A Serious Game with Intelligence Based on Evidence Theory

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Abstract— **Serious Games have been used to education and training purposes in several areas. The main purpose of such applications is providing interactive and motivating tools for specific situations. The present paper presents a game to support Geography teaching that uses intelligence based on the Evidence Theory to assess users movements and change the screenplay. It allows decision making to provide dynamism to the game screenplay and allows evaluating the degree of belief of student about the concepts used. The game was developed for students of the 4th and 5th grade of primary education and implemented the intelligent system with success.**

Keywords-serious games, artificial intelligence, evidence theory

I. Introduction

The electronic games, or just games can be defined as a tool of entertainment for different age groups, but under a scientific view, such games are computational systems with an interdisciplinary characteristics. In general, games have a narrative, some times with realistic graphics (some times not), sound quality, option to play using networks and an intelligent system which sets the difficulty levels of game, among others.

Basically, the games can be classified into two main groups: entertainment and serious games and each of them can be classified into their own subgroups. The entertainment games can be classified as strategy games, first-person action adventure games and multiplayer, where multiple players share the same game. In games like RPG (Role Playing Game) you interact socially with other characters, which provides a psychological development in various cognitive areas [4]. By other hand, serious games can be classified as advertisement, planning, awareness, education and training [13].

Serious Games (SG) has potential to promote user motivation, to stimulate cognitive functions and to favor the knowledge acquisition. The combination of these special purposes requires the support of professionals associated to the specific content of the game. They can help the development team to outline the scope of the game, as well as the most adequate way to address the content [14].

For the development of SG, it is necessary first of all a plan, where the main phases are: production of the script, staging and production of graphic art, choice of adequate intelligence, a programming language and development tools [3]. The screenplay is one of the most important to the success of an electronic game, as the design, story and plot are at this stage [5], obviating the need for intelligence and their points of action.

An important point of the game development that has not been deeply explored, such as the Artificial Intelligence (AI) techniques, deserve to be addressed. Intelligent strategies can be used to control the game behavior, as well as the characters and the user performance. The intelligent control allows the game to do an auto-reconfiguration to ensure that a particular concept has been assimilated. Intelligence can be centered on a subsystem of the game, making decisions about specific actions, or decentralized in the characters, allowing them to have isolated actions. Eventually, both can be combined, reducing the computational cost of centralized intelligence and allowing a greater number of options throughout the game [14]. The term Intelligent System (IS) contains both the AI classic, used in predicate logic and expert systems, computer as well as intelligence systems used in probabilistic, fuzzy, neural networks and evolutionary systems [12].

Educational Games (EGs) are a particular class of SGs in which the idea of learning or its reinforcement overcomes entertainment. Various forms of learning can be achieved, especially for children [7]. The EGs enrich the player's skills training, such as acquiring strategies for problem solving, reasoning and encourage training and retention of concepts. EGs as well as any game, let the understanding and knowledge of rules, providing the player with an easy to interpret everyday problems. Thus, they act as catalysts for the process to rescue the student's interest, improving their learning, because the student, tired of trying and not achieving the desired school, end up unhappy and may block the progress of their learning [11]. EGs promote school programs so attractive to the student. However, the challenge is to transform this learning tool into something attractive for the player, causing the student to be aware that he is learning while playing [2] [11].

Once it is reached the level where the balance attractiveness-learning is satisfactory, then the software built becomes an EG really manages to keep the concentration of the student and teach him (or reinforce his learning) at the same time. One of the techniques used to make an educational game is to promote an attractive degree of competitiveness. Adding intelligence to the EG makes it become more challenging, intriguing and dynamic. The use of this intelligence must be well-balanced not to make the game difficult and discourage students and become difficult to be running by small computers. In EG, this intelligence is what promotes difficulties levels, and helps the player to make decisions: it can teach some concepts to the student [1] and may also serve as an instructor for the student.

Among various models adopted in IS for entertainment games (strategy games, sports, racing, adventure, RPG, etc.), they must work in EG for assistance to certain courses. Thus, they can be implemented using several approaches such as probabilistic models, fuzzy models or hybrid models. In this work we adopted the model likelihood for development of an educational game type RPG (Role Playing Game) to aid the teaching content of geography to students of 4th and 5th grade elementary school, using commodity computers (with processing power between down to medium) taken into account technologies used to make this transition and implementation of Virtual Reality (VR), particularly 3D vision.

