ISA 88 Int. Conf., Intelligent Process Control, Houston, Oct. 17-24, 1988, USA

TEACHING AND TRAINING OF THE FUZZY PROCESS CONTROL

Dr. Juraj Bozicevic
Department of Measurement and Control
Faculty of Technology University of Zagreb
41000 Zagreb, Croatia, Yugoslavia

and

Dr. Darko Stipanicev
Faculty of Electrical, Mechanical and
Naval Engineering University of Split
58000 Split, Croatia, Yugoslavia

ABSTRACT

An approach to teaching and training of graduate students of chemical engineering in fuzzy process control is presented. Fuzzy feedback control, fuzzy feedforward and composite fuzzy control are considered, and theoretical lectures, simulation exercises and laboratory work are composed in a harmonious syllabus.

INTRODUCTION

Recent developments in fuzzy modelling and control have motivated us to introduce the first courses and laboratory exercises on fuzzy systems and fuzzy control for graduate students of chemical engineering. Our approach and experience are presented in this paper.

It is well known that conventional methods of control theory, which have been taught to generations of students have slightly changed since early sixties. We have however permanently improved laboratory exercises with application of the new hardware and giving more attention to computerized measurements and control, to mathematical modelling and simulation, to identification and parameter estimation. Further, the emphasis has been shifted from continuous process control theory on digital process control. The newly developed software made the possible to computerize the synthesis and the analysis of the control system and to train students significantly better than ever before. Nevertheless, our lectures have been mainly restricted to simple and well defined processes, considering that such a programme is good enough to allow students in their future practical work equally good communication with the control and instrumentation engineers as in advancement in their own discipline. On the other side the methods of conventional control theory have been treated as unsuitable for the synthesis of control units of the complex and of ill-defind processes.

In early eighties the first succesful industrial application of the fuzzy process control been an enough strong motivation to enrich the conventional programme in automatic process control and add to the fuzzy control theory. So we have been able to familiarize our students with some basic concepts and procedures of the newly developed fuzzy sets theory (1,2) linguistic modelling (3), with the synthesis and analysis of the fuzzy feedback control (4), with fuzzy feedforward and composite control (5,6) and tackle various tasks of ill-defind process control. Considerable attention has been then given to the development of laboratory exercises to support the teaching and to train the students in new ways of reasoning. Attention has been given to presentation of knowledge by fuzzy relations, to knowledge diagrams as models of fuzzy systems and to approximate reasoning (7).

Aside to this experience at Faculty of Tehnology University of Zagreb, similar approach to teaching the fuzzy systems has been freshly implemented at Faculty of Electrical, Mechanical and Naval Engineering University of Split, but with more emphasise on the knowledge engineering and expert systems.

THE APPROACH TO TEACHING

The solving of process control tasks by means of fuzzy set theory is based on the way of thinking which is entirely different form the usual, cultivated at conventional engineering study. The emphasise on exactness, precision, determinism and quantitative solving of the tasks is regular, while we have had to introduce indeterminism, inexact reasoning and thinking in rules, dealing with such situations in which requests for higher precision may be even a limitation (the incompatibility principle) and in which only qualitative thinking is appropriate. Therefore, it was extremly significant to develop an appropriate approach to the teaching and explain to students the co-existance and the need of these two ways of thinking and to point out when and why the fuzzy set approach may be used. Our special interest however has been the use of fuzzy set theory in the solving the process control tasks. Let us stress that the treatment of fuzziness is a critical issue, and that indeterminancy is supposed to reside in the state of our knowledge, because to say that a phenomenon is fuzzy, is to say that sometimes there is no definite answer as to whether or not the deterministic perception is applicable.

As an introduction to the course, the basic theory of fuzzy sets is presented as a tool for the expression of natural languages and for linguistic modeling. It is our experience that the best approach is to teach the methods of fuzzy set theory on carefully selected examples by using comparative illustration of differences between exact, inexact and approximative reasoning. Also, the examples of the human behaviour and thinking are used whenever suitable as a support for the explanation. Students have accepted such an approach as being easier than the strict teaching of fuzzy sets theory.

