Development of Pupil Detection in Eye Movement with Raspberry Pi

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Abstract—**Human Computer Interaction (HCI) is an evolving technology. Eye movement is one of the method of HCI that plays an important role for disease identification and retail advertising effectiveness. Current system has types of movements that can be classified to fixation, rotation and drift, which based on electronic, mechanical or optical or video based movements. Moreover, the eye is authentic and moves faster than input media. In fact, no training is required for normal users. However, the equipment is still expensive. Therefore, a cost effective prototype of pupil detection for eye movement is proposed. This paper introduced a development of pupil detection using fixation length of distance with video based eye movements using Raspberry Pi and web camera. The implementation of software and hardware installations are using Haar Cascade Technique. The system detects the movement of eye and capture the image of pupil using a webcam. Later, the image of pupil is compared at the matching process using String Array Concatenation on Raspberry Pi. The impact of this study is to provide a lower cost device for pupil detection in eye movement for human computer interaction system.**

Keywords— **Human Computer Interaction; Eye Movement; Video Based Eye Movement; Human Pupil.**

I. INTRODUCTION

Eye movement-based human computer interaction has been a significant research in assisting for identifying disease[1] and retail advertising effectiveness[2] for consumers. Human computer interaction refers to different techniques and methods of physical and non-physical entity in communicating with the computing devices. Physical means the use of software and hardware that can sense and respond to the cyber world for instance sensor to detect heartbeat. Meanwhile, non-physical is the use of frequency signals to transmit data for conversation between computing devices such as human identification. There are various types of instructions to computing system that can be given according to non-physical ways such as approaches to capture eye movement, hand, face or voice, which use for detection, analysis and recognition. Fig. 1 shows human computer interaction as in general illustration.

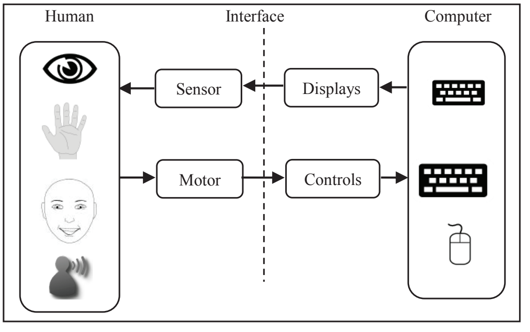

Fig. 1. Human Computer Interaction

In recent trend of studies [3-5], eye movements are seemed to have a potential implication on this field [6].

Moreover, the eye is suitable to be used at the interface level of human and computer interaction also as an authentication process to access to the computerized system. The interface layer involves with data communication process that involved data transmission layers from hardware (i.e.: sensor), software, policies,

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controls to the application layer that act as an intermediate edge component as illustrated in Fig. 1. Sensors and motors are hardware that involve directly to human through the interface, for example, wearable products that people used to measure blood circulation or heartbeat. On the other hand, interfaces that interact with computer that displays and control, manage to execute the operations using hardware and software to perform certain tasks. Thus, both interfaces will communicate to each other for data transferring from human to computer and vice versa.

On the other hand, the eye is an internal organ that can be viewed from external of the body. The eye is unique and represents human characteristics and behaviors. Inside the miracle eye, it contains several distinctive features such as pupil, cornea, retina and iris. Nevertheless, pupil provides solution to measure the unique patterns in the colored circle around pupil especially in contraction as light enters into the eye. Due to unique features that the pupil possesses such as black in color and the shape is almost circle [7], make pupil suitable for human identification. In fact, the matching scores of left and right pupil from the same person is identified as not the same [8]. Fig. 2 shows the illustration of eye anatomy.

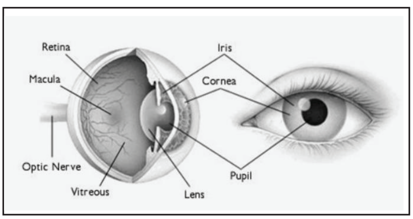


Fig. 2. Anatomy of human eye [7]

Pupil detection has a very high accuracy [8] in comparison with many other features inside a human eye. The pupil detection technique is using two light sources and is using the image of different methods, one light source set in coaxial with the camera is switched on during the odd fields of the video signal, and another one is set in non-coaxial with the camera is switched on during the even fields. Then the difference images are obtained by subtracting the even field images from the consecutive odd field images.

