DEVELOPMENT OF TELEMEDICINE SYSTEM FOR REMOTE BIOMEDICAL OPERATION

ABDULHAKIM ABDULLAH AL-EZZI MOHAMMED

A thesis is submitted in partial
fulfillment of the requirement for the award of the
Degree of Master of Electrical Engineering

FACULTY OF ELECTRICAL AND ELECTRONICES ENGINEERING

JUNE 2017

Dedication

I dedicate this piece to my beloved father, mother, my brothers and sisters who had inspiring me during my study time and to all my beloved family and friends.

ACKNOWLEDGEMENT

Foremost, all praises to Almighty ALLAH, who give me strength and perseverance to make me able to complete this master degree, without ALLAH I cannot do anything in this life. Therefore, he is the only one I have to be thankful for him from heart.

I would like to express the deepest gratitude to my honorable supervisor ASSOCIATE PROF DR. MUHAMMED MAHADI BIN ABDUL JAMIL for his kind support, valuable ideas, assistance, guidance and encouragement throughout this thesis.

My greatest appreciation goes to all my friends who always helped and motivated me during my master degree and through this project especially my eldest brother DR Hani bin Abdullah AL-Ezzi for being guiding star throughout my education time.

Last but not least, with all of my love, I would like to express my honest thanks to all my family members for their love, encouragement, prayers and motivations a long all years of my life. I am deeply and forever indebted to my parents and brothers for their unconditional support, both financially and emotionally throughout my entire study. Without them I could not have made my study. I would like to truthfully acknowledge the sincere help and the moral support of all those inspired me to complete my study.

ABSTRACT

This study presents a system of teleoperation as a practical solution in order to eliminate the barriers and obstacles linked with deficiency of qualified medical experts in rural areas of the country. Therefore, in this work we presented an artificial robotic hand with comparable abilities to a human hand, such a multi finger gripper by using low cost artificial hand gripper (AHG). The (AHG) was printed in-house with a 3D printer. The (AHG) was designed with feasibility and flexibility for gripping activities such as opening and closing of hand by using 5 flex sensors, couple of force sensors and accelerometer sensor (master unit) positioned at each finger to measure finger flexion, extension, pressure and movements axis (x,y,z). The 5 fingers fixed activities controlled using a master unit which referred to as the smart glove. This system uses an Arduino mega microcontroller programmed for accurate and delicate detection respond via the master unit and transmitting to the slave unit. (AHG) has fast and real-time movement respond towards the activities created via the smart glove. An Ethernet shield and visual basic software were upgraded further in which master unit motion data were recorded and transmitted online through user friendly GUI system software, and the logged data can be further analyzed by other medical doctors for research, reference or diagnostic purposes.

ABSTRACT

Kajian ini membentangkan tentang sebuah sistem ' teleoperation' sebagai penyelesaian secara praktikal dalam mengurangkan halangan yang berkaitan dengan kekurangan tenaga pakar perubatan yang berkelayakan di kawasan luar bandar di negara ini. Oleh itu, dalam kajian ini, kami membentangkan tangan sebagai robot buatan yang berkebolehan setanding dengan tangan manusia yang sebenar. Contohnya seperti menggenggam jari dengan menggunakan penggengam tangan tiruan berkos rendah (AHG). AHG ini akan dicetak dengan menggunakan pencetak 3D. Ianya telah direkabentuk dengan fleksibiliti untuk melakukan aktiviti menggenggam seperti membuka dan menutup tangan dengan menggunakan 5 'flex' sensor, beberapa sensor kuasa (force sensor) dan sensor pecutan (master unit)

Ianya diletakkan di setiap jari untuk mengukur akhiran jari (flexion),sambungan (extension), tekanan dan pergerakan paksi x,y,z. Aktiviti yang dilakukan oleh 5 jari ini dikawal dengan menggunakan unit induk yang dikenali sebagai sarung tangan pintar. Sistem ini menggunakan Arduino mega mikropengawal yang diprogramkan untuk bertindakbalas pengesanan yang tepat dan halus melalui unit induk dan penghantaran ke unit haba. AHG mempunyai pergerakan masa yang cepat untuk bertindakbalas terhadap aktiviti yang diciptakan melalui sarung tangan pintar. Perisai 'Ethernet' dan perisai asas visual telah dipertingkatkan dimana data pergerakan unit induk telah direkodkan dan dihantar secara talian melalui perisian sistem GUI yang mesra pengguna.Data log juga boleh dianalisis oleh doktor perubatan bagi tujuan penyelidikan, rujukan atau tujuan diagnostik

