# A Study on Augmented Reality Application in Situational Simulation Learning

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***Abstract*****—*In recent years, hardware and software advances in digital technology have prompted not only the commercial use of augmented reality (AR) systems, but its implementation in education. Marker-based AR systems allow users to input pre-designed markers, and generate new scenes blending together the real world and computer-generated 3D images. Nevertheless, few AR systems permit simultaneous interactions of multiple markers. This study aims to construct an interactive multimedia learning system. The story script showcases the growth of flowers by applying a series of markers, where interactions with 3D objects can be achieved through AR technology. Learners can use a camera to capture the information of multiple AR markers, and 3D objects and media can be generated on-screen. With variations in AR markers, and time changes of the Arduino Clock, one can learn the growth of plants during day and night through a mixed-reality virtual experience that brings fun to learning. Accordingly, this e-learning system is capable of boosting students' learning interests and improving their learning effectiveness.*

***Keywords—Interactive E-learning, Augmented Reality, Interactive Multimedia, Interactive Installation, Computer Human Interface***

## I. INTRODUCTION

The maturation of digital technology in the 21st century is rapidly changing the way human and machines (e.g. computers) interact. Digital technology has gradually become an integral part of daily life, where it is used in visual arts, performing arts, living arts, cultural creativity, entertainment and education. With advances in digital technology, interactive digital media works are widely recognized and used by all sectors. By integrating digital animation and real scenes using webcam and computer processing that capture and project the images, this system allows users to experience the merging of the virtual and physical worlds. The core of this interactive system consists of video image processing techniques and interactive 3D media module design.

In recent years, augmented reality (AR) technology, a virtual-reality (VR) extension, has been widely used in interactive media products. For instance, assume the environment is comprised of two elements, i.e. scene and object. In a virtual reality environment, scenes and objects are virtually rendered, while AR exploits computer algorithms to draw the virtual objects in real space, fusing the virtual objects in real-life scenes. The 3 essential attributes of AR put forward by Azuma [1] in 1997 define that AR: (1) combines real and virtual; (2) is interactive in real time; (3) and is registered in 3D.

Augmented reality (AR) technology is quickly becoming one of the popular research topics today, and with advances in the software and hardware front, AR is now commercially used and commonly implemented in learning environments. AR holds the edge in not needing special equipment to enhance the visual effects in a real environment, producing virtual 3D objects in front of our very eyes that merge together the reality and the virtual world.

FLARToolKit [2] is a new flash library that provides an integrated interface for Flash and AR, and allows the use of webcam to control 3D animation for media designers to easily design and control the animations.

In addition, research on the integration of Arduino and interactive technology has gained popularity. Arduino is an open source physical computing platform based on a simple input/output (I/O) board and a development environment that implements the Processing language [3]. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators.

The purpose of this article is to present an AR-based interactive e-learning platform that uses FLARToolKit module to bridge between the hardware and software, and integrates Arduino analog signals by means of digital media technology. This system is targeted at young children (aged 9 to 10 years), where they use pictures with AR markers for hand-on operation. The interactive 3D graphics generated on-screen strengthen children's learning incentive and help them commit what they have learned to memory, in turn enhancing their learning experience.

## II. RELATED WORK

AR technology adds virtual objects in the real world to enrich an imagined environment for designers to construct a series of interactive experiences [1] [4]. Moreover, through state-of-the-art tracking technology and computing power, AR not only allows fully-interactive game play in the comfort of user's home, but enables the integration of environment characteristics, such as buildings, signs and landscapes by simply using a PDA or cell phone [5] to experience the all-around and compelling gaming experience.

3D is an innovative digital application that presents objects in three-dimension in a visual scene, taking user observation and operation to another level. Virtual objects can be designed to be controllable events to be triggered upon real-time interactions. Compared with conventional virtual-reality interface, AR provides users with a more immersive experience; therefore, AR is regarded as a

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promising technology in educational material production. Wood *et al*. [6] and Asai *et al*., [7] believe that AR presentation of graphics has the advantage of time and space, where manipulators can trigger contents in book through movements, creating a dynamic virtual reality in real-time that acts as a new learning tool for learners. In applying AR in education, Billinghurst *et al*. [8] used AR technology and concepts to create a children's book *MagicBook*, which can be digitally displayed on hand-held devices. When flipping through the pages, the contents of the book are animated with visual effects and sound right in front of the reader, which adds more enjoyment to learning. On another hand, McKenzie *et al*. (2003)[9] also used AR technology in the design of *EyeMagic Book*, where users can see movements of characters in the book and listen to vocal instructions thanks to the AR makers, ultimately changing people's reading experience that may very well improve reading efficiency.

