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# Feedback generation using Fuzzy Cognitive Maps to reduce dropout in situation-aware e-Learning systems

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***Abstract*— E-learning is becoming increasingly popular among learners of any age, thanks to its many advantages related to the possibility to learn anywhere and anytime and the low costs. Despite this success and diffusion, the student dropout rate of e-learning systems is very high. The main reason is the lack of motivation and engagement of the students with the online course. An adequate design of the e-learning system and its capability to adapt to the characteristics of the learners can reduce the dropout rate. In this work, we propose an approach, based on Fuzzy Cognitive Map, to identify the situation of the learner (mainly in terms of motivation and engagement) and to provide the learners with a set of feedback aiming at improving the retention of the learners in a situation-aware adaptive learning system. A prototypical system is proposed to preliminary verify the feasibility and utility of the approach.**

***Keywords—Situation Awareness; Fuzzy Cognitive Map; e-Learning.***

## I. Introduction

The electronic learning (e-learning) has become increasingly important in recent years, involving all the levels of education, from primary school to workplace and lifelong learning, in many domains [1]. This is mainly due to the many advantages, of e-learning, like the possibility to learn anywhere and anytime, the reduced costs, the capacity of reaching a wider audience, etc. However, a common issue of many e-learning platforms is the frequent lack of motivation and engagement of the students, which leads to a high student dropout rate from the e-learning platform, thus vanishing all the efforts of teachers and learning creators and without any significant improvement in the learning processes.

An e-learning platform, in order to be effective in retaining the learners and supporting them in reaching their learning objectives, cannot limit its duties to the simple learning contents delivery. Rather, it should support the learners in their entire learning process, by adapting its behavior to the specific characteristics, preferences, and situations of every single learner. Consequently, the e-learning system should be an adaptive system in the sense that its behavior should adapt to the learner's needs [2]. In previous works [3]-[6], we defined the Situation-aware Adaptive Learning System, an e-learning system for seamless learning able to identify the situation in which the learner is involved thus to support her to achieve her learning objectives. The situation, in this case, was defined according to the learning process: it takes into account the number of completed learning activities, the current learning goals, the way by which the learner chooses her tasks, etc. In this first proposal of a situation-aware adaptive learning system, the situation of the student takes into account only the aspects related to the learning activities. As aforementioned, one of the major drawbacks of the e-learning system is the high student dropout. For this reason, this work explicitly focuses on the reasons leading to student dropout in e-learning systems. Many studies and researches [7] identify low motivation and low engagement of the students as the main factors leading to student dropout. For these reasons, we expand the previous definition of the learner's situation by considering the concepts of student motivation and engagement as a fundamental part of the situation. In such a way, a situation-aware adaptive learning system will be able to monitor motivation and engagement and will be able to anticipate a possible learner dropout and react accordingly [8] .

The objective of the work is to identify the current situation of the learners by measuring their level of motivation and engagement through the analysis of their behavior in an e-learning platform. According to these levels, the system sends feedback to the students to maintain and increase their motivation and engagement. Different kinds of feedback can be sent to the learners with further information, stimulus, new content, encouragements, and hints, etc., with the aim to retain learners in the platform. This approach mimics the role of the teacher in the classroom, which, among the other things, has the duty to understand the situation of the students and, when needed, has to stimulate, motivate and encourage the students for achieving their learning goals. In this work, we propose an approach for feedback generation which uses a Fuzzy Cognitive Map to analyze the situation of the learner in terms of her engagement and motivation. According to the levels of engagement and motivation, the most suitable feedback is generated and presented to the learner. A prototypical system has been implemented to preliminary verify the feasibility of the proposed approach.

