Timed Fuzzy Cognitive Maps for Supporting Obstetricians' Decisions

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Abstract— **A crucial decision during delivery is whether a pregnant woman is going to have a physiological delivery or a caesariansection. This decision depends on many factors that regard both the woman and the fetus. An obstetrician continuously monitors the health status of both mother and fetus and he regularly has to make a decision estimating all the possible cases/alternatives, but always eliminating the possibility of setting the woman's life or the fetus at risk. Medical Decision Support Systems (MDSS) offer doctors a tool to evaluate and/or dispute their decision. This work introduces the use of Timed Fuzzy Cognitive Map (T-FCM) for the case of obstetrics, where time is necessary to be included, as it can influence and change and the overall procedure, leading to a different decision.**

Keywords— **Fuzzy Cognitive Map, time, obstetrics, decision making.**

I. INTRODUCTION

Medical Decision Making is a complex procedure, usually performed by an expert doctor who takes into consideration a variety of factors and infers a diagnosis/decision. The complexity of the procedure has led to the design and proposal of Medical Decision Support Systems (MDSS) that support clinicians' decision making in being able to evaluate information from different sources, combine them so that to infer diagnosis, therapy planning and monitoring of the disease and treatment processes.

Any medical decision procedure has to consider a high amount of data and information from interdisciplinary sources (patient's records and information, doctors' physical examination and evaluation, laboratory tests, ultrasound and other medical devices etc.) and, in addition, information may be vague, missing or not available. Medical Decision Support Systems are complex involving inexact, uncertain, imprecise and ambiguous information [1]; but such systems can provide assistance in crucial clinical judgments, particularly for inexperienced medical professionals.

Medical Decision Support Systems (MDSS) follow the general nature of medical interventions: predict (predictive medicine), prevent (preventive medicine), heal (curative medicine), or at least comfort (medical assistance) [2]. For this goal, a patient's particular situation must be considered (diagnosis or prognosis) and possible strategies be evaluated. Medical Decision Systems are complex systems consisting of irrelevant and relevant subsystems and elements, taking into consideration many factors that may be complementary, contradictory, and competitive; these factors influence each other and determine the overall diagnosis with a different degree. A MDSS usually extracts causal knowledge from the appropriate medical domain, builds a causal knowledge base and inferences with it. Fuzzy Cognitive Maps (FCMs) is a soft computing technique used for causal knowledge representation and supporting causal knowledge reasoning process. The FCM modeling approach resembles human reasoning; it relies on the human expert knowledge for a domain while making associations along generalized relationships between domain descriptors, concepts and conclusions. It models any real world system as a collection of concepts and causal relation between concepts. FCMs have been used for medical purposes and a number of FCM extensions for MDSS have been developed [3].

II. FUZZY COGNITIVE MAPS AND TIMED-FUZZY COGNITIVE MAPS

An FCM is illustrated as a causal graphical representation consisting of interrelated concepts. It was introduced [4]as an extension to Cognitive Maps[5]. The general graphical illustration of FCM is a signed, weighted graph with feedback. Nodes of the graph are concepts that correspond to variables, states, factors and other characteristics essential to model and describe the behavior of the system. Causal relationships interconnect the FCM concepts as illustrated in fig.1.

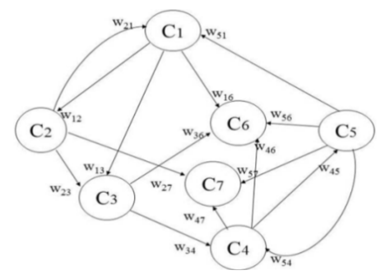

Fig. 1 The fuzzy cognitive map model

A FCM is developed by experts who describe each interconnection with a fuzzy rule. This rule infers a linguistic variable that corresponds to the relationship between the

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two concepts according to each one expert that has contributed to the procedure and determines the grade of causality between the two concepts. The inferred fuzzy weights from many experts are aggregated and deffuzified, giving an initial numerical weight within the interval [-1,1].

Generally, a significant weakness of FCMs is the critical dependence on the experts' opinions; another one is the potential convergence to undesired steady states. The use of learning procedures can enhance FCMs and increase their efficiency and robustness.