CONTENT

LIST OF SYMBOLS AND ABBREVIATIONS

ADC	-	Analog to Digital Converter
ADL	-	Activity of Daily Living
AROM	-	Active Range Of Motion
AAROM	-	Active Assisted Range Of Motion
AC	-	Alternate Current
COM	-	Communication
CTRL	-	Control
DC	-	Direct Current
DOF	-	Degrees Of Freedom
EE	-	Energy Expenditure
EMG	-	Electromyography
FSR	-	Force Sensitive Resistor
GB	-	Gigabytes
GND	-	Ground
Hz	-	Hertz
ICSP	-	In Circuit Serial Programming
IDE	-	Integrated Development Environment
IMU	-	Inertial Measurement Unit
I2C	-	2 wire serial computer bus
LCD	-	Liquid Crystal Display
mm	-	milimeters
MMC	-	Multimedia Card

MTC	-	Minimum Toe Clearance
PC	-	Personal Computer
PIC	-	Programmable Integrated Circuit
PROM	-	Passive Range Of Motion
PWM	-	Pulse Width Modulation
RM	-	Measurement resistor
RROM	-	Resistive Range Of Motion
SD	-	Secure Digital
USB	-	Universal Serial Bus
UTHM	-	Universiti Tun Hussein Onn Malaysia
Vref	-	Reference Voltage
WSNs	-	Wireless Sensor Neworks
A	-	Ampere
g	-	Gravity force
K	-	Kilo
M	-	Mega
V	-	Voltage
W	-	Watt
X_Acc	-	Accelerometer’s X axis
Y_Acc	-	Accelerometer’s Y axis
Z_Acc	-	Accelerometer’s Z axis
˚C	-	Degree celcius
°	-	Degree
μF	-	Microfarads
μ	-	Micro
Ω	-	Ohm
%	-	Percent
3D	-	Three Dimensions
mV/g	-	Milivolt/force
ms^2	-	Acceleration

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

1.0 INTRODUCTION

This primary report gives a complete brief of the project. This project will start with background, in which it provides the general idea of this study. Then, problem statement will be discussed and stated. It gives an understanding about the trends and reasons to analysis and develops telemedicine system. Next, the objectives and scopes of project were listed, following by the outline of this report. The discussion of the result and analysis has an important aspect in this project, so we had discussed in chapter 4, finally the report will be concluded and give some recommendations.

1.1 Background of the study

Telemedicine and Surgical Robotics Technology have become adapted by world-wide medical surgeons, and had been integrated into today surgical procedures. There are many described systems have assisted the surgeon to perform their operation easier, more precise, more convenient and more confident than standard surgical. There are many researches had been conducted involved several surgical applications, such as, laparoscopic surgery, percutaneous breast biopsy, neurosurgery. Supporting and integrating information technology in medical sector have created several innovative concepts that create revolution in technical diagnosis and hand length patients [2, 4], such as remote robots and teleoperation system feeding the octagonal signal to the antenna.

A wearable completed glove-based master-slave tactile feedback system was created to provide users with a remote sense of touch. The constructive system features a force-sensing master glove with piezo resistive force sensors mounted at each fingertip, and a pressure-transmitting slave glove with silicone-based pneumatically controlled balloon actuators, mounted at each fingertip on another hand. A control system translates forces detected on the master glove system, either worn by a user or mounted on a robotic hand, to discrete pressure levels at the fingers of another user. This paper describes a complete prototype of tele-operation system by using low cost artificial hand gripper. The artificial hand grippers were printed in-house with a 3D printer. The artificial hand designed with feasibility and flexibility for gripping activities such as opening and closing of hand. The smart glove is equipped with 5 unit of flex and force sensors positioned at each finger with accelerometer sensor.

