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NI LabVIEW를 이용한 동적 제어용 FCM 제어기

Fuzzy Cognitive Maps built in NI LabVIEW for control of dynamic process

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Abstract

This paper studies method of controlling dynamic process with Fuzzy Cognitive Map (FCM) built in NI LabVIEW software. FCM is the hybrid methodology that combines fuzzy logic and neural networks. A FCM will be developed using NI LabVIEW software to model and control a process of dynamic system. Nowadays more autonomous and intelligent systems are very useful in many areas of people lives especially related with Complex Systems.

Key Words : FCM, LabVIEW, Control of process

1. Introduction

Modern systems are characterized as Complex Systems with high dimension and variety of variables and factors. For complex dynamic systems conventional methods have a limited using in modeling and controlling and new techniques are required for developing intelligent systems. New methods have proposed for complex systems that will utilize existence knowledge and human experience and will have learning capabilities and advanced characteristics such as failure detection and identification qualities [1]. The application of Fuzzy Cognitive Map (FCM) may contribute to the attempt for more intelligent control methods and to the development of autonomous systems. A FCM draws a causal picture to represent the model and the behavior of system. The concepts of an FCM interact according to imprecise rules and the operation of complex systems is simulated using powerful software environment NI LabVIEW which is able to create models of different control systems.

2. Problem statements

Fuzzy Cognitive Maps are symbolic representation for the description and modeling of the system. They consist of concepts that illustrate different aspects in the behavior of the system and these concepts interact with each other showing the dynamics of the system [2]. The human experience and knowledge of the operation of the system are used to develop the FCM. A FCM describes the behavior of a system in term of concepts; each concept represents a state, a variable or a characteristic of the system [3]. An FCM illustrates the whole system by a graph showing the cause and effect among the concepts in symbolic manner.

A graphical representation of FCMs is depicted on Fig. (1).

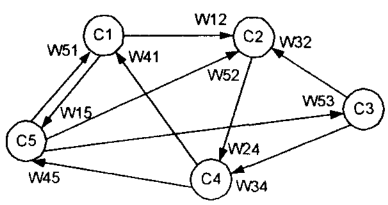

Fig1. Graphical representation of FCM.

Each concept represents a characteristic of the system and is characterized by a number that represents its value and it results from the transformation of the real value of the system's variable for which this concept stands in the interval . Causality between concepts allows degrees of causality and is not the usual binary logic so the weights of the interconnections can range in the interval .

FCMs have been applied in a variety of scientific areas: to describe and model the behavior of a system and its application in modeling the supervisor of distributed systems [4] or, for example, controlling of micro robots [5]. Such methodologies are crude analogs of approaches that exist in human and animal systems and have their origins in behavioral phenomena related to these beings [6].

3. FCM for control dynamic process

Fuzzy Cognitive Map can be used to model and control a process [3]. The FCM is constructed by using special components made in NI LabVIEW software. An important issue in development of FCM is the determination of the concepts that best describe the system and the direction and grade of causality among concepts.

Constructed FCM should control the model of system which consists of two taps with cold and hot water. Temperature and intensity of streams of both waters are known. Rate of opening of the taps should be control automatically to make desired temperature and intensity of mixed stream. System is depicted on Fig. (2).

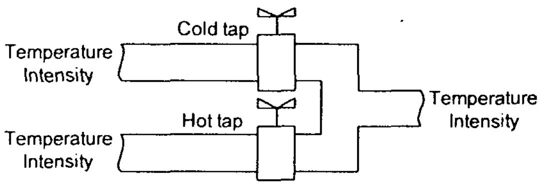

Fig. 2.The drawing of a process problem.

The first step in constructing the FCM which will model and control the system is the determination of the concepts of the FCM. Concepts will stand for the variables and states of the process as the temperature and intensity of mixed water stream. So a primitive FCM is developed with six concepts and later any new concept which can improve the model and control of the system can be added.

C1 is desired temperature of stream. This amount influences the rate of opening cold tap and rate of opening hot tap.

C2 is desired intensity of stream. It influences the rate of opening cold tap and rate of opening hot tap.

C3 is rate of opening hot tap. It depends on desired temperature and actual temperature of stream.

C4 is rate of opening cold tap. It depends on desired temperature and actual temperature of stream.

C5 is actual temperature of stream. It influences the rate of opening cold tap and rate of opening hot tap.

C6 is actual intensity of stream. It depends on the desired intensity of stream.

Then operating behavior and the interconnections between concepts must be determined. At first, experts decide for each concept with which other concept it will be connected and they determine the sign and weight of each connection. Dynamic of the system is shown by the interconnections: Constructed FCM is depicted on Fig. (3).

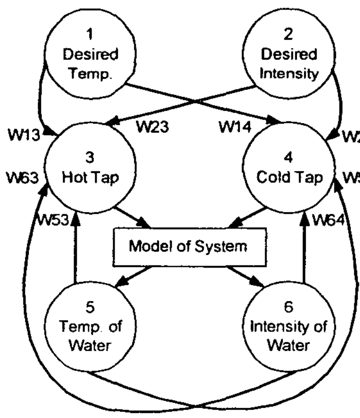

Fig. 3.FCM for controlling of the system.

The connections between concepts are events below:

E1 connects C1 (Desired temperature of stream) with C3 (Rate of opening hot tap). It relates the state of opening of the hot tap with value of desired temperature of stream.

E2 connects C1 (Desired temperature of stream) with C4 (Rate of opening cold tap). It relates the state of opening of the cold tap with value of desired temperature of stream.

