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Optometric-lab: a Stereophotogrammetry Tool for Eye Movements Records

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***Abstract*—**In this paper as showed a non-invasive 3D eye tracker for optometry clinical applications. Measurements of biomechanical variables in clinical practice have many font of errors associated with traditional procedments such cover test (CT), near point of accommodation (NPC), eye ductions (ED), eye vergences (EG) and, eye versions (ES). Ocular motility should always be tested but all evaluations have a subjective interpretations by practitioners, the results is based in clinical experiences, repeatability and accuracy don't exist. Optometric-lab is a tool with 3 (tree) analogical video cameras triggered and synchronized in one acquisition board AD. The variables globe rotation angle and velocity can be quantified. Data record frequency was performed with 27Hz, camera calibration was performed in a know volume and image radial distortion adjustments.

***Keywords*—**Eye Tracking, strabismus, eye movements, optometry.

I. INTRODUCTION

EYE movements examination is a important part of optometric evaluation for diagnostics of strabismus and binocular vision anomalies, strabismus is one of many ophthalmologic conditions addressed because it affects quality of life [4],[11].

Ocular examination of the patient have many tests such cover test (CT), near point of accommodation (NPC), eye ductions (ED), eye vergences (EG) and eye versions (ES).

The determination of presence eye deviations such heterotropias (manifest strabismus) and heterophorisa (latent strabismus) tested by CT, this test provide a clear result about eye alignment and results in information on the presence, magnitude, direction and frequency of the deviation, these test need a subjective interpretation by practitioner, test accuracy is limited further by the minimum movement, some experienced ophthalmologists have claimed they can detects shifts as small as 0.6° or even 0.3° but for the most practitioners under optimal conditions the accuracy is about 0.6° [5],[11] , relatively few studies have reported on the repeatability of heterophoria measurement procedures, but experience examiners provides high interexaminer and intraexaminer repeatability [7].

The evaluation of ocular motility plays an important hole on the diagnosis of eye muscles palsy or paresis. Some signs like eye misalignment and closing or covering one eye could be seen in ocular motility tests such ED, EG and ES, these testes in clinical approach the examiner move a penlight in patient's vision field and look his eye gaze movement, sometimes one or both don't move or have a uncommon position, the diagnosis need a examiner interpretation in order wise association of subjective interpretation about results.

The NPC is also considered an important diagnostic finding in the assessment of convergence insufficiency.[10] , The NPC is the point in space located directly in front of the patient's face in the medianplane and defined by the intersection of the lines of sight when maximal convergence is used, if a patient have an insufficiency of convergence some sings like poor reading, headaches after close work will appear. In eye consultation the practitioner should look these fiding, but the eye movement always have monitored by eye care professional without data record by electronic device.

Eye trackers are instruments with multiplies applications like cognitive data acquisition, neurology studies[8], marketing research, and ophthalmology research.

Since observation of the responses alone does not allow an objective assessment, several techniques for quantitative eye movement recording have been proposed [3],[6],[9],[12] like video eye trackers, these methodology is based on the measurement of the relative position of the reflected image of an infrared source on the cornea and the pupil center.

In these days application of eye trackers in eye care clinic is so rare because implementation costs and applicability in clinical work.

In this paper we present a non-invasive 3D eye tracker for optometry and eye care clinical application for eye moments records and his validation.

II. METHODS

Optometric-lab (fig.1) is an instrument composed by 3 (tree) analogical video cameras CCD 1/3 470 lines SONY triggered in AD board Geovision GV-800 with 27 fps (frames

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per second) in a computer Intel Pentium Dual CPU E2180, 2,00 GHz, 1,00 GB RAM, one head set held in a table, over the table was an illumination system made by 6 (six) incandescent light bulbs, all of light rays were filtered by a white plastic board, for subjects face illumination.

Calibration: The image calibration was performed by direct linear transformation (DLT) [1] using a calibration frame with 68 points distributed in 8 bars, four in corners and others four in the middle sides, our calibrate frame have sides about 300mm.

Data acquisition: The eye tracking position was calculated by an image processing by math morphology in dilatation, erosion and segmentation frame by frame.

The image, acquired by our cameras come with radial distortion, undistortion process was made by video transformation in sequence of JPG images undistorted by a freeware GML undistorter, next all images pictures were transformed in AVI video again.

All data sample was calculated in cartesian 3D coordinates, eye rotations were abstraction made by two equations above to quantified all rotations in two cords horizontal and vertical trajectories:

$$\theta_h = arcsen \frac{\sqrt{(x_2 - x_2)^2 + (y_1 - y_2)^2}}{r} \quad (1)$$

$$\theta_v = arcsen \frac{\sqrt{(y_1 - y_2)^2 + (z_1 - z_2)^2}}{r} \quad (2)$$

θ_h and θ_v is eye angle x, y and z is a 3D axis, x means horizontal, y longitudinal z vertical, variable r mean eye bal radius, in human eyes it means 13mm.

Validation apparatus: Validation device synchronization was made by cameras record from metronome flywheel in some frequencies.

