DIGITAL PHOTOSCREENER VIrA (VIDEO INFRARED AMBLIODETECTOR)

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Abstract: This work deals with screening system for detection of ambliogenic eye's defects in infants. Designed video metric system VIrA consists of two parts. The first one is measurement system based on the NIR sensitive digital camera. The lens of the camera is provided by excentric photorefractor. The second one is off line image analysis software. This article describes main principles and methodology of this system and image analysis. Results of the analysis are presented in article. Results of patient investigation are printed out in result form as is presented in article.

Introduction

Centre for Functional Disorders of Vision, Hospital Litomysl, Czech Republic has been providing the population based photoscreening system detecting the ambliogenic eye's defects in young children for five years. Age of target population is from 9 to 12 months. Modified analogous camera Yashica 109 with attachment to lens aperture for eccentric photorephaction was used as a photoscreener. Next step of investigation was invocation of cine-film. Evaluation of photos was made "manually" without objective measures.. Results were just approximate. Evaluation could be distorted by subjective mistakes.

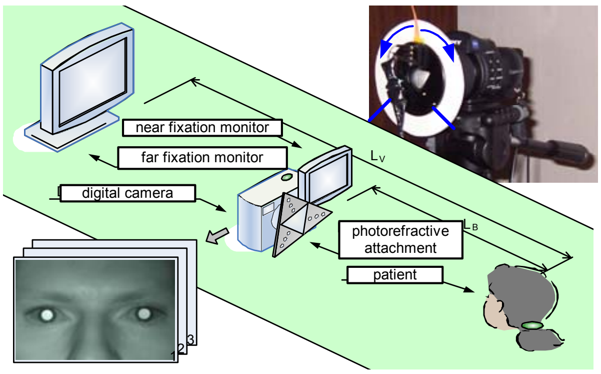

Figure 1: Scheme of VIrA

Similarly as in other disciplines of medicine, digitalization offers changes of the improvement of the routine valuations. Automatic image analysis offer better accuracy, eliminates subjective mistakes, is easier and quicker. Moreover, archiving of the patient's documentation is easier. First works that deals with digital format in photoscreening were made by prof. Schaffel at al. [2]. Results of his work were implemented in photorefractor Power Ref I. – III by PlusOptix company.

Our system VIrA offers better, more complex and robustness extraction of image data for clinical practice if compared to Power Ref. It is more appropriate for screening infants. And finally, it has suitability of individual calibration.

Materials and Methods

Digital photoscreener VIrA comprises of infrared measurement system, control computer and two fixation monitors as is shown in figure 1.

Measurement system consists of digital camera SONY DSC-F828 (working in night shot mode sensitive for near infrared (NIR) spectra) with special photorefractive attachment (for eccentric photorefraction in three meridians – the blue arrows in the figure shows direction of rotation of the attachment for measuring in 0°, 120°, 240° meridians) and measuring source of light.

Figure 2: Screen shot of the image analysis software

The source of light is designed as multi-point array of infrared LEDs similar to design used by Schaffel [3]. The wavelength of light is in NIR field to avoid

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disturbing of patient's attention. Fixation monitors are used for attracting of patient's visual fixation and for calibration of measurement (as fixation motive we used short fairy tale interesting for infant).