The video based pupil detection system is influenced by visual attention in tracking the eye movement and the information captured from the eye will highlighting the behavioral and physiological features [9]. Many visual attention features such as, geometric, acceleration and muscle properties, are drawn out from eye gaze records and are used as biometric attributes in order to verify a person. Nearly, each component of individual body has been implemented as biometric data for verification, which provides reliable performance.

Eye tracking approach was initially introduced into a verification method where the sequences and locations of eye gaze records to differentiate a person. Based on common details of the extracted attributes, a feature selection formula is used to determine a group of the most discriminative attributes for individual verification.

Threshold value is decided for every kernel such that it provides the best classification results. After that, weights are assigned to pupil images based on number of miss-classifications and these steps are repeated (with regard to weighting) to optimize the setting of thresholds. After sufficient result is achieved, features with lowest error rate is determined. One feature with set threshold value is called "weak classifier" as it provides only slightly better result in pupil detection than the random selection. They must be used in group to provide useful results.

Therefore, classifier is a weighted sum of these weak classifiers. With increasing size of the dataset, the computational complexity will naturally increase as well. The dataset is grouped into the trained set and testing set. The trained set is 6,000 features and developed using OpenCV library classification cascade. To detect pupil features with trained classier algorithm uses sliding window to explore all images of sections. However, in a real life, most public database contains selected human pupil that not belong to the organization or local use. Thus, the computer computational is a waste since need to apply all feature to a kernel. For this reason, kernels are split into groups. Groups are applied gradually and their size increases. If any group decides that window does not contain image of a pupil, the process is stopped and window moves to another position. If all the groups agreed, then a pupil is detected.

The current system of pupil tracking has several drawbacks such as a) long period of time for data collection to decide the sustainability of pupil image, b) need good mechanism to detect the area of pupil within the eye images regardless the non-pupil images likes eyebrow, iris, sclera and eyelashes, and c) too much head movement during pupil tracking causing problem during the process of pupil detection.

II. DEVELOPMENT OF PUPIL DETECTION USING RASPBERRY PI

In this project, the experiment is setup by using two main devices which are Raspberry Pi 2 Model B and Logitech Webcam c120. The main software platform is installed using Python 2.7.9 in order to develop the system for detecting the pupil and capture the eye images. While matching process code also develop on Python using String Array Concatenation Theory, which is a very simple matching algorithm process. Next, Logitech Webcam c120 is a plug-in USB webcam connected to Raspberry Pi 2 Model B used to capture the image of the pupils.

A. Hardware Development

The configuration of this project need a support software tools. The project has chosen OpenCV 2.4.13 since Python requires OpenCV libraries to execute the code. The OpenCV is installed on Raspberry Pi using terminal by executing this command *sudo apt-get* and install OpenCv to put in the packages needed. The flowchart explains the configuration setup for this study in Fig 3.

