Iris Movement Tracking by Morphological Operations for Direction Control

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ABSTRACT

The research presented in this paper aims to minimize the complexity involved the in detection & tracking of the iris. A robust and adaptive algorithm for accurate iris detection and continuous tracking of the same is presented in this paper. The proposed algorithm uses morphological operations, performed on high resolution images of the subject's eye to compute the iris movement in left & right direction with respect to the centre of the eye. The computed iris position data can be used for application based processing. The research has various applications in the field of Human-Computer Interaction (HCI) like wheelchair control, mouse cursor control, vehicle control, fatigue detection.

Keywords: *Eye tracking, iris movement detection, Wheelchair, cursor control, Human-Computer Interaction, Morphology.*

1. Introduction

Iris movement tracking is a technique whereby an individual's eye movements are measured so that the researcher knows both where a person is looking at any given time and the sequence in which their eyes are shifting from one location to another. Tracking people's eye movements can help in understanding visual and display-based information processing and the factors that may impact upon the usability of system interfaces. Eye movements can also be used as control signals to enable people to interact with interfaces like computers & wheelchairs directly without the need of any other medium (mouse, keyboard, steering), which can be a major advantage for certain populations of users such as motor disabled individuals.

The field of mathematical morphology contributes a wide range of operators to image processing, all based around a few simple mathematical concepts from set theory. The operators are particularly useful for the analysis of binary images and common usages include edge detection, noise removal, image enhancement and image segmentation.

Through our research we have developed an effective method to detect iris movement by estimating the position of the left and the right portion of sclera with respect to the iris and to use the information in controlling the direction of a robotic vehicle.

2. Literature Survey.

Many different methods have been used to track eye movements since the use of eye-tracking technology was first pioneered by Rayner & Pollatsek, 1989. Electro-oculographic techniques, for example, relied on electrodes mounted on the skin around the eye that could measure differences in electric potential so as to detect eye movements. These methods proved quite invasive, and most modern eye-tracking systems now use video images of the eye to determine where a person is looking.

Poonam S. Gajwani & Sharda A. Chhabria[1] proposed a new algorithm, the coherence algorithm, for eye movement tracking. The coherence algorithm extracts the pixels which lie on the vertical edges of the rectangular area selected by the user. Which is the basic flaw of the algorithm as the user has to select an rectangular area each time the system is started. An iterative algorithm for iris detection was introduced by Topi Maenpaa[2]. It was based on the fact that relatively accurate initial guesses for the unknown parameters can be obtained based on the location of the pupil. The pupil was first defined and then the data was utilized to identify the iris.

Danish Chopra[3], gave a robust method to track the eyeball by estimating the size of the left and right sclera region with respect to the center i.e. the iris. This was done by splitting the image into 2 parts (left & right sclera part) and counting the number of black & white pixels in each region. This gives an idea as to where the iris is located. However the user had to maintain his position firmly aligned to the centre of the camera so as to get high accuracy. Accuracy dipped drastically as the distance from the centre varied.

3. Proposed Algorithm.

Through our algorithm we propose a very fast and robust methodology to achieve the desired objectives (detection and tracking of the iris). MATLAB Development Environment was used for all Image Processing and Serial Communication programming. The entire system is implemented in 3 parts.

3.1 Image Acquisition.

Firstly PC needs identify the video device connected to it & via which serial port it is connected. RGB format for video which is supported by video device was selected so that while reading data from device it should not lead to complications due to modification of format. 640*480 resolution was seen to give the best results when considering the memory requirements, quality and speed of computation. To obtain 1 frame per trigger we set the “Frames per trigger” value to 1. By setting “Trigger repeat” equal to infinite we extract images one at a time from the video.

3.2 Image Processing.

Morphological operations on an image require the image to be in binary format. Since the acquired images are in RGB format, we first convert the RGB image into pure black and white image. This is done by de-quantizing the 8 level RGB image into 2 levels, 1 and 0. All pixel values above 126 are considered to be white pixels and pixel values below 126 are considered as black pixels. This image is then complimented to reverse the order of black and white pixels. This results in an iris area which is white and other area to be black.

Due to limitations of video device we get some unwanted noise in the captured image which is mainly caused due to reflection of light from eyeball. This is seen as black spots in Fig 3.2.2 So in order to remove this noise from image “imfill” operation is performed which removes unwanted pixels from our area of interest. Also image boundaries need to be cleared so as to remove the region of the eyebrow captured by the camera. This is done by using a MATLAB function “imclearborder”.

Erosion of the image is performed next. For this we first create a structuring element. The shape is chosen to be disk so that the structuring element closely resembles the iris. The erosion process moves the disk shaped structuring element from left to right and top to bottom. At the centre point (indicated by the centre of the structuring element), the process will look for a complete overlap of the image region with the structuring element. If there is no overlap then the centre pixel will be set to be white.

