提升約 41~43%的氫反應物，且沒有觀察到炭化的沉積物。

(2) Ultrasonic Atomization by Difference between Vibration Displacements of Two Circular Vibrating Plates

本研究成果由日本大學科學與技術學院 Takuya Asami 等人所發表，提出一種改善超音波霧化液體的方法，由於霧化液體顆粒間距的值是由超聲波振動的頻率所決定，因此代表可透過使用多個具有不同驅動頻率的超音波振動源來控制霧化液體顆粒間距。然而，由於常規的超音波振動源通常只具有一種共振頻率，因此只能產生一種霧化液體顆粒間距。因此，本研究提出一種不需依賴於振動源的共振頻率來霧化液

體的新方法，主要是利用控制兩個橫向圓形振動板的形狀與間距來實現，並提出實驗後所得的最佳參數。

(3) Graft Chitosan onto Bamboo Charcoal Sulfonated Carbon-Based Solid Acid by Sulfonation Reaction to Reinforce Natural Rubber Latex

本研究成果由韓國科技與教育大學應用化工工程系 Li, Xiangxu 等人所發表，由於脫乙酰殼多醣（CS）是一種天然高分子材料，且具有強大的生物相容性和非毒性，因此廣泛的應用於醫藥領域和生物化學領域，例如繃帶及抗菌劑，亦可協助藥物透過皮膚進行傳遞。然而，未經加工的純殼聚醣無法直接應用於天然橡膠材料上，因此本研究利用竹炭表面上多孔結構的特性來進行改善。在本研究中，首先純殼聚醣（CS）通過磺化反應的方法固定於竹炭上，使磺化殼聚醣結合竹炭形成強大的鋼筋屬性，接著再以備竹炭碳基磺化殼聚醣（CBSE）與天然橡膠（NR）混和後，提升橡膠之抗菌屬性，以達到應用於生物複合材料作爲醫療及食品應用之目的。

四、2 月 20 日

本日爲發表論文安排報告的期程，預定於 10:30 至 12:00 的 Lotus Room 場次進行，議程主持人爲韓國成均館大學的 Seokho Yoon 教授，本次發表的論文內容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。現場學者於報告結束後對機電整合及實現方法等相關內容提出疑問，並給予相關建議與經驗交流，對未來此領域進一步的研究方向有良好的參考價值，並奠定持續研究之信心。

五、2 月 21 日

在經過連日的研討會行程後，今日上午於飯店充分休息後，於中午搭乘地鐵抵達樟宜機場後，搭乘當地 15:45 起飛之長榮班機，並於晚間 20:15 抵達國門，順利完成本次新加坡國際研討會論文發表行程。

参、心得及建議：

出席研討會實爲寶貴之經驗，不過因自身忙於發表內容準備等事項，疏於了解當地之交通方式、生活習慣與風土民情（例如地鐵路線、搭乘手扶梯要靠左等），幸虧同行老師從旁協助提點，才免於鬧出許多笑話，建議未來參與國際學術活動的同仁在專注於專業之餘，也能抽空對前往當地多做點功課，才能讓任務更加順遂。而在異地生活後，才深刻體會在國內生活的寶貴之處，例如高昂的物價，隨便一碗路邊攤的麵食就要百來元台幣，而水資源更是彌足珍貴，在台灣餐廳視爲理所當然應該提供的濕紙巾，在新加坡使用後則是要額外付錢的！而新加坡雖然僅數個台北大小，卻必須長途跋涉才能找到一間在台灣隨處可見的便利商店，規模更只有台灣傳統雜貨店的規模！便利商店都不便利了。儘管如此，新加坡還是有令人佩服的地方，例如國際化的程度，在地鐵搭乘的人們可以用上一秒用英文傳遞 LINE 訊息；下一秒卻切回觀看中文字幕的韓劇，而大部分具有華人面孔的人們還能同時用英文與中文交替溝通，這是我國推行多年國際化尚不能達到的境地，一個國土不大的國家能融合如此多的族群，且還能維持如此旺盛的活力，著實是難能可貴的！

最後，也感謝各級同仁在繁瑣的行政程序中所給予的各項熱心協助，更感謝科技部所提供寶貴經費，才能讓這次的發表行程順利成行。期許自己能維持這樣的動力與勇氣，堅持在國際學術領域上展現自我！

肆、參考資料：

補充參加研討會所記錄之場地及議程照片。

研討會地點指示牌(1)

