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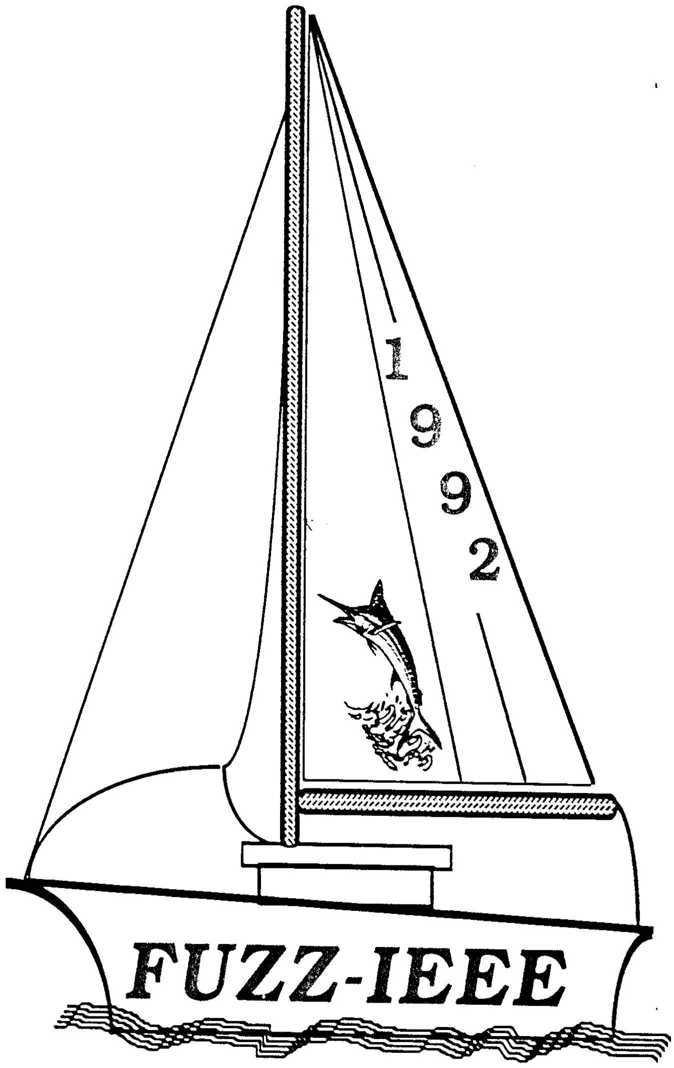

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EYE-HAND COORDINATION BASED ON FUZZY VISION TRANSDUCER*

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ABSTRACT

Fuzzy control system based on principles of eye-hand coordination is described. As a vision sensor a simple device called fuzzy eye is applied. Its output transformed in the fuzzy form is used as an input to a fuzzy control system whose output is a control signal of the electric motor connected to a vision sensor. The control task is to perceive the point source of light, to position vision sensor into its direction and than to use this information to control the hand movements. Theoretical results are illustrated by simulations.

1. INTRODUCTION

The application of fuzzy set theory has become over the last few years an important research topic in the domain of automatic control. Although the first publications appeared in the early 1970's, in the last few years we are witnesses of rapidly growing interest for fuzzy control. Today two main streams of fuzzy control exist. The first one is commercialization and industrial application of simple, well known fuzzy control algorithms. The second one is further innovation, theoretical development and experimental verification of more sophisticated form of fuzzy control and its application in the fields where they have not yet been applied. The research described in this paper belongs to the second group. The paper describes principles of an intelligent sensory guided fuzzy control system based on eye-hand coordination.

The idea of fuzzy transducer was introduced in 19SS [1]. It was conceived as an intelligent measuring device which consists of a simple selected, sensor and the inference engine and which transforms the measureand into the signal suitable for human perception. With adequate knowledge stored in the rule-base it is possible to use simple, non expensive sensors in measurement of quite complex phenomena. More recently [2] the simple fuzzy vision transducer was defined and described. In this paper after a short presentation of fuzzy vision transducer principles, its application in position control based on eye-hand coordination will be introduced and then illustrated by simulation.

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3. FUZZY POSITION CONTROL BASED ON PRINCIPLES OF EYE-HAND COORDINATION

The system layout is schematically shown on Fig.3. It consists of an eye and a hand. The eye is a vision sensor and the hand is a pointing device or manipulator with one degree of freedom