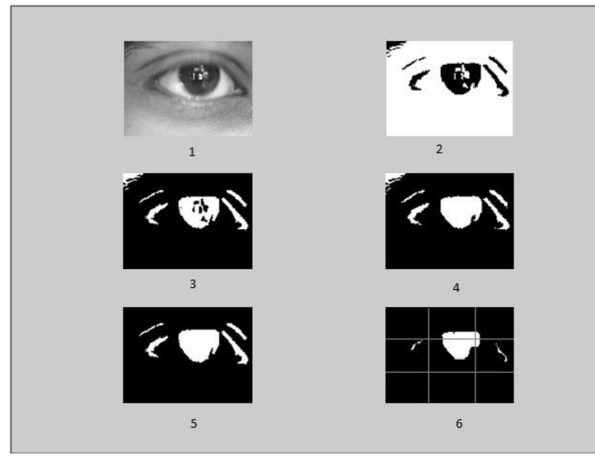

Fig. 1 Image at various Stages.
1.Captured Image, 2.Black & White image,
3. Complimented image, 4. After filling Holes,
5. After clearing Boundaries, 6. Final Image.

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Thus the result of erosion Process is a well defined iris area. This final image is then split into 9 cells. The main concept of such a division is to increase the accuracy when alignment with the camera is disturbed. We then calculate the sum of the values of each pixel in each cell. A black pixel is represented by 0. Thus the cell with the maximum white pixels will have the highest count. This gives the position of the iris. If cell 1, 2 or 3 return this highest count iris is in right position. Similarly if cells 4, 5 or 6 return this highest count iris is in centre position. And if cells 7, 8 or 9 return this highest count iris is in left position. If the count returned is less than 500 for continuous 20 frames (1 second), the algorithm decides that eyelid was closed and a stop signal is generated. Similarly to start the algorithm again the user has to close his eyelids 2 successive times for 1 second each.

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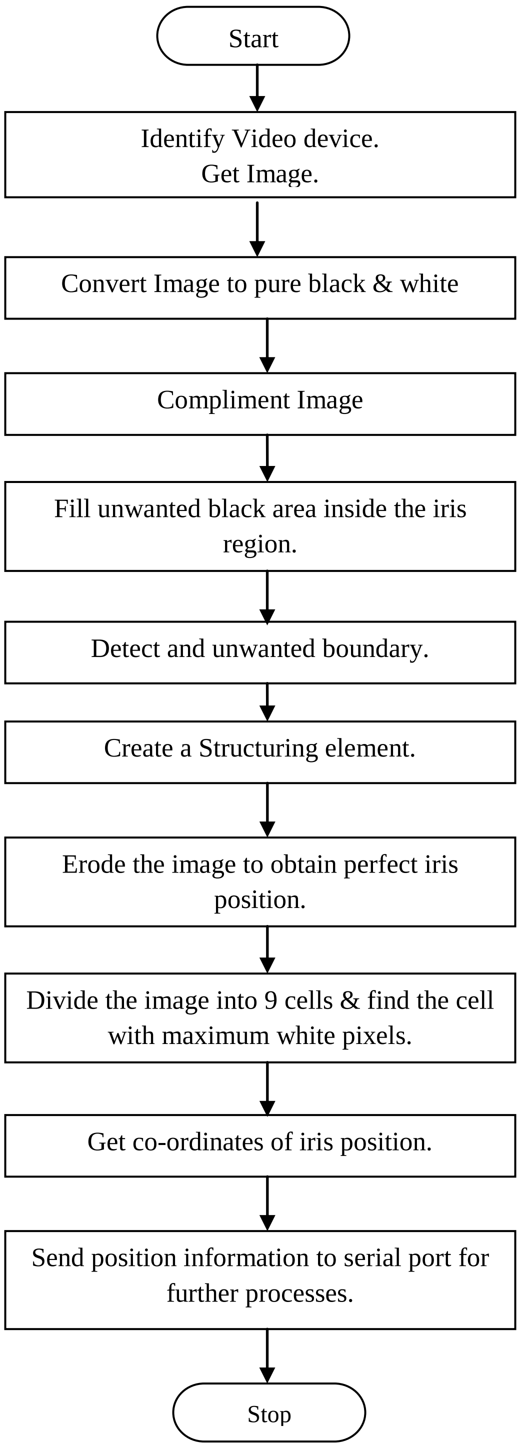

Fig. 2 Flowchart for the morphological approach.

3.3 Hardware Interface.

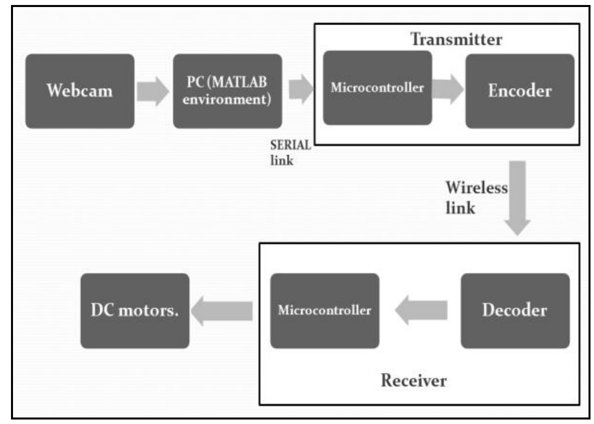

Figure 3 Block diagram of the complete system.

