Application of Fuzzy Cognitive Map Techniques in Family Decision Making

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Abstract: *For many family problems it is difficult to make decisions, homework or develop plans based on precise quantitative models. Fuzzy Cognitive Maps (FCM) is a well-known tool for qualitative analysis of systems that uses a simple representation of knowledge in the form of a graph of concepts linked by causal relationships. The advantages of FCMs are the ease of gathering and representing knowledge and the simplicity of reasoning techniques, very close to neural networks. This paper discusses the solutions of experiments aiming at application of FCMs to the analysis of development scenarios for examine and training units (e.g. family within members). The motivation for the work was an intention to investigate FCM techniques on a real, yet appealing example. The problem was chosen for two reasons. The first is a potential interest in the real life community in outcome of analyzes; the second is the ease of perception of the problem domain, what facilitates the interpretation of obtained solutions.*

Keywords — *Fuzzy Cognitive Maps, Complex Systems, Casual Relations, Decision Making, Simulation.*

Introduction

Modelling dynamic systems can be hard in a computational sense and many quantitative techniques exist. Well-understood systems may be open to any of the mathematical programming techniques of operations study. First, developing the model usually requires a big deal of effort and specialized knowledge outside the area of interest. Secondly, systems involving important feedback may be nonlinear, in which case a quantitative model may not be possible.

In the past years, conventional methods were used to model and control systems but their contribution is limited in the representation, analysis and solution of complex systems. In such systems, the inspection of their operation, especially from the upper level, depends on human leadership. There is a great demand for the development of autonomous complex systems that can be achieved taking advantage of human like reasoning and description of systems. Human way of thinking process for any method includes vague descriptions and can have slight variations in relation to time and space; for such situations Fuzzy Cognitive Maps (FCM) seem to be appropriate to deal with it.

1. **Fuzzy Cognitive Map**

Cognitive maps were first proposed by Axelrod as a tool for modelling political decisions, then they were extended by Kosko by introducing fuzzy values. A large number of applications of FCM were reported, e.g. in project risk modelling, crisis management and decision making, the analysis of the development of economic systems, the introduction of new technologies , ecosystem analysis , signal processing and decision support in medicine. A survey on Fuzzy Cognitive Maps and their applications can be found in FCMs are directed graphs whose vertices represent concepts, whereas edges are used to express causal relations between them. A set of concepts $C = \{c_1, \dots, c_n\}$ appearing in a model encompasses events, conditions or other relevant factors. System state is an n-dimensional vector of concept activation levels ($n = |C|$). In contrast to condition/events Petrinets or state machines, where only two activation levels are used: 0 (inactive) and 1 (active), in FCM an activation level can be a real value belonging to [0, 1] or [61,1] Causal relations between concepts are represented in FCM by edges and assigned weights. A positive weight of an edge linking two concepts *ci* and *cj* models a situation, where increase of the level of *ci* results in growing *cj*; a negative weight is used to describe opposite report.

In the simplest FCM form, values from the set {1, 0, and 61} are used as weights. They are graphically represented as a minus (6) sign attached to an edge, absence of edge are plus (+) sign. While building FCM models, more fine-grained causal relations can be introduced. They are usually specified as linguistic values, e.g.: *strong_negative*,*negative*,*medium_negative*, *neutral*, *medium_positive*, *positive*}, *strong_positive*, and in a computational model mapped on values uniformly distributed over [61, 1]. Causal relations between concepts in FCM can be represented by $n \times n$ influence matrix E = [*eij*], whose elements *eij* are weights assigned to edges linking *cj* and *ci* or have0 values, if there is no link between them. Figure 1 gives an example of FCM graph, whose vertices were assigned with concepts*c*1, *c*2, *c*3 and *c*4, whereas edges with linguistic influence weights. The corresponding E matrix is given by the formula (1). The selection of values corresponding to linguistic values is arbitrary, in this case values: 61, 60.66, 60.33, 0, 0.33, 0.66, 1 were taken.

FCM construction

It is implemented in two steps:

• The *concepts* (N) have to be provided by medical experts and/or guidelines that sufficiently describe the decision making task, including the input and the output knowledge. Each concept is modelled as a *variable Ci*, *i*=1,2,…*N* that can take fuzzy or discrete values according to the problem data. The fuzzy values express the degree to which the concepts occur.

