Towards Control and Modeling of Complex Systems Using Fuzzy Cognitive Maps

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***Abstract*—In this paper we present a current state of our research in the area of intelligent control and modeling of complex systems. We focus on recent progress in solving this research task with a proposal for a novel approach to system modeling using modified Fuzzy Cognitive Maps (FCM) which we refer to as the Three-Term Relation Neuro-Fuzzy Cognitive Maps (TTR NFCM). With regard to this novel method we describe the need for a new multi-purpose FCM library and introduce its proposal. In the last section of the paper we outline our plans for further work which will be based on application of given method to modeling and control of selected complex systems, in our case the small turbojet engine (STJE) model ISTC-21V and TJ-100.**

***Keywords*—fuzzy cognitive maps, modeling, control, complex systems,**

I. Introduction

The main objective of our research as stated by the title of my future PhD thesis is the "Utilization of means of computational intelligence in situational control of complex systems". We have chosen the FCM as the selected intelligent method because of its universal properties which suitably combine the approximation capabilities of neural networks and readability of rule-based fuzzy systems. The STJE was chosen as the object of control because of its complex nonlinear internal structure and characteristics.

II. Initial State of Research

As a starting point for research in the recent year we used the FCM survey [1] and our own overview manuscript [2]. We based our further work on fundamental assumptions as stated in introductory article [3]. We used monograph [4] to acquire knowledge about state-of-the-art methods used for control, modeling and diagnostics of small turbojet engines.

III. Current State of Research

As stated in [3], the basic conception of FCM has several drawbacks which restrain its capability to model dynamic nonlinear relations within complex systems. Therefore our initial goal was to deal with these shortcomings.

A. Three-Term Relation Neuro-Fuzzy Cognitive Maps

In [5] we proposed a new TTR NFCM methodology, which enhances the conventional FCM by adding two new features. The first one solves the problem of relation dynamics by inclusion of trends in the concept update formula using the *Three-Term Relations* (TTR – see Fig. 1), which are inspired by control engineering methods, namely the PID controllers.

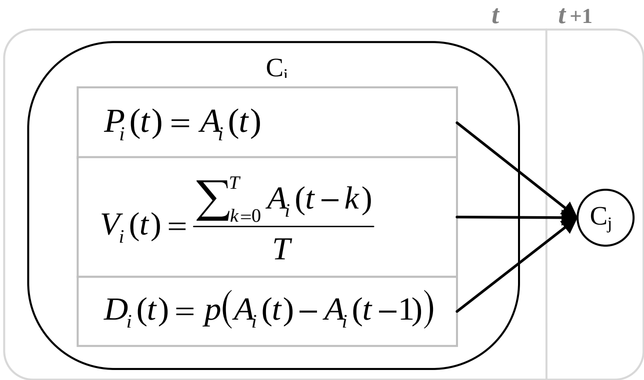

Fig. 1. Three-term relation between concepts C_i and C_j with proportional component P_i , moving average component V_i and derivative component D_i . T is the size of the time window used to calculate the moving average [5].

The second main feature is the replacement of simple linear weights between concepts by nonlinear feed-forward neural networks or multilayer perceptrons (MLPs). The applicability of the feed-forward MLPs instead of conventional weights comes from the fact, that every single FCM can be unwrapped into several simple feed-forward cognitive maps (see Fig. 2).

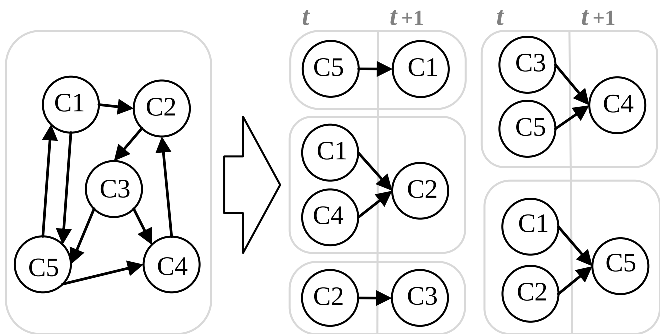

Fig. 2. Unwrapping of a simple FCM [5].

