Modeling a VGSCL System to Analyze Collaboration

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Abstract—Several studies claim for the benefits that collaborative learning has to the students’ comprehensive development as well as many benefit of introducing new technologies into the educational field. By other hand, interaction analysis in collaborative learning processes has become an important research field. Starting from these two realities, this work presents the modeling of a Video Game Supported Collaborative Learning System (VGSCL). By using these models, we will be able to analyze the quality of collaboration occurred during this process and to make the players’ learning processes better.

Index Terms—CSCL, Educational Video Games, Players and Group Modelling, Collaboration Assessment.

I. INTRODUCTION

Several studies, such as those cited in [12], claim for the importance of games in the children’s development process. Also, it is proved enough that games favor many social and cognitive skills. In particular, the Vygotsky’s theories are worth mentioning: He presents the game as a test space. From this standpoint, game promotes the comprehensive development of children since it allows them to test rules, capabilities or constraints that they will use in real situations latter.

Nowadays, the video games are the preferred games for children (and adults). Although one could think that video games are funny or entertainment devices only, several studies (i.e. [8], [4]) show that they are powerful personal and educational tools for children.

The most important type of video game for our research is educational videogames, which teach some contents related to the scholar curriculum. So, following the model presented by Vygotsky [7], the game acts as “mediator” in the learning processes because educational contents are hidden inside the game. One of the factors that contribute to the success of this type of videogames is the fun component since students, became into players, face the educational challenges without be aware of it [5]. So, the design of educational video games must be done without losing the basic relaxation element. To do this, it is necessary to have a good story and to design video game’s tasks in order to achieve a relation in which to pass a funny task can be equivalent to pass the educational content inside it.

Specifically, our interest is focus on the use of collaborative activities in educational video games. It has an additional difficulty in the design process because new relations and premises in group tasks appear. So, we have defined a set of design guidelines [9] to do the design of educational video games with collaborative activities easier in order to favor collaborative processes between group members and to keep the many advantages that this type of learning has [3], [6]: Students learn to value another standpoints, enhance their levels of respect and tolerance, they learn to engage with partners and to share with other the responsibility of common success or failure.

If we want that students obtain all benefits from collaborative learning, it is necessary that collaboration be effective: Some people around the same table and working in the same task can be working in a non-collaborative way [1]. So, collaboration occurring in a task must be analyzed to allow introducing some changes to do this collaboration better and to observe the groups’ evolution along the time. To achieve this goal, we need to record and to organize all useful information in order to analyze it later. The only way of getting it is to model the system properly and exhaustively, recording interesting data about players, groups, and the game process.

In addition, we need to store some of this information permanently in order to analyze the progress of students about their learning and collaboration along the time.

So, in this paper we present a proposal about the models that we think that are necessary to assess the collaboration
quality during the learning process and to increase possibilities of better results.

The paper is organized as follows: In the section II we show the main characteristics and elements of VGSCL systems. In the section III we explain in detail the model proposal. Finally, in the section IV some conclusions and future works can be read.

II. DESCRIBING THE VGSCL SYSTEM

Our objective is to give to teachers a tool with which students can achieve educational goals in an attractive way. One of the most complex elements in this tool is the possibility of including mechanisms to intervene in the students' collaborative process and to do this collaboration better. In this way, the learning can be better too. For this reason, we have to give significant information to the teacher about the collaborative learning to allow him to act in a really effective way.

In particular, our proposal is a system for collaborative learning by means of videogames (Video Game Supported Collaborative Learning, VGSCL). As we have mentioned earlier, it is necessary to model what players make during the game and to draw some conclusions from it in order to do an exhaustive analysis of collaboration and others aspects that can have influence on learning. To do these models, we have into account three main elements in the collaborative learning: 1) educational and recreational goals, 2) educational and recreational tasks and 3) interaction between players/students.

A. Goals

Goals that a student (player) must face during the learning process can be educational or recreational and both of them are related since recreational goals contribute to achieve educational goals, as we define in the Tasks and Goals Model (section 3, A). In both cases, the set of goals is dynamic because it can change along the match.

According to the number of people that faces a goal, we have two types: individual and group. Individual goals must be achieved by each of players without be helped; group goals must be achieved by the group in a common way. Group goals favor interdependence between group members.

