DEVELOPMENT OF REAL-TIME MULTI POSE FACE RECOGNITION AND TRACKING SYSTEM

MANIMEHALA NADARAJAN

FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
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Taman Seri Gombak,
68100 Batu Caves,
Selangor Darul Ehsan

(Ir. Dr. Muralindran Mariappan)
Penyelia Utama

Tarikh: 31 Mei 2016

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been fully acknowledged.

31 May 2016

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MANIMEHALA NADARAJAN
MK1211006T

CERTIFICATION

NAME	:	**MANIMEHALA NADARAJAN**
MATRIC NUMBER	:	**MK1211006T**
TITLE	:	**DEVELOPMENT OF REAL-TIME MULTI POSE FACE RECOGNITION AND TRACKING SYSTEM**
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VIVA DATE	:	**28 MARCH 2016**

DECLARED BY;

1. MAIN SUPERVISOR

Ir. Dr. Muralindran Mariappan Signature

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2. CO- SUPERVISOR

Dr. Rosalyn R. Porle

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ABSTRACT

The birth of telepresence robots in healthcare industries has made a significant transformation in the last few decades. Telepresence robot is remotely connected and embodied to perform several task such as patient monitoring, diagnosis, surgery and other task. Due to poor infrastructure especially in the interior of developing countries, a Medical Telediagnosis Robot (MTR) which works with a low bandwidth and on a low cost platform was developed. Unlike other tele-presence robots, MTR is capable of performing remote diagnosis during medical emergencies as it is equipped with basic medical instruments and dual vision system which comprises of a visual diagnostic system and a visual communication system. Visual communication system in MTR provides a basic face-to-face communication. The application of biometric system using face can greatly improve the current visual communication system as it is currently limited for only manual face recognition and tracking. It is difficult for the remote medical specialist to keep the patient and medical staff in an ideal field of view (FOV). It is also necessary for the remote medical specialist to identify the correct patient and medical staffs for diagnosis and verbal communication. To circumvent this problem, a real time face detection, recognition and tracking system (DRiT) is developed. To achieve a real time system, the DRiT system is designed with four modules which are operated in sequence and thus minimizing the execution time. Other challenges that were circumvented by the DRiT system are multi face pose, varying background condition during camera movement and changes in environment lighting with respect to time. DRiT is fully designed in LabVIEW platform which integrates software, hardware and GUI modules to complement with the current MTR platform. The background, lighting conditions and face pose were solved using hybrid approach utilizing skin color information to detect face. Neural Network was deployed to identify the profile of a person in multi poses and distances. A hardware together with software based face tracking is designed to ensure that the face region is still within the tracking view. Tracking a person continuously in a wider angle is a challenging task but this has been successfully achieved with DRiT system using a pan and tilt unit. DRiT is a standalone platform which is activated once the robot is navigated to the desired area. DRiT system creates a better visual communication between remote specialist and hospital members as the remote medical specialist will no longer require to execute manual control of the robot. The developed DRiT system was experimentally tested in real time and it yields an accuracy of 98% with an execution time of 56 ms.

