MONITORING AND FUZZY CONTROL DEVICE TEMPERATURE (DITECO)

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ABSTRACT

The fuzzy controllers were developed to create alternative ways to classic control in order to avoid complex mathematical calculations involved in the design and have the characteristic to adapt itself to changes that may occur in the plant due to external sources. This paper shows the design of a fuzzy PD control for a furnace, which can be initialized to work with different temperature sensors that are commonly found in industry (PT100, J Thermocouple, K thermocouple, S thermocouple). In this paper we discuss the advantages and disadvantages of working with fuzzy control, plus it is orderly explained the different stages of the process to create it, from the signal processing of the sensors to the controller output.

Keywords: fuzzy control, signal conditioner, membership function, fuzzification, desfusification.

INTRODUCTION

Fuzzy logic is used in many systems to develop control devices. It is widely used in nonlinear plants or when the mathematical knowledge of the plant is not well known. In these cases, is preferred the fuzzy logic rather than traditional methods that can see a big problem in many small, developing them from the fuzzy rules, which dictate the strategies that will follow the control, depending on the status of the plant. The state in which the plant is actually is important because from it depends the control to be efficient, because of that emphasis should be placed in the conditioning of the signal, for a suitable signal conditioning, you should consider the types of passive or active elements to be used, because the signal that will be received depends on them.

METHODOLOGY

Input sensors and signal conditioning

DITECO has two inputs, one two-wire thermocouple input (type J, K, T, S) and a three-wire input for PT100 RTD. These are transducers that convert physical phenomena like temperature into electrical signals such as voltage and resistance.

These transducers require a special signal conditioning and that is why each entry has its signal conditioning circuit for the acquisition of the measurement to perform in an accurate and efficient, and also through software is performed the open sensor detection.

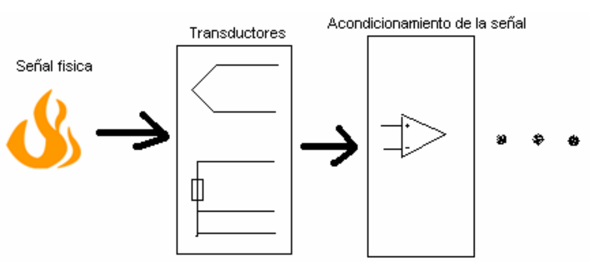

Figure-1. Input sensors and signal conditioning.

Thermocouples

It is the most common transducer for measuring temperature due to its low cost, and resistance.

A thermocouple operates on the principle that a board of dissimilar metals generates a voltage that varies with temperature.

In addition when the thermocouple wire is connected to the cable that connects to the measuring device is created an additional thermoelectric junction known as cold junction. Then the measured voltage includes the voltage of the thermocouple and cold junction voltages (Figure-2). The method for these voltages to compensate for unwanted cold-junction compensation is known as cold junction (Robert Babuska, 2001).

DITECO compensates this unwanted signal by an additional sensor such as LM35, (manufactured by National Semiconductor) a low cost sensor, linear and precise. The voltage from the LM35 which is proportional to the temperature at the reference junction or cold junction is then filtered in the microcontroller by software for processing these data and to obtain the actual value of temperature measurement.

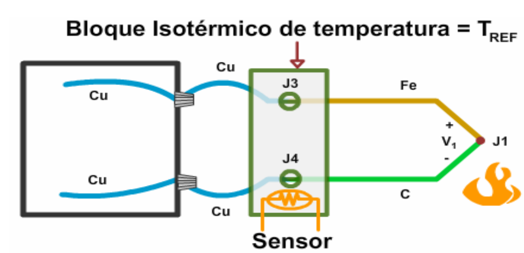

Figure-2. Thermocouple connected to the measurement system.

Due to the voltage output of the thermocouples a very small change from 7 to 50μV per degree (1°C) for change in temperature, making the signals very susceptible to the effects of electric noise, therefore DITECO has low-pass filters and software has implemented a median filter to remove these unwanted signals as well as the LTC1052 amps (manufactured by Linear Technology) low noise amplifier, low offset voltage 5µV to increase the signal level.

DITECO has a compensator block for temperatures below room temperature, this block is necessary if one wants to measure temperatures below room temperature, which is composed of an adder, where one of the inputs is the signal from the conditioned output of the thermocouple and the other input is a fixed voltage.

