OBER2, eyemovements, squint, strabismus,
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MODEL OF THE OCULOMOTORIC SYSTEM FOR DIAGNOSIS OF SQUINT

At this paper we outline a system for simulation of the neural activation signal based on simple visual stimulation. We have used the idea of a three-layer brain structure. Different layers of the brain are responsible for subsequent layers of perception. Measurements made with the OBER2 system allowed us to evaluate the relationship between two signals: visual stimulation presented on the screen and eye movement measured by detectors. Applying the proposed multilayer model to generate a signal that will be the input for classical model of the oculomotoric system make it possible to estimate some parameters that describe the work of muscles. We do not need to measure neural activity, provided that the neural system is working normally.

1. INTRODUCTION

1.1. OBJECT OF RESEARCH

Squint (strabismus), often called "crossed-eyes", is a condition in which the eyes are not properly aligned with each other. One eye is either constantly or intermittently turned inwards, outwards, up, or down. This ocular misalignment may be accompanied by abnormal motility of one or both eyes, double vision, decreased vision, ocular discomfort, or abnormal head posture. Although the exact cause cannot always be determined with reasonable certainty, strabismus is usually attributable to sensory, organic, anatomic, motor, or innervational causes. Any of these factors alone can result in strabismus; however, strabismus may be the result of multiple factors, which, occurring alone, might not cause the disorder. For some individuals, squint can result in permanent loss of vision. Young children with strabismus often develop amblyopia (lazy eye) and impaired stereopsis (binocular depth perception). Early identification and treatment of strabismic children may prevent amblyopia. The strabismic child with amblyopia has a significantly higher risk of becoming blind by losing vision in the nonamblyopic eye due to trauma or disease.

Remediation of strabismus requires treatment by an eye care practitioner, and the results are usually best when treatment is instituted early. Preservation of vision and binocular function result from proper diagnosis, treatment, and patient compliance. In more serious cases a surgical intervention is needed. The purpose of our work is to design a computer-based system to help in the

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early detection, measurement and diagnosis of squint. We are developing methods that will help plan the surgical intervention and evaluate its effects.

1.2. MEASUREMENT SYSTEM

Several methods have been described in the literature for the recording of eye movements. In general, we have listed and described some of that techniques in [10]. In our work we used the OBER2 system. This is an infrared light eye movement measuring system. It uses very short flashes of infrared light (80 microsecond) that are safe for a patient. The system has an advanced analog-digital controller and converter, which includes background suppression and prediction mechanisms ensuring the elimination of slow changes and fluctuations of external illumination frequency up to 100Hz, with effectiveness better than 40dB. The active measurement axis, sampling rate (25-4000Hz) and measurement start and stop can be set from the PC. By appropriate gain control it is possible to attain high position resolution of 0.5 minute of arc even for large-amplitude eye movement (+/- 20 degree).

2. CLASSICAL MODEL OF OCULOMOTORIC SYSTEM

Modeling of the oculomotoric system is an important area of research in ophthalmology and physiology. One of most known model of eye movements is the Clark and Stark model. [1]

For this model we can write the following equations (1-3):

$$\frac{dy_L}{dt} = \frac{F_L - K_{LA}(y_L - \Theta)}{B_L} \tag{1}$$

$$\frac{dy_R}{dt} = \frac{-F_R + K_{RA}(\Theta - y_R)}{B_R} \tag{2}$$

$$\frac{d\omega}{dt} = \frac{1}{J}\left(-F_o + K_{LA}(y_L - \Theta) - K_{RA}(\Theta - y_L) - (K_{LP} + K_{RP})\Theta\right) \tag{3}$$

$$\text{where: } \quad \omega = \dot{\Theta} \text{ and } \quad F_o = K_o\Theta + B_o\dot{\Theta}$$

This model describes movements of the eyeball along the horizontal axis. Three active elements are represented. The eyeball, which is described by its mass (*m*), and two muscles, described by the forces exerted on the eyeball (*FR*, *FL*). The forces are a function of the neural stimulation generated by the brain to control the muscles.

There are some coefficients specified for each element. For the eyeball we need an absorption (*Bo*) and elasticity (*Ko*) of the environment. For the muscle there are two elasticity coefficients. Active coefficients (*KRA*, *KLA*) describe the extensibility of the muscle when it is working, and passive coefficients (*KRP*, *KLP*) describe the elasticity of the muscle when other muscles affect it. Theta is movement of the eyeball.

