Pre-processing of Hartmann-Shack images for refractive errors diagnosis

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Abstract. We describe the image processing module of a system for automated diagnosis of refractive errors (astigmatism, axis of astigmatism, near- and short-sightedness) from Hartmann-Shack (HS) images. Image processing relies on histogram analysis and spatial and geometrical knowledge of the application domain. The objectives were two-fold: a) to generate images of a unique size and ROI positioning; and b) to eliminate noise. The processing guarantees that HS images are handled more efficiently by the feature extraction and classification modules of the diagnosing system.

1. Introduction

This work describes the image processing module of a system that recognises refractive errors (astigmatism, axis of astigmatism, near-sightedness and short-sightedness) from images of the human eye obtained with the Hartmann-Shack (HS) or Shack-Hartmann technique [1]. Imperfections and optical non-alignment in the acquisition equipment introduces noise and other problems in the images that must be treated prior to their input into the recognition system. Analysis is done on feature vectors obtained from the images, and prior to feature extraction and classification images must be processed to identify and align the Region Of Interest (ROI) and remove noise. The standardisation process performs an automatic cropping operation over all images, aligning each ROI along an imaginary common axis.

The standardisation of the image set contributed to reduce computation time considerably and also provided means of identifying the correct refractive error.

2. Pre-processing

The pre-processing procedure is based on an histogram analysis and on spatial and geometrical information about the application domain [2] [3]. It comprises two distinct stages. First the ROI (or HS circle) of every original HS image is identified and positioned at the centre of a new image. The ROI of an HS image is a circular region that contains a set of ´white´ dots. After this step all the resulting images have the same horizontal and vertical dimensions (reduced from the original ones), defined by the largest ROI on the image database.

To identify an HS circle and its centre one must identify its boundary. Most HS circles are not actual circles, and thus instead of trying to compute its radius we calculate the four outermost dots within the circle along the X and Y directions. We end up with four points (top, bottom, left and right) that allow us to frame the entire HS circle. To identify those points a threshold is calculated from an histogram analysis of the two relevant objects in the image, namely dots and background. Finally, the isolated ROI is copied and positioned at the centre of a new image

The image is then segmented with threshold technique to separate the dots, i.e., to identify regions that ideally should contain a single dot (a set of pixels within a certain threshold). Noisy regions may include pixels beyond the dot threshold, which are eliminated using a user-assisted procedure and a 5x5 low pass concentric mask filter. After a user select the central point of a dot region with the mouse, a region growing process is triggered. As a result, dot pixels are isolated and noisy pixels around the dot are replaced with the mean value of the pixels in its neighbourhood. This ensures pixel intensity is uniform in neighbouring regions.

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