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Abstracts
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Programme

Soft Computing: Where Theory Meets Applications

Trojanovice, Czech Republic, December 13-16, 2009.

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	Coffeebreak	
11:15-12:00	Palm	Fuzzy time clustering and TS modeling and its application in robotics
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15:15-16:00	Da Ruan	A Fuzzy Set based DSS for Society and Policy Support at SCK•CEN
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Mining Temporal Patterns in Real-world Applications

Rudolf Kruse, Christian Moewes, Matthias Steinbrecher
Otto-von-Guericke University of Magdeburg

Data analysis has become an integral part in many economic fields. In this talk, we present several real-world applications occurring in the fields of automobile manufacturing, finance, health, and online communities.

The automobile industry for example is very much interested in product planning, fault analysis and quality monitoring due to global competition and ever-shorter production cycles. The vital objective is to quickly identify meaningful patterns within the collected data volumes. Since such patterns rarely occur alone, it is beneficial to identify them w.r.t. their temporal occurrence relations, i.e. whether patterns occurred simultaneously, consecutively, overlapped, etc.

We present a distinct type of temporal mining. A special pattern type comprises so-called co-occurrence graphs. They can be considered a condensed representation of a set of frequent item sets. If the data volumes were collected for a longer period of time it is likely that patterns have changed, emerged or disappeared. Therefore, we have to deal with a sequence of graphs. However, only small subgraphs which show some user-specified change behavior may be interesting. We introduce an approach to identify subgraphs of co-occurrence graphs whose change in structure satisfies a user-specified linguistic concept w.r.t. certain graph measures. To justify our proposed method, we are going to present evidence from a real-world dataset.

In finance, decision makers for instance are concerned about accurate credit scorings, socio-economic customer properties and the assessment of bad contracts. Rule-based models, e.g., decision trees, are well accepted by financial administrators and managers. We show how extracted rules can be made plausible to non-data miners visually.

The health care sector uses intelligent data analysis for instance to either support or falsify medical theories that have been stated before experiments are conducted. Pattern mining might be even used to come up with new theories that are based on empirical evidence.

Scotoma therapy, for instance, evolves methods for patients having lesions of the visual cortex. Patients might partially reactivate blind spots in their fields of view by this restitution therapy. One objective is to predict the outcome of possible treatments based on formerly conducted ones. We show how self-organizing maps can be used to transform the visual cortex into diagnostic maps.

In neurobiology, experts try to understand the complex behavior of the human brain by, e.g., measuring the response of the Blood Oxygen Level Dependency (BOLD) using functional Magnetic Resonance Imaging (fMRI). Measuring the temporal behavior of the BOLD response in different regions of the brain leads to time series that needs to be analyzed further. Therefore we propose to represent each time series symbolically by a word over a small alphabet. The symbols constitute different amplitudes of the BOLD response. Temporal pattern mining could then be applied to the set of words in order to find causalities related to special orderings of the symbols.

Applications of Fuzzy Logic in Machine Learning and Bioinformatics

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This talk presents a number of applications of mathematical concepts, methods and tools that originated within the fuzzy logic community and are sometimes subsumed under the general term soft computing. The applications are mainly taken from bioinformatics and machine learning, including related fields such as data mining and statistics. An important goal of the talk is to highlight the benefits and advantages of using a fuzzy instead of a conventional (non-fuzzy) approach. Besides, an effort will be made to indicate and explain new developments on a theoretical or methodological level as far as they have been initiated by specific requirements of the respective application.

The first application concerns the modeling and simulation of *dynamical systems in biology.* In contrast to more exact sciences such as physics, knowledge about the dynamical behavior of a biological system and related functional dependencies between variables is often vague and afflicted with uncertainty. More often than not, only qualitative or semi-quantitative knowledge is available, sometimes expressed in natural language terms. To predict or simulate the dynamics of a system on the basis of this kind of knowledge in an adequate way, the concept of *fuzzy differential inclusion* was proposed. A corresponding Cauchy problem leads to the prediction of *fuzzy reachable sets*, describing the more or less plausible systems states at a certain point in time, for which both theoretical results and numerical methods were developed.