This system uses a microcontroller programmed for precise detection respond via the master unit and transmitting to the slave unit. The artificial hand has fast and real-time movement respond towards the activities manipulated via the smart glove.

1.2 Problem statement

The accurate and precise grasping of the robotic hand is the most difficult challenges that face engineers in designing any humanoid. Most of the previous robotic hands are providing this humanoid with high cost especially in medical field, so we have to design a robotic hand with low cost. Robotic hand that had been designed before have limited freedom of movement, so that invites us to create robotic hand with high flexibility bending. Many of previous researches and project just apply only three finger robots, through this project humanoid will be implemented with five fingers robot. Due to the luck of robotic hand that is connected to an online system, here will design humanoid robot connected to an online system. Moreover, the high cost of medical operation and monitoring invites us to create a simple and cheap product for medical operation.

1.3 Objectives

- To develop a telemedicine system for remote medical operation by using visual basic
- To develop a controller unit using microcontroller which enables to control five artificial fingers movement using tele- operation method and read the data online.
- To produce a teleoperation artificial five fingers robotic hand which imitates the human hand on with reliability and feasibility.

1.4 Scope of the project

The scopes of this project are as follow:

- The telemedicine system will be applicable & implemented for medical care.
- This study will focus on remote teleoperation electrical activity and movement by flex, force and accelerometer sensors.
- Communication part will be provided to transmit and receive data to slave unit by using microcontroller.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

The background of literature studies undertakes the development knowledge of the current state research in the selected area. This project is mainly concern about the system that used for telemedicine system for medial operation. In this section, we will discuss about the journal or research (literature review) activities that relate to the process with respect to the project. These have been done by author similarly to this project and can give some basic idea of what includes in this project as well.

This part of thesis continues discussion of the previous chapter which focuses on background of this work. It is embracing the literature review of project which includes the concept, theory, perspectives and the method of the project that is use in order to solve the problem that occur. This project was conducted in University Tun Hussein Onn Malaysia. For this literature review we are focusing on telemedicine system for online medical operation and surgery for patient who are away from the treatment center.

Many intensive works had been done in the trend of surgical side to perform and develop telemedicine system for surgery and operation on a patient even though they are not physically in the same location. It is a form of telepresence. A robot surgical system generally consists of one or more arms or artificial hand (controlled by the surgeon) a master controller (console), and a sensory system giving feedback to the user.

Remote surgery combines elements of robotics, cutting edge communication technology such as high-speed data connections and elements of management information systems.

While the field of robotic surgery is fairly well established, most of these robots are controlled by surgeons at the location of the surgery. Remote telemedicine for medical surgery is essentially advanced telecommuting for surgeons, where the physical distance between the surgeon and the patient is immaterial. It promises to allow the expertise of specialized surgeons to be available to patients worldwide, without the need for patients to travel beyond their local hospital.

A healthcare system in the last decade was made possible due to the recent advances in wireless and network technologies, linked with recent advances in nanotechnologies and computing systems. The term telemedicine refers to the utilization of telecommunication technology for medical diagnosis, treatment, and patient care.

The aim of telemedicine is to provide expert-based healthcare to understaffed remote sites through modern telecommunication and information technologies. One of the benefits of telemedicine is cost savings, because information is less expensive to transport than are people. Advances in medical technologies have led to accelerated growth of the elderly population in many countries, resulting in an increasing requirement for home health monitoring to ensure that elderly patients can lead independent lives. Many physiological signals can be measured and transmitted to control any humanoids activities for teleoperation purpose.

Surgical robot systems have been developed from the first functional tele-surgery system to the Surgical System, which is currently the only commercially available surgical robotic system. Used mainly for “on-site” surgery, these robots assist the surgeon visually, with better precision and less invasiveness to patients. The Surgical System has also been combined to form a Dual Da Vinci system which allows two surgeons to work together on a patient at the same time. The system gives the surgeons the ability to control different arms; hands switch command of arms at any point and communicate through headsets during the operation.

