Mechatronic eye: modeling and design

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Abstract: In this paper both model and prototype of a human eye are developed. We are aimed on building and control of the simplified eye model, which is able to simulate some real eye biological functions. Control of the prototype has been motivated by monitoring the human eye behavior in different environment conditions. In addition, optical properties, functions and operation of the applied electrical control of the pupil (apple of the eye) and control of the prototype movement focused on detection and tracking a light source are also presented.

Keywords: artificial eye, control, eye movement

1. Introduction

Vertebrates eyes are highly complicated structures consisting of many components, such as sclera, cornea, iris, lens, vitreous humour, retina, fovea, optic nerve and muscles (see [1–3]). These elements interacting together yield the proper eye behavior. It is well known that bionic structures are often imitated by biomechanical and mechatronical mechanism being used in robotics (see, for example [4]). Review of state of the art devoted to the eye modeling shows that only a few papers have been focused on mechanical behavior of the human eye ([5–6]). We are aimed on building an optical-electrical system with structure similar to the biological system, which allows simulating and recreating the biological behavior of the eye under influence of various external factors.

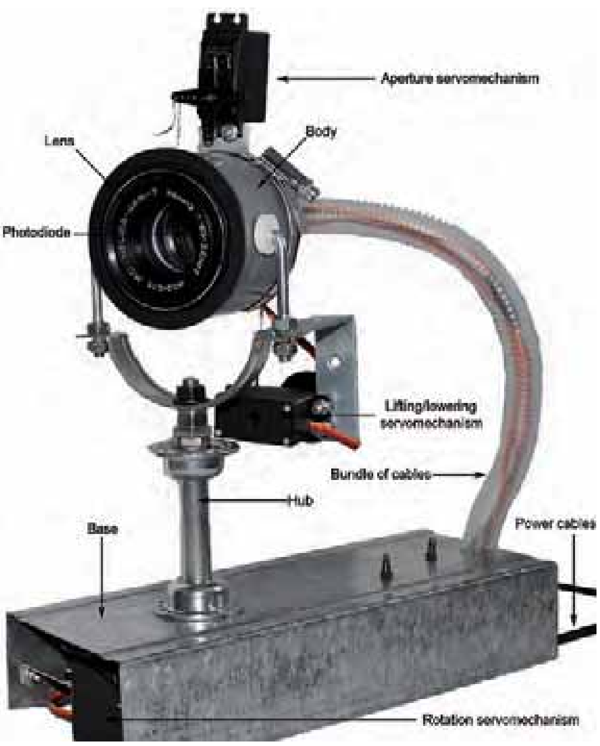

Fig. 1. Mechatronic model of human eye
Rys. 1. Schemat budowy mechatronicznego modelu oka

Mechatronic model of human eye contains (see also fig. 1):

(i) camera lens with aperture of ø58 mm, with similar field of view to human eye (40 degrees) and well optically corrected,
(ii) light sensor BPSP34 with sensitivity in range of 440–1150 nm,
(iii) "Pololu Mini Maestro" – the programmable servo-controller,
(iv) servomechanisms "Tower Pro SG-5010".

The proposed mechatronic model can be controlled from PC class computer using the USB. Simplified scheme of work includes the following steps. First, light coming through the lens is focused on the light sensor. This generates a voltage reaction. Then, the information from sensor goes to the servo controller fixed in the base, which sends signals to the servos. This model has the ability to rotate around two axes (vertical and horizontal) and to manipulate the aperture accordingly to the light.

2. Control

The prototype is controlled by servo controller accordingly to values of light intensity received from a photodiode. In order to keep its proper use, servo-controller is programmed on the basis of human eye behavior examination.

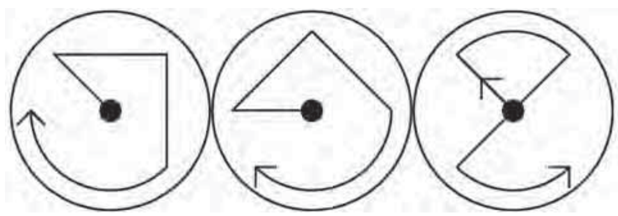

Fig. 2. Human eye`s trajectories of light source search
Rys. 2. Trajektorie szukania źródła światła przez oko człowieka

Trajectory of light source search (see fig. 3) is created based on experiment, where the subject is searching for a laser spot, using eye movement only. Examples of the human eye movement obtained during experiments are presented in fig. 2. Black points refer to start position, circle field of view without head movement. Fixation of the eye model is greater then the biological structure (90° to about 75° [7]).

