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IDENTIFICATION OF OCULO-MOTOR SYSTEM IN THE FORM VOLTERRA MODEL

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ABSTRACT. A new method of constructing nonparametric dynamic model of the human oculomotor system on the basis of experimental data "input-output". This takes into account nonlinear and inertial properties of the eye of the rectus muscles. A technology for tracking eye movement based on the videos. It is possible to determine the dynamic characteristics of the oculomotor system functions as a transition of the first and second order - integral transforms Volterra kernels.

Introduction. The innovative technology «Eye tracking» which is rapidly developing nowadays – is the process of determination of the point where look being sent to or the determination of eye movements relatively to the head. This high-tech innovation has been further developed and effectively used in the construction of a mathematical model of process of tracking eye movement to detect anomalies in data tracking to quantify the motor symptoms of Parkinson's disease [1, 2].

The Aim of Work. The purpose of work is development method for constructing nonparametric dynamic model of oculo-motor system (OMS) in the form Volterra series [2], based on experimental studies of «input-output» and also computational tools and software for the information technology processing experimental data [3].

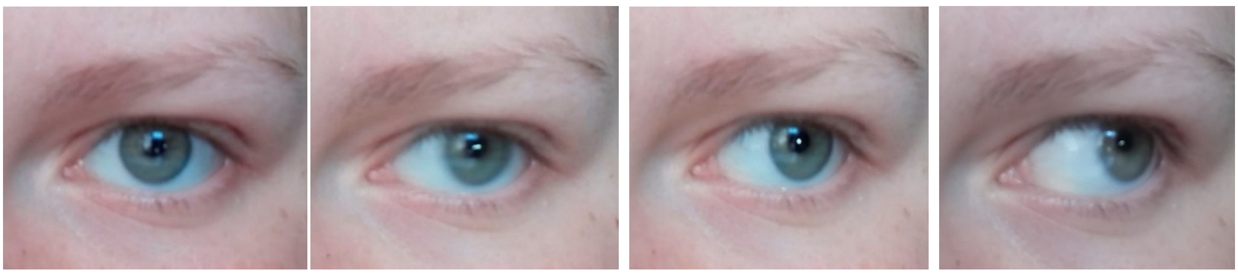
Results of Identification OMS Transient Function. Taking into account specificity investigated object to identification used test multistep signals. If test signal $x(t)$ represents an identity function (Heaviside function) – $\theta(t)$, the result of identification the transition function of the first order and the diagonal section n-th order.

To determine the sections subdiagonal transition functions n-th order ($n \geq 2$) OMS tested using the n step test signal with given amplitude and different intervals between signals. With appropriate processing responses get subdiagonal section n-dimensional transition functions $h_n(t-\tau_1,...,t-\tau_n)$, which represent n-dimensional integral of Volterra kernel n-order $w_n(\tau_1, ..., \tau_n)$ [3]:

$$h_n(t-\tau_1,..., t-\tau_n) = \int_0^{\infty} \dots \int_0^{\infty} w_n(t-\tau_1-\lambda_1,..., t-\tau_n-\lambda_n) d\lambda_1 \dots d\lambda_n. \quad (1)$$

To determine the diagonal section of the transient response second order OMS is tested at first step signal with an amplitude of the a (horizontal distance to light spot from the starting point, represents the original position the pupil) [4].

For OMS studies the selected camera shooting speed is 120 (frames/sec). For an array of pupil coordinate values when moving eyes based on the footage, it is necessary to divide the video into individual frames. One study time is 408,17 ms (50 frames). Processing video recording data associated with the release of each frame of video on the center of the pupil of the eye (Fig.1)



In mm: x=31,9, y=27,4	In mm: x=33,9, y=27,4	In mm: x=36,0, y=27,5	In mm: x=37,9, y=26,9
In pixels: x=90, y=78	In pixels: x=94, y=77	In pixels: x=99, y=77	In pixels: x=107, y=76

Fig. 1 – Result eye image analysis

Measured response of the eye $y_1(t)$, $y_2(t)$, $y_3(t)$ to the input test signals $a_1\theta(t)$, $a_2\theta(t)$ and $a_3\theta(t)$ (L=3) for values of the test signal amplitudes a_1=0,33, a_2=0,66 and a_3=1.

