Determining Which Touch Gestures Are Commonly Used When Visualizing Physics Problems in Augmented Reality

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Abstract. Touch gestures can be a very important aspect when developing mobile applications with enhanced reality. The main purpose of this research was to determine which touch gestures were most frequently used by engineering students when using a simulation of a projectile motion in a mobile AR application. A randomized experimental design was given to students, and the results showed the most commonly used gestures to visualize are: zoom in "pinch open", zoom out "pinch closed", move "drag" and spin "rotate".

Keywords: Augmented reality · Physics · Education · Usability
Touch gestures

1 Introduction

Augmented Reality (AR), as defined by Azuma, is an interactive system presented in real time that combines real and virtual realities registered in three dimensions [1]. Klopfer and Squire state that AR is "a real-world context dynamically overlaid with coherent location or context sensitive virtual information" [2]. Kipper and Rampolla mention in their book "Augmented Reality: An Emerging Technologies Guide to AR" that it is a variation of a Virtual Environment (VE). Our purpose is to use "digital or computer-generated information: whether they are images, audio, video, and touch or haptic sensations and overlay them in a real-time environment" [3]. Briefly, virtual information becomes real by using AR.

2 Related Work

Searching for a theoretical framework, Martín-Gutiérrez et al. introduced an AR application that worked with an AR book called AR-Dehaes, to enhance the acquisition of engineering students' spatial abilities. They made an experiment with undergraduate students from the Mechanical Engineering program and determined that the application

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had a positive impact in relation to easiness, learnability, controllability and intrusiveness [5].

Regarding the scope of physics, Cai et al. created a system for a convex imaging experiment that transmitted an interactive AR video by means of the internet, allowing (eighth-grade) students to interact with three-dimensional models in the technologically advanced environment. The results showed that the main grades from the experimental group, were better than those belonging to the control group, but there was no significant difference in the main scores of the subsequent tests [4].

A mobile collaborative AR simulation system of elastic collisions developed by Lin et al. showed a notorious improvement in the learning outcomes of undergraduate students compared to those who studied in the traditional manner. They identified three different knowledge construction behaviors among students: construction of problem space, construction of conceptual space and construction of relations between conceptual and problem space. The results showed a significant difference in the subsequent test grades in both, the control and experimental groups and demonstrated that studying with the AR Physics system denoted better learning results than those achieved by students using the traditional method [6].

Akçayır et al. also investigated mobile AR applications in science laboratories by including undergraduate students in an experimental controlled group, which showed an upgrading in laboratory skills and attitudes when using improved physics laboratories instead of employing printed laboratory manuals. They developed five applications for five different physics experiments (water electrolysis, Ohm's law, Wheatstone bridge, Kirchoff's law and three phase transformer connections) and gave students attitude questionnaires, pre-tests, subsequent tests and interviews [7].

Martin-Gonzalez et al. developed an AR system with a Kinect sensor to teach Euclidean vectors in College institutions, in physics and mathematics courses, which enabled the understanding of concepts such as magnitude, direction, orientation and operations related to vectors (addition, subtraction and cross product). The user's hand positions were the final position for the vectors, and the origin was located on his chest [8].

Another work was done by Kaufmann and Meyer, who developed an enlarged reality application for mechanics education to simulate physical experiments. High School students were allowed to build their own physics experiments in a three-dimensional virtual world. As they mentioned in their research, the applicability of the app was for students aged 12 to 18, depending on the specific physics course; the researchers also thought that the app could be used for basic college courses [9].

An investigation on the use of a haptic augmented simulation of gravitational forces between the sun and the earth for undergraduate students, made by Civelek and Kemal explored the effects of this technology on the students' results and their attitudes towards physics. To determine those effects, they used an experimental and controlled group and the outcomes showed a positive effect on the students' grades [10].