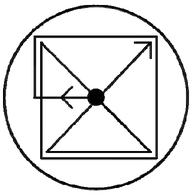

Fig. 3. Path of light source searching produced by the mechatronic model of a human eye

Rys. 3. Trajektorie szukania źródła światła przez mechatroniczny model oka

Second experiment shows the difference in pupil size depending on light intensity (see fig. 4). First of the photography shows eye behavior during low light, whereas the second one corresponds to the high light examination.

Fig. 4. Pupil sizes depends on the light intensity

Rys. 4. Rozmiary źrenicy w zależności od natężenia światła

On the basis of the carried out experiments the following algorithm for the prototype control has been designed and applied in to the servo-controller (see fig. 5).

If the light level is higher than a set value, the aperture subroutine is executed. In case of light loss the developed control signal goes back to the beginning. If the value of light intensity is lower than the set value, the experimental eye model starts to search for the light, following

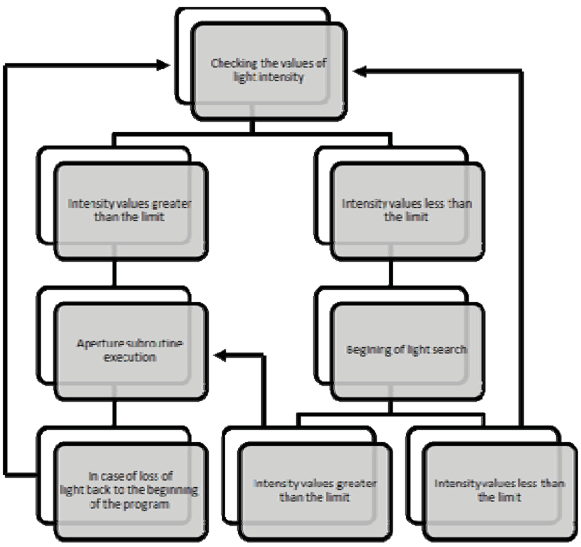

Fig. 5. Scheme of mechatronic eye light search

Rys. 5. Schemat działania modelu oka

the programmed trajectory. If the light intensity is higher than the assumed limit, program reacts as described earlier. However, if intensity is not sufficient throughout, the trajectory program goes back to the beginning.

Third experiment has been carried out to show the difference between human eye and mechatronic model of eye in time needed to find the laser spot. Human eye in low light environment conditions (high contrast between laser spot and environment) finds it almost imidiatelly, while in the high light environment conditions it is often prolonged to about 3–4 s before the subject is able to find it. Sometimes subject was unable to find it at all. For mechatronic model of an eye, on the other hand, time needed to find the spot depends on direction of the light (because the model tracks the programmed trajectory), the servo's speed and the trajectory itself. On higher speed time needed to follow the whole trajectory takes about 2.5 s. Therefore time needed to find light source varies between 0 and 3.5 s.

3. Conclusions

It should be emphasized that the constructed and presented prototype possesses the movement range similar to that of the biological eye. Diaphragm control has a human like behavior. All this makes it possible to simulate some phenomena like the light search, light level control or movement.

Bionic structures can also have variety of application. The developed by the authors mechatronic eye model can be also used for teaching purposes. However because of its simple construction, after some modifications it can be used also for other purposes like a solar panels setting, storm warning system, as well as a counter of passing objects (cars, humans, etc.).

Acknowledgements

This paper is supported by "MASTER Programme" of The Foundation for Polish Science.

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Mechatroniczny model oka

Streszczenie: W artykule autorzy prezentują mechatroniczny model oka. Celem budowy stanowiska było zasymulowanie i odtworzenie funkcji oka wraz z odwzorowaniem jego sterowania. Na podstawie budowy biologicznej, badań zarówno własnych, jak i innych autorów zaproponowano konstrukcję obejmującą budowę optyczną oka, funkcje i działanie źrenicy oraz sterowanie, które umożliwia wykrywanie i śledzenie źródła światła.

Słowa kluczowe: sztuczne oko, model oka, reakcje oka, sterowanie

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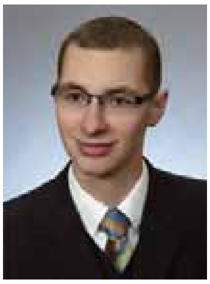

He was born in Łódź, Poland on July 20, 1989. From 2008 he is studying at Lodz University of Technology. In 2012 at the Department of Automation and Biomechanics he gained engineer's degree for his Mechatronic eye model. Later same year he participated in the International Conference – Mechatronics: Ideas for Industrial Applications which took place in Warsaw (Poland).

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