A PROCESSES CONTROL SIMULATION TOOL

Assoc. Prof. Hyniova K.
Faculty of Information Technology– Czech Technical University in Prague, Czech Republic

hyniova@fit.cvut.cz

Abstract: *The paper deals with a variable multifunctional simulation tool that enables to design and assemble animated models of various technological processes controlled by externally connected fuzzy logic unit. It enables to verify the correctness of fuzzy controller settings in the future control of real technological processes in practice. This tool represents an effective, innovative, and creative concept important to understanding control approach of technological processes modeling as an insight to behavior of real industrial processes and their control which is based on fuzzy logic. On the base of this animated simulation, real technological processes control can be realized successfully according to producer demands afterwards. Models of technological processes assembled by this simulation tool can be then externally controlled by various control strategies (traditional PID controllers, ON-OFF controllers,PLC controllers, fuzzy logic controllers etc.) via a proper real controller connected to the computer. In the paper, two-conveyor-belt system for product packing is shown. The goal consists in control of synchronization of products and boxes placed on individual conveyor belts in order to pack the product into the box. The main concern here is to improve dynamic performance and control efficiency with the help of assembling an animated model of the controlled technological process and its external control by a fuzzy logic unit.*

Keywords: CONTROL, CONVEYOR, SIMULATION, FUZZY LOGIC, PROCESS, CONTROLLER

1. Introduction

It is desirable nowadays for researchers in engineering to try to use some of their more understandable and/or practical work as a material to give an insight to behavior of real industry processes to industry technologists as much as possible. In industry, there are still mostly used PID control, sliding mode control for multi degree of freedom analytical structural systems, PLC control, fuzzy logic control, and their modifications like neuro-fuzzy techniques etc.

The main goal of the research was to create a variable multifunctional simulation system that enables to design and assemble animated models of complicated technological processes with the help of personal computers and their external control by a real fuzzy logic control unit connected to the computer. In the paper, the main concern is to study dynamic performance of conveyors synchronization and control efficiency with the help of assembling an animated model of the controlled technological process and its external control by fuzzy logic unit. The simulation technique that is discussed in the paper can take many forms and offers interesting ways for the technologists to explore and navigate them through the possibilities [1].

The presented paper reports how the work, we carried out in the areas of control of technological processes, has been used as a simulation tool to gain optimal settings of technological processes fuzzy controllers to reach the best process behavior in practice. In case of control of technological processes, the research is concerned on the development of advanced solutions in fuzzy control strategy. These solutions are simulation-based and implement an active approach whereby control schemes react to random disturbances.

2. Simulation Tool

At the Czech technical University in Prague, a variable multifunctional simulation tool that enables to design and assemble animated models of technological processes with the help of personal computers has been developed.

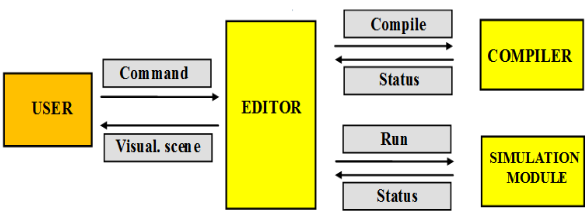

Fig. 1 *Communication between modules*

Such models of technological processes can be externally controlled by traditional PID controllers, PLCs, fuzzy logic controllers, etc.

The attention was focused on creating a universal, modular and user friendly system that would be easily extendable according to user demands. To satisfy all these requirements, we created a system with a built-in editor, compiler, and simulation modules that allows assembling wide class of technological scenes. The block diagram illustrating communication between the individual modules is shown in Fig.1.

