THE PRESENT STATE-OF-THE-ART
FUZZY TECHNOLOGY IN FINLAND
Docent Vesa A. Niskanen*

1. Introduction
In Finland fuzzy systems have been examined since the middle of the 70's. Among
the pioneers in this field are Prof. Christer Carlsson and Assoc. Prof. Hannu Nurmi, and a
few years later, Docent Vesa A. Niskanen, Docent Patrik Eklund, Docent Jorma K.
Mattila, Assoc. Arof. Allan Lehtimäki and Dr. Osmo Kaleva. At the beginning the focus was
on basic research, in such areas as logic, mathematics, methodology and decision making.

Today several practical applications have been developed, as will be illustrated in
elements below. Although the total number of researchers is fuzzy forty, we have enthusiastically
participated in fuzzy activities at the international level. During the last two years,
thanks to the invasion of Japanese applications, among others, interest in fuzziness has clearly
awakened in Finland, and, for example, several radio and tv programs as well as newspaper
articles have considered fuzziness. As a matter of curiosity it can be mentioned that the famous
Finnish rally drivers Ari Vatanen and Markku Alen utilize fuzzy shift control in their Subarus.
Hence, the fuzzy future seems to hold great promise for Finnish researchers.

2. Applications
2.1. University of Helsinki
Vesa A. Niskanen has designed fuzzy

modules for an expert system which is used in
the Okobank of Finland. These modules are
utilized in decision-making processes such as in
the assessment of creditworthiness. Dr. Nis-
kanen is also developing fuzzy control for the
milk evaporation process. This project is being
carried out with Dr. Seppo Lahtinen of the
Department of Food Technology. Contact
person: Vesa A. Niskanen, vesa.a.niskanen
@helsinki.fi.

2.2. University of Technology, Helsinki
The Laboratory of Chemical Engineer-
ing (Assoc. Prof. M. Järveläinen) at the Hel-
sinki University of Technology is specialized in
the computer and AI methods for preliminary
process plant design. The preliminary phase of
process design involves generation, comparison
and selection of different process alternatives.
The comparison is done by using vague criteria
whose values are often expressed in linguistic
terms (e.g. safety, reliability). This compari-
son is done traditionally on the basis of experi-
ence. By using fuzzy mathematics it is possible
to systematize and computerize these vague
data and methods. It is also possible to get an
estimate on the uncertainty of the reasoned
results as well as the most 'probable' value.

To aid the decision-making process both
a method for multicriteria decision making and
methods for estimating the values of the criter-
ia (cost, profitability and safety) were publi-
shed. The fuzzy method for multicriteria
decision making is based on the weighted-score
decision table method, which is fuzzified. The method involves comparison of alternatives based on several criteria. Fuzzy scores are given to the criteria of alternatives. The importance of the criteria is defined by weights. The goodness of alternatives is described by the fuzzy value of acceptability, which is calculated as a weighted average.

Fuzzy equipment cost estimation based on a fuzzy cost databank was developed as an alternative to regression models. This method has several benefits: The results are more accurate than those obtained from conventional models. Also min and max cost values describing the uncertainty of data are received. The databank can also display primary data (i.e. data which was used to create the rule base). It is easy to add or remove database data since no regression is needed. Cost estimation can be made also with only partially available data.

Fuzzy plant cost estimation methods based on functional units and factorial cost estimation were also created, since these methods involve linguistic variables. A method for profitability calculation was developed based on the extension principle. Fuzzy cash flows and fuzzy internal rate of return (IRR) can be calculated from uncertain data.

Fuzzy methods to process safety analysis were presented. Methods can be used for failure detection and diagnosis. These methods include reasoning rules on failures and their causes. The methods for the planning of recovery actions include both the diagnostic system and a recovery system. A fuzzy predictor for future states of process was created for reasoning on fast and dangerous processes.

For accident analysis a fuzzy expert data base on vapour cloud incidents was developed, including estimation of the possible consequences. The system can be used for evaluating accident contributors. Methods such as extrapolation in consequence analysis and estimation of missing data, extension of fuzzy linear regression and a method for fuzzy linear programming were also presented.

Fuzzy approaches for bioprocess modelling (bioreactors and ultrafiltration) were developed. The experience is that the fuzzy models are generally as good as polynomial models and they represent a feasible approach for modelling in cases where vague data is included.

