Current State of 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 an implementation of a new multi-purpose Fuzzy Cognitive Maps library and accompanying graphical user interface. In the last section of the paper we outline our plans for further work in which we will make the proposed library available on cloud via web API and use it to apply the Three-Term Relation Neuro-Fuzzy Cognitive Maps methodology to modeling and control of selected complex systems, specifically the multi-agent robot system and the small turbojet engine.**

***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 Fuzzy Cognitive Maps (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.

II. Initial State of Research

In the previous period we focused on finding a solution to several drawbacks [1] related to the vanilla FCM, which are tied to its capabilities to model dynamic nonlinear relations within complex systems.

In order to tackle these problems, we proposed a novel Term Relation Neuro-Fuzzy Cognitive Maps (TTR NFCM) methodology [3] which enhances the conventional FCM by two new features. The first addresses the dynamics of concept relations by inclusion of trends in the concept update formula using the Three-Term Relations (TTR), which are inspired by control engineering methods, namely the PID controllers. The second main feature is the replacement of simple linear weights between concepts by small nonlinear feed-forward neural networks or multilayer perceptrons (MLPs).

In order to evaluate this method and to tackle the problems and deficiencies of existing tools which are available for FCM modeling, we proposed a new general multi-purpose library [4] which is currently being implemented.

III. Current State of Research

In our recent work we dealt with the implementation of the proposed library [4] along with a compatible graphical user interface. We also successfully deployed the library for simple computations and modeling within the Matlab environment.

A. Implementation of Multi-Purpose FCM Library

We proposed the FCM library (see Fig. 1) with the simplicity of model prototyping in mind. The library is also designed to supports various methods for relation expression (e.g. the TTR-NFCM) and in the future it will also provide built-in learning mechanisms to adjust the FCM parameters.

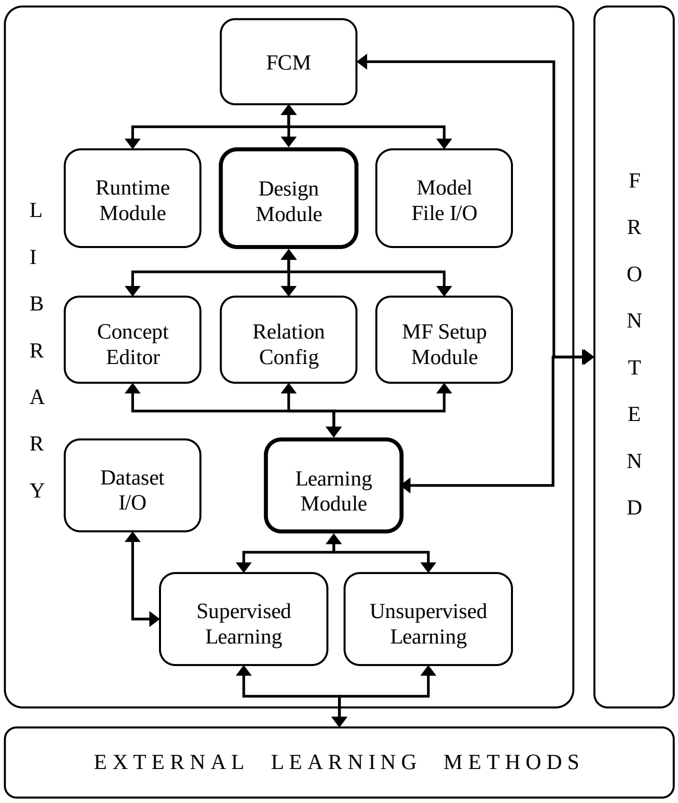

Fig. 1. A system diagram of the proposed FCM library[4].

After a careful consideration of several aspects related to the library implementation [4], we decided to develop it as a shared dynamic library (DLL) using the .NET framework, which is well integrated within modern versions of Windows OS. This way it can be easily incorporated into various programs within several programing languages and environments, such as Python, Matlab, Simulink, WPF, etc.

Among the functions which the library offers, we can count the following:

- add, remove, connect, disconnect concepts,
- change concept relations (weights),
- list concept names, rename concepts,
- get and set concept activation value,
- set concept fuzzification function,
- save and load the map.

The library has already successfully undergone a preliminary tests within the Matlab environment and is freely available to download at [5].

B. Implementation of Graphical User Interface

Along with the library we also developed a graphical user interface (see Fig. 2) based on Windows Forms with help of Microsoft Automatic Graph Layout (MSAGL) library [6]. The MSAGL provides a support for online user interaction with the designed FCM and also allows to render the updates of the concept activation values in the real-time during the map simulation. The GUI wraps all the functions provided by the FCM library mentioned in the previous section of this paper.

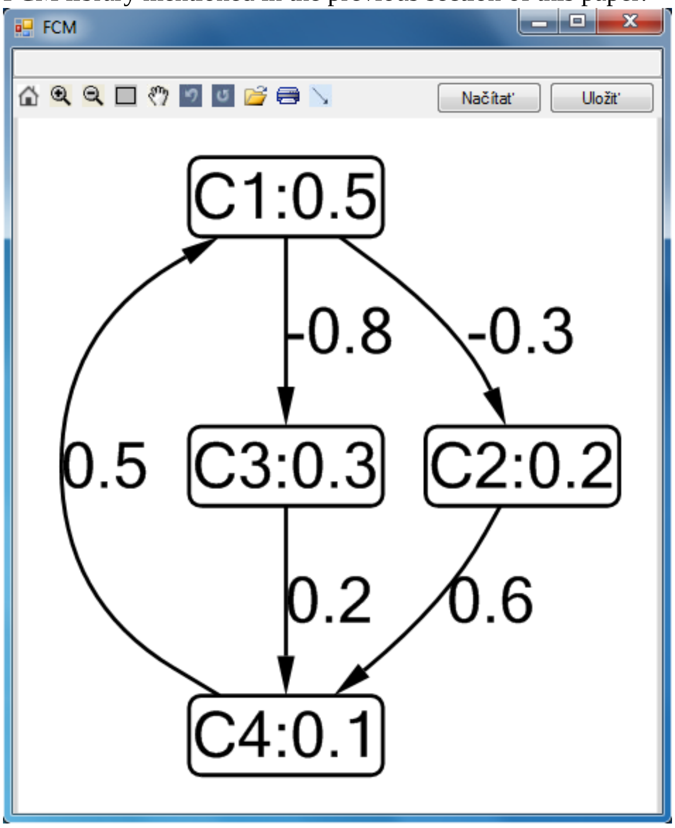

Fig. 2. Current state of FCM graphical user unterface.

IV. Future Work

Our current goal is to finish the library implementation and complete the learning module which will support the adaptation of the map using evolutionary and population based optimization and also the supervised learning using the backpropagation of error method.

Consequently we will proceed with the exposure of the library FCM engine running on cloud via API, which will provide access to all the functions of the library as stated in the end of the section III.A of this paper.

After that, in accordance to the objectives of my future PhD thesis [7], we will use the library to specific control-related tasks in the area of multi-agent robot systems and also to create an experimental model of the ISTC-21V engine (see Fig. 3) using the proposed TTR NFCM method.

Fig. 3. 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 currently consists of several different control algorithms) with a single unified approach.

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