Development analysis of Logic Games in Traditional and 3D Digital Environments

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ABSTRACT
The progress of technology and its access to a large number of people, especially in mobile devices, make digital games a very popular tool, also in academic environment. Although, to have acceptable quality in education for digital games, mainly those of logic, they must be developed in a way that human-computer interaction enable further learning. This article presents a study of human-computer interaction in a logic game in traditional and in 3D digital environment. The study shows that human-computer interactions need to be improved in digital and virtual reality environments to preserve learning.

CCS Concepts
• Applied computing ~ Education • Human-centered computing ~ Empirical studies in HCI • Applied computing ~ Interactive learning environments • Human-centered computing • Theory of computation~Logic

Keywords
Logic game; puzzle; virtual reality, 3D, Education.

1. INTRODUCTION
The development of information and communication technology has provided children, adolescents and adults an easy way to use different applications in mobile devices. Regardless the knowledge area they are in, their logic and cognitive development can be qualified do play digital logic games [1].

Fraiman [2] and Sato [3] consider digital logic games as virtual tools and when they are applied in the teaching-learning process, they optimize time and work from teachers and students of this digital group.

From studies conducted in the resolution of the Magic Cube in digital environment by touch resources in smartphones and tablets and by mouse and keyboard in desktop computers, compared to the resolution of the Magic Cube in the traditional environment, we can observe the results in research present by Tabuti that shows digital Magic Cube needs to be improved [4].

To expand this research and to verify different applications that consider other human-computer interaction environments [5], considering digital environment in the third dimension, we have developed new applications to make new researches, where we can verifiy which 3D environment and virtual reality is the best for the development of Magic Cube.

In this way, virtual reality researches [6], as human-computer interaction environment research, with Oculus Rift, Google CardBoard, Hydra Controller, Leap Motion [7], and others, were made to understand how they can be useful in the development of new applications and for the Magic Cube.

Besides, we have performed previous researches with students of technology courses to identify how the human-computer interactions are developed by the logic game Magic Cube in a digital environment, in digital applications and in third dimension. From the results, we expect to deepen research to verify which 3D digital environment and virtual reality is more appropriate to the resolution of the Magic Cube, comparing to the students results solving the logic game by traditional ways.

1.1 Objectives
For an analysis and a comparison in the construction of 3D applications in virtual reality, we developed three applications to distinguish which is the best to the development of a logic game named Magic Cube, solved by touch, mouse and keyboard, when compared to the traditional Magic Cube.

From the results obtained of previous researches with the Magic Cube, we developed an application for smartphone/tablet, with each tier of the Magic Cube, where touch interaction was replaced for some icon indicating the interactions by buttons.

We developed another application to solve the Magic Cube with Oculus Rift and Leap Motion. In this case, an Oculus Rift can visualize the Magic Cube and the movements to manipulate the Magic Cube can be captured by a Leap Motion.

For the last application considered to solve the Magic Cube, we developed it with Oculus Rift and an Xbox controller. In this case, Magic Cube can be visualized by Oculus Rift and the Xbox controller makes the movements of the Magic Cube.

1.2 Related Works
Researches related to the development of traditional or digital logic games have been made such as Tonéis [8], who studied the development of a digital game for the learning of math, which improved the learning from students. In this study, the Magic Cube, besides being a game, which involves logical reasoning, can also be used to develop math concepts.

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Related to the application of cognitive skills of the Magic Cube in virtual reality, studies from Frade, Alixandre e Souza [9] present a game developed for virtual reality to improve cognitive skills and logical and math reasoning.

As part of the research of the Magic Cube in virtual environments, researches of Dourado et al. [10] proposed a digital game with augmented reality. These researches were used in the development of skills to solve math problems.

Jseixas, Cardoso and Dias [11] present the results of an experiment designed to characterize the Leap Motion moving tasks that link 2D and compare it with a mouse and touch.

Giloth and Tanant [12] explore IHC aspects in a variety of devices including desktops, laptops, android smartphones and tablets for the experience augmented reality and Oculus Rift for immersive experience. Each device and experience places different demands on the user interface.

2. FOUNDATION

2.1 User Interface and Human-Computer Interaction

According to Barbosa and Silva [5], an interface of Interactive System contains all the parts of the system which users have physical contact (motor or receptive) or conceptual during interaction.