TICEAS, GCBENS, APSSSM, ICEASS

Conference Floor Guide

Lilac Room

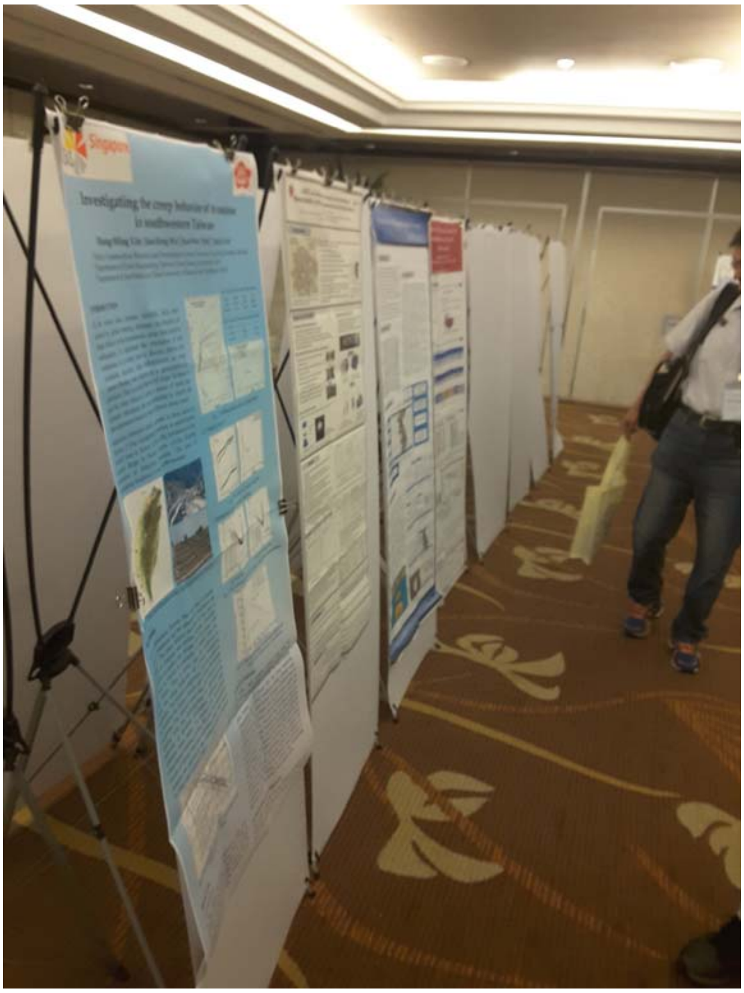
Lotus Room

Conference Schedule

研討會地點指示牌(2)


LOTUS
Oral Session
Lotus, 5F
Saturday, February 20, 2016
08:45-10:15
Computing Science & IT Engineering
10:30-12:00
Electrical & Electronic Engineering
13:00-14:30
Mechanical Engineering
Civil Engineering (2)
14:45-16:15
Education (4)
16:30-18:00

