FUZZY CONTROLLER FOR HAND PROSTHESIS

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Abstract: The present paper presents a fuzzy controller for the DC motor. This motor was designed starting from the idea that it will actuate hand prosthesis. Simulation of the motor and fuzzy controller was done using Delphi programming language. The program was design to be a flexible one and to be able to test different functional parameters.

Keywords: hand prosthesis, DC motor, Delphi program, fuzzy controller

1. CLASSICAL CONTROLLERS

An automatic controller compares the actual value of the plant output with the reference input (desired value), determines the deviation, and produces a control signal that will reduce the deviation to zero or to a small value. The manner in which the automatic controller produces the control signal is called the *control action* [1].

Industrial analog controllers may be classified according to their actions as:
a) two-position or on-off; b) proportional; c) integral; d) proportional-plus-integral; e) proportional-plus-derivative; f) proportional-plus-integral-plus-derivative.

2. FUZZY LOGIC

Most of us have had some contact with conventional logic at some point in our lives. In conventional logic, a statement is either true or false, with nothing in between. Of course, the idea that things must be either true or false is in many cases nonsense. The idea of gradations of truth is familiar to every one. In fuzzy logic, a statement is true to various degrees, ranging from completely true through half-truth to completely false. Fuzzy theory gives a completely new approach to the mathematics of thinking; it is a *change of paradigm*.

3. FUZZY CONTROLLERS

3.1. Structure of FKBC (Fuzzy Knowledge Based Controllers)

The principal design parameters of a FKBC include scaling factors, fuzzification methods, rule base and membership function construction and representation. The principal structure of a FKBC, as illustrated in figure 1 consists of the following components [1].

Fuzzification Module. The Fuzzification module (FM) performs the following functions: **FM-F1**: performs a scale transformation and **FM-F2**: performs the so-called fuzzification. The design parameter of the Fuzzification module is *Choice of the Fuzzification strategy*

Knowledge Base. The knowledge base of a FKBC consists of a ***data base*** and a ***rule base***.

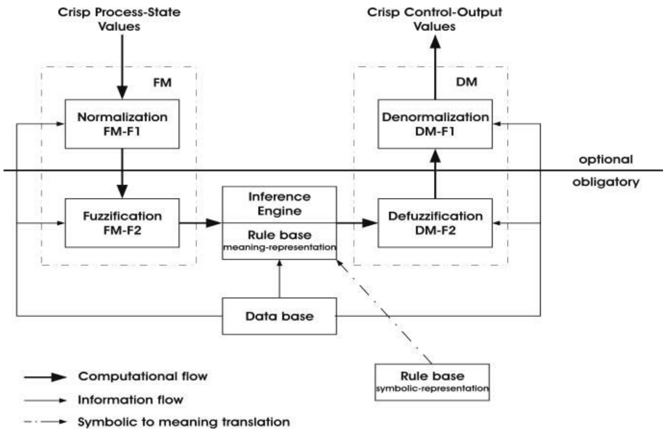

Fig.1. Structure of a FKBC

The basic function of the ***data base*** is to provide the necessary information for the proper functioning of the fuzzification module, the rule base and the defuzzification module. This information includes: *choice of the membership functions; choice of the scaling factors.*

The basic function of the ***rule base*** is to represent in a structured way the control policy of an experienced process operator and/or control engineer in the form of a set of production rules such as ***if*** <process state> ***then***<control output>

Inference Engine. There are two basic types of approaches employed in the design of the inference engine of FKBC: *the composition based inference (firing)* and *individual rule base inference (firing).*

Defuzzification Module. The functions of the defuzzification module (DM) are as follows: **DM-F1**: performs the so-called defuzzification and **DM-F2**: performs an output denormalization.

3.2. Fuzzy controller for DC motor

The necessity of designing such a controller appears from the desire to control a hand prosthesis using a fuzzy controller. A hand prosthesis controller should satisfy some requirements: a high-speed reaction in the case of appearance of disturbances (the object that is gripped slips out), an easy adaptation to the ill person requirements (the problem of including new constrains). Such a controller is based on human experience and is not a very accurate and precise system. These few motives lead to a fuzzy controller. The hand prosthesis is design by having five fingers with three joints per finger, except the thumb that have only two. The palm of the prosthesis is designed using a differential system with articulated plates and wires. The hand prosthesis is capable to manipulate also cylindrical and spherical objects. The program, created in Delphi, proposes a simulation of a DC motor controlled by a fuzzy controller (figure 2).

