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Eye Tracking Based Directional Control System using Mobile Applications

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Abstract: Recently, eye tracking system occupies a wide area in the researching fields. Different applications were produced to tackle numerous problems in real-time systems. This paper proposes a directional control system based on human eye tracking strategy using a mobile application. The introduced system can control any electric device power or the movement direction for the mobile objects, such as cars, robots, and wheelchairs. The proposed mobile application, which applied to an Android smartphone, detects and tracks the human eye depending on Viola-Jones based Haar-liked features cascade classifiers algorithm. Ultimately, it estimate the eye movement direction and the blinking action. The control system includes Raspberry Pi III, which control the ON/OFF of five LEDs connected to it representing the four eye movement directions and the blinking action. The detected eye actions by the mobile application are transferred via a wireless channel (Wi-Fi) to the Raspberry Pi for controlling. The Raspberry Pi controls the LEDs status as a prototype applicable to any other device or moving object.

Keywords: Eye tracking, Blink detection, Control system, Android application, Raspberry Pi III.

1. Introduction

Nowadays, one of the important social problems is the vastly increasing of the aged people; moreover many of them are somehow handicapped in different meanings. Therefore, the development of supporting devices and controlling systems for the handicapped is desired [1].

Human-Computer Interaction (HCI) has become an important part of our daily lives. In addition, the movement of user's eye can provide a natural and convenient source of input. Moreover, the eye can move very quickly in comparison to other parts of the human body. Theoretically, this means that if the user's eye gaze can be detected and effectively tracked, no other input method can act as quickly as it. Therefore, eye tracking field has been considered and investigated frequently in techniques that integrate eye movements into the human-computer interaction because they are non-invasive and inexpensive [2].

Recently, the most commonly used eye trackers are the non-contact trackers which depend on the light that reflected from the eye and sensed by the eye tracker or an optical sensor [3].

Real-time gaze-based entry is not restricted with HCI, furthermore, it can be considered as a powerful convenient mean for controlling systems to serve people in-need and to improve their life especially the physically disabled people. It can be employed in real time applications as an alternative to the traditional manual techniques [4].

In this paper, a directional control system based on eye tracking is developed. The eye gaze direction and eye-blink signals are detected and processed using an android based mobile application for controlling LEDs ON/OFF actions as a representation of the blink action and the four directional movements. The Raspberry Pi is used as prototype controller to any device or robot. The significance of the proposed system lies in helping disabled people to gain control in some aspects of their lives; accordingly, they will no longer require a therapist to help. This template, modified in MS Word 2007 for the PC, provides authors with most of the formatting specifications needed for preparing electronic versions of their papers. All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are

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not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

2. Related Work

Eye tracking based real-time controlling applications has become a crucial part of researches in recent years, especially under the recent enormous increase of the elderly and disabled people.

In [5], the authors designed an eye tracking based directional control system to help handicapped people control home appliances without the need for an assistant. The camera of an eye-sight placed laptop was used as a sensor to track the pupil movement and passing it to the MATLAB for processing. Then, it translated the pupil movement to a cursor movement over a specially designed interface. They used the Arduino microcontroller to connect home devices to it. The results proved that the system is accurate and precise.

The system in [1], presents an affordable and simple system for controlling a patient's wheelchair depending on the movement of the eyeball. The system consisted of a camera, PC with MATLAB for image processing, an Arduino microcontroller with the L298D motor driver. The weakness point of this system was the need an assistant to observe and control the user interface of the system.

A type of human-computer interaction was adopted in [6], wherein the patient wears an eye tracker helmet which consists of two cameras used for pupil position detection. A communication board that consists of 27 words, symbols and 3 action buttons (forward, backward and reload) was designed as an interface to use it in writing sentences by on-screen focusing. The results showed that the system was highly affected by the calibration, therefore, the wrong calibration will cause wrong gaze tracking.

In [7], an EOG based eye tracking system for HCI was proposed. The significance of the system was to control the TV, eye controlling game and eye-sight level check using a SPCE061A microprocessor and depending on gaze directions detection. The results proved that the system works precisely more than 90% only in the first 30-90 min because of the sweating of skin attached to it.

In 2016, Eric W. et al. [8] proposed an eye-contact, scleral coil based eye tracking system. They used five eye-wearable coils which create a magnetic field different from each other. The magnetic field orientation used to detect the eye position which varies with the eye movement. The results proved that the system can estimate the eye orientation with 0.094% accuracy besides the obtained high speed.

