Video Game Story Analysis Using Layered Graphs and Eye Tracking System

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***Abstract*— This paper discusses the prospects of using layered graphs and eye-tracking system for describing and analyzing player activity and his/her decisions in video game stories. Understanding how the game interface affects the user's decision is a very interesting problem, especially in the serious game field, because of real-life applications of acquired skills. Very often, the game winning strategies lead players to fall into bad habits. Reasoning based on the formal game system gives tools to game analysis and to collect information about players' behavior for further analysis. Eye-tracking information, i.e., gaze plot and heat maps give us knowledge about user perception of the game screen and helps with answering the question: what has affected the user during the decision making process? The main goal of the paper is to show usefulness of the proposed model while answering the sample questions about players' decisions.**

Keywords-game design; user decisions; narrations; eye tracking system; layered graph

I. INTRODUCTION

During the narrative game design process, especially for games with educational aim and real world dependencies and knowledge base, there are a few conditions that are extremely important. Scenarios and situations must be authentic and adequate and push the player to act. The scenarios should create the illusion of unlimited possibilities, but they should be precisely connected with the scope of knowledge and trained skills. It should be possible to replay and to explain the meaning of the winning strategies [1].

The comparison of user decisions in the game and in the real life is connected with both problems of the real life object representation in the game and the problem of the perception of the Heads-Up Display (HUD) elements. The challenge is how to prepare the "computable" model, i.e, the one which helps us compare different players' activity as well as connect user physiological reactions (eye perception) with the decisions taken.

The holistic model is based on the gameplay graph that represents the current state of the game. Different groups of elements can be identified: e.g., characters, locations, items and abstract narrative elements. These four categories reflect how players perceive games [2]. These elements could be identified in traditional narratives as well, but such formal models were not needed for their analysis. The usage of such model is connected with gameplay based on user's decision while comparing user's strategies. Our aim was to make all these elements uniform – so our model would process elements in the same way. Player actions and all other interactions in this world are denoted by connections between these elements [4].

Decision making process is correlated with elements available in the game, especially those noticed on the screen at the moment of decision making (others had to be seen prior) and player's general knowledge. Especially in narrative and serious games, it is extremely important to examine why the user picks a certain game strategy and condition of decision process. Researchers can speculate on them using two elements of a given system: typical sequences of gameplay graph states and information from the eye-tracking system.

A. *State of the art*

Eye-tracking is more and more often used in research game studies, especially as a game controlling device. Many researches were conducted ease, immersion and player satisfaction while using eye-tracker as input device, e.g. as described in [16]. Eye-tracker as an evaluation tool was also used in research studies to investigate the visual search patterns and heap maps describing the main area of interest on the screen [18]. The most popular approach is to collect heat map data and take into consideration the player activity throughout the game.

The approach presented in this paper is based on the dependence between the gaze direction immediately before decision. This approach is possible due to the graph of user strategy connected with the eye-tracker data. The gaze patterns and decision-making patterns can be associated in this approach.

B. *Research goals*

The research goal is to find a correlation between players eye-movement patterns and decision-making actions during the gameplay. During the work, the simple adventure game developed in the Department of Games Technology at Jagiellonian University was tested on a group of students and a question about their decision on choosing one of the three strategies was asked. The purpose of the research works is to show which elements of the user interface influenced the user's decision and which are useless in this context. The idea of the graph representation of the game state is presented in Section II and formal definitions are explained in Section III. Sections IV and V show the experiment and implementation details and describe user-game interactions noticed during research, especially the visual elements influence controlled by the eye-tracking system. The last two sections describe conclusions and future development.

II. GAMEPLAY GRAPH

The basis for our further considerations will be a gameplay graph, showing the game state in a specific moment. It has been developed on a layered hierarchical graph due to the expansions of the graph structure that layers and hierarchies offer. Layered graphs have been used in research models [5] and in video game design [6].

A. *Structure homogeneity*

First, as mentioned, the representation of the story with graph nodes and edges is inherently arbitrary. Our goal was to make it intuitive and homogeneous at the same time. It means that all nodes and edges are identical in their structure, so any transformation in the game world is processed in the same way, independent from its narrative meaning.

B. *Graph representation*

The key for understanding the universe of discourse is the game world with its current state. It is quite intuitive, because video game is commonly imagined as a virtual reality – simulation of the elements of the real world [3]. Two types of edges are distinguished: internal edges between nodes of the same layer and external edges between different layers. The external relational structure for the game world is represented by means of the layered graph. Figures 1 and 2 show the general structure of the used graph model and its specific subsets. Figure 1 shows the general horizontal dependences between subsets in the game word structure elements of which layers interact with each other and which can be embedded. Figure 2 shows the vertical segment of the graph (a sheaf graph), elements of all layers describing the character.