Enyedy et al. invented a project named LLP (Learning Physics through Play) to teach physics topics to 6 to 8 years old students with activities using augmented reality [11]. The results showed that students developed a conceptual understanding of speed, force, net force, friction and motion at an earlier age using the AR technology.

An empirical study made by Ibanez et al. used an augmented reality simulator in a physics course. This simulator was used by 112 students to interact with magnetic fields in 3D. The results showed that AR is a technology that has a positive impact on the students' motivation [15].

Buchanan et al. developed a toolkit with AR and rigid body simulations to teach chain reactions and physical contraptions by means of a game. This toolkit provided an imitation of a chain reaction based on augmented objects that were visualized using different indicators. It was a success because the results showed that this toolkit helped participants learn Newton's forces since they all finished the simulation correctly [16].

A study made by Pasareti et al., which was conducted in a high school and dealt with augmented reality in education, showed that participants of an AR group obtained the following results: 60% had the best marks, 38% had average grades and only 2% had worse results compared to those obtained in a previous test; and the results of the control group showed 27% had better grades, 42% had average results and 31% had worse grades. After analyzing those results, they came to the conclusion that AR is a very good technology to be implemented in addition to textbooks [17].

Freitas and Campos in their study about SMART, an educational system with augmented reality, to teach 2nd grade students, presented the results of an experiment which was organized in three different elementary schools. There, 32 girls and 22 boys ranging from 7 to 8 years old, were divided in two groups: an experimental group that worked with SMART and a control group that studied with the traditional methodology. The results, based on the Portuguese educational system, were divided into three groups: poor students, average students and good students. The first group showed 34% better learning results which derived from the use of SMART, the second group showed 62% and the last one 33% [18].

As it was previously expressed, AR improves learning in physics topics, so we planned, worked and developed an AR mobile application to test which touch gestures are frequently used by college engineering students when using simulations of projectile motion problems in mobile applications. A collection of qualitative and quantitative tools was employed, such as ethnography observations and open interviews.

3 Methodology

3.1 Participants

The participants were all college students enrolled in Physics I course at Universidad de Monterrey in Mexico, during the Fall semester of 2017. With a population of 375 students, a confidence level of 95% and an interval of 15%, a sample of 26 students was obtained and two groups were formed according to their level of spatial intelligence: an outstanding and an average one. The following question was asked at the beginning of the experiment in order to establish the amount of spatial intelligence each student had: "When a physics problem is presented to you, how easily can you visualize it in your mind?" In this research work, 18 male and 8 female students were included, whose ages ranged from 17 to 20 years old, 12 of them showed an outstanding spatial intelligence

(9 males and 3 females) and 14 showed an average spatial intelligence (9 males and 5 females).

3.2 AR Physics Application

In order to carry out our research, we looked for an app with augmented reality that included tactile gestures and a simulation belonging to a physics subject. But nothing was found in the applications markets. So, a mobile application had to be built to carry out the tests on the participants. This system was created to help physics students improve their classroom participation and to enable student-technology interactions.

A mobile AR application was developed using Unity version 2017.2 with Vuforia version 6.5 and the Java Development Kit version 8, in order to export the app to Android System. The Vuforia package was imported to use the AR Camera instead of the main camera [12]. First, a marker was used to be recognized by the AR Camera in order to present the 3D model in augmented reality as shown in Fig. 1. Next, the LeanTouch package was downloaded to implement the mobile gestures for the 3D model. The following tactile gestures were programmed: moving, zooming in, zooming out and rotating, as shown in Figs. 1, 2, 3 and 4.

Fig. 1. Move simulation to any place of the screen with a touch gesture.