Image correction was valided by angular grind compound by points with 40mm distances some records in diferent angulations was performed to evaluate reproducibility of measurements.

To simulate eye movements we used two stepper motors with 7.5°±0.5° controlled by computer parallel port by MATLB© R2008A rooting, in motor axis was fixed a sphere with 10mm of radius, in these sphere was placed a march simuling a pupil position on equator's sphere, all movements were on zigzag about 7.5°±0.5°

Data filtering: The data was filtered by digital filter Buttherworth 4° ordering with cut frequency 0.06Hz low pass, definition of cut frequency was performed by spectral analysis by Fast Fourier Transformation (FFT).

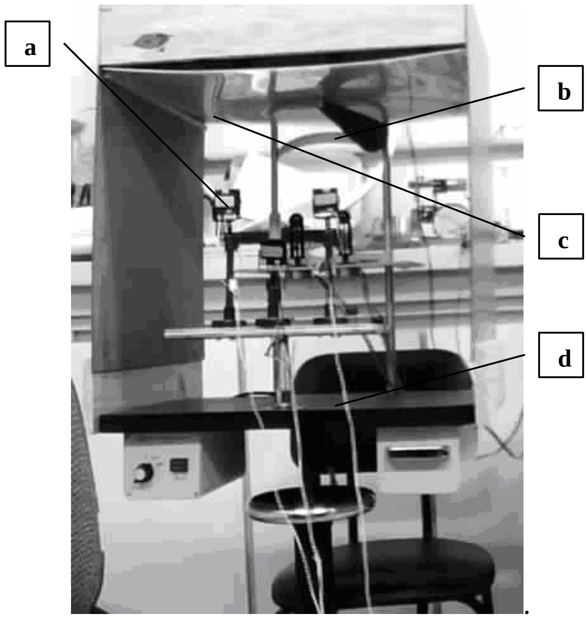

Fig. 1 OPTOMETRIC-LAB developed in UMC. (a) cameras, (b) head set, (c) illumination system and (d) table

III. Results

In these section we describe a results to validate the optometric-lab.

Synchronism validation: The data processing shows an angular trajectory of flywheel by the time, these data describe a wave symmetry and reproduction of oscillations, we used a various Flywheel Frequency in cycles per minute (FFc/m), we compared real frequencies with data processed frequency as see in table I.

TABLE I
SYNCHRONISM VALIDATION DATA

FFc/m Real	*FFc/m quantified by optometric lab*	*Standard desviation of optometric–lab measurements in c/m*	*Number of tasks*
17.8	17.8	1.3	9
21.4	21.4	1.1	9
25.8	25.7	1.9	9
37.5	37.7	2.2	9
49.7	49.6	1.1	9
64	63.4	1.2	9

Based on previous data exist high synchronization in low frequencies than in fast frequencies, fig. 2 shows a bar error plot from these data.

The line shows a linear relationship with real flywheel frequencies and optometric-lab flywheel measure, vertical bars represent a standard deviation of measures, in these graphic is easy to understand a robustness synchronism in these interval of frequencies. The correlation of variables real frequencies and optometric measure was 0.9.

The fig 3 shows a plot of confiance bounds in a dispersion diagram with adjusted regression line with 95% confiance.

The linear regression model have a 0,1% of error about synchronism.

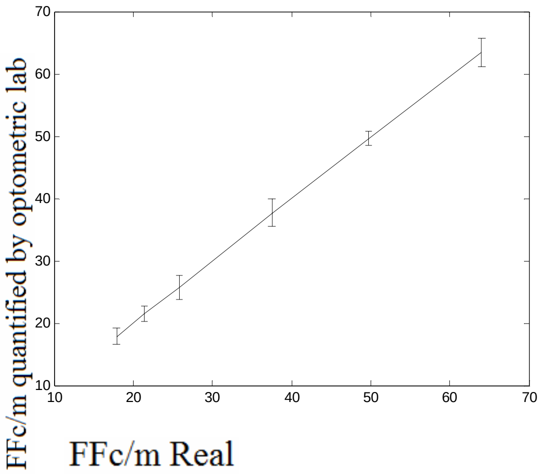

Fig. 2 graphical visualization of error bar plot, continuously line show relationship with real flywheel frequency and optometric lab quantifications

ANALYSIS OF FIT FOR DATASET FFc/m BY OPTOMETRIC-LAB

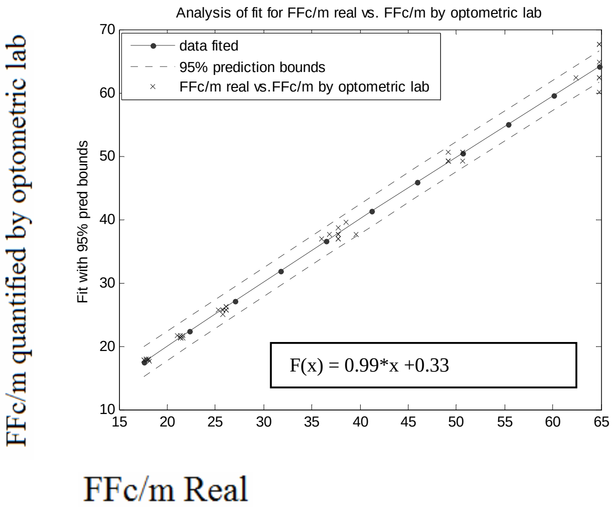

Fig. 3 analysis of fit for dataset FFc/, rea; vs FFc/m by optometric lab at 95% pred bounds, look a simetrical line with both variables

The validation of radial distortion correction was performed by tridimencinal reconstruction of a grind of points in 5 (five) tasks.

