Towards Real-Time Visual Biometric Authentication Using Human Face for Healthcare Telepresence Mobile Robots

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***Abstract*—Telepresence Mobile Robots have prominent attributes in many fields as it provides virtual presence for human robot interaction. The deployment of this robot in healthcare sector has improved patient care and health. The vision system in a telepresence robot allows two way audiovisual communication between people at different location. In spite of such advancement, the manual way of controlling a robot to recognise and track people during an emergency is not favourable for a long duration. To circumvent this problem, biometric method using human face is proposed in this research which is implemented on Medical Telediagnosis Robot. This paper details the design of the face recognition and tracking system with four automated modules which are motion detection, face detection, face recognition and face tracking. The modules are developed with different algorithm and tested individually to ensure the stability of the system. Artificial Intelligence technique was applied at the face recognition stage while a two degree of freedom mechanism for actuator control was used at face tracking stage. A sequential mode operation is proposed to reduce the execution time in a real-time environment. To achieve this, only one module is operated at each time. A Graphical User Interface was developed to ease the users at the local and robot environment. The system is designed in LabVIEW platform. The biometric system proposed with hybrid algorithm at each module adapts for face images detected at different distances, poses and lighting condition. This system was tested in real-time and has an execution time of 55ms and 98% accuracy. The stand alone system designed for Medical Telediagnosis Robot can be will be very fruitful for various biometric system using facial technology.**

***Index Terms*—Healthcare; Telepresence Robot; Face Biometric System; LabVIEW.**

I. Introduction

Robots are developed to cater the growing number of roles in today's society. Robots are known to have diverse application from sea to space. Generally, robots are categorised according to the application as depicted in Figure 1. The use of robots in healthcare sector has remarkably transformed the industry in several ways. Many hospitals are deploying robots for many purpose. In order to accommodate various function, different types of robots were developed. For an instance, surgical robot, rehabilitation robot, therapy robot, patient lifting robot and many more. Meanwhile, telepresence robot constitutes a promising area for healthcare industry. Persistent studies on benefit of telepresence robot were explored by many researchers. The birth of this robot created a new state-of-the-art technology. The term "tele" is a Greek word which means "far off" or known as operating a device from a distance [1]. This term is usually combined with another word forming compound word like telepresence, telediagnosis, telesurgery and many more. Telepresence robots are developed with three main modules which are navigation, network and audiovisual system [2].

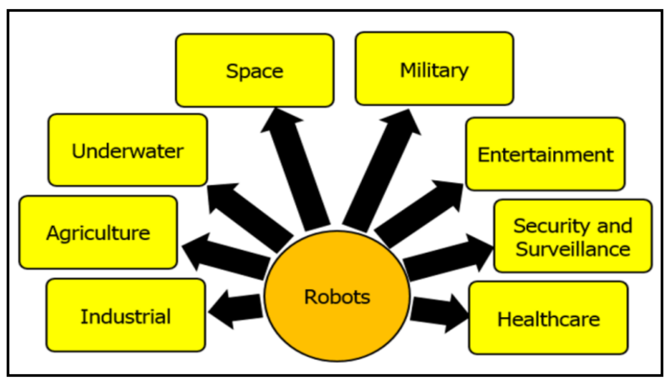

Figure 1: Application of robots

Medical Telediagnosis Robot (MTR) developed by [2] is a form of telepresence robot developed to attend patient during medical emergencies. The two major issue addressed in rural healthcare sector are lack of specialist and facilities. In any emergency case, the specialist will communicate with members in rural clinics via telephonic way to guide in certain medical procedure. However, the information may not be delivered as expected. The lack of facilities may cause a time delay in transferring the patient to main hospital which may lead to a more complicated issue. These issues were solved with MTR. MTR is equipped with several medical instruments to collect the vital sign of the patient. It has a bone fracture classification system to treat patients with limb injuries. Unlike any other telepresence robots, MTR is designed with low bandwidth and under a low cost platform to suit developing countries. The joystick on the robot is controlled by the specialist to make sure that the person he is communicating with is in the ideal field of view. In addition to that, identifying a person is done via manual way. However, during an emergency, it was found that using a joystick to track a face and verbal way of identifying a person is not favourable. In a long run, this may lead to misdiagnosis as the specialist cannot fully participate during the treatment process. A biometric system is needed to automate the manual way of controlling the joystick and identifying the profile of the person.

