# Software Project Risks Management Using Extended Fuzzy Cognitive Maps with Reinforcement Learning

Ahmed Tlili, Salim Chikhi and Ajith Abraham



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Ahmed Tlili[1], Salim Chikhi[2], Ajith Abraham[3]
[1,2] Complex Systems Modeling and implementation (MISC Labs), Abdelhamid Mahri University, Constantine, Algeria
[3]Machine Intelligence Research Labs (MIR Labs). Scientific Network for Innovation and Research Excellence. Auburn, Washington 98071, USA
[1]a.tlili@univ-emir.dz, [2] Salim.chikhi@univ-constantine2.dz, [3]ajith.abraham@ieee.org

**Abstract**. In last decades risk management of Software projects has become a priority. Risk Management is defined as a whole process for identifying, analyzing and controlling risks in projects or organizations. It is used in all stages of project planning and control purposes during execution phase. The principal objective of research in this field is to be able to resolve conflicting problems through preventive intervention. We focus here on the adaptation of the organization to its environment by endowing it with the means that help's to face to all unexpected in an intelligent way. Fuzzy Cognitive Maps emerged as a powerful tool for studying dynamic interactions in complex systems. There are two manners to construct them, the first one by experts of domain and the second by learning methods. In this paper, we develop a learning extended fuzzy cognitive maps based on a reinforcement learning algorithm so called Q-learning and we give an improve formulation of kosko causality principle. This connection allows us to choose, based on learning historical data process, the best and the most important connections between concepts. In this work, we illustrate the effectiveness of the proposed approach by modeling and studying project risk management as an economic decision support system.

**Keywords**: Extended Fuzzy Cognitive Maps, Complex System, Reinforcement Learning, Project Risk Management

## 1. Introduction

Risks represent a major challenge for organizations and more particularly for organizations developing applications. All activities in general, present risks. The objective of risk management is to better understanding of the factors that contribute to software project risk and to propose an approach to deal them. This approach is no longer reserved for the space or nuclear fields; it has become one of the crucial elements of project management, as well as the management of people, resources, planning and performance. Today, the success of a project is strongly conditioned by the way its leaders know how to recognize the risks. Risk prevention and risk analysis is an important task of the managers that threaten it, to study and overcome them. The information's absorbed by humans; quite complex processes are usually imprecise or approximate [1].

'While we can never predict the future with certainty, we can apply structured risk management practices to peek over the horizon at the traps that might be looming, and take actions to minimize the likelihood or impact of these potential problems' [2]..

The strategy adopted is usually imprecise in nature with no or partial knowledge of the problem, and generally possible to be expressed in linguistic terms. Thus the main problem with risk estimation is that the input data is imprecise or uncertain in nature and it is difficult to accurately represent them in mathematical models [3]. Usually and naturally, the risk analyst is specified in language terms as high, very high, medium, low… etc., rather than in exact statistical terminology. Therefore, the use of the Fuzzy Inference System (FIS) theory to risk analysis seems suitable because it deals with inaccurate and ambiguous information and the basic idea of this approach is to allow an element to belong to a set with membership degrees within the continuous real interval [0,1], rather than in the set {0,1}.

In risk analysis and management RAM, the most important factors contributing to the risk of failure for any type of socio-economic organization are related to the different criteria as: time constraints, high cost, weak operating resources, poor performance…etc., and the identification of the relationships between the risks and the ones that cause them remains a major challenge for experts in this field because they are in most cases very complex [4].

In this paper, we took, for the validation of our proposal, as a case study the risk analysis and management in software project management (SPM). The comparison here is done under Matlab R2014a between our reinforcement learning FCMs proposal with classical FCMs.

## 2. Literature review

Several methods can be found in literature review for the risks management mainly classified in deterministic and stochastic approaches: what-if analysis, task analysis, Hazard and Operability (HAZOP), Quantitative Risk Assessment (QRA), the Critical Risk and Error Analysis (CREA), Fault Tree Analysis (FTA), the Event Tree Analysis (ETA), Failure Mode and Effects Analysis (FMEA), Probability Distribution of Failure and Reliability (PDEA), Petri networks, Bayesian networks,… etc.

In [5] Samantra et al., explain that the risk associated with a specific risk factor is expressed as a combination of two parameters: the probability of occurrence and the effect. The concept of risk matrix is here to categorize different risk factors at each levels of occurrence to create a plan of actions.

Taylan et al. in [6] illustrated risk assessment using AHP and fuzzy TOPSIS where many construction projects were studied according to these main criteria: time, cost, quality, safety, and environmental sustainability. Authors showed that these methods are able of evaluating the overall risk factors of projects and selecting a project with the lowest risk with a relative weight matrix.
In the work of Dziadosz & Rejment [7] , risk and risk factor are a measurable part of uncertainty and can be estimated from the probability of occurrence. This risk and risk factor represent a deviation from the desired level, which can be positive or negative. Consequently, risk analysis is very important for selecting a win project.
The main idea in the paper related by Muriana & Vizzini [8] is that total weight method is used to calculate the current risk level of the project and the risk of the whole project is reduced taken preventive measures.

