Augmented Reality-Based Interactive Simulation Application in Double-Slit Experiment

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Abstract. Experimental teaching is an essential link in teaching and learning activities, holding an important position in the modern education. However, it is impossible or difficult for some physical phenomena to be carried out in the classroom. With the advantages of portability and combining both the real and virtual world, mobile device and Augmented Reality (AR) technology are having a positive influence on the creating of cognitive tools. In this paper, we develop DSIAR, an AR-based interactive application on mobile devices, to simulate a physical experiment, double-slit experiment. DSIAR allows students to control and interact with a set of 3D models of laboratory apparatus through markers, to change the parameters to observe the dynamic variable phenomenon which is not easy to observe in the real world. The results of pilot testing show that DSIAR can have a positive impact on assisting teaching and learning, attracting students' attention and stimulating their interest, suggesting significant potential for this learning application in practice.

Keywords: Augmented reality · Simulation experiment · Mobile device · Double-slit experiment

1 Introduction

Due to limited opening hours and lacking physical materials, it is difficult to access to relevant references from the laboratory in the middle or high school. As a consequence, many experiments cannot be carried out, especially in the teaching of physics, such as the double-slit experiment. Therefore, students in such school learn physics still through the traditional learning models, including attending a lecture, taking notes on what the teachers write on the blackboard, memorizing facts from books or slides. However, abstract concepts such as optical wave are formidable to high school students, and their imaginative abilities are limited, so it is a challenge for them to imagine the experimental progress just based on the information they got from books or slides. This could be a barrier to in-depth understanding of the subject matter. Yet, these problems could be solved by introducing alternative teaching resource such as Augmented Reality-based learning tools (Jamali et al. 2015).

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Augmented Reality (AR), an extension of Virtual Reality (VR), creates an enhanced reality with bridging virtual and real worlds. With the coexistence of virtual objects and real scenes around them, AR allows learners visualize complex spatial relationships and abstract concepts, observe phenomena which is not easy to observe in the real world, interact with the virtual objects in the most natural way, like interacting with the interposed virtual objects just by moving the marker. Augmented Reality, therefore, can enhance students' interest and motivation, as well as, learning experience (Gausemeier et al. 2003; Nincarean et al. 2013).

Mobile learning based on smart device is a new learning method. Besides, with the integration of Augmented Reality technology and mobile device, a new trend of applying AR to disciplinary teaching has appeared.

2 Literature Review

AR-based application in teaching and learning is most applicable in the following two cases: (a) when the phenomenon is not easy to be simulated in reality, such as inquiry-based micro-particles interactive experiments (Cai et al. 2014); (b) when real experiment is limited by various factors which is hard to deal with, such as the convex imaging experiment (Cai et al. 2013), as it is dangerous to keep a lighted candle in a classroom.

Creating a mixed and enhanced reality, AR has compelling features for educational purposes, such as learning content in 3D perspectives, offering learner with senses of presence and immersion and visualizing the invisible (Wu et al. 2013). Additionally, these features coincide with ideas in education theories. For instance, the theory of situated learning insists that the actual and complete knowledge is acquired in real learning situation, which AR technology could create by bridging virtual and real worlds. Behaviorism which holds learning is the result of association formed between stimuli and responses is another example. Within an AR-based learning environment, learners could receive corresponding feedback immediately as they interact with the environment or objects in it, while stimulus-response ties are forming and corresponding knowledge is grasped. Besides, in an AR-based learning environment, learners could gradually construct their recognition structures by conducting various activities, which satisfies both Piaget's assumption and practice of "bring laboratories into classed" and the argument of constructivism that "learning is embedded in authentic social experiences" (Cai et al. 2013).

A considerable number of AR-based learning and teaching tools are developed and used in physics teaching (Castillo et al. 2015; Cai et al. 2013; Cai et al. 2016; Kaufmann and Meyer 2008), what's more, a great number of researchers have designed suitable activities to test the influence generated by using these tools in students' learning performance (Akcayir et al. 2016; Cai et al. 2016; Wang et al. 2014).

