# Control of Intelligent Complex Systems

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***Abstract*—In this paper we present a current state of our research in the area of control and modeling of intelligent complex systems using means of Artificial Intelligence, mostly the Fuzzy Cognitive Maps. We outline our previous work which resulted in a program library and user interface utilizable for the purpose of system control and modeling. We have also developed the modified version of the method aimed towards simplicity of model design. We further explain the recent work which revolves around implementation of the proposed program library as a cloud service and its use in control of multi-agent robot system in intelligent space which is currently being developed at our workspace.**

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

## I. Introduction

Artificial intelligence (AI) and its methods have significant impact in many areas of everyday life. Technical systems which are used to implement AI are also progressively becoming more complex. These intelligent systems (IS) are getting increasingly interconnected via various networks (including the Internet) and these connections are progressively becoming not only mutual (system to system) but also open to other systems including systems implemented as cloud services. The ideas of the Internet of Things and consequently the Internet of Everything are well on its way of becoming de facto standards in the development of technical systems in close future.

The research presented in this paper, deals with control of complex systems implemented over networks using AI methods. The focus has been oriented specifically towards Fuzzy Cognitive Maps (FCM) and its adaptations since its graph structure is well suited for system modeling and control. As the scientific goals, we have stated 1) the modification of basic FCM concept with goal of enabling modeling and control of complex systems and consequently 2) the evaluation of the proposed method on selected nonlinear dynamic system. As the technical goals, we defined: 3) the implementation of program library oriented towards system modeling using FCMs and also 4) the extension of the library as a cloud service. Finally, we also aim to propose at least a basic draft for implementation of complex system composed of networked components within the specified area, specifically an intelligent space based at the Center for Intelligent Technologies.

## II. Initial State of Research

In the previous period, we focused on finding a solution to several drawbacks [1] related to the vanilla FCMs, 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) method [2] which solves several of the issues.

In order to evaluate this method and to tackle the problems and deficiencies of existing tools which are available for FCM modeling, we proposed (see Fig. 1) and implemented a new general multi-purpose FCM library [3]. We successfully deployed the library for simple computations and modeling within the Matlab environment.

Along with the library we also developed a graphical user interface based on Windows Forms with help of Microsoft Automatic Graph Layout (MSAGL) library [5]. The MSAGL provides a support for online user interaction with the designed FCM and also allows to render the updates of the activation values in the real-time during the simulation.

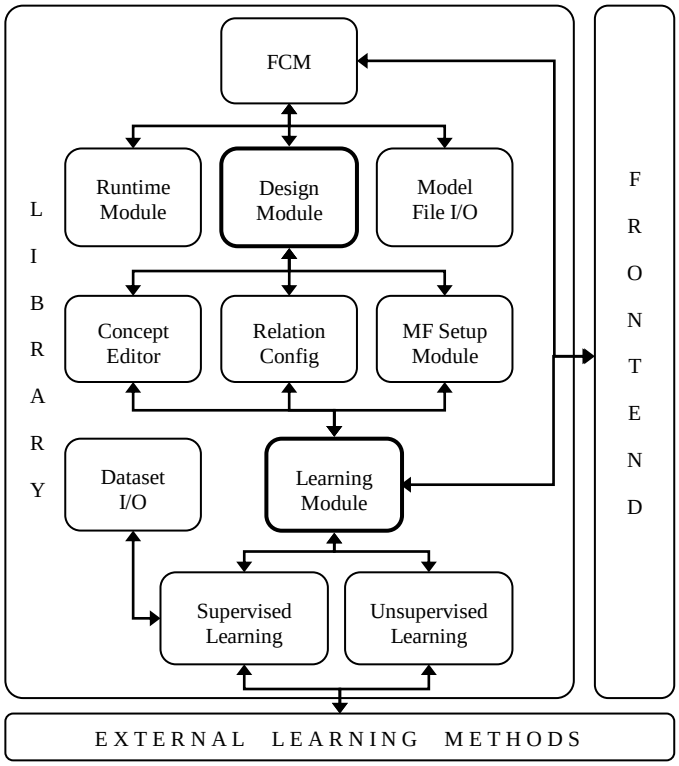


Fig. 1. A system proposal of FCM library [3].