FCMs develop a behavioral model of the system that exploits the experience and expert knowledge. This FCM's applicability to model complex system has been successfully used in many different application areas. A description of the fields and some of their basic applications are in [3]. However, these FCM models lack of the time dimension. Time is a crucial characteristic and it can influence the evolution of a case completely.

In real world systems, time plays an important role and it can influence and formulate the final decision. As a result, time in combination with additional parameters, which represent specific characteristics of every pregnant woman, can influence the route of decision.

Specifically, in obstetrics Stylios et al. proposed the hierarchical architecture, the two-level architecture for decision support during labor[6]. In this structure, m-FCM can be used to model the supervisor which constitutes the medical decision support system. The upper layer contains the concepts that obstetrician should evaluate. Some concepts can have only external input which comes from the lower layer. In this level the final decision is taken whether a caesarian or a normal delivery should be followed.

In this structure three types of FCM architectures can be used;i) the competitive FCM when one single decision should be made[7], ii) a distributed FCM for handling cases of large and complex systems, breaking the large problem into a number of sub-systems (sub-FCMs)[8] and iii) the hierarchical architecture with the m-FCM, where it receives information from all the subsystems in order to reach to a final decision. However, the concept of time had not been taken into consideration. In some cases, there is evidence from previous time periods that should be co-estimated for deciding the final way of delivery.

In this work an attempt to incorporate time to the overall procedure[6]is made by introducing a novel methodology. This method introduces time dependence within FCM and it takes into consideration the influence of time in the final decision. A different use of timed-FCM has been described in[9] for the case of differential diagnosis between two pulmonary diseases. This new methodology is now introduced in the area of obstetrics where some parameters are heavily dependent on time. The time influences and changes the weight dependencies and therefore, the evolution of a process can follow a different route, leading to a different decision.

Here a new decision making model is introduced that includes additional parameters. These parameters are elements that determine and describe all the possible, external characteristics that fit better to a particular case. The activation of all/or some of these parameters in combination with the obstretrician's examination can lead to different results according to the corresponding time unit. Thus,we will have a FCM with various weight values corresponding to the individual characteristics and time unit. Fig. 2 represents the FCM with the the time-dependent weights from acase ($w_{\gamma,t,ij}$).

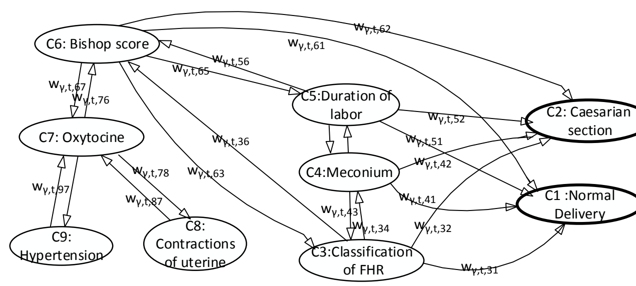

Fig. 2 Timed-FCM for obstetrics decision with timed dependent weights ($w_{\gamma,t,ij}$)

The steps to construct the FCM, using the additional parameters occurs in the upper layer. Experts should define each weight according to the activated parameters' combination. In real situations, the estimations and evidences that are normal and physiological for some women, frequently may be regarded as dangerous and abnormal for others. These individual characteristics should be taken into account by the experts during the process of weight determination, in order to represent each possible case, even the rarest. Table 1 contains some possible features that will cause a change.Thus, experts should give different values to each combination according to their knowledge and experience, illustrating the evolution of a case. They also have to answer "what-if" questions and determine the influence of time regarding the direction of change (increase, decrease, stable) for each possible combinaton of parameters.

III. DESCRIPTION OF THE TOOL

This tool inserts the concept of time and tries to follow the evolution of the corresponding characteristics leading to the appropriate decision: normal or caesarian delivery. T-FCMs enhance the initial FCM by adding the appropriate parameters for a case. These parameters take on binary values, which are 0 or 1, representing the two states: deactivated or activated. Experts, also define the appropriate time unit corresponding to the obstetrics case. More specifically, the basic components that should be defined are the concepts, in the same way as in the basic FCM's concept definition. However the procedure of weight definition is different compared to the basic FCM weight definition. Fig. 3 summarizes the basic steps for constructing the T-FCM.