ABSTRAK

PEMBANGUNAN SISTEM PENGECAMAN DAN PENGESANAN MUKA DALAM MASA NYATA BAGI PELBAGAI POSISI

Kelahiran robot telekehadiran di industri kesihatan menjangkau transformasi yang ketara sejak kebelakangan ini. Robot telekehadiran yang dikawal dari jauh berupaya melaksanakan beberapa tugas seperti pemantauan pesakit, diagnosis, pembedahan dan sebagainya. Kemudahan yang kurang memuaskan di kawasan pedalaman di negara- negara membangun menjurus kepada pembangunan Robot Perubatan Telediagnosis (MTR) yang berupaya untuk beroperasi pada bandwidth dan platform yang berkos rendah. Berbanding dengan robot telekehadiran yang lain, MTR berupaya membuat diagnosis dari jauh semasa kecemasan kerana robot ini dilengkapi dengan alat- alat perubatan asas dan juga sistem dual visual yang terdiri daripada sistem diagnostik dan sistem komunikasi visual. Sistem komunikasi visual dalam MTR menyediakan komunikasi asas muka-ke-muka. Aplikasi sistem biometrik menggunakan muka boleh mengembangkan sistem komunikasi visual semasa yang terhad kepada pengecaman dan pengesanan secara manual. Ianya sukar bagi pakar perubatan yang berhubung dari jauh untuk memastikan bahawa pesakit dan kakitangan perubatan berada di medan penglihatan yang sesuai (FOV). Selain itu, pakar perubatan harus mengenal pasti identiti pesakit dan kakitangan perubatan yang betul semasa diagnosis dan komunikasi verbal. Bagi mengatasi masalah ini, sistem pengecaman dan pengesanan muka dalam masa nyata telah dibentuk (DRiT). Bagi membolehkan operasi dalam masa nyata, sistem DRiT dibentuk dengan empat modul yang diproses mengikut turutan. Oleh itu, masa perlaksanaan dapat dikurangkan. Antara cabaran-cabaran lain yang ditangani oleh sistem DRiT adalah posisi muka yang berlainan, latar belakang yang berubah berikutan pergerakan kamera dan keadaan cahaya yang berubah pada satu- satu masa. DRiT direka sepenuhnya dalam perisian LabVIEW yang mengintegrasikan perisian, perkakasan dan modul GUI bagi memastikan DRiT berfungsi di atas platform yang sama seperti MTR. Masalah latar belakang dan pencahayaan telah diatasi dengan menggunakan pendekatan hibrid yang menggunakan maklumat warna kulit untuk mengesan muka. Rangkaian Neural telah digunakan untuk mengenalpasti profil seseorang dalam pelbagai posisi dan jarak. Pengesanan muka secara perkakasan dan persisian direka bagi memastikan muka masih berada di pandangan pengesanan. Mengesan seseorang secara berterusan dalam sudut yang lebih luas merupakan satu tugas yang mencabar tetapi telah berjaya dicapai oleh sistem DRiT dengan menggunakan pan dan tilt unit. DRiT berfungsi atas platform sendiri yang diaktifkan apabila robot telah digerakkan ke kawasan yang diingini. Sistem DRiT mewujudkan komunikasi visual yang lebih baik antara ahli yang berhubung jauh dengan ahli di hospital kerana pakar perubatan tidak perlu mengawal robot secara manual. Sistem DRiT telah diuji dalam masa nyata dan menghasilkan kejituan sebanyak 98% dengan masa perlaksanaan sebanyak 56 ms.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligence
ANN	-	Artificial Neural Network
BP	-	Backpropagation
BPNN	-	Backpropagation Neural Network
CAMSHIFT	-	Continuously Adaptive Mean Shift Algorithm
CCP	-	Capture Compare PWM
CCPR	-	Capture Compare PWM Register
CMOS	-	Complementary Metal-Oxide Semiconductor
COMPORT	-	Communication Port
CRT	-	Cathode Ray Tube
DC	-	Direct Current
DCT	-	Discreet Cosine Transform
DOF	-	Degree of Freedom
DRiT	-	Detection, Recognition and Tracking System
EBGM	-	Elastic Bunch Graph Matching
FOV	-	Field of View
GUI	-	Graphical User Interface
HMM	-	Hidden Markov Model
HSI	-	Hue Saturation Intensity
HSL	-	Hue Saturation Luminance
HSV	-	Hue Saturation Value
I/O	-	Input Output
ICA	-	Independent Component Analysis
ID	-	Identification
JPEG	-	Joint Photographic Experts Group
LabVIEW	-	Laboratory Virtual Instrument Engineering Workbench
LBP	-	Local Binary Pattern
LDA	-	Linear Discriminant Analysis
LED	-	Light Emitting Diode
MATLAB	-	Matrix Laboratory
MLP	-	Multi Layer Perceptron

MSE	-	Mean Squared Error
MTR	-	Medical Telediagnosis Robot
NN	-	Neural Network
OSC	-	Oscillator
PC	-	Personal Computer
PCA	-	Principal Component Analysis
PIC	-	Peripheral Interface Controller
PIN	-	Personal Identification Number
PLL	-	Phase Locked Loop
PT	-	Pan Tilt
PTZ	-	Pan Tilt Zoom
PWM	-	Pulse Width Modulation
RAM	-	Random Access Memory
RBF	-	Radial Basis Function
RFID	-	Radio Frequency Identification
RGB	-	Red Green Blue
ROI	-	Region of Interest
SIFT	-	Scale Invariant Feature Transform
SOM	-	Self Organizing Map
SVM	-	Support Vector Machine
USB	-	Universal Serial Bus
USB Cdc	-	USB Communication Device Class
VISA	-	Virtual Instrument Software Architecture