By other hand, group goals can be divided according to the number of players that can pass it each time. So, we have: competitive goals and non-competitive goals. Competitive goals are those that can be passed by one player each time. In this case, when a player wins, the rest of players usually lose. This kind of goals is not used to be presented at educational level, but they are especially important at recreational level because they suppose an additional motivation. Non-competitive goals can be achieved by all players independently of some players pass it before than others.

Individual and Group goals can be assigned by the teacher or by players (students) themselves. In the first case, the teacher assigns some goals to the player that has to achieve them. This option is used when the teacher thinks that a player must learn, practice or reinforce a specific part in the curriculum. So, he wants that learner make educational goals related to educational goals that he needs. In the second case, each player faces the goals that he wants during the game. This option is used when the group level regarding to the didactic contents is homogeneous and students are able to decide which aspects they prefer to learn. By using this second way of play we favor planning and taking decisions skills in students.

B. Tasks

To achieve their goals, players (students) must carry out a set of tasks. The way in which tasks are related to goals is shown in the Tasks and Goals Model, that will be explained in section 3, A. In some cases, to achieve a goal, students can carry out different subsets of tasks. Similarly to goals, the set of tasks that can be carried out to achieve a goal can be assigned by the teacher of by students themselves. To pass a task, students must carry out a set of activities, which will have a set of resources to do it. Tasks can be individual or group, and we distinguish three types in group activities:

- Simultaneous: All group (or sub-group) members working in the task have to face each activity at the same time. This kind of tasks favors collaboration inside the group and, in an indirect way, individual learning for each group member.
- Ordered task: To achieve the task some group members must take part. It is not necessary to do it at the same time, but activities must be done in a specific order. So, to do an activity, the previous ones must be achieved before. Constraints about order can affect some of the activities in a task, and not others. In any case, this way of facing tasks favors interdependence between group members because they are aware of they need the partners to achieve the task.
- Non-ordered task: Each player can carry out his part (subset of activities) when he wants and it does not have any influence in the rest of the group members’ work. To achieve a task they only have to do the corresponding activities. This kind of tasks, in a similar way that ordered tasks, improve cooperative attitudes since group members face the task as a team, but they have responsibilities only in a part of it.

Regarding to the way in which players can achieve a goal, we allow three game modes:

- Free: A player (student) faces the tasks that he wants and which goal is passed with these activities does not matter.
- By goals: A player (student) can only face tasks that help him to achieve his goals. We have two possibilities:
  - All at the same time: A player has a set of available tasks regarding to the set of goals and he can carry out these tasks in any order.
  - One by one: A player must achieve a goal before faces another one. In this way, he cannot face a goal if he has not achieved the previous one. For this reason, he carries out tasks corresponding to one goal until this goal is achieved.

In a similar way as in goals assignment, the game mode can
be assigned by the teacher or the group can decide it, if they have capabilities to do it.

C. Interaction

During a collaborative learning process by means of video games, three types of interactions can appear: communication, collaboration and coordination. We think that to detect and to classify messages occurring between group members while they are interacting is a basic element in the analysis process. In order to do this classification easier, we have done a strong messages categorization [10], using three categories:

- Communication Messages: They are messages whose intention is to inform about something. For example, in this category we have: question and answers, sharing information, checking how the partners are working or social messages. The last kind of messages is this which is not related to the game, but informs us about relationships existing inside the group.

- Collaboration Messages: They take place during a collaborative situation, such as pose a proposal, ask for help or ask for resources.

- Coordination Messages: We use this kind of messages when we organize methods or strategies to achieve a goal. Taking decisions or planning tasks are included in this category.

III. MODELING THE VGSCL SYSTEM

Our proposal is a set of models focused on the analysis of the collaboration in the videogame with the purpose of perform future adaptations which improve collaboration between its users. Therefore, we do not model the complete VGSCL system. In particular, we define four interconnected and interrelated models: The Tasks and Goals Model represents the list of goals and tasks of the videogame, as well as their relations. The State of the Game Model stores information about the current game (goals, tasks and interaction). This information will also be processed to extract important information about each of the players and groups. The Player and Group Models maintain the evolution of each player and group and it is updated with the information extracted from the State of the Game Model at the end of each match.

A. Tasks and Goals Model

Since the educative videogames try to achieve an implicit learning (without the users be aware of their learning process), we consider that it is necessary to separately define the didactic goals and the recreational goals. However, both types of goals must be connected, so that when the user reaches a goal of the videogame he also achieves the didactic goal or goals associated with that satisfied recreational goal.