2. The Proposed System

Generally, the proposed system's structure consists of two main parts: the android based eye tracking application and the Raspberry Pi microcomputer. The general scheme for the overall system developed in this paper is delineated in Fig. 1. Movement of eye pupil is tracked for estimating the user's gaze direction which is used as an input technique to the mobile phone. Therefore, this application replaces the need to button pressing by finger touching. Based on this estimated eye movements, the command is transferred to the Raspberry Pi via Wi-Fi connection for real-time directional controlling. For easing the follow up of the reading, this section can be divided into three sub-sections as follows.

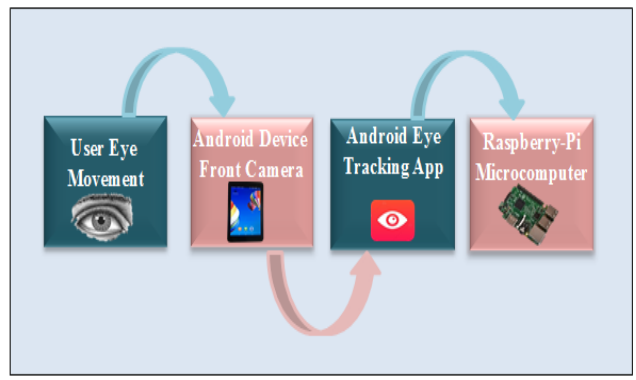

Figure 1. Basic block diagram.

A. The Proposed Algorithm

As mentioned above, the proposed system divided into two main parts one for processing and sending and the other for receiving and controlling. A flowchart in Fig. 2 explains in details the whole tasks and the processing steps related to each part of the system. Fig. 2a shows the algorithm used in the application processing which adopted on the algorithm used in [9].

