Automatic generation of interactive narratives for an educational adventure game using Petri net

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ABSTRACT

Getting students' attention to content teaching today has become a challenge to teachers. Digital educational games have become relevant in resolving this impasse between the attention span of current generations and teaching methodologies, creating a playful learning environment. Application of the game by itself may not have the desired effect if the student fails to form his knowledge. Therefore, the objective of this work was to develop a method of automatic creation of interactive narratives for educational digital games based on the constructivism theory using Petri nets.

Keywords: narrative interactive, digital games, Petri net.

1 INTRODUCTION

The constructivist theory, based on Piaget [1], argues that learning is done by the construction of our cognitive structure and not by the memorization of content, and that the learning environment in which the student is inserted is a fundamental part of this construction. According to [2], this learning allows the student to have a non-literal relationship to new knowledge and maintain an information base, intrinsic to its cognitive and often symbolic structure, that allows it to serve as an auxiliary material for the acquisition of new information.

According to [3], learning environments involve four requirements, namely access to information, structure, interest and evaluation. The interest is the position favorable to the satisfaction of a need that provides emotional orientation and motivates the student to a cognitive involvement in the exploration of the information; The structure will guide this exploration by contributing and refining knowledge, which promotes meaningful learning. The evaluation, however, enters the context of information exploitation.

Educational games include the requirements of a learning environment, both by its objective of providing fun and entertainment to the player, by assisting the increase in student interest, and by its characteristic playful activity, allowing, at the same time, they play and perform reflections and analysis on the structure of the game, allowing them to develop their abilities to solve problems in various ways. Finally, the evaluation may be related to the fulfillment of the goal proposed in the game or to the debriefing activities after the game session, in which the teacher talks with the students to detect possible learning problems.

According [4], the Z generation, made by people who were born after 1990, grew up in the midst of a technological revolution contemplated by access to computers, the Internet, which is full of information in various media, and, currently, to mobile devices. To understand the learning deficit of this generation, the author compiled a set of information that indicated the students' lack of motivation to learn from the traditional teaching methodology, which uses an expository class and evaluation, since the contents, in general, are taught in a static way, without interaction and challenges, being totally opposite to what they have access outside the classroom.

Therefore, as mentioned previously, the digital game-based learning becomes interesting when it comes to resolving the impasse between the attention given by current generations and teaching methods as it allows you to include the interaction, reflection and critical thinking, which may be intrinsic to the game or through a process of reflection and evaluation with a teacher in the learning of content, and still make it fun and motivating.

Stories have been an integral part of the human experience, consisting of a basic cognitive resource. These allow people to escape from reality and become explorers of new worlds. This transformation encourages the ability to create coherent sequences of facts that can be imagined and interpreted by many people, and often could not be experienced in real life. The immersion of the player in the game causes him to transcend his reality to explore the world he is in, in order to explore and solve challenges. This circumscribed world, according to Johan Huizinga, in his book, 1938, "Homo Ludens", is called the magic circle [5].

Within the scope of narrative creation, interactive narrative is one of the most promising areas of research related to the development of digital games and is intended to give the player the ability to make choices and develop relationships within the game world. According to [6], when interactive narratives are generated in a procedural way, they induce players to unique experiences and the story being essentially of co-authoring the player. For [7], in this type of narrative, the actions of the player must have great influence on the upcoming events, while the sequence of events generated by the system must cover a continuous history, not just a random series of events.

In the context of interactive narratives, we have the Adventure Game, which allows the player to take the role of protagonist in an interactive story directed to the exploration and solution of problems that, when solved, liberate new areas to be explored in the game [8][9][10].

Algorithmic interactive narratives, which aim to dynamically create original stories around what the player does, manipulating plot construction or character actions, can be used in the context of adventure games, allowing not only the pre-defined progression in Story, but the changing environment and narrative according to events triggered by the player. According to [6], the plot-based systems are used models of stories that can be divided into several subplots algorithmically planned. In contrast, character-based construction involves changing your opinions and beliefs as a result of an interaction with the player.

Considering that the algorithmic interactive narrative consists of a discrete-events system, where each new function depends on the current state and an input, these being represented, respectively, by the current situation and by the action of the player, it becomes propitious to use the of Petri net for its harmonic structure to the

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problem and its set of techniques that allows to analyze the behavior of the network [11].