## III. Current State of Research

Our current work is tied to the implementation of a specific complex system, namely the intelligent space [6] based at the Center for Intelligent technologies. The space is composed of several types of sensors, including 16 IP Cameras with microphones, 6 Kinects and also other IoT sensors, for acquisition of environment variables such as light intensity, temperature, air quality, loudness, ultrasound, infrared light, etc. In addition, we expect utilization of RFID cards and readers, E-beacon technologies and more. It is also equipped with service robots such as TheCorpora Qbo, Robotnik TurtleBot and Hanson Zeno, but also other robots including simple Lego Mindstorms NXT and EV3, and older models such as Sony AIBO and Aldebaran Nao. The implemented Intelligent Space will gather various data including video streams (see Fig. 3), depth map streams (from Kinects), audio (from microphones built in cameras and Kinect) and other data from remaining sensors. Therefore, it is necessary to define viable strategies for transmission, processing and storage of this data. This is going to be mostly the goal of future work (which is not directly related to this paper), however, preliminary system proposal is depicted on Fig. 2.

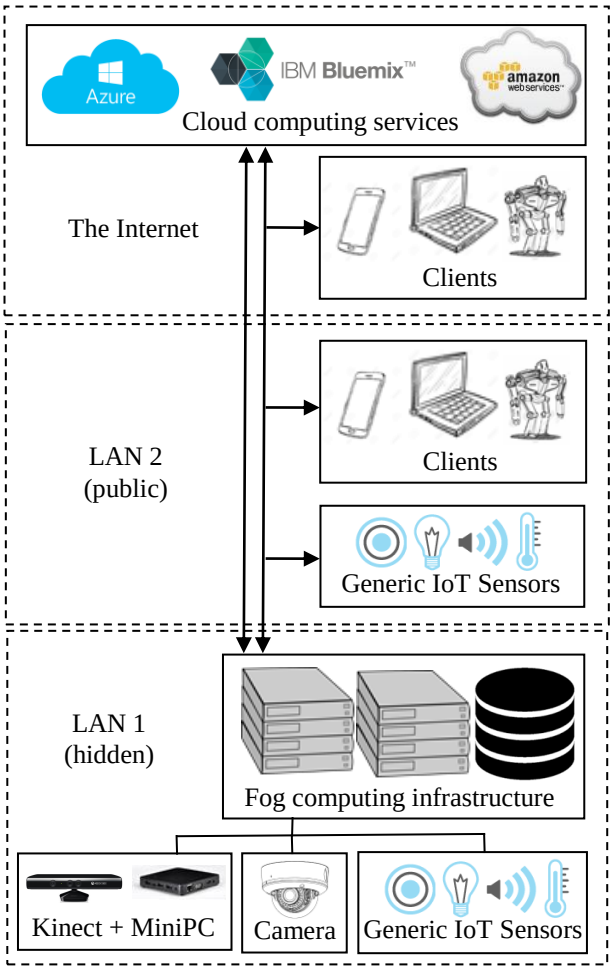


Fig. 2. Intelligent space at CIT – Networking proposal

What is currently being done is the selection and creation of suitable methods and tools in the form of network services (a.k.a. AI bricks) which would be necessary to perform sufficient control of the space. When it comes to robot control and navigation, we propose the usage of FCM and specifically the novel TTR NFCM method. We are also considering the use of cloud technologies [7], whenever possible. However, in order to respect the network limitations (since estimated data generation of 16 cameras and 6 Kinects is more than 250 Mb/s) we also aim to utilize private could servers and fog computing methodologies [8].

Fig. 3. Camera monitoring system in CIT.

## IV. Future Work

We have already successfully fulfilled two of the stated objectives including 1) the proposal of modified TTR NFCM and 3) the implementation of standalone FCM library. We are currently working on 4) the extension of the library as a cloud service which will be consequently used to 2) perform experiments using the proposed method in multi-agent robot system based in implemented intelligent space. Viable use cases of the intelligent space are being investigated, but currently we propose mostly problems tied to robot navigation, path planning and human-robot interaction.

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