ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume IX (XIX), 2010, NR2

EXPERIMENTAL RESEARCH REGARDING THE ADAPTIVE DRIVING OF ROBOTS USING FUZZY LOGIC

TRIPE VIDICAN Călin, TRIPE VIDICAN Aron, TOCUȚ Pavel Dănuț
University of Oradea
tripetrophy@yahoo.com, atripe@uoradea.ro, tocutpd@yahoo.com.

Key words: fuzzy logic, fuzzy regulators, adaptive, adaptive robots

Abstract: In this paper are presented practical and experimental achievements regarding the constructive and functional optimization of the running and driving system of the robots, using regulator based on fuzzy logic. By this it has been realized a running stability of a translation module of the robot in contact with the environment and on variations of its reactions.

1. Introduction

The problem in stabilizing the robot running under the environment action and especially for the work robots and for the micro robots, represents a relatively new preoccupations which have attracted a relatively great attention.

This paper's objective was to establish, to conceive and to realize a industrial robot module with electric auctioning and to investigate the possibilities of using fuzzy logic for improving the module control in position and force. The authors have searched to build a hierarchy on two levels, in which is implemented a conventional design of driving, using P.I.D regulators (proportional – integrative – derivative) and derivate's, and on the second level is a fuzzy interference system. The aim is to obtain a stable response for a large scale of parameters of each type of contact with the environment (disruptive system).

2. Notions of dynamic control of position-force

The objective of controlling the position or the force or the position and force is to provide the tracking of nominal trajectories in the simultaneous tracking of the contact forces on a certain movement direction. By dynamic control are synthesized the control forces necessary in general for each robot axis (cinematic driving couple), in contact with the environment.

In general the robot dynamic with rigid structure can be represented by the relation:

$$A(q)\bullet\ddot{q}+B(q\bullet\dot{q})+Q(q)=\tau \qquad (1)$$

Where:

$A(\bullet)$ represents the insertion matrix
$B(\bullet)$ represents the centrifugal forces
$Q(\bullet)$ represents the gravitational forces component
τ represents the generalized force (for control)

To experiment the control it was taken in consideration the problem of the bi-dimensional contact which implies a translation axis of the robot with the environment. The assumed task is to maintain a nominal contact force during the nominal trajectory of the axis.

The results obtained while simulating the translation axis functioning, and those experimental are foreseen in the followings.

3. Experimental stand

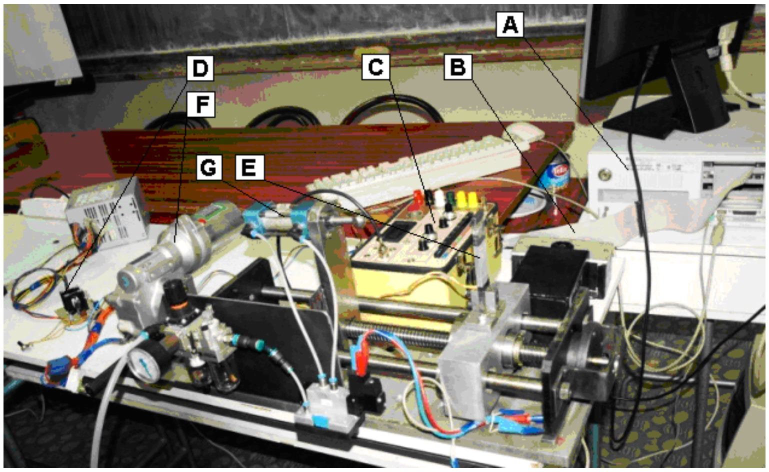

Figure 1.Sample of the translation module, operated by the computer.

The components of the system are:

- calculus system (A)
- coupling point of data acquisition board (B)
- voltage bridge (C)
- command circuits (D)
- power encoder (E)
- execution element – electric engine (F)
- exterior disturbing system (G)