LIST OF SYMBOLS

$\oplus$	-	Dilation
$\ominus$	-	Erosion
d	-	decimal
D	-	distance
h	-	hexa
M	-	Mega
π	-	pi
μ	-	Mean
Pdv	-	Decimal Value Parameter
θ_T	-	Total Angle of Rotation
V_{max}	-	Maximum Decimal Value
V_{min}	-	Minimum Decimal Value
θ'	-	New Angle
θ	-	Old Angle
Vc'	-	New Coordinate in Decimal
Vc	-	Old Coordinate in Decimal
$\triangle\theta$	-	Angle difference

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CHAPTER 1

INTRODUCTION

1.1 Overview of Robots

Robots are developed to accommodate the growing number of tasks in today's society. The use of robots are undeniable since many years ago. With the advancement of technology, robotics has been developing vastly and has a diverse application from sea to space. By and large, robots have major contributions as they are capable in doing many tasks. Robots are categorized according to the type of application as summarized in Figure 1.1.

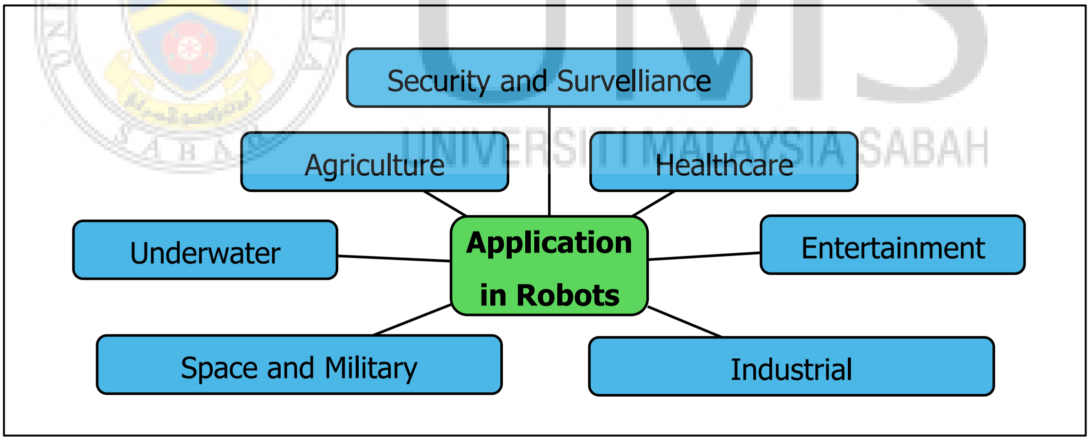

Figure 1.1: Applications of Robots.

Robotics has achieved a remarkable transformation in the healthcare industry in the last few years. The dawn of medical robots in hospital applications has immensely enhanced the services offered in the hospitals. There are many mundane tasks in hospital that require the assistance of a robot and thus, many robots were built to execute corresponding chores. Such featured robots are surgical robot

(Bergeles and Yang, 2014), patient lifting robot (Ding *et al.*, 2013), rehabilitation robots (Veneman *et al.*, 2007), service robot (Carreira *et al.*, 2006) and therapy robot (Wada and Shibata, 2007). Meanwhile, the rise of telepresence robot resulted in a large reap in medical fields. Telepresence robot have the benefit of providing a closer connection between two ends of users. This case is often highlighted in healthcare industries (Lu and Hsu, 2011).

1.2 Vision System in Telepresence Robot

Telepresence robots are designed with several modules such as navigation, communication and vision system. At present, the most common vision system deployed is usually used for the basic remote visual communication which is focused on a face-to-face communication. The people in the hospital communicates with the remote personal through a screen fixed on the robot. In fact, the patient will feel as if the doctor is near to them.

In the last few years, the development of vision system in medical telepresence robot has been improving drastically where biometric methods have been incorporated. Biometric is defined as the science of knowing a person from his inherent attributes (Reza *et al.*, 2012). There are many existing biometric methods such as face, fingerprint, gait, keystroke and others. The selection of a biometric method is based on the application of robot.