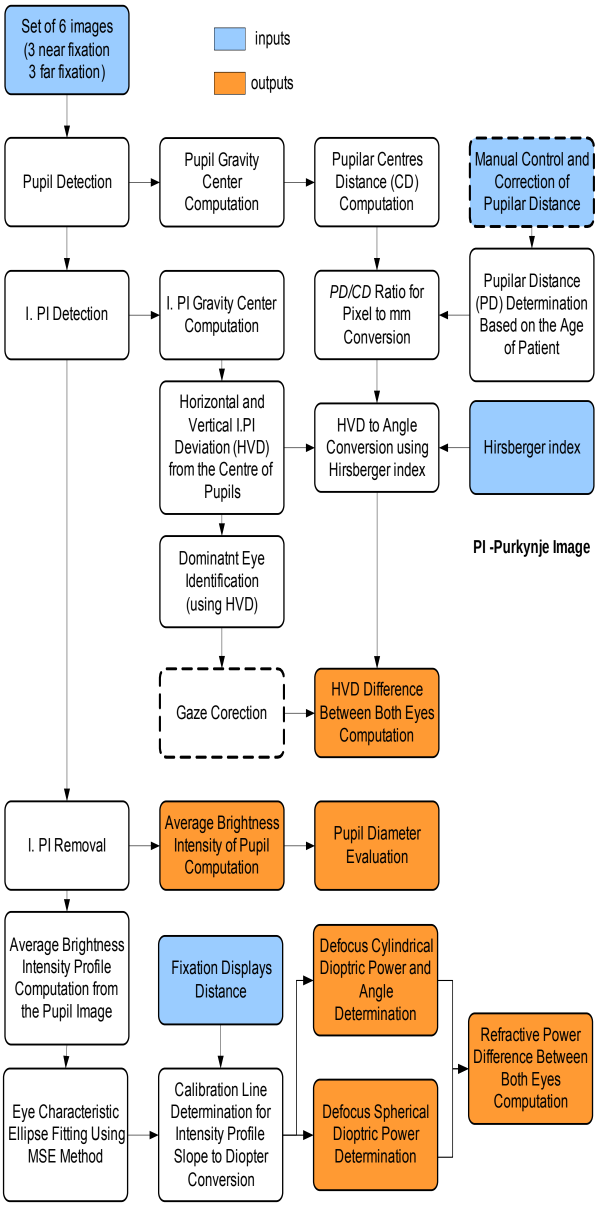

Figure 3: Block scheme of the image analysis

As the near fixation monitor is used Fujitsu Siemens Pocket PC POCKET LOOX 710. As a far fixation monitor is used LCD display of the control computer.

The caption procedure is divided into some steps. First is start of the video movie on near fixation monitor. Consequently, the measurement starts. When the switch is pushed the source of infrared light is switch on and consequently the image in particular meridian is captured.

The same procedure is repeated twice, but in the other meridians (120° and 240°). Then the fixation video movie is switched to far fixation monitor and the second set of three images of eyes is captured. For image analysis the images are loaded from the camera to the control computer. Screen shot of this software is presented in figure 2.

Corneal and retinal reflexes of both eyes are detected in all images. Employing the Hirschberg principle, the corneal reflex (I. Purkynje image of the point source of light) is used for determination of horizontal and vertical heterotrophy. As an equivalent of eye's vergency is used distance between the centre of corneal reflex and the centre of gravity of pupil. Refractive state (accommodation) of eye is determinated by analysis of the brightness distribution of the retinal reflex acquired in the conditions of eccentric photorefraction.

Block scheme of the image analysis is presented in figure 3. First step of the image analysis is detection of both pupils. For this detection is used vertical and horizontal brightness profile of maximal values in each row or column of the image. These profiles detect two areas of highest brightness. Only these two areas (regions of interest) are used for further processing.

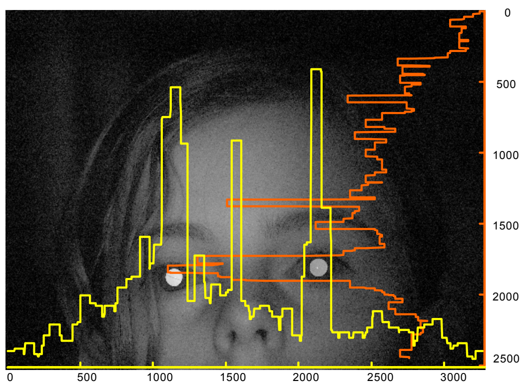

Figure 4: Smoothed horizontal and vertical brightness profiles of maximal values

Profiles smoothed by convolution are shown in figure 4. Pupils are determinated in the regions of interest by thresholding and I. Purkynje images represent the pixels with maximal values of brightness.

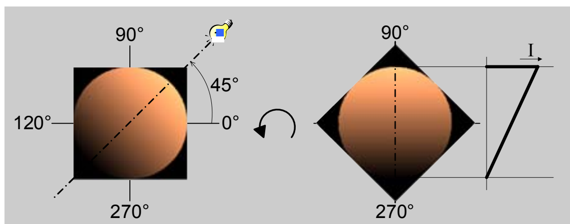

Figure 5: Average brightness profile without I.PI

Then are computed centres of pupils as gravity centres [5]. Consequently the distance between these centres in pixels (Centres Distance - CD) determinated. The average (inter)pupilar Distance (PD) in millimetres can be obtained by statistical formula based on age of patient in weeks. Optionally the user can set this value manually as real measured value. The ratio PD/CD is used as a conversion constant K from pixels to millimetres. I. PI gravity centre is computed by the same way as pupil gravity centre [5].