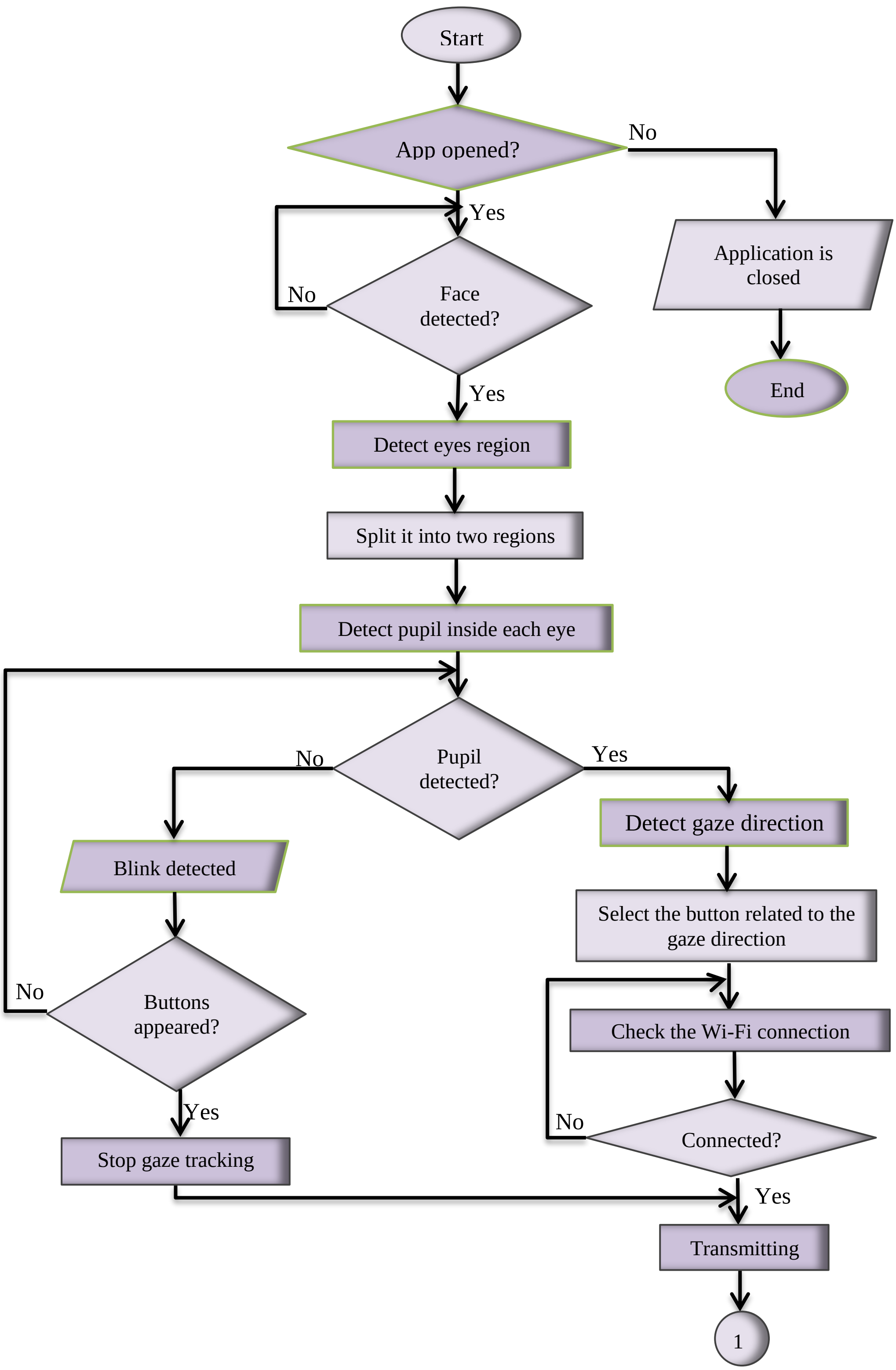

Figure 2a. the overall system flowchart: the application side.

All processing operations are continuing since the application running until shutting it down thus opening it is the beginning of the processing steps which automatically run in the background of the application without the need to an observer to control it. The detection of human face is the first step which accomplished using Haar cascade classifier. It followed by computing the eyes region and splitting it into two regions to separate the two eyes and shrink the Region of Interest (ROI) for easing the detection of both eyes separately without unwanted skin regions. Using another Haar cascade classifier, the left and right eyes are perfectly detected. The next step is searching on the pupil point in the detected eye region (which is the darkest point in that region). Two types of actions are effectively detected which are the gaze direction that depends on the pupil existence and the blink detection which depends on the pupil absence. The gaze directions are estimated in four different directions (up, down, left and right) using predefined thresholds in the eye region. A button pressing indicate the response of the application as a result to the estimated gaze direction. The disabled user can stop the system (the gaze direction detection and buttons pressing) by the blinking action. Eventually, the resulted signals are sending via Wi-Fi connection to the Raspberry Pi microcomputer to use it as control signals.

Fig. 2b shows the receiving and controlling operations performed by the Raspberry Pi. The incoming signals are five signals which are the four gaze directions and the blink action. They received as strings to the microcomputer which classify them and perform an action associated with the received signal. The applied processing operations are the same relating to each signal which begins by checking the incoming string to specify the intended action which followed by checking a LEDs ON/OFF that used as indicators to the detected actions. Checking the LED status is accomplished by checking the microcomputer's PIN connected on it. The final response of the microcomputer is lighting a specific LED related to its assigned action and turn it OFF if the same action is received again.