Thus, a face recognition and tracking system is proposed for MTR. A biometric system using human face is integrated to the robot. It is an automated system which operates on a real-time mode for authentication purpose. This paper highlights the design methodology of the system which is comprised with four modules operating in sequence. The sequential operation proposed in this research reduces the execution time and improves the overall system accuracy. This paper is organised as follows; Section 2 details the Previous Work followed by Section 3 with System Design. Results and Discussion is explained in Section 4 and finally Conclusion in Section 5.

II. Previous Work

A. Healthcare Telepresence Robots

Telepresence robots are gaining attention recently in healthcare sector especially in hospitals, clinics and home around the world. The benefit of this robot in providing virtual presence has been proven in many literature studies. The patient will feel as if the specialist is near them. The appearance of this robot caused re-admission was lesser and the recovery time was faster. In addition, it has reduced the length of stay in hospitals and increased the response time during emergencies [4]. Associating telepresence robot with human being, it is closely related with touch, hearing and vision [3]. This robot is used to conduct most of the daily activities in hospitals such as diagnosis, therapy, patient monitoring and communication [3].

The specialist can diagnose the patient remotely and monitor patients at home after post-surgery. The families can visit their loved ones more frequently which was initially difficult due to physical distance. Most of the telepresence robot is equipped with autonomous remote navigation which can ease telerounding. Some of the telepresence robot has medical instruments which are used to collect vital sign of the patient such as blood pressure, temperature, heart rate and others. Table 1 shows some of the most appearing telepresence robot in healthcare sector. Some of the telepresence robots operating in hospital environment are VGo, QB, MantaroBot, Giraff, Beam, PadBot, Double and Jazz which are summarized by [5]. TELEROBOT [6], TRIC [7], Kompai [8] and UBot [9] are non commercialised robot intended for research purpose. RoNA [10] and RehabOT [11] are designed to assist patient for patient lifting and rehabilitation treatment respectively. Only few robots are developed with biometric system with face and voice which are RP- Vita, Synergy SWAN, PeopleBot [5], Security Warrior [12], SIRA [13], Matilda [14], FURO [15] and MARGO [16].

Table 1
Telepresence Robots in Healthcare Sector

Robot	Biometric System	Reference
RP- Vita	Face	[5]
Vgo	No	
QB	No	
Synergy SWAN	Voice and Face	
PeopleBot	Voice and Face	
MantaroBot	No	
Giraff	No	
Beam	No	
PadBot	No	
Double	No	
Jazz	No	
TELEROBOT	No	[6]
TRIC	No	[7]
Kompai	No	[8]
uBot-5	No	[9]
RoNA	No	[10]
RehaBOT	No	[11]
Security Warrior	Face	[12]
SIRA	Face	[13]
MTR	No	[2]
Matilda	Face	[14]
FURO	Voice and Face	[15]
MARGO	Speech	[16]

B. Biometric Method

Biometric system is used since many decades ago due to its applications in many field such as surveillance, security, robotics, education and others. Biometric is known as knowing a person a person's identity based on some traits. Biometric can be called as "something you are" compared to "something you know and might forget- PIN number" or "something you have and might loose-Token" [17]. Biometric system can be classified into physiological and behavioural as shown in Figure 2.

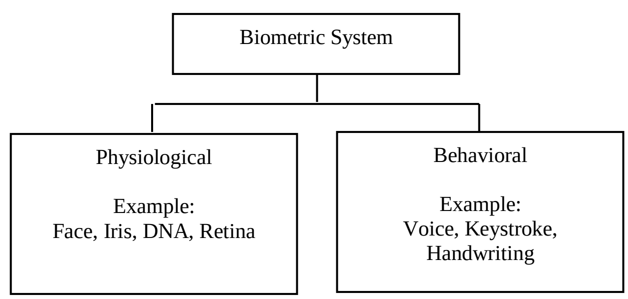

Figure 2: Biometric system classification

Physiological characteristics are traits that are inherited and difficult to be altered unless due to severe injuries. Behavioural patterns are something that is learnt and can be affected by fatigue or illness. In a system design, there are several identifiers that is taken into consideration such as universality, distinctiveness, permanence, collectability, performance, acceptability and circumvention [18].