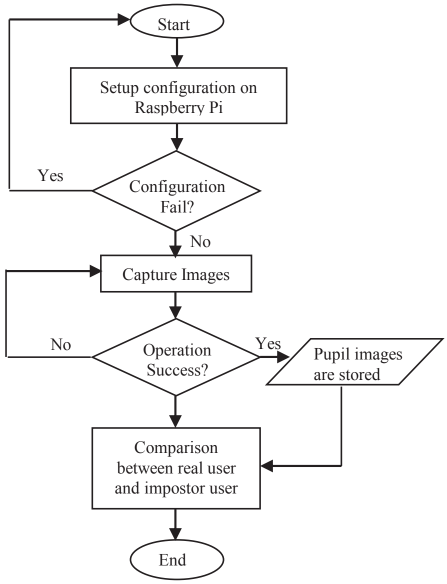


Fig. 3. Flowchart of the experimental setup process

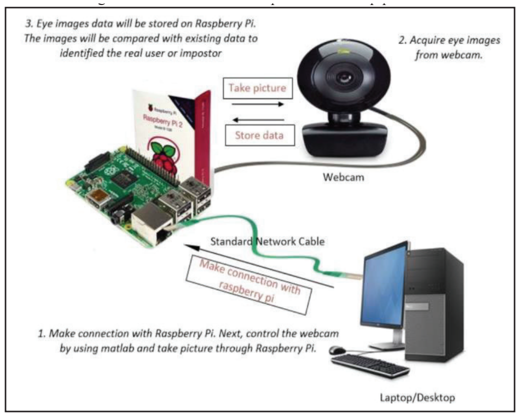


Fig. 4. Configuration on hardware and software setup

The source code is develop using Python 2.7.9, when the user clicks on Run Module or F5 button, a small window appears to detect and capture the images of the pupil. User need to place their eye close to the webcam. When the camera finds the circle of the eye, the system starts capturing since the project use only standard webcam thus images are in low resolution and not really accurate. The image is automatically stores inside the same folder as the source code.

B. Hardware Testing

After that, the captured pupil images need to matching in verification process. The matching code is develop using Python on Raspberry Pi. At this stage, a simple code need to be executed in order to start the matching process. Two images either same image or different image is compared for similarity. The system searched whether it is a “match” in Fig 5 or “not match” as in Fig 6 by producing the output image file.

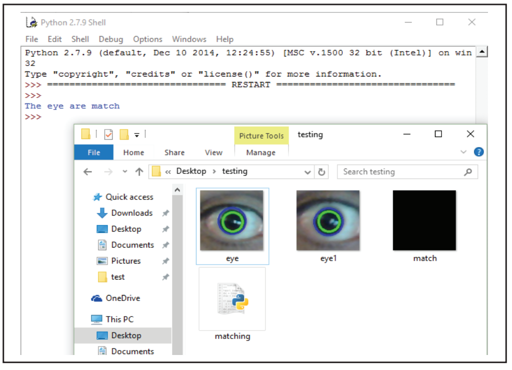


Fig. 5. Pupil Detection Hardware Testing - Match (Success)

Fig. 6. Pupil Detection Hardware Testing – Not Match (Non - Success)

III. RESULTS AND DISCUSSION

On this section, testing on detecting and capturing the pupil using standard webcam that is attached on Raspberry Pi has taken in place. The system marks a green circle as iris and green circle as pupil. System captured pupil image when the camera detecting both circles. This section explains about testing to match processing between two pupil images. The code is implemented using Python on Raspberry Pi and testing by clicking on the Run Module (F5) button as in Fig 7. When the system detects a matching with the same pupil images, the system produces image output called match.jpg. On the other hand, as the system detects a matching with a different pupil image, the system will produce image output called notmatch.jpg.

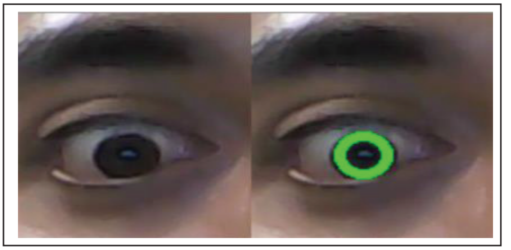


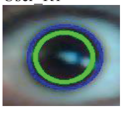
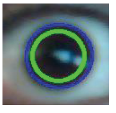
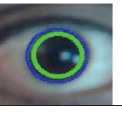
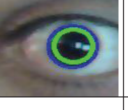
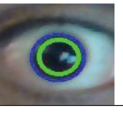
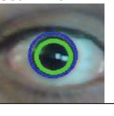
Fig. 7. Testing of Pupil Detection

The calculation of accuracy using Haar Cascade method is as:

$$10 / 100 \times 100 = 10\% \quad (1)$$

Based on the experiment conducted at Table 1, only 10% of pupil is successfully matched using the proposed technique. This is due to non-ideal images, which is not robust enough to determine whether the image is the real user or impostor.