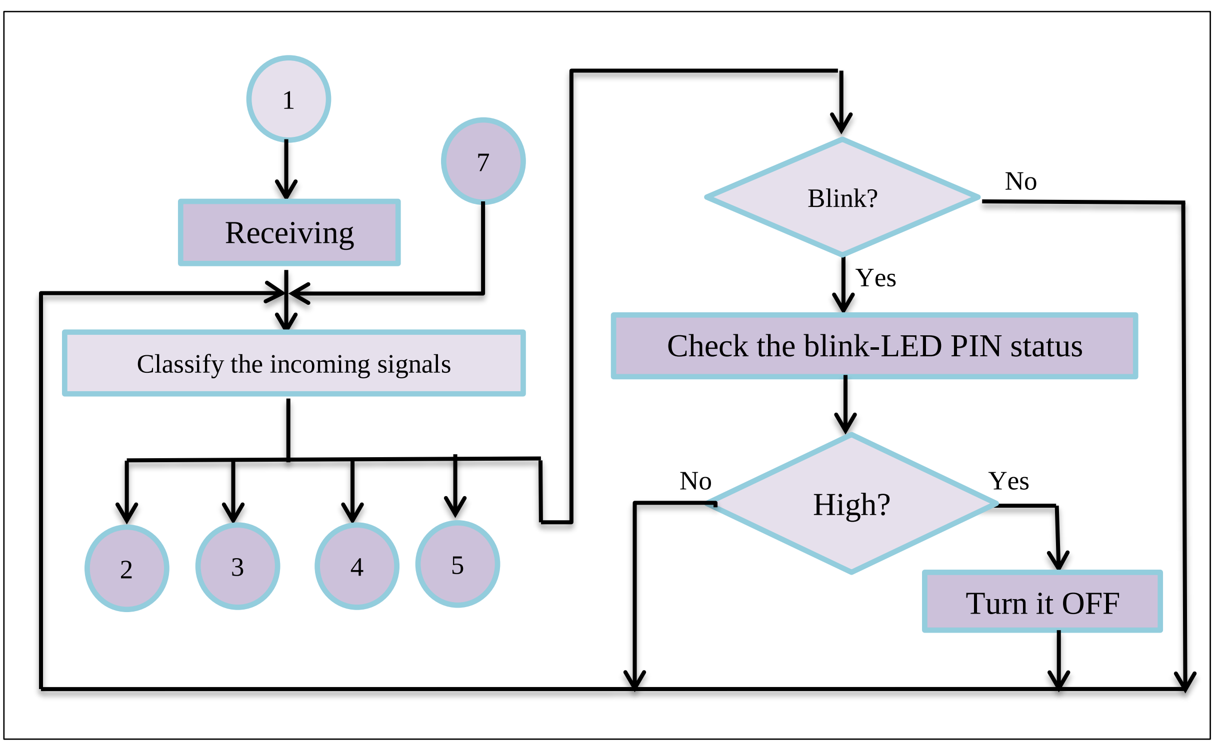

Figure 2b. The overall system flowchart: the Raspberry Pi side (continued).