## 3. RESEARCH METHOD

### 3.1 Risk and risk management

Risk is an uncertain event that may have positive or negative impact on project and, risk management is the process of identifying and prevents risk. Risk analysis and management is more important because it affects all aspects of the project as schedule, budget, delay…etc.
In [9], taxonomy-based questionnaires to identify the risk factors are used. In this way, software taxonomy is classified in three classes:
1) Product engineering, this includes technical aspects of the work to be accomplished.
2) Development environment, which includes the methods, procedures, and tools to produce the product;
3) Program constraints, which include contractual, organizational, and operational factors within which the software is developed but which are generally outside the direct control of the local management.
One of the main difficulties of risk management is that it is not "an exact science", and by definition, a risk is a probability of a loss; in this way:

- It is not possible to predict in the long term without admitting a part of the uncertainty,
- Risks are present at all stages of a project and can take a variety of forms with internal and / or external origins,
- We can reduce the risks of a project, but we cannot eliminate them completely,
- Due to the diversity of the risks and their management, in particular according to the size of the project, the mobilized resources and the sector of activity concerned, there is a difficulty in invariant identifications.

Researches in RAM using fuzzy sets [10] have provided several models in recent years. However, we have found, there are very few sufficiently representative approaches to be used for complex problems in this area.
Risk identification is the first and most step of the process that involves listing out potential risks and there factors. Quantifying or assessing risk and its factors consists

in measuring the linguistic probability of occurrence by defining a scale of linguistic values associated with it as follows:

- Frequent risk with high probabilities of realization, very high.
- Occasional or average risk, can be realized
- Rare, unlikely or low
- Very unlikely or high.

### 3.2 What-If Analysis method

What –If Analysis is defined as a structured brainstorming method of determining what things can go wrong and estimate the likelihood and consequences of those situations occurring. The answers to these questions are not evident and form the basis for determining a recommended course of action for those risks or risk factor. our proposed method here constitute an automatic alternative to expert review team and can effectively and productively discern major issues concerning a software project or with any other risks project. Lead by an energetic and focused facilitator, each member of the review team participates in assessing what can go wrong based on their past experiences and knowledge of similar situations.

After the "What-If" answers are generated by different simulation, the review manager then makes judgments regarding the probability and severity of the risk. If the risk is judged unacceptable then a recommendation is made by the manager for further action. The completed analysis is then summarized as mentioned below:

| ***What-if?*** | ***Answer*** | ***Likelihood*** | ***Consequences*** | ***Recommendations*** |
|---|---|---|---|---|
| | | | | |

### 3.3 Fuzzy Cognitive Maps

The cognitive maps were studied by computer scientists from the 80s when Bart Kosko (1986) [11] chooses to provide a new formalization of Axelrod's cognitive maps [12] aiming to give people a scientific and realistic way to express their point of view on systems, especially political systems, and to provide a basis for calculating possible scenarios based on this system. .

Kosko (1986) notes that Axelrod's cognitive maps applied to fields such as politics, history, international relations, contain concepts and influences between concepts that are by nature fuzzy. He thus formalizes the model of fuzzy cognitive maps using the theory of fuzzy sets [13].

Fuzzy cognitive map is a directed graph in the form $< X,W >$ where $X = [X_1, ...,X_n]$ is the set of the concepts, W is the connection matrix describing weights of the connections, $w_{j,i}$ is the weight of the direct influence between the j-th concept and the i-th concept, taking on the values from the range $[-1, 1]$. A positive weight of the connection $w_{j,i}$ means $X_j$ causally increases $X_i$. A negative weight of the connection $w_{j,i}$ means $X_j$ causally decreases $X_i$ and a null weight of the connection $w_{j,i}$ means there is no causality between $X_j$ and $X_i$.

Fuzzy cognitive map can be used for modeling behavior of dynamic systems. The state of the FCM model is determined by the values of the concepts at the t-th iteration. The simulation of the FCM behavior requires an initial state vector. Next, the values of the concepts can be calculated according to the selected dynamic model. Simulations show the effect of the changes in the states of the map and can be used in a what-if analysis [11].

$$X_i^{k+1} = f(\sum X_j^k . \omega_{ji}) \quad (1)$$

Where $X_i(k)$ is the value of the i-th concept at the *k-th* iteration, i = 1, 2, ..., n, n is the number of concepts. Transformation function $f\ (x)$ normalizes values of the concepts to a proper range. A logistic function is most often used [14]:

$$f(x) = 1 / 1 + e^{-\beta x} \quad (2)$$

Where $\beta > 0$ is a parameter

Other alternatives are taking into account the past history of concepts and jointly proposed a popular dynamic model which was used in this work summarized in the following equation [14]:

$$X_i^{k+1} = f(X_i^k + \sum X_j^k . \omega_{ji}) \quad (3)$$

### 3.4 . Extended Fuzzy Cognitive Maps

Hagiwara [15] in 1992 years, mentions three weaknesses of FCMs:

1. Relationship of two events should be linear;
2. Lack of time in all developing stage;
3. Causes are independent and managed separately.

In Hagiwara proposed Extended Fuzzy Cognitive Maps E-FCMs, total input to node $C_j$ at each time $t$ can be expressed by Equation 3 as follows:

$$input_j = \sum_{1}^{n} w_{ij}\left(C_i\left(t - delay_{ij}\right)\right) C_i\left(t - delay_{ij}\right) \qquad (4)$$

Where the $C_i(t)$ is a causal concept at time t, $w_{ij}$ is a weight function from concept $C_i(t)$ to concept $C_j(t)$, and $delay_{ij}$ is a time delay from concept $C_i(t)$ to concept $C_j(t)$.

