Teaching Physics Using Equidistant AR/VR-Projections

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ABSTRACT

Modern augmented/virtual reality (AR/VR) technologies offer us new educational opportunities. They possess the immense untapped resources for significant improvements of the physics education. The transformation of the learning scene (or arena) to the abstract symbolic environment leads to the emergence of the new views at teaching. The AR/VR-glasses allow us to do this, changing, supplementing and augmenting the picture of the physical world around the observer (teacher or student) and even completely replacing it. The paper deals with the teaching experience of the equidistant (spherical) projection use in the physics classes. It describes the list of useful tools to facilitate the perception of AR/VR 360-panoramas, recommendations for the practical use, the students' opinion about this technology. It also presents the description of equidistant panoramic slides that are already available, tested in the practice, and ready for physics teaching. Here we consider the place of equidistant AR/VR-projections in the educational process, characteristics of the educationally tested AR/VR-devices, the most effective techniques of their use.

CCS Concepts

• Computing methodologies→Virtual reality; Applied computing→Education

Keywords

Physics Teaching, Augmented Reality, Virtual Reality, Equidistant Projection, Educational Process, New Technologies

1. INTRODUCTION

Educational researchers have different opinions about the aims and place of augmented/virtual reality (AR/VR) technologies in teaching [1-4]. This time every teacher is an owner of a mobile phone (students too). The screen of a smartphone inserted in the AR/VR helmet can create a new reality around the observer. The events of AR/VR lessons unfold here: the panoramic AR/VR slide is on the inner surface of the sphere in which our observer (student/teacher) is located. The student is always in the center of the sphere.

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This projection method is very simple. In our version of AR/VR-teaching the teacher can use ready-made slides, or he can make them himself. On the one hand, as a rule, teachers already have simple computer and telephone skills. On the other hand almost every student has elementary skills to install, turn on/off the mobile applications. This is enough to work with AR/VR slides according to the principles "Take and Use", "Plug and Show/Play".

Most teachers have no access to the expansive hardware and software. The price range of the educationally tested AR/VR devices is 1-20 dollars. We used only free mobile applications to view the AR/VR demonstrations (Fulldive VR for iPhone and Android), and open-source software to create them (the free editor GIMP is a completely powerful tool, fully capable of creating AR/VR slides).

The teacher and students put on the AR-glasses, launch the recommended mobile application, customize the necessary options, enter into the AR/VR arena and start to learn a new lesson.

The paper is organized as follows: section 1 (Introduction) includes the general information on the discussed problem; section 2 (Panoramic Slides in AR/VR Teaching) describes the practical aspects of the AR/VR projection, and subsections 2.1-2.5 detail the project); section 3 (Findings and Discussion) concerns to the results; furthermore section 4 (Students about the AR/VR Projection Teaching Technology) surveys the results of interviewing of students; section 5 (Conclusion) provides some concluding and very important remarks. References finalize the paper.

2. PANORAMIC SLIDES IN AR/VR-TEACHING

There are many kinds of projections traditionally used for panoramic imaging [5]. We use a simple flat representation of the sphere where the latitude concerns directly to the horizontal line, and the longitude concerns to the vertical one.

This projection is often applied for the source images in the panoramic AR/VR viewer mobile applications, and it may be a very convenient and inexpensive way to see the sphere around us with a smartphone embedded to the AR/VR glasses or directly on the phone screen [6].

An equidistant projection maintains scale along one or more lines, or from one or two points to all other points on the image. The teacher creates the flat image only, and then a mobile application converts this into a sphere.

An abstract symbolic environment is natural for physics and physics teaching, but of course AR/VR projections are suitable for studying different disciplines. Here is the list of equidistant panoramic slides (learning arenas) that are already available, tested in the practice, and ready for teaching.

2.1. "What Time is it in the Universe?"

Horizontally (from left to right) on the top row (first line): «1. What Time is it in the Universe?»; «2. The Planck Time»; «3. The smallest fragment of time that scientists have measured»; «4. The visible light»; «5. The Length of Nowness»; «6. The Reaction Time»; «7. The Human Heart beat».

Then we go along the arrow to the bottom row (second line): «8. Digestion»; «9. The circadian rhythm»; «10. Our Earth Revolves Around the Sun»; «11. The Human Life Cycle»; «12. The Anthropocene: The Age of Mankind»; «13. The Age of the Earth»; «14. The Observable Universe».

And we see the portrait of Isaac Newton vertically downward from the observer (at the nadir) and then the portrait of Albert Einstein at the highest point, vertically above the observer (at the zenith).

2.2. "Physicists" (the gallery of portraits)

Horizontally (from left to right): Aristotle; Nicolaus Copernicus; Galileo Galilei; Isaac Newton; Michael Faraday; Albert Einstein; Max Planck; Erwin Schrödinger; Richard Feynman; Stephen Hawking.