To ensure correct understanding behavior of the simulated technological processes, we created a concept of real-time animation. The only part with the help of which standard users can build up the simulated technological scene is the editor module. It contains a library of various objects which is comfortably extendable according to user demands. The objects can be sorted into six categories:

- input objects (generators of analog and binary signals ...)
- drives
- actuators (conveyor belts, robots, start and destination points of transported subjects, ...)
- sensors (position sensors, tachogenerators, counters, etc.)
- output objects (scales, displays...)
- connections / linkages (cables, wires, pipelines)

The editor is equipped with a built-in checker for testing if all objects of the created scene are correctly located and do not cover each other. After the compilation command has been received, the compiler executes syntactic tests of the built scene and creates connections between the individual objects. If the compilation process is successful the compiler gives control back to the editor module that runs the simulation phase and announces a message about successful compilation.

In case of abortive compilation, the editor takes over the error code and announces an error message. The simulation module is represented by a simulation cycle that ensures testing of all scene objects every 50 ms. The simulation process can be externally interrupted by the user (by pushing a key) or internally by an error whose code is immediately announced in the form of an error message.

The simulation module is a useful tool to check the knowledge of hardware structure and connections in the controlled process. It leads not only to understanding which components are suitable or necessary for the real design but also gives a real imagination of all parameter levels in the process (supply voltages, actuator revolves, etc.). The simulation itself gives immediately information to the user whether the created configuration of the simulated scene is correct or not.

3. Simulated Technological Process

To illustrate a built up scene and its connection to external control executed by a fuzzy logic controller, an illustrative example- externally controlled conveyor belt process by the modular PLC C200H with fuzzy logic unit FZ001 OMRON is shown in Fig.2.

The unit is used to control two conveyor belts for products packing. The products are carried on the conveyor belt A at random intervals, but at a fixed speed. The boxes are carried in regular intervals on conveyor belt B, which runs in parallel to conveyor A at speed controlled by fuzzy logic unit. The fuzzy logic unit adjusts the speed of conveyor B so that the boxes arrive to the same point at the same time as the products. Actually, the goal is to synchronize occurrence of boxes and products at a specific place where the product will be packed in the box. The required information for conveyor B control is the offset E between the product and the box and the rate DE that the offset is changing.

The components of the simulated process and their function are given in the part list (Tab. 1).

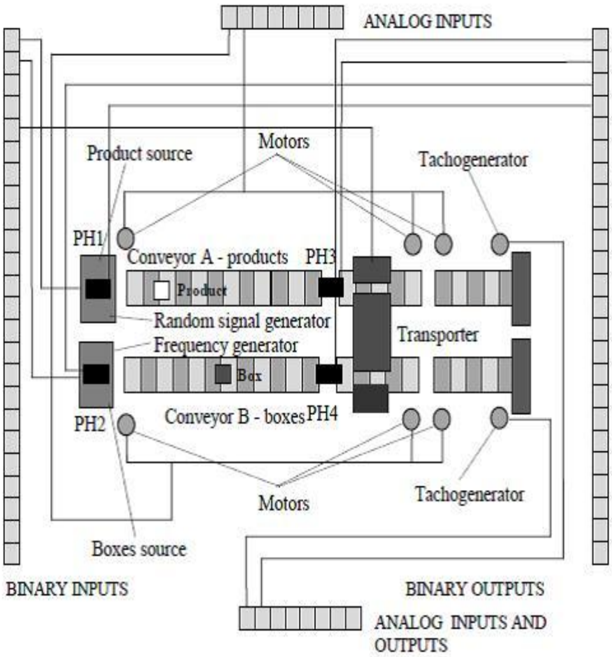

Fig. 2 Simulated technological process - two conveyor belt system

Table 1: *Component list*

Component	Component function
Motor A (B)	Drives conveyor belt A (B)
Tachogenerator A (B)	Tachogenerator for conveyor belt A (B)
Photoelectric sensors (4)	Sense passing products and boxes
Input unit	Receives photoelectric sensor inputs
Output unit	Outputs to motors and conveyors
Analog input unit	Converts analog speed data to digital form
Analog output unit	Converts the digital output from fuzzy logic processing to analog data and outputs it