Current research projects began recently in the laboratory. They include fuzzy neural networks for control systems, fuzzy control of pressure filtration process, integration of qualitative and fuzzy methods for reasoning purposes and the development of fuzzy chemical process synthesis. Contact person: Markku Hurme, m hurme@sampo.hut.fi

The Laboratory of Biotechnology and Food Engineering at Helsinki University of Technology has been involved since the mid 80's in AI-related subjects, such as fuzzy modelling and control, expert systems, neural networks and hybrid systems. These methods have been used for example to control modern food processes, such as extrusion cooking, or to identify and predict of biotechnical processes, such as glucoamylase and lactic acid fermentations. Various licentiate and doctoral theses have been published on these subjects. Contact person: Tero Eerikäinen, teerikai@hila.hut.fi

2.3. University of Oulu

The Control Engineering Laboratory, in the Department of Process Engineering, has extensive experience with applications of both conventional and fuzzy control, and it enjoys firm relationships with industry in Finland. Application of Artificial Intelligence and
Knowledge-Based Systems is one of the laboratory's main research areas. Two years ago, a new linguistic equation approach was developed in our laboratory. A wide variety of applications is based on this methodology, although some of these applications are implemented by conventional techniques.

**Process Control/Fuzzy control and it’s tuning in Finnish industry (SUSSU) (Kauko Leiviskä, Kari Haataja, Esko Juuso):**

The aim of the research is to develop fuzzy control systems for different industrial processes in Finland. Systematic methods will be developed to improve the start-up and the use of fuzzy control in industrial applications. Special interest is being shown in the development of methods for the tuning of fuzzy controllers. The project is being done in co-operation with the Computer Technology Laboratory of the Technical Research Centre of Finland (TEKES), Imatran Voima Oy, Kaukas Oy, Kemira Oy, Wisaforest Oy Ab and Rautaruukki New Technology Oy are involved as industrial partners. Main financing comes from Technology Development Centre. The project started in June 1993 and will last for one year.

**Fuzzy Logic in Lime Kiln Control.** The lime kiln control problem is a multivariable problem by nature. The reaction time in a rotary kiln system is long, and there is a large quantity of lime mud and lime in process within the system at any given time. Classical model-based supervisory control of process is nearly impossible, therefore, rule-based Fuzzy logic control (FLC) was used to augment traditional model-based control strategies. Construction of the rule-base and tuning of the controller was executed with the co-operation of personnel. The FLC was implemented in an Alcont-II system, and testing is continuing in an industry-scale lime kiln at Wisaforest (Kymmenne) Pietarsaari mills.

**Process Control/FuzzyCon (Jaakko Myllyneva, Esko Juuso, Kari Haataja):**

FuzzyCon is a fuzzy controller specially designed for adaptive tuning in the process industry. The tool was developed because of difficulties and restrictions in the existing tools. FuzzyCon is a Windows application created in Visual Basic 3.0 by the Control Engineering Laboratory. Data is transferred between FuzzyCon and a data acquisition application using DDE links. In FuzzyCon, users can create interactively membership functions and rules. Alternatively, this information can be obtained from hard disk before any computing. In this way, membership functions and rules produced by MATLAB programs or some other applications are available as well. FuzzyCon has been put into practice in the temperature control of a laboratory process.

**Process control/Fuzzy control for D 0-Stage in Pulp Bleaching process (Kari Lampela):**

The purpose of this study is to develop a fuzzy logic control (FLC) for D 0-stage in the pulp-bleaching process. The bleaching is a non-linear process with a long delay. This makes difficult to apply conventional control methods to a bleaching process. The control is accomplished by using a FuzzyCon control program. The project was started in September in 1993 and will continue until March 1994. The research is being done in co-operation with Kajaani Elektroniikka Ltd. The control will be tested in Veitsiluoto Oy Kemi’s Pulpmill.

**Process control/Modelling and control of a drying process (Leena Yliniemi, Timo Virtanen, Paolo Lombardo):**

The aim of the research is to develop new control systems for rotary dryers, such as model-based control, adaptive control and fuzzy control. The control experiments are
made with a pilot plant rotary, which is connected to Damatic XD instrumentation system. The fuzzy control has been simulated with MATLAB and control experiments will be done with the pilot dryer during next year.


The hierarchical simulation system was combined with fuzzy models and linguistic relations to improve its application facilities, especially in diagnostic and control applications. The knowledge base of the expert system is represented by linguistic relations which can be changed into matrix equations. The reasoning is based on these equations or on the aggregated sets of linguistic relations. The system is adaptive since the meaning of the linguistic values depends on the working point of the process.

Managerial Decision Making/Hybrid Knowledge-Based System for Managerial Decision Making in an Uncertain Environment (Esko Juuso):

Hybrid knowledge-based systems based on linguistic equation approach have been developed for managerial decision making in an uncertain environment. The present systems are applied to pricing problems with several products and competitors.

Membership functions for the decision variables are generated on the basis of fuzzy constraints and used in developing scenarios for experts. The response produces data for the estimation of membership functions for the output variables. Optimization is the basis of the decision making. The handling of constraints takes place on an appropriate level compared to the knowledge extracted from the experts. The number of active constraints decreases drastically during the calculation stages. Even for conventional optimization methods, the problem at the final stage is much easier than the original one. The research was done in cooperation with UMIST in England.