• The *connections* between the concepts and their *strengths* should be assigned also by medical guidelines and/or physicians' knowledge using if-then *rules*. These rules infer a fuzzy weight given in Table I. These fuzzy sets express the degree to which a concept *Cj* influences another concept *Ci*, *i*=1,2,…*N*, *j*=1,2,…*N*.

$$C_i^{(k+1)} = f\left(C_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} C_j^{(k)} \cdot W_{ji} \right)$$

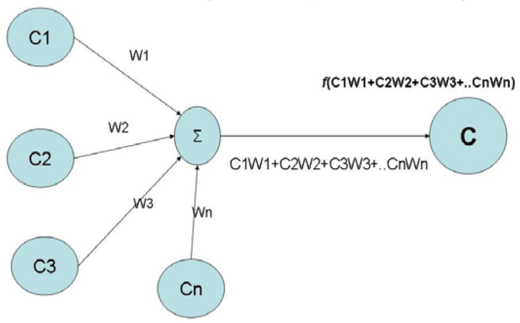


Fig. 1 FCM model for making decisions

In this next section, we elaborate on how to model human emotions and an individual cognitive assessment of the epidemiological situation, respectively. Then, we present an FCM denotative model that describes individual emotions and cognition for infectious disease simulations.

1. **Human Emotions**

Emotions play an important and indispensable role in affecting human memory, attention, and reasoning. Human intelligence enables not only rational thinking and logical reasoning but has strong emotional capabilities as well. Psychologically speaking, emotions stand for an individual's reaction to and evaluation of its own internal states and interactions between themselves and their environment. As a type of intelligence and a psychological tool for agents to adapt to an environment as well as a means of communication, emotions can activate psychological and behavioral motives. Damasiostates that emotional capability is crucial to normal behaviour, and it does not contradict rational thinking and logical reasoning.

In contrast, emotional capability is complementary to rational thinking and logical reasoning and vice versa. Additionally, emotional capability is regarded as a sign of human intelligence. Artificial emotion recognizes and understands human emotions based on information science, which enable machines and virtual humans to have subhuman emotions and communicate with humans in a natural and harmonious way. It emphasizes the influence of the internal states on artificial entities such as virtual persons. An internal emotion model is needed to construct emotional agents. In this model, the transition and mapping between stimuli, emotional status, and behaviour is predefined in a given context.

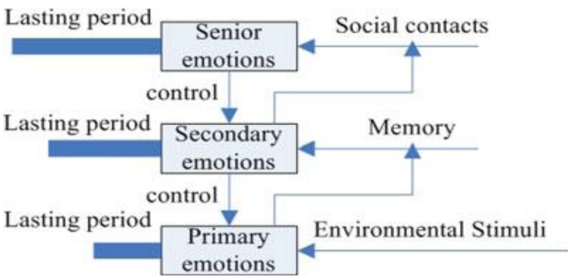
Emotional agents that interact with an environment agent and with other agents can generate human-like emotion outputs, which subsequently affect decision making. The transition between emotions is related to outside stimuli and environment inputs, as well as current emotional status. Therefore, it is essential to investigate how external stimuli and internal status arouse emotion changes and how emotional changes affect behaviour. Human emotions can be psychologically categorized by three levels, i.e., primary emotions, secondary emotions, and senior emotions. Damasio regarded primary emotions as intrinsic responses of a human to external stimuli; secondary emotions are triggered when primary emotions connect with current and past perception; senior emotions come into being during the course of long-term social contacts in a given environment.

Dao-Ping elaborates on the formation mechanism of emotions at different levels. Instantaneous emotions are intense and short-lasting, due to specific causes and perception content, and they easily transform into other statuses; therefore, instantaneous emotions are primary emotions. Moods are more mild, fuzzy, and long-lasting, which contain no specific perception content. Moods appear and vanish slowly with no obvious causes, and last short at emotional peaks. Thus, moods are secondary emotions. Society competence is relevant in each social and cultural environment, which forms more potential and underlying emotional context for people's cognition and behaviour.

The appearance and vanishing of society competence is more slowly compared with moods, which suggests that society competence is a senior emotion. Primary emotions are partially dominated by senior emotions, although they are mainly influenced by environmental stimuli and self-perception. The domination gets even more obvious when primary emotions conflict with senior emotions. For instance, an optimistic person (with respect to senior emotions) has less intensive instantaneous emotions (with respect to primary emotions) when facing frustrations (with respect to environmental stimuli). Additionally, there exist adjustments between emotions at the same level, which lead emotions to change toward an advantageous direction, as shown in Fig. 2.