Kaufmann and Meyer (2008) had introduced an AR-based application in teaching mechanics. They developed a computer game to simulate experiments in the field of mechanics. Involved in the 3D virtual world created by this application, students engaged themselves in their own experiments. What's important is that this application offered students a considerate number of tools to measure mass, force and other physical property of an object, during and after the experiments.

In the convex imaging experiment (Cai et al. 2013), learners need to (1) operate 2D-code cards to change the object distance and the distance between the object and the lens; and (2) imagine that the 2D-code cards are the experimental facilities. The learning effects could have been compromised due to the increased cognition load caused by the information migration. The experiment would have been more interesting if not only the virtual objects were integrated into a real scenario with AR, but also the learner's interactive operation behaviours were the same as the real experimental condition.

AR-based application has been also developed for teaching magnetism. Cai et al. (2016) implemented an AR and motion-sensing learning technology to teach the fields of magnetic, where the magnetic model and magnetic induction line are simulated and presented in real time. It demonstrated that the AR-based motion-sensing software can improve students' learning attitude and learning outcome.

As mentioned above, AR technology can improve development of simulation systems and foster students' learning of science. Therefore, our research targets double-slit experiment, which phenomenon is not to be observed and is difficult to carry out in most high schools. It is for this reason that we decide to develop an AR-based interactive simulation application. With video recording the process of such experiment, learners just can observe the phenomenon instead of interacting with them by changing relevant parameter. Furthermore, Constructivism advocates that "knowledge originate from activities and recognition starts from practice". In the proposed AR environment, learners can change relevant parameter with markers to observe the variable phenomenon, furthermore, comprehend the process of such experiment. Our research aims to design and develop a physical AR cognitive tool named DSIAR for double-slit experiment and measure its reliability and usability.

3 Augmented Reality-Based Interactive Simulation Application

3.1 DSIAR Overview

DSIAR integrates double-slit experiment with AR on mobile devices. The development can be divided into three phases: capture real scene, track and compare the marker, and compositing rendering, as shown in Fig. 1. We build a fluorescent screen model, a point source of light and a slits model according to double-slit experiment using 3DS Max. Then we plant the models into Unity3D environment and adjust the coordinate system and the interactive mode between users and the models. Through the AR software development kit (SDK) Vuforia, DSIAR can render virtual models and the real scene to create a mixed real-time interactive environment.

DSIAR consists of three pieces of cards (as shown in Fig. 2(a), (b) and (c)) and a mobile smart device (cellphone or tablet) (as shown in Fig. 2(d)). Three cards are used as markers to represent the corresponding virtual models. The mobile smart device is