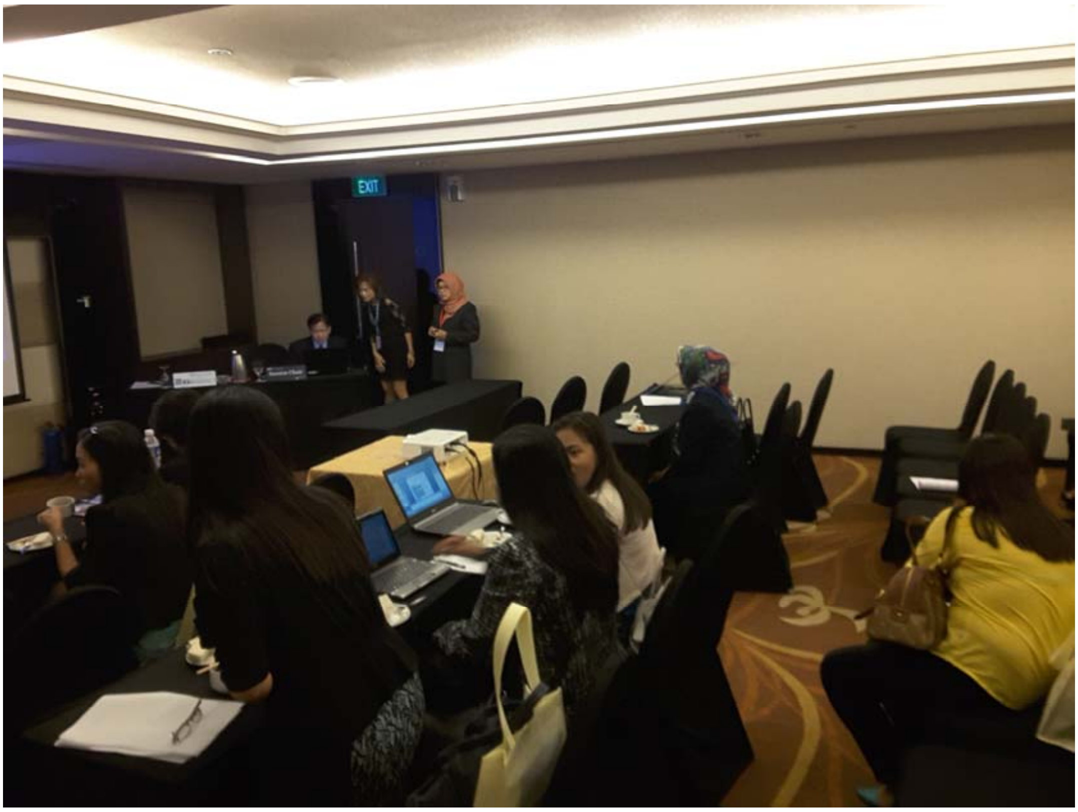
研討會場外



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)

伍、會議資料：

（收錄於論文集光碟片自然科學領域第 205 頁，編號第 1316 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.

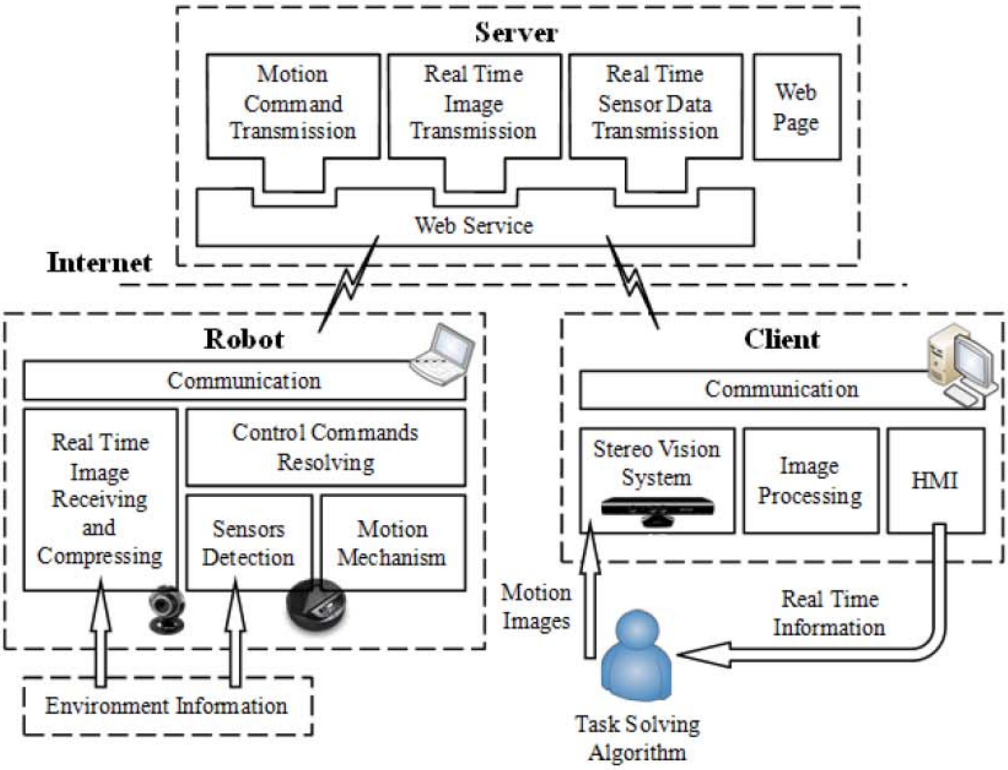


Fig. 1: System architecture of SVSRC on mobile robot [10].

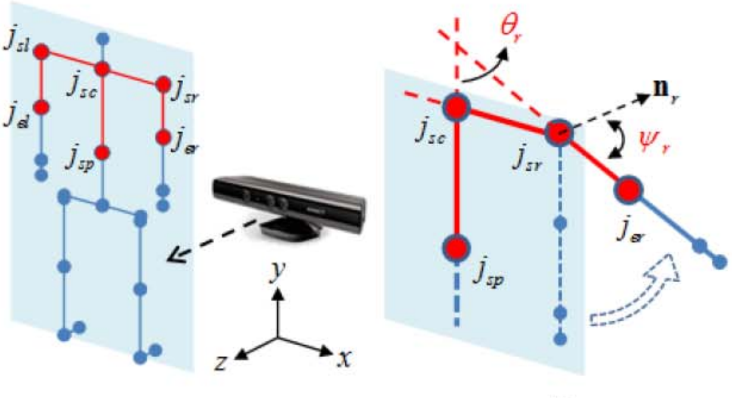
3. Motion Analysis and Control Command Creation

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.



(a) (b)

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.