RPG type games make players create and / or act on characters, manipulating his actions and reactions, which leads to the character interaction with the scenario where rules are set, reaching the goal of providing an interactive environment with rules and intelligent to the aid of geographical teaching the player. These rules may be different in each situation according to the choices the user makes during the game, developing the player's creativity. When practiced in groups under supervision of a teacher, develops socialization, cooperation and interactivity. During the games of this type, the user is who makes the decisions and ends up taking a critical character. Because of these potential this approach has been used in game development. IS embedded in this game was responsible for handling the difficulty levels as well as monitor the player's behavior on the past use of geographical concepts and assimilated. It was also used to reinforce concepts and questions at different levels of difficulty, according to the player's ability observed during the game. The IS also helps the player to not lose in this scenario, which can discourage student or making the game boring. Techniques of VR were used to make the game more attractive and the user can be immersed and interact in a 3D environment.

II. Intelligent Systems Based on Evidence Theory

A. The Dempster-Shafer Theory

The basis of theory or Dempster-Shafer Theory of Evidence, is the distribution of beliefs which in turn uses a frame of discernment, denoted by U, defined by an exhaustive set of mutually exclusive events. There are three important functions in this theory [8]: The first, called the probability mass, belief and plausibility, respectively denoted by m, Cr and Pl the probability mass of a subset $A \subset U$, is a primitive theory Evidence and defines a mapping of the family of all subsets of U, denoted by $F(U)$ on the real interval [0,1], where:

$$m(\varnothing) = 0 \text{ and} \quad (1)$$

$$\sum_{A \subseteq U} m(A) = 1. \quad (2)$$

It expresses the totality of available evidence on the elements of the subset A, but not its subsets. For example, if $B \subseteq A$, $m(B)$ should be expressed as a probability mass function for this specific subset. When $m(A) > 0$, the subset A is considered a focal element. If the focal element A contains only one element, then the probability mass is reduced to classical probability distribution.

From the probability mass function, the superior and infimum values of a range can be defined, which is contained the true probability of the subset in question. These values are not additive and continuous measures, called belief and plausibility. Belief function of the subset A is defined as the sum of all probability masses of its proper subsets B, $B \subseteq A$:

$$Cr(A) = \sum_{B \mid B \subseteq A} m(B). \quad (3)$$

The plausibility function of a subset is defined as the sum of all probability masses of its proper subsets B, or $B \cap A \neq \varnothing$:

$$Pl(A) = \sum_{B \mid B \cap A \neq \varnothing} m(B). \quad (4)$$

These measures have among themselves a relationship: $Pl(A) = 1 - Cr(\sim A)$, where $\sim A$ denotes the subset of the classical complement subset A.

B. Intelligent Systems (IS)

An IS based on a belief uses an logic approach where knowledge is defined with a degree of belief associated with a sentence, which defines the certainty with which this sentence can be considered correct. For a better understanding, let be the following classes [10]:

PLANAR FIGURE = {NOT POLYGONAL, CONVEX}

NOT POLYGONAL = {RING, CIRCLE}

CONVEX = {CIRCLE, SQUARE, TRIANGLE}

A probability mass function m over $F(U)$ is done by:

$m(A) = 0.2$, $m(C) = 0.3$, $m(CQT) = 0.4$, $m(U) = 1$ and

$m(\varnothing) = m(Q) = m(R) = m(AC) = m(CQ) = m(CT) =$

$m(AQ) = m(AQ) = m(TA) = m(QT) = m(ACQ) =$

$m(ACT) = m(TQM) = 0,$

where A corresponds to the class {RING}, the class C {CIRCLE}, QC to the class {CIRCLE, SQUARE} and so on (note that U corresponds to the class {$ACQT$}). Then:

$Cr(A) = m(A) = 0.2$, $Cr(C) = m(C) = 0.3$

$Cr(CQT) = m(C) + m(Q) + m(T) + m(CQ) + m(CT) +$

$+ m(QT) + m(CQT) = 0.7$

$Cr(ACQT) = Cr(U) = 1.$

The Plausibility of CQT is given by:

CQT = CONVEX = {CIRCLE, SQUARE, TRIANGLE};

$\sim CQT$ = U - {CIRCLE, SQUARE, TRIANGLE}

= {RING} = *A*

and therefore:

$$Pl\ (CQT) = 1 - Cr\ (A) = 1 - 0.2 = 0.8.$$

Belief intervals are determined by an expert who assists in the implementation of the IS and they are then tested for premises that have a belief factor defined by the context of the application. If the belief factor in a context satisfies a belief interval in a particular rule, then it is executed an action for this rule. Thus, taking the example: I (CQT) = [0.7, 0.8], that is believed to be convex class with a factor of not less than 0.7 and not greater than 0.8.