## II. Background Knowledge: Fuzzy Cognitive Map

A Fuzzy Cognitive Map (FCM) [9] is a graph structure for representing casual relationships. It is suitable to represent and correlate, in a symbolic nature, events, processes, states. In a FCM, a node of the graph is called concept and an edge is called weight. The edge allows for implementing a causal relationship between two concepts, and the weight represents the strength of the influence of the relationship, described with a fuzzy linguistic term (e.g., low, high, very high, etc.). Formally, a FCM is a 4-tuple ($N$, **E**, **C**, $f$), where

1. $N = \{N_1, N_2, \dots, N_n\}$ is the set of $n$ concepts which are represented by the nodes of the graph;
2. $\mathbf{E} : (N_i, N_j) \rightarrow e_{i,j}$ is a function ($N x N \rightarrow [-1,1]$) which associates the weight $e_{i,j}$ to the edge between the pair of concepts ($N_i$, $N_j$);
3. $\mathbf{C} : N_i \rightarrow C_i$ is the activation function which associates to each concept $N_i$ a sequence of activation values, one for each time instant t: $\forall t$, $C_i(t) \in [0,1]$ is the activation value of the concept $N_i$ at time $t$. $\mathbf{C}(0) \in [0,1]^n$ is the initial activation vector containing the initial values of all the concepts; $\mathbf{C}(t) \in [0,1]^n$ is the state vector at a certain time instant $t$.
4. $f$: $\mathbf{R} \rightarrow [0,1]$ is a transformation function with a recursive relation for $t \geq 0$ between $\mathbf{C}(t+1)$ and $\mathbf{C}(t)$:

$$\forall i \in \{1, \dots, n\}, C_i(t+1) = f\left(\sum_{\substack{i=1 \\ j \neq i}}^{n} e_{ji} C_j(t)\right) \quad \text{(Eq. 1)}$$

Different kinds of functions can be used as f(x), like the sigmoid function, the logistic function or the linear function. The FCM can be used to make what-if inference, starting from a given initial activation vector C(0), to understand what will happen next to the modeled system/environment. In our case, we will use an FCM to understand what happens to some variable representing the learner's situation (e.g., her motivation and engagement) considering for the activation vector, a sequence of known values regarding her activities in the e-learning platform (e.g., number of completed lessons, number of posts, etc.).

## III. An Approach to Feedback Generation based on Fuzzy Cognitive Maps

The approach defined for generating feedback considering the situation of the learner is depicted in Fig. 1. We refer to the situation-aware adaptive learning system described in [3]-[6] to define this approach. This platform, besides the traditional ways for presenting learning contents and assignments to the students, has also social learning features, like a forum and a social messaging tool used by the students and teachers to communicate.

The approach starts by analyzing the information regarding the learner, gathered by the e-learning platform. Some of the information to identify the situation of the learner is:

- n° of chapters/sections: the courses in an e-learning system are typically organized in chapter or sections. This data is the number of chapters or sections the learner has completed;
- n° of videos: the number of videos the learner has seen on the platform;
- n° tasks done: the number of tasks the learner has completed for each assignment;
- n° of posts/questions: the number of posts/questions published by the learner on the forum;
- last event: the date on which the learner has performed the last action on the platform;
- last lesson: the date on which the learner has completed a chapter/section;
- last forum activity: the date on which the learner has published a comment/post on the forum.

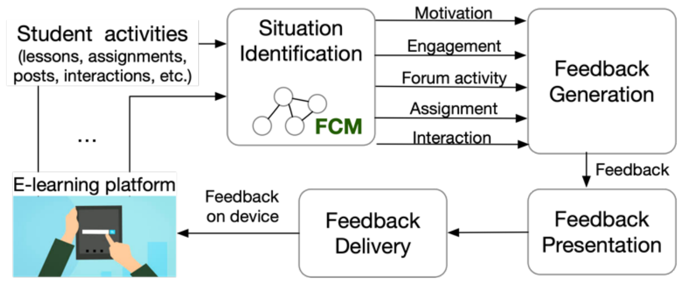


Fig. 1. Overall approach for feedback generation to reduce dropout.

Furthermore, in order to have an accurate evaluation of the learner's motivation, we submit a survey through the platform and collect the answers of the learner at regular time intervals [7]. All the collected information is used as input of the FCM which allows identifying the situation of the user, consisting of the following indexes:

- motivation: the level of interest of the learner in the course;
- engagement: the level of involvement of the learner with the platform, and her availability and predisposal to participate in learning activities and to complete tasks;
- forum activity: the level of activity and participation of the learner on the forum or, in general, the participation in the social activities;
- assignment: the level of completion of the assignments and tasks of the learners;
- interactions: indicates how much the learner interacts with the platform.

