Dimiter Driankov Peter W. Eklund
Anca L. Ralescu (Eds.)

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Series Editors

Jaime G. Carbonell
School of Computer Science, Carnegie Mellon University
Schenley Park, Pittsburgh, PA 15213-3890, USA

Jörg Siekmann
University of Saarland
German Research Center for Artificial Intelligence (DFKI)
Stuhlsatzenhausweg 3, D-66123 Saarbrücken, Germany

Volume Editors

Dimiter Driankov
Department of Computer and Information Science, Linköping University
S-58183 Linköping, Sweden

Peter W. Eklund
Department of Computer Science, University of Adelaide
GPO Box 498, Adelaide SA 5001, Australia

Anca L. Ralescu
Laboratory for International Fuzzy Engineering Resesarch
89-1 Yamashita-cho, Naka-ku, Yokohama, 231 Japan

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Preface

Why have a fuzzy control/logic workshop at a major AI conference?

Despite the indisputable success of Fuzzy Control (FC) there remains an important issue which requires further investigation and more solid and thorough treatment. This issue, considered to be the weakest point of FC, is the lack of formally sound procedures for FC design and analysis based on fuzzy (or other types of quantitative/qualitative) process models. In other words, there is a strong need for the development of fuzzy dynamic systems theory with an emphasis on the modelling the linguistic structure of the process (or deriving it from existing quantitative/qualitative models). This theory should extend in a qualitative way the fundamental notions of state, controllability, and stability and provide a means for automatic derivation and analysis of fuzzy controllers allowing at the same time for easy incorporation of expert knowledge.

On the other hand, some recent developments in the area of qualitative modelling in AI seem to point in the direction of providing qualitative models for the behaviour of complex nonlinear systems using qualitative descriptions of phase-plane structures.

The ultimate goal is to develop a class of intelligent controllers that "understand" the phase-planes of complex nonlinear systems, sense the world, synthesize control commands, and affect processes. Accomplishing such a difficult task would be hard to imagine without the controller being able to understand and analyse the qualitative behaviour of a system, especially when the system is of higher order and operates in a nonlinear regime.

However, these two approaches to intelligent control, although aiming at similar objectives, have developed very much independently from each other and there has not been an exchange of ideas between the two scientific communities. In control theory terms, a fuzzy rule based formalism can be likened to a qualitative input/output model whereas, in AI the approach is akin to qualitative state-space description and performs the function of an internal representation of the process. Thus, the fuzzy control representation describes what an experienced process-operator does, rather than why he does it. The answer to the latter can only come from the internal representation of the process, i.e. its model.

It is in this context that the need for the workshop was conceived. Its purpose was seen in terms of providing a framework within which the similarities and differences between the two approaches could be highlighted and discussed.

The workshop programme and its goals

The morning session of the workshop (10.00-12.30 am) contained three long presentations (45 minutes each) – all three were given by Japanese participants and devoted to providing a complete picture of the Japanese large-scale effort in the area of fuzzy control and fuzzy expert systems. The latter are built using basic fuzzy control techniques augmented with object and frame-based knowledge representation techniques as well as some means for temporal and causal reasoning.

The speakers were able to pinpoint the need for fuzzy treatment in a number of comparatively large-scale applications, to systematize the lessons learned and specify in a systematic way the advantages and the limitations of the fuzzy approach as well as its integration with AI techniques. The talk by Professor Hirota [Deputy Director of the Laboratory for International Fuzzy Engineering (LIFE)], provided for an excellent description of major ongoing projects at LIFE, e.g. an expert system shell for automatic analysis of economic indicators incorporating quantitative, qualitative, and temporal information about these indicators; the linguistic control of a robot; and high-level conceptual analysis of images using fuzzy object and frame-based representations.

Professor Hirota [Hosei University, Tokyo] concentrated on explaining why the fuzzy approach has acquired such prominence in Japanese academic and industrial circles. He also gave a detailed picture of the very well orchestrated Japanese research in the area of fuzzy control and pointed out the benefits from close co-operation with industry.

Dr. Wakami [Matsushita Electric] gave an exhaustive survey of the applications of fuzzy control to a wide range of low-tech consumer products and also described Matsushita's research effort in the area of neuro-fuzzy controllers.

Thus the morning session achieved a number of goals, it gave;

- an introduction to the basic fuzzy techniques employed in fuzzy control and fuzzy expert systems, pointing out their advantages and limitations in the context of specific application areas;
- an idea how the fuzzy approach can be combined with basic AI techniques and approaches (frames, object-oriented approach, temporal reasoning, neural networks);
- a description of the applications domains where the fuzzy approach was successful and is worth applying.

The afternoon session was divided into three parts. The first part included two long-presentations (45 minutes each) concerning novel theoretical results about fuzzy control rules and the modeling of fuzzy dynamic systems.