The people insights and his interpretation compared with users interface, as his objectives, are affected by the context of the system utilization. Besides, when we explore the user's interface, it is necessary consider his education, knowledge and experiences [5].

To Carvalho [13], the human-computer interaction, that is a group of processes, actions and discussions where user interacts with computer, in addition of the multidisciplinary feature, has the main purpose of making sophisticated machines more available to potential users, related to interaction.

The human-computer interaction can be studied, as shown by Barbosa and Silva [5], (i) on the nature of the human-computer interaction; (ii) in the context use of interactive systems use; (iii) in the human characteristics; (iv) in the computer systems architecture and in the user interface; and (v) in the process of development related to the use of it. In this case, the human-computer interaction is related to the devices input and output, and in the ergonomics.

2.2 Virtual Reality and Augmented Reality

To Kirner and Kirner [14], virtual reality, augmented reality, and as their variation, consider the 3D in the computer interface technics performance, considering the multi-sensorial interactions and the processes in real time.

The virtual reality can be defined by Kirner and Kirner [14] as a computer interface which allows users interact in real time, in a 3D created by a computer, using their senses through special devices.

In the augmented reality, space is the traditional environment and the virtual environment is transported to the traditional environment by some technological device. In this way, Kirner and Kirner [14] say that the human-computer interaction happens naturally and intuitively without adaptation or practice.

2.3 Logic Games, Digital Games and Magic Cube

Logic games are not logical reasoning games that can be introduced as a daily issue and its resolution requires analytical reasoning [15].

Digital games, according to Correia et al. [16], are electronic games developed for computers, consoles or other technological devices, where a human-computer interaction exists, using these technologies.

In 1974, Erno Rubik, a professor from Hungary, developed the Rubik cube, a logic game known as Magic Cube. The Magic Cube were created to show the Rubik's students the space relations, and it became the best-selling toy in the world, because it is challenging, with logical intelligence, simple and complex, stable and dynamic, order and chaos problem [17].

3. APPLICATIONS

For this study, we have developed three applications. The first was developed for smartphone/tablet, with the movements of each tier of Magic Cube controlled by buttons. The Magic Cube movements as a whole, to observe all the sides, were developed with buttons.

Another application was developed to solve the Magic Cube using Oculus Rift and Leap Motion. In this case, we visualize Magic Cube by Oculus Rift and we perform interaction with Magic Cube by Leap Motion that capture our hands movement.

The last application considered to solve the Magic Cube was developed using Oculus Rift and the Xbox controller. In this case, we are able to visualize Magic Cube by Oculus Rift and we use the Xbox controller to move the Magic Cube.

3.1 Smartphone/Tablet Applications from Buttons

The application was developed for smartphones and tablets to solve the Magic Cube with the purpose to give a different way to solve it in a 3D environment, with icons that indicate and move the Magic Cube as a whole, as one of the sides is selected.

Figure 1 shows the application screen of the Magic Cube for smartphones and tablets, in such way that it is always possible to see its three sides, while the hidden sides can be seen in the planned cube, the left arrows move the cube as a whole, the right arrows move the tiers of the Magic Cube. Figure 2 shows some students experimenting the application.

Figure 1. Smartphone application screen.

Figure 2. Students testing smartphone application.

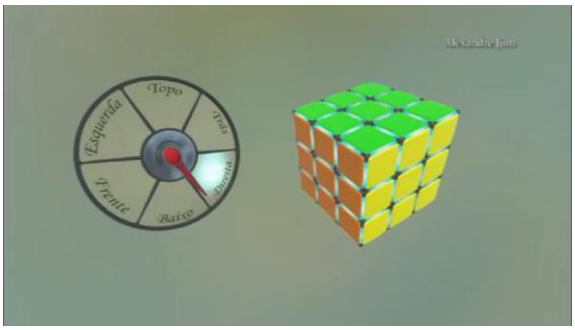

Figure 3. Unity application screen.

The application was developed in Unity 3D, using programming language C#. The first version was developed to play in desktop computers by two scripts: the first to map the cube and the other for its movements.