In a telepresence robot, audiovisual communication is one of the modules which corporates audio and visual (Mariappan *et al.*, 2014c). This enables the remote doctor to hear and talk (audio) and see (visual) with the patient and nurse. Besides, it was mentioned in a study that sight carries the highest percentage in a telepresence robot which is 70% and followed by hearing which is 20% (Salvini *et al.*, 2006). A study conducted by Vespa *et al.* (2007) shows that visual (face) information obtained a higher score than the verbal information (speech). This justifies that vision is a more powerful tool than audio.

Since visual carries more weight than audio, thus face is utilised to develop the advance vision system in telepresence robot. Therefore, biometric system using face is the most favourable to be applied in a telepresence robot. Some of the telepresence robot operating in hospital environment that has biometric face technology system are RP- Vita by Intouch Health (2015), Security Warrior by Luo *et al*. (2007) and SIRA by Bergasa *et al*. (2004). However, these robots has several disadvantages such as manual tracking and limitation for non-frontal face poses. This explains that the use of vision system with biometric method is still in developing stage for application in hospital telepresence robot.

1.3 Research Motivation

The use of telepresence robots has gained advantage recently. The benefit of the appearance in telepresence robot has been proven in many literature studies. In developing countries, rural healthcare lack of specialists who are the decision maker for every patient admitted. A specialist cannot commit or make any decision without having a firsthand contact with any patient. These concepts were then adapted by Mariappan *et al*. (2014c) to develop Medical Telediagnosis Robot (MTR) as illustrated in Figure 1.2.

Figure 1.2 : Medical Telediagnosis Robot (MTR).
Source : Mariappan *et al*. (2014c)

MTR is a form of telepresence robot that can aid in performing diagnosis during medical emergencies for patient with severe limb injuries. MTR allows medical specialist to remotely communicate live with the recipients (patient, nurse or medical officer) and being virtually present to provide directions in a medical procedure during an emergency or telerounding.

The visual communication system designed in MTR is focused on basic face-to-face communication which does not recognize or track the person's face automatically. In brief, MTR is manually controlled by the remote specialist with an aid of joystick which can be rotated at different directions. The control of joystick will allow the recipient to be in the ideal field of view (FOV) throughout the communication process. This is merely a traditional way of controlling a robot which will create a detachment between the specialist and the recipients because the doctor may not be able to pay his attention to the patient during diagnosis. This condition worsens when the recipients unintentionally leave the camera's FOV during the examination period. Once the switching between recipients takes place, the specialist will have to request for identity verification to ensure that he communicates with the right person. The repeated process of this action is not suitable to be done during an emergency.

To circumvent the problem, a real-time face recognition and tracking system (DRiT- detection, recognition and tracking) is designed to enhance the performance of visual interaction of MTR. DRiT can recognize a person who is registered in the database and thus a verbal communication is no longer needed. An automated face tracking with a hardware mechanism will ensure the person is still within the FOV. Thus, reducing the control of joystick by the remote specialist. The overall idea of DRiT system can fasten the tracking and verification process as DRiT system takes over the manual control of the robot. This system is comprised of several automated modules to execute various tasks namely face detection, face recognition and face tracking.

The DRiT system involves the implementation of biometric system using human face. There are several challenges that occurs in designing a real-time face recognition and tracking system. In an ideal environment, human face will appear to be different due to changes in face poses and sizes at different background. This changes happens when the person moves away or tilt their face. In most systems, tracking is limited due to the usage of a stationary camera. Thus, a moving camera will increase the FOV for tracking. A real-time intelligent system is needed which can automatically recognize and track human face at different poses and distances under varying background.

1.4 Research Objective

The main objective of this research is to design and develop a real-time face detection, recognition and tracking system (DRiT) for Medical Telediagnosis Robot (MTR) application. The objective can be achieved through the following tasks:

a. To detect human faces with multi pose.

The involuntary reactions will cause the human face to have variation in roll, yaw and pitch angle. The face detection module is designed with hybrid algorithm that will detect human face regardless of pose, size and background.

b. To recognize the profile of a person via Neural Network.

Recognition of the detected face is done through the face recognition module using Neural Network. The database consists of facial images taken at different angles and distances. The detected face is matched against the trained database.

c. To develop a pan and tilt hardware module for face tracking.

Face tracking module is implemented with template matching algorithm that tracks the detected face irrespective of pose, size and background. The two degree of freedom (DOF) pan and tilt unit is implemented to increases the tracking view.