One way to represent decisions is using decision rules, presented as a pair ACTION-CONDITION. In addition to the rules used in IS, is common to find a belief value in the premises of these rules. This belief value determines how much a premise can be correct. For example, the premise IF IT RAINS, may have a belief value 0.7. In some approaches this belief can be in a certain interval of belief. This interval determines a minimum value and a maximum value for the premise is true. In “IF IT RAINS [0.5, 0.8] THEN THE LAND WILL BE WET”, it is believed that if this premise exists in a context, then it must have a belief value, which belonging to this interval for that the decision THE LAND WILL BE WET is taken. If the fact to be evaluated is IF IT RAINS (0.4), the decision THE LAND WILL BE WET not be performed because there is enough truth in fact that it will rain.

III. Educational Game for Teaching Geography

An educational game, named SilvesterPEC, was developed and implemented as an RPG type game Treasure Hunt for reinforcement of learning concepts in Geography for students of 4th and 5th series of elementary education (around 12 years-old). RPG games are generally developed in the third person, where the player can see their avatar. The educational content for the game deals with concepts addressed the high priority of Geography education, called primary concepts. The concepts are [6]:

- Differentiation: the individual must be able to differentiate visually objects that surround him.
- Density: a measured of concentration of a particular object per unit area.
- Intensity: a measure of concentration of certain phenomenon per unit time.
- Distribution: critical evaluation mode that must be developed by student in relation to the environment that surrounds him.

The game covers the primary concepts of density, intensity, differentiation and distribution in its first version, and other geography concepts as bush, river, cardinal points, lake, pond and mountain.

For the production of the game, the display of graphics, the player's status, text, images, etc., was adopted Panda3D tool [9] using the Python scripting language. The IS was implemented in C++ language and was divided into two parts: the main intelligent system (SIP) and the monitoring intelligent sub-system (SIM). The SIM is able to monitor the player and check the terms used in the game, stored them in a list containing the events of the map. The SIM is responsible to send a set of data to the IS that will serve to build the structure to be compared with the rules of the game. Initially, it creates four data structures that receive the values of two vertex of a quadrilateral that contains the events at each site. Then it is created a data structure consisting of the four previous structures containing different regions of the map: Plain, Swamp, Field and Forest. Thus we get a list of events of the scenario and the regions which contain these events. In SIP, all functions of the IS are treated and managed and in SIP are made logical inferences which are necessary for the game operation and monitoring of the concepts. The SIP includes the rules of the system, the structure in which the rules are stored, and Inference Engine, which is responsible for inferential form to be applied to rules. SIP is responsible for handling uncertainty of user´s actions and by the actions which the game will take with respect to student.

The student receives a tip about the event to be found in some area of the game scenario. This tip will always have a direction given by a cardinal point and some other primary concept. If the player spent less time than expected to get to the event, two conditions are possible: a) the student did not use the concept needed or b) student used, but he / she was not able to find it in scenario (student found the place by accident, or spent too much time to do it). Then IS can generate a question about one of concepts to infer the belief about student´s knowledge. In another situation, the time used can be very higher than expected and the player did not find the event. In this case, the system can make use of a question seeking to understand the difficulty of the student and then send new tips to him.

If the student exhaust all tips, the IS can handle the game map (with predetermined actions) so that the student is able to finish the game with the necessary concepts presented. For example, if the student needs to understand what is a bush and he / she received all about it and he / she was not able to find it (or does not interact with him), the IS can add a bush at any other point on the map (predefined) for the student to get to it. This fact also applies to control points in the map, such as broken bridges, blocked passages, etc..

Using rules based on beliefs, it is necessary to define the beliefs intervals, which act on a given rule. In this case the beliefs must be derived from user interaction with the concepts assimilated in the game. Belief in evaluation is given by:

(A AND (B OR C) AND D ...) -- Belief Factor

=> CONCLUSION (with estimated value of Belief)

where A, B, C and D are concepts which must be used during the game as (A = river), (B = mountain), etc.. and “Belief Factor” is an estimated value based on the belief which IS must infer from the student´s actions on those concepts. For example, when the game gives a factor of Belief on certain premise, according to the student´s position relative to the center of a given event, the calculation is as follows:

$Y_{Temp} = abs[(y - y_0) / (y / 7)]$

$X_{Temp} = abs[(x_0 - x) / 50]$

$Cr = 0.35 + (Y_{Temp} + X_{Temp})$

$Pl = 0.8 - 0.5 * (Y_{Temp} + X_{Temp})$

$Fc = [1 - (Y_{Temp} + X_{Temp})]$

where (x_0, y_0) is the center of the event covered and (x, y) is the current position of the player; Y_{Temp} and X_{Temp} are calculated values, which they are used to assign [Cr, Pl]. Fc is calculated in order to find an appropriate value for the distance between the current position of the student and the position addressed.