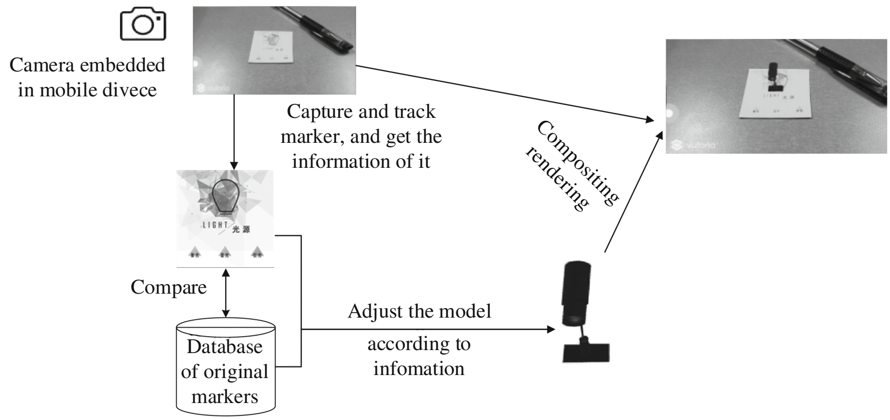


Fig. 1. DSIAR overview

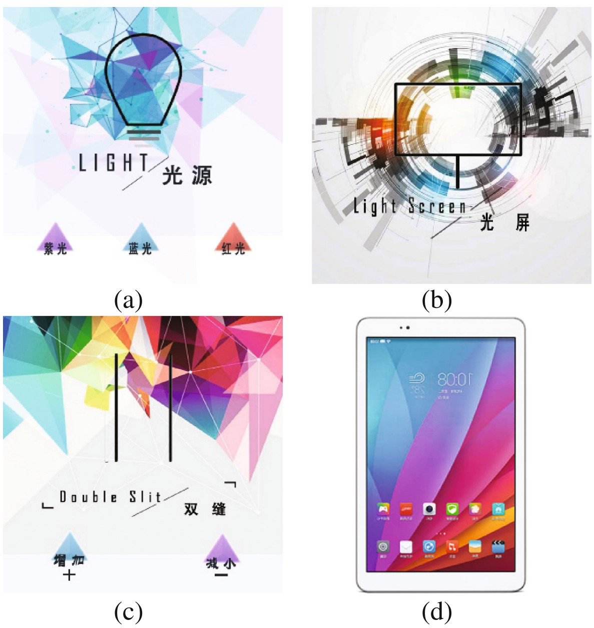


Fig. 2. Markers of DSIAR

used to capture and present the real world and the virtual models while the camera embedded in it detects markers.

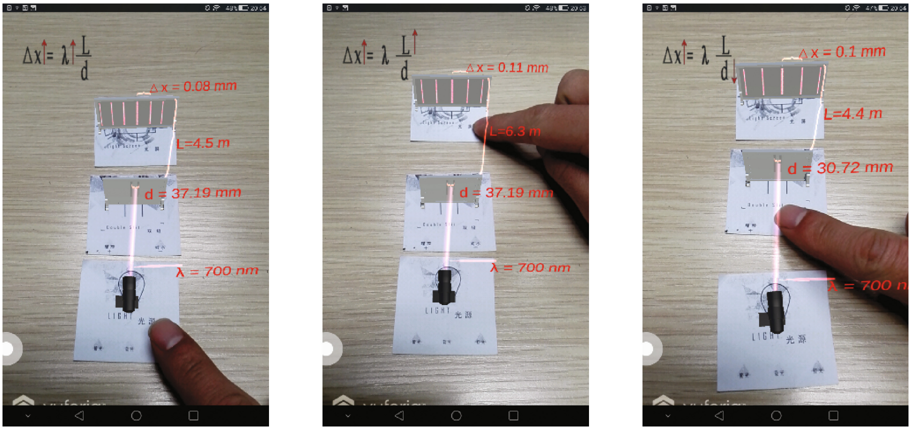
DSIAR runs on an android mobile smart device (cellphone or tablet). In particular, it focuses on in-depth understanding of relation between phenomenon and relevant parameters (including distance between slits, distance between slits and fluorescent screen, wavelength), and visualizing the changing of phenomenon with operation of such parameters.

3.2 User Operation

With DSIAR, double-slit experience could be directly simulated using three different cards to replace point source of light, slits and fluorescent screen. 3D models of point source of light, slits and fluorescent screen and the values of relevant parameters will be displayed on the mobile device's screen as camera captures all three cards.

Assuming distance between slits as d, distance between slits and fluorescent screen as L, wavelength as λ, and the spacing of the fringes as Δx. According to the formulate of double-slit theory $\Delta x = \frac{\lambda L}{d}$:

(1) when d, L are constant, Δx increases with the increasing of λ; otherwise, Δx decreases with the decreasing of λ, as shown in Fig. 3(a).
(2) when λ, d are constant, Δx increases with the increasing of L; otherwise, Δx decreases with the decreasing of L, as shown in Fig. 3(b).
(3) when λ, L are constant, Δx decreases with the increasing of d; otherwise, Δx increases with the decreasing of d, as shown in Fig. 3(c).



(a) (b) (c)

Fig. 3. The phenomena with operation of cards (adjusting relevant parameters)

3.3 Pilot Testing

User pilot testing was conducted for measuring the reliability and usability of this application. 1 teacher and 3 students who had never experienced AR-based application before were interviewed. First, a brief introduction and training of the system's function was conducted. The teacher and students were exposed and familiarized with the simulation application for around 30 min, while they did a simple teaching and learning activity with it, as shown in Fig. 4. Then, we had an interview with them,

Fig. 4. Teacher and students are using DSIAR

expecting them to share their feelings as well as comments on this application in the experimental operation.