3. THREE-LAYER MODEL OF VISION

In view of the above we proposed a three-layer model of visual perception. The visual stimulation is converted by the eyes into neural signals. Next, the information is transmitted to the brain, and analyzed in its successive levels. At first, in the reflex level, the motion and other fast changes of view are detected. At the second – fixation level, we focus on the object of interest. And finally at the third level – we recognize this object.

From all those levels neural stimulations are transmitted to the muscles of the eyeball. In each layer, a part of the information from one eye is also used to stimulate the muscles of the other eye.

4. IMPLEMENTATION OF THE MODEL IN SIMULINK

Simulink is a platform for simulation and Model-Based Design for dynamic systems. It provides an interactive graphical environment and a customizable set of block libraries.

4.1. REPRESENTATION OF THE CLASSICAL MODEL

At first we have implemented the mechanical part of the model. We have applied the classical model of oculomothoric system proposed by Clark and Stark.

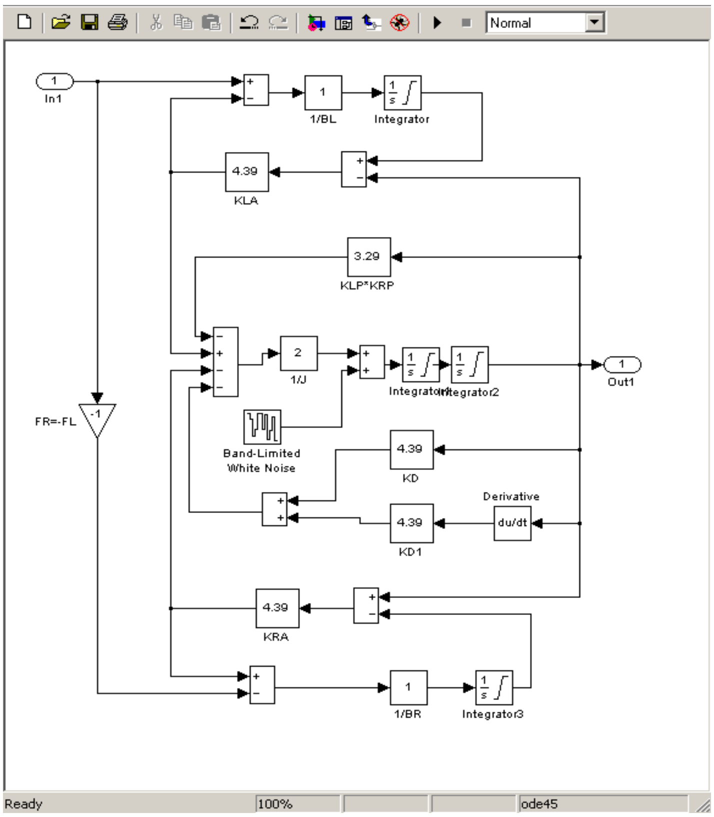

Fig.1 Implementation of classical model of oculomothoric system in simulink

In previous section we have described theoretical principles of this model. Our implementation of it in simulink is shown at figure 1.

We needed to generate an input signal for our model. We have defined this signal as difference between a current position of eyeball and the current position of the visual stimulation. As a visual stimulation we used the light point on the dark screen. The point is moving, and the patient have to follow it with his eyes. So the input can be defined as difference between current and expected position of the eyeball. Additionally we have defined an area of insensitivity. The moves of the point on the screen, that were smaller then two arc of angle were ignored, and the eyeball oscillated around its current position. The scheme of feedback and insensitivity module is presented on fig.2.

