



3D simulation, visualization, animation and modeling of eye movements, pupillary response and visual evoked potentials for ophthalmological studies

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Abstract

We present a technique for the visualization, simulation, animation and modeling in 3D of some ophthalmological parameters such as: eye movements, pupilar response, visual field and visual evoked potentials (VEP) based on Professional Broadcasting system called Newtek Video Toaster (NVT). With the NVT we can perform real-time digital video effects, broadcast-quality titling, crystal-clear freeze frames, luminance-based color processing, stunning 3D graphics and associated with a PC, it works like Desktop Broadcast.

1 Introduction

The new image processing tools for TV in 3D: visualization, simulation, animation and modeling applied to neuro-ophthalmologic diagnostic, in special to eye movements, pupillary responses studies, visual field and visual evoked potentials (VEP) in Perimetry, have let us obtained objective diagnostics in patients. The NVT is the base of the video processing system used jointed with the ophthalmologic instrumentation developed by our group: Opto-nystagmogram (ONG), Video-oculograph (VOG), Pupillometer, Perimetry with index projector based on fiber optics, pre-amplifier of VEP signals and specialized software of digital processing of signals and images.

Three-dimensional modeling is based on two simple elements: points and polygons, the polygons is some number of points joined by lines to form a solid face. The process of creating 3D objects is a lot like drawing in dot-to-dot



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coloring books. With 3D modeling systems, we place the dots, connect them with lines to form a recognizable shape. Appearance consists of color and texture qualities that connote realism to the eyes, called surface attributes, or material properties by Watt⁹.

Later we select portions of an object by their names. Names are given to polygons when they are first created. The image will be rendered and placed in the first available frame buffer. Once we have a complete structure, we will give position and movement of all objects, camera and light sources. The final step is to render the scene using high resolution. It must be ultimately rendered to video tape, videodisk, or film, for real-time playback.

2 Method

NVT 4000, PC Amiga and lightwave 3D program are the basis for a very high quality animation workstation, with the help of these tools, we generate the high resolution 3D model of human eye and extra ocular muscles. To this model, we applied information of ocular movements by means of Fine-Tuning motion paths with the motion control editor and a GPI trigger (general purpose interface), it also works either signals and images such as pupillary responses, VEP of patients, obtaining images of visualization, simulation, animation and modeling of the ocular biomechanical dynamical reported by Suaste, et al.⁷, generating a virtual environment of the neuro-ophthalmologic pathologies like as nystagmus, strabismus, glaucoma, pupillary responses diseases, visual pathways diseases, etc.

The surfaces of model components are made by means of polygon series with textures, dimensions, colors and movements similar to real obtaining an animated virtual eye. This eye responds to programmed movement through contained information into files related to ocular movement obtaining with ONG and VOG. At the same time, we applied files with the respective information about the patient pupillary response and VEP's obtained from perimetric studies, Suaste et al.⁸, generating the pupillary reflex simulation based on the studies of Stark⁵ and the physiological behavior of the visual pathway.

Using the infrared sclera reflection technique (900 nm) limbus tracking with the fixed head, it is obtained a diagnostic system which is able to detect, register and analyze horizontal, vertical and oblique eye movements and congenital nystagmus (CN), the VOG consists of a digital image processing of the iridial profile for torsional nystagmus by Suaste, et al.⁶ the interpretation of images are most objectives and illustrative by adding a computer visualization technique that joins these ONG (Figure. 1) and images with 3D figures immerses into virtual environments. By means of the ONG associated with the programmable stimulus, the spectral analysis in frequency, position, velocity and latency time are realized. We make mention of these ONG because they

let us analyze and visualize common eye movements such as saccades, accommodation, smooth pursuit, convergence and divergence.

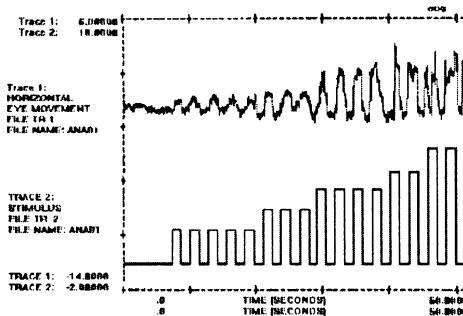


Figure 1: Optonystagmogram (ONG) with the control stimuli (lower trace).