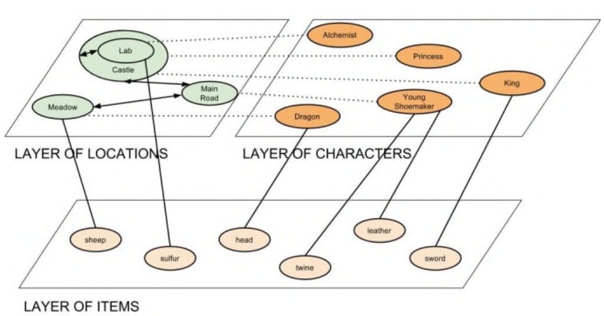

Figure 1. An example of a layered graph structure.

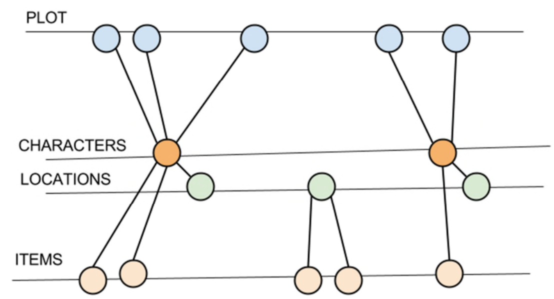

Figure 2. A sheaf graph – an arrangement of the structure

The research mode of the gameplay shows how the graph model changes after every player's decision. Researcher can investigate single players activity, creation and destruction of the edges in the graph or seek for activity patterns e. g. picking up items, changing locations, etc. it is possible to calculate time between different activities and other factors.

III. FORMAL DEFINITIONS

Graphs used for gameplay modeling were formally defined in [7][8], which in turn were inspired by [9][10]. According to them let us define the terms.

Let L be an alphabet of labels for nodes and edges. Let A be a nonempty, finite set of attributes.

Definition 1. A *hierarchical graph* is a system

$$G = (V, E, s, t, ch, lab, atr), \qquad (1)$$

where:

- V and E are finite disjoint sets of *nodes* and *edges*, respectively,
- $s : E \rightarrow V$ *and* $t : E \rightarrow V$ are *edge source* and *target functions*,
- $ch : V \cup E \rightarrow 2^{V \cup E}$ is a *child nesting function*
- $lab : V \cup E \rightarrow L$ is a *labeling function*, and
- $atr : V \cup E \rightarrow 2^{A}$ is an *attributing function*.

Def. 1 determines types of attributes for nodes and edges. A graph instance needs values of attributes and is defined as follows:

Definition 2. Graph *G* or is *layered* if and only if:

$$\forall\, x \in V : \mathrm{lab}(x) \in Y_i \Rightarrow \mathrm{lab}(V \cap ch^{+}(x)) \in Y_i \qquad (2)$$

(i.e., a node and all its descendant nodes have labels from the same layer).

IV. GAME STORY STRUCTURE AND USER DECISIONS ANALYSIS

A. *User strategy graph*

Commercial video games use high performance game engines, so graph-based models would not be used beyond design phase. The main goal of this model is to analyze player strategies through simpler graph structure – user strategy graph.

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Knowledge is strong limitation for a player, whose design activity involves manipulating on the word state using elements of the language over the vocabulary [10]. As we compare the graphs created – unconsciously – by the player, we can analyze these productions.

B. Participants

Data was collected during the sessions of gameplay (students of the Jagiellonian University and the author). The used equipment was The Eye Tribe tracker (specification in [15]).

The game is based on Polish folktale, where a young shoemaker slays a dragon by feeding it sulfur-stuffed sheep (by being a shoemaker, he can easily sew the sheep back together). Apart from this, we have added a way of killing the dragon by conventional armed force. There are two versions of the game, each promotes one solution over the other. The relative difficulty between victory paths in these versions, as well as player performance are the focus of our ongoing research.

The player takes the role of the young Shoemaker and his quest is to defend the land against a Dragon. After doing it, he may marry the Princess and has the right to rule the land as a consequence.

C. Implementation

The model is currently developed in the Games Technology Department of Jagiellonian University. The game engine was built in C++ using Qt5 [18]. The communication with the eye-tracking system (The Eye Tribe tracker, 60 Hz, with latency <20 ms) was established with open Application Programming Interface relying on the standard TCP/IP protocol using open-source Node.js runtime environment.

V. EXAMPLES OF USER-GAME INTERACTIONS

Thanks to the graph model, it is now possible to connect user decision moments with the specific game state and exact sequence of eye movements preceding the moment of the decision.

There were three main factors influencing players during the decision making process:

- textual scene characteristic with hints and characters dialogs,
- visualization of game scene and player condition (e.g., equipment, lives),
- players general knowledge.

In most cases, deliberated decisions were based on these factors. Of course, there are decisions made by chance, as a result of free exploration of the game world.

A. Free exploring effects

The group of players can be indicated with specific user strategy graph: many visited locations (significantly more then others), some of the locations visited repeatedly, but in unusual order (other players choose mostly one of a few sequences of locations visited). Additionally, the time of each visit was rather short.