4. Process Control

To control the technological process described above the modular PLC C200H with fuzzy logic unit FZ001 OMRON [1], [2], [3], [4], [5] is used. It controls the process via interface boards AX 5212 (8 output analog voltage/current channels) and AX 5411 (16 input and 2 output analog channels, 24 input and output binary channels) manufactured by AXIOM. External control of the simulated process is executed by PLC C200H OMRON with fuzzy logic unit FZ001 of the following configuration:

- binary inputs (sensors PH1, PH2, PH3 and PH4)
- analog inputs (conveyor A speed, Conveyor B speed)
- binary outputs (random frequency generator generating products and adjustable frequency generator generating boxes)
- analog outputs (conveyor A speed, conveyor B speed)
- PLC configuration [4] :

C200H-CPU31	C200H-FZ001
C200H-OD212	C200H-ID21
C200H-PRO15-E	C200H-DA001
C200H-AD002	C200H-BC081
C200H-LK20	

The way how to set the fuzzy controller is explained in the next paragraph. Fuzzy logic controller provides an effective tool of capturing the inexact nature of the described industrial process. Basically, fuzzy logic controller converts linguistic control rules based on expert knowledge and experience into automatic control [1]. As the process behaves randomly conventional precise mathematical control is impossible.

4. Fuzzy Controller

The basic configuration of the fuzzy logic controller is shown in Fig.3. It consists of four basic components: fuzzification interface, knowledge base, decision making logics (fuzzy inference system), and defuzzification interface.

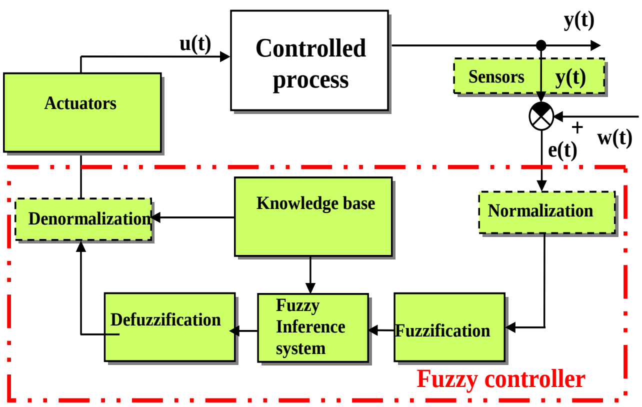

Fig. 3 Fuzzy controller structure

The fuzzification converts crisp output data of the controlled process into suitable linguistic variables [5].

To adjust the conveyor B speed VB to move the boxes to the same point where products occur at the same time, the information about offsets E between the products and the boxes and the rate DE that the offset is changing is necessary.

- The input data for product/box offset are taken from the relative product/box offset position E:

(1) $E=POS(Product) - POS(Box)$

- The input data for the rate of change of the offset DE is the difference between the most recent value of E (i.e. E(n)) and the previous value of E (i.e. E(n-1)):

(2) $DE=E(n)-E(n-1)$

The condition/conclusion membership functions that assign numerical values to how well a specific value of a fuzzy variable (E, DE, VB) satisfies the condition/conclusion part of the rule are shown in Fig.4.

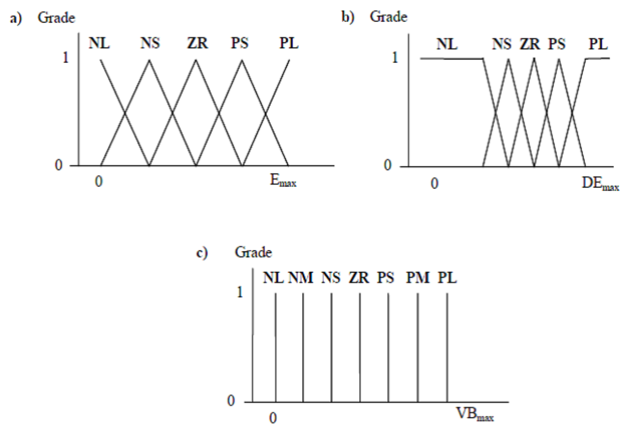

***Fig. 4**. Condition membership functions for: product/box offset E (a), offset rate of change DE (b), and conclusion membership function (conveyor B speed VB adjustment) (c)*