After the teaching of the fuzzy sets theory and its application, the fuzzy process control is being introduced. The behaviour of a process operator, his process monitoring and his control actions, manipulation of the process inputs are studied first, and then compared with the work of a fuzzy controller. Step by step new conceptions are being presented: fuzzy set presentation of linguistic values, principles of collection and definition of the control values, definition of various algorithms for fuzzy control by emphasising the fuzzy relations, the implication and selection of the transformation rule, selection of the composition of fuzzy relations and finally the interpretation of the results.

In the beginning all our instructions were directed at the feedback control tasks. Then the linguistic and fuzzy models of the process suitable for the fuzzy feedforward control were introduced and the fuzzy feedforward and composite control examined (6). Again, the human behaviour was discussed as an illustration.

Various examples were critically examined and students had to prepare own presentations of selected examples from literature in the form of communication, for example on a warm water plant (8),heat exchange (9), neutralization (10), continuous fermentation (11), steam generation (12), waste water treatment (13) or on the assignment of work places (14), maintenance scheduling (15) and water resource planing (16).

A survey of contemporary development in knowledge representation and in approximate reasoning introduces students to a new field of expert systems.

SIMULATION AS A PRIMARY TRAINING AID

Simulation and experimentation are very important part of our course and are conceived as a support to previously described theoretical lectures. Students study by means of computer simulation first.

A process with one output and with two inputs, the manipulated and the disturbance inputs, is created and is being simulated on an analog computer. The inputs and the output are made observable by means of indicating instruments, on which only the position zero and maximal negative and positive deflections of the pointer are marked. The first student's task is to develop static fuzzy model of the process.

The analog computer is interconected with a digital computer, and then the next student's task is to investigate the behaviour of the process and of the selected control procedures under various transient conditions. Aside of monitoring the indicating instruments, he may print or plot the process or system responses. The investigation of fuzzy feedback and fuzzy feedforward control is considered.

As the final task a student uses the values of the input and output quantities acquired by process monitoring and developes static regression model of the process and then by means of this model he designs the static feedforward controller. It permits him to study comparatively the behaviour and the efficiency of the conventional and fuzzy approches to the process control tasks.

The second exercise deals with the development and the use of a simple expert system of linguistic values used in simulation of process bahaviour. The core of the expert system has been developed by students themselves. It contains 90 permitted linguistic values. So, by using the observed values and the linguistically estimated value from the expert system, the simulated behaviour process is compared with the 'real' behaviour presented by the analog computer. The expert system is able to answer the question "why" and warn the student if an estimation of the process behaviour of the input data is wrong. Various transformation rules for defining the fuzzy relations, the implication, anable the analysis and the comparison of the results obtained with particular transformation rules and with definition of composition.

The representation of knowledge by fuzzy relations, the representation of knowledge diagrams as models of fuzzy systems, as well as the training in approximate reasoning are also parts of the training.

The training in simulation is a very valuable preparatory work for the laboratory exercises.

LABORATORY EXERCISES

Our basic experimental aid is a laboratory plant consisting of three vessels and various accessories, which make possible to set-up diverse thermal processes. The set-up in Figure 1 shows a two stage heat exchanger process, which is suitable for the training of the fuzzy process control:

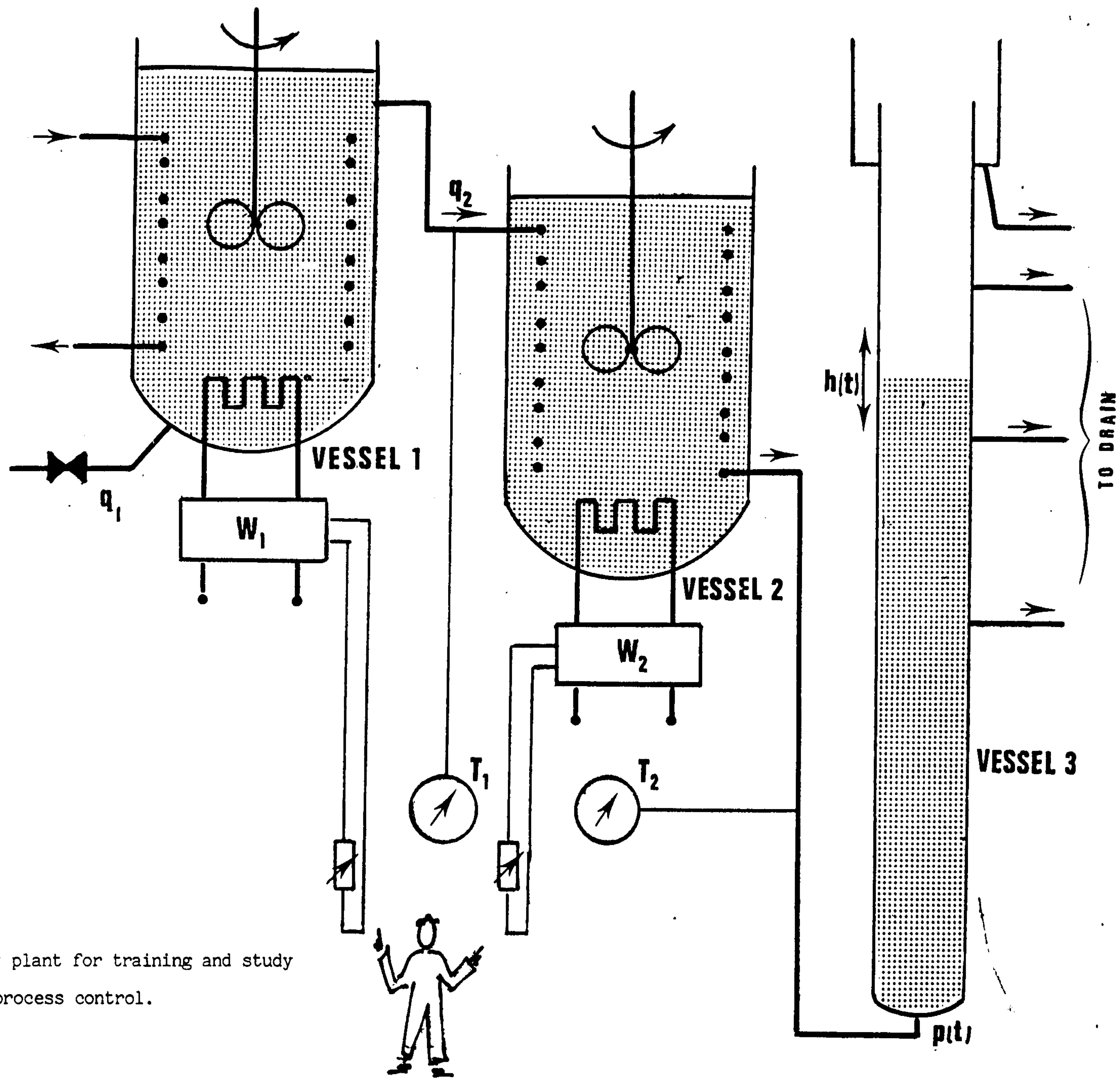

FIGURE 1 - The laboratory plant for training and study of the fuzzy process control.

Fresh water flows from a reservoar in the vessel 1, where is heated at the temperature T_1, and then transported through a tube in the vessel 3, a column which simulates a process stage with variable inside pressure. A segment of the tube, formed in a coil, is immersed in the warm oil in the vessel 2, which acts as a heat exchanger and heats up water from the temperature T_1 at the temperature T_2. At the upper part of the column the water outlets are distributed on different heights and are opening randomly controlled by the random signal generator. Monotonious random variations of water level are produced and the changes of the pressure head as the consequence. Because of the strong coupling between the bilance of heat and the bilance of material, the process is sufficiently complicated to show wether a fuzzy controller is suitable or not.

The input variables are thyristor controlled powers, W_1 and W_2, consumed for heating the water and the oil in the vessels 1 and 2, while the output variables are the water level in the vessel 1, the flow of the water through the cooling coil and the temperatures of the water at the inlet and the outlet of the tube, T_1 and T_3 respectively, and the temperature of the oil, T_2. The control problem, which is used to study the practical applicability of fuzzy process control consists in maintening the temperature of water, T_2, within given values. Then, it may be extended to multivariable process control problem, that is a control problem with two input and two output variables.