B. General knowledge influence

In general, it is hard to prove that some players' actions arise due to general knowledge, not the game hints. An interesting result of analyzing user strategy graph was finding a fault in the story by our students. Their task was to complete the game and they had several different paths to do so. Some of them were stuck in a dead end when they fed a sheep to the dragon. The sheep was designed to be fed to the dragon, but according to the original story it should have been stuffed with sulfur before. Designers knew the story and did not try to feed the dragon with a raw sheep. However, some students did not know the story very well and fed the dragon with the sheep (as the folktale said), but they did not remember why, so they did not fill the sheep with the sulfur. As a result, the Dragon was thrived and killed the player.

C. Textual description influence

Getting information from texts or images in the gameplay is impossible to deduce from the graph, but there are sequences of eye-tracking data – gaze plot – preluding each decision made in the game.

Due to eye tracking studies taken on part of the participants, there are two main strategies of gathering information: take into consideration images, then text (an example is shown in Figure 3); take into consideration text, then images (different direction of gaze plot, as shown in Figure 4) or, surprisingly, taking into consideration only the text (as shown in Figure 5). In the figures mentioned, yellow numbers show the order of object examined before the players take action (keyboard event).

Figure 3. Most participants first stare at the screen images, then take a look at the text

Figure 4. Some participants have chosen a different order, first read the text and then look at an image

Typical behavior in the difficult moments of the game is to slow down (long time between state changes in the user strategy graph) and to follow several times different elements of the scene (textual and visual as well) with player eyes (Figure 6.)

Figure 5. Surprisingly, a few participants did not take images into consideration.

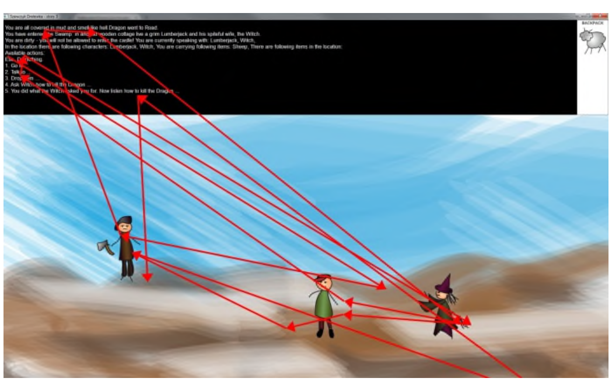

Figure 6. Typical process of looking for a solution of a difficult situation in the game

D. Visual elements influence

In most cases, after gathering visual information from the scene, the user has focused on the text and only then has made the decision.

There was a way to check whether the visualization bothered the reception of the gameworld or not. A scene was prepared where text gives the user advice to take a bath, but there was no visual hint to do so (Figure 7). This was the least often chosen way in the entire the game.

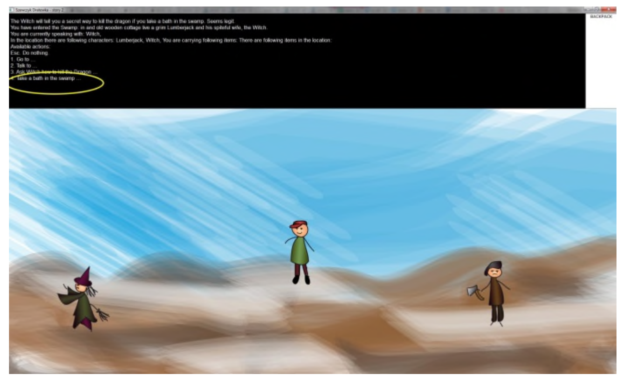

Figure 7. Textual hint (indicated by the yellow ring) not visualized in the image

A surprising result of eye-tracking data analysis is the fact that no one noticed the equipment backpack located in the right top corner of the screen (Figure 6: backpack with the item, Figure 7: backpack without any items). No one throws a single glance at it throughout the entire game. It is undoubtedly the fault of the user interface designer.

VI. FURTHER DEVELOPMENT

The next step of the planned research is to take into consideration educational serious games where information of the reasons of player decisions is extremely important and affects the estimate of learning efficiency.

Another problem is to prepare player strategy graphs not only in the games designed by researchers, but also for popular commercial games (in the individual cases of experiments participants, but in such way automatically).

Research field of further challenges is to find closer correlations between sequences of user decisions (currently collected in user strategies graph) and eye movement as a signal of user mental state (seeking the solvation, determined, sure or lost, etc).

VII. CONCLUSION

The proposed graph model can be considered as a tool that can be used for testing storylines, as well as analyzing user strategies. Thanks to automation and standardization, several variations of a story can be reliably compared. Players can also be surveyed for their strategies, perceived difficulty level and general satisfaction with the stories.

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Furthermore the graph-based mechanisms are easily used for deduction in the assigned logic. Using this approach to the universe of discourse gives us a way to investigate designer intentions and decisions.

One of the outcomes of the eye-tracking research is the unique possibility of comparing effects of the users decisions made in the game.

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