There are several advantages using human face as a biometric method. Face region can be clearly seen on the screen provided in a telepresence robot. The subject does not have contact with the system and thus making it more hygienic. Thus, this biometric system does not carry any health issues. Face information can be captured without the knowledge from the subject where no additional authentication is further needed [18]. Face region contains information like expression, gender, race which can be a powerful tool for human robot interaction which can be further extended to other applications like face recognition and face tracking [19]. Human face can be captured from a far distance using an inexpensive camera. To aid a system that captures face from a far distance, the Zoom function in a camera is utilised. The existing camera can still be used as the biometric system involves more on software processing.

There are several challenges in designing a system using human face for authentication purpose. Human face tends to have changes in pose and size, which is an involuntary reaction [20]. Human face pose can change in terms of roll, yaw and pitch angle. The changes in face size or scale occurs when the subjects move away or closer to the camera. Besides that, environmental lighting can significantly change the light distribution in an area, which is also called as illumination problem [21]. Background can be divided into simple and complex background. Appearance of the face image may change if the image is captured after years apart [22].

III. SYSTEM DESIGN

A comprehensive biometric system design for Medical Telediagnosis Robot (MTR) is described in this section. Figure 3 shows MTR and the remote station. The biometric system in this robot uses human face for face recognition and tracking. The vision system will act as the "robot eye" to aid the communication process between the hospital members in rural clinic with the specialist from the main hospital. The vision system is developed with a camera mounted on pan and tilt unit of servo motor.

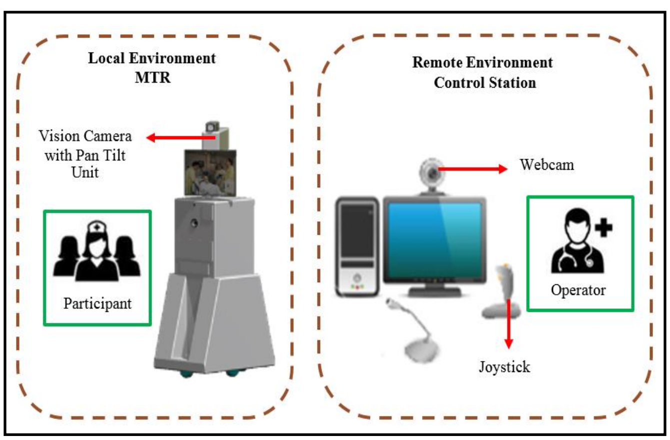

Figure 3: System architecture

The main idea of the research is to design modules that operates in sequence to reduce the overall execution time. The modules are designed with algorithms that works for real-time mode. A control user interface is designed for remote communication. The system is designed in LabVIEW platform integrating hardware and software modules. The system is activated once the robot reaches the patient and in stationary position. The system is designed with four modules; motion detection, face detection, face recognition and face tracking.

Once activated, the remote user will insert the login details. This is to ensure there is no unauthorized person accessing the system. The first module of the system is motion detection. The purpose of this module is to detect if there is any motion present in captured frames. For this module, two frame differencing technique is used. The second module is to detect the location of face in a captured frame. In this module, skin color algorithm is used.

The third module; face recognition is designed with backpropagation neural network algorithm where the detected face is matched against the stored database. If the face profile does not match the database, the system will return to the default state where the motion detection module will begin once again. The last module; face tracking is implemented with both software and hardware module. The software based face tracking is done with color template matching. The hardware based tracking is developed with two degree of freedom mechanism. The use of pan and tilt module widens the tracking view.

If there is any error found during the tracking stage, the user will have option either to "Continue Track", "Restart" or "Exit". "Continue Track" option will return the system to current tracking stage while "Restart" will return the system to default mode. Finally, "Exit" option will end the whole system. Each module is activated when the previous module returns a "TRUE" value. Only one module is operated at each time to ensure that the overall execution time is minimised. A feedback mechanism is included in the design to increase the overall accuracy. The complete flow of the system is represented in Figure 4. There are several algorithms implemented at each module.