We also developed a method of measuring head movements using a search coil in a magnetic field similar to method for eye movements developed by Robinson⁴, later with the ONG realize us the coordination and postures of eye-head movements in CN reported by Abadi¹.

The automatic perimeter (Figure 2) is based on the physical dimensions of Goldmann perimeter and the index projector is based on fiber optics target presented by Suaste, et al.⁴, we obtain automatic and objective determinations for each spot of light in peripheric and central zones.

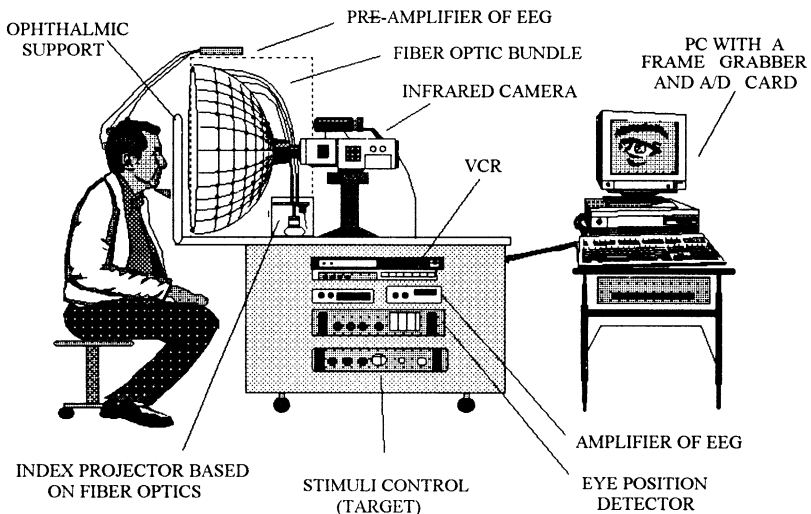


Figure 2: Objective Perimeter with index projector based on fiber optics.

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The pupillary response are captured by means of an infrared-sensitive camera and recorded in a VCR to analyze off line with an image processing system. This system consists of a computer equipped with a frame grabber DT2853 and eye movements detector for monitoring the initial position of the eye, during the examination. VEP's are obtained by means of an amplifier of EEG and averaged the trials like to Iwanowa & Henning³. The light source is a stroboscopic lamp and the diameter core of the optical fiber (light guide) is 1 mm. For timing the system we recorded the pupilar response, VEP's, signal of the eye position detector, stimuli position and light intensity on time on VCR-HiFi.

3 Results

The instruments built and designed in our lab are the basis of the system for 3D simulation, modeling, visualization and animation (Figure 3). We have an extensive patients records, and the method is being applied in studies relationated with ocular diseases in two Ophthalmological Clinics.

In the next figures, it shows 3D graphs for visualization, simulation, animation and modeling of eye-pupil movements and visual field, Eye movements in Congenital nystagmus waveforms by Del'Osso & Daroff², such as 1) Pendular Nystagmus: pure, assimetric and with foveation saccadics, 2) Jerk unidirectional: pure, extended foveation, pseudo cycloid and pseudo jerk, 3) Jerk bidirectional: pseudo pendular and triangular, etc (Figure 4); the trajectories of saccadic eye movements and extra-ocular muscles (Figure 5); visual pathway associated with a light stimuli and the propagation of the VEP in occipital area (Figure 6), pupilar escape and pupilar capture applied to Perimetric studies (Figure 7), Head-eye movements play an important role in gase, the interaction between eye and head movements involves both their shared role in directions gaze and the compensatory vestibular ocular reflex (Figure 8) and a system of search coil in a magnetic field for monitoring compensatory head postures in CN and head movements (Figure 9).

Conclusion

This technique will permit objective diagnostics of pathologies presented in people submitted in biomechanic studies and pre-post surgery analysis. The video can be manipulated at different velocities, projections, movements and it creates 3D animations producing a video-diagnostic immerse in virtual environments and man-machine interaction.