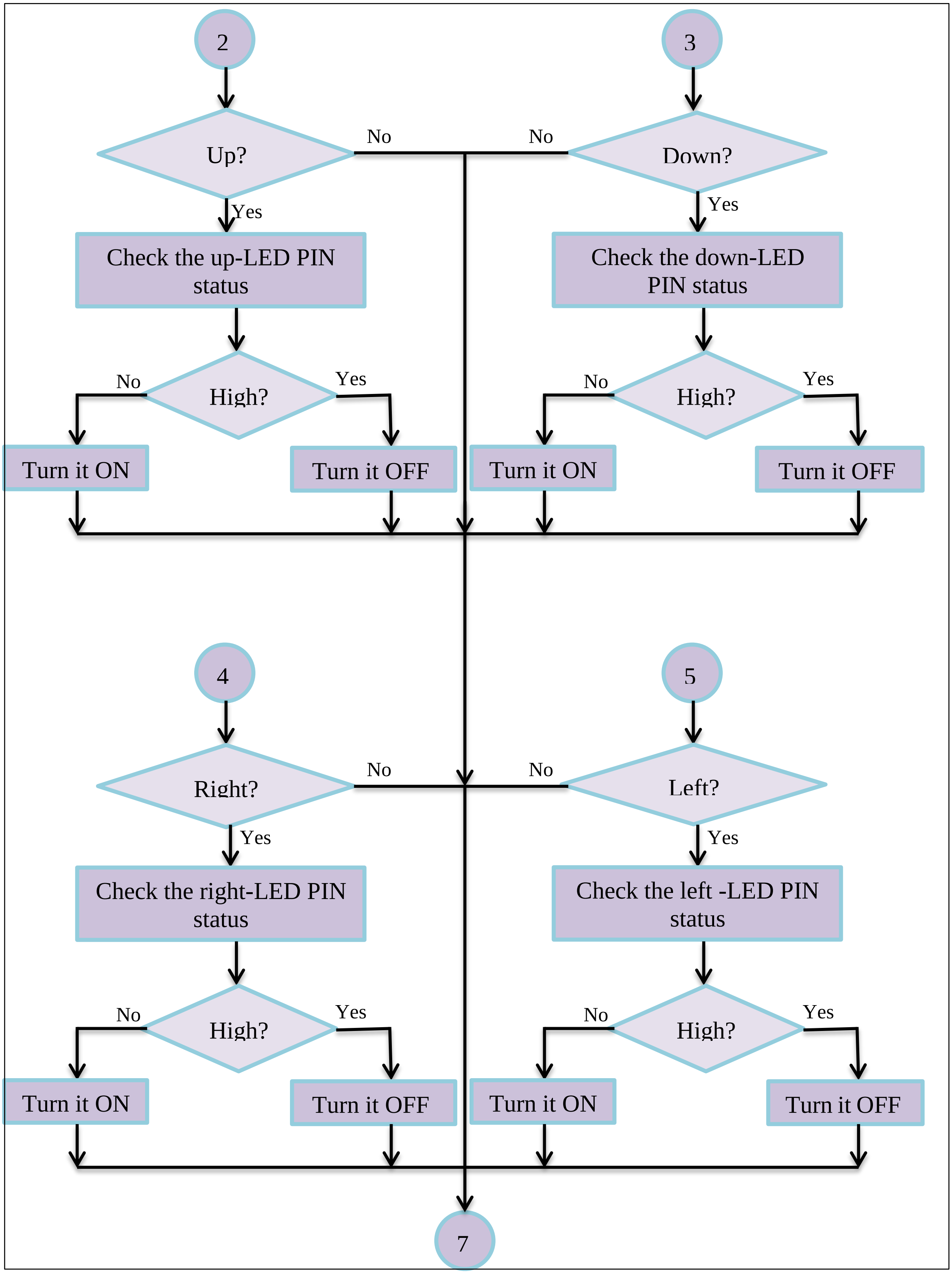

Figure 2b. The overall system flowchart: the Raspberry Pi side.

B. Eye Tracking Based Mobile Application

As aforementioned, the proposed android based eye tracking application in [9] is adopted in this work as it depends on eye movement that is sensed in real-time by the built-in front camera of an android device without the need for an external sensor. The real-time video processing operations are performed using Viola-Jones algorithm with HAAR cascade classifiers for detection and tracking. It passes through four stages ended by the selection of a specific button of the application user interface, shown in Fig. 3.

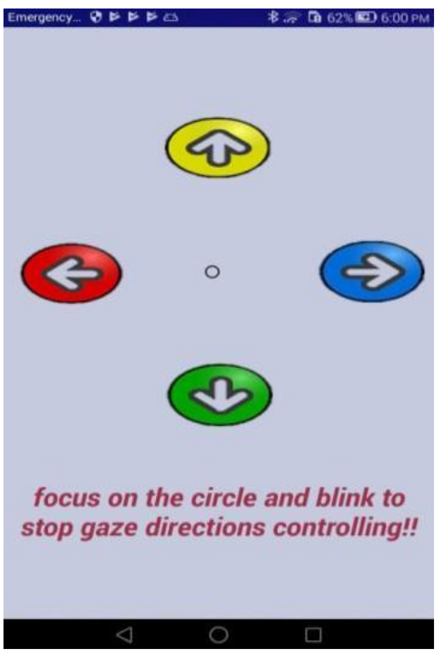

Figure 3. The application user interface.

These stages are the face detection, eye region detection, pupil tracking and gaze direction detection respectively as illustrated in Fig. 4.

In the last stage, two types of actions can be performed which are the gaze direction and the blink detection. For the gaze directions, application response is presented by selecting a specific button depending on the intended detected gaze direction (up, down, right and left). In addition, the blink action is detected, which must be hard and lasting for two seconds, used for activate/deactivate the proposed system.

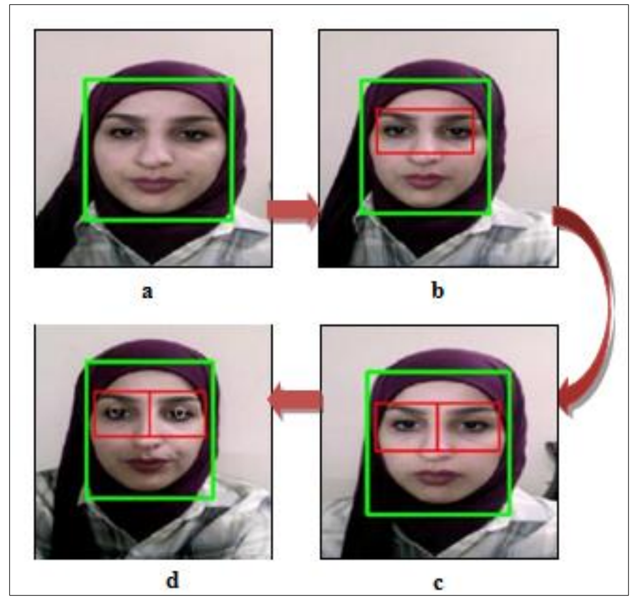

Figure 4. The first three stages of processing: (a) is face detection, (b and c) are eye region detection and (d) is pupil tracking.