Developing a new glove interface that can manipulate many kinds of objects in virtual space by real hand movements is becoming crucial attention of researchers and clinical engineers for an online medical operation. This idea has the same form and material as a surgical glove, and the user's movements are unrestricted. Thus, while performing operations on a real human body, the user can control many kinds of data that are displayed in virtual space.

During operations, the surgeon can handle many kinds of data, for example, synchopexia, MRI images, 3DCT images, and time sequential 3D images by using this glove. Wireless technologies which are the most important development areas in the twenty-first century and Wireless Body Sensor Networks which are developed for use in health care continues to be the focus on attention of researchers. Wireless Body Sensor Networks are used for monitoring health signals such as body temperature, heart pulse, EEG, and ECG of the people who are old, chronic illness or weak and surgical and operation purposes

2.2 Construction of an artificial hand

The construction of an artificial hand able to reproduce the functions of the human hand has never been of interest in industrial robotics. The study of the natural systems can offer interesting solutions to many robotics problems. However, the objective has been more to copy the natural hand function than to build some new robotic hand. Out from our imagination, we found that many natural solutions can be implemented, and it had built a prototype. In the next future, we expect to continue on adding sensors to the hand. The future development includes a possible cooperation with a medical school to study the use of the hand as a prosthesis, and the development of the controller for the full hand in the direction of autonomous robotics. This figure will illustrate the structure of the human hand and propose a choice of materials and actuators that can copy the Human Hand in Structure and function.

The complete model and the prototype are also must be as the same functionality and size. For this project, it is highly preferred to use the 3D printing hand. It’s the 3D printed prosthetic devices that have been among the most revolutionary products made available with low cost and customizable nature of additive manufacturing.

While some of the earliest prosthetic devices provided basic functionality for those with minimal use of their fingers, the 3D printed prosthetic designs have literally created an entirely new industry that includes both non-profit organizations and professional designers aimed at further revolutionizing these amazing and low-cost enabling devices.

Figure 2.1: Shows 3D printed prosthetic designs (http://www.chw.net/2013/06/softhand-la-mano-bionica-con-el-mejor-desempeno-hasta-el-momento/,2013)

2.3 Construction of natural hand

The skeleton of the human hand consists of 27 bones the eight short carpal bones of the wrist are organized into a proximal row (scaphoid, lunate, triquetral and pisiform) which articulates with the bones of the forearm, and a distal row (trapezium, trapezoid, capitated and hamate), which articulates with the bases of the five metacarpal bones of the hand. The heads of the metacarpals will each in turn articulate with the bases of the proximal phalanx of the fingers and thumb. These articulations with the fingers are the metatarsophalangeal joints known as the knuckles.

The fourteen phalanges make up the fingers and thumb, and are numbered when the hand is viewed from an anatomical position. The four fingers each consist of three phalanx bones: proximal, middle, and distal. The thumb only consists of a proximal and distal phalanx. Together with the phalanges of the fingers and thumb these metacarpal bones forms five rays or poly-articulated chains.