This procedure is performed as the analog-digital converter does not take negative input values, and for temperatures below the room temperature the signal at the output of the thermocouple conditioner circuit is negative. For software this extra tension is removed and with the value of the reference or cold junction temperature found above is calculated the actual temperature value.

RTD type PT100

These transducers have as characteristic the variation of the electrical resistance that presents the material with temperature.

The most used type of RTD is made of platinum and counts with a nominal resistance of 100 Ω at 0 ° C known as PT100.

To take the value of the RTD's temperature, we have to measure the resistivity and then make the conversion to temperature. You must use a method to measure low resistances. This is accomplished by applying a constant current through the RTD, and measuring the voltage across its terminals. Thus a change in resistance causes a variation in voltage. Figure-3 shows the equivalent circuit for the operation of an RTD.

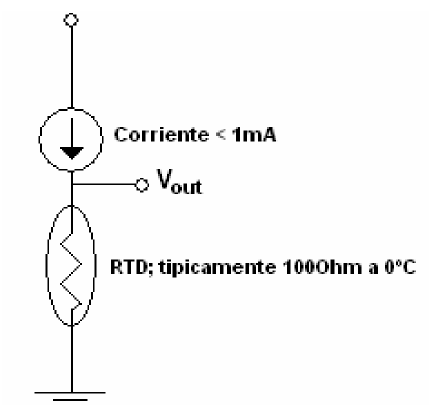

Figure-3. Simplified basic circuit for operation of an RTD.

DITECO has a configuration with a three-wire current excitation, using the MCP609 instrumental amplifier, (manufactured by Microchip Technology) a low noise amplifier and that has 4 operational inside.

Description of the plant (oven)

The oven in which they were tested has a heating element (20Ω/20W) that heats a small block of copper. It has an analog thermometer which displays the current temperature increase in the range between 50°C and 250 °C. It also has two holes in which the thermocouple can be inserted or Pt100 to perform the respective steps.

The oven serves as a heat source for temperature sensors. On the inputs may be connected to a voltage of 20V, which should not be exceeded during continuous operation by, for example, a power amplifier.

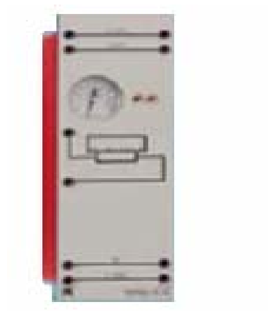

Figure-4. Plant (oven) (20Ω/20W).

Fuzzy logic control

To understand the concept of fuzzy control it should be classified in a structured way its component parts, for it takes into account the most prominent parts of their operation which are fuzzification, inference mechanism and desfusification (R. Babuska, methodologies for industrial control applications, 1999). Figure-5 shows the block diagram of a fuzzy controlle).

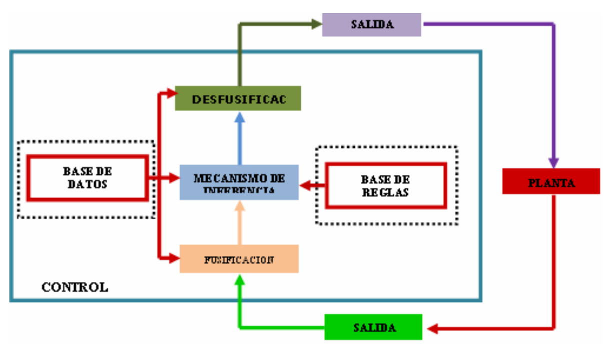

Figure-5. Block diagram of a fuzzy controlle.

Fuzzification

It obtains the values of the input variables to the fuzzy controller. Convert the actual data input in fuzzy sets, which allows it to be treated as such (Galindo Gomez, 2006). The fuzzy data are obtained through fuzzy membership function denoted by. The resulting value is a number between 0 and 1 where the number one (1) represents a membership of one hundred percent and the number zero (0) a zero percent membership.

Figure-6 shows an example of fuzzification of the input (ln). For an input of ln = 5 is obtained a degree of membership from 75% to fuzzy set represented by the function marked by the red color.

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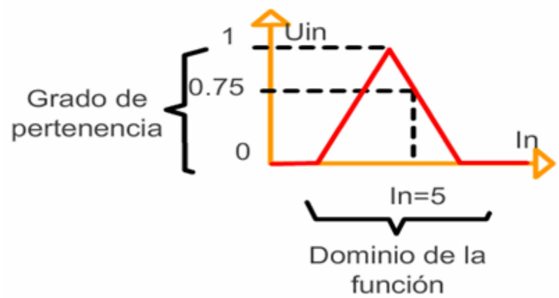


Figure-6. Input fuzzification.