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In consequent step, the vertical and horizontal position difference between I. PIs and centres of pupils (Horizontal and Vertical Deviation - HVD) is computed. The dominant eye is determinated as a eye with the smaller horizontal deviation. Angle of deviation is computed using Hirschberg formula equation 1:

$$\beta = HD \cdot K \cdot H \,, \qquad (1)$$

where β is measured angle [°], HD is horizontal deviation between I. PI and centre of pupil [px], H is Hirschberg index [o/mm], K is conversion constant [mm/px].

As a marker of horizontal, respectively vertical heterotropia the differences in vertical and horizontal deviation between both eyes are used. These values are in angels.

For the further analysis the I.PI is removed from next processing. From modified image (without I. PI) the average brightness intensity in each pupil is computed. Next results are pupil diameters of the left and the right eye.

The basis of the next analysis is computing of the vertical average brightness profiles (on the figure 5 on the right side). For every measured meridian (0°, 120°, and 240°) is obtained one profile. Computation of images obtained in other measurement meridians then 0° comprises rotation of image to position 0° as a fist step. The average vertical brightness profile is calculated as the mean values of brightness of horizontal pixel rows in pupil.

The slope of the brightness profile, obtained by linear regression procedure, corresponds to the refractive power in particular meridians. For consequent analysis, the slopes are plotted in the vector gram, where the distance of the vector end points from centre equals the slope of the brightness profile and the direction of the vector represents the direction of the measurement meridian. Based on the ray tracing study of the light cone envelope rays passing thought sphere-toric plane we suppose the ideal shape of the vector gram should be the ellipse (see figure 6).

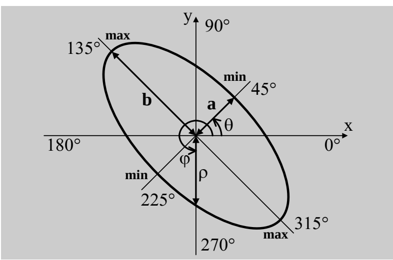

Figure 6: Characteristic ellipse

We assume the photorefractive measurements in particular photorefractor rotation obtains the single refractive power of the eye in this meridian which represents actual combination of the spheric and cylindric power in that meridian. The ellipse is fited to the set of six endpoints (three measurements and three "mirror" vectors) using Mean Square Error method (MSE). Result of fitting is presented in figure 7.

This ellipse presents spherical (a) and cylindrical (a-b) part of eye's defocus relative to the camera lens aperture plane. The rotation of ellipse presents angle (θ) of astigmatism.

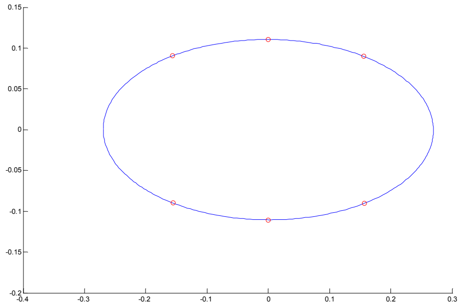
Figure 7: Characteristic ellipse fitting

The calibration of these values is made by comparison of two sets of measuring obtained during fixation of near and distant monitor. Known value is the distance between these two fixation monitors. This value defines known defocus and it is used for calibration (see figure 8 calibration line). There are two states in this figure (refractive state d_B for near fixation and d_V for far fixation a_B, a_V are analogous half-axis sizes). This calibration determinates a as a spherical value in dioptres, difference between a and b as a cylindrical value in dioptre and θ as an angle of astigmatism.

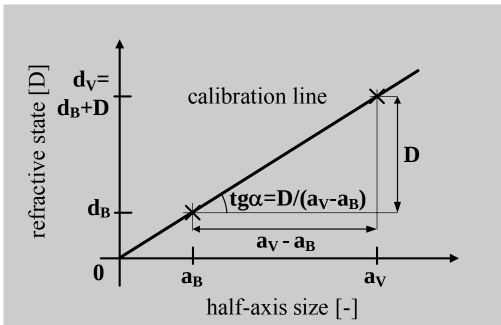

Figure 8: Calibration line

The refractive power of the eye is consequently calculated as the defocus during fixation of the target at optical infinity, i.e. at 6 meters. Last calculated values are differences of spherical and cylindrical parts of the refractive power between both eyes.