Professor Prade, after summarising the main features of the existing fuzzy control rules and pointing out their limitations, proposed a new type of rule called a "gradual rule", e.g. "The more x has the property A, the more y has the property B" instead of the conventional interpretation, "If x is A then y is B". The main advantage of such a gradual rule is that the defuzzification part of a fuzzy control algorithm becomes unnecessary. The underlying motivation for getting rid of the latter is that whenever the controller stems from a single set of rules it seems that a preprocessing of these rules which transforms the fuzzy controller into a standard, possibly non-linear, control law is more reasonable than a two-step process that computes first a fuzzy control output and then defuzzifies it. However, the appropriateness of such control rules, though reasonable from a theoretical point of view, remains to be tested in real control applications.

Professor Pedrycz's presentation identified the major approaches to modeling dynamic fuzzy systems, concentrating on first-order systems. These approaches can be classified into three different types:

1. direct relational structures
2. state equations with a difference operator
3. referential fuzzy dynamical systems

Professor Pedrycz pointed out some similarities between system descriptions coming from AI-based qualitative reasoning and the referential fuzzy dynamic systems.

The second part of the afternoon session was devoted to short presentations (20 minutes each) describing work in the following areas:

- fuzzy systems modelling: Z. Cao reported a mapping algorithm for fuzzy reasoning as an alternative to the fuzzy rule-based reasoning. However, its relevance with respect to control applications remains to be investigated. B. Das reported work on dynamic systems based on fuzzy non-linear functions with emphasis on their temporal and uncertainty management aspects.
- design methods for fuzzy control: D. Stirling and S. Lamba described a fuzzy logic based expert system for stainless steel cold rolling mill. The approach taken incorporates a qualitative model of the process based on causal graphs and a set of heuristics based on IF-THEN fuzzy rules.
  B. Graham described a method for the identification of a process-model from plant input/output data. The model is in the form of qualitative linguistic relationships, by adding on-line identification of the model he showed how a fuzzy adaptive controller can be constructed.
- applications of fuzzy control: Y. Darvish talked about a project to develop a fuzzy controller for the lateral axis of an autopilot for the Boeing 737. Kieronska and Vankatesh reported on the use of fuzzy control techniques in a robot's navigational system. Y. Katz identified the parts of a system for the management of large computer networks which require real-time fuzzy control. S. Libberstein talked about using fuzzy logic techniques in the construction of any-time algorithms.

The third part of the afternoon session was devoted to a discussion which concentrated on the following two topics:

- what should a fuzzy control design methodology consist of?
- the need for QM techniques in FC.

Concerning the first topic the following view emerged: It is important to distinguish between the following three tasks from which a methodology would consist:

- the elicitation of fuzzy control rules;
- the synthesis of a control law from the rules;
- the study of the properties of the control law.

The first requires careful analysis of what redundancy, completeness, and consistency mean for a set of fuzzy rules where subsets of rules can be fired in parallel. It has to be stressed that such an elicitation makes sense only if the process-operator's expertise is available. If it is lacking, a learning methodology based on neural nets might be more appropriate. However, in practice, it is likely that in most cases the expertise will be available, but without being sufficient for a precise determination of the controller, i.e. some learning will be required anyway.

The second task could be tackled by regression methods from fuzzy data. The third task is considered to be beyond the competence of knowledge-engineers and should be rather left to specialists in automatic control.

Thus, there is a strong need to develop methods and computerized tools for improving and automating each one of these three tasks in order to go beyond the existing fuzzy control development techniques.

One can see here that the proposed ingredients of the methodology rely heavily on the fact that there is an absence of a well-understood model of the process. In such cases one can resort to the process-operator's operating knowledge as a way of building the controller by implicitly taking into account his knowledge of the process.

But what about processes where the lack of a well-defined model is further aggravated by lack of expertise? The answer to this question, as all participants agreed, lies in the combination of AI-based qualitative reasoning and fuzzy control techniques.

The idea is to develop a system which by interacting with a qualitative description of the process, e.g. high-level symbolic description of a phase-plane, will automatically construct a fuzzy controller. More specifically, the system will derive the fuzzy control rules and the fuzzy sets describing the components of these rules which best fit certain desired behaviour resulting from the qualitative model of the process. This is especially attractive in cases when expertise does not yet exist. Furthermore, if any modifications are made to the physical system being modelled, they can be reflected only in the model, and the fuzzy rules and sets will be automatically adjusted as a result of these changes.

Another possibility is to create qualitative models based on fuzzy logic rather than existing AI techniques for qualitative modelling. In this case the relationships between the system-variables are defined in fuzzy terms, e.g. "slight increase in temperature will significantly increase the volume" and so on. This type of approach can be combined with such qualitative techniques as causal graphs and/or bond graphs which give good structural models and will be very well suited for representing analog, mechanical, and hydraulic systems.

At the end of the discussion J. Katz, the IJCAI official responsible for the IJCAI Workshop Programme, suggested the publication of workshop proceedings with full versions of the presented long and short papers. It was decided that work presented in the IJCAI Workshop on Fuzzy Logic should also be reflected in the proceedings.

This volume is a consequence of that initial suggestion. The editors would like to acknowledge the assistance of the Department of Computer and Information Science, The University of Linköping, the Department of Computer Science, The University of Adelaide, the Laboratory for International Fuzzy Engineering (LIFE), Seimens AG, SAAB Missiles AB, and an IJCAI '91 travel grant.

Dimiter Driankov
Peter W. Eklund
Anca Ralescu

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