From these beliefs can be obtained the general belief about the conjunction (AND) of the primary concepts that will serve to answer about the general belief in learning on this application. In summary, whenever a concept is used by the player, a question should evaluate this concept For example: “A forest has many trees (Y / N)”; “How certain are you about this? [1, 10]”. From the conjunction of the beliefs of learning these concepts (example: Forest was Learned [0.3] AND Bush was learned [12:14] AND Rio was learned [0.67]) one obtains a set of beliefs about a set of concepts that can be used to find out the general assessment for the student. So, CONCLUSION (student learned the concepts playing) will have a belief calculated on data obtained in the game. To calculate the range of belief in learning to use the following rule:

$$I(A) = [F * Cr(P), 1 - F * (1 - Pl(P))] \quad (5)$$

where: *I (A)* is the belief interval for *A*, *P* is the premise of a decision rule *R*, *F* is the belief factor; *Cr (P)* is the belief in *P*, *Pl (P)* is the plausibility in *P*.

It is also used in the Beliefs interval for conjunctions and disjunctions:

$$I(X \text{ AND } Y) = [\min(Cr(X), Cr(Y)), \min(Pl(X), Pl(Y))] \quad (6)$$

$$I(X \text{ OR } Y) = [\max(Cr(X), Cr(Y)), \max(Pl(X), Pl(Y))] \quad (7)$$

with: $I(X) = [Cr(X), Pl(X)]$ and X is satisfied if and only if $Cr(X) >= CMIN$ and $Pl(X) >= PMIN$ where *CMIN* and *PMIN* are limit values which they are defined by an expert in the game.

IV. Results

Briefly, the storyline of the game consists on an extraterrestrial (ET), whose spaceship crashed on Earth. To return to his planet, he needs to use student´s knowledge of Geography to find some pieces of his spaceship that were spread over a region. The information given by the ET always include an orientation using cardinal points and another geographical concept that limits the search. For example, the tip can be: find a transmitter into the north of this position in a density of rocks. So, in order to continue the game, the student should use geographical concepts learned in classes to find the pieces of the spaceship and help ET back to his home planet. To make the game more attractive, the environment visualization is in 3D, providing a better sense of depth and spatial location in the game. The IS designed was implemented in this game.

The Figure 1 shows the student helping ET to find an object. Depending on the user's actions, the IS is able to make different decisions. If the student reaches the goal within the given time, then the IS just provides the next tip. In the Figure 2, the time used by the student is less than expected. So, it is necessary to infer the certainty that the player has on the concept discussed in this event through a question. The Figure 3 presents a reassessment of player´s certainty about a concept. In another situation, the player has already expended more time than expected and has not reached the goal. That means the student seems to be lost in the scenario. In this case, additional information can be presented to guide him / her. In the Figure 4 the IS identifies that situation and add a tip that test student´s knowledge about some concept to assist him to get closer to the main goal [14].

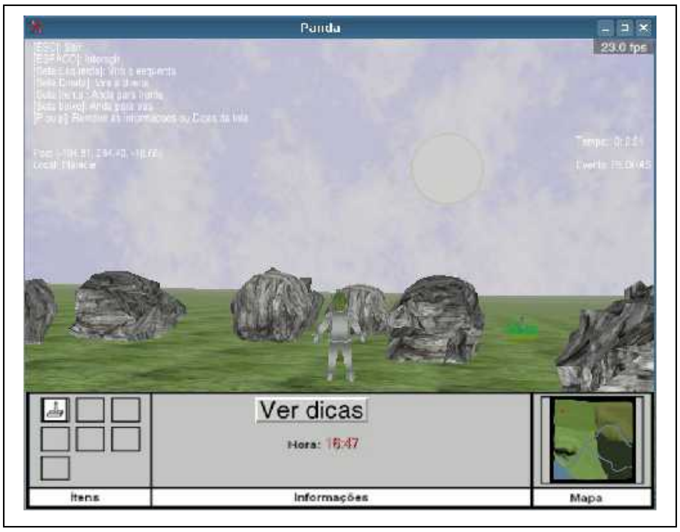

Figure 1. Finding an object.