In *machine learning*, mathematical tools from soft computing can be used in various ways. In this talk, the focus will be on *generalized measures of information.* Such measures are needed for different purposes, for example in decision tree or ensemble learning. Motivated by concrete problems of that kind, two generalizations of the well-known Shannon entropy are introduced and their mathematical properties are discussed. The first measure is related to the notion of specificity in possibility theory and defines a partial instead of a total order on probability distributions, whereas the second measure combines properties of a measure of information and a dispersion measure.

In *data mining*, fuzzy methods have been used for modeling vague patterns, and algorithms for extracting such patterns from data have been generalized correspondingly. Fuzzy patterns are typically represented in the form of fuzzy predicates combined by means of fuzzy logical operators. The choice of these operators is important for several reasons, notably as it determines the semantic meaning of a pattern. In this talk, the question of how to choose proper operators in the context of *fuzzy association analysis* will be considered from a theoretical point of view. As will be shown, this question leads to solving specific types of functional equations.

In the final part of the talk, questions related to the definition of proper *distance functions in data analysis* will be addressed. Motivated by applications in gene expression analysis, a fuzzy generalization of a *statistical rank correlation* measure will be considered. This generalization is based on fuzzy order relations and combines properties of numerical and rank-based correlation. Moreover, an approach for measuring the *distance between two fuzzy clustering structures* (fuzzy partitions) will be proposed.

Fuzzy time clustering and TS modeling and its application in robotics

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Modeling of trajectories is a key point in robotics especially in the context of Programming-by-Demonstration (PbD) of robot tasks by a human operator. In order to model trajectories performed either by an operator or a robot we a need a model that reflects the behavior of the object in time where the following requirements should be considered

- Approximation of complex motions with a high accuracy
- Modeling of dynamic motion primitives by a small set of parameters
- Easy online and offine training by incorporating new samples.
- Easy comparison of model data and process data for recognition of motion primitves

Such a model is generated by fuzzy clustering and subsequent Takagi-Sugeno fuzzy modeling. The basic idea is to consider the time instants as model inputs and the trajectory coordinates as model outputs. A trajectory that is described by a nonlinear function in time is linearized at selected time points t_i. With the help of these local linear models the nonlinear time function is expressed in terms of an interpolation between local linear (affine) models by Takagi-Sugeno fuzzy modeling. The principle clustering and modeling steps are

1. Pick an appropriate number of local linear models (data clusters)
2. Find the cluster centers in the product space (position $\times$ time) by Fuzzy-c-elliptotype clustering (Gustafson-Kessel clusters)
3. Find the corresponding fuzzy regions in the space of input data (time) by projection of the clusters in the product space (position $\times$ time) onto the input space (time)
4. Calculate local linear (affine) models using the GK clusters from step 2.

One important application of fuzzy time clustering and modeling is the recognition of human grasps which is a central part of the PbD-approach for five-fingered robotic hands. A human operator wearing a data glove instructs the robot to perform different grasps. For a number of human grasps the finger joint angle/fingertip trajectories are recorded and modeled by fuzzy time clustering and Takagi-Sugeno modeling. This leads to grasp models using time as input parameter and joint angles/fingertip positions as outputs. Given a test grasp by the human operator the robot classifies and recognizes the grasp and generates the corresponding robot grasp. Another field of applications is the programming of robot skills by human operators. Robot skills are low-level motion and/or grasping capabilities which constitute the

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basic building blocks from which tasks are built. Teaching and recognition of such skills are accomplished by a PbD-approach. A human operator demonstrates certain skills while his motions are recorded by a data-capturing device and modeled, like for modeling of grasps, by fuzzy time clustering and a Takagi-Sugeno modeling technique. The resulting skill models use again the time as input and the operators actions and reactions as outputs. Given a test skill by the human operator the robot control system recognizes the individual phases of skills and generates the type of skill shown by the operator.

It could be shown that because of the excellent performance and modeling accuracy fuzzy time clustering and modeling appears to be our favored method for time series approximation. In simulations and experiments for recognition of human grasps and skills it could also be shown that the fuzzy approach leads to better results and is more efficient than commonly used methods like Hidden Markov Models (HMM) or Gaussian Mixture Models (GMM).