Membership functions. A membership function is associated with linguistic variables (mathematical symbols FIN1 = {Z, S, M, B}).

Each not diffuse input variable (Input) is defined within a domain (universe of discourse), which is associated with a set of membership functions. Each fuzzy input value has one or more linguistic variables (Input→(µS (Input1), µM (Input1))), (Rincón Márquez, 2006). Figure-7 shows an example of the above.

There are many types of membership functions, used according to the application to develop, the most used are: triangular, trapezoidal, Gaussian, and sigmoidal singleton (Vojislav, 2001).

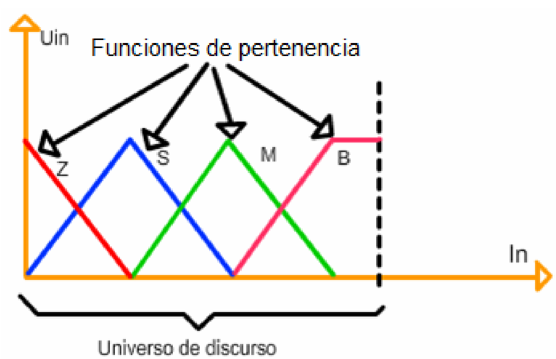


Figure-7. Fuzzification membership.

Involvement

The implication is responsible for the way the rules are activated and how the results of these rules are obtained.

Application of implication

If the background has a value less than one, the output fuzzy set is cut according to the implication.

Aggregation

It consists of superimposing each of the outputs in total.

Desfusification

Desfusification is the method by which a fuzzy input is converted into a not diffuse output (Robert Babuska, 2001).

Project development

A PD fuzzy control was developed in a 30f4013 dsPIC to control an oven. In the first instance is got the temperature sensors to be used, the used are: J Thermocouple, K Thermocouple, S Thermocouple, T Thermocouple and PT100.

Then we already have the processed signal, we proceeded to introduce it to the dsPIC by an analog port, with this signal in the dsPIC we proceeded to use the fuzzy control methods (fuzzification, inference mechanisms and desfusification).

The fuzzy controller that has been developed, were used two inputs: one is the error and the other is the change of the error. Figure-8 shows the block diagram of the PD controller.

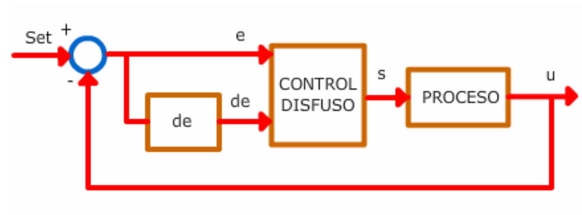
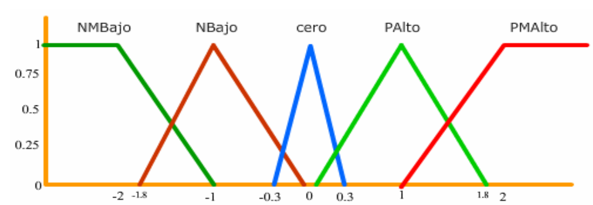
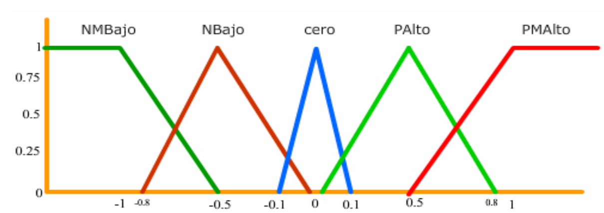


Figure-8. Block diagram of PD controller.

With these two entries were created membership functions to fusification each one of them; in Figure-9(a) and Figure-9(b) is shown the membership functions used. The input functions must overlap to ensure the fuzzification of the input signal in the selected universe of discourse.



a) Error



b) Change of the error

Figure-9. Membership functions of inputs.

After obtaining the input functions, membership functions for output were developed. Figure-10 shows the membership functions of the output that dictate the action of the control. The membership functions are singleton functions which can only be used at the output.