In this paper we exploit the improvements of features made by Hagiwara to the classic FCMs. we consider that the three introduced corrections, namely the absence of time, the nonlinearity of weights and the interdependence between concepts, are justified by the nature of the complex systems found in this domain.

For more details about E-FCMs, please refer to [15].

### 3.5 Reinforcement Learning

Reinforcement Learning (RL) is one effective method in the solution of multi stage decision making problems. For a comprehensive study of the subject, refer to [16] [17] [18].
The Markov Decision Processes (MDP) defines the formal framework of reinforcement learning [12]. More formally, an MDP process is defined by:

- S, a finite set of states. s Є S
- A, a finite set of actions in state s. a Є A(s)
- r, a reward function. r(s, a) Є R
- P, the probability of transition from one state to another depending on the selected action. P (s '| s, a) = $P_a$(s, s').

The problem is to find an optimal policy of actions that achieves the goal by maximizing the rewards, starting from any initial state. At each iteration, the agent being in the state chooses an action, according to these outputs the environment sends either award or a penalty to the agent shown by the following formula: $r_k$ = h ($s_k$, $a_k$, $s_{k+1}$).
To find the total cost, which is represented by the formula Σ h($s_k$, $a_k$, $s_{k+1}$), the costs are accumulated at each iteration of the system. In [19] the expected reward is weighted by the parameter γ and becomes Σ γ h ($s_i$, $a_i$,$s_{i+1}$) with $0 \leq \gamma \leq 1$. The RL is to find a policy or an optimal strategy π*, among the different π possible strategies in the selection of the action. Considering that an optimal policy π exists, then the Bellman [19] optimality equation is satisfied:

$$V^{\pi^*} = V^*(s_i) = \max\left\{R(s_i, a) + \delta\left(\sum P(s_i \to s_{i+1}, a) V^*(s_{i+1})\right\} \forall s \in S \qquad (5)$$

Eq. (4) sets the value function of the optimal policy that reinforcement learning will seek to assess:

$$V^{/*}(s) = \max V^{\pi}(s) \qquad (6)$$

In Q-Learning algorithm technique [17], the agent, For any policy *π* and any state $s \in S$, the value of taking action *a* in state *s* under policy *π*, denoted $Q^{\pi}(s, a)$, is the expected discounted future reward starting in *s*, taking *a*, and henceforth following *π*. In this case the function (4) can also be expressed for a state-action pair:

$$Q^{*}(s,a) = \max Q^{\pi}(s,a) \qquad (7)$$

Q-learning is one of the most popular reinforcement learning methods developed by Watkins (1989) in 1989 years and is based on TD (0). It involves finding state-action qualities rather than just state values. Q-Learning algorithm technique is to introduce a quality function Q represents a value for each state-action pair and $Q^{\pi}$ (s, a) is to strengthen estimate when starting from state s, executing action a by following a policy π: $Q^{\pi}(s, a) = E\ \Sigma\gamma r_i$ and Q*(s, a) is the optimal state-action pair by following policy π* if $Q^{*}(s,a) = \max Q^{\pi}(s,a)$ and if we reach the $Q^*(s_i, a_i)$ for each pair state-action then we say that the agent can reach the goal starting from any initial state. The value of Q is updated by the following equation:

$$Q^{k+1}(s_i,a_i)=Q^{k}(s_i,a_i)+\alpha\left[h(s_i,a_i,s_{i+1})+\gamma \arg\max(Q^{k}(s_{i+1},a)-Q^{k}(s_i,a_i)\right] \qquad (8)$$

## 4 Software project Risks and Risk Management Perception

Risk perception is the trend for people to have different estimates of risk probability given the same information. recent perceptions about risk management from majority of software project organizations contributes to the lack of project stability in addition to the inherent challenges posed by the nature of software projects. Ibbs and Kwak in [20] identified risk management as the least practiced discipline among different project management knowledge areas. Boehm and DeMarco [21] mentioned that "our culture has evolved such that owning up to risks is often confused with defeatism". In many organizations, the tendency to 'shoot the messenger' often discourages people from bringing imminent problems to the attention of management. This attitude is the result of a misunderstanding of risk management. Boehm in [22] identified 10 software risk items to be addressed by software development projects:

1. Developing the wrong user interface
2. Personnel shortfalls.
3. Real-time performance shortfalls
4. Unrealistic schedules and budgets.
5. Developing the wrong functions and properties.
6. Gold plating (adding more functionality/features than is necessary).
7. Straining computer-science capabilities.
8. Shortfalls in externally furnished components.
9. Shortfalls in externally performed tasks.

10. Continuing stream of requirements changes.

Jones in [23] further presented three key software risk factors and concerns of both executives and software managers. Risk factors always generate a loss, i.e. an event or situation that causes the occurrence of a loss. The risk factor therefore constitutes the origin of a risk or a set of risks.

1. Risks associated with inaccurate estimating and schedule planning.
2. Risks associated with incorrect and optimistic status reporting.
3. Risks associated with external pressures, which damage software projects.