Section III.A describes the FCM that computes the aforementioned indexes. The situation of the learner is used in the "Feedback Generation" phase of the process in order to identify the feedback needed to maintain or increase the level of engagement and motivation to retain the student in the online course. Section III.B describes this phase with further details. Once feedback has been selected, it should be presented to the learner. The feedback can be presented using different media formats, like text, images, audios, videos, etc. Lastly, the feedback is delivered to the learner by using the appropriate format for the device of the learner (notebook, smartphone, etc.).

### A. *FCM for learner's situation identification*

The Fuzzy Cognitive Map (FCM) which identifies the indexes composing the situation of the learner is depicted in Fig. 2. Such FCM has been defined by leveraging on the work of Xiong et al. [7], which defined a structural equation model of

Fig. 2. Fuzzy Cognitive Map for learner's situation identification.

motivation and engagement of the learner and the factors that influence them. The inputs of the FCM are the values of the variables described in the previous section. Each of these values is transformed into an activation value of the corresponding concept in the FCM. The casual relationships between these and the concept values related to the indexes representing the learner situation (motivation, engagement, forum activity, interactions, and assignment) allow to infer the current situation of the learner, by applying the function in Eq. 1. Specifically, we use the linear function as the transformation function *f*:

$$C_i(t+1) = \alpha \sum_{\substack{i=1 \\ j \neq i}}^{n} e_{ji} C_j(t) \qquad \text{(Eq. 2)}$$

The weights on the edges of the FCM have 9 values, in the range [0.0, 1.0], each one with an associated linguistic term, as depicted in Fig. 2.

The concept `Assignment` is influenced by the number of `Task Done` by the learner. The `Forum Activities` concept is influenced by the date of the last forum activity and by the number of posts published by the learner. Another important concept is the `Interactions`, which takes into account the level of interaction with the system. It is influenced by: the date of the last action made by the learner (`Last Event`), the date of the last lesson completed by the learner; and by the percentage of video seen by the learner. It is also influenced by the activities performed by the learner in a given session. A session represents the time interval that we want to analyze to identify the situation of the learner. Usually, such analysis is performed weekly. We represent this with the `Session` concept. The `Session` concept is influenced by the number of chapters completed by the learner; the number of posts published by the learner and the number of seen videos during the considered session. The session influences the `Interactions` concept. The `Interactions`, `Assignment`, and `Forum Activities` concepts influence the level of `Engagement`. The concept of `Motivation` consists of three different dimensions, as highlighted by Xiong et al in [7]: intrinsic, extrinsic and social motivation. Each of these dimensions is represented by a concept in the FCM and influences the concept of `Motivation`, together with the `Forum Activity` concept, which represents how much a learner uses the forum. The levels of intrinsic, extrinsic and social motivation are identified by means of a survey administered to the learners at regular time intervals (usually at the end of each session, in order to perform a complete analysis of the learner's situation) as suggested in [7].

### *B. Feedback Generation Process*

The FCM computes the values of the indexes representing the learner's situation. Starting from these indexes, the Feedback Generation phase in Fig. 1 identifies the most suitable feedback to send to the learner to improve her current situation. The Feedback Generation phase consists of different steps, depicted in Fig. 3. The phase is divided into two main steps: "Feedback Classes Generation and Selection" and "Feedback Generation and Selection". The former identifies a class of feedback using the values of the concepts `Motivation` and `Engagement`. A class of feedback comprises all the feedback that could be effective in that situation, considering only motivation and engagement. From this category, the second step selects one single feedback by considering the activation values of the concepts `Forum Activity`, `Interaction`, and `Assignments`.

