Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 1, 2015.
Strane: 1 – 9

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 1, 2015.
pp: 1 – 9

UDK: 631.372

Originalni naučni rad
Original scientific paper

REAL TIME FUZZY LOGIC SYSTEM FOR CONTINUOUS CONTROL SOLENOID VALVE IN THE PROCESS OF APPLYING THE PLANT PROTECTION PRODUCT

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Abstract: In the area of spray technique complex dynamic systems are very often faced with nonlinear or time-variable behavior. Therefore, such a process is difficult to determine in the model, since it can be inaccurate and therefore useless. So we decided in our application for real time fuzzy logic system, by which we can proportional controlled a process of applying plant protection product (PPP). The real time fuzzy logic system was realized with the HP laptop 6830s Compaque NA779ES, software Matlab/Simulink R2013b, fuzzy logic tool FIS (Fuzzy Inference System), proportional solenoid valve, ultrasonic measurement system and Lechler nozzle. With the help of fuzzy logic system for control consumption amounts process of PPP was found, that we can reduce the quantitative use of PPP, through the solenoid proportional control valve in the range of 0 to 100 %, depending on the intensity of the reflected signal from canopy of the tree.

Keywords: *fuzzy logic system, plant protection product, control, solenoid valve*

INTRODUCTION

A recent wave of commercial fuzzy products, most of them from Japan, has popularized fuzzy logic. In 1980 the contract firm of F. L. Smith and Company in Copenhagen first used a fuzzy system to oversee the operation of a cement kiln. In 1988 Hitachi turned over control of a subway in Sendai, Japan, to a fuzzy system, [1].

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Since then, Japanese companies have used fuzzy logic to direct hundreds of household appliances and electronics products. The Ministry of International Trade and Industry estimates that in 1992, Japan produced about 2 billion worth of fuzzy products. U.S. and European companies still lag far behind. Applications for fuzzy logic extend beyond control systems. Recent theorems show that in principle fuzzy logic can be used to model any continuous system, be it based in engineering or physics or biology or economics or agriculture. Investigators in many fields may find that fuzzy, commonsense models are more useful or accurate than are standard mathematical ones.

Controlling these problematic processes take place mainly on the basis of human experience and its direct intervention in the process, [4]. Fuzzy controllers are able to summarize human knowledge of the system and introduce them to the laws of control. This is possible by solving management problems, without creating a precise model required by classical control engineering. This is the reason that the use of fuzzy logic took hold mainly in control engineering. The use of fuzzy logic in industrial applications is increasing in the recent years. Japanese industry has launched an aggressive marketing of fuzzy ideas in the form of the first commercial outputs [1].

Industrial Engineering (IE) is concerned with the design, improvement, and installation of integrated systems of people, material, equipment, and energy. Industrial engineers face many problems with incomplete and vague information in these systems since the characteristics of these problems often require this kind of information. Fuzzy sets approaches are usually most appropriate when human evaluations and the modeling of human knowledge are needed. IE brings a significant number of applications of fuzzy set theory. The major application areas are Control and Reliability, Engineering Economics and Investment Analysis, Group and Multi-criteria Decision-making, Human Factors Engineering and Ergonomics, Manufacturing Systems and Technology Management, Optimization Techniques, Statistical Decision-making, [2] and in the future process in Agriculture.

MATERIALS AND METHODS

The Matlab R2013b and fuzzy logic toolkit FIS adds sophisticated control algorithms to our instrumentation software development system. By combining the control functions in toolkit with the math and logic functions in the Matlab development environment, we can quickly develop programs for automated control, [5]. Integrate these control tools with NI data acquisition hardware to easily create control systems.

Be aware of the need to that control quantitative dose PPP very dynamic process. Therefore, it is necessary to draw attention to changes that occur outdoors or. field, where various forms of tree crown and barriers between lines of canopy trees can lead to wide ranges of tractor speed, pulling behind a sprayer.