With an unwrapped FCM it is possible to replace all of the relations preceding a single concept with an MLP and transform the FCM into the hybrid *Neuro-Fuzzy Cognitive Map* (NFCM – see Fig. 3).

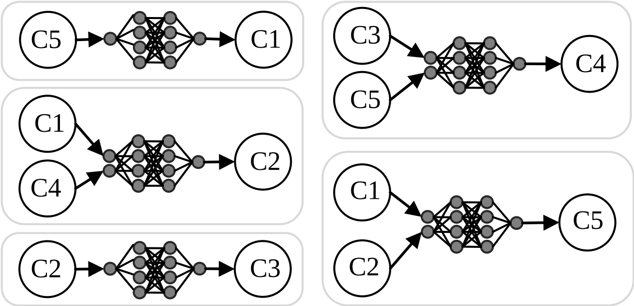

Fig. 3. Nonlinear relations between concepts using the MLPs [5].

B. Multi-Purpose Fuzzy Cognitive Maps Library

In order to implement the presented method and to tackle the problems and deficiencies of existing programs and tools used for FCM modeling, we proposed a new general multi-purpose library [6] (see Fig. 4).

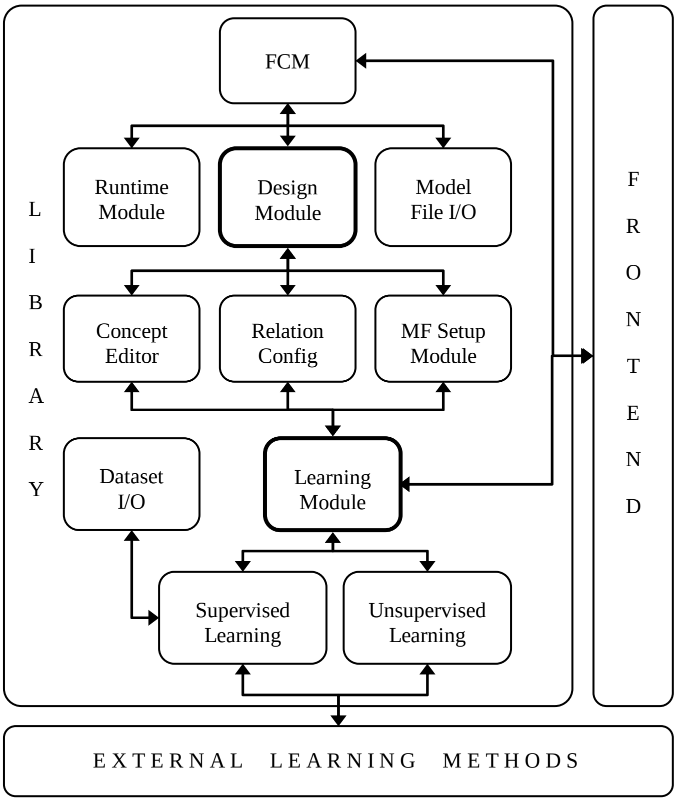

Fig. 4. A system diagram of the proposed FCM library[6].

We proposed the library with a goal of enabling fast and simple prototyping of system models. The library is also designed to supports various methods for relation expression (nonlinear, dynamic, neural, etc.) and to employ built in automatic learning mechanisms to adjust FCM parameters.

IV. Future Work

In accordance to the objectives of my future PhD thesis [7], our next goal is to implement the library and use it to create a model and an automated control system for STJE [8].

A. Implementation of Multi-Purpose FCM Library

After a careful consideration of several aspects related to the library implementation [6], we decided to develop it using the .NET framework, which is well integrated within modern versions of Windows OS. We aim to create a shared dynamic library (DLL), which can be incorporated into programs in various languages and environments. e.g. Python, Matlab, Simulink, WPF, etc.

B. Modeling and Control of STJE with use of FCM

The library will be used to create an experimental model of the ISTC-21V engine (see Fig. 5) and possibly also TJ-100 engine using the proposed TTR NFCM method.

Fig. 5. Small turbojet engine ISTC-21V [8].

After the method is successfully applied and evaluated for the purpose of system modeling, we will proceed with a design and implementation of an FCM controller for the ISTC-21V engine. Our goal is to simplify and outperform the existing control system (which consists of several different control algorithms) with a single unified approach.

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