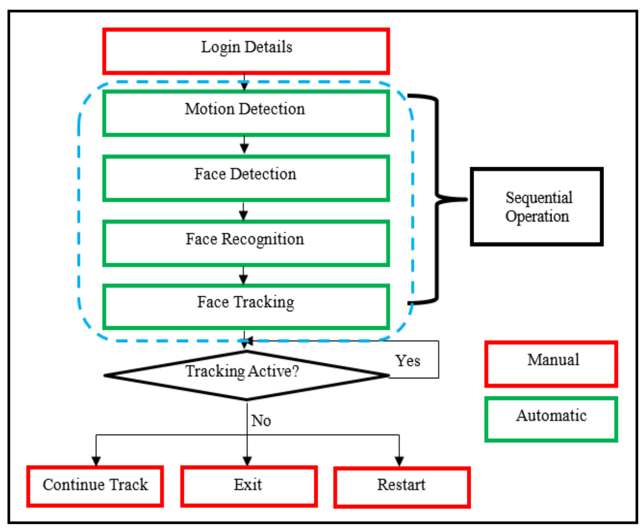

Figure 4: System flowchart

IV. Results and Discussion

This section discusses the result of the complete system with the designed GUI. A login password is required upon start up. A maximum of 3 attempts are allowed. The LED at “Access Denied” will light up when the maximum attempt is reached. The user has a choice to select the camera that will be used which is selected at option “Camera Control”. Besides that, the user can control the joystick manually at four different directions at the option “Servo Control”. This will rotate the camera at pan and tilt direction. During the tracking stage, the user can update the patient health record and the data is updates instantaneously. The LED indicators represents the module that is active.

Figure 5 displays a condition when no motion is detected. At this condition, none of the LED indicator lights up.

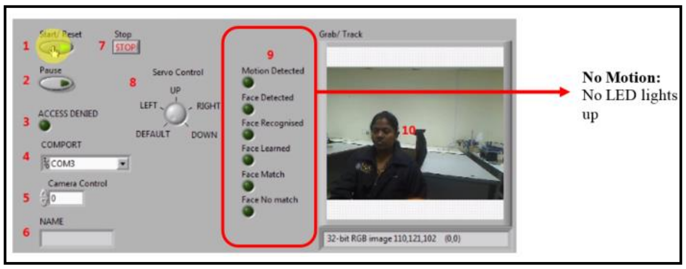

Figure 5: No Motion Detected

Figure 6 shows an example where all the four modules return a TRUE value. At this stage, motion and face is detected while the face is recognised correctly. Once the face is recognised, the name of the person is displayed as a string constant. The tracking stage is indicated with face match. From this figure, it can be said that the system works for face images at different pose and background. The detected face size is extracted out whereby it is used as template to track the face region at every frame. During the tracking stage, the face size will differ if the person moves closer or away from camera. Template based tracking method used in this research shows that it can track face images at different pose and size. For the image in Figure 6, the distance between the face and camera is about 80cm. The camera will continuously be adjusted to track the face. To ensure the system delivers a high accuracy for tracking stage, the window size for the tracking area is adjusted based on the face position at every frame. Figure 7 displays a condition where the same person is detected at different background and lighting distribution. The background in Figure 7 has objects with similar skin color.

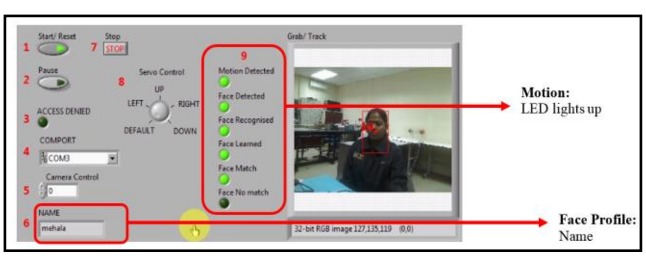

Figure 6: All modules activated

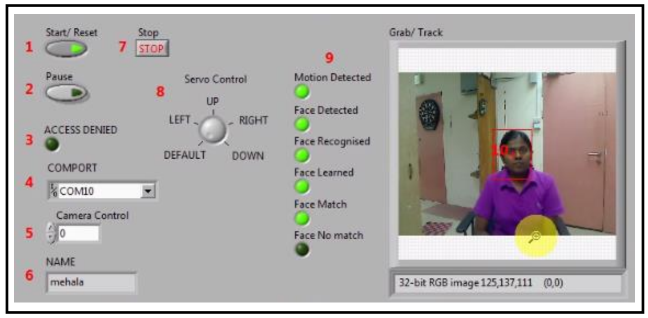

Figure 7: Different Background and Lighting

Figure 8 shows a sample frame captured for a person who is registered in the database. All the modules returns a TRUE value for an authorised person who is registered to the database. Figure 9 illustrates the tracking condition when two people found in frame. The system will track the person that is recognised. This is due to the sequential operation that tracks the face based on the information stored from previous stage.