Results

Main results are overall values of cylindrical and spherical components of reaction and axis of astigmatism. Main results of the image analysis are average brightness profiles in each meridian, ellipse in vector gram as an interpretation of refractive power and defocus. Other results of the image analysis are diameters and differences of diameters of corneas, differences of diameter of left and right eye pupil, average brightness of pupils. All these values can be

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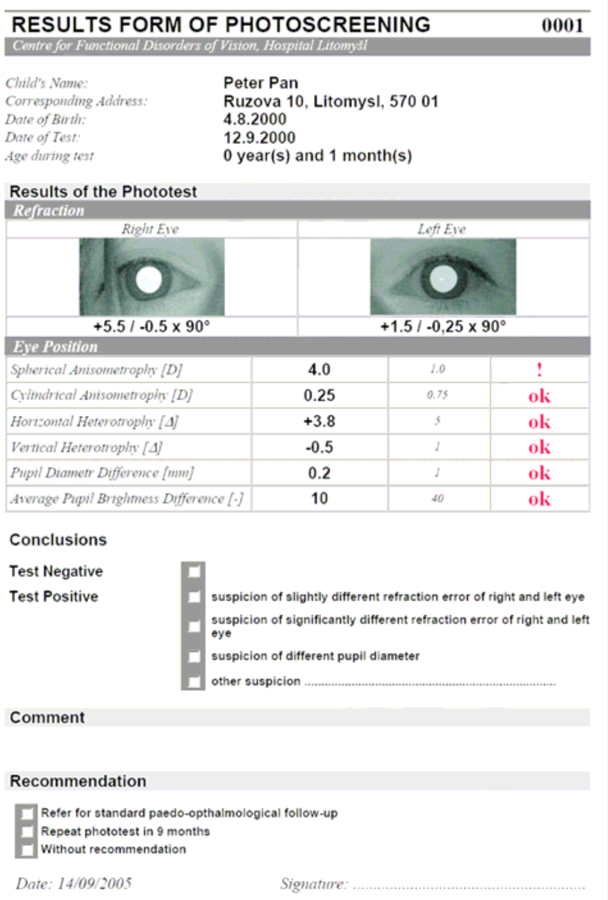
printed out or stored in computer in transparent form. Example of resulting form is presented in figure 10.


RESULTS FORM OF PHOTOSCREENING 0001

Centre for Functional Disorders of Vision, Hospital Litomyšl

Child's Name: Peter Pan
Corresponding Address: Ruzova 10, Litomysl, 570 01
Date of Birth: 4.8.2000
Date of Test: 12.9.2000
Age during test: 0 year(s) and 1 month(s)

Results of the Phototest

Refraction

Right Eye	Left Eye
+5.5 / -0.5 x 90°	+1.5 / -0,25 x 90°

Eye Position

Spherical Anisometrophy [D]	4.0	1.0	!
Cylindrical Anisometrophy [D]	0.25	0.75	ok
Horizontal Heterotrophy [Δ]	+3.8	5	ok
Vertical Heterotrophy [Δ]	-0.5	1	ok
Pupil Diametr Difference [mm]	0.2	1	ok
Average Pupil Brightness Difference [-]	10	40	ok

Conclusions

Test Negative
Test Positive
suspicion of slightly different refraction error of right and left eye
suspicion of significantly different refraction error of right and left eye
suspicion of different pupil diameter
other suspicion ....

Comment

Recommendation

Refer for standard paedo-opthalmological follow-up
Repeat phototest in 9 months
Without recommendation

Date: 14/09/2005 Signature: ....

Figure 9: Example of resulting form.

Conclusions

Designed prototype of the photo-screener VIrA is precise enough to measure ambliogenic defects in infants. It is has reproducibility of the results and good robustness. From resulting form is possible to detect some non-symmetrical values between both eyes that can show on tumours. Also there is a set of parameters that is important for ambliogenic detection. This system is still in development. It is open for changes and additional image analysis. Next developing targets are acceleration of the caption procedure and enhance fixation movie attraction. This is necessary for better improvement of patient attention and improving of screening test relevancy.

Acknowledgement

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