In the first step, the value of `Motivation` and `Engagement` are discretized in three ranges: Low [0.0, 0.33]; Medium [0.34, 0.75]; High [0.76;1.00]. A subset of classes of feedback for pairs of motivation and engagement values are reported in Table I. The sets of feedback to be used in each of these four situations has been identified by combining and harmonizing the results of the works of Jung and Lee [10], Abeera and Miria [11], El-Seoud et al. [12]. As an example, according to these works, when both motivation and engagement have a low value, some correcting actions and learning support actions should be taken to improve the learner's situation. When the values are in the medium range, instead, it is better to send hints and praises to the learner. The Feedback Class Generation step proposes a set of classes for each situation, as can be seen in Table 1. In order to proceed with the next step, only one single class should be selected in the proposed set of classes (see Fig. 3). This process can be completed automatically or a teacher can take part in this selection. In this case, we want to give the teacher the possibility to exploit her expertise to improve the process of feedback selection, while giving her the possibility to influence the feedback generation and delivery. In such a way, the proposed approach works like a decision support system rather than a completely automatic system.

Fig. 3. Feedback generation process.

The idea is to improve the capability of the teacher in analyzing learners' behavior and providing feedback, combining the accuracy of the proposed computational approach with the experience and feelings of the teacher.

| Engagement | Motivation | Feedback Classes |
|---|---|---|
| Low | Low | Clarity of explanation<br>Visualization of abstract concepts<br>Support and communication<br>Variety of assignment |
| Low | Medium | Teaching presence<br>Academic self-efficacy<br>Perceived usefulness |
| Medium | Low | Build study groups to reduce the student's isolation<br>Give students various choices<br>Use different type of examples<br>Add a variety of types of activities |
| Medium | Medium | Praise effort<br>Mark milestones to show progress<br>Turn everyday task into a fun competition<br>Gamification process |

Table 1. An extract of the feedback classes for engagement and motivation

Once the appropriate feedback class has been identified, the second step identifies the specific list of feedback that can be used. The list of feedback is identified according to the other three concepts included in the learner's situation: `Forum Activity`, `Interactions`, and `Assignments`. As in the previous step, the three values are discretized in the three ranges, Low, Medium and High, and for each combination of values, a list of feedback is generated. The Feedback List Generation (Fig. 3) produces a list of feedback, among which the system (or, optionally, the teacher) will select the specific feedback that will be sent to the learner.

## IV. E-Learning System Prototype

The proposed approach for feedback generation has been implemented into an e-learning system prototype, currently in development at the CORISA[1], in the context of the research project MOLIERE. One of the objectives of this project is the adoption of a motivational approach to learning by creating an engaging experience for the learner, in order to reduce the student dropout in interactive teaching. The prototype is implemented with an MVC architecture developed using the opensource Play 2.7 framework[2], AKKA[3] and Java. The Fuzzy Cognitive Map has been implemented using the Java library JFCM [13]. The data gathering and processing has been realized using the architecture of the Adaptive e-Learning System described in our previous works [4][5][6].

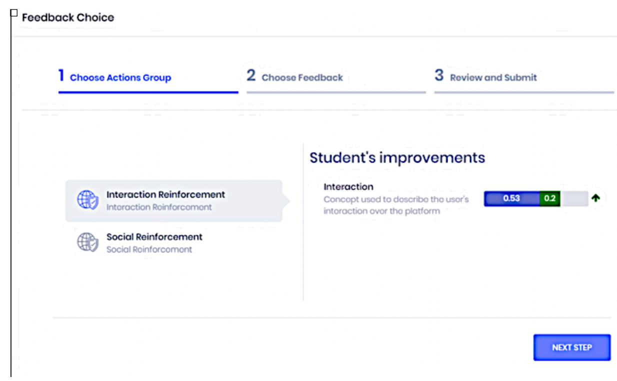


Fig. 4. Selection of the feedback class.