With this propose we establish two levels in the Tasks and Goals Model: 1) The Educative Level – $L_E$ (inferior layer in figure 1) and 2) The VideoGame Level – $L_V$ (superior layer in figure 1). We have named $tv_i$ the tasks included in $L_V$ and $te_i$ the tasks included in $L_E$. The relation among the tasks of both levels is named “implementation”. The videogame task, $tv_i$, implements the educative task, $te_i$, whether the task $tv_j$ in the videogame is useful for teaching the educational contents of the task $te_i$. This relation is represented with a continue line connecting the tasks in both levels (for example, $tv_3$ implements $te_2$ in Figure 1). In this way, for each task in $L_V$ a task (at least) in $L_E$ must implement it. Nevertheless, as we can observe in figure 1, not all tasks in $L_V$ have to be associated with tasks in $L_E$, since some tasks in the videogame can be entertaining, without any educational contents (equation 1).

$$tv_i \in L_V, te_j \in L_E, \forall j \exists i \mid tv_i \text{ implements } te_j$$

As shown in Figure 1, each task in $L_V$ can satisfy one or more objectives of the videogame. Similarly, a task in $L_E$ can satisfy one or more learning objectives. Although it can not be observed in the example in Figure 1, in both levels, the goals are organized in a hierarchy. The hierarchy allows us to structure a goal into sub-goals which are directly associated with tasks. A same sub-goal can be associated with several goals. In addition, tasks associated with a goal can be obligatory or optional to accomplish that goal. So, the players must perform all the obligatory tasks but not necessarily the optional tasks, which contribute additional aspects. In the model we use the symbol * to represent obligatory tasks and the symbol ? to indicate voluntary tasks. Due to a task can be associated to one or more goals, the optionally symbol must be written on each association, not on the task. Thus, a task can be obligatory for a goal but optional for another one. In addition, different ways of accomplish a goal can be established. Each way is defined as a specific subset of tasks that must be performed. For example, in order to satisfy the goal Objetivo v A, we can complete the obligatory tasks $tv_1$ and $tv_4$, or complete the obligatory task $tv_3$ and optionally perform the voluntary task $tv_5$. Each subset of tasks is identified by a sequential number, in the example, the subset $\{tv_1, tv_4\}$ has the number 1, and the subset $\{tv_3, tv_5\}$ the number 2. The intersection of the subsets of tasks can not be empty, so an optionally / optionally symbol can be labeled with several numbers separated by colons (Figure 1).

![Figure 1. Tasks and Goals Model.](image)

Finally, another aspect related to the Tasks and Goals Model is the set of tools that can be utilized to perform tasks. Basically, a player, while executes a task, can need two kinds
of tools: collaborative tools (chat, forum, discussion room, group stock, etc.) and game tools (a map of the virtual world, a key, a notebook, etc.). Each task has associated a set of tools, so it is possible to detect if the players have used all the available tools. In negative case, the teacher can promote the use of certain tool in the next games (for example, the discussion room makes that the students clarify their questions more easily, and in addition allows them to reach a consensus and extend the learned concepts).

Let’s see it with an example. Let’s suppose a game related to the language area in which we have three educational objectives: spelling, synonyms, and verbs. This game is inspired by the story of Snow White and the Seven Dwarfs. We have seven characters, who are the dwarfs. The video game’s objectives are three too: 1) Catch butterflies in the wood, 2) come into the witch’s house, and 3) wake Snow White up.

The objective 1) is individual. To achieve this goal each dwarf has to catch several butterflies. Each of these butterflies has a letter and he has to build a word by using this letters. The difficulty level can be modified according to the difficulty of the selected words, the number of letters in the word or by introducing some letters which do not contribute to build the word. To come into the witch’s house (objective 2) they have to achieve a group goal: they have to pair them off making couples of synonyms in order to be able to come into. If selected words are not synonyms, they cannot cross the door. The last objective (objective 3) is a group one. When they are in the house, one of the dwarfs takes a verb out from a trunk. According to the difficulty level, it can be an infinitive or a specific form of the verb. By using this verb and some of the built words, they have to make a sentence. When they have made the sentence, they put it in the potion’s book to obtain the potion that wake Snow White up.