Production Planning and Scheduling/Fuzzy Scheduler for Short Term Scheduling (Esko Juuso):

For detailed scheduling, the linguistic equation approach provides a method for a smooth adaptation of scheduling rules to the changing operation conditions. Some testing of the methodology has been performed in the scheduling of a single stage manufacturing cell consisting of several parallel and dissimilar facilities. The scheduling algorithm takes easily into account changes in manpower and product constraints, and it reschedules the remaining workload in such a way that the overall make-span is not exceeded. The flexibility of the less busy production lines can be utilized. The changes in connections require a reallocation phase as well. Possibilities for adaptation decrease with decreasing numbers of alternatives. The research was done in cooperation with UMIST in England.

Neural Networks/Neural Networks in Pharmaceutical Research (Kauko Leiviskä, Jouko Yliruusi, Pirjo Kinnunen, Ere Murtojärvi):

The aim of this study is to apply neural networks in some applications in the area of pharmaceutical technology. The first application has been to predict the granule size and the granule friability from the fluidized bed granulator. The neural networks were trained by two different procedures; by the Weigend weight eliminator and the usual back propagation algorithm. The results were compared with the regression models. The first method had the best generalization ability. The results gained with the back propagation algorithm and the regression analysis were quite close to
each other.

Contact person: Esko Juuso, esko@smtplink.oulu.fi

2.4. VTT Electronics, Oulu

Our group at VTT Electronics in Oulu has developed fuzzy control applications for process control, machine automation and the electronics industry. The applications we have worked with include temperature control of superheated steam at a power plant and control of granule size at a fertilizer plant. To a minor extent, we have used fuzzy sets theory in fault diagnostics of mechatronic devices.

The main goal of our research work is to find general, systematic methods for different stages in the development of fuzzy controllers, such as knowledge acquisition and tuning. We work in close cooperation with industry and thus emphasize the applicability of these methods to real-world problems. Contact person: Pekka Isomursu, epi@tko.vtt.fi.

2.5. bo Akademi University, Turku

Research on fuzziness at bo Akademi University, Department of Computer Science, aims at creating a generic software environment for developing applications in control and diagnostics, thus promoting interchange between university and industry research and development.

A toolkit set, called AboaFuzz, has been developed, this set including features like automatic rule generation, on-line tuning, DDE linkage and integration with major commercial tools, have been developed, thereby integrating successful methods and techniques in a flora of tools to support development of hybrid solutions to neural fuzzy problems in industrial environments. Further, a medical decision support tool in the form of a clinician’s worksta-

tion, called DiagaiD, has been developed and installed in hospital use. The research group consists of about 10 researchers, and developments present high quality basic scientific research, together with an ability to apply results in industrial environments.

The department maintains international cooperations and organizes international seminars (MEPP) on neural fuzziness. Contact person: Patrik Eklund, peklund@finabo.abo.fi

2.6. Waste water plant, Tampere

The plant creates biogas by using the sludge from the waste water treatment process. In one process phase there is biological method to clean the water. It needs a certain amount of oxygen to maintain the process. If there is too much oxygen the process is only a waste of energy. Oxygen is supplied by using one gas compressor and three electric motors. A fuzzy controller monitors the oxygen level. The fuzzy approach is used to control the gas motor and one of the electric motors and to optimize the use of biogas. Other criteria of optimizing are stability of controls and the use of the gas motor on its best behaving areas. Contact person: Jukka Salo, Omron Electronics Oy, fax +358 0 502 4150

2.7. Rautaruukki Oy, Steel Works, Raade

On the hot plate lane the marking of the plates had caused problems because there is large variety of different dimensions of the plates. The lightest weight 1000 kg and the heaviest weight 11500 kg. In addition, the stopping for marking is done by using four different conveyors, and each of them with different dynamics. Now fuzzy control measures the speed and distance. Control creates setpoints for all four conveyors. By using fuzzy control lane speed was increased by 10% compared
with the old system. The old system was tuned for average plate dimensions.

Contact person: Jukka Salo, Omron Electronics Oy, fax +358 0 502 4150

2.8. Partek Sementti Oy, Parainen

Fuzzy cement kiln control has been utilized since 1992.

2.9. Kemira Oy, Uusikaupunki

Fuzzy control has been used in fertilizer manufacturing.

Contact Address:
Dr., Docent Vesa A. Niskanen
Dept. of Economics and Management
University of Helsinki
P.O. Box 27, Fin-00014 Helsinki, Finland
fax: +358 0 708 5096
vesa.a.niskanen@helsinki.fi