However, most software developers and project managers perceive risk management processes and activities as extra work, not part of their job, and more expense. Risk management tasks are therefore to be removed from project activities when the project schedule is operational. Jones always in [24] mentioned that "complex computer systems can be built with a very low level of control by intelligent and motivated people." Many software development professionals believe that risk management and control prevent creativity.

### 4.1. Software Project Management Modeling

In the software project management (SPM), one of the main issues is the consistency of the project in terms of cost, completion time, quality, performance, etc. However, the most significant risk factors (causes) are of external natures and are part of the third argument of the risk factors cited by [23]. Among these, there are five main risk factors:

- **Fuzzy objectives**: in [25] Boehm and Ross argue that the different stakeholders in a software project have individual objectives and can often conflict with the objectives of another stakeholder. These differing expectations, according always to Boehm and Ross create fundamental conflicts when simultaneously approached, resulting in unclear or fuzzy objectives of the project..
- **Deficient developers**:[Keil et al., in [26] mentioned that Project personnel may not have adequate knowledge of the technology related to development tools , or may just not have the necessary experience to particpate to the project .
- **Bad task scheduling**: in [27] Ropponen and Lyytinen stated that the ‘Bad Task scheduling’ risk is the principal complicating factor as it is difficult to estimate schedules with acceptable accuracy and consistency. Very often, organizations embark on a large project having underestimated its size and complexity. This risk leads to the difficulties in scheduling the project correctly and they believe that performance with scheduling risk can be improves with project experience.
- **Budget limitation**: in [28] Abdel-Hamid et al., argue that a limited budget may lead to schedule pressures and people under pressure do not necessarily work better, resulting in the inability to produce satisfactory results.
- **Technological aspect**: In [27] Ropponen and Lyytinen, explain that Incorrect evaluation of performance requirements related to technological aspects can result in an inability to implement the solution system as a result of inappropriate technical solutions in computing area.

In the model schematized in Figure 1, the rectangles are used to represent the risks, the circles to represent the risk factors and arcs to represent the links between risk factors and the risks.

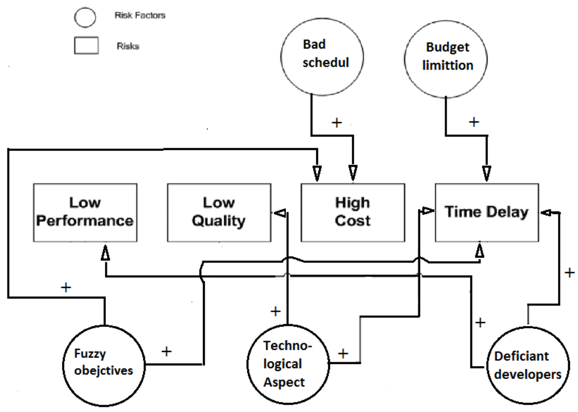


**Fig 1**. Main different risks, risk factors and influence links of the SPM model

The links schematized in Figure 1 have specificities that characterize them. Among these specific links, we quote:

- The Technological Aspect risk factor, generally, will not necessarily have an immediate effect on the Time Delay risk concept, but it will affect it after a certain time or duration. Indeed, if, for example, the operating system is slow that is used, the immediate effect on the Time Delay concept will not be so obvious, but in the long run, it will certainly cause an increase in the risk of time delay and low quality. We denote this weights by weighted links with duration:
- To respect deadlines, we can play on the risk factor developers deficient by increasing the number of developers and this can help in the first place. But if we increase more than necessary can become useless and leads to an opposite result. We therefore find that this link is a non-linear link.
- An enviable situation is that when there is a lack of budget and if there is also a bad schedule, these two risk factors will simultaneously affect the concept of Risk Time delay and risk concept High Cost. We categorize them as conditional links, because they affect only if they both occur. For example, if the scheduling of tasks is not optimal, but on the other hand, the organization is very experienced in its field to handle this type of frequent situations, the effect would certainly be different. We call this link by conditional link.

Once the influences between the risks and the factors are identified, we move on to the second stage, which consists in defining the fuzzy rules by considering the three attributes of the prototype schematized in Figure 1, namely the temporal delay and its conditional links. It remains to be noted here that the construction of fuzzy rules in a general way requires a detailed and complete knowledge of the field studied.

The three fuzzy rules above reflect an influence or a linear link between the time delay risk and the risk factor deficient developers.

- If the risk factor deficient developer is low Then the time delay risk is low.
- If the risk factor deficient developer is Medium Then the time delay risk is medium.
- If the risk factor deficient developer is high Then the time delay risk is high.

For relationships with time weights, we define an additional input delay variable parameter in fuzzy inference rules. For our example application, two fuzzy rules indicating the existence of the delay parameter can be as follows:

- If the technological aspect risk factor is high and the delay is short Then the high cost risk is Low.
- If the technological aspect risk factor is high and the delay is long then the high cost risk is high.