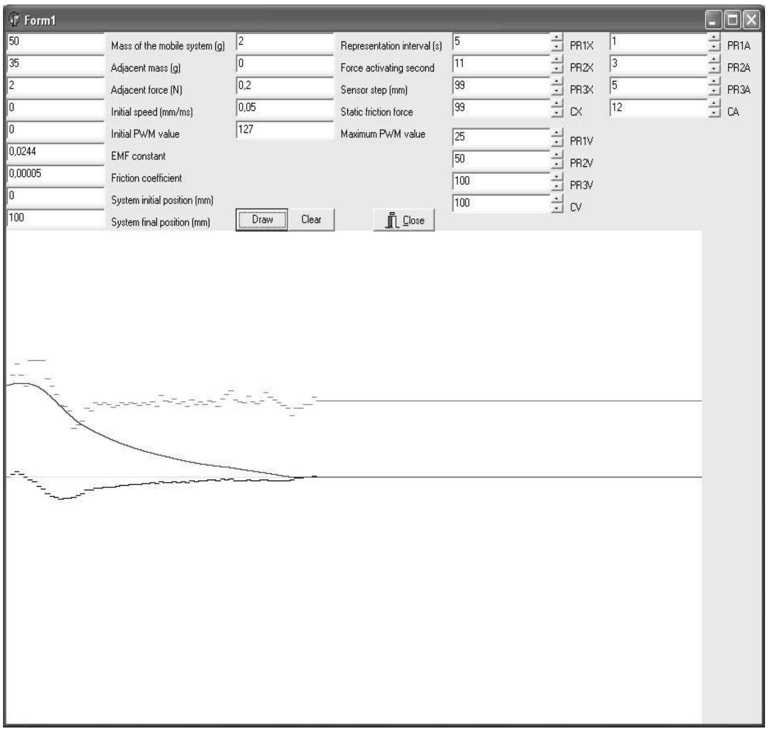

Fig.2 Controller interface

In the following will be presented the main steps that were followed in designing the controller. First, it was designed the program window that has the input elements and the window used to show the result of the simulation. As constant inputs were considered: the mass of the mobile system. After that were included also as inputs: the initial speed of the whole system; the initial PWM value; the gain of the E.M.F. (electromotive force). It was also considered: the friction force constant; the static friction force (at zero speed); the initial and final position of the systems that are related one to each other and define the distance and sense that the system has to move along. After all these input data were defined, it was written the corresponding source code. This code describes the movement physic laws of the system based on the instantaneous speeds, inertia forces, friction forces, EMF, instantaneous control PWM value, the external forces and time. There were experimentally determined the most of the inputs: the system mass by weighing; the adjacent force by estimation; the gain of the EMF was deduced by calculus; constant of friction force was deduced by calculus and experimentally.

The control system is composed from a programmable microcontroller that has only digital inputs/outputs. This microcontroller uses as input a position incremental sensor with two channels and as output a PWM signal applied to the motor by a current amplifier. This microcontroller is capable to sample the two channels of the position sensor with certain frequency that is constrained to be constant. The presented controller will work using only two interface parameters to the motor (instantaneous position as input and PWM value as output). This means that the controller, which is a real conditions one, has to consider the time variable and from position input has to extract, by calculus, the speed and acceleration inputs (useful at some moment).

The fuzzy controller has instantaneous position input, instantaneous speed input and also instantaneous acceleration input. For the first two position and speed inputs were chosen fuzzy weights, the constrain rules based on which it is determined the PWM output. The instantaneous acceleration input is used in the situation when upon the system act a constant force. There was introduced a calculus variable used to determine the control PWM value and that considers the instantaneous acceleration. This variable was needed because the system has to equilibrate itself in the exact desired position.

4. CONCLUSIONS

The necessity of a fuzzy controller was given by the characteristics of the control of hand prosthesis. The program described above was practically implemented and can be used not only for the hand prosthesis but also for any other situations when a fuzzy controller is considered appropriate.

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