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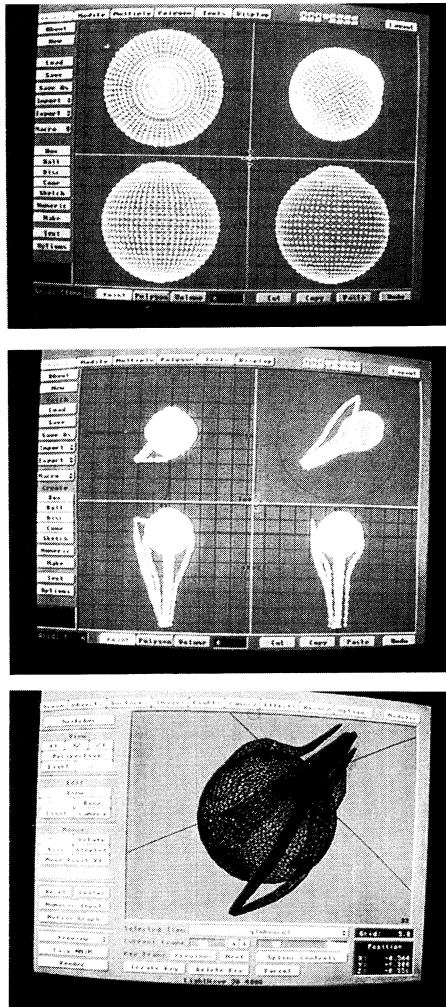


FIGURE 3: SYSTEM OF SIMULATION, VISUALIZATION, MODELING AND ANIMATION.



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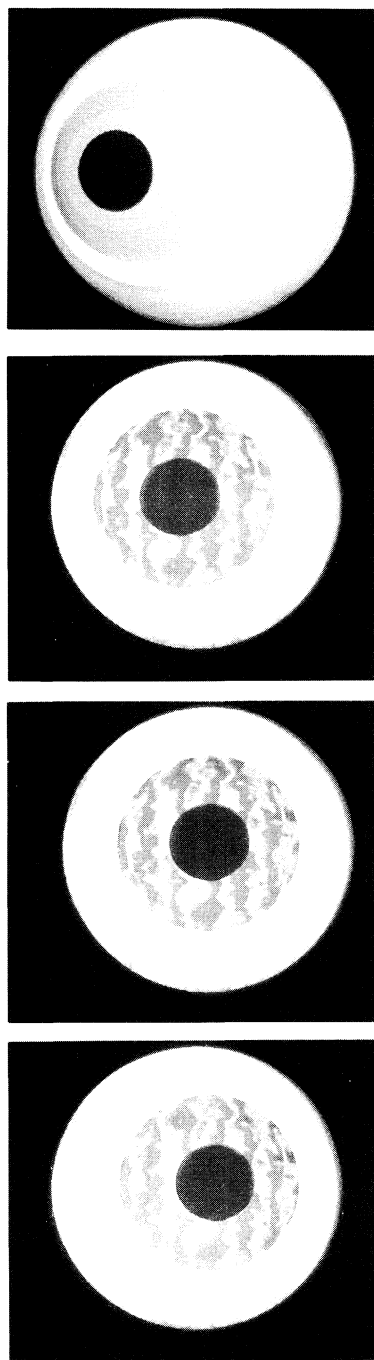