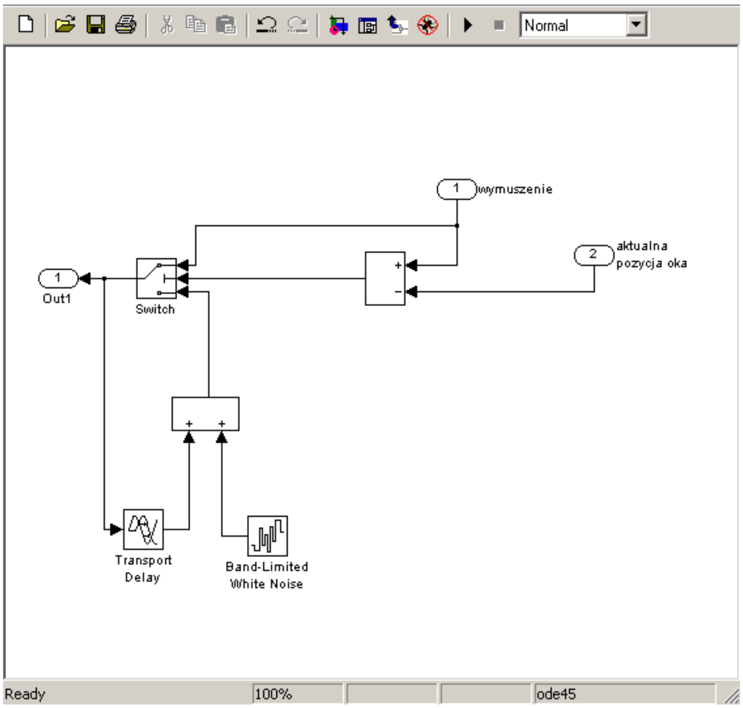

Fig.2 The scheme of feedback and insensitivity module

4.2. IMPLEMENTATION OF THE THREE-LAYER MODEL

In the next step we implemented the module that represents a three-layer model of processing the visual information. The first layer is differentiating a signal. This layer is corresponding to this functions of brain, that lets to see a move and fast changes of light. At this layer is realised fast, unaware move of the eyeball in direction of the object of stimulation. This move is stopped in second, integration layer. In this layer, the eyeball is correcting its position and fixating on the stimulation. There is delay element in third layer only. This layer is corresponding to observation, and recognition of the object.

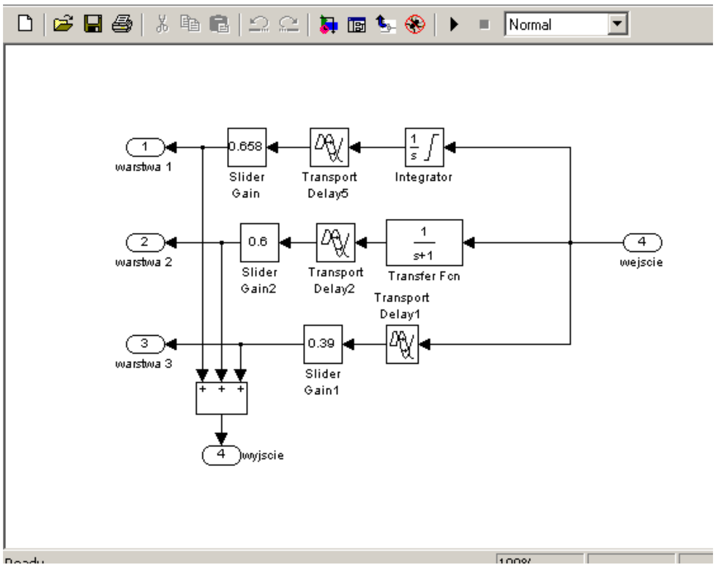

Fig.3 Implementation of three-layer module.

5. Tests and conclusion

We have performed some tests for our model. At first, we have tested a responses of the model to simple changes of position of stimulation point on the screen. A sample plot of response the model to the step move of the stimulation is presented on fig.4.

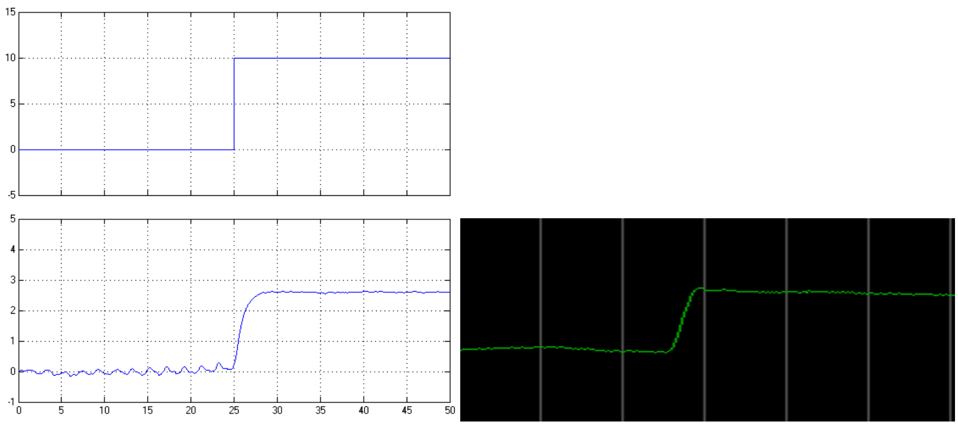

Fig.4 Sample model output (left) and eyeball move (right) in response to step move of stimulation (upper)

We have also done tests with a longer sets of data that we have measured. Our model allow us to simulate the basic functionality of the oculomotoric system. It is possible to detect an abnormality in measured signal, too. Because of usefulness for early prediction of medical consultation necessity, this method seems to be usable for screening examination of squint.

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