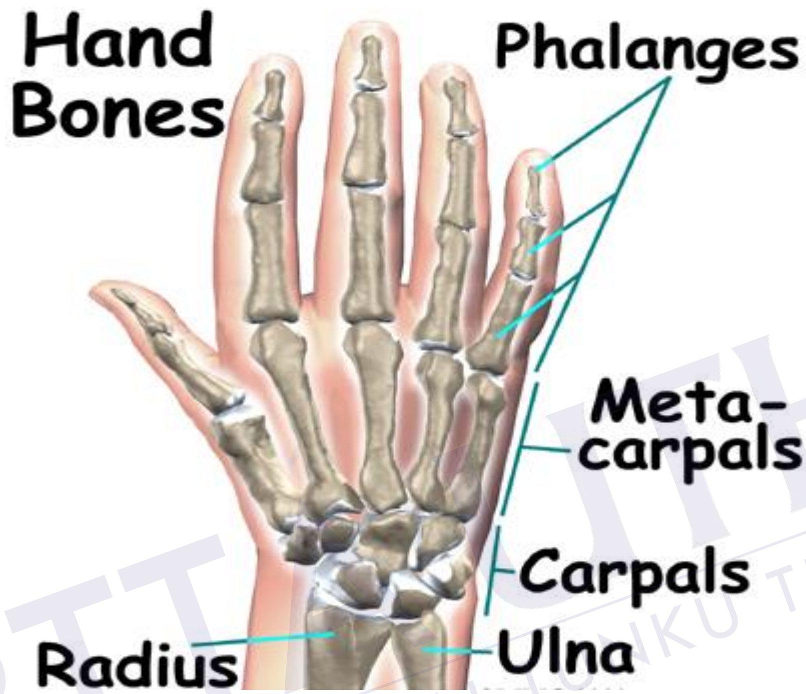

Figure 2.2: Shows construction of human hand (MMG 2013)

2.4 Literature review

Structurally and functionally human hand is a complex end-effector capable of a large variety of postures and shapes. Multifigured robot hands, such as the Belgrade SC hand, can approximate human hand functionality, and it is possible to consider their use in prosthetics. Sukhumi et all (1994) had developed a system, that can translate user commands into motor signals using the virtual finger concept. For control, electromyography (EMG) signals from forearm muscles are used. This paper described the system and its use of EMG signals. Simulation results were presented as well. These electromyography (EMG) signals had resulted from the activation of individual muscle fibers during contractions. Raw EMG signals are amplified, rectified, and filtered to produce a relatively smooth control signal. The amplitude of the hand motor voltage, and thus its speed and force, varies in direct proportion to the amplitude of the EMG signal generated by the user. Forces exerted between the fingers are proportional to the magnitude of the myoelectric control signal. The user has more sensitive slow and fast control of the hand, depending on the strength of the muscle contraction. These EMG controlled systems also fall far short of displaying the adaptability and versatility of the human hand. The design of more versatile prosthetic hands has been hampered by the need for small finger actuators, light weight, low power requirements, sensors, intelligence without large computation loads, and control sites. Clearly, these are major engineering problems. However, perhaps the biggest single problem in the past has been the lack of a theory of grasping, which could provide a parametric description of the hand and allow for an analytical determination of the appropriate match between the hand properties and task requirements. In order to control a multifunctional prosthetic hand, they designed and developed a human-prosthesis interface which allows the user to control the device as naturally as possible with free motions.

Brain Computer Interface (BCI) had opened up a new hope for people suffering from severe motor disabilities, having no physical activities caused due to disease or injury to the central or peripheral nervous system.

A BCI based robotic arm movement control is designed and implemented by Shashibala et al (**2016**). The proposed system acquires data from the scalp of subjects a group of sensors. Emotive EPOC a commercially available EEG headset is used, which analyzes the acquired EEG signals real time. The signals are processed and accordingly commands are issued for different movements which will be based on the characteristic patterns for various facial expressions, human emotions and cognitive actions. The idea is to combine the user intent with a robotic arm to achieve the user initiated motor movements. The basic idea of Brain-computer interfaces (BCI) is to transform user created patterns of brain activity into corresponding commands. BCI systems bypass regular channels of communication to supply direct communication and management between the human brain and physical devices by translating different patterns of brain activity into commands in real time. With these commands robotic devices can be controlled.