Advantages and Limitations of Fuzzy Cluster Analysis

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Fuzzy cluster analysis is an extension of crisp clustering allowing for membership degrees instead of unique assignments of data to clusters. Apart from the advantage of having the possibility to handle ambiguous data that cannot be assigned uniquely to a single cluster, fuzzy clustering seems to be less sensitive to local minima of the underlying objective function than the corresponding crisp clustering technique. Nevertheless, a formal proof for this empirical observation is not available yet. In special cases, fuzzy clustering can also be analysed in terms of M-estimators known from robust statistics. But a general theory is missing here as well.

Another advantage of fuzzy clustering is the availability of more validity measure to determine the number of clusters which turns out to be a crucial problem in many applications.

However, fuzzy clustering introduces also new problems. High-dimensional data cause more difficulties for fuzzy clustering.

The talk will address these questions in more detail, motivated by practical examples based biological data from high throughput techniques. Possible solutions are presented to some problems, but a list of open of open questions will also be provided.

A Fuzzy Set based DSS for Society and Policy Support at SCK•CEN

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In the framework of society and policy support at SCKCEN, decision support system (DSS) is a core component of any designed complex systems. The DSS will foster the information exchange, command and control across the boundaries within and among the ongoing and future research projects, namely, energy policy study, nuclear weapon inspection, and security support when it comes to some of the real world situations. Due to the potential difficulties of dealing effectively with such projects, information (or data) obtained by the dedicated DSS will be of very different nature. It may be heuristic or incomplete or data that is either of unknown origin or may be out of date or imprecise, or not fully reliable, or conflicting, and even overloaded. To allow an adequate interpretation of the information and to reach a conclusion by the DSS, there will be an urgent need to establish or update DSS that is able to deal with various uncertainties in real time. Hence, it is considered advantageous to have a sound and reliable mathematical framework available that provides a basis for synthesis across multidimensional information of varying quality, especially to deal with information that is not quantifiable due to its nature, and that is too complex and ill-defined, for which the traditional quantitative approach (e.g., the statistical approach) does not give an adequate answer. In this talk, we will report our current project experience, i.e., how to apply a fuzzy set based DSS to both energy policy study and nuclear weapon inspection when missing information appears during the decision analysis within the DSS. We will provide with some basic solutions and show some of the practical problems from these two projects. We hope to get into the next security project by having more support from the latest development of fuzzy set theory and soft computing techniques.

Aggregation of intensities of preferences: how theory affects practice

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We consider a social choice or decision making problem where a number of respondents have expressed intensities of preferences over a set of alternatives. We consider it advantageous to employ the resulting distributions of intensities for as long as possible, rather than summarizing them in a single (representative) value, as seems to be current practice. Distributions are by definition more informative than a single value, and decision making techniques able to process distributions will benefit from the corresponding wealth of information.

A similar line of reasoning can be considered to hold in fuzzy reasoning, where it is also considered advantageous to defuzzify later rather than sooner. Nevertheless, single values are much easier to interpret and compare than distributions, which might overwhelm decision makers or render decision making processes overly complex, to the point of making them intractable.

The method we describe will prove useful in this regard: we employ distributions, but minimally adjust them in order to render them more easily summarized and comparable. This allows using a best fitting total order on the set of alternatives as a way to summarize the collection of preferences without resulting in an outcome contradictory to the supposed best fitting total order. We illustrate the method on a real-world application of environmental decision making with conflicting social groups.

Sentiment classification and bipolar aggregation

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Sentiment classification of text documents is often based on an aggregation of sentiment degrees of features (single words or phrases) from bipolar scale $[-1, 1]$. In sentiment classification a document is usually classified as positive (negative) if the output of this aggregation of sentiment degrees of features contained in the discussed document is positive (negative). The focus of the sentiment classification is mainly on the method that assigns sentiment degrees to individual features, while the aggregation method is always linked to the (weighted) arithmetic mean. To increase the flexibility of potential aggregation models appropriate for sentiment classification (analysis), bipolar extensions of the Choquet integral have been considered. We recall some of such extensions known in literature, namely the asymmetric Choquet integral [1], the symmetric Choquet integral [5], CPT models [6], and bicapacity based Choquet integral [2, 4]. Moreover, we propose two new types of such extension, the merging Choquet integral and the fusion Cho-quet integral. Properties, advantages/disadvantages of all these extensions will be discussed. Relationship with the symmetric maximum [3] and OWA operators [7] will be shown, too.