B. State of the Game Model

The State of the Game Model stores information about the current game. We distinguish two parts in this model: individual players’ area and group’s area. This model is destroyed when the game finishes, therefore, it is a short-term model [11] which temporal life is limited to the duration of each the game.

Information maintained by this model is an events’ log. The log registers the events that we have defined as interesting, that is, all the significant events in the game. These events will be analyzed later to identify the relevant information about the players, the group and the context in which tasks are executed.

The group’s area registers information concerning to tasks that the group performs together. The individual players’ area keeps the information concerning to tasks performed by each player alone. In both areas, the following set of elements for each task is registered:

- The ID of the task, obtained from the Tasks and Goals Model. When the task is a group task, the type of task is also registered: non-ordered, ordered or simultaneous.
- The point of the game in which the task is being carried out: phase or level of the videogame in which the players are at this moment.
- The pursued goal: The goal of the videogame that the player or group desires to achieve by performing that task in that point of the videogame.
- Beginning of the task: Date and time in which the task starts.
- End of the task: Date and time in which the task finishes. Along with the beginning of the task, this data permits to know the duration of the task.
- The set of activities: For each activity developed during the task, the following data are registered: Beginning of the activity, end of the activity, number of failures, and obtained score.
- Other interesting events: Type of the event (check life, lend a resource, etc.), beginning of the event, end of the event and other data needed depending on the type of event.

In addition to the previous information, in the group’s area the following information is maintained for each task:

- The members of the group working on the task. Since all members have not taken part in all of the activities of a group task, we store the subset of members that execute each particular activity. This information allows the teacher to identify the degree of participation of each student during the educational process implemented in the videogame.
- The group members interchanging messages. For each activity, the messages sent are registered. Associated to each message we store the following data: date, time, communication tool, sender, recipient and content of the message. Through the messages’ log the teacher can track the processes of coordination and planning performed by the students.

C. Player and Group Models

They are long-term models [11] since their information persists during the whole learning process and it is updated with relevant information from the analysis of State of the Game Model.

From users’ point of view, it is necessary to use different models in collaborative learning systems, a Player Model for each of players in the group and a Group Model for the group itself. This is because, in this collaborative context, the Group Model represents more than the addition of its parts, that is, the addition of the Player Models that are part of the group.

As we commented previously, there are individual goals and group goals and they are different to each other but complementary. This also happens with the tasks.

Although this work is focused on the part of the model that registers the players’ activity, it is necessary to point out that our Player and Group Models also include the player's and
group’s profiles. For example, the preferences of the players and of the group or their experience are stored in these profiles. This information allows us to control the game execution. For example, the level of difficulty of the game will be higher for a player (student) with more educational goals achieved than another one with less educational goals achieved.

Regarding to the Group Model and based on group learning methods, we can distinguish two kinds of groups:
- **Formal Groups:** Students are grouped permanently for a long period of time, for example, a semester.
- **Temporal Groups:** Students are grouped for specific activities but this group disappears when the activity finishes.

Only for formal groups a long-term group model is needed. In this case, group’s information is updated after a match by analyzing information in the group zone of State of Game Model. So, the Group Model exists while the corresponding group exists in the learning process. For temporal groups, information is used to complete some aspects in the Player Models of players belonging to this group, but a Group Model is not created.

Specifically, elements in Player and Group Models are listed below:
- Educational goals proposed for the player / group: Teacher can assign a set of educational goals to each player / group in order to be solved in one or more matches.
- Educational tasks proposed for the player / group: Also, teacher can establish specific educational tasks that the player / group must achieve by using the game.
- Educational tasks achieved by the player / group: They are educational tasks that the player/group has completed properly in previous matches. For each task we store the date and the mark obtained. Also, we have to store values of experience and difficulty with which the player / group has overcome the task.
- Educational goals passed by the player / group: They are goals that the player / group have passed in previous matches. The realization date and the obtained note are stored for each task.
- Educational goals achieved by the player / group: They are goals that the player / group have achieved in previous matches. The degree of satisfaction can be deducted by the set of tasks carried out, applying specifications in the Tasks and Goals Model.