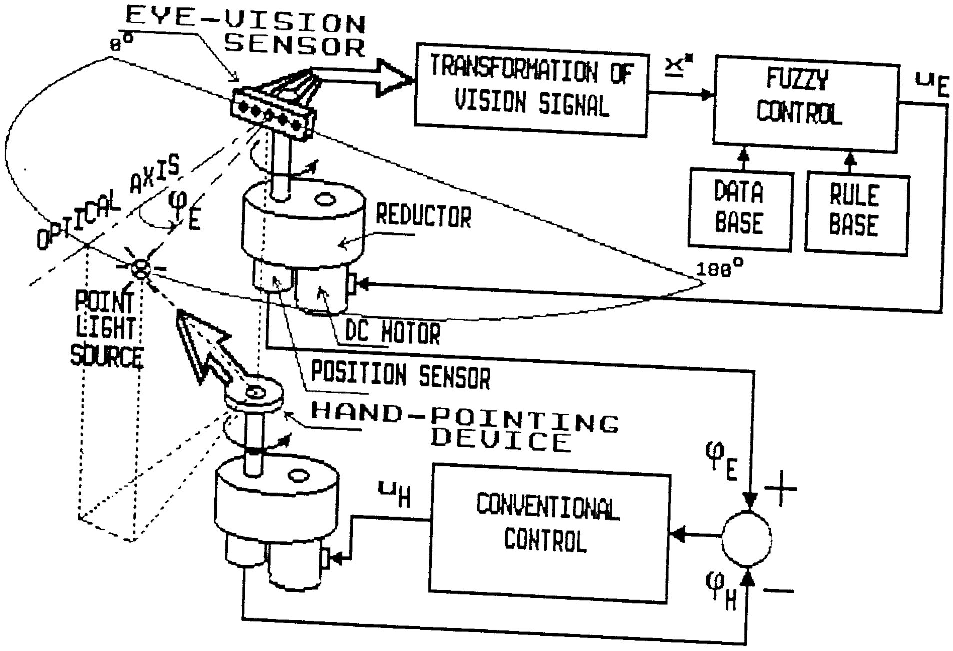

Fig.3. Fuzzy position control based on principles of eye - hand coordination

The eye and the hand have independent motors, so each of them can rotate independently. When of light turn on anyway on the semicircle, the eye produces the vision signal which carries information about light source angular position. After transformation into the form of the fuzzy vector $\underline{x}_1^*$ the vision signal is used as a input to a fuzzy position control system whose output is a voltage u_E of the DC motor which rotates the eye.

The eye angle ϕ_E is measured by an angular position sensor whose output is used as a reference input to a conventional feedback control of the DC motor which rotates the hand. The final goal is to position the hand into the direction of the light source. The vision sensor is controlled by a simple fuzzy algorithm. It stops rotating when its optical axis intersects the light. The pointing device start to rotate at the same time as the vision sensor and for its final adjustment the precise information of the vision sensor angular position is used. In this paper one main interest is fuzzy control unit, so it will be described in details in the next section.

4. FUZZY CONTROL UNIT

Input to the fuzzy control unit is a fuzzy vector $\underline{x}^*$ which carries information about the position of the light source. In our case it is a five element vector $[x_1 \ x_2 \ x_3 \ x_4 \ x_5]$. The fuzzy control algorithm is based on two types of control rules stored in the rule base. The first one are conventional fuzzy rules expressed linguistically:

1) If the light is LEFT than u_E is POSITIVE.
2) If the LIGHT is IN CENTER than u_E is NULL.
3) If the light is RIGHT than u_E is NEGATIVE.

where LEFT, CENTER and RIGHT are discrete fuzzy sets given by five elements fuzzy vectors $\underline{x}^*_L$ = [1 0.6 0.3 0 0], $\underline{x}^*_C$ = [0 0.5 1 0.5 0] and $\underline{x}^*_R$ = [0 0 0.3 0.6 1]. POSITIVE, NULL and NEGATIVE are continuous fuzzy sets whose membership function is given on Fig. 4.

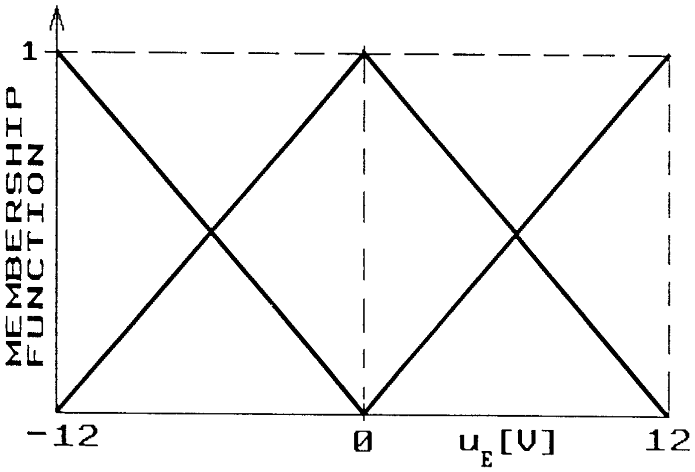

Fig. 4. Definition of fuzzy sets NEGATIVE, NULL and POSITIVE

The second type of control rules are rules for situations when the light source is located far left or far right. Light source is far left (right) when the signal received from the first (last) sensor is the biggest. When the light source is far left or far right the control signal is positive or negative maximal. In our case that was +12 V or -12 V, so these control rules could be defined as Boolean rules:

4) If $x_1 > x_2$ and $x_1 > x_3$ and $x_1 > x_4$ and $x_1 > x_5$ then u_E = 12V.
5) If $x_5 > x_4$ and $x_5 > x_3$ and $x_5 > x_2$ and $x_5 > x_1$ then u_E = -12V

In each discrete time moment rules 4) and 5) are tested first. If they are not satisfied then real fuzzy control algorithm is activated. Fuzzy control procedure have three steps. The first one is calculation of the degrees of fulfillment using equation

$$\lambda_i = \bigvee_j (\underline{x}^*[j] \wedge \underline{x}_i^*[j]) \qquad i \in \{L,C,R\} \tag{1}$$

where j represents the j-th element of the fuzzy vector.