For the above, it is justified to create interactive narratives by granting the player the ability to make choices within the game world. This allows two players may not have the same experience, since there is explicit game history and implied history of each player. When applied to educational games, this individualized experience acts on theory of constructivism, allowing the player to interact in his own way, and in his time, to assimilate the learning contents.

Therefore, the goal of this work was to develop a digital educational game, of adventure and for mobile devices, with the aim of creating a learning environment for diverse contents, specifically in this paper, as a study work, the content of JavaScript programming language. The construction of the narrative is done from the execution and analysis of a Petri net model and based on the Constructivism theory, therefore, the interactions of the player about the presented contents, correct or not, can alter the narrative, maintaining problems consistent with the decisions taken.

2 Related Works

As for the works related to the generation of interactive narratives, we have the works [12][13]. In the first work planning was considered as one of the main points for the creation of interactive narratives, since the challenge, according to the authors, was to deal with the multiple sources of uncertainty inherent in this task, such as intention, beliefs and experience of the users and the absence of the complete plot. Also in that paper, the authors developed a digital game of medical research and used decision theory to address the uncertainties described above. Already in the second work, the authors created a history whose actions of the user are confronted with those of semiautonomous agents, impacting significantly on the plot. In this work, the authors used a director responsible for supervising the agents so that their actions did not create incoherent or unsolved frames.

The use of Petri nets in the area of games is becoming more widespread, as described in the other paragraphs of this section. In the work of [14] it is described the generation of a quest for a game of the genre RPG (Role-Playing Game) using a Bayesian network to analyze the model of the game in Petri net. This quest is generated from the simple selection of random events, such as the inclusion of Non-Player Characters (NPC) in the game and from this inclusion, it is analyzed if the model is feasible.

In the work of [15], an alternative is presented for the modeling of serious games using Petri net. The execution of the Petri net model allows the definition of the number of problems solved or abandoned by the player. Based on these data, the authors classify the data using Learning Vector Quantization (LVQ), which consists of a supervised Artificial Neural Network. The rating refers to the motivational behavior of the players in the game in order to determine if they are frustrated and need help or if they are motivated and need more challenges. The authors indicate making changes in the game, based on the classification in future works.

In the work of [16], the authors use the Petri nets to evaluate the players' learning in Serious Games. From the actions in the game, represented by transitions, a network analysis is done to identify if there is an understanding of the presented content. This evaluation consists in verifying the sequence of actions taken, from the analysis of the reachability tree. If the sequence is not adequate for the proposed content, learning failure is identified. Not explicitly, the work uses the concept of Learning Path, which indicates the best order of presentation of content for learning.

Regarding related works, this work has as a differential the generation of interactive algorithmic narratives, that is, there is no third-party intervention on the generated narrative and no pre-defined sub-plots. In addition, also different from related works, the narrative does not block the continuity of the game according to the learning, but provides a view to the player that a content may not have been assimilated correctly.

3 Development

In this section we discuss both the development of the Petri Net model, used in the automatic generation of the interactive narratives of the game, and the adventure game itself.

3.1 Petri net model

The main advantage of using Petri nets, proposed by Carl Adam Petri in 1962, is that they have a support for the analysis of various properties and problems associated with systems with concurrency. Reachability is used for analysis of behavioral properties and is a fundamental method for studying the dynamic properties of any system, where the firing of an enabled transition will change the token distribution in a net (the marking of the net).

In order for a transition to be enabled to fire, it is necessary that all places – represented by ellipse – of input have the required number of tokens, which is defined by a positive integer be informed in the arcs that from places to transition. When the transition – represented by the rectangle – is enabled and fired, the tokens of the inputs places are removed, according to the weight of the arcs connecting the places in the transitions, and tokens are created at the exit places, according to the weight of the arcs connecting the transition to the places.

The High Level Petri net is an extension of original Petri net. This extension allows modeled the Petri net using individual tokens, which has information that can be used on firing of transitions. In our work, the information of tokens consists of attributes of the player and its path inside the model [11].

In Figure 1 is shown part of the Petri net model used in the modelling game proposed here. The "Cena" places contemplate the content to be presented to the player and the "Quiz" places represent the activities to be performed by the player based on the content displayed in the "Cena" places.