The analysis of variance shown no variance of measurements (f=0.05), the coordinate reconstruction show a symmetry of points equal than real condition (see in fig 4).

The accuracy in quantification of angle rotation of stepper motor was 0.3° in 23 tasks, the mean measure was 7.2°±0.22° in fig. 5 shows a graphical representation of these experiment.

GRAFICAL RECONSTRUCTION OF GRIND OF POINTS

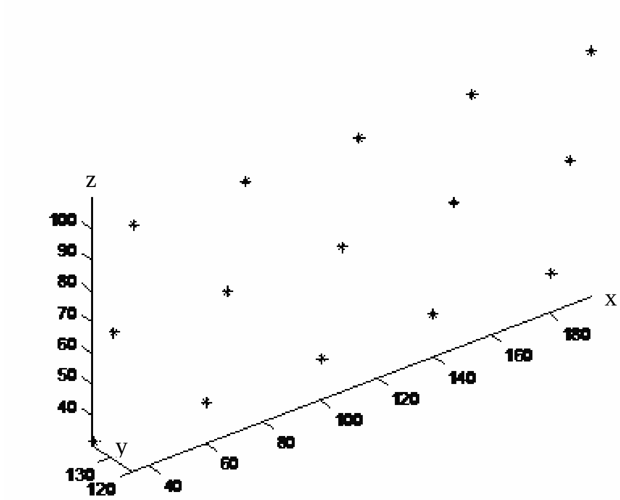

Fig. 4 graphical visualization of 3D reconstruction (x, y and z) of a grind formed by symmetrical points in a same plane

PLOT OF ZIGZAG MOTOR’S AXES

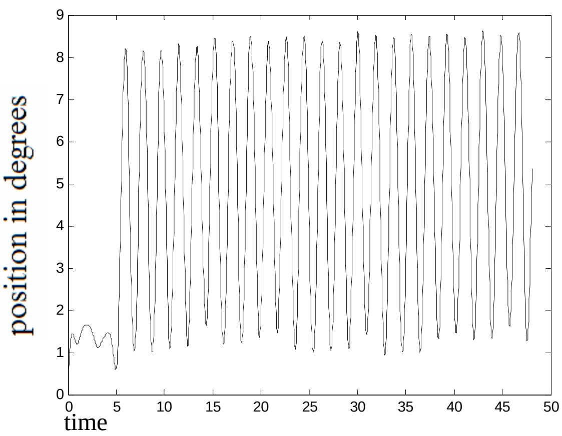

Fig. 5 this figure shows a angle position of sphere moved by a stepper motor, all measured was made optometric-lab in 50s of record

IV. Discussion

We present a eye tracker device named optometric-lab, this instrument wants to help eye care professionals in data acquisition from eye movements examinations, this instrument is a low cost alternative to make eye tracking because all elements are easy to find in local market, the ccd analogical cameras and AD board is common used in surveillance applications, all validation testes shown a synchronization, accuracy and reproducibility of measurements in static and dynamic tasks.

Stereophotogrammetry methodology is used to analyze human movements, the performace of optometric lab was not inferior than other instruments, the signal acquisition frequency is lower than others eye trackers, but in this special application don't need a high acquisition frequency.

The table 2 (two) show a relation system model, acquisition frequency, and accuracy in degrees.

TABLE II
RELATIONS WITH ORDER SYSTEMS

Brandy	Acquisition frequency	Accuracy in degrees
iView X™ Hi-Speed	1225Hz	0.25 to 0.5
iView X™ Hi-Speed PRIMATE	1250 to 50Hz	0.25 to 0.5
iView X™ MRI/MEG	50Hz	0.5
EyeLink 1000	2000 to 1000Hz	0.25 to 0.5
EyeLink II	500Hz	0.5
Tobii X60 & X120 Eye Trackers	60 to 120Hz	0.5
Optometric-lab	**27Hz**	**0.3**

Optometric-lab have a slow frequency of acquisition but the price is shorter than some systems.

The most practitioners have accuracy about 1° at 95% of confiance, optometric-lab is 39% more precision than human evaluation [2], but a secure limit of accuracy in humans quantification for CT is 1.7° to 2.2° [11].

The application of optometric-lab can make some benefits in eye clinic practice to make a more detailed eye movement evaluation and in objective records.

V. Acknowledgments

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VI. future work

In a future work we will present a application in humans to quantification biomechanical variables from eye moments in optometric and eye care precedents.

VII. References

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