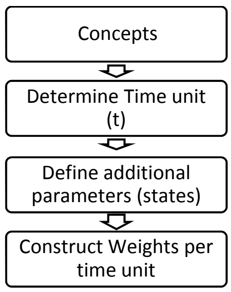

Fig. 3 Basic steps for TFCM construction

More specifically, each step for the case of obstetrics includes the following process:

- *Concepts*

The basic concepts for the case of obstetrics are described in[6]: decision for normal delivery, decision for caesarian section, fetus heart rate (FHR) evaluation, presence of meconium, time duration of labor, bishop score, quantity of the medicine oxytocin given, contractions of the uterus, hypertension. The values and the intensity of these concepts can vary based on additional activated parameters, i.e. the individual characteristics of each woman.

- *Determine Time Unit*

Experts need to define the time unit, which is the time span that they regard as critical, that is the time that a change (either minor or significant) can influence the evolution of a case. This time unit can be related to either a short-term or a long-term observation.

- *Define additional parameters*

Each case is a specific circumstance with its particular characteristics. Thus, some parameters can create a completely different evolution. For this reason, experts have to define these parameters and characterize their influence over time. For the case of obstetrics such parameters can be the age, the case of previous abortions etc. (table 1).

- *Weights per time unit*

Experts define the weights linguistically for each time unit and for each combination. Firstly, the weights will follow the default case, where all the additional parameters are deactivated (case woman's age 18-35 and no addition parameters activated). Consequently, experts should specify the degree of change (small, medium, large or no - increase, reduction) for each time unit, modifying in this way the initial weight. This causes different influences among the concepts.

Experts need to construct the FCM by answering "what-if" questions. In the event there is a change, the appropriate value is estimated and replaces the previous one.

Thus, there will be different weights for each time unit and activated case using equation (1):

$$w_{\gamma,t,ij} = \begin{bmatrix} w_{\gamma1,t1,ij}, w_{\gamma1,t2,ij} \dots w_{\gamma1,tn,ij}, w_{\gamma2,t1,ij} \\ , w_{\gamma1,t2,ij} \dots w_{\gamma n,t1,ij}, w_{\gamma n,t2,ij} \dots w_{\gamma n,tn,ij} \end{bmatrix} \quad (1)$$

where γ shows the activated state of additional parameters. Table 1 defines the possible states that each parameter can take. Thus, the index n of γ shows the weight combinations that will be used during the specific runtime. In order to take the final value$w_{\gamma,t,ij}$,a process should be followed to define the rest individual variables. Table 1 contains the states that a case can belong to.

Table 1 Additional parameters (states)

γ_n	Age:<18, Age:18-35, Age:>35, Previous abortions, fetal weight>4kg, Co-morbidity,…
γ_0	000000
γ_1	000001
γ_2	000010
…	….

For each case and for each time unit there will be a dependence weight, d(γ,t,ij), defined for all concept interconnections. This weight characterizes the change. Thus, there will be for each time unit, interconnections that need to be changed accordingly and others that keep their default values. In this way, only the values that are time-dependent are changing. Thus, the final weight matrix for each time unit will be as in the table 2.

- *Simulation and Results*

A repetitive procedure provides an estimation of the decision for each time unit.This tool can incorporate the changes for one time unit to another, giving a decision. The simulation will stop when sufficient decision's difference is reached. In this case the doctor has the opportunity to insert values during the days before the delivery and s/he would be able to test possible increase or decrease of the concepts' values.