The without learning FCM that model the SPM of figure 1 is shown in figure 2:

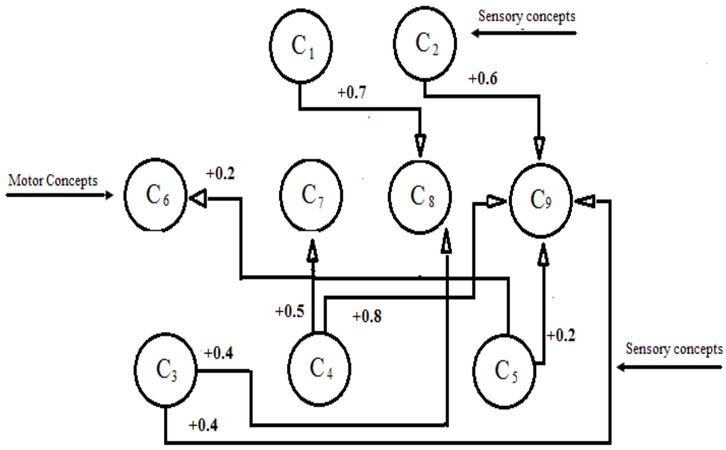


**Fig 2.** Without learning fuzzy cognitive map associated with SPM model

**Table 1** *FCM initial matrix without learning*

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.7 | 0 |
| $C_2$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.6 |
| $C_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.4 | +0.4 |
| $C_4$ | 0 | 0 | 0 | 0 | 0 | 0 | +0.5 | 0 | +0.8 |
| $C_5$ | 0 | 0 | 0 | 0 | 0 | +0.2 | 0 | 0 | +0.2 |
| $C_6$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $C_7$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $C_8$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $C_9$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 2.** Concept's final values without learning fuzzy cognitive maps

| Concept | Initial Value | Final Values | Activation Function | Transfert Function | Numb. of Iteration |
|---|---|---|---|---|---|
| 1. $C_1$ | 1 | 1.00 | A + A.W | Sigmoid | 56 |
| 2. $C_2$ | 0 | 0,65904607 | | | |
| 3. $C_3$ | 0 | 0,65904607 | | | |
| 4. $C_4$ | 1 | 1.00 | | | |
| 5. $C_5$ | 1 | 1.00 | | | |
| 6. $C_6$ | 0 | 0,69586237 | | | |
| 7. $C_7$ | 0 | 0,83569675 | | | |
| 8. $C_8$ | 1 | 0,72975341 | | | |
| 9. $C_9$ | 0 | 0,90204315 | | | |

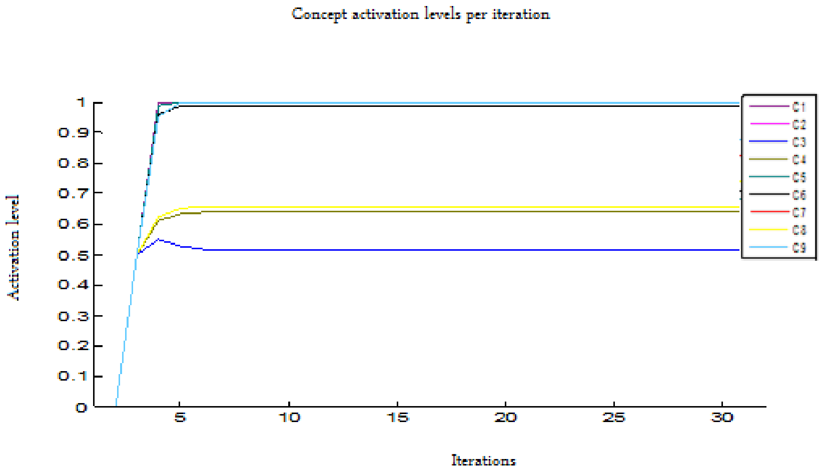


**Fig 3.** Evolution of activation values of FCM concepts without learning (Matlab R2014a).

As can be seen on Figure 3, the risk factors $C_1$, $C_4$ and $C_5$ that activated the high cost concept $C_8$ and time delay concept $C_9$ risks are still active despite the convergence of the non-learning FCM after 46 step. for the organization this implies that the risk remains active.

Among the concepts mentioned in Figure 2, we will discuss the concept of high cost risk and see how based on the proposed approach the organization adapts to its environment by treating this risk.

The High Cost concept is affected by risk factor concepts bad schedule and fuzzy objectives. Adaptation is translated here by the action or actions (decisions) undertaken by the organization to deal with this type of risk. One can imagine that in order to stabilize costs, we must act on the risk factors that directly affect this concept. In other words, either improve the scheduling of tasks, or seek to clarify objectives related to its field or both in parallel. This search is guided by, on the one hand, the values associated with the pairs (state, action) found in the table of the function Q, and on the other hand by the probabilities of the actions as mentioned above.

If the possible or permissible actions are no longer able to meet the needs of the organization, it is called upon to look for other mechanisms that allow it to meet its needs. For example, in our case, the organization can play on the risk factor deficient developers with which the concept High Cost has no direct influence link, this action results in the creation of a connection between concept risk high cost and the concept risk factor deficient developers. This last case is represented by figure 4.

The rules that go along with the organization in the search for the optimal actions or decisions allowing it to adapt to the new environmental data in the proposed approach are of the form:

- If High Cost Risk is Active Then // depending on the factor that activated the risk

If state $Q$ *(state,* $a_i$*)* already visited then executes action $a_i$ ($a_i$ action here is either the increase or the decrease link).
Otherwise select the $a_i$ action that has the highest probability or choose any other actions.