FIGURE 4: EYE MOVEMENTS IN CONGENITAL NYSTAGMUS

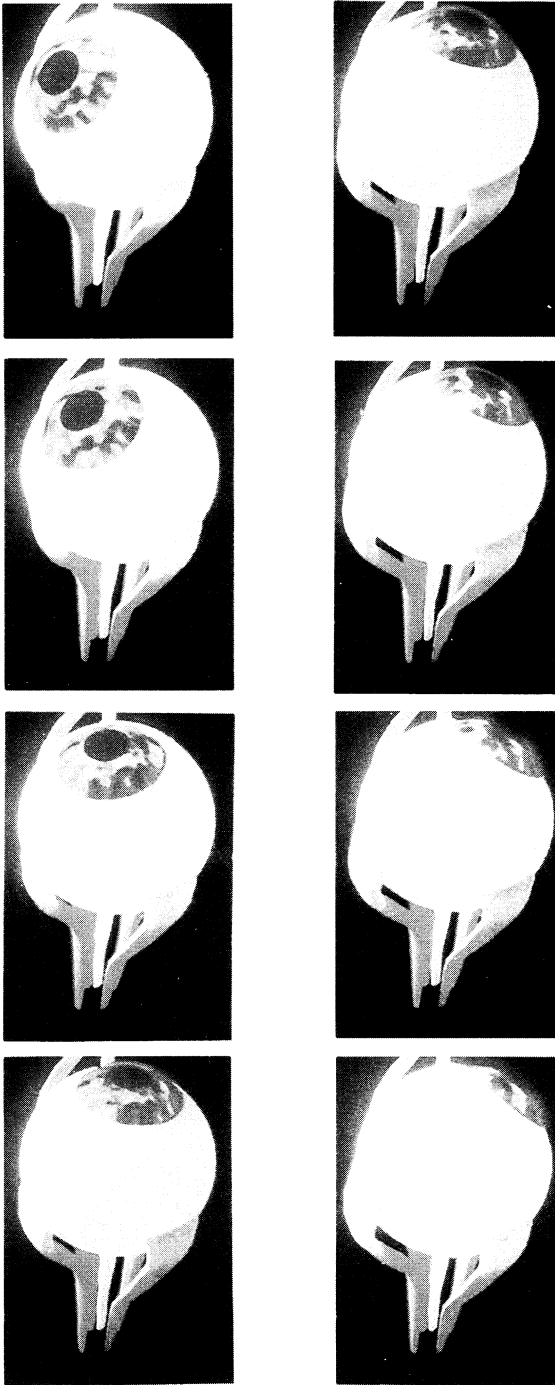


FIGURE 5: THE TRAJECTORIES OF SACCADIC EYE MOVEMENTS AND EXTRA-OCULAR MUSCLES.

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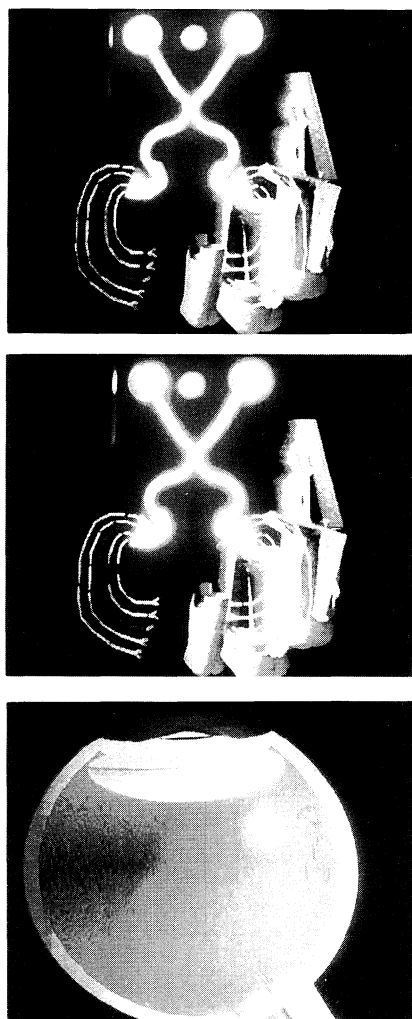


FIGURE 6: VISUAL PATHWAY ASSOCIATED WITH A LIGHT STIMULI AND THE PROPAGATION OF THE VEP IN OCCIPITAL AREA.