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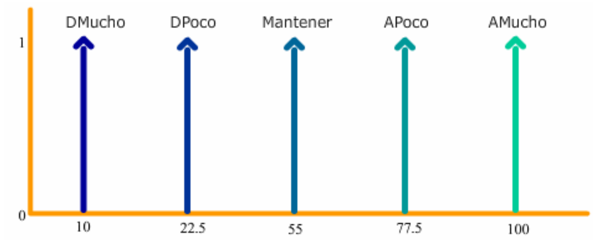

Figure-10. Membership functions of output.

These features alone do not develop control, it is necessary to develop a rule base to operate the control system. 25 fuzzy rules have been selected; Table-1 shows the rules.

The shaded regions in the table indicate the fusificated output part and unshaded region shows the control action.

Table-1. Rules base for PD fuzzy control.

Error/Δerror	NMBajo	Nbajo	cero	PAlto	PMAlto
NMBajo	DMucho	Dpoco	DPoco	APoco	Apoco
Nbajo	DMucho	Dpoco	DPoco	APoco	Apoco
cero	DMucho	Dpoco	Mantaner	APoco	Amucho
PAlto	DPoco	Dpoco	APoco	APoco	Amucho
PMAlto	DPoco	Dpoco	APoco	APoco	Amucho

Figure-11 shows the control device implemented.

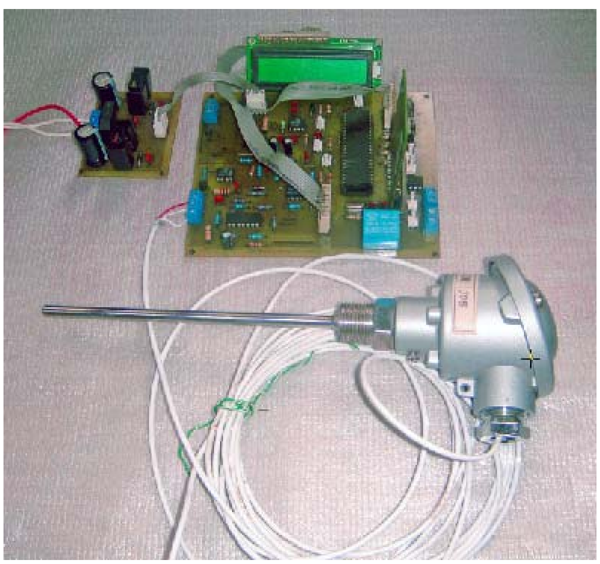

Figure-11. Control device implemented.

For display, Bluetooth technology has been used to connect the control device with a computer. Figure-12 shows the eb-500, Bluetooth device driver that communicates with the computer.

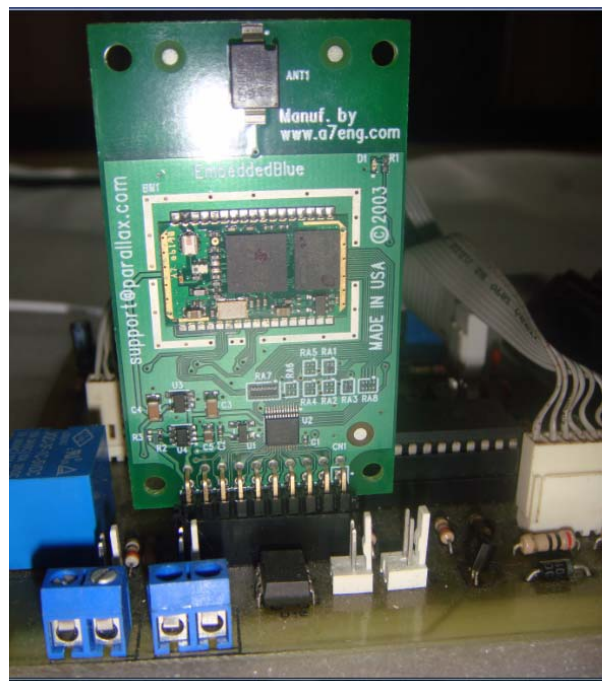

Figure-12. Eb-500, Bluetooth device to transfer.

Monitoring information is sent via Bluetooth to the computer which in turn collects this information in software developed in Lab View, this software has several features, the first is to display on a graph the plant temperature and the second is to send this information to a server to be viewed through a web page. Figure-13 shows the web page where the temperature is displayed.

