

Eye Contour Extraction For Fetal Alcohol Syndrome Screening

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Abstract

Conventional screening for Fetal Alcohol Syndrome in children involves time-consuming and intrusive facial distance measurements. We are developing an alternative method that will allow automatic measurement of the relevant distances from a pair of stereo photographs, as a screening aid. This paper describes a method for automatic extraction from such photographs of the points on the eyes used in the distance measurements, using peak and valley maps of face images. The extracted points are compared with points extracted manually.

Keywords

Fetal alcohol syndrome, eye feature extraction

1. Introduction

Fetal Alcohol Syndrome (FAS) is the most common preventable cause of mental retardation worldwide [2],[6], and is a consequence of the teratogenic effects of excessive maternal alcohol ingestion on the fetus *in utero*. Studies have indicated that the incidence of FAS in the disadvantaged communities of Wellington in the Western Cape far exceeds that in developed countries [2],[5],[6].

The phenotypic features of FAS comprise [4]: pre- and post-natal growth retardation, central nervous system abnormalities, a characteristic facial dysmorphism, and malformations of other organ systems.

There are no biological markers for FAS. Diagnosis is made on clinical grounds alone, requiring a positive maternal history of excessive alcohol ingestion during pregnancy, in addition to the classical phenotypic features and neuropsychological evidence of developmental delay.

The unique facial phenotype of FAS, mainly contraction of the middle third of the face with resultant shortened palpebral fissures, flattened nasal bridge, shortened and upturned nose, smooth philtrum, and thin upper lip, has been emphasized in clinical diagnosis since it is the only aspect of the syndrome that is specific to FAS [1]. These features are thought to be associated with atrophy and flattening of the frontal lobes of the brain [6]. Conventional diagnosis of the facial phenotype involves time-consuming and intrusive distance measurements on the face performed by trained specialists; these distance measurements are compared to a standardised range to determine whether or not subjects are possible victims of FAS.

No automated measurement systems for obtaining the relevant distances are available; however, screening tools using single frontal photographs exist [1]. We are developing an alternative method that will allow automatic measurement of some of the relevant points from a pair of stereo photographs of 6 to 7-year old children. The measurements that we concentrate on are depicted in figure 1. In order to

obtain these, the locations of the eye corners and pupil centres are required.

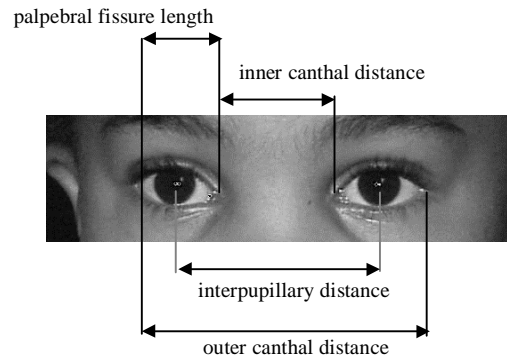


Figure 1. Distance measurements for FAS screening

This paper describes an algorithm to detect automatically the eye corners and irises in these photographs.

Peak and valley maps have been used for eye feature extraction in several applications [3],[7],[8]. These methods rely on various search strategies to match an eye template to images. Yuille et al. [8] and Xie et al. [7] used search strategies operating on complex energy functions consisting of terms due to valley, edge, peak, image and internal potentials, to find the desired points in the eye. Esme et al. [3] used a fitness function based on fused peak, valley and edge maps to match templates to images and a genetic algorithm to search for the optimal match.

Our approach relies entirely on peak and valley maps to extract eye regions from face images; no search strategies are used and simple image processing techniques such as histograms, thresholding, extraction of connected components and fitting of polynomials and circles are applied. The algorithm was developed in MATLAB.

2. Methodology and results

2.1 Study Population

Data for this study were collected during a screening of first-grade children for FAS in the disadvantaged communities of Gauteng Province.