Other studies indicate that AR application in digital learning can enhance user's acceptance. Kye & Kim [10] investigated the promotion of learning outcomes through AR on 260 fifth-grade students, which explored five factors, i.e. perceptual immersion, guidance, operation, display, and smoothness. The results showed that perceptual immersion, operation, display, and smoothness affect students' satisfaction, understanding and knowledge, as well as the outcome of application learning. Operation, in particular, is directly related to satisfaction and learning outcomes of knowledge application. Thus, enhancing AR touch-screen user interface can improve learning satisfaction and effectiveness. The integration of AR technology in teaching can improve student's learning outcomes

Moreover, AR can be implemented in virtual navigation systems [12]; when a visitor accesses a certain location or observes a certain object, detailed information or directions can be provided to enhance the visitor's experience of the environment or road use. Another interesting AR application is AR virtual books. AR markers are tagged in a hard-copy book page for virtual 3D object generation in the computer; and through webcam capture, animated content can be displayed on the computer screen. This form of book reading is more attractive and interesting than static 2D images, especially for children [13]. This book form can also be used as a virtual user guide, such as user manual for home appliances or mixed reality laboratory experiments.

The eco-learning system proposed in this study centers around the growth of plants (flowers), which we named ARFLora. The design purpose of this learning platform is two-fold: (1) to create innovative and interactive multi-media enriched learning experience by applying AR technologies in the integration of entertainment and education; (2) to allow users, in groups or parents with children, to interact with the system and learn about natural cycle of plant life in the short time. In addition, an Arduino Clock is devised for users to operate the changes in time, so as to better understand the growth of plants in day and night. This system offers an alternative approach to conventional text-book learning, giving users the opportunity to acquire ecological knowledge through an entertaining interactive process.

## III. Design Process

### *A. System Overview*

This study presents an AR-based interactive e-learning platform that is used to construct a learning script of plant growth in varying ecological environments. It allows users to experience the relationships between changes in plant growth and the environment to better understand the links between the natural environment and our daily life.

This interactive learning platform is developed using open source FLARToolKit with Adobe Flash /Flex, and integrates an analog clock produced by circuit chip Arduino. A series of digital interactive learning models are designed to diversify the learning experience and add realism to the interactive learning setting. Figure 1 shows the system architecture of this platform, where various AR Markers are signal inputs that are received by a webcam; the signals are then processed by the FLARToolKit module and Flash to detect and identify the image content of the AR Markers; lastly, pre-loaded 3D animation and effects are generated on-screen.

This system employs the growth of creeping woodsorrel as the story script. A range of AR markers are designed after analyzing the growth stages and the necessary growing conditions, e.g. seeds, seeding, watering, sun, rain and photosynthesis et. al., (Figure 2). The system is operated as follows:

Step 1: The webcam receives AR markers with scenes or objects.

Step 2: Detection and identification by the FLARToolKit module.

Step 3: The generated 3D objects produce variations of interactive effects with angle changes of the marker.

This system also utilizes a physical Arduino clock that allows users to toggle the hands to control the digital clock in the virtual scene for improved realistic interactions.

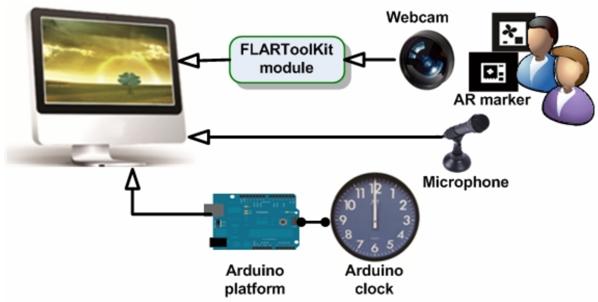



Fig. 1. The system architecture diagram.

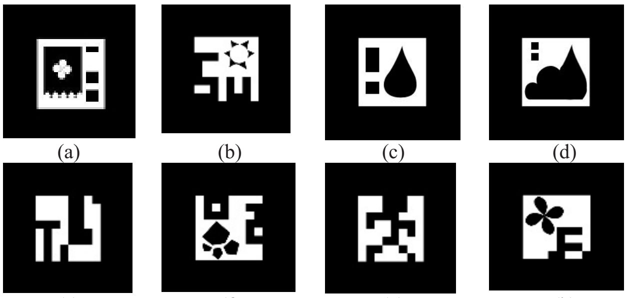



Fig. 2. The sample of AR markers. (a) the seeding, (b) the sun, (c) watering, (d) rain, (e)clock, (f) photosynthesis, (g) people, (h) flower.

### *B. Feature Detection and Verification*

In this system design, AR Marker feature extraction and recognition are key elements to successful results. In general, the user can customize the AR Marker images, where each image is required to have a detectable feature for the detection of different markers. Meanwhile, each AR Marker represents different 3D objects that can be displayed on-screen via image capture and recognition technology. AR Marker feature generation and recognition are explained in two stages as follows.