C. The Raspberry PI Microcomputer

The second piece of hardware that controls all the actions is a Raspberry Pi III Model B which is a small, credit card-sized computer developed in the United Kingdom by the Raspberry Pi Foundation [10]. The module is well equipped with different kinds of input/output ports and it performs quite well in the tasks that are related to our system. Five LEDs, Male-Female connectors, resistors and breadboard to connect the LEDs to the Raspberry Pi are used as expressed in Fig. 5. Raspberry Pi III model B is adopted for controlling and communication purposes of this work because it has built-in Wi-Fi and due to the little usage of this platform as compared to the Arduino which has become the core hardware for most of embedded systems projects.

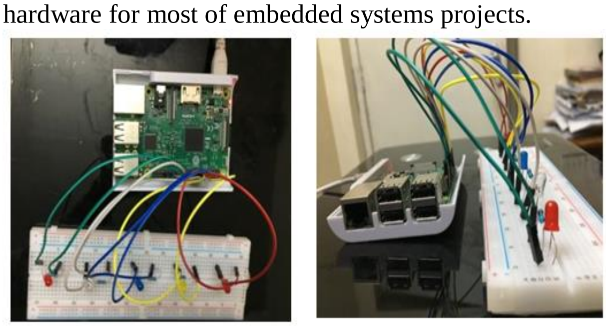

Figure 4. LEDs connection to the Raspberry Pi.

The LEDs have been used as indicators of the control signals from the Raspberry Pi which are the four gaze directions and the blinking action. The built-in Wi-Fi communication feature in the Raspberry Pi is exploited, every detected action in the application is sent to the Raspberry Pi via Wi-Fi and a specific LED ON/OFF that indicates the detected action. It is worth mentioned that python programming language has been used in this side.

4. EXPERIMENTAL RESULTS

As mentioned above, the aim of this research is to use the application based detected eye action (gaze direction or blinking detection) as control signals. These signals are sent the Raspberry Pi to control ON/OFF LEDs as a prototype that can be replaced by any other device circuit for controlling. Fig. 6 illustrates the LEDs related to eye actions detected by the application depending on the changes when the eye blinks or moves up, down, left, and right.

The obtained results prove that the system is running under high accuracy and precision with fast latency after signal transfer without any significant delay.

The experiments results interface are depicted in Fig. 7-11 that show the button selection in the mobile application by eye movement and the related action represented as a LED.

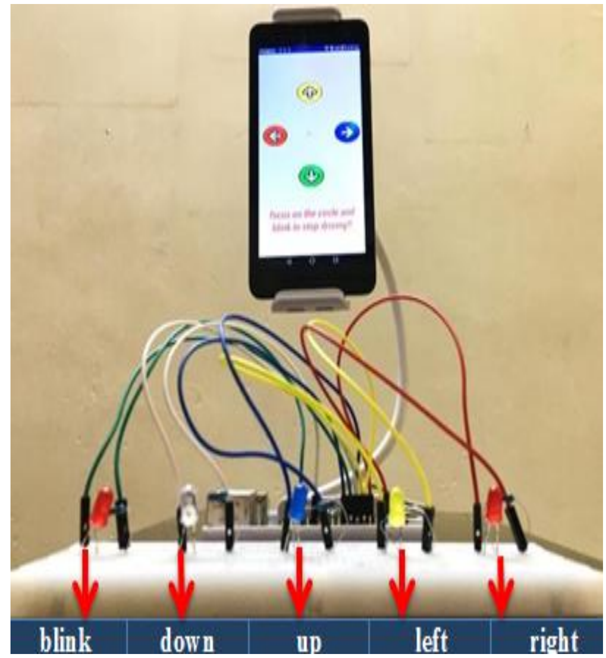

Figure 6. LEDs-actions definition.