Acknowledgement
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Soft Computing Challenges in Space Applications

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In many decision-making Space applications, data preparation & manipulation are essential issues to achieve good results. Obtaining partial or incorrect data, or even missing the occurrence of events that might imperil aircrafts, are important aspects to be handled in Space missions.

Moreover, when tackling problems such as monitoring and/or classification or selection, to be able to deal with dynamically changing input data as well as imprecision in data, is of paramount importance.

In this talk, I will discuss topics related with data preparation and manipulation, using Soft Computing techniques, in the context of applications developed in the Space domain (projects financed by the European Space Agency – ESA).

Interpolation and Extrapolation of Fuzzy Data

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1 Introduction

It is well known that a fuzzy rule base is a characterization of a partially given mapping (fuzzy function) between fuzzy universes. Each rule characterizes a node (argument-value) of a respective fuzzy function in a sense that antecedent of the rule characterizes the argument, while consequent of the rule characterizes the dependent value. Thus the whole finite rule base characterizes behavior of that function at the respective finite set of nodes. In many practical applications, it is desirable to interpolate that partial fuzzy function in order to know its values at an arbitrary node (fuzzy or crisp). Therefore, the problem of interpolation of a partial fuzzy function consists in its extension to a fuzzy function which is defined on an extended domain. Moreover, interpolation assumes that if we restrict thus extended (interpolating) fuzzy function to its original domain then we obtain the original partial fuzzy function.

Let us stress that the word "interpolation" is used in literature in two meanings:

(A) as a method of extension of a partial fuzzy function to a total one on a respective extended domain,

(B) as a method of computation of values of an extended fuzzy function at points that are different from those known originally.

It is easily seen that both meanings coincide if a fuzzy function is defined as a mapping between two universal sets. However, in some applications, interpolation in the meaning (B) is realized algorithmically without explicit characterization of a domain and a range of an extended fuzzy function. As a result, some of proposed algorithms failed when they were applied to fuzzy sets which were outside of a respective domain (such "unhappy" example has been proposed in [1, 2], and analyzed in [7]). A precise description of the extended domain of fuzzy interpolation is especially important in the case of a sparse rule base interpolation.

2 Interpolation and Extrapolation in Time Series Processing

In classical mathematics, interpolation is considered on a linearly ordered universal set of reals, so that an extended domain of an interpolating function is bounded, and boundaries belong to the domain of an original partial function. However, if a domain of an extension of a partial function is not bounded by the above mentioned boundaries, then this extension is called extrapolation.

Extrapolation of fuzzy data appears in time series processing. In particular, time series analysis decomposes a time series into three parts: trend, season and residuum. Then forecast extends each part to an extended domain. Especially the forecast of trend can be realized by extrapolation of a partially given fuzzy function where the latter is represented by a set of fuzzy IF-THEN rules [4].

In our contribution, we will investigate a specificity of fuzzy interpolation and extrapolation in applications to time series processing. Two approaches will be considered: the one based on perception-based logical deduction [3], and the other one based on fuzzy relation equations [5, 6].

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Many-valued Inference without Defuzzification

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Many researches observe that fuzzy inference is based on *similarity.* We study systematically many-valued equivalence, i.e. fuzzy similarity, a binary fuzzy relation that is reflexive, symmetric and weakly transitive. Dubois and Prade set the following problem in 1994: *The evaluation of similarity between two multi-feature descriptions of objects may be specially of interest in analogical reasoning. If we assume that each feature is associated with an attribute domain equipped with similarity relation modelling approximate equality on this domain, the problem is then to aggregate the degrees of similarity between the objects pertaining to each feature into a global similarity index. This means that the resulting index should still have properties like reflexivity, symmetry and max*$\odot$*-transitivity. Moreover, we may think of a weighted aggregation if we consider that we are dealing with a fuzzy set of features having different levels of importance.* We solved this problem in 2002. Indeed, starting from fuzzy logic with graded syntax and semantics introduced by Pavelka in 1979, we are able to construct a method performing fuzzy IF-THEN reasoning such that the inference relies only on experts knowledge and on well-defined logical concepts. Therefore we do not need any artificial defuzzification method to determine the final output of the inference. We call this approach *total fuzzy similarity method* as the task is to find *the most similar* IF-part and fire the corresponding THEN-part.