Therefore, in practice, more frequently use applications that is the most adaptable to the current situation on the ground. That, we can define quality process control application of PPP, at selected canopy trees, we are in the process model integrated the fuzzy logic system, [6]. The entire structure of the application process of PPP shown in Fig. 1. Structure of the real time process of application PPP, we have done with the help of software tools Matlab / Simulink and hardware components.

Figure 1. Structure of the real time process of application PPP

Hardware

The hardware of the process for the application of PPP consists of:

- A hardware control cycle consists of the HP Compaq 6830s. A HP 6830s Laptop has a 3 GB DDR2 800 Mhz memory, expandable to 8 GB. Hard Drive has capacity of 320 GB, supports SMART SATA bus communicates and operates plants in 5400 in a minute,
- Posiflow Proportional Solenoid Valves, ASCO procuder, type 2/2 8202 with a flow rates adjustable between 0 % and 100 % of rating and flow rate can also be regulated by a range of electrical inputs (sensors, transmitters, PLC, etc.),
- Lechler nozzle type TR 80-015,
- NI USB-6009 card and
- Ultrasonic measurement system, [3].

Software Matlab/Simulink R2013a

Matlab is a software package designed for numerical calculations, such as arithmetic operations of vectors, differential equations and presentation of results. For such extensive use the Matlab has available libraries through, which more knowledge about the regulation (continuous, discrete, fuzzy), designing of filters, XPC Target System can be reached, [7]. Due to the ease of use Matlab to become a tool, they have become widely used. It is suitable for teaching, research and solve practical problems. MATLAB language has rich data structures and also object-oriented. Because Matlab interprets own files, the loss of much valuable time, but it is possible to code m-files to translate and thus significantly speed up the implementation of the program. On the other hand, bottlenecks program, who spend the most time, encoded in any other programming language, such as C. Matlab code can be translated into mex-file, it know how to use Matlab as its own m file, only that translated performed much faster. Matlab has some distinctive advantages:

- quickly and easily writing programs,
- available to receive high-quality tools for visualization,
- program running on multiple operating systems and
- special offers software tools for working with fuzzy logic systems (FIS; fuzzy inference system), which may include the acquisition and processing of data from external devices by using the tools DAQ (Data Acquisition Toolbox).

As a basic tool for the design of fuzzy logic system, we used Matlab Simulink subsystem, through which you can expand the area of nonlinear dynamical simulations, time-dependent processes.

Simulink enables the development of functional units of fuzzy systems in a simple way, with the known structures of different process models and control loops. Such are created possibilities for the combination of fuzzy logic and conventional techniques and their simulation testing. The simple and open system architecture Matlab program it is possible to realize all the usual procedures and a Simulink tool also offers the possibility of optional finishing and extension.

Fuzzy logic tool FIS

Three partial processes of fuzzy logical system we planned with the help of fuzzy logical tool FIS, which is implemented in the Matlab program.

For the construction, editing, and monitoring fuzzy logic system, exists in the FIS five basic components. These are:

- editor for the determination of fuzzy inference system FIS ("FIS Editor"),
- membership function editor,
- rule editor,
- rule viewer and
- surface viewer.

In the system of the FIS are dynamically integrates and interconnected all core components, [8]. Any changes that have an impact on individual functional components, such as various settings membership functions of input and output variables, can be set in the fuzzy logic system FIS. In the FIS, we set a different number of input and output variables for our fuzzy logic system, with which was continuously controlled the synthesis process of application of PPP. In the editor membership functions was identify their triangular, trapezoidal and rectangular shape. Editor of the rules we used to edit the list of rules, through which was determined the response of fuzzy logic system. Rule viewer represent Matlabs technical tool, that shows fuzzy diagrams of membership functions in the field of operating point. The rule viewer is used for the diagnosis of active rules and provides, how different forms of membership functions repercussions on the final calculation of the output value linguistic variable of fuzzy logic system. With the help of the surface viewer the characteristic fields can show the output values of the variables of the fuzzy system, which depend on different sets of input values of the variables of the fuzzy system.