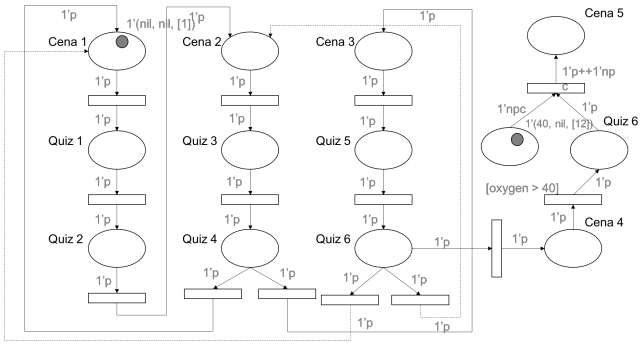

Figure 1: High level Petri net model.

It can be seen in Figure 1 that the initial marking has only one token in place "Cena 1". This token represents the player and his current position in the game. Using the structure presented in the Colored Petri nets [17], initially the color sets (colset) were created, namely Oxygen (product of integer between 0 and 100 and string) and Connected (Boolean). Next, it defines the complex color that represents the own character in the game (Character), composed by the product of Oxygen and Connected and that consists of the set of color of each place of the Petri net. Finally, the colors *p* and *npc*, of Character type, are declared to be used as weight of the arcs between the transitions and places, where *p* represents the Player and *npc* represents the Non-Player Characters.

The player is free to go through the whole environment of the game (Petri net places). To do so, it is necessary for him to answer some questions in order to get his understanding on the subject addressed in the "Cena" places. In this example, in order for the player to move from "Cena 1" to "Cena 2", he should pass through the "Quiz 1" and "Quiz 2" places. When these places are reached, the questions are displayed to the player.

The act of answering the questions displayed in the "Quiz" places is equivalent to the triggering of exit transitions from these places. Once the transition is triggered, the data is stored locally on the device where the game is running and also on a Firebase NoSQL database available in the Google Cloud [18]. These data stored in the clouds will be used in future works to apply Analytics Learning in the presented contents to the players.

Some transitions, such as the exit transition from the place "Cena 4", contain guards, inherent in High-level Petri nets, and which purpose is to validate a token data to enable or not to fire its shot. In this specific case, the token may go to the "Quiz 6" place only if it has the value of the "oxygen" color greater than 40.

3.2 Mobile Adventure Game

Vladimir Propp (1928), analyzed the Russian tales and defined 31 narrative phrases, contained in most tales, and condensed them into metalinguistic lexemes such as distance, interdiction, damage, and so on. These narrative atoms, called functions by Propp, linked together by the mechanism of causality, constitute the framework of the fable of a narrative [19].

Some of these functions were used in the elaboration of the game narrative. The first function defined by Propp is the removal, in which it indicates that a character moves away from his house to go to work, go to war, do business, etc. This action implies the passage from a topical or safety site (home) to an atopic or insecure location (space). In addition to this function, others such as interdiction, transgression, interrogation, information, deception, and complicity are listed as preparatory to the damage function.

In Figure 2 is shown the initial sequence of game screens, which exhibit the aforementioned function of moving away from a safe location (home) to an unknown and uncertain location (space). Still in Figure 2 (right screen), the damage function is displayed. According to Propp, this damage can be caused by evil (robbery, abduction, etc.) or lack of something.

Figure 2: Initial game screens presenting the narrative.

According to [20], the experience of being transported to an exquisitely simulated place is pleasurable in and of itself, regardless of the content of the fantasy. This experience of going to space, for example, is called immersion. In an interactive medium, immersion involves learning to do things that the new environment makes possible, such as programming JavaScript in a spaceship to solve the damage presented.

To maintain interactivity, and following the structure of Piaget's constructivist theory, an analysis of the Petri net is done at every user interaction, in real time. That is, even without demonstrating understanding of a subject, the player may continue to play, but the narrative is altered in order to demonstrate that there is an error in the concept acquired and this action will cause greater problems if the concept is not understood correctly. Hence the need to contemplate the liveliness behavior (all tokens are reachable from any initial marking) so that the player can come back in the learning content and try to remake their concepts.

4 Discussion

In the game, at first, the user is inside his Cabin. The Cabin represents the initial content being presented to the player and contemplates the concepts of variables and data types in JavaScript. In Figure 3, leftmost screen, there is a map of the network macro-transitions. Each of these items has a different content.