The first developed script starts by a method with takes the position, the size and the length of the sides. Another method takes these positions and calculates the angle and the coordinates of the cube. The third script controls the movements of the cube and its sides, as well as the execution of the shuffle button that shuffles the Magic Cube and the reset button that resets the Magic Cube.

Manipulating the Magic Cube by buttons is the differential of this application because most of the applications developed for smartphones and tablets to solve the Magic Cube are controlled by touch interfaces.

3.2 The Oculus Rift Application and the XBox Controller

The development of this application to solve the Magic Cube uses Oculus Rift as an output device and the XBox controller as an input device. The application has the purpose to give a different way to solve it in the virtual environment using commands that indicate and make the movements of the Magic Cube as a whole, as well as the movement of the selected side.

For this application, it was used a motor from Unity. The advantage of using the Oculus Rift and the Xbox controller is the creation of an immersive experience to make the gamer closer during the solving the game.

Figure 3 shows the application screen of the Magic Cube from an Oculus Rift perspective, where it is always possible to see three sides of the Magic Cube. The hidden sides can be seen with one controller command and with the other commands it is possible to select the movements of the cube or the tier movements of the Magic Cube. Figure 4 shows some students experimenting the application.

Figure 4. Students testing Unity application

The first challenge in the development of this application was learning the Unity engine and then learning the C# programming language. First, during the development and learning of the application, it was used the mouse to interact with the Magic Cube, and then adjust the development for Xbox controller. For the mechanics of the functional game, it was set some stages: rotation of the cube links between the cubes, selection of the neighbor cubes, shuffle of the cube, Magic Cube model import, recognition of the cube settled and rotation of the view all over the cube.

At the final development, project had been the interaction attributed of the cube by a controller, and the visualization of the virtual environment by Oculus Rift. There were two steps in this stage: implementation of the controller and implementation of the Oculus Rift.

3.3 Applications with Oculus Rift and Leap Motion

The development of a Magic Cube application, with Oculus Rift as an output device and Leap Motion as a input device, was made by five stages.

Figure 5 shows the application screen of the Magic Cube visualized by the Oculus Rift, where it is always possible to see three sides of the cube, and the movements of hands captured by Leap Motion can be used to see the hidden sides. Figure 6 shows some students experimenting the application.

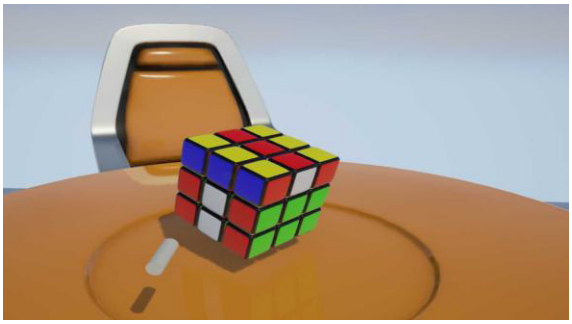

Figure 5. Unreal application screen

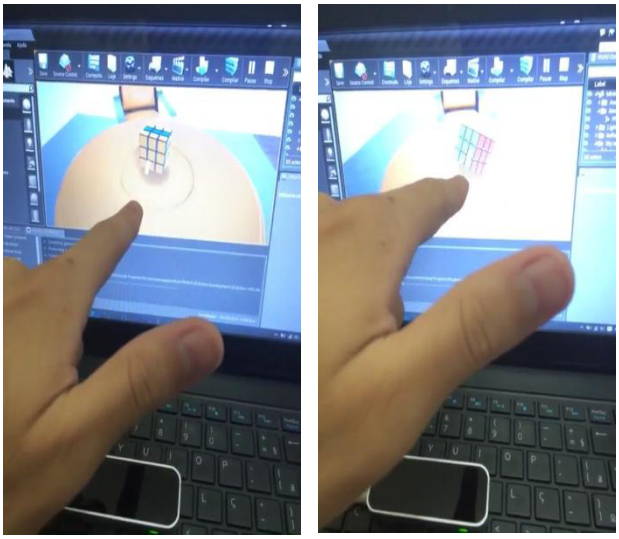

Figure 6. Students testing Unreal application

The first stage relates to 3D modeling and used the Maya Autodesk to do the Magic Cube modeling. The second stage relates to the cube modeling in the motor using the Unreal Engine, the Visual Studio 2013 and the XCode. By this time, the development started by using C++. After learning how to use the motor for programming in the elements, texture and the application of materials, it was possible to build the Magic Cube storing the references position in matrices.