2.2 Image acquisition

The face of each child was photographed in a control frame simultaneously on a pair of high-resolution digital cameras (Sony DKC-FP3 Digital Still cameras) mounted at the same distance from the child, 26 cm apart. The cameras were triggered simultaneously by remote control. Subjects were

asked to have a relaxed facial expression with eyes fully open, lips gently closed, and not to smile (figure 2).

The control frame comprises a chin- and head rest with vertical supports each side. Eleven well-distributed control markers, i.e. markers with known three-dimensional coordinates, are mounted on the control frame so that they are visible on both the left and the right image. These markers allow the images to be calibrated and placed in a three-dimensional co-ordinate frame. If the eyes are located and the relevant points identified on each of the two images, the required distances in the three-dimensional coordinate frame can be calculated.

All photographs were captured at 1344 x 1024 pixel resolution and saved in a JPEG file format.

This image capture platform fits into a robust wheeled carrying case and can be assembled within minutes, for easy transport to remote sites.

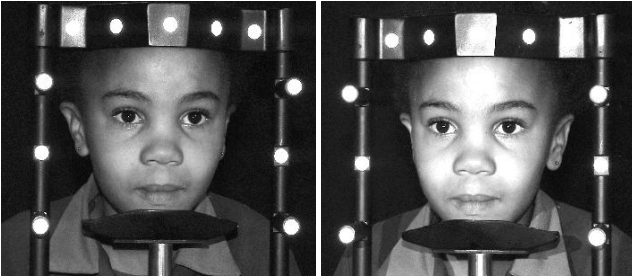


Figure 2. Stereo photographs using reference frame

2.3 Pre-processing

Peak and valley maps [3] are calculated as shown in equations (1) and (2).

$$I_v(x, y) = \frac{u(I_w(x, y) - I(x, y)) \times |I_w(x, y) - I(x, y)|}{I_w(x, y)} \cdot 255 \quad (1)$$

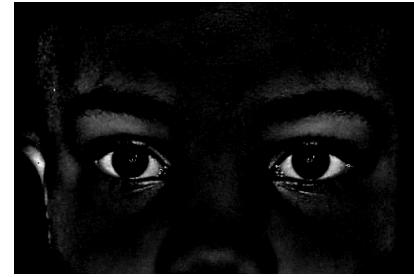
$$I_p(x, y) = \frac{u(I(x, y) - I_w(x, y)) \times |I_w(x, y) - I(x, y)|}{I_w(x, y)} \cdot 255 \quad (2)$$

The valley map (I_v) selects dark regions in the image, such as the iris. It compares pixels in an image window (I) with the window average (I_w), assigns the value '0' to those pixels greater than the window average, and assigns to those pixels less than the window average a value proportional to the difference between the pixel and the average. The new pixel values are normalized to the range 0 to 255. I denotes the original image, and u denotes the unit step function.

The peak map (I_p) selects bright regions in the image, such as the sclera, in a similar manner: it assigns the value '0' to those pixels less than the window average, and assigns to those pixels greater than the window average a value proportional to the difference between the pixel and the average.

Since the face is always photographed in a fixed position, an image window in which the eyes are expected to appear can

be specified in order to reduce the image area being examined. The peak and valley maps for windowed version of the image on the right in figure 2 are shown in figure 3.



(a)



(b)

Figure 3. Pre-processing: (a) peak map (b) valley map

2.4 Estimating Eye Locations

Histograms of the combined peak and valley maps indicated the peak intensities in these images; these were assumed to correspond to the location of the eyes. Once a location estimate was obtained for each eye, further image processing concentrated on regions around the location estimate, and each eye was extracted separately.

2.5 Extracting Sclera Regions

The peak map was converted to binary by thresholding and the largest 8-connected components in the eye region were extracted. This region represented the brightest parts of the sclera. In order to ensure that all of the sclera was captured and the width of the eye would not be underestimated, the region was expanded to fill the corresponding areas in the valley map that fell within the bright contours of the eye; this was achieved by comparing each sclera region on a row-by-row and column-by-column basis to the valley map, and growing the sclera region with the valley contours as a boundary. Figure 4 shows the extracted sclera regions before and after expansion.