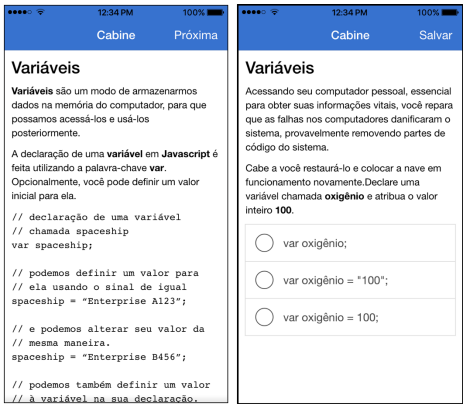

Figure 3: Content and exercise screens.

From the perspective of the game in the Petri net (Figure 4), it is possible to observe that the place "Cena 1", initially, contains a token that represents the player, and that it has empty or null values for the properties indicated previously in the text, which are Oxygen and Connected and the list of places it has accessed. The transitions represent the actions of the player, and T_NEXT only indicates that the user will go from one screen to another and T_QUIZ represents a challenge to the player. This challenge (Figure 3, right), when answered, changes the properties of the token.

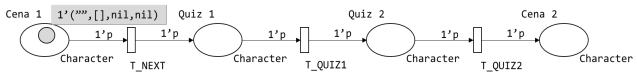

Figure 4: Partial model of Petri net referring to Figure 1 (Cena 1).

In the central screen of Figure 3 was presented the content to be learned by the player. The contents, as well as the challenges, are related to the plot of the game. Once the content is read, the player can choose to continue with the game by tapping the "Next" button. With this, the game displays the challenge (pictured far right of Figure 3) and the player interacts with the plot from the resolution of this. As discussed earlier, the wrong choice (first or second option) does not disable the player to proceed with the game, but changes the plot in their own actions, as can be seen in Figure 5.

For example, if the player opted for the option *var oxygen = "100"*, where the value is a string and not an integer, the system still stores this value in the Petri net token, even though it is an incorrect answer to the challenge in question. Thus, the player's next actions

will be defined based on these options, as can be seen in the transition shot shown in the Petri net model of Figure 5.

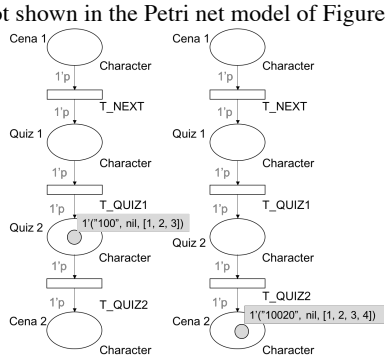

Figure 5: The firing of transitions in Petri net.

Figure 6 shows part of the reachability tree referring to the Petri Net model shown in Figure 1. The root of the tree indicates the initial marking. The branches on the left represent the markings with correct values, that is, the player has hit the challenge. You can see that the yellow markings are the same, obtained from different actions.

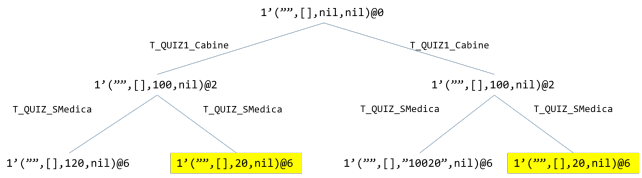

Figure 6: Initial game screens presenting the narrative.

This possibility of being able to reach a correct or at least coherent value, such as the case of the leaves of the tree highlighted in yellow, indicates that the player can understand the content after some attempts, or after verifying its error and returning to the content that did not understand, resolving then the challenges. With this, the game generates several subplots. For example, in later phases (Cena 4), when accessing the engineering section and attempting to rescue another crewmember (from a challenge) by providing his oxygen, he will realize that there has been a previous misunderstanding in his own oxygen and this may cause death of his friend, drastically altering the narrative.

5 Conclusion

Generation Z students have grown up in the midst of a technological revolution in access to computers, specifically the Internet, which is full of information in a variety of media. In order to resolve the impasse between the attention paid by current generations and traditional exposure/assessment teaching methodologies, digital-based learning has been developed, which allows for interaction, reflection and critical thinking to be included in a way about the content to be taught.

Narrative plays an important role in this context as it attempts to perform the analysis on the content to be taught and not only to encourage basic operational actions such as clicking or tapping buttons, as in several games. Starting from this premise, this work was developed with the objective of creating automatically interactive narratives for educational digital games. As a case study, a game was used to teach the JavaScript language.