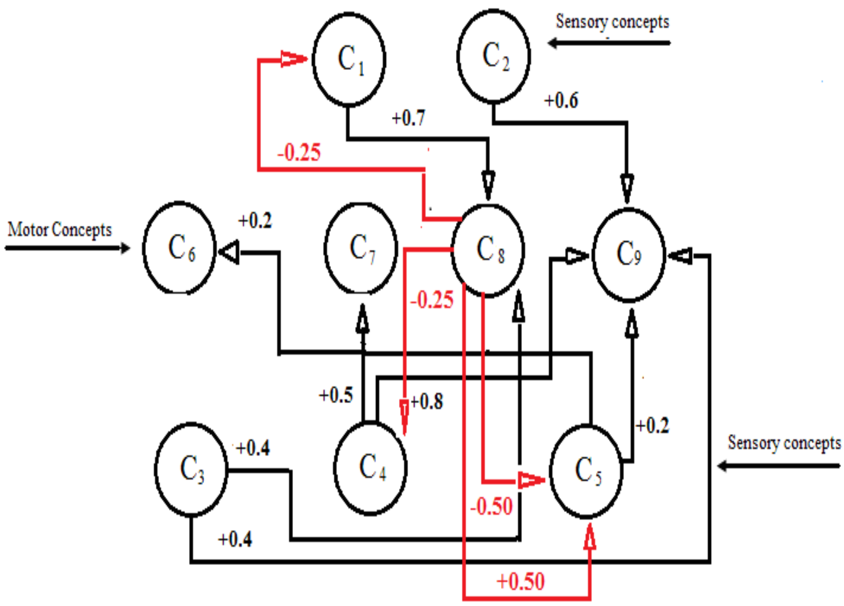


**Fig 4.** SPM Reinforcement learning extended fuzzy cognitive maps model.

The two links ( increase, decrease) from $C_8$ to $C_5$, figure 4, shematise that in complex systems it is difficult to know if a concept causes or decreases another concept only after several simulation of the model. It also happens that a concept can under certain conditions causes one concept and inhib it in others.
taking into account this characteristics of complex systems, we give an another formulation that we consider equivalent to Kosko (1986) principle of causality wich will be applyed in our cases study.

***Defintion 1*** : *($C_i$ causes $C_j$)* ***OR*** *($C_i$ causally decreases $C_j$)* ***Iff*** *( $Q_i \subset Q_j$ and $\sim Q_i \subset \sim Q_j$)* ***OR*** *( $Q_i \subset \sim Q_j$ and $\sim Q_i \subset Q_j$).*
Were $\subset$ stands for fuzzy set inclusion.The logical operator **OR** is used here with the reward received from the environment, which allows to select the best link, attributed to each applied weight of the two links that connect the concept $C_i$ and $C_j$ and it is defined as follows:

$$r_{\max} = Max(r_{increase}, r_{decrease}) \qquad (9)$$

therefore, definition 1 is written in our case study as follows:

***Defintion 2** : princile of Kosko causality with reward*

*($C_i$ causally increases $C_j$) **iff** ($Q_i \subset Q_j$ and ~$Q_i \subset$~$Q_j$) **and*** $r_{Max}= r_{increase}$.

*($C_i$ causally decreases $C_j$) **Iff** (~$Q_i \subset Q_j$ and $Q_i \subset$~$Q_j$) **and*** $r_{Max}=r_{decrease}$.

Based on the theoretical aspects described above, the pseudo code of Algorithm 1 summarizes our aproach [29][30].

**Algorithm 1**: Pseudo code of the proposed approach

**Step 1:** Read the vector $A^{(k)}$ and weight matrix $W$

**Step 2:** Calculate the output vector $A^{(k+1)}$ : $A^{k+1} = f(A^k + \sum A^k W)$

**Step 3:** Depending on the response of the environment:

If $r_{action}$ = 1 / / Award

(Updating by increasing the probability $P_{ij}$ and the Q value function according reward $r_{action}$ associated to action)

$Q^{k+1}(s_i, a_i) = Q^k(s_i, a_i) + \alpha[1 - Q^k(s_i, a_i)]$

$P^{k+1}(a_i) = P^k(a_i) + \beta[1 - P^k(a_i)]$

If $r_{action}$ = o / / Penalty

(Updating by decreasing the probability $P_{ij}$, and the Q value function according reward $r_{action}$ associated to action)

$Q^{k+1}(s_i, a_i) = (1 - \alpha) Q^k(s_i, a_i)$

$P^{k+1}(a_i) = (1 - \beta) P^k(a_i)$

**Step 4:** If the termination conditions are realized Stop. Otherwise go to Step 2.

Thereafter, the organization evaluates its actions towards its environment by the feedbacks of the latter (in the form of positive or negative answers) by updating its decision-making policy that allows it to adapt and improve its behavior towards its economic and social partners.