Modeling real time application of PPP with fuzzy logical system

Fuzzy logic system for continuous control of the proportional solenoid valve, which was made by using Simulink subsystem, Matlab R2013a and software tools FIS, can be considered as a system with non-linear static characteristic in the application process of PPP. Therefore, we are in the process of application of PPP include fuzzy logic system, where form of non-linearity of the fuzzy logic system depends on the rule base and membership functions of input and output linguistic variables depends on the rule base and membership functions of input and output linguistic variables tagged with: Sensor, R□ and El-mag. Optimization of fuzzy system, we started with the process of fuzzification two input and one output linguistic variables. Input and output linguistic variable fuzzy controllers we are define each of them with a reference value in the interval [0, 600]. Reference values for each input linguistic variables of the system represented the normalized intensity values reflection of the ultrasound signal from the tree canopy, which was captured via the ultrasonic sensor, [3].

The input linguistic variable we are defined with a reference value in the interval [0, 1] and represent a traveling speed of sprayer. Reference values for each output linguistic variables of the fuzzy system represented values, with which we can continuously controlled solenoid valves in the range from 0 % to 100 %. Input and output linguistic variables was by using tools FIS, described by three membership functions trapezoidal shape, shown in Figs. 2 and 3, whereas, in this case trapezoidal membership functions shown as the most suitable. Membership function was presented with linguistic values described in Tab. 1.

Figure 2. Membership functions of linguistic variable Sensor

Figure 3. Membership functions of linguistic variable El-mag

After completing the process of fuzzification two input and one output linguistic variables was continue with the procedure inference, which represents the decision-making process. The procedure was carried out, that we wrote a multitude of rules in the form of Tab. 2, for the control of the proportional solenoid valve.

Table 1. Description of the degree of linguistic value membership functions

Linguistic value (label in the FIS)*	*The rate of linguistic values (describe in words)*
M	*Low*
S	*Middle*
V	*Lot*
MOV	*A little open valve*
SOV	*Medium open valve*
VOV	*Lots of open valve*

**The rate of linguistic values ranged between 0 and 1.*

The total number N of possible rules for the fuzzy logic system was defined by the formula:

0 L E L u6 L (1)

Where:

p [-] - number of levels linguistic values for each input linguistic variable,

m [-] - number of input linguistic variables.

Table 2. Rules for controlling solenoid valve

The rules for controlling solenoid valve			
Rule	*Input 1 (Sensor)*	*Input 2 (R)*	*Output (El-mag)*
1	*M*	*M*	*MOV*
2	*M*	*S*	*MOV*
3	*M*	*V*	*MOV*
4	*S*	*M*	*MOV*
5	*S*	*S*	*SOV*
6	*S*	*V*	*SOV*
7	*V*	*M*	*SOV*
8	*V*	*S*	*VOV*
9	*V*	*V*	*VOV*

Importance of levels membership functions of each linguistic variable shows Tab. 1. Language description of the fuzzy logic system, we have made with the form "IF THEN" and the total number of rules is 9.

The rules was added to the rules editor in the fuzzy logical tools FIS. In the language of control techniques we have assumed: if the input value of the ultrasound sensor, [3], small and average speed sprayer a small, then the solenoid valves a little open, depending on the working area of a proportional solenoid valve. After the establishment of rules for controlling the solenoid valves we have created inference, which represented the set of fuzzy output, using the operator inference. In the fuzzy logic system was used Mamdani operator inference, with whom we have created a set of membership functions of the rules, relating to the output parameter, [1]. Then followed a procedure focus, where we have chosen gravity method, which, in practice, the most frequently used and contribute best results. The method allows the calculation of the sharp in control technology useful variables, by which can be controlled executive actuators, such as proportional solenoid valves. After of three procedures, was completed the planning of fuzzy logic system. Optimization of fuzzy logic system was carried out, that we are taking configure stability, robustness, quality of the system and behavior change in the value of the linguistic membership functions and their forms and rules. Then, we have included the design of fuzzy logic system into the final mathematical model. In the mathematical model of the system we have take into account its dynamic properties.