In this work, the objective was reached by generating several interactive narratives automatically based exclusively on the content assimilated by the player, following the theory of constructivism and using the Petri net model to support this generation. The model also allows the addition of new places of content or exercises, keeping the analysis consistent with learning. This allows the use of this project in several educational games, changing only the educational content.

In future works, it is intended to use the Multiple Intelligence Theory of Gardner, so that the return to content not yet assimilated in the "Cena" places can be presented in different ways and the model can follow the most outgoing intelligences of each player in the course of the narrative.

References

[1] J. Piaget. The Development of Thought: Equilibration of Cognitive Structures. The Viking Press, New York, USA. 1977.

[2] J. L. Eguia-Gomez; R. S. Contreras-Espinosa; L. Solano-Albajes. Os Games Digitais como um recurso cognitivo para o ensino da história da Catalunha: Um estudo de caso. In *Revista do Curso de Letras da UNIABEU*, vol. 3, n. 2, pp. 120-133, 2012.

[3] P. Duchastel. Learning Environment Design. In *Journal of Educational Technology Systems*, vol. 22, n. 3, pp. 255-233, 1994.

[4] M. Prensky. Digital Game-Based Learning. McGraw Hill, 2001.

[5] J. Huizinga. Homo Ludens: A Study of the Play-Element in Culture. Tradução. 5.ed. Perspectiva, 2008.

[6] S. Rabin. Introdução ao desenvolvimento de games: entendendo o universo dos jogos, vol. 1, 2.ed., Cengage Learning, 2011.

[7] L. M. Barros; S. R. Musse. Introducing Narrative Principles Into Planning-Based Interactive Storytelling. In *ACM SIGCHI 2005 International Conference on Advances in Computer Entertainment Tecnology ACE 2005*, Valencia, Spain, 2005.

[8] L. A. Diehl; E. Lehmann; R. M. Souza.; J. B. Alves; R. Z. Esteves; A. A. Pedro. Serious Game Prototype for Education of Medical Doctors and Students on Insulin Management for Treatment of Diabetes Mellitus. In *IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH)*, 2011.

[9] M. P. P. Melo; S. Roza; L. Lima; R. Dantas. The use of interactive fiction as a tool for distance learning. In *XII SBGames (Proceedings of SBGames, 2013)*, p. 264-267, 2013.

[10] D. Kozdras; D. M. Haunstetter; J. R. King. Interactive Fiction: 'new literacy' learning opportunities for children. In Journal E–Learning, vol. 3 (4), 2006.

[11] T. Murata. Petri Nets: Properties, Analysis and Applications. In *Proceedings of the IEEE*, 77(4)541-580, 1989.

[12] B. W. Mott; J. C. Lester. U-director: a decision-theoretic narrative planning architecture for storytelling environments. In *Proceedings of the fifth international joint conference on Autonomous agents and multiagent systems*, ACM Publisher, p. 977-984, 2006.

[13] B. Magerko; J. Laird; M. Assanie; A. Kerfoot; D. Stokes. AI characters and directors for interactive computer games. Ann Arbor, vol.1001 (48), p. 109-2110, 2004.

[14] Y. S. Lee; S. B. Cho. Context-Aware Petri Net for Dynamic Procedural Content Generation in Role-Playing Game. IEEE Computational Intelligence Magazine, vol. 6(2), p. 16-25, 2011.

[15] M. A. Syufagi; M. Hariadi; M. H. Purnomo. Petri Net Model for Serious Games Based on Motivation Behavior Classification. International Journal of Computer Games Technology, pp.1-12, 2013.

[16] A. Yessad; P. Thomas; B. Capdevila; J. Labat. Using the Petri Nets for the Learner Assessment in Serious Games. In *International Conference on Web-Based Learning* (ICWL), pp. 339-349, 2010.

[17] K. Jensen; L. M. Kristensen. Coloured Petri Nets: Modeling and Validation of Concurrent Systems. Springer Verlag, 2009.

[18] Google. Firebase. Available at: https://firebase.google.com. Access: 10/7/2017.

[19] S. D'Onofrio. Teoria do Texto 1: Prolegômenos e teoria da narrativa. Ática, 1995.

[20] J. H. Murray. Hamlet no Holodeck: o futuro da narrative no ciberespaço. Editora Unesp, 2003.