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Designing a low-cost eyeball tracking keyboard for paralyzed people☆

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A B S T R A C T

This paper aims at designing a scanning keyboard that serves people with paralysis. This keyboard works on detection and tracking of the user eyeball movements. The main objective of this research work is to implement a simple and less expensive technique that produces the best possible results with a higher level of accuracy. The design of the system is done in phases; these are eye detection and tracking, followed by classification. The tracking phase incorporates skin color segmentation, black pupil detection and support vector machines. We also explored the role of eye red-channel, eye width and height for eye tracking. A scanning keyboard is developed and tested to work with three eyeball movements with 90% double detection accuracy. The performance of the algorithm is experimentally analyzed and the benefits of the proposed approach are highlighted. Also, the simulation results are presented.

1. Introduction

Physical challenges emanate from problems and diseases such as spinal cord injuries, accidents, paralysis of various forms, etc. These problems cause a number of challenges to the sufferer, especially if he/she cannot communicate or move his/her body muscles. The number of such affected people is quite large in the Gulf Cooperation Council (GCC) countries, though the exact number is not known since research results in this direction are not up to the expectation of the public.

Over a number of decades, different solutions in the domain of support for physically challenged people have been suggested and put in practice, but they are not up to the mark as they lack in technology-assisted communication to enable automated mobility, etc. One such solution is the use of alternative ways to interact with devices for people with physical challenges. A Partner-Assisted Scanning (PAS), a form of Augmentative and Alternative Communication (AAC) is a well-known technique, where a nurse uses a keyboard in front of the physically challenged person to scan his/her eyes in selecting different characters or words to enable communication with the physically challenged.

The object tracking (both moving and stationary) is not a new field, and applications exist in various disciplines like engineering and healthcare. Conventionally, technology has been exploited to build systems that try to simplify human life. These systems utilize concepts like human-computer interaction, image processing, virtual/augmented reality, and so on, to build devices by which humans can communicate easily with the machines [1,2]. An example is the Kinect Sensor developed by Microsoft, and the Wii Remote developed by Nintendo Inc. However, these machines or tools help automate human-machine interaction to be used by normal individuals, while the physically challenged as addressed in this research

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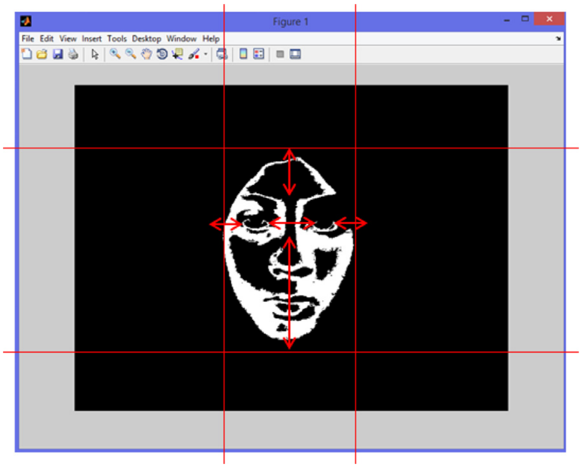

Fig. 1. Feature extraction (skin color, face measurements).

may be able to blink eye only once. Though algorithms exist in the literature for accurate measurements for eye detection and tracking, but such results are achieved once at least 66 frames are available for processing [3]. The challenge in eye tracking of the physically challenged is the availability of only a few frames as the physically challenged person may blink only once, which may provide approximately 20–25 frames, unlike other situations [3] where a significant number of frames is available to reduce errors over a series of frames.

The work in [4,5], though not exactly related to this work, exemplify real time image processing applications including healthcare. With recent technological developments, gesture recognition has the potential to introduce new ways of human-computer interaction and these could serve as a substitute for people with physical challenges. In this domain, the focus is on designing a system that is able to detect eyes of the user automatically. In that, one approach could be to train the system to detect the face of the user prior to detecting the user's eyes. When the face is detected, the eyes' location can be extracted from the face. This type of system can be developed for users with communication or mobility difficulties with the user assumed to have his/her head placed straight in front of the system screen. Head movements and tilting are not considered since the users targeted are with physical paralysis.

To achieve gesture recognition, researchers have used different approaches. In [6], the authors perform gaze estimation using the Scale Invariant Feature Transform (SIFT) along with Random Sample Concensus (RANSAC) and homography model. In another work [7], the authors apply the famous Viola-Jones classifiers for face detection, along with a mean shift tracking algorithm. With a different approach, the authors in [8] performed skin color segmentation for face detection, followed by circular Hough transform to detect the iris.

In this work, a low-cost algorithm is introduced, which investigates the role of red channel in the eye, black pupil, and eye height and width to track the center of the eye. This algorithm is experimentally analyzed and results are compared. In these experiments, data is acquired by a typical low-cost webcam (Logitech C110), where images are captured at 640-by-480 pixel resolution. The first phase of camera calibration or face detection is performed by a trained support vector machine (SVM), the details of which are discussed in a comparative experimental analysis in [9].

The paper is structured as follows. In the next section, eye tracking phase is discussed that outlines different steps needed to complete eyeball tracking. Section three presents classification phase with three user eyeball positions. Simulation results are presented in section four. In section five, benefits of the proposed system are discussed, followed by discussions and the concluding part in section six.

2. Eye tracking phase

In order to track eyes, calibration or eye detection phase is completed first, followed by feature (like skin color, facial measurements) extraction, as shown in Fig. 1.

In this phase, the face is detected by skin color segmentation, after which face coordinates are extracted. After detecting the face, eyes are tracked by two methods. In the first method, black pupil detection is performed, while in the second, eyes are detected by a trained SVM. If both methods detect eyes in the same region, a check is carried to make sure that both left and right eyes are horizontally inclined at the same angle. If yes, eyes are correctly tracked. As a summary, the steps of this algorithm are displayed in Fig. 2 with resulting corresponding visual displays in Fig. 3.

With reference to step 2 in Fig. 2, the face is detected by skin color segmentation, followed by extraction of face coordinates from the black and white image. These face coordinates refer to the width and height of the face with respect to the image size (typically found in every human face), as well as other measurements like the user's forehead area, chin area, and space occupied by the user's eyes. Using these facial measurements, the eye region is predicted as stated in Eqs. (1) and