4. The Command system of the experimental installation

4.1. The logical scheme of the commanding system and the program conceived are presented in figure 2.

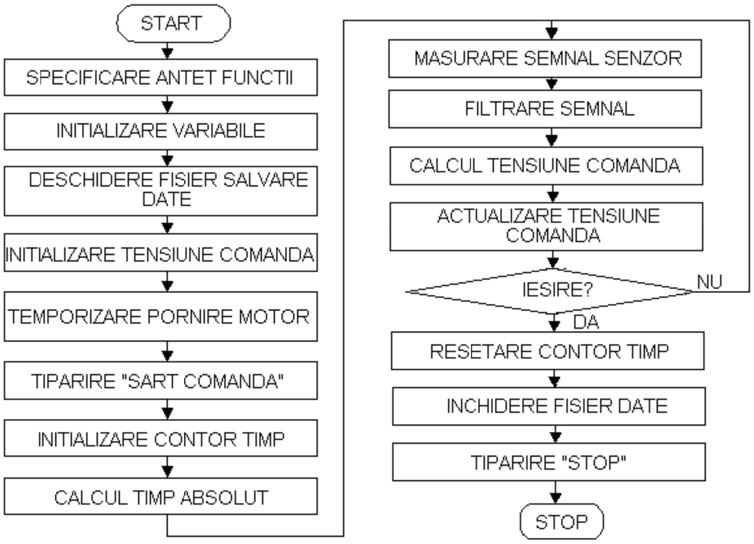

Figure 2.The logical scheme of the commanding system.

In the following are presented the main equipments of the commanding system:

The acquisition board: National Instruments PCI 1200

The acquisition board is delivered by the manufacturer together with a software package which contains the drivers necessary for the board integrations and a function library for the C++ language. These functions have been used for the acquisition software writing. The software realizes the acquisition of the signals with a acquisition rate of 20 kHz, which implies a sampling period of 1/20000 = 0, 05 ms. The received data are saved in binary files in a integer format on 16 bit. The quantification frame is calculated with the relation $10V/2^{12}$ = 10V4096 = 2, 44 mV, for acquisitions where it's not used the internal amplification of the board.

The calculation system used is a PC system with a Pentium IV processor. The A/D Interface (NI PCI 1200) is connected directly to the PCI bus of the computer. It has the role to run the adaptive adjustment of the program for the engine. Also it records the received data which afterwards will be adapted.

The measuring system of the disturbing forces. It has been used a force transducer with a strain gauge stamp.

4.2. The "in force" commanding software

The engine works being commanded by software for adaptive adjustment presented below. The software realizes the D.C. engine command with the help of the electronic interface, which is commanded by the acquisition board with a voltage of 0 – 10V.

The main component parts of the adaptive adjustment program of the force are:

The function libraries declarations. There have been used the following functions:

nidaget.h – library with the acquisition function of the PCI 1200 board
math.h – mathematical functions for C++;
stdio.h – standard input-output for C++;
canio.h – console function, input-output for C++;
io.h – input/output function at low level for C++;
stdlib.h – standard libraries for C++;
time.h – function for time counting;
sys/stat.h – system and state functions;
ctype.h – function for the writing characters type;
string.h – working function for the characters rows;
sys/typs.h – system functions and variable types;

The declaration and initialization of variables; Are declared and initialized the counting variables, for analogical exits, for the position and speed calculus and for the file (name and type);

File opening;
Counting initialization;
Command voltage initialization;
Command and measure loop:

- *Acquisition of data by the strain gauge*
- *Commanding voltage calculation based on the measured force.*
- *Commanding voltage value actualization.*
- *Writing in a file the read and actualized values of the force.*
- *Closing the adjustment loop.*

In the initial phase of the experiments, in the commanding program, has been used a classic adjusting algorithm which uses proportional and derivate elements. The chart resulted from the experiments is presented in figure 3.

As it can be observed in the picture above, the response of the system is delayed because of the frictions and the imperfections which interferer with the mechanical system at the movement starting.

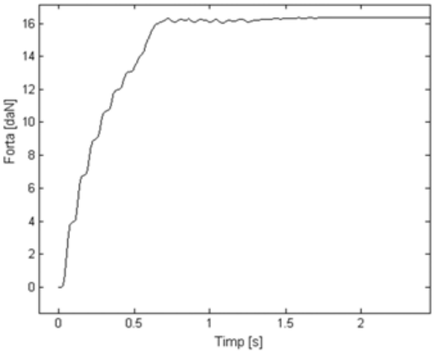

Figure 3. The transducer chart with a proportional-derivate adjustment K_P = 55,34; K_d = 2,45.