***Stage 1:*** *Generation candidate image regions AR marker*

This system makes reference to ARToolkit [14] to design AR features and recognition. Through image processing, the captured webcam images are subjected to binary image processing, with the set-up of threshold values to obtain the object's shape and contour; and then the edge and corner data of the marker are extracted to generate a candidate image region.

***Stage 2:*** *Verification/ Identification*

After the detection of a candidate image region, the second stage is the verification and identification of the candidate image. The most important step is to verify the marker's features and conduct matching and identification with existing ones in the marker library.

Marker design and the threshold for detection algorithms generally affect recognition accuracy. When conducting marker image acquisition, markers in the library using the same camera lens and lighting would result in better identification outcomes.

Figure 3 shows AR marker feature extraction and examples generated from the detection algorithm. To improve the accuracy of webcam image captures and meet the needs of the ARToolKit Library, black framings are primarily used for the markers. The image design stresses marker feature uniqueness for improved identification and interaction effects.

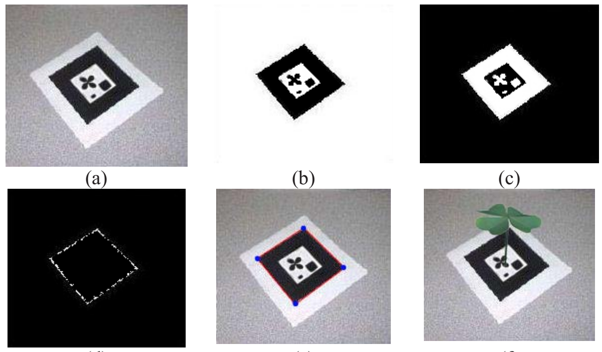


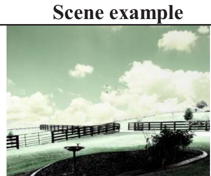
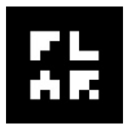
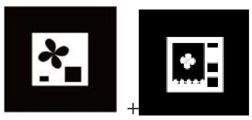

Fig. 3. Examples of feature detection algorithm. (a) original image, (b) thresholded image, (c) connected components, (d) contours, (e) extracted marker edges and corners, (f) fitted square (virtual object).

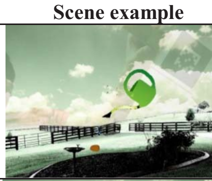
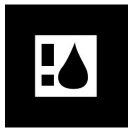
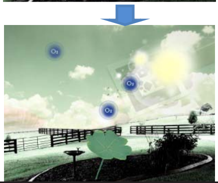
### *C. Learning and Entertainment*

This learning platform is designed to present learning scripts for three kinds of plants, i.e. creeping woodsorrel, peanut vines, and mimosa, based on their respective characteristics, so that children learners can understand the growth process of different plants, from germination, seedling growth to flowering. The platform exploits digital rendering to present plant responses to natural environmental stimuli, such as phototropism, plant's sleep movements, and the effects of oxygen and carbon dioxide on human, providing learners with knowledge contents. The Table I shows the scenario script of the growth cycle.

This story script design is based on the growth of plants and variations in time. Users may sequentially select AR markers for operation. With multiple markers, interactions allow children to learn the growth process of plants and freely add environmental settings to experience varying plant growth under different conditions. As illustrated in Table I(d), the plant carries out photosynthesis under sunlight and releases oxygen; whereas Table I(e) shows that leaves droop under the weight of water during rainfall.

TABLE I. THE SCENARIO SCRIPT.

| | Script description | Scene example | AR maker manipulate |
|---|---|---|---|
| (a) | The farmland scene |  |  |
| (b) | Planting flower seeds from seed packets |  |  |

| | Script description | Scene example | AR maker manipulate |
|---|---|---|---|
| (c) | Watering the seed |  |  |
| (d) | • Plant photosynthesis<br>• Release of $O_2$ during photosynthesis | <br> | <br>• +<br> |
| (e) | • Water vapor produced by plants condenses into clouds<br>• After the clouds become heavy with water, rainfall begins to sustain life on earth |  |  |
| (f) | • Adjusting the Arduino Clock to change the scene from daytime to night<br>• Plants sleep at night (leaves droop) | <br> |  |
| (g) | Plants absorb $CO_2$ and release $O_2$, while humans breathe in $O_2$ and exhale $CO_2$, an intricate mutual relationship between plants and humans |  |  |

## IV. EXPERIMENT AND DISCUSSION

### A. Implementation

The ARFLora learning system applications allow virtual imagery to be superimposed over live video of the real world. The secret is in the black squares used as tracking markers. The system tracking works as follows:

1. The camera captures video of the real world and sends it to the computer.
2. The ARFLora learning system on the computer searches through each video frame for any square shapes.
3. If a square is found, the ARFLora system uses some mathematics to calculate the position of the camera relative to the black square.
4. Once the position of the camera is known a computer graphics model is drawn from that same position.
5. This model is drawn on top of the video of the real world