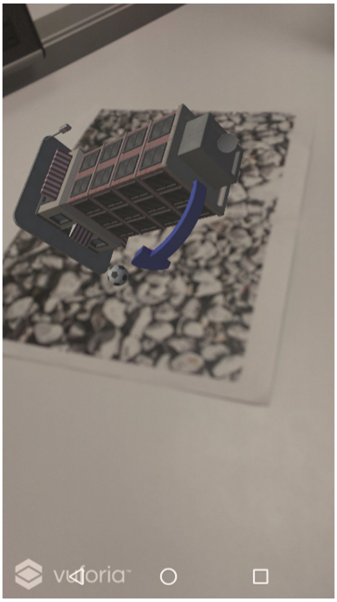

Fig. 2. Rotate simulation with a touch gesture.

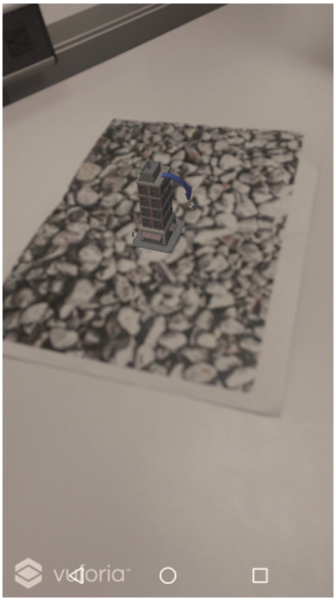

Fig. 3. Zoom-out simulation with a touch gesture.

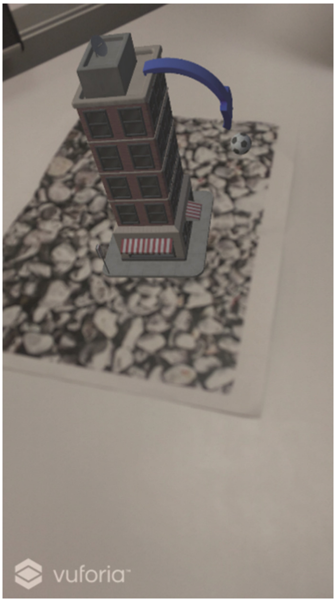

Fig. 4. Zoom-in simulation with a touch gesture.

As we can see in the previous images, the parabolic problem is working in augmented reality by applying the gesture to the 3D object (formed by the building and the blue arrow indicating where the ball will fall).

Finally, in order to export the application for Android System, an Android Studio 3.0 was downloaded with the SDK, in order to have the API's for each Android Version. The mobile app was able to work with Android 4.0 onwards, to the most up-to-date version (Android 7.1.1).

3.3 Procedure

The experiment was prepared individually for each participant. First, a tutorial was shown with the touch gestures that were implemented in the app in order to let students know which ones could be used. Then, we presented to them the following projectile motion problem: "From the top of a 15 meters-high tower, a projectile is launched with an initial velocity of 5 m/s and an elevation of 40°. Determine the horizontal distance travelled by the object". Then, we asked them to answer the following questions with the app.

- Question 1: What touch gesture would you employ to see the ball at a closer distance?
- Question 2: What touch gesture would you use to see the whole simulation?
- Question 3: What touch gesture would you use to move the simulation to the left?
- Question 4: What touch gesture would you practice to look at the horizontal distance the ball must travel?

Finally, we gave students an open interview in order to know what they had achieved when they finished the four tasks. The following questions were asked to find out what they thought about using AR in an application to be employed in the physics course.

1. Did the AR app help you understand the problem?
2. Did you understand the problem better by reading about it or by using the app?
3. Would the app motivate you to learn the material of the physics' course?

4 Outcome and Discussions

4.1 Touch Gestures Results

After carrying out the experiment, the touch gestures were obtained and analyzed. The results are presented in Table 1.

Table 1. Touch gestures results of the research

Question	Gesture	Times that the touch gesture was used	% of used gesture in each question
Question 1	Zoom-in with two fingers	24	92.30
	Zoom-in with double tap	2	7.70
Question 2	Zoom-out with two fingers	25	96.15
	Zoom-out with double tap	1	3.85
Question 3	Swipe	17	65.38
	Keep pressed and swipe	9	34.62
Question 4	Swipe to rotate	19	73.07
	Spin with two fingers	7	26.92

4.2 Students' Achievements

The data collected from the questions in order to obtain the students' results is presented in Table 2. Most students commented that the app helped them understand the problem we presented to them; They also commented that the best way to understand the physics' problems is by interacting with the simulator.