Vertically above the observer we see the mural of Physics by Walter Shirlaw (Thomas Jefferson Building, Library of Congress, Washington D.C.), and vertically downward we see the full-view photo of our planet.

2.3. "Electromagnetic Spectrum"

It shows the AR-range of frequencies (wavelengths) of electromagnetic radiation. Horizontally (from left to right): gamma rays; X-rays; ultraviolet; visible light; infrared; microwaves; radio waves. There is the frequency of the radiation above the slides, and the wavelength under the slides. The second (down) line describes the diagram of the visible spectrum in detail.

At the zenith there is a portrait of James Maxwell, who formulated the classical theory of electromagnetic radiation.

2.4. "What is the Temperature of the Universe?"

Horizontally from the first slide to the thirteenth one (in the direction from 'Absolute Zero' to 'Absolute Hot'): «1. Title: What is the Temperature of the Universe?»; «2. Absolute Zero»; «3. Coldest (lowest) temperature achieved»; «4. Cosmic microwave background»; «5. Water freezes»; «6. Normal human body temperature»; «7. The Death Valley» and «Antarctica»; «8. Water boiling point»; «9. Iron melting point»; «10. Sun's surface»; «11. Sun's core»; «12. The hottest human-made temperature»; «13. The Planck temperature» (there is a schematic image of the Big Bang at the end of the panorama).

And we see a pair of images each at the nadir and zenith of the teaching arena: the portraits of Anders Celsius and William Thomson (Lord Kelvin).

2.5. Other AR/VR slides

Teachers can offer and create other kinds of AR/VR slides, which easy to apply with the technology of the AR/VR equidistant projection: "Comparison of the sizes of objects in the Universe"; "Energy in the Universe"; "Masses of Objects in the Universe"; "The Range of Densities in the Universe"; "Examples of Different Speeds"; "Magnetic Fields"; "Electric Fields"; "Dimensions of Physical Quantities"; etc.

3. FINDINGS AND DISCUSSION

Many researchers have conducted several analyses of teachers' and students' views on using AR/VR environments in physics education [7, 8]. As a rule, all the major participants of the educational process answered positively to the questions concerning AR/VR in physics teaching and they are very excited about using it in learning for a first time [9]: new technology takes easy their attention. AR/VR should be used in the subjects of science which are difficult to comprehend [10]. AR/VR devices allow students to explore 360-degree and three dimensional worlds [11], to immerse into imaginary learning environments [11, 12], to study abstract physics concepts which are difficult to understand through a traditional way [13, p.54], to support learner and teacher communication [14], to develop an experiment in a virtual physics laboratory [15], to learn physics through game-like simulations [16]. This area is developing so fast that any literature review will be incomplete.

During the academic year 2018/19 we had the opportunity to discuss peculiarities of the technology applied to the physics teaching process with teachers of Yugra State University.

360-degree spherical equidistant AR/VR-panoramas, according to the interviewed teachers, are good in the following cases:

- Introduction to a new topic, a new object, a new model, a new academic discipline.
- Learning of the general plan of actions.
- Studying of schemes, models, maps, diagrams and tables.
- Systematization and generalization of knowledge.
- Demonstration of the scientists' galleries.
- Increasing of the interest for the most difficult and tedious topics of the physics course.
- Tours to the natural and industrial objects.

In my practice the most effective panoramic lectures were those that aimed at systematization and generalization of the studied material (with the use of tables and diagrams located on the inner side of the AR/VR sphere).

The advantages of such technique also include:

- The presence effect inside a fictional learning environment;
- The possible view angle of the virtual space is the maximum, in our case - 360 degrees;
- Students can see images and texts not only along the horizon, but also both under their feet and above their heads;
- The simplicity and availability of instruments for the creation of panoramas;
- A lot of viewing tools are already developed for AR/VR devices;
- You can turn (transform, convert) any presentation into the 360-panoramic lecture.

Images placed at the zenith (the top point of the spherical panorama) and at the nadir (the bottom point) contain information that is important for the entire lecture. These can be portraits of scientists who have made a great contribution to this field of physics, formulations of fundamental laws, fundamental prerequisites, definitions, famous quotes from the classical scientific literature. In addition, near the nadir point the AR/VR creators can naturally place a service menu.

Distortions in the flat variants of 360-images make it difficult to view them in a printed version, especially at the top and bottom points: both areas near the poles get stretched horizontally. However, such flat blanks can still be used by the teacher.

It is recommended clearly and truthfully highlighting the horizon line to avoid the disorientation of the observer in the space, as well as falls and injuries. Also it can be the basis for grouping of visual information (for example, above the horizon line or below the one). The direction of the line may indicate the next step of the lesson. And you can use the panorama slide with one, two or three horizontal rows along the line of the virtual horizon.