TABLE I. RESULTS OF DETECTED PUPIL (SUCCESS/ NON-SUCCESS)

User Eye Site	Match Target	Match Point (0-Not Accurate) (1-Accurate)
User_R1 	User R1-1 	1
	User R1-2 	0
	User R1-3 	0
	User R1-4 	0
	User R1-5 	0

Good position of eye improves the accuracy of pupil tracking compared to bad eye position. The steadiness of eye position right in front of USB camera with less movement make the pupil image easier to be captured and provide better accuracy.

Bad eye position with too many movements affected the accuracy of pupil image captured. Using this system, if the eyes are not correctly position and having too much movement, the USB camera difficult and also unable to capture the pupil images.

IV. CONCLUSION

The summary of the project must consist objectives in order to solve the problem statement. The first objective is to study pupil detection system in biometrics. Then to design pupil detection system using Raspberry Pi. Lastly, to implement pupil detection system for better tracking system. All the objectives need to completely gone through all phases from analysis to implementation before proceed to testing. The weaknesses of this study is the system unstable and not accurate enough to capture the real time movement. Moreover, it is difficult to detect the eye from far and produce low resolution image.

As a results, the solution has been obtained using Haar Cascade method on the Raspberry Pi, which is suitable in eye detection and tracking. Besides that, researcher investigates an alternative method for matching process using concatenation theory on Raspberry Pi.

The limitation of this prototype is the system execution with a small percentage of computation, which took a few seconds before detecting pupil. Moreover, the images that has been captured are in low resolution, memory installed on Raspberry Pi is very limited and the data processing consume time. Thus, the Raspberry Pi requires another device to analyze the data and image frames in achieving a higher computation process, faster and smoother performance.

As a conclusion, the prototype development of Pupil Detection System has fulfilled the objective of this study. Meanwhile, the development of the system demand investigation and has been done for pupil detection frame transmission in network environment using AdaBoost. Next, the implementation of the prototype system on Raspberry Pi manage to stimulate the real scenario of the project development. Thus, a better solution in proposing the detection of human pupil localization need to be addressed.

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REFERENCES

[1] Menon, R.V., Sigurdsson, V., Larsen, N.M., Fagerstrøm, A., and Foxall, G.R., "Consumer attention to price in social commerce: eye tracking patterns in retail clothing," J. Business Research, vol. 69, 2016, pp.5008–5013.

[2] Beltrán, J., García-Vázquez, M.S., Benois-Pineau, J., Gutierrez-Robledo, L.M., and Dartigues, J.F, "Computational techniques for eye movements analysis towards supporting early diagnosis of alzheimer's disease: a review," Hindawi Computational and Mathematical Methods in Medicine vol. 2018, Article ID 2676409, 2018, pp. 1-13.

[3] Osawa, R., and Shirayama, S., "A method to compensate head movements for mobile eye tracker using invisible markers," J. Eye Movement Research, vol. 11., no.1, 2018, pp. 1-13.

[4] Strukelj, A., and Niehorster, D. C., "One page of text: Eye movements during regular and thorough reading, skimming and spell checking," J. Eye Movement Research, vol. 11, no.1, 2018, pp.1-22.

[5] Radisavljevic-Gajic, V., "Dynamics of eye movements under time varying stimuli," J. Eye Movement Research, vol. 11, no.1, 2018, pp. 1-7.

[6] Puurtinen, M., "Eye on music reading: a methodological review of studies from 1994 to 2017," J. Eye Movement Research, vol. 11, no. 2, 2018, pp.1-16.

[7] Michael, F. Land., "Visual optics: the shapes of pupils," Current Biology, vol.16, no.5, 2006, pp.167–168.

[8] Luo, Z., "Survey of applications of pupil detection techniques in image and video processing," vol.2, 2013, pp.180–181.

[9] Liu, Y., He, F., Zhu, X., Chen, Y., Han, Y., and Fu, Y., "Video sequence-based iris recognition inspired by human cognition manner," J. Bionic Engineering, vol.11, no.3, 2014, pp. 481–489.