From the interview, we can draw the following conclusions:

(1) The changing of phenomena with the operation of cards (adjusting relevant parameters) is conform to reality.

After experiencing this AR-based application, the teacher expressed a wish to apply it in her class. *"It's a wonderful teaching aids for this chapter. With it, the content will not be dull and abstract."* which suggests that the simulation matches reality.

(2) All students felt that this application is very novel and interesting.

In the pilot testing, we offered the students with the AR-based simulation application which they never experienced before. For them, therefore, this is very innovative and interesting. They expressed that *"Great, it's a brand-new interaction way that I can operate the object on the screen with my hands"*; *"I have never learning anything with such application, if it were applied in class, my friends will be very interested!"* Students were impressed by the application, and it attracted their attention.

4 Conclusion

In this paper, an AR-based experiment simulation with the integration of augmented reality technology and mobile smart devices (cellphone or tablet) was developed. Double-slit experiment using augmented reality, assisting teaching and learning, could be performed at any time, any place just with a mobile smart device.

Based on preliminary results of pilot testing, DSIAR can have a positive influence on assisting teaching and learning, attracting students' attention and stimulating their interests. Although the development of Augmented Reality-based interactive simulation application is finished, however, the sample size is not large enough. In order to further explore the effect of AR-based simulation application, future work will involve a large sample under rather more naturalistic conditions to collect enough data to verify the effect and potential of AR-based simulation application, while an inquiry-based learning activity will be designed.

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References

Akcayir, M., Akcayir, G., Pektas, H.M., Ocak, M.A.: Augmented reality in science laboratories: the effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. Comput. Hum. Behav. **57**, 334–342 (2016). doi:10.1016/j.chb.2015.12.054

Castillo, B., Iván, R., Sánchez, C., Guadalupe, V., Villegas, V., Osiris, O.: A pilot study on the use of mobile augmented reality for interactive experimentation in quadratic equations. Math. Probl. Eng. **2015**, 1–13 (2015). doi:10.1155/2015/946034

Cai, S., Chiang, F.-K., Wang, X.: Using the augmented reality 3D technique for a convex imaging experiment in a physics course. Int. J. Eng. Educ. **29**(4), 856–865 (2013)

Cai, S., Chiang, F.K., Sun, Y., Lin, C., Lee, J.J.: Applications of augmented reality-based natural interactive learning in magnetic field instruction. Interact. Learn. Environ. **25**(6), 1–14 (2016)

Cai, S., Wang, X., Chiang, F.-K.: A case study of augmented reality simulation system application in a chemistry course. Comput. Hum. Behav. **37**, 31–40 (2014). doi:10.1016/j.chb.2014.04.018

Gausemeier, K., Bruseke, U., Wortmann, R.: Virtual and augmented reality in education and training: an interactive, multimedia training and information system for use in an exhibition. In: Third International Conference on Virtual Reality and Its Application in Industry, vol. 4756 (2003). 304-313428

Jamali, S.S., Shiratuddin, M.F., Wong, K.W., Oskam, C.L.: Utilising mobile-augmented reality for learning human anatomy. Procedia Soc. Behav. Sci. **197**, 659–668 (2015). doi:10.1016/j.sbspro.2015.07.054

Kaufmann, H., Meyer, B.: Simulating educational physical experiments in augmented reality. In: Applications of Mixed Reality, pp. 1–8 (2008)

Nincarean, D., Ali, M.B., Halim, N.D.A., Rahman, M.H.A.: Mobile augmented reality: the potential for education. In: 13th International Educational Technology Conference, vol. 103, pp. 657–664 (2013). doi:10.1016/j.sbspro.2013.10.385

Wang, H.-Y., Duh, H.B.-L., Li, N., Lin, T.-J., Tsai, C.-C.: An investigation of university students' collaborative inquiry learning behaviors in an augmented reality simulation and a traditional simulation. J. Sci. Educ. Technol. **23**(5), 682–691 (2014). doi:10.1007/s10956-014-9494-8

Wu, H.-K., Lee, S.W.-Y., Chang, H.-Y., Liang, J.-C.: Current status, opportunities and challenges of augmented reality in education. Comput. Educ. **62**, 41–49 (2013)