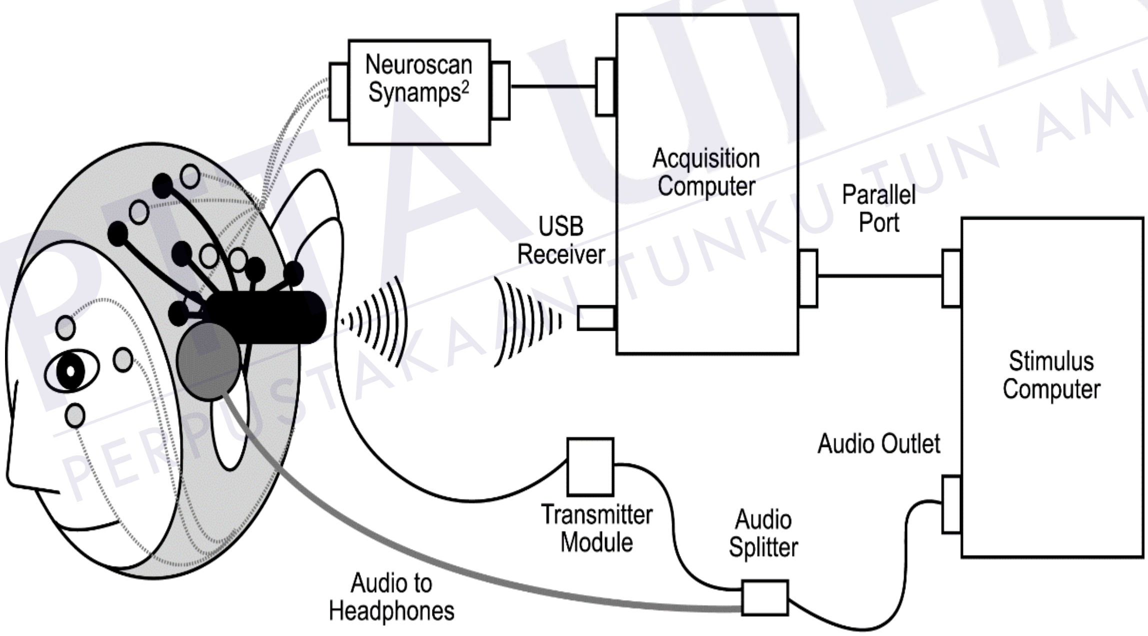

Figure 2.3: Shows brain computer interface system (Shashibala 2016)

A brain machine interface (BMI) facilitates the control of machines through the analysis and classification of signals directly from the human brain. Damodaran et al had designed a new implementation of the BCI system addressed here that has proven to be effective for identifying actions from the EEG brainwave signals. This work will enhance the successful controlling rate to the robotic arm with that of the normal human thoughts and brain actions evolves as of the normal human penetration and working Using an electroencephalograph (EEG) to detect neurological activity permits the collection of data representing brain signals without the need for invasive technology or procedures. A 14-electrode headset is used to capture live data, which can then be classified and encoded into control signals for a 7-degree -of-freedom robotic arm. The collected EEG data is classified into one of four control signals: lift, lower, rotate clockwise, and rotate counter -clockwise. Additionally, the system watches the collected data for electromyography (EMG) signals indicative of movement of the facial muscles. Detections are used to incorporate two additional control signals: open and close. A personal set of EEG data patterns is trained for each individual, with each control signal requiring only a few minutes to train initially. EMG signal detections are measured against a generic threshold for all users. Once a user has trained their personal data into the system any positive detection triggers a signal to the interfaced robotic arm to perform a corresponding, discrete action.

One more advanced work had presented by Raheja et al (2010) who applied a new approach for controlling robotic hand or an individual robot by merely showing hand gestures in front of a camera. With the help of this technique one can pose a hand gesture in the vision range of a robot and corresponding to this notation, desired action is performed by the robotic system. Simple video camera is used for computer vision, which helps in monitoring gesture presentation. This approach consists of four modules: (a) A real time hand gesture formation monitors and gesture capture, (b) feature extraction, (c) Pattern matching for gesture recognition, (d) Command determination corresponding to shown gesture and performing action by robotic system. Real-time hand tracking technique is used for object detection in the range of vision. If a hand gesture is shown for one second, the camera captures the gesture.

The object of interest is extracted from the background and the portion of hand, representing the gesture, is cropped out using the statistical property of hand. Extracted hand gesture is matched with the stored database of hand gestures using pattern matching. Corresponding to the matched gesture, action is performed by the robot. The main purpose of gesture recognition research is to identify a particular human gesture and convey information to the user pertaining to individual gesture.

EFERENCES

[1] Shashibala, T., & Gawali, B. W. Implementation of Robotic arm control with Emotiv Epoc.

[2] Damodaran, S. EEG–ZigBee based Brain Controlled Robotic Arm (EZB-Arm).