In addition, in the Group Model we store information about interaction occurring during group activities. From this information stored in the State of the Game Model, we can build a set of networks in order to study interactions inside a group. To build and to analyze these networks, we use formal methods from Social Network Analysis (SNA). In this kind of networks, a node represents a member of the group and a link between two nodes represents an interaction between these two particular nodes. Next, we explain the indexes that we extract from a network by using SNA in order to do our knowledge of interactions deeper:
- **The most prestigious node:** It is the group member who receives the greatest number of messages from his partners. It is related to personal accountability [2] needed for the collaborative learning since each of the partners must share his knowledge to the group and learn for his partners’ knowledge.
- **The most influential node:** It is the player who sends the greatest number of messages. It is named as most influential because he distributes more information by the network than his partners. Similarly to the previous one, it is related to the personal accountability of group members.
- **Network’s density:** It indicates the relation between the existing and possible links. By means of this value we can know if all group members are related and it informs us about the quantity of interaction [2] that occurs inside a group.
- **Adjacency matrixes:** We build an adjacency matrix for each of the types and subtypes of messages (section 2.1) sent between two nodes. This allows us to know how many messages in each category have been sent. After processing this information, a teacher can obtain SNA indexes or graphical representations that will allow him to detect several kind of problems (for example, two group members without any interaction or two many messages between two partners) and act to solve these problems.

### D. Integration of Models in the Analysis Process

The main objective of the proposed models is to analyze collaboration to do adaptations during and after the game. At the beginning of the game, the teacher assigns goals and tasks to players and groups and this information goes to the Player and Group Models (Figure 2, arrows A and B). During the game, the State of Game Model (section 3.2) registers actions performed by players and stores them in the player and group zone, depending on the type of activity. The State of the Game Model remains during the whole match. During this time, we can make analysis of the information in order to adapt some aspect of the game, apart from the final analysis, when the match is over. After the match, the whole State of the Game Model is analyzed and the information extracted from it is stored in the Player and Group Models (section 3.3).

![Figure 2. Integrating models for Analysis Process](image-url)
In this way, information transferred from the State of the Game Model (players' zone) to Player Models (Fig 2, arrow F1) outlines significantly how actors have performed during the match. For example, video game tasks and goals are translated into educational tasks and goals that are those that the Player Model stores. In this way, the teacher can assess the learning process in an easier way. The Tasks and Goals Model is used to do this transformation. If a player has solved several tasks regarding to the same educational content, the mark stored for this educational content is the average mark of all related tasks. The mark for a task is a lineal combination of the number of mistakes, the score awarded and the time spent in that task. Since we have a historical record, the teacher can observe the player's evolution along the time.

In a similar way, information in the State of the Game Model (group's zone) goes to the Group Model (Fig 2, arrow F2). Apart from transformations cited before, now we have to analyze messages stored in the log in order to classify them according to the message categorization and to build the adjacency matrixes in each level. Also, we have to calculate indexes in each network (section 3.3) in a match.

The Video Game Control Module checks that tasks faced by players are related to goals assigned by teacher (Fig 2, arrow C). Their act depends, among other factors, on the mode of game selected (section 2.2): If the teacher has proposed neither goals nor educational tasks, or if he has done it but a free mode of game has been set, the module doesn't impose restrictions on tasks. If goals have been proposed, the Control Model avoid to carry out a task that doesn't benefit to the current goal (if it is for one to one goals) or to some of the proposed goals (if it is all goals at the same time).

IV. CONCLUSION AND FUTURE WORK

In this paper we have proposed a set of models to analyze the collaborative learning in educational video games. We have presented a Tasks and Goals Model that implements the relationship between educational and recreational contents. So, the teacher knows the implicit learning that is obtained by performing each of the videogame tasks and goals. This relation makes the assignation and evaluation processes easier for teachers and allow them to know which contents are acquired by learners.

Also, we have defined two persistent models called Player Model and Group Model. These models' main aim is to outline relevant information, translate it into educational contents and show it to the teacher ordered in the time. This comes from the State of the Game Model, which stores all important events that occur during the game.

The Group Model is especially important because it can show information of the group activities to the teacher in real time. This allows us to take the necessary steps to improve the collaboration. So, the improvement in the collaborative processes has influence upon the improvement of the processes of individual and of the group learning.

At the moment, we work on the formal specification of the proposed models, without losing of view that we need a standard specification that allows their integration into other educational tools. At the same time, we are working on the method for collaboration assessment which will be based on social networks and on a new module included into VGSCL system to carry out automatic and semiautomatic adaptations of the video game. In this way, we think that the collaborative work can be carried out in the best possible way.

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