There is the spectacular hypothesis that physical movements of our body can affect the ability to remember the complicated learning material [17]. Students learn physics concepts performing actions, gestures, movements of the head, body, hands due to the AR/VR projection, being in the AR/VR world and interacting with it. We have to note here, that gesturing, natural for a person in an AR/VR sphere, becomes strange and unusual for someone who watches it outside.

It is also strongly recommended to ensure the safety of the student in the AR/VR helmet. Some variants of lectures do not imply the arbitrary movement of students around the class due to potentially traumatic events. The teaching experience shows that students can use their motor skills, which are unfortunately erroneous in the AR/VR world. This is very important to know especially for beginners.

Several 360-panoramic presentations can be merged by interactive transition links, forming the united virtual learning tour.

In addition to spherical 360-panoramas (and 360 video), students can study panoramas in a cylindrical and cubic projection, virtual 3D objects, ordinary drawings, pictures and photos, 2D or 3D video [18]. Besides, the slides may have soundtracks.

AR/VR objects can be studied on the background of objects from the real world (and in addition to them). They can be "attached" to real-world bodies, but that is not necessary.

The screen mirroring wireless technology allows transferring the image from AR/VR-glasses onto the lecture screen. It is technically possible. However, in practice the screen picture trembles badly, fluctuates, and has little didactic meaning due to unstable movements of the head, hands, body. It is advisable to show another picture on the large lecture screen related to what the students see in the AR/VR helmets.

Existing mobile applications offered by developers do not allow making notes during the AR/VR lecture. If a student wants to write something in his notebook, he (she) should take off his (her) AR/VR glasses.

The list of useful tools to facilitate the perception of 360-panoramas through the AR/VR devices:

- Controlling of the view direction by the head rotations: left-right and up-down (a gyroscope is necessary in order to rotate the head and look around inside the AR/VR sphere);
- Changing the distance to the observed part of the panorama: back and forth, closer-further (a joystick is required);
- Moving smoothly from one panoramic slide to the next (various kinds of the mobile application menu).

4. STUDENTS ABOUT THE AR/VR PROJECTION TEACHING TECHNOLOGY

It is interesting to know the students' opinions about this version of the AR/VR projection teaching technologies.

In our pilot experiment the physics teacher delivered a lecture (research period: 2017-2018). Students used their AR/VR glasses voluntarily, without any coercion, but in accordance with the teacher's instruction. The maximum duration of AR/VR lesson was limited to 20 minutes.

Before class, students listened to safety instructions: we have designed short AR/VR training sessions. There was another person (a teacher or a student) who watched for the unsafe movements. Students could keep all AR/VR slides themselves for viewing afterwards and detailed study at home.

After lessons they answered the question: "What do you feel about the lecture?" The Table 1 illustrates the results.

Table 1. The results of interviewing of students: "What do you feel about the lecture?"

Answers of students	Number of students
That was exciting and I want next lesson like this one; I was interested in it	23
It was unusual, but I'd prefer the teacher not wearing AR/VR-glasses	7
I do not care; that does not matter; there is no difference	4
I refused to get on the AR/VR glasses	2
I was scared and I wanted to run away	1
Total	37

It was easy to notice that students studying the physics topics through AR/VR projection found it more interesting and less abstract than students studying the same topics through the ordinary demonstration on the lecture screen. Some of them returned to the AR/VR slides again, reliving and revising the AR/VR demonstration.

And of course it should be emphasized that some students have refused to put on AR/VR-glasses. This means that AR/VR-teaching not only a pedagogical, but also a psychological problem.

5. CONCLUSION

The learning arena based on the abstract symbolic environment is natural for physics and physics teaching. Spherical AR/VR-panoramas where you can see the fictional and real environments (or both of them at the same time in the same space) have great recognized teaching potentialities, which are practically not used yet.

In this paper we have considered the peculiarities of equidistant projections in the case of physics teaching, described the practical aspects of panoramic slides using, found out the teachers' and students' opinions about this technology, formulated recommendations for the further teaching practice, critically characterized the available AR/VR devices, suggested the most effective techniques of the equidistant projections in physics classes.

The equidistant AR/VR-projection matches to the skills of teachers, interests of students, and requirements for the organization of the educational process.

This area of didactics needs further researches and has far-sighted perspectives. However, the described AR/VR-technology can be applied by physics teachers right now. In addition the unusual lessons attract the students' attention.

Despite the number of participants (students and teachers) was limited to make final conclusions, the results of the equidistant AR/VR-projection use are encouraging.

In the nearest future the activity of enthusiasts of AR/VR teaching should be directed to the demonstration of opportunities of AR/VR projections, learning of the AR/VR slides creation methods, noting the simplicity and availability of applying this technology.

In the longer term our expectations are determined by the progress in improving of the AR/VR hardware devices, their mobility, compactness, comfortableness, prices and societal attitudes to them.

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