USING FUZZY COGNITIVE MAPS TO INTEGRATE DIFFERENT MODELING TECHNIQUES

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INTRODUCTION

Development of adequate models for real industrial plants and complex systems is a complicated task because of large uncertainties, lack of direct measurements and necessity of inferential approach, high level of non-linearity and different types of disturbances. Building of accurate models for a broad range of operational conditions may be successful if discipline hybrid modeling techniques are used.

Fuzzy systems and neural networks have been attached the growing interest of many researchers [Jang at al. (1997)]. Fuzzy sets and fuzzy logic were developed as a means for representing, manipulating, and utilising uncertain information and to provide a framework for handling uncertainties and imprecision in real-world applications, while neural networks were developed to provide computational power, fault tolerance, and learning capability to the systems. Both fuzzy systems and neural networks have capabilities of modeling complex nonlinear processes to arbitrary degrees of accuracy. A promising approach for reaping the benefits of both fuzzy systems and neural networks is to merge or fuse them into an integrated system. Recently integration and synthesis techniques have been proposed [Jang at al.,1997, Juang *et al*. 1998]. Kosko (1986) introduced Fuzzy Cognitive Map (FCM) theory that is an integration of fuzzy logic and recurrent neural networks. They have a potential to be used as a tool for aggregation of separate models (Stylios *et al*.,1999). Some hybrid methodologies, presenting integration of First Principles model and Neural Network models have been investigated [Albert e*t al*.,1997, Garcia,1997, Yazdizadeh e*t al.*,1998].

In this paper an aggregation structure consisting of multiple hybrid models: combinations of First Principle (FP), Fuzzy Logic (FL) models, Neural Network (NN) models and Regression (R) models is examined. Combining some modelling techniques in a hybrid structure, which has the ability to model system behaviour in different environments, has been also investigated. An augmented FCM has been used to aggregate multiple models and to create a hybrid model according to the current operational conditions of the industrial process.

ELEMENTS AND STRUCTURE OF THE HYBRID MODELS

The objective of this paper is to develop inferential hybrid models being able to model system behaviour in wide ranges and to perform on-line estimation of directly unmeasurable process variables on the basis of the available (usually scarce) on-line process information. The main idea of the proposed methodology is to employ multiple models in order to describe the different environments. Such modelling system performs an efficient model design in dynamical environments possessing a high degree of uncertainty. This approach is well suited for complex processes. Specifically, the operating range of the process is partitioned into a number of mutually exclusive and exhaustive subranges and models are designed for each subrange.

This approach based on the combination of First Principles, fuzzy logic and neural network concepts looks very promising for implementations of hybrid models design strategies using different architectures. A variety of different modelling techniques are proposed:

- First Principles (FP) models
- Fuzzy Logic (FL) based models
- Neural Network (NN) models
- Statistical (S) models (regression models).

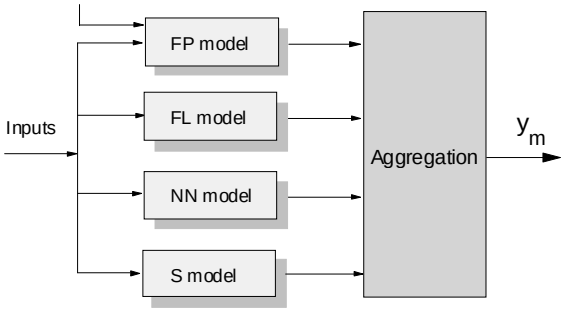

Figure 1. Parallel structure of hybrid model

The decision which kind of models to be used depends on many factors: degree of understanding of

internal process (chemical, physical); complexity; ability, quantity, quality of measurements; availability of expert knowledge about the process; level of uncertainty etc.

A structure of hybrid model is presented on Figure 1. In parallel here work First Principles (FP) model, Fuzzy Logic (FL) based model, Neural Network (NN) model and Statistical (S) (regression) model.

It is proposed a set of separate models to be used forming hybrid models, modelling process behaviour at different operational conditions. Each of the separate models possesses its own input subspace and is tuned to be optimal for corresponding operation conditions. An augmented FCM is used to aggregate the set of different models and to choose the appropriate model according to the current operational conditions.

FUZZY COGNITIVE MAPS

By incorporating fuzzy principles into a neural network, more user flexibility is attained and the system becomes more robust. Fuzzy Cognitive Maps (FCM) are dynamical systems that relate fuzzy sets and rules [Kosko (1986), Kosko (1992)]. An FCM has the topology of a directed fuzzy graph with cycles or feedback. It is a set of nodes and edges. The concept nodes C_i are fuzzy sets or even fuzzy systems. The edges e_{ij} define rules or causal flows $C_i \rightarrow C_j$ between the concept nodes. At time t the state of the FCM is the concept vector $C = (C_1, \ldots, C_n) \in [0,1]^n$ or point in the fuzzy-cube state space. The n concepts or nodes all belong to the event C to some degree at time t. The n-by-n matrix E lists the n^2 rules or pathways in the causal web. FCM dynamics depend on the dynamics of the concept nodes and causal edges. Researchers have applied FCM to model a wide range of problems and have put forth many schemes to grow and combine FCM [Stylios *at al.* (1998), Jang *at al.* (1997)].

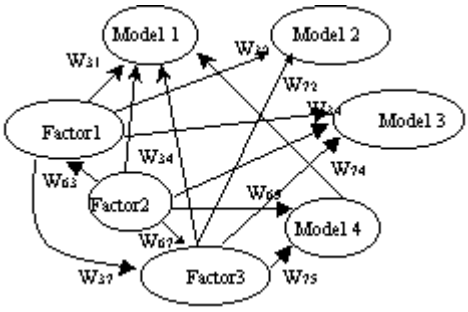

Figure 2. FCM structure to aggregate models

In this paper, FCM are used to aggregate the separate models and to perform a kind of maintenance of the system by integrating alternative modeling techniques. FCMs best utilize existing experience in the operation of the system and are capable in modeling the behavior of complex systems. FCM seem to be a useful method in complex system modeling and control, which will help the designer of a system in decision analysis. FCM appear to be an appealing tool in the description of the modeling techniques, which teamed up with other methods will lead to the more sophisticated model and control design systems. Figure 2 represents a Fuzzy Cognitive Map that can be used to aggregate between different models according to the influence of the corresponding factors. At the conference an example will be developed and presented.

CONCLUSIONS

A new hybrid approach based on the combination of First Principles, fuzzy logic and neural network concepts was presented in this paper. The introducing of multiple models structure is a prospective way to improve the current estimation of plant behaviour. For the sophisticated plants with unmeasurable or hard measurable variables and large uncertainties the scheme using multiple separate models received by aggregation of different modelling techniques is an efficient approach in model design. As it has been described an augmented FCM can accomplish identification of the process models and cope with limited uncertainty situations. It may comprise different models, identification and estimation algorithms. It can perform a kind of maintenance of the system by integrating alternative modeling methods. The results reveal that the proposed hybrid structure is capable of successfully identifying a highly non-linear technological system.

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