Human emotions, especially primary emotions, consist of eight types including anger, sadness, surprise, and enjoyment, and each type can be further categorized into subtypes which indicate how intense emotions are [34]. This study describes the human status in a continuous space, and selects an interested subset of primary emotions, such as enjoyment and surprise, to compose an emotion space. Besides primary emotions, secondary and senior emotions can also be appended as components to the emotion space, such as historical memory of emotion, which belongs to secondary emotions, and personality, which belongs to senior emotions. Let the emotion set be Emotion = $\{i.e.|i = 1 \ldots l\}$, where l is the total of involved components in the emotion space. Each component in the emotion space is mapped to a concept of which the value is in the range [0, 1]. Bigger values of concepts show that the corresponding basic components in the emotion space are more active. A simple example of an emotion FCM is shown in Fig. 3, where "Optimistic" belongs to senior emotions, "Emotion memory" belongs to secondary emotions, and "Enjoyment" and "Surprise" belong to primary emotions.

Fig. 2. Emotions at different levels and their interactions



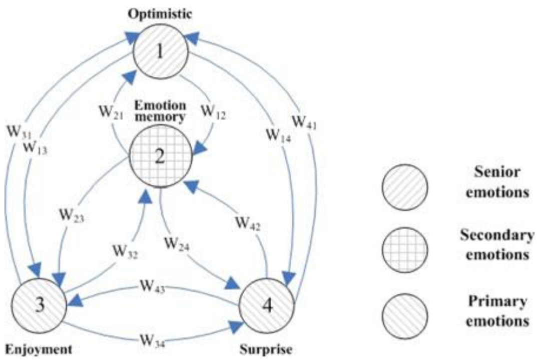


Fig. 3. Simple emotion FCM.

1. Discussion

FCM is a computing technique for modelling complex systems, which follows an approach similar to human reasoning and the human decision-making process. FCMs can successfully represent knowledge and human experience; introduce concepts to represent the essential elements and the cause and effect relationships among the concepts to model the behaviour of any system. It is a very convenient, simple, and powerful tool, which is used in numerous fields.

Using the FCM to determine the SP proves useful and looks promising for a move from the conventional modelling toward developing computer based models. The FCM is the only model that is capable of considering all the variables involved in the determination of the planning process factors and the relationships among them. It is also capable of showing the dynamics involved in the planning process determination. The proposed model enables the experts to simulate different ideas from various viewpoints. Another distinct characteristic of this model is its capability to react to changes in the factors involved in determining strategic information system plans.

In this approach, we utilise fuzzy linguistic labels instead of real numbers to determine the weights. This makes the FCM even more sensible. The obtained FCM emphasises the importance of the three main factors of planning process including business strategy, IS strategy, IT strategy, heterogeneity, hostility, dynamism, planning team involvement, user and management involvement in IS planning, implementation problem by identifying their impacts as "strong" impacts on satisfying the customers. The map also leads managers to spend more of their resource on that group of factors which have stronger impacts on planning process. The proposed FCM enables the managers to augment their jobs by establishing and developing scenarios and evaluating the alternative paths to reach the better strategic information system plans. On the other hand, the model's state of being dynamic enables the managers to establish and analyse specific scenarios for different categories of the plans. Due to the diversity of the categories of the plans and even the diversity of culture in different regions, different solutions to increasing the applicability of the plans are available. This map, by producing a clear picture of the affecting factors, is a good means for managers to help them identify the solutions and alternatives.

Scenarios help the users understand the process of planning and state and analyse their own ideas about the future changes. The proposed FCM can be used as a basis for establishing scenarios for the following purposes:

• evaluating the capabilities of the organisation for gaining the suitable plans

• analysing different alternatives for determining the planning factors.

1. Conclusions and future research

Handling the SP has always been important to the managers. On the other hand, the strategic factors involving this notion are complicated and vague and cannot be easily quantified. There are lots of qualitative techniques to analyse the structured problems, but these techniques are not sufficient for analysing such problems. In order to deal with such problems, former researchers focused on SP success, and its factors and problems, the role of top management, SP process, IS planning methodologies and approaches, planning scope, business change, IT change, and their alignment, and various other aspects of the planning process. However, less attention is paid on contextual factors of SP process. Thus, this research tried to fill the gap by utilising FCM for simulating the planning process.

In this paper, the usefulness of the FCM for modelling and simulating the planning has-been studied. The proposed model is applicable to establishing projects and augmenting the planning process. Using it, various businesses and practitioners are able to effectively design and implement the process. It is noteworthy to mention that limited access to experts in the field of SP could be considered as the main limitation of this research. For future research, it is proposed to design an expert system based on the FCM which could be adjusted to different organisational environments. It is also advisable to use other methods of determining the fuzzy weights. Finally, this paper leads to proposing a new method for determining and demonstrating the SP process. The model considers various variables and enables the managers to study the effects of different factors on the planning process.

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