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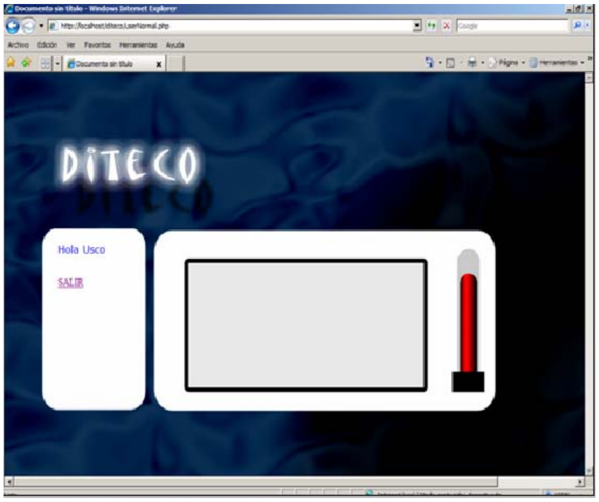

Figure-13. Website display.

RESULTS

Monitoring tests

The monitoring tests were developed in order to obtain the proper temperature in which the plant was. These tests were developed using an LCD that is connected to the device and software developed in Lab View.

Testing control

Control tests were developed using multiple temperature points, to see if the device properly executed fuzzy rules, to take the plant to the proper temperature in Figure-14 is shown the graph for a control to a temperature of 60°C.

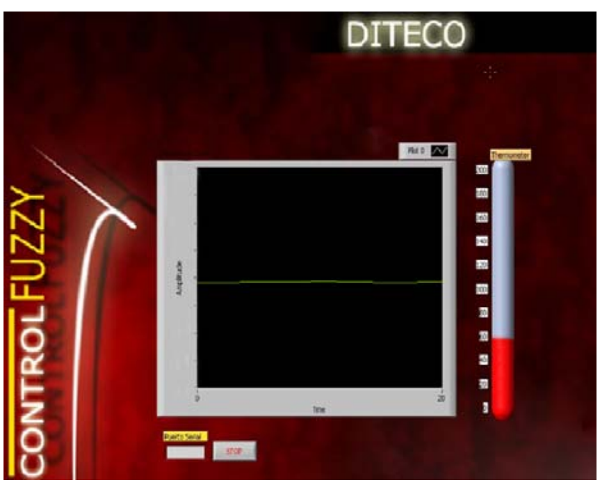

Figure-14. Lab view software for visualization.

CONCLUSIONS

- With the development of this project is shown that we can create reliable applications using a fuzzy control, which achieved in most cases, a better performance that conventional control such as PI, PD and PID, with the advantage of not requiring extensive calculations for controlling implementation, something that does not happen with traditional controllers.
- the main factors were identified for the development of fuzzy control, that although they are the most basic, they lead to a control that accomplish the necessary expectations and requirements for the system, although it should be noted that there are real applications that do not use the fuzzy control, because the control systems implemented are very basic, only with the use of classical proportional control can accomplish the expectations.
- Using Bluetooth wireless communication provides ease of interfacing to the computer, since it avoids the use of cables that can withstand the time to take action. The Bluetooth is a good alternative to the computer connection. Furthermore, the information transmission rate is high, which can help to solve systems requiring high data transfer rate.
- Various algorithms were developed to implement fuzzy logic in the pic, evaluating each one of them and watching the best performance. The best performance implications of this study are the Mamdani and Lukasiewicz, being chosen for the development of the project the Mamdani performance being the easiest for development in the microcontroller.
- The height desfusification provides a fast and reliable performance, its low computational cost causes it to be the most suitable for implementation on a microcontroller, especially if it is a dsPIC. The values obtained by the method of high desfusificación approximate values to ideal values, the results diverge in small steps, almost negligible.
- The use of low noise instrumental amplifiers provided an accurate and reliable measurement of temperature, thanks to its internal characteristics.
- The use of a Web site to view information, allows different users from different locations to access real-time information for potential research. The website was developed so that only authorized persons have access to information.

RECOMMENDATIONS

- If the desired control needs better performance, we recommend using a fuzzy control with inverse dynamic system, which adapts the inference mechanisms and application rates, according to the requirements of the plant. It should be noted that the computational cost is increased.
- The use of proprietary software or software licenses Copyright is a monetary cost disadvantage that it triggered and the computational cost for its use, such as Lab View. Therefore, we recommend the use of Free Software or GPL licenses for the development of applications with connection ports. To replace Lab view is recommended the use of gambas2 or QT Creator

under the ubuntu operative system, which makes available to the developer all the necessary tools for creating appropriate software that accomplish the customer expectations.

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