The following table 3 represents the initial matrix of the reinforcement learning extended fuzzy cognitive maps RL-EFCM that model the software project studied in this paper and summarizes the different weights between the concepts of the map. Especially the links that express the behavioral adaptation, in particular the concept High cost $C_8$ and its links with the concepts Bad schedule $C_1$ with weight $w_{81}$=*-0.25*, Technological aspects $C_4$ *with weight* $w_{84}$=*-0.25* and deficient developers $C_5$ with

weight $w_{85incfrease}$=+0.50 if $C_8$ increases $C_5$ and with decreases weight $w_{85decrease}$=-0.50 in case where $C_8$ decreases $C_5$.
In the next paragraph 6, we discuss the results obtained after simulation of the SPM model in the proposed approach and in the conventional FCMs approach. This simulation is carried out under Matlab version R2014.a, but before we start the discussion, we show the three types of conditional, nonlinear, and temporal links used in this case study.

- Conditional weight:

Risk factors Bad Schedule and Budget Limitation conditionally influence Time delay and High cost risks.

$$(C_1 \oplus C_2) \rightarrow (C_8 \oplus C_9) \quad (w_{18} = +0{,}7,\ w_{29} = +0{,}6)$$

- Duration weight:

The risk factor Technological Aspect influences the concept of Time Delay risk with variable duration.

$$C_4 \rightarrow C_9 \quad (w_{49} = +0{,}8)$$

- Nonlinear weight:

The risk factor Deficient developers influences the concept risks Low Performance and Time Delay in a nonlinear way as explained above.

$$C_5 \rightarrow (C_6 \oplus C_9) \quad (w_{56} = +0{,}2,\ w_{59} = +0{,}2)$$

## 5. Results and Analysis

Simulation of the prototype associated with the SPM model of figure 4 is carried out under MATLAB R2014a. The two scenarios are represented by the results obtained in table 5 in the case where the concept $C_8$ decreases concept $C_5$ and in table 6 where the concept $C_8$ increases the concept $C_5$. It can be seen that the best result is obtained in the case where the $C_8$ concept decreases the $C_5$ concept.

**Table 3.** Initial matrix Reinforcement learning FCM (RL-FCM)

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.7 | 0 |
| $C_2$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.6 |
| $C_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.4 | +0.4 |
| $C_4$ | 0 | 0 | 0 | 0 | 0 | 0 | +0.5 | 0 | +0.8 |
| $C_5$ | 0 | 0 | 0 | 0 | 0 | +0.2 | 0 | 0 | +0.2 |
| $C_6$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $C_7$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $C_8$ | -0.25 | 0 | 0 | -0.25 | ±0.5 | 0 | 0 | 0 | 0 |
| $C_9$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 4.** Actions probabilities and Q-function values with α, β=0.5

| Action $a_i$ | Initial Probability $P(a_i)$ | Final Probability $P(a_i)$ | $Q(s_i, a_i)$ | Initial Value | Final Value |
|---|---|---|---|---|---|
| $(C_8, C_1)$ | 0,25 | 0,25 | $Q(C_8, C_1)$ | 0 | 0,25 |
| $(C_8, C_4)$ | 0,25 | 0,25 | $Q(C_8, C_4)$ | 0 | 0,25 |
| $(C_8, C_5)$ ***increase*** | 0,25 | 0,125 | $Q(C_8, C_5)$ ***increase*** | 0 | 0 |
| $(C_8, C_5)$ ***decrease*** | 0,25 | 0,625 | $Q(C_8, C_5)$ ***decrease*** | 0 | 0,50 |

Table 4 gives the probability and the Q function quantity values before the simulation, the initial values, and after the simulation, the final values, obtained by application of our algorithms 1 while taking into account the natures of the different weights described above. In the next simulation our simulator will consider the model with the weight that will decrease the concept of deficient developers $C_5$ from high cost concept $C_8$ as being the action taken by the organization to adapt to its environment.

**Table 5**. Simulation Results with decrease weight from $C_8$ to $C_5$ as the best weight

| Concept | Initial Values | Final Values | Activation Function | Transfert Function | Number of Itérations |
|---|---|---|---|---|---|
| 1. $C_1$ | 1 | 0,59937409 | A+AW | Sigmoid | 24 |
| 2. $C_2$ | 0 | 0,65904607 | | | |
| 3. $C_3$ | 0 | 0,65904607 | | | |
| 4. $C_4$ | 1 | 0,59937409 | | | |
| 5. $C_5$ | 1 | 0,69329384 | | | |
| 6. $C_6$ | 0 | 0,74556292 | | | |
| 7. $C_7$ | 0 | 0,76593465 | | | |
| 8. $C_8$ | 1 | 0,78606504 | | | |
| 9. $C_9$ | 0 | 0,65904607 | | | |

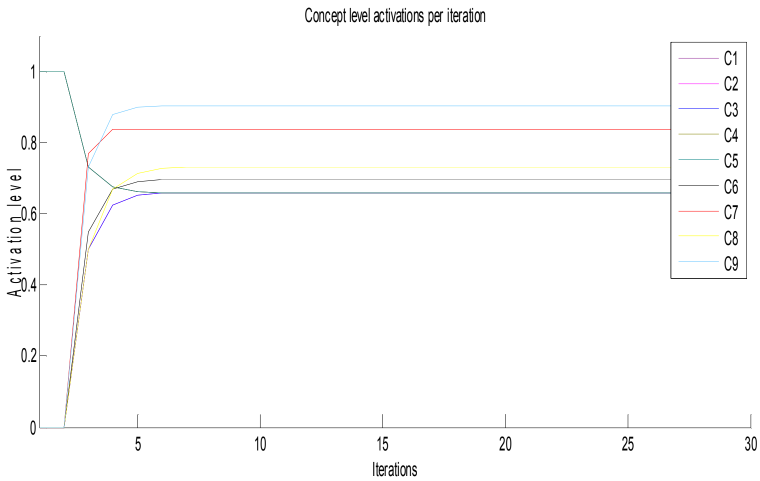


Figure 5. Concept values evolution, the reinforcement learning E-FCM converge in 24 steps.