With the use of the subsystem Simulink we have compiled a model of fuzzy logic system by showing in Fig. 4. In the planning system we have take advantage of simulation tools such as Matlab and its associated subsystems.

Figure 4. Fuzzy logic system design for process of application of PPP

RESULTS AND DISCUSSION

Figs. 5 and 6 show the different types of ramp output signals with which can continuously controlled proportional solenoid valve in the range of 0 % to 100 % and control voltage from data acquisition card NI USB-6009, in the range of 0 V to 5 V.

Figure 5. Different types of ramp in the range of 0 % to 100 %

Figure 6. Real time output control voltage in the range of 0 V to 5 V

The figures clearly show that in the case of low numerical values, which represented the intensity of the reflected signal from the tree canopy and which bring in first input of the fuzzy logic system is obtained at the output of the fuzzy logic system openness proportional solenoid valve in the range of 15 %. In the case of greater numerical values to the input fuzzy logic system, is obtained at the output of fuzzy logic system the openness of the proportional solenoid valve in the range 85 % and at middle numerical values to the input fuzzy logic system, is obtained at the output of fuzzy logic system the openness of the proportional solenoid valve in the range 50 %. On the second input of the fuzzy logic system we brought the average value of the travel speed of the sprayer, which are 1 $m \cdot s^{-1}$.

CONCLUSIONS

The research results confirm that could be used model of fuzzy logic system in real process of automated application of PPP in selected parts of the tree canopy, where the method of constant-direct application usually does not produce satisfactory results. We found that the fuzzy logic system allows the user to use their own knowledge of the problem and transferred to the appropriate system environment, which is close to the human way of thinking.

Since this is a more complex task than simply inserting control parameters, we used the special user interface (FIS) for planning fuzzy logic applications. Fuzzy logic system in the application control process of the proportional solenoid valve proved to be a very good choice, because the process of planning a fuzzy logic system quite simple and appropriate for engineering practice. The results showed that it is possible with the help of fuzzy logic system reduce the use of PPP, as the system adjusts the density of leaf area, travel speed of sprayer and according to the input numerical value of the density of leaf area, and a travel speed if necessary, the fuzzy logic system controls the flow of PPP through the proportional solenoid valve.

So far, we have made the real time process of volume application plant protection product implemented with a fuzzy logic system, for one proportional solenoid valve. In the future we want to do real design control process which will be supported by the control and more actuator units, where we controlling in the real time more proportional solenoid valve.

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MEKANI LOGIČKI SISTEM ZA KONTINUIRANU KONTROLU MAGNETNOG VENTILA U REALNOM VREMENU, U PROCESU OBLAGANJA ZA ZAŠTITU BILJA

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Sažetak: U oblasti primene tehnike za zaštitu bilja složenim dinamičkim sistemima istraživači se suočavaju sa nelinearnim i vremenski promenljivim ponašanjem procesa. Za takav proces je u praksi veoma teško odrediti model, pa su zato neki modeli netačni i beskorisni u praksi. Zato smo se odlučili za aplikaciju koja će raditi na principu realnog mekanog logičkog sistema, kojim možemo kontinuirano upravljati magnetnim ventilom u primeni sredstava za zaštitu bilja. Mekani logički sistem realizovan je pomoću hardver alata HP laptop 6830s Compaque NA779ES, proporcionalnog magnetnog ventila, ultrazvučnog mernog sistema, LECHLER mlaznice i softver alata Matlab/Simulink R2013b, mekanog logičkog alata FIS (Fuzzy Inference System). Otkrili smo, da korišćenjem mekanog logičkog sistema kontinuirano kontrolišemo upotrebu sredstava za zaštitu bilja, preko proporcionalnog magnetnog ventila u opsegu od 0 % do 100%, u odnosu na ultrazvučni signal koji se oduzima od krune drveta.

Ključne reči: *mekani logički sistem, zaštita bilja, kontrola, magnetni ventil*

Prijavljen: *Submitted*:	12.09.2014.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	08.03.2015.