In order to make things simple & remove the complications caused due to wires for data transmission purpose we used a wireless transmitter-receiver module. Due to this reason the range of robotic vehicle is also increased & results in better performance as compared to wired one. For wireless transmission purposes, IC's HT12E & HT12D along with A 434 RF transmitter & receiver module are used. After MATLAB processing on image, PC will give out appropriate control signals to the serial port (01 if iris position is towards left, 02 if iris position is towards centre, 03 if iris position is towards right and 04 if eyelid is closed). This serial data is given to microcontroller through an FRC cable. This FRC cable will give serial data to microcontroller (80C51) through pin no. 10 & this microcontroller converts the serial data stream into a parallel data of 4 bits which is given to lower bits of port 2 (if RI = 1). This data of 4 bits is then given to transmitter IC i.e. HT12E which again encodes the parallel data into serial data & gives it to A434 transmitter module which transmits the data at frequency of 433.92 MHz with the help of antenna. With the help of wireless link, antenna connected at the receiver of A434 module will receive the data from pin no. 8. This data is further given to decoder IC HT12D which decodes the received data into parallel data stream & will give out the decoded data to microcontroller at the receiver end which is placed on the robot. This data is given at port 2 of microcontroller. The microcontroller generates proper signals to drive the motors in the appropriate direction.

4. Results.

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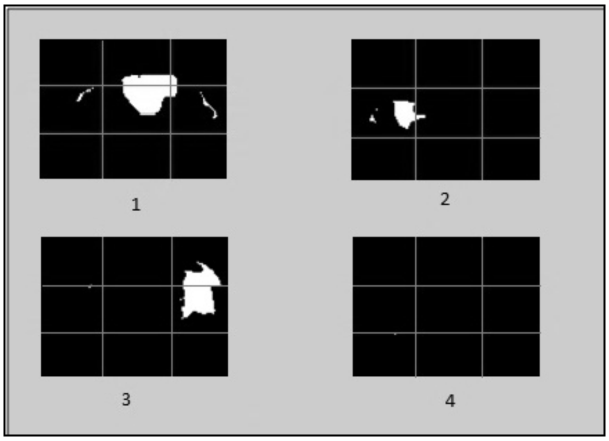

Figure 4 Results for various iris position.
1. Centre Position, 2. Right Position,
3. Left Position, 4. Eyelid closed.

The algorithm has excellent accuracy when tested under normal lighting conditions. Whereas the accuracy decreases as the light conditions are dim. The above figure shows the various iris positions detected by the algorithm.

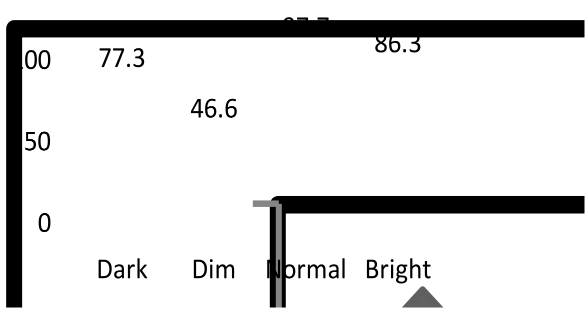

Figure 5 Accuracy Vs. Lighting Conditions.

Alignment of the user with respect to the camera centre has lesser effect to the accuracy due to partitioning of the image into 9 cells.

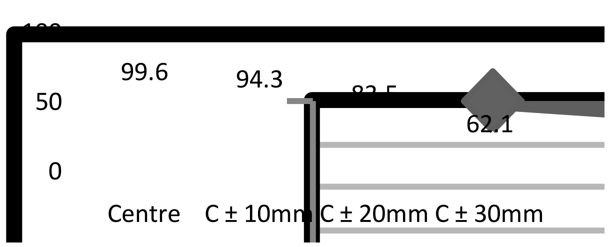

Figure 6 Accuracy Vs. Camera Alignment.

5. Conclusion.

We have presented a simple ,robust & adaptive technique to detect the eyeball movement. The algorithm is fast and efficient enough to detect any kind of movement of the iris and can be adjusted to detect movements of specific intensity. We have also presented a simple method to make use of the the movement to control a robot. The approach can also be used to control a computer mouse, in virtual environments to interact with virtual objects, etc.

Eye movement detection is an important form of human computer interaction and can be utilized to develop many innovative applications and to interact with the computers in a more natural way. Our contention is that eye-movement tracking represents an important, objective technique that can afford useful advantages for the in-depth analysis of interface usability. The user has to only look left or right to move the robotic vehicle towards the desired direction. The diagonal motion is achieved when user looks left or right for only small duration of time .The system is tested on equal terrain and indoor environment. The proposed robot vehicle system is easy to operate by the user. The experimental results are satisfactory.

6. References.

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