[3] Raheja, J. L., Shyam, R., Kumar, U., & Prasad, P. B. (2010, February). Real-time robotic hand control using hand gestures. In *Machine Learning and Computing (ICMLC), 2010 Second International Conference on* (pp. 12-16). IEEE

[4] Li, C., Ma, H., Yang, C., & Fu, M. (2014, July). Teleoperation of a virtual icub robot under framework of parallel system via hand gesture recognition. In *2014 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)* (pp. 1469-1474). IEEE

[5] Wongwirat, O., & Ohara, S. (2006). Haptic media synchronization for remote surgery through simulation. *IEEE MultiMedia*, *13*(3), 62-69.

[6] Iberall, T., Sukhatme, G. S., Beattie, D., & Bekey, G. A. (1994, May). On the development of EMG control for a prosthesis using a robotic hand. In *Robotics and Automation, 1994. Proceedings., 1994 IEEE International Conference on* (pp. 1753-1758). IEEE

[7] Tanikawa, T., Arai, T., & Hashimoto, Y. (1997, September). Development of vision system for two-fingered micro manipulation. In *Intelligent Robots and Systems, 1997. IROS'97., Proceedings of the 1997 IEEE/RSJ International Conference on* (Vol. 2, pp. 1051-1056). IEEE

[8] Villarruel, J. E. G., & Corona, B. T. (2008, September). Proposal for a Remote Surgery System Based on Wireless Communications, Electromyography and Robotics. In *Electronics, Robotics and Automotive Mechanics Conference, 2008. CERMA'08* (pp. 93-98). IEEE

[9] Yang, Y., Chen, H., Lou, Y., & Lin, W. (2014, December). Remote master-slave control of a 6D manipulator for cardiac surgery application. In *Robotics and Biomimetics (ROBIO), 2014 IEEE International Conference on* (pp. 1799-1804). IEEE

[10] Meng, C., Wang, T., Chou, W., Luan, S., Zhang, Y., & Tian, Z. (2004, April). Remote surgery case: robot-assisted teleneurosurgery. In *Robotics and Automation, 2004. Proceedings. ICRA'04. 2004 IEEE International Conference on* (Vol. 1, pp. 819-823). IEEE

[11] Kim, D., Kim, J., Lee, K., Park, C., Song, J., & Kang, D. (2009). Excavator tele-operation system using a human arm. Automation in construction, 18(2), 173-182.

[12] Gupta, G. S., Mukhopadhyay, S. C., & Finnie, M. (2009, May). WiFi-based control of a robotic arm with remote vision. In Instrumentation and Measurement Technology Conference, 2009. I2MTC'09. IEEE (pp. 557-562). IEEE.

[13] Low, J. H., Lee, W. W., Khin, P. M., Thakor, N. V., Kukreja, S. L., Ren, H. L., & Yeow, C. H. (2017). Hybrid Tele-Manipulation System Using a Sensorized 3-D-Printed Soft Robotic Gripper and a Soft Fabric-Based Haptic Glove. IEEE Robotics and Automation Letters, 2(2), 880-887.

[14] Zubrycki, I., & Granosik, G. (2013, July). Test setup for multi-finger gripper control based on robot operating system (ros). In Robot Motion and Control (RoMoCo), 2013 9th Workshop on (pp. 135-140). IEEE.

[15] Wang, D., Ni, L., Rossi, M., & Tuer, K. (2004, October). Implementation issues for bilateral tele-mentoring applications. In Haptic, Audio and Visual Environments and Their Applications, 2004. HAVE 2004. Proceedings. The 3rd IEEE International Workshop on (pp. 75-79). IEEE.

[16] Marín, R., Sanz, P. J., Nebot, P., & Wirz, R. (2005). A multimodal interface to control a robot arm via the web: a case study on remote programming. IEEE Transactions on Industrial Electronics, 52(6), 1506-1520

[17] Diner, Daniel B., and Steven C. Venema. "Composite video and graphics display for camera viewing systems in robotics and teleoperation." U.S. Patent 5,182,641, issued January 26, 1993.

[18] Abbou, C. C., Hoznek, A., Salomon, L., Olsson, L. E., Lobontiu, A., Saint, F., ... & Chopin, D. (2001). Laparoscopic radical prostatectomy with a remote controlled robot. The Journal of urology, 165(6), 1964-1966.