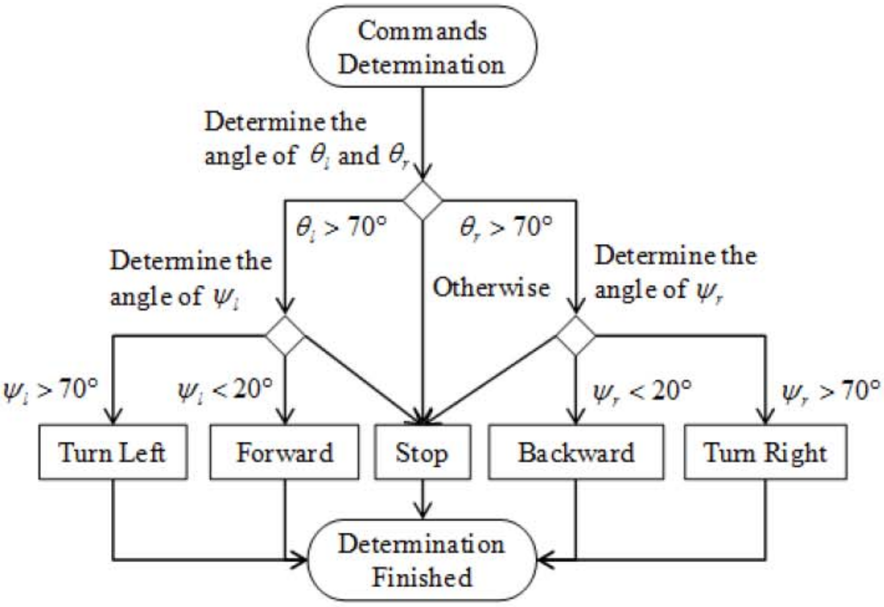


Fig. 3: Control commands determination flowchart.

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.

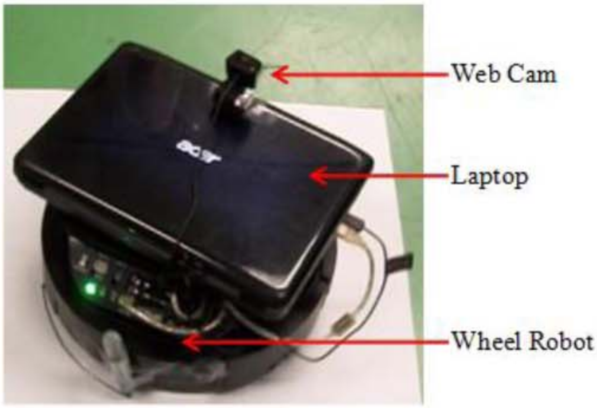


Fig. 4: Structure of robot module.

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.

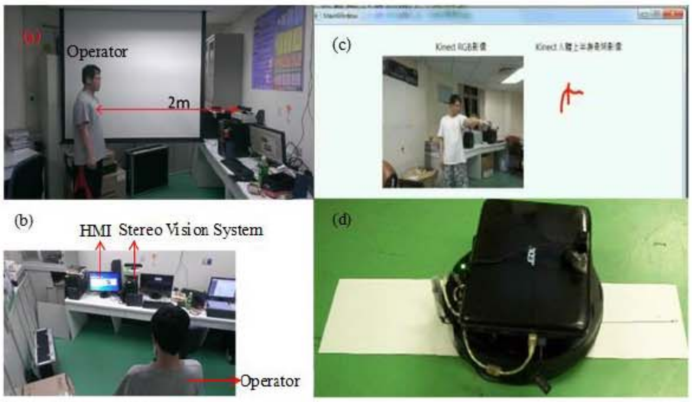


Fig. 5: (a) Operator, (b) Computer with stereo vision system and HMI, (c) HMI, and (d) operation result.

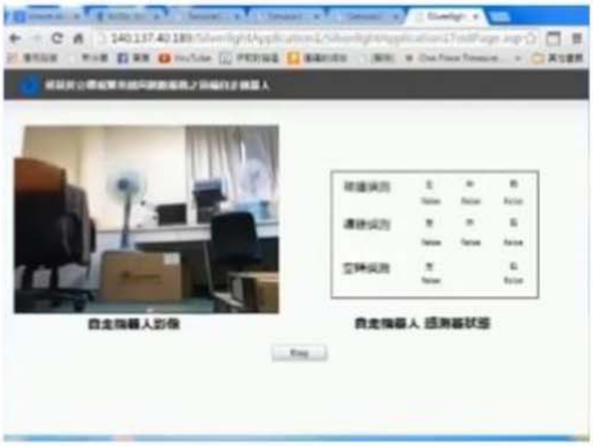


Fig. 6: Image of web cam on remote robot monitored by browser.

4.3 Acknowledgments and Legal Responsibility

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