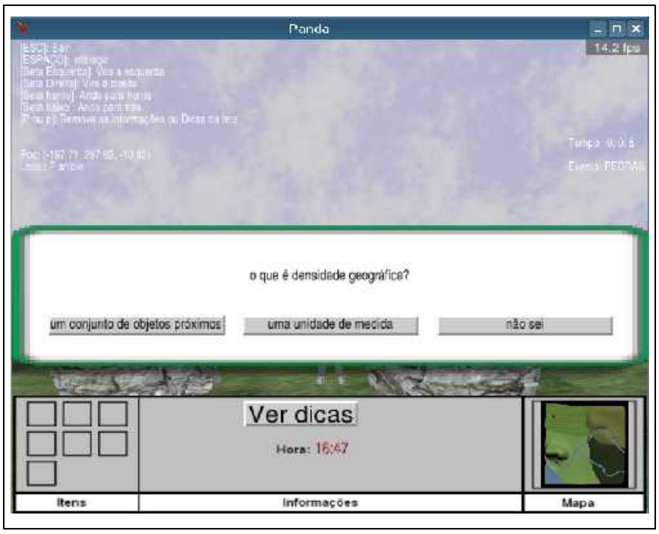

Figure 2. Checking the appropriate concept.

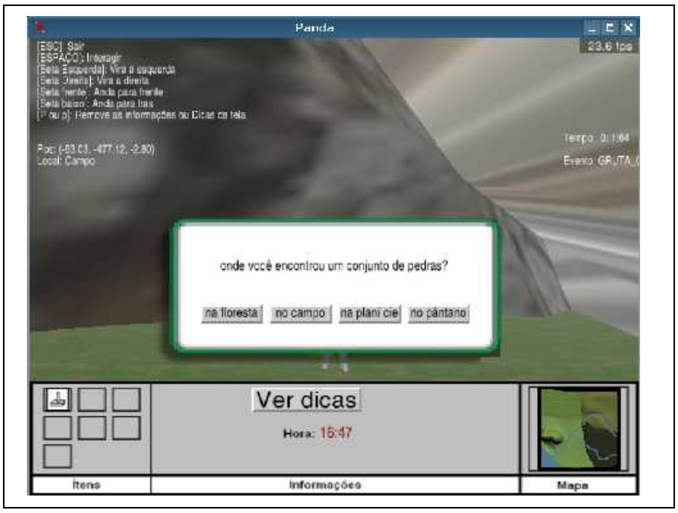

Figure 3. Reassessment of concepts assimilated by student.

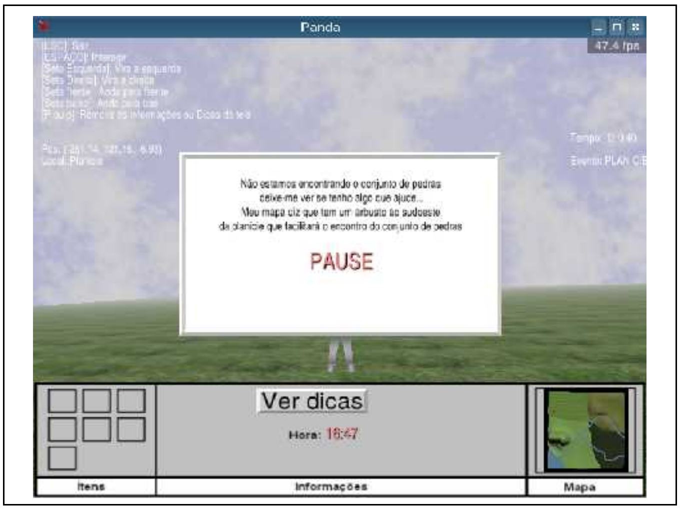

Figure 4. Assisting the student to follow the correct path.

The final version of that game is available for free download (linux version only) at LabTEVE-UFPB webpages (http://www.de.ufpb.br/~labteve/projetos/jogos.html). An installation manual comes with the Zip file available in the website. The SilvesterPEC can be used with a projection system for group activities driven by the teacher. In the same webpages, other educational games developed by LabTEVE are available for download.

V. Conclusions

This paper presented an application of the Evidence Theory (Dempster-Shafer) in building an intelligent system for a educacional game. The intelligent system was used to measure the level of understanding of the concepts used by the student in the game. This intelligent system is able to modify the game in progress to include events in order to more accurately measure student learning. An educational game for reinforce concepts of geography to students in 4th and 5th grade of elementary school was implemented to test the intelligent system designed.

The SilvesterPEC can be individually used by each student or with a projection system for group activities driven by the teacher. Linux version of the game is available for free download at LabTEVE-UFPB webpages (on http://www.de.ufpb.br/~labteve/projetos/jogos.html).

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