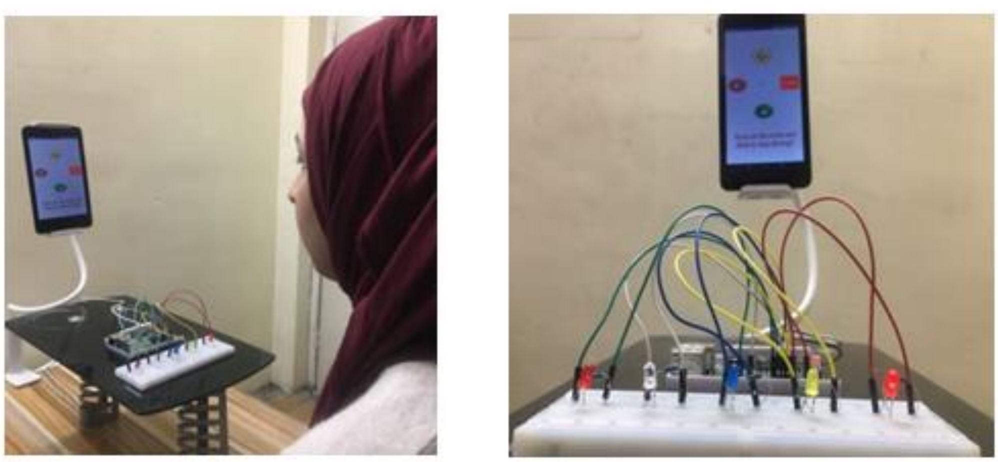

Figure 7. Right gaze direction (input and output).

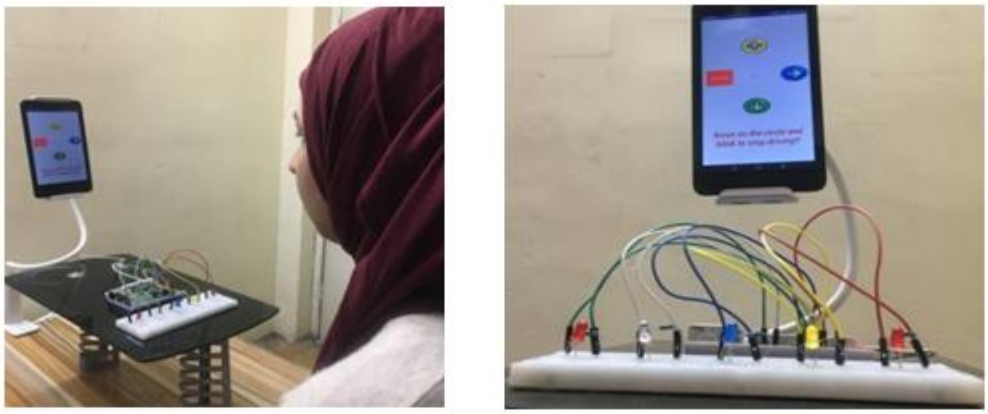

Figure 8. Left gaze direction (input and output).

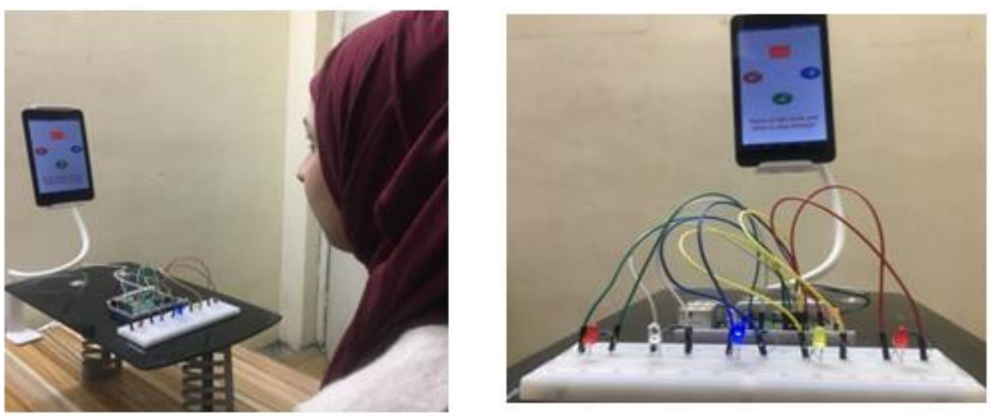

Figure 9. Up gaze direction (input and output).

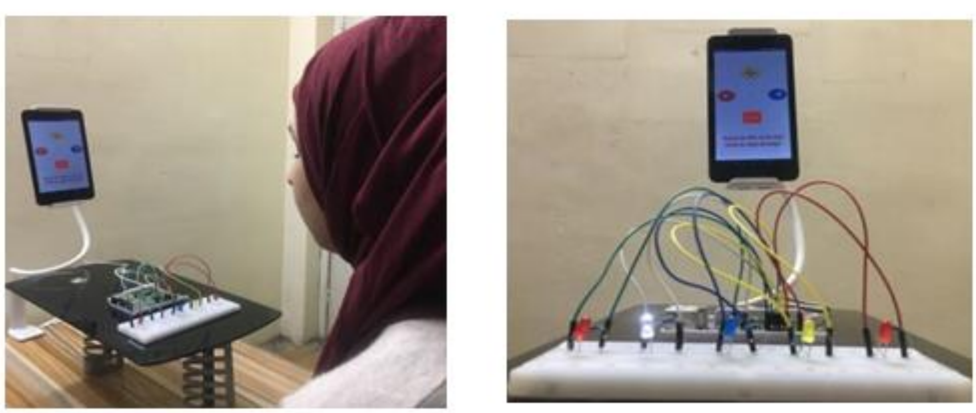

Figure 10. Down gaze direction (input and output).