**Table 6.** Simulation Results with increase weight from $C_8$ to $C_5$.

| Concept | Initial Values | Final Values | Activation Function | Transfert Function | Number of Itérations |
|---|---|---|---|---|---|
| 1. $C_1$ | 1 | 0,82352251 | A+AW | Sigmoid | 32 |
| 2. $C_2$ | 0 | 0,65904607 | | | |
| 3. $C_3$ | 0 | 0,65904607 | | | |
| 4. $C_4$ | 1 | 0,97252654 | | | |
| 5. $C_5$ | 1 | 0,85343066 | | | |
| 6. $C_6$ | 0 | 0,74556292 | | | |
| 7. $C_7$ | 0 | 0,76593465 | | | |
| 8. $C_8$ | 1 | 0,78606504 | | | |
| 9. $C_9$ | 0 | 0,65904607 | | | |

## 6. Discussion

In this paper the What-If Analysis technique is automated and used and has been effectively applied to a variety of processes. It can be useful in other processes per example in job shop scheduling with mechanical systems such as production machines. The results of the analysis are immediately available for managers and usually can be applied quickly. On behalf the firm to be able to make an adequate decision, it has to compare the simulation of its SPM model, in our case study, with two links (increase, decrease) from concept $C_8$ to concept $C_5$. Similarly, in our proposed approach, another's situations can arise, in which concept influences another concept with two weights (increase, increase) or with two weights (decrease, decrease). Initially the vector $A$ is taken as follows (1 0 0 1 1 0 0 1 0) where the value 1 means that the concept is active, otherwise it is inactive. The results for both the FCM and RL-E-FCM methodology and their comparison are presented in Table 7.

**Table 7.** FCMs and proposed RL-E-FCMs comparaison results.

| Method used | Results | Conclusion |
|---|---|---|
| Classical FCM | Final concept values are<br>***$C_1$ 1.00***<br>*$C_2$ 0,65904607*<br>*$C_3$ 0,65904607*<br>***$C_4$ 1.00***<br>***$C_5$ 1.00***<br>*$C_6$ 0,69586237*<br>*$C_7$ 0,83569675*<br>*$C_8$ 0,72975341*<br>*$C_9$ 0,90204315*<br>This shows factors risk $C_1$, $C_4$ and $C_5$ are after simulation also active. | In classical FCMs, there is no consideration of the propriety of the links found in the studied systems such as: the notion of time, conditional relationship between concepts and the non-linearity of links. |
| RL-EFCM with decrease weight | Final concept values are<br>*$C_1$ 0,59937409*<br>*$C_2$ 0,65904607*<br>*$C_3$ 0,65904607*<br>*$C_4$ 0,59937409*<br>*$C_5$ 0,69329384*<br>*$C_6$ 0,74556292*<br>*$C_7$ 0,76593465*<br>*$C_8$ 0,78606504*<br>*$C_9$ 0,65904607*<br>In this case all the concepts are flattened and none of them is active, therefore the organization can judge that the problem will be solved if it performs the chosen actions. | In this simulation all the risk factors are inactive, which means that the decisions taken by the organization are good and optimal. The best connection retained is where the concept $C_8$ decreases the concept $C_5$. |
| RL-EFCM with increase weight | Final concept values are<br>***$C_1$ 1***<br>*$C_2$ 0,65904607*<br>*$C_3$ 0,65904607*<br>*$C_4$ 0,97252654*<br>*$C_5$ 0,85343066*<br>*$C_6$ 0,74556292*<br>*$C_7$ 0,76593465*<br>*$C_8$ 0,78606504*<br>*$C_9$ 0,65904607*<br>This shows factors risk $C_1$ after simulation also active and it means that the problem is not solved for the organization. | Here we have a $C_1$ concept that stays active and so the problem is not solved completely. |

## 7. Conclusion

The nature of software projects generates many risks that must be managed carefully to avoid the project's loss. In this paper we have presented E-FCMs improved by introducing of a connection between reinforcement learning and extended fuzzy cognitive maps for studying risk analysis and management in software projects. In this way we can summarize our contribution in relation to Axelrod and Kosko by a new cognitive map where a concept can increases and decreases another concept according to environmental conditions. Here we point out that in the proposed approach, if all the appropriate What-If questions are not intuitive, they can immerge from simulation and so the answers to this questions.

Computer simulation results have demonstrated the effectiveness of the efficient connection between reinforcement learning paradigm and E-FCMs proposed in this article and will seriously improve the behavior of E- FCM and so FCM which are adapted to study of RAM system. We have also presented an improvement formulation of Kosko causality principle in which one concept increases or decreases another concept according to environmental conditions. The work is realized under MATLAB R2014.a platform version.

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