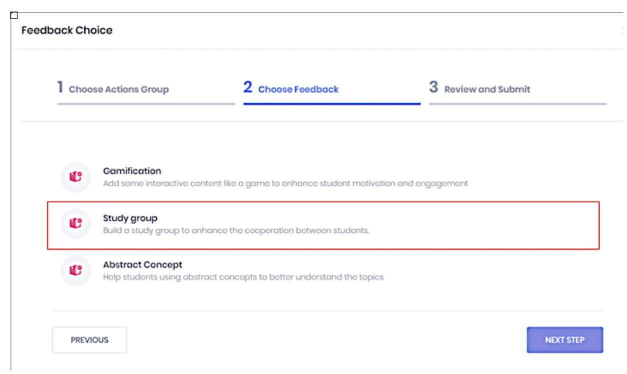


Fig. 5. Selection of the feedback.

Let us consider the following scenario to demonstrate how the proposed approach works. A student has the objective to pass the exam of Algorithms and Data Structures with a good vote. Unfortunately, he does not have much experience with programming and computer science, and the lessons are quite demanding. Even if he has done a good job with many tasks of the assignment of the course on the platform, the obtained results are not satisfying. Therefore, he started to diminish his

[1] http://www.corisa.it
[2] https://www.playframework.com/
[3] https://akka.io/

interaction with the platform, since he is currently discouraged by his latest results. The teacher, thanks to the analysis made via the platform, noted this situation and decide to intervene to send feedback to the student. The teacher uses the view of the system depicted in Fig. 4 in order to analyze the situation of the student. Specifically, the FCM analyzed the situation of the student and identify that he has a low level of motivation and a medium level of engagement. Between the different classes that the system proposed to the teacher (in Fig. 4), the teacher decided to use the approach "Interaction Reinforcement", which includes all the actions to stimulate the student in interacting again with the platform. The interface in Fig. 4 shows also a prediction of the student's improvement in terms of motivation. In the subsequent step, the system proposes a list of feedback that can be sent to the student, belonging to the chosen class of feedback (Fig. 5). The teacher selected the "Study Group" to suggest the student participating in a study group on the platform to improve his performances. The selected feedback is sent to the student as a new notification, showed both on his homepage and in the notification area, as depicted in Fig. 6. In this case, the student is invited to participate in the study group.

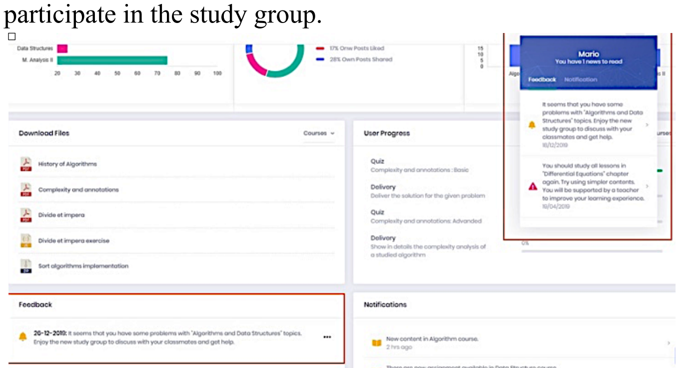


Fig. 6. Delivery of the feedback to the student.

## V. CONLUSION AND FUTURE WORK

An e-learning system can be a valid approach to support learners in achieving better results and fulfilling their learning goals, even autonomously. A main challenge with the e-learning platform lies in the high rate of student dropout due to the lack of motivation and engagement. In this work, we proposed an approach for feedback generation aimed at improving the learners' motivation and engagement within an adaptive e-learning system in order to reduce student dropout. A Fuzzy Cognitive Map has been implemented to identify the learner situation by analyzing her activities on the platform. The identified situation is then used to identify the most suitable feedback that should be sent to the learners to improve their motivation and engagement. Regarding future work, we are currently evaluating the prototypical system, realized in the context of the MOLIERE project, with the participation of university students. The hypothesis we want to test during the evaluation is if an increase in the students' situation awareness regarding their learning process may lead to an increase in student motivation and engagement, thus reducing student dropout. Furthermore, we will extend the definition of learner's situation by including other types of contextual information, as activities the learner is performing outside the e-learning system, to better measure motivation and engagement. Lastly, we will improve the automatic feedback selection mechanism of the system by considering the decisions made by the teachers. The decisions of the teachers for each learner's situations could be considered as feedback that can be considered in reinforcement learning algorithms to improve the automatic selection strategy.

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