After this area the system runs relatively correct. This delay could not be corrected neither by using proportional parameters at the highest value. If there are applied different proportional derivative types, it can be obtained a faster response time but appear over adjustments (unwished responses). Because of this it has been tried the optimization of the system running by replacing the classical adjustment with a fuzzy regulator capable of outfacing the determined irregularities. The implementation way of the system with a fuzzy regulator is described in the following.

5. System optimization by using a fuzzy regulator for commanding in position/force (impedance) of the translation axis with electric operation.

5.1. General considerations. There are a great variety of ways in which we can use the fuzzy interference systems in the robot commanding, either in what regards the location in which is applied the operation scheme, as for the shape of the interference systems. From the studied bibliography we can detach the conclusion that the fuzzy interference systems are used, among others, at the trajectory generation, for the engine type definition, replacement of the classical regulators or in combination with them. Many of the researches in the field try a systematic approach for the fuzzy interference system design (development of a projection method), which is for eliminating the uncertainty in choosing the belonging functions and the set of rules, in which they raise the question of establishing the parameters of the fuzzy interference systems, based on a clear methodology.

The programming software, MATLAB, has defined functions for realizing different steps of the fuzzy calculation (fuzzyfication, interference, unfuzzyfication).

These functions are bound by two external modules (realized in C++) and namely: “the interference system” and “the fuzzy engine”. With the help of the defined functions there is the possibility of calling the SIMULINK simulation software too. The user’s applications are bound to the mentioned modules with the help of the defined functions.

The typical basic structure of the fuzzy interference systems represents a model which realizes certain equivalence:

- fixed entry value – entrance belonging functions – rules of interference – exit characteristics – function of exit belongings – fixed values of exit.

Also, a typical fuzzy interference system, demands a structure of defined rules towards the user, which tries to interpret the model variable characteristics. But if it desires to realize a fuzzy interference system for molding a process in which there are entrances-exits, these can be used for the automatic generation of the belonging functions, so as default for the system identification. In the MATLAB software, adjustment of the reminded parameters can be realized with a module that runs similarly to a neuronal network, called ANFIS (Adaptive neural Fuzzy Interference System). As for a learning algorithm is used the backward spread of the error and, for the optimization of the studying process of learning ANFIS is used the gradient method, followed by a optimization algorithm based on the quadratic sum of the errors between the whished exit measure and the generated one.

*5.2. Time modeling with a fuzzy regulator*The application which uses a fuzzy regulator was developed on the previous open system, modified by introducing a fuzzy regulator instead of a classic regulator.
In figure 4 are shown the main charts of variation of the system measures according the time.

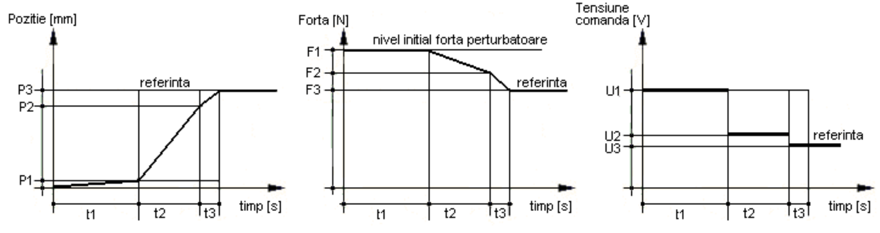

Figure 4. Main charts for the variations of the systems measures: a) position; b) force (transducer signal); c) commanding system.

The fuzzy interference system was developed establishing the following:

- the entrance belonging function type trapezoidal, which describes three linguistic of the entrance variable “transduction signal”
- the exit belonging functions type triangular also describing three linguistic terms of the exit variable “Command signal”
- there have been defined three rules of fuzzy interference:
  - if the “transduction signal” is “BIG” then the “commanding signal” is “BIG”
  - if the “transduction signal” is “MEDIUM” then the “commanding signal” is “MEDIUM”
  - if the “transduction signal” is “SMALL” then the “commanding signal” is “SMALL”
- the defuzzyfication is realized with the “centroid” function

In figure 5 are given the charts of the belonging functions of the fuzzy system.
Based on the fuzzy system defined was realized with the SIMULINK model of the commanding and running system, presented in figure 6.