Table 2. Students' commentaries on their success.

Comment	Number of persons
It helps me because I can see it in 3D	20
I will not have grammar problems to understand the text	4
I will not have any problems to sketch a traditional 3D drawing	3
I will not have to waste time outlining the problem	1

4.3 Discussion

The majority of the students' commentaries on their results, it expressed was that the app fulfilled its purpose. The participants showed a positive reaction to the application when it was presented to them and they were interested in using it during the course, to get a better understanding of the physics problems that they were working with. To answer any problem and to be able to solve it, one must understand and outline it, so it can analyzed. However, there are cases in which students are unable to visualize it and delineate it. So, our application will help students solve both problems, outstanding spatial intelligence and average spatial intelligence.

With regards to the application, we must say that we are encouraged to continue working with it because of the participants' positive opinions since most of the students said that they would like to have augmented reality included as part of the curricula, to help them solve problems. That would save them time to sketch any problem presented to them and they would interact with it by means of gestures, in order to understand it.

In a future research work, we would like to add some exercises covering all the topics presented in the Physics 1 course, at Universidad de Monterrey, so that it can be integrated as a class tool.

4.4 Restrictions of the Study

When the experiment was carried out, there were two restrictions in our research work. The first one was the mobile application's development because it was impossible to program all the gestures shown in Table 1. The "LeanTouch" library of tactile gestures used for models working in augmented reality, only offers the gestures of zooming in, zooming out, rotate with two fingers, and swipe to move the simulation. To solve those problems, we gave the participants four questions, and also gave them instructions to refrain from touching the screen. Then, we asked them to pretend they made motions in the air. Finally, we let the participants interact with the application so that they could be in contact of the programmed gestures.

The second restriction was the size of the sample: it was not as big as we had planned at the beginning. One of the requirements was that students should be enrolled in the Physics 1 course and there was a problem to contact students who wanted to participate in our research. To find a solution and get an adequate sample to test our research, we spoke to the person in charge of the Physics Department of the University of Monterrey, who teaches the subject to three groups. He supported us by allowing us to take students to the classroom where we had the prepared equipment for the test.

5 Conclusions

After having carried out this research project and obtaining the results of the test, we counted the gestures used in each task and determined which one was used most frequently in each of the following classification: movement, zoom out, zoom in, and rotation.

The classification of the two gestures in order to approach the simulation to the application, the most frequently used gestures were "pinch open" (92.3%), "pinch closed" (96.15%), "drag" (65.38%), and rotate (73.07%).

In the classification of the two gestures for rotation of the simulator in the application, the most frequently used was the "Swipe" gesture showing a total of 19 times against 7 which was the gesture of "Spin with two fingers". This was the classification with the most difficulty in the test for the participants to be able to successfully complete the task defined in the fourth question.

The results obtained in this study show that it is easy for physics students to perform a certain gesture to complete a task in the application. We verified that the app is easier to use by the type of user to whom it is being directed. According to Joan, in his study about enhancing education through augmented reality, students are able to enrich themselves by the use of augmented reality through electronic devices, since they are capable of relying on this tool anywhere and anytime; the pedagogical effects of using it in classroom were studied and it is stated that the students, who experience the use of augmented reality, developed better thinking skills [13]. It is deduced from this study that the development of the application would be a helpful tool for students who need a better understanding of physics problems and that tactile gestures are the right way to interact with augmented reality. Finally, with this app, an interactive education can be integrated in the near future into the physics course; Lee said in his study, that AR is a great way to make education interactive, since this technology allows "educational environments to be more productive, pleasurable, and interactive than ever before" [14].

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