We applied our method to mimic sports physician's decision making: based on measurements containing information on changes in chemical composition of a breathing gases and blood lactic acid as a function of heart pulse rate caused by physical exertion, the physician is able to determine a sportsman's aerobic and anaerobic threshold, information that is an absolute prerequisite for an adequate training of muscles. By our method we were able to write software that, based on the given measurement data, is able to determine reliably these tresholds. This software is under commercializing process.

Another area of application of our method is in traffic signal control. Based on information of amount of approaching vehicles, discharging queue indicator, pedestrian waiting time etc, an experiences policeman is able to control traffic flows on junction of the streets. We have modeled such control rules by total fuzzy similarity method in several Finnish cites with great success.

Key words: MV-algebras, fuzzy control.

Linguistically Specified Knowledge in Modeling

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One of the most important features of fuzzy set theory and fuzzy logic is their power to model semantics of a certain part of natural language. This topic plays essential role in the, so called, Fuzzy Logic in Broader Sense (FLb). This is extension of fuzzy logic in narrow sense which encompasses theory of evaluative linguistic expressions, theory of of fuzzy IF-THEN rules, theory of perception-based logical deduction, and intermediate (linguistic) quantifiers. FLb has interesting applications in wide spectrum of human activities.

First, we will briefly discuss the theory of FLb. Its main constituent is a theory of the, so called, evaluative linguistic expressions will be presented. These are expressions such very large, extremely deep, roughly one thousand, more or less hot, etc., i.e. just the expressions considered in many applications of fuzzy logic. This theory is further extended to fuzzy IF-THEN rules to obtain genuine conditional clauses of natural language. Sets of such IF-THEN rules form linguistic descriptions of decision or classification situations, control strategies, and other.

By perception we understand an evaluative expression assigned to a specific value provided that the context of use is defined. Linguistic descriptions together with concrete perceptions can be used in derivation of a conclusion. The resulting method is called perception-based logical deduction and can be taken as an alternative to the well known Mamdani-Assilian method. The perception-based deduction is demonstrated to behave in accordance with human way of reasoning. A lot of simulations in control, classification and decision-making as well as real applications corroborate that it works very well and is easy for the user because of natural language comprehension.

Our theory has a wide spectrum of applications. We will focus on the applications in fuzzy control but briefly mention also other applications, namely in geology and decision making.

Linguistic Approach to Time Series Analysis

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There is no doubt that the analysis and forecasting of time series have a wide practical use in economy, industry, meteorology, and other parts of life [1]. There are two standard approaches to the analysis and forecasting of time series. The first one stems from the so called *Box-Jenkins methodology* [2]. It consists of autoregressive and moving average models and it has been demonstrated to be very powerful and successful in forecasts.

The second approach, which is called *decomposition*, assumes a given times series to be an additive or multiplicative composition of the *trend, cycle, season*, and a *noise* term. The components of the above mentioned composition have clear meanings, so models decomposing a given time series into these components are very transparent in contrast to complicated autoregressive and moving averages models of the Box-Jenkins methodology.

We combine both approaches to adopt their benefits. First, we decompose the time series into the so called trend-cycle and the seasonal component. The trend-cycle is determined by the *F-transform* [3] of the time series. Autoregressive relationships between successive values in the trend-cycle are then described with help of the linguistic description consisting of fuzzy rules. These are automatically generated by the *linguistic learning algorithm* [4] which is implemented in the LFLC software package [5]. The *perception-based logical deduction* [6] is then used as an inference method to forecast future trend-cycle values.

Seasonal component is analyzed and forecasted separately using the Box-Jenkins methodology and added to the forecasted trend-cycle as in case of the decomposition.

Thanks to the use of both of these methods, the methodology is successfully applicable to robust long time predictions, which has been experimentally justified [7]

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