[19] Bejczy, A. K., Kim, W. S., & Venema, S. C. (1990, May). The phantom robot: predictive displays for teleoperation with time delay. In Robotics and Automation, 1990. Proceedings., 1990 IEEE International Conference on (pp. 546-551). IEEE.

[20] Corke, P. (2011). Robotics, vision and control: fundamental algorithms in MATLAB (Vol. 73). Springer.

[21] Hirai, K., Hirose, M., Haikawa, Y., & Takenaka, T. (1998, May). The development of Honda humanoid robot. In Robotics and Automation, 1998. Proceedings. 1998 IEEE International Conference on (Vol. 2, pp. 1321-1326). IEEE.

[22] Fisher, S. S., McGreevy, M., Humphries, J., & Robinett, W. (1987, January). Virtual environment display system. In Proceedings of the 1986 workshop on Interactive 3D graphics (pp. 77-87). ACM.

[23] Wang, Yulun, and Louis Kavoussi. "Apparatus and method for patient rounding with a remote controlled robot." U.S. Patent No. 7,289,883. 30 Oct. 2007.

[24] Morgrey, Richard. "Remote controlled, multi-legged, walking robot. " U.S. Patent No. 5,158,493. 27 Oct. 1992.

[25] Wang, Yulun, Charles S. Jordan, Marco Pinter, and Michael C. Chan. "Remote controlled mobile robot with auxillary input ports." U.S. Patent Application 11/542,605, filed October 2, 2006.

[26] Wang, T., Zhang, D., & Da, L. (2010). Remote-controlled vascular interventional surgery robot. The International Journal of Medical Robotics and Computer Assisted Surgery, 6(2), 194-201.

[27] A.H. Arieta, R. Katoh, H. Yokoi and Y. Wenwei, "Development of a multi-DOF electromyography prosthetic system using the adaptive joint mechanism", ABBI, 2006 vol 3, No. 2, pp. 1-10.

[28] R.N. Scott and P.A. Parker, "Myoelectric Prosthesis: state of the art", Journal of Biomed. Eng. & Tech., 1988, 12(4), pp. 143-151.

[29] S.L. Pullman, D.S. Goodin, A.I. Marquinez, S. Tabbal and M. Rubin, "Clinical Utility of surface EMG", Neurology, American Academy of Neurology, July 20005(5), pp. 171-177.

[30] Javier González, Francisco Ramírez, Daniel Santana, "RF System Concepts applied to Digital wireless receivers design", presented in ENINVIE 2005, Encuentro de Investigación en Ingeniería, Zacatecas, México

[31] Reza Hassanpour, Stephan Wong, Asadollah Shahbahrami, "VisionBased Hand Gesture Recognition for Human Computer Interaction: A Review", IADIS International Conference on Interfaces and Human computer Interaction, pp. 25-27, July 2008.

[32] Jae-Ho Shin, Jong-Shill Lee, Se-Kee Kil, Dong-Fan Shen, Je-Goon Ryu, Eung-Hyuk Lee, Hong-Ki Min, Seung-Hong Hong, "Hand Region Extraction and Gesture Recognition using entropy analysis", IJCSNS International Journal of Computer Science and Network Security, vol. 6, no. 2A, pp. 216-222, 2006.

[33] Moezzi, R. Jain, "ROBOGEST: Telepresence Using Hand Gestures", VCL-94–104 University of California San Diego, 1994.

[34] D. Kortenkamp, E. Huber, R. P. Bonasso, "Recognizing and Interpreting Gestures on a Mobile Robot", AAAI96, 1996.

[35] Didier Coquin, Eric Benoit, Hideyuki Sawada, Bogdan Ionescu, "Gestures Recognition Based on the Fusion of Hand Positioning and Arm Gestures", Journal of Robotics and Mechatronics, vol. 18, no. 6, pp. 751-759, 2006.

[36] L. Brthes, P. Menezes, F. Lerasle, J. Hayet, "Face tracking and hand gesture recognition for human robot interaction", International Conference on Robotics and Automation, pp. 1901-1906, 2004.