Images where sclera regions could not be extracted adequately were rejected at this stage, on the basis of the symmetry of the extracted sclera region. Such images were usually of subjects whose gaze was not directed at the cameras. A total of 60 sets of images underwent the sclera extraction process, and 34 were retained after rejection of unsuitable images.



(a)



(b)

Figure 4. Extracted sclera regions superimposed on valley map
(a) before and (b) after region expansion

2.6 Extracting Eye Corners and Iris

Third order polynomials were fitted to the outer perimeter of the sclera regions in figure 4 (b) in order to obtain smooth contours representing the eye corners.

A circle was fitted to the inner boundary points of the sclera region for each eye, in order to obtain the iris.

Figure 5 shows the extracted eye corners and irises derived from the extracted sclera regions.



Figure 5. Polynomials fitted to eye corners and circles fitted to irises.

The extracted eye corners and irises for 7 children are shown in figure 6.

The vertices of the polynomials and the centroids of the irises represented the eye corners and the pupil centres respectively.



Figure 6. Results for 7 children.

3. Accuracy

Distance measurements required for FAS screening, as shown in figure 1, calculated using the extracted points, were compared with measurements calculated using eye corners and pupil centres identified manually. Four sets of points were obtained manually by clicking the computer mouse on the desired location based on visual inspection of an image on the monitor, and averaged. The student's t-test was used to compare palpebral fissure length (PFL), inter-pupillary distance (IPD), inner canthal distance (ICD) and outer canthal distance (OCD); the results are shown in table 1.

	PFL	IPD	ICD	OCD
Average value (automatic) (mm)	22.9	55.3	33.6	78.7
Average value (manual) (mm)	23.5	55.3	32.2	78.6
Maximum absolute difference (mm)	3.00	1.88	4.74	0.76
Mean absolute difference (mm)	1.06	0.34	1.70	0.60
Standard deviation (mm)	0.78	0.40	1.20	0.49
p-value (paired student's t-test)	2.2×10^{-3}	0.51	4.0×10^{-6}	0.66
Statistical significance	yes	no	yes	no

Table 1. Comparison of manual and automatic methods

4. Discussion and conclusion

There is no statistically significant difference between measurements of IPD and OCD obtained from automatically and manually extracted points on the eye. The significant differences for PFL and ICD might be ascribed to difficulties in accurate location of the inner eye corners in the photographs by the algorithm. Some subjects did not have a clear demarcation between the sclera and the skin at the inner eye corners, as illustrated in figure 7.

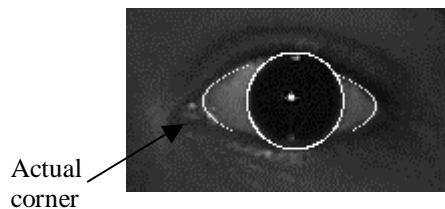


Figure 7. Underestimation of inner eye corner

We have presented an algorithm for automatic eye feature extraction from stereo photographs that yields results comparable to those obtained using a manual method for two of the four eye distance measures conventionally used in screening children for FAS, namely IPD and OCD. Conventional FAS diagnosis is based on examination of the four eye distance measures in addition to the other phenotypic features, as well as maternal history of alcohol ingestion and neuro-psychological evidence of developmental delay. An automatic initial screening method that identifies possible FAS victims on the basis of stereo photographs would reduce the manual load in the diagnostic process. Although only 56.67% (34 out of 60) of the images were suitable for application of the algorithm, a 56.67% reduction in the number of images manually examined represents a considerable amount of time saved when large

numbers of children are being screened. In order to determine whether IPD and OCD would be sufficient for initial screening, further studies, to determine the correlation between final clinical diagnosis and IPD and OCD measurements, must be performed.

5. Acknowledgments

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