Both, the simple manual control and computer control of the process are performed. However, the first student's task is to investigate the process and to develop static fuzzy model of the process. Then, more and more complex tasks are being executed. Student develops verbal formulation of a possible strategy for control of the process, study feedback control, design the model of the process for the fuzzy feedforward control etc. etc.

The PC AT compatible computer adapted for process control is used in these exercises.

CONCLUSION

An approach to teaching and training of the fuzzy process control is described. Theoretical lectures, simulation exercises and laboratory work are composed in a harmonious syllabus. Theoretical part of the course covers the theory of linguistic modelling and introduces students to the basic theory of fuzzy sets as a tool for expression of natural languages and mathematical modelling of reasoning process. The fuzzy process control is very important and therefore supported by many examples worked out independently by students.

Simulation and experimental exercises are planned as independent parts which support theoretical lectures and help the students to learn and applying practice, the new way of process modelling and control.

It is important to stress that our guiding thought in seting up such a course is to motivate the students to mastermind the new way of thinking when dealing with the well known and established modelling and control practice.

ACKNOWLEDGMENT

Part of this work was supported by the Self-Managment Community for Scientific Research of Croatia.

The authors thank to Mr. Alojz Caharija and Mr. Mladen Glasner for their assistance with development of the laboratory plant and to Mr.Ivan Dobranić for his skill in the construction of the plant.

REFERENCES

(1) Zadeh, L.A., "Fuzzy sets", Information and Control, 8, 1965, 338-358
(2) Negoita, C.V., Fuzzy systems, Abacus Press, Tunbridge Wells, England, 1981
(3) Tong, R., "The construction and evaluation of fuzzy models", Advances in fuzzy set theory and applications, M.Gupta, R.Ragade and R.Yager, Eds., North Holland, Amsterdam 1979, 559-576
(4) Tong, R., "Some properties of fuzzy feedback systems", IEEE Trans.Syst. Man Cyb., 10, 1980, 327-330
(5) Božičević, J., "Verbal model for feedforward control", Internal note, Faculty of Technology University of Zagreb, Zagreb 1983
(6) Stipaničev, D. and Božičević, J., "Fuzzy feedforward and composite control", Trans.Inst. M and C, London, 8, 1986, 67-75
(7) Negoita, C.V., Expert Systems and Fuzzy Systems, The Benjamin / Cummings, Menlo Park, Califormia, 1985
(8) Kickert, W. and Van Nauta Lemke, H., "Application of a fuzzy controller in a warm water plant", Automatica, 12, 1876, 301-308
(9) Østergard, J.J., "Fuzzy logic control of a heat exchanger process", Int. report DTH No. 7601. Tech. Univ. of Denmark, Lyngby, 1976
(10) Jaspersen, T., "Self-organizing fuzzy logic control of a pH-neutralization process", Int. report DTH No. 8102, Tech. Univ. of Denmark, Lyngby, 1981
(11) Sotirov, G. at al., "A hierarchical system for control of continuous fermentation process, synthetised on the basis of linguistic approach", Proc. IFAC Symp. Real Time Control of Large Scale Systems, Patras, Greece, 1984, pp. 308-313
(12) Ray, K.S. and Majumder, D.D., "Fuzzy logic control of a nonlinear multivariable steam generating unit using decouplin theory", IEEE Trans. Syst. Man Cyb., 15, 1985, 539-558
(13) Tong, R.M. and all., "Fuzzy control of the activated sludge wastewwater treatment process", Automatica, 16, 1980, 659-701
(14) Kaprzyk, J., "Fuzzy set theory approach to the optimal assignment of work places", Proc. IFAC Symp. Large Scale Syst. Theory and application, Udine, Italy, 1976
(15) Etschmaier, M.M., "Fuzzy controls for maintenance sheduling in transportation systems", Automatica, 16, 1980, 255-264
(16) Esogube, A.O. and Ahipo, Z.M., "Fuzzy sets and water resource planing", Fuzzy sets and Possibility theory, R.R. Yager, Ed., Pergamon Press, New York, 1982, pp. 450-466