The second step is determination of the output fuzzy set.

$$u^* = \bigvee_i (\lambda_i \wedge u_i^*) \tag{2}$$

Final stage is interpretation of the output fuzzy set. Crisp control u_E is calculated using center of gravity method:

$$u_E = \sum_{u=-12}^{12} u \cdot u^*(u) \Big/ \sum_{u=-12}^{12} u^*(u) \tag{3}$$

This control algorithm is quite simple but the obtain results are quite satisfactory as the simulation results, described in next section, will show.

5. ILLUSTRATIVE EXAMPLE

We have simulated the rotation of the vision sensor under the fuzzy control using five element fuzzy eye. Sensitivity curve of each photo detector is shown on Fig.2., and photo detectors are located 5 mm each from the other without partition screens between them and treated as points.

The parameters of the real DC motor GLOBE 102-A 191-11 with 1000:1 reduction was considered, and the motor was modeled by transfer function $G(s)=\phi_E(s)/u_E(s) = 0.0833/s(0.327s+1)$.

Fig.5. shows the results of simulations. Angle (ϕ_E), speed (ϕ_E) and control (u_E) are shown for the case when the starting position of the eye was 90° and the light was located at 110°. ϕ_E was defined as a difference between actual and started eye position.

The time instant between two control action were 8 ms but motor dynamics were simulated using Runge-Kutta at 100 discrete prints between two control actions. At the beginning Boolean rule No.5. was triggered. Fuzzy control rules were active when the angle was approximately 4.5° left or right from the position of the light.

One of disadvantages of fuzzy controllers is difficulty in tuning their input and output gains. In our case there were not such gains, so there were no need for their turing.

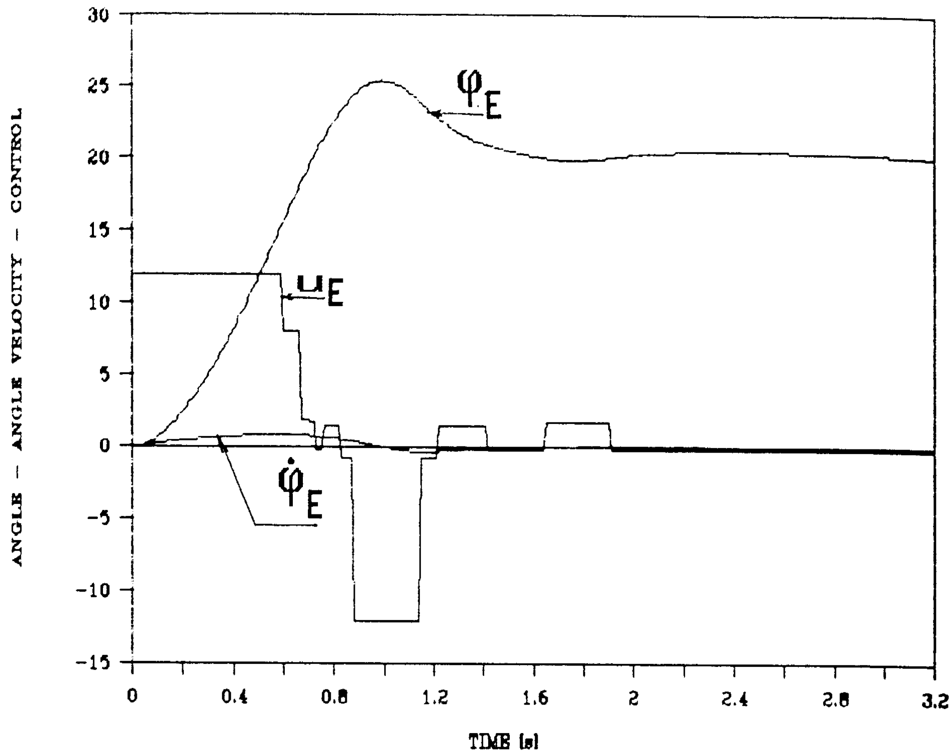

Fig.5.Results of simulation of fuzzy vision transducer based control

The controller performances could be changed by changing the shapes of membership function, by changing the composition operator and of course by changing the rule base. In our case we have defined membership functions at the beginning, using humans feelings about their shapes. The some was done with the rule base, but in our further work we intend to investigate influences of these parameters more deeply.

6. CONCLUSION

A simple vision sensor called fuzzy eye was developed and used in a control system based on principles of eye-hand coordination. Fuzzy eye was inspired by apposition compound eye of insects and although it is quite simple it could be successfully used in a sensory-based control system, whose task is to perceive and than to follow a point source of light. The control algorithm was based on a simple fuzzy control algorithm having a vision signal as an input and a motor control as an output. Simulation results shows quite satisfactory system behavior.

7. REFERENCES

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