E3 connects C2 (Desired intensity of stream) with C4 (Rate of opening cold tap). Desired intensity of stream causes the changing of rate of opening of the cold tap.

E4 connects C2 (Desired intensity of stream) with C3 (Rate of opening hot tap). Desired intensity of stream causes the changing of rate of opening of the hot tap.

E5 connects C5 (Actual temperature of stream) with C3 (Rate of opening hot tap). It shows the effect of actual temperature of stream into rate of opening hot tap.

E6 connects C5 (Actual temperature of stream) with C4 (Rate of opening cold tap). It shows the effect of actual temperature of stream into rate of opening cold tap.

E7 connects C6 (Actual intensity of stream) with C4 (Rate of opening cold tap). When the actual intensity of stream changes the rate of opening cold tap is changing too.

E8 connects C6 (Actual intensity of stream) with C3 (Rate of opening hot tap). When the actual intensity of stream changes the rate of opening hot tap is changing too.

Then system was modeled in NI LabVIEW using powerful graphical tools. The initial value of each concept, the interconnections and the weights among concepts are illustrated. Each concept has a value which ranges between and it is obtained after thresholding the real value of the concept with sigmoid function. Initial measurements of the real system have transformed to concept values and the initial vector is formed:

$$A_0 = [A_1 \ A_2 \ A_3 \ A_4 \ A_5 \ A_6].$$

Then algorithm for determining weights was applied and the weight matrix was produced.

For these initial values of concepts FCM starts to simulate the behavior of the process. At each step of simulation values of concepts are calculated according to following equation:

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j \neq i}}^{n} A_j^{t-1} \cdot W_{ji} + A_i^{t-1} \right)$$

Time step is defined as simulation step of the FCM. During this time the values of the concepts are calculated and changed. Then a threshold function is used and so the result belongs to the range.

The FCM program was written and simulation runs in NI LabVIEW 7.1. Powerful tools of NI LabVIEW software allows to make visual and intuitive interface of program very easy. Control panel of the program is shown on the Fig. (3).

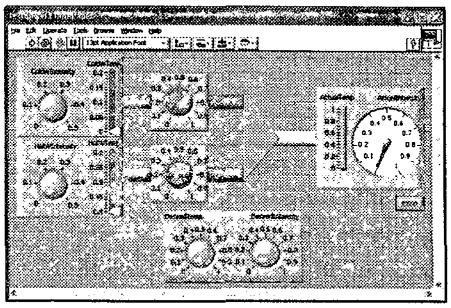

Fig. 3. Control panel of the system.

User can set Desired temperature and Intensity of stream by two knobs at the lower part of the control panel. System collects the initial data (Actual temperature of water and Actual intensity of stream) and changes Rates of opening of both taps. The main task of control of the system is minimizing the difference between actual and desired parameters.

Simulation of the system was made with input parameters Desired temperature and Desired intensity of water (Fig. 4). Let Desired temperature be set as 0.3 (it means 30 Celsius degrees) and Desired intensity of stream 0.5 (it means the mixed stream of water is half of the maximum allowed). Rates of opening of both cold and hot taps must be regulated by the system automatically. After running of simulation display part of the system shows Actual temperature and Actual intensity of stream. User can see that Actual parameters are near Desired parameters: Actual temperature is 30 Celsius degrees and Actual intensity of stream is 50%.

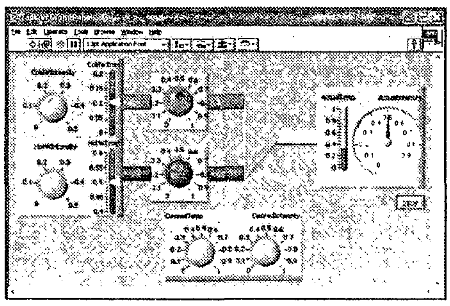

Fig. 4. Simulation.

Results of simulation show that system automatically makes the Rates of opening of both taps as 50%.

The main purpose of successful using of FCM in control of process (minimizing difference between Actual and Desired parameters) is reached. So we can consider the FCM was constructed correctly and NI LabVIEW software can be used for control of process by constructed FCM too. The system can be advanced easily by adding some new features.

4. Conclusions

This paper examined the method of control of a process using Fuzzy Cognitive Maps that are constructed in NI LabVIEW software. Usually FCM theory like a new Soft Computing approach is used to model the behavior of Complex Systems. This techniques best utilizes existing human experience of the system operating. Moreover LabVIEW software of National Instruments Company has very powerful toolkit to make visual and intuitive model of the system and easily control it using new methodologies.

For Complex Systems it is extremely difficult to describe the system by a precise mathematical model. FCM approach represents systems in a graphical way showing the causal relationship between states-concepts and powerful tools of NI LabVIEW can help in this purpose very well. FCMs offer the opportunity to produce better knowledge based system applications addressing the need to handle uncertainties and inaccuracies associated with real world problems.

A FCM model for supervisory control represents the supervisor that is consisted of concepts show the irregular operation of some elements of the system: failure mode variables, failure effects variables, failure case variables, severity of the effect or design variables. In the development of the FCMs the integration of several expert opinions are needed in order to achieve its diagnosis and predictive task that is really important and difficult in case of complex system.

FCM is a type of symbolic methodology which can increase the effectiveness, autonomy and intelligence of systems. Since this symbolic method on modeling and controlling a system is easily adaptable and relies on human expert experience and knowledge. So it can in a sense be considered intelligent.

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