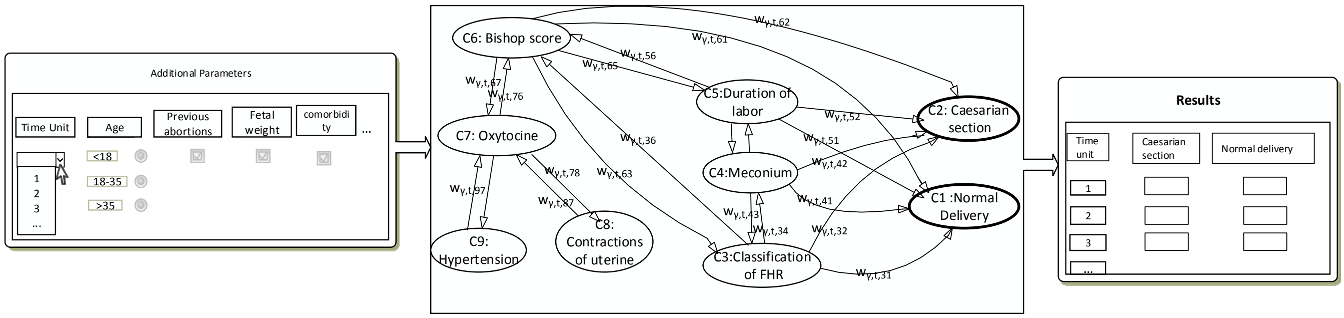

Fig. 4 The described FCM for the upper level

Table 2 Weights among concepts in time unit $t_1(d_{\gamma1,t1,ij})$

	C_1	C_2	.....	C_n
C_1	$w_{\gamma1,t1,11}$	$w_{\gamma1,t1,12}$	.....	$w_{\gamma1,t1,1n}$
C_2	$w_{\gamma1,t1,21}$	$w_{\gamma1,t1,22}$	.....	$w_{\gamma1,t1,2n}$
....	….	.....	.....	.....
C_n	$w_{\gamma1,t1,n1}$	$w_{\gamma1,t1,n2}$	.....	$w_{\gamma1,t1,nn}$

Fig.4 gives the illustration of the described FCM with the supplemented characteristics for the upper-layer. The user has to insert the values of the additional parameters in order to activate the appropriate weights. Thus, the doctor has a tool that can predict and, as a result, to prevent an undesirable situation and danger for each case separately.

IV. CONCLUSIONS

Time is a significant parameter for most medical cases. Frequently, in obstetrics, the choice between normal delivery and caesarian section is crucial and may be emergent. This tool inserts the concept of time in the model that was introduced in[6]. Furthermore, this model can follow the evolution of a case by controlling the additional parameters. Additional parameters are the special characteristics that make a case unique and make the result representative and approximate to reality.

This tool constitutes an assisting tool that can offer valuable assistance to an inexperienced professional, as it can incorporate knowledge, experience and literature into a system that infers a decision. The professional is able to judge the particular results in order to agree and/or disagree with them.

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REFERENCES

1. Sprogar, M.; Lenic, M.; Alayon, S., "Evolution in medical decision making," *Journal of Medical Systems,36*, pp. 479-89, 2002.
2. Bart Kosko, "Fuzzy Cognitive Maps," *International Journal of Man-Machine Studies,24*, pp. 65-75, 1986.99
3. R. Axelrod, *Structure of Decision: the cognitive maps of political elites*. NJ: Princeton, 1976.
4. E. Bourgani, C. D. Stylios, G. Manis, and V. C. Georgopoulos, "Fuzzy Cignitive Maps modeling and simulation," , Athens, 2013, pp. 561-570.
5. P. Degoulet and M. Fieschi, "Medical Decision Support Systems," in *Introduction to Clinical Informatics*.: Springer New York, 1997, ch. 12, pp. 153-167.
6. C. D. Stylios, V. C. Georgopoulos, G. A. Malandraki, and S. Chouliara, "Fuzzy cognitive map architectures for medical decision support systems," *Applied Soft Computing*, vol. 8, no. 3, pp. 1243–1251, June 2008.
7. V. C. Georgopoulos, G. A. Malandraki, and C. D. Stylios, "A Fuzzy Cognitive Map Approach to Differential Diagnosis of Specific Language Impairment," *Journal of Artificial Intelligence in Medicine*, pp. v.29, 221-278, December 2003.
8. M D Mesarovic, D Macko, and Y. Takahara, "The Theory of Hierarchica lMultilevel Systems," New York, 1970.
9. E. Bourgani, C. Stylios, G. Manis, and V. Georgopoulos, "Time Dependent Fuzzy Cognitive Maps for Medical Diagnosis," in *8th Hellenic Conference on Artificial Intelligence, SETN2014*, 2014, pp. 544-554.