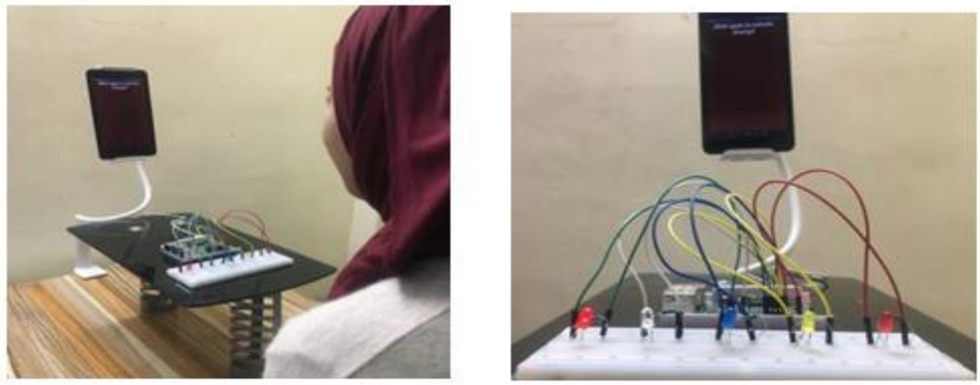

Figure 11. Blinking action (input and output).

The most important two factors that affect the system performance, especially its precision, are the resolution of the camera and the surrounding lighting condition. Neither high intensity nor low intensity of the environment light is preferred due to low system precision. Moreover, the accuracy is directly proportional to the variation of the camera resolution.

Table I shows the accuracy ratio of performing the directional movement actions tested on GALAXY tab (2.3 OS version, 2MP front camera, and Dual-core 1.3 GHz). The distance between the user's eye and the device's camera is limited to 50cm indoor and 54cm outdoor. In addition, the camera is placed and adjusted to be horizontal with the eye-sight of the user.

TABLE I. THE OBTAINED RESULTS

Action	*Accuracy*	
	Indoor	***Outdoor***
Right gaze direction	*90%*	*70%*
Left gaze direction	*100%*	*80%*
Up gaze direction	*80%*	*70%*
Down gaze direction	*70%*	*70%*
Blinking	*70%*	*90%*
The whole system accuracy:	*82%*	*76%*

From Table 1, we can observe that the low detection accuracy ratio of the up and down directions as compared to the right and left directions is appeared because the horizontal line of the eye is wider than the vertical line. As a consequence, the horizontal movement range of the eye from left to right and vice versa is faster to detect than the vertical movement range between up and down directions.

Each accuracy ratio mentioned in the above table has been computed by taking the average value of 10 continuous experiments upon the intended action by considering the right detection is 10 and the wrong detection is 0.

3. CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

In this paper, a directional controlling system based on eye-tracking technology is presented for supporting elderly, especially those with a lack in the physical ability to control limbs movement, in terms of self-reliance and stop being a burden on others. The system consisted of two main parts: eye tracking mobile application and the microcomputer. The eye tracking application is designed under an Android operating system using the device's front camera as a sensor. This sensor captured a real-time video which was processed using Viola-Jones algorithm with HAAR cascade classifiers to detect four gaze directions in addition to the blinking action. The resulting signals were sent via Wi-Fi to the second part of the system which is the Raspberry Pi III microcomputer. Depending on the incoming signals, the Raspberry Pi controlled the ON/OFF of five LEDs affixed to a breadboard. Eventually, the confirmed results proved that the system was affordable and is running accurately under a suitable light intensity and a powerful android-based device. The obtained overall accuracy was 82% indoor and 76% outdoor.

The developed system in this paper represents a prototype that can be futurity easily modified to allow any aspect in the patient’s dwelling to be controlled whether it was an ordinary wheelchair controlling, home appliances or personal devices controlling which make it eligible and adequate to be used as an assistant to the physically disabled people.

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