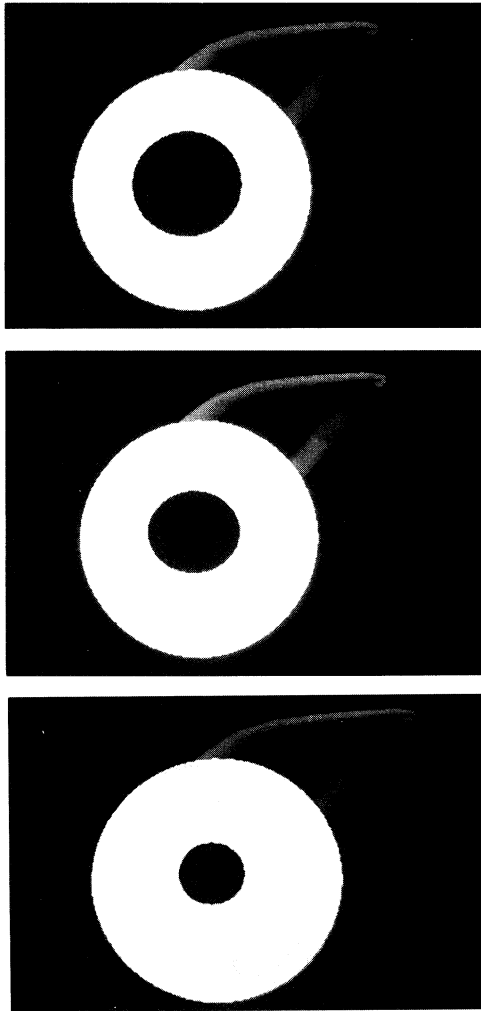


FIGURE 7: PUPILAR ESCAPE AND PUPILAR CAPTURE APPLIED TO PERIMETRIC STUDIES.



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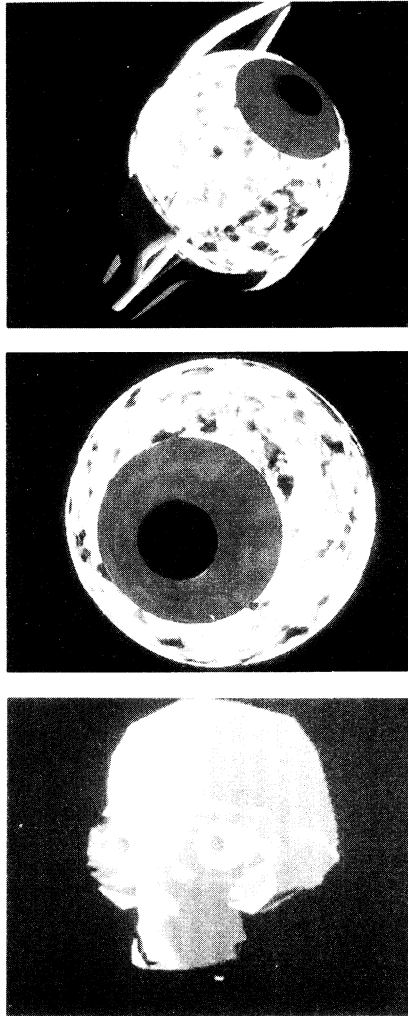


FIGURE 8: HEAD-EYE MOVEMENTS INTERACTION IN DIRECTIONS
GAZE AND THE COMPENSATORY VESTIBULAR OCULAR REFLEX.

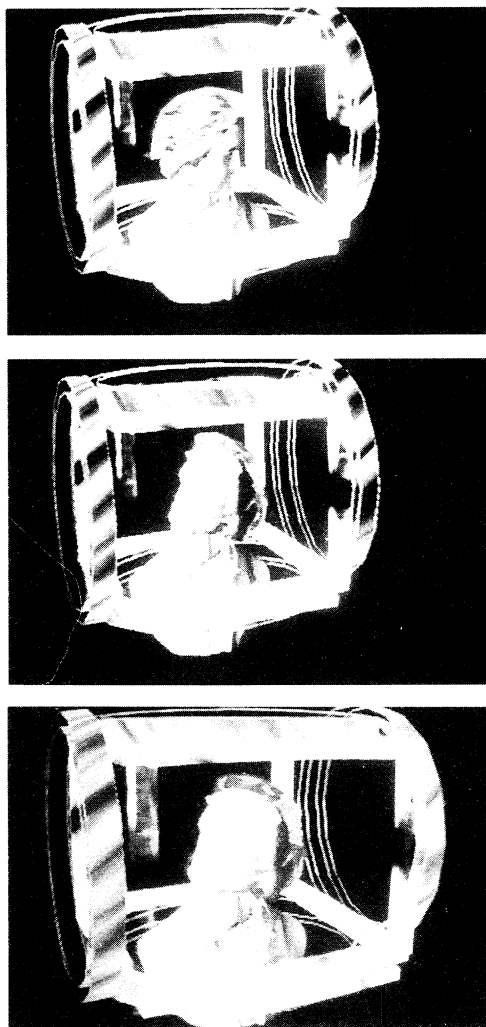


FIGURE 9: SYSTEM OF SEARCH COIL IN A MAGNETIC FIELD FOR MONITORING COMPENSATORY HEAD POSTURES IN CN AND HEAD MOVEMENTS.



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