In Fig. 4:

- NL… Negative Large
- NM… Negative Medium
- NS … Negative Small
- ZR … Zero
- PS … Positive Small
- PM … Positive Medium
- PL … positive Large

The rules were created by organizing common know-how about the simulated process in everyday expressions. These IF-THEN statements that show how much the conveyor B speed has to be adjusted depending on E and DE are presented in Table. II.

The linguistic rules given in Tab. II need to be converted to a simplified form (Table III) than can be entered into the fuzzy logic unit.

The final result of the fuzzy logic processing for the fuzzy logic outputs is calculated by center of gravity method.

The final result of the fuzzy logic processing for the fuzzy logic outputs is calculated by center of gravity method.

The crisp value of the controller output defuzzification is calculated according to the following center of gravity formula:

$$x_T = \frac{\int_{-FFF}^{+FFF} \mu^*(x) x dx}{\int_{-FFF}^{+FFF} \mu^*(x) dx} \quad (3)$$

where $\mu^*(x)$ is the area line determined by the output value membership function. reliability and long lifetime, their usage as shock absorbers seems to be ideal.

***Table 2:** Expressing rules*

E \ DE	Box is ahead a lot	Box is ahead	About even	Product is ahead	Product is ahead a lot
Box is much faster	Slow box a lot	Slow box	Slow box a little	Speed the box up a little	Speed the box up
Box is faster	Slow box a lot	Slow box	Slow box a little	Speed the box up a little	Speed the box up
About even	Slow box a lot	Slow box a little	Do not change	Speed the box up a little	Speed the box up a lot
Box is slower	Slow box	Slow box a little	Speed the box up a little	Speed the box up	Speed the box up a lot
Box is much slower	Slow box	Slow box a little	Speed the box up a little	Speed the box up	Speed the box up a lot

***Table 2:** Converting to lables*

	Product/box Offset E					
		NL	NS	ZR	PS	PL
Offset Rate of Change DE	NL	NL	NM	NS	PS	PM
	NS	NL	NM	NS	PS	PM
	ZR	NL	NS	ZR	PS	PL
	PS	NM	NS	PS	PM	PL
	PL	NM	NS	PM	PM	PL

Centre of gravity method computes the center of gravity of singletons (Fig.4c) that have been defined by firing of any of the rules. These singletons are weighted by the given rule weight. It can be immediately verified on the computer screen that the simple knowledge base shown above gives surprisingly good results.

5. Results

A simple example of simulated externally controlled technological process has been presented. A series of such illustrative examples is used in the university courses "Processes Control" at the Dept. of Digital Design at the Czech Technical University in Prague to make control strategies and techniques more understandable and creative.

The simulation tool has been tested in industry, namely in a soap manufacture. On the base of the simulation, they reached satisfactory results in fuzzy logic control of synchronized conveyor belts in practice. They set the same fuzzy controller parameters like during the simulation and gained very satisfactory synchronization of products and boxes carried on the conveyer belts.

Acknowledgement: This research has been supported by the MSMT CR project INTER VECTOR No. LTV 17019.

References

[1] K.Hyniova, A. Stribrsky, "Instrumentation of Processes," FEE CTU. Prague, pp. 160-189,2014, 1964

[2] OMRON Programming Tool for OMRON PLC, OMRON, 1996

[3] OMRON C200H – Operation Manual, OMRON, 1992

[4] OMRON C200H –FZ001Fuzzy Logic Unit-Operation Manual, OMRON, 1992

[5] L. A. Zadeh, "Outline of A New Approach to The Analysis of complex Systems and Decision Processes, Trans .Syst,. Man, Cyber. Vol-SMC- 3,No.1, pp.28-44, 1973