Obtained graphs of OMS transient functions first, $\hat{h}_1(t)$ second $\hat{h}_2(t,t)$ and third order $\hat{h}_3(t,t,t)$ shown in Fig. 2.

The model response is calculated on the basis of estimates of the transient functions $\hat{h}_1(t)$, $\hat{h}_2(t,t)$ and $\hat{h}_3(t,t,t)$

$$\tilde{y}(t,a) = a\hat{h}_1(t) + a^2\hat{h}_2(t,t) + a^3\hat{h}_3(t,t,t)\,. \tag{2}$$

Comparison of responses the OMS of identify $y(t)$, model $\tilde{y}(t,a)$ and partial components of response OMS first $\hat{y}_1(t,a_1)$, second $\hat{y}_2(t,a_1)$ and third order $\hat{y}_3(t,a_1)$ at an amplitude a_1=0.33 shown in Fig. 3.

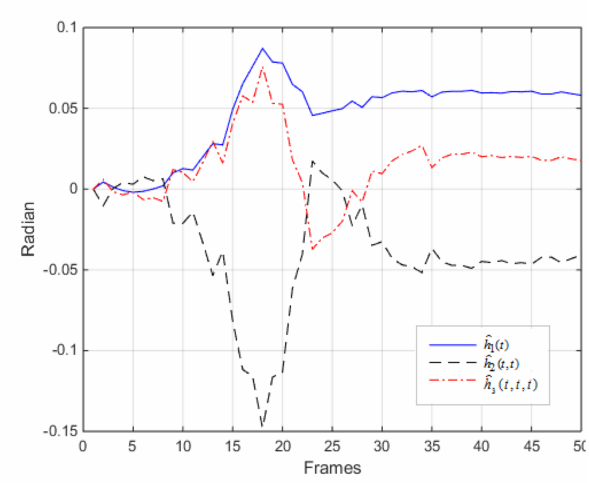


Fig. 2 – Transient functions $\hat{h}_1(t)$, $\hat{h}_2(t,t)$ and $\hat{h}_3(t,t,t)$

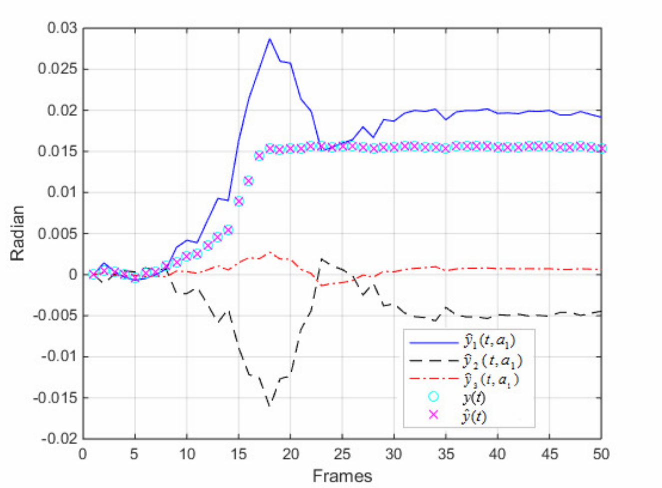


Fig. 3 – Responses of the OMS $y(t)$ and model $\tilde{y}(t,a_1)$, $\hat{y}_1(t,a_1)$, $\hat{y}_2(t,a_1)$ and $\hat{y}_3(t,a_1)$

Conclusion. Proposed a new method and information technology of construction nonparametric dynamic models of human OMS given its nonlinear and inertial properties on the basis of experimental data "input-output". This uses a mathematical model in the form of integral-power polynomial Volterra (multidimensional transition functions). Has been the further development of information technology «Eye tracking» and developed software tools identify OMS.

Basis on these experimental studies OMS for different amplitudes of input signals (distance eye point perturbations on the initial position on the screen). Using the method of least squares consruct nonparametric dynamic model of the human OMS in the form of transition and diagonal sections of the two-dimensional and three-dimensional transition functions. This mean square error (MSE) of identification is at σ=0.0009.

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