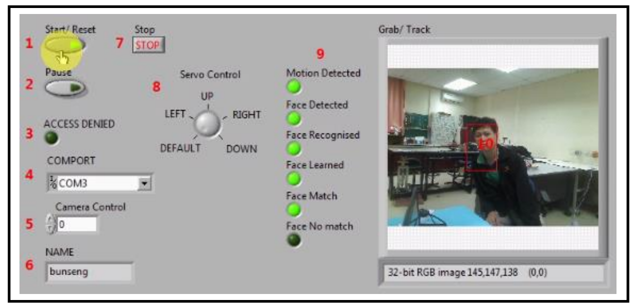

Figure 8: Person registered in database

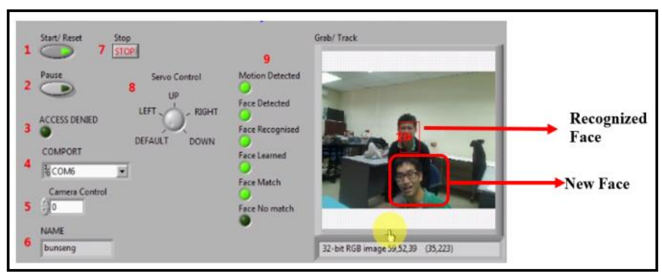

Figure 9: Two people in a frame

Figure 10 shows an example when the person is not in database. At this condition, the motion and face is detected. Since the person is not trained in the database, thus, the face recognition LED does not light up. Once the person is not identified, the system will automatically return to its default stage where it loops to the motion detection stage. Figure 11 shows the modules, which are returned to the default stage and an “error” is displayed at the string, which indicates an unauthorised person is detected. This research is focused on designing a system that can adapt to different background. Thus, the motion detection method based on pixel difference between consecutive frames is found to be suitable for moving camera. The implementation of a moving camera requires a less complex algorithm that can detect the moving object at a moving background.

Figure 10: Person not registered in database

Figure 11: System initialize

Figure 12 displays a sample window when an error occurs in the system. At this stage, a sub window pops up where it allows the user to select any of the three option provided. For this example, when the "Continue Track" option is selected, the tracking stage continues and it returns to similar image in Figure 6.

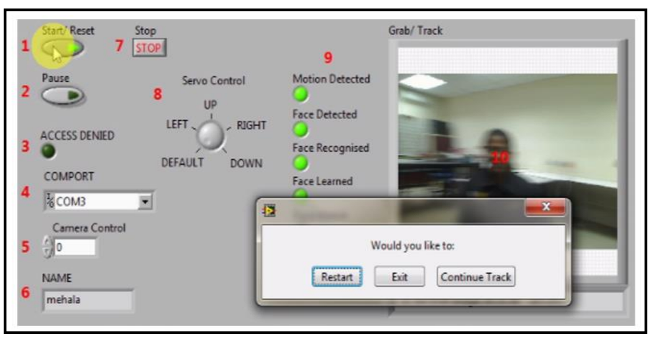

Figure 12: Error condition

The designed system was tested under different lighting condition, face pose, face scale and also at different background. The system achieves an accuracy of 98% with 55ms execution time. This data was obtained at a real-time condition. The accuracy and execution time is obtained based on the average obtained at four different module; motion detection, face detection, face recognition and face tracking. The system is activated 10 times for every person in the database, which captures about 1000 frames at every activation. The system can detect, recognise and track up to 1.5 m.

V. Conclusion

This paper presents the implementation of a biometric system for telepresence robot with an interactive Graphical User Interface in LabVIEW platform. It was found that the use of biometric system on a telepresence robot as a part of vision system delivers an acceptable output with 98% accuracy. The sequential operation mode proposed in this paper reduces the execution time where only one module is operated at each time. The system will loop into the previous stage until a TRUE value is obtained which is used to monitor the system accuracy, reliability and stability. The system gives authentication for people who are registered to the database. The use of a hand controller can be reduced as the pan tilt unit takes over the manual way of controlling the robot. Backpropagation neural network enhances the recognition rate and thus reduces the verbal way of recognizing a person. It is important to design a system with less complex technique so that it can be operated at a real-time condition. This system will certainly create a closer connection between the remote medical specialist and the hospital members for better visual interaction. This work can be further extended for emoticon recognition for social robots, crowd monitoring and surveillance system.

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