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Abstract

Title	**Eye Shape Detection Methods Based on Eye Structure Modeling and Texture Analysis for Interface Systems**

(800 words)

Human-Computer Interaction systems (HCI) are being an attractive field for both researchers and companies in order to increase the human life quality and safety. This is because of the revolution in producing mobile devices that have the capabilities to connect the internet and process information in a very short time frame. Eye is considered as a very promising interactive component because it can be employed to achieve many tasks that usually done by hands as well as it has a faster behavior and response. For example, suppose that many products are randomly distributed on a production line and an operator wants to pick one of them by a manipulator robot. The conventional strategy is whether to use a joystick to control the robot's clip or to move the courser on a PC screen and click on the desired object. The robot will then generate the motion matrix to get the location of the object.

More sophisticated approach is to use eyes. The operator should only look at the object whether on the screen or directly in the real world on the production line.

This work aims to develop and implement three methods to automatically extract the eye features. The eye features are represented by the term "eye shape". The eye shape consists of a set of points called eye shape points. The eye shape points are distributed equally to represent the two eye corners and the two eyelids. The eye shape identifies the eye state (open, nearly close and in-between). In addition, it describes the appearance parameters such as scale, rotation angle and translation in eye images.

In order to detect the eye shape, Active Shape Model (ASM) is developed. The developments are done in terms of enhancing initial estimation of the eye shape in a testing eye image using an object recognition technique. The object recognition technique tries to understand the topological eye structure in the testing image. Based on this understanding, the eye state is estimated and an initial eye shape is suggested.

Searching on eye shape points is also enhanced by describing the local structure around the eye shape points using Principal Component Analysis (PCA). The capabilities of PCA in terms of generalization have increased the robustness of detecting the locations of eye shape points under different lighting conditions.

The improved ASM has outperformed the standard/original ASM with increasing accuracy and reducing detection time.

In the second approach, a totally new method in the domain of object shape detection is proposed. Log-polar transform (LPT) is utilized to convert the change of eye scales and rotations in Cartesian coordinate system into translations. Consequently, the task of detecting x,y coordinates of an eye shape point is facilitated into detecting only $\log\rho$ coordinate in Log-Polar domain. LPT maps the pixels in equal size and hence the geometrical details are preserved regardless the eye size/scale and state in the testing images.

In addition, the existence of eye components such as pupil, iris, eyelid and sclera makes the color variation between the eye and skin very sharp. This variation is measured by applying PCA on RGB color channels of the testing image against wide range of changing of lighting conditions. Based on these properties of eye representation by PCA and LPT, the eye shape is extracted regardless the change of scale, rotation, translation, eye states and lighting conditions.

This new method has performed very high accuracy with significantly reducing the detection time compared to ASM and Deformable Template (DT). This means that it is very appropriate to be employed in real time systems. Moreover, the design has proven that Log-Polar domain should be the baseline of implementing any eye shape detection technique.

In the third model design, as long as LPT has been proven as the initial step of any eye shape detection technique, a recurrent neural network is trained to model the pixel profile in each row of Log-polar eye images. Each pixel profile (row) contains a few pixels that represent the eye contour. The pixel values in a pixel profile vary smoothly and there is no sudden or rapid change exists. Based on this fact, the pixel value of the eye contour in a pixel profile is changed to create a sudden peak. The recurrent network is trained to predict the location of this peak based on some past outputs and previous inputs of pixel values.

By utilizing the above training approach for eye shape detection in a testing image, a Log-polar eye image is described by a fixed number of pixel profiles. The locations of the eye contour in these profiles are highlighted by creating peaks. The recurrent network is trained using different Log-polar eye images. This strategy has significantly enhanced the recurrent network prediction ability because the recurrent network has learned the patterns of pixel values as well as it has modeled the eye shape by learning the different frequency of peak occurrences in an eye image.

The experimental results verified a robust performance of the proposed method based RNN compared to ASM and DT performances. On the other hand, it emphasize that using neural network is very promising for detecting the eye shape and more investigations should be conducted.