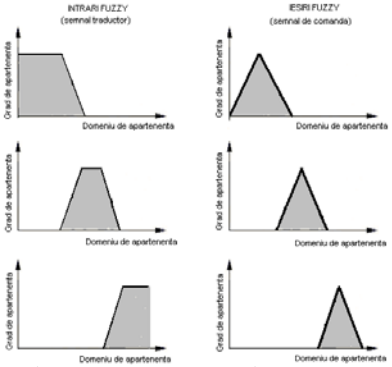

Figure 5. The belonging functions charts of entrance and exit of the fuzzy system.

From the simulation results have been established the belonging fields laps for the mentioned functions and have been established tat the chosen functions are according to the requests of the corresponding adjustment.
Based on the fuzzy regulator parameters, analyzed with the help of the SIMULINK model, have been implemented the numeric regulator on the experimental system, replacing so the classic regulator.

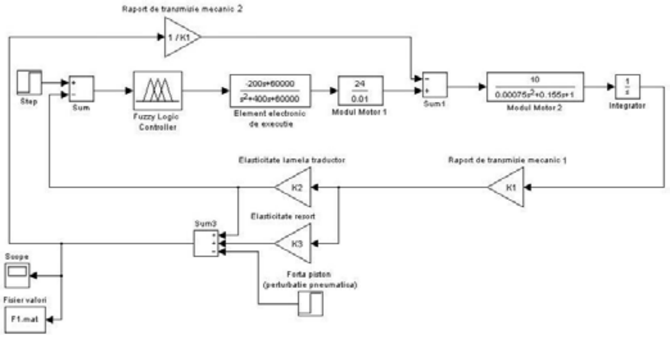

Figure 6. The SIMULINK model of the fuzzy regulator system after the reaction in position/force (impedance)

After the realized experiments with the fuzzy system, it has been observed the substantial improvement of the adjustment, eliminating the delays produced by the fictions and the mechanical system movement (chart from figure 12), without introducing other errors: over adjusting or areas with dynamic instability).

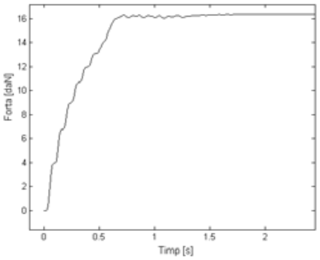

Figure 12.The transduction signal chart for the commanding system with the fuzzy regulator

The experimental system was realized in the Robotics Laboratory of the Managerial and Technological Engineering Collage of the University of Oradea, and can be used for field research activities, as for laboratory studying by the students.

6. Conclusions. From those presented it results the advantage of using the fuzzy regulators in running some processes and mainly the adaptive running "in force" of the industrial robots, processes frequently met in the robotized applications, both in manufacturing and in handling. These results can be used in running mobiles robots in areas hard to reach or on heavy to reach terrain.

Bibliography

[1] Tripe Vidican C. - Studiul optimizării funcţionale a modulelor cu acţionări electrice din structura roboţilor şi microroboţilor – Teză de Doctorat, Oradea 2009
[2] Ţarcă, R. Conducerea adaptivă a roboţilor industriali utilizând informaţii furnizate de senzori, Referatul doctorat nr.3, Universitatea Politehnica Timişoara, 1998.
[3] Tripe Vidican A, Ţarcă R, Tocuţ P, Tripe Vidican C – Proiectarea şi Construcţia Sistemului Mecanic al Roboţilor – ISBN (10) 973-759-216-6; ISBN (13) 978-973-759-216-3 - Editura Universităţii din Oradea, 2006
[4] Jang, R., MATLAB – Fuzzy Toolbox - The MathWorks, Inc. Revision: 1.12 Date: 2000, 15.
[5] MATHWORKS – MatlabR12 –Programing Guide, 2000.
[6] MATLAB SIMULINK 5.1.2. Users Manual. Mathworks Inc. 1998.
[7] Pham D.,T., Karaboga D., Self-tuning fuzzy controller design using genetic optimisation and neural network modelling, Artificial Intelligence in Engineering 13 (1999) 119–130.
[8] Sofron, E., ş.a., Sisteme de control fuzzy – Modelare şi proiectare asistate de calculator, Ed., All, Bucureşti, 1998.
[9] Călin TRIPE VIDICAN, Pavel Dănuţ TOCUŢ, - C*ontributions regarding the adaptive drive of robots* – Analele Universitatii din Oradea 2010