Third stage relates to the manipulation of the cube in the motor, and in this stage it was necessary the restructuring of the code to match the rotation of the cube through math calculus which involved trigonometry to generate the traverse and rotation movements. The fourth stage relates to the integration of the game with Leap Motion, and uses the sensor values by API, without the ready motor resources to avoid problems of the reference.

3.4 Conclusions in the Applications Development

In the development of the Magic Cube application for smartphone and tablet, we observed some problems because the programmer did not know how to solve the Magic Cube. Researches about the traditional Magic Cube were necessary and how it works as its vertical and horizontal movements, and then develop an algorithm to do the cube movements.

The major difficulty was comprehending that the cube has predefined movements. In this way, the development of an algorithm depended on learn the logic of the cube movements.

A very important learning was the software engineering used in the development of the Magic Cube application by Oculus Rift and Xbox controller. Because of the lack of knowledge by tools, logic game and its possibilities, it was not designed a model to explore, plan and organize the development of the game. The results of it were the repetitive, poorly implemented and poorly organized methods. Besides, game is functional and works well, but in case it was necessary to modify the game or implement a new function, might result in changing all the scripts. That is the importance of building a software engineering before the development of any applications.

Playing the Magic Cube with Oculus Rift and Leap Motion with virtual environment sensors causes a strange feeling. The fact that moving the cube without touching it causes a strange and sometimes bad feeling. The movement of arms in relation to its and the cube position resulted in unpleasant feeling.

Another important element is the flow of development that ended without a viable solution. It was noticed that there was waste of time testing functions and methods with a stagnant solution. Notebooks and pencils were used to draft the reasoning ideas and it was better than the language grammar.

Possible sensor reading error of the Leap Motion, as shadows or bad position of the hand, resulted in misunderstanding movements. An unnecessary contraction of hand muscles and the suspension of arms to make the movements caused fatigue. The first movements of manipulation were interesting but after some time it began to cause exhaustion.

3.5 Informal Research Subject

We have made an informal research to students of a technology university and we have analyzed the preliminary data in the qualitative and quantitative form. The preliminary data from the Magic Cube application for smartphone had satisfactory results where the research subject could easily understand the movements of the Magic Cube as a whole and its sides. In case of a wrong movement, they could simply push the close button. In this way, students who knew the algorithm to solve the Magic Cube easily solved the logic game.

The preliminary data of the Magic Cube application from the Xbox and Oculus Rift version showed that the research subject got satisfied solving the logic game. Some reported that solving the Magic Cube with these devices motivated them more and students engaged in the learning of an algorithm to solve the Magic Cube. Students who knew the algorithm to solve the Magic Cube easily solved the logic game because the movements selected were the same suggested by the research subject.

The preliminary data from the Magic Cube application from the Leap Motion and Oculus Rift showed initial satisfaction manipulating the logic game. However, the movement control of the Magic Cube rotation and the selected sides could have been badly understood, which discouraged the solving of the Magic Cube. Experienced students to solve the logic game easily solved the Magic Cube because the selection and manipulation of the logic game, besides being intuitive, were not always as expected.

4. CONCLUSIONS AND FUTURE WORKS

After we studied tools and technologies for the development of the Magic Cube application, we have observed that these

technologies are appropriated to the development of logic games as Magic Cube.

The development could be more appropriated if all the phases of the software engineering were planned and made without the need of redoing it.

Although it was necessary to learn the concerned technologies for the development of the applications, time for the learning and the development of the application did not exceed the deadline.

The previous research to some technology students from the university could authenticate if applications were well developed. Part of the results showed where we could improve the application.

We have done a questionnaire to capture the human-computer interactions results observed from the research subject when solving the three Magic Cube applications. However, there is the expectation for deeply studies that might show which 3D interface and virtual reality are more appropriated to the development of the Magic Cube application, comparing to solving the traditional Magic Cube.

Besides, we might do more appropriated and qualified researches to check if the skills and competences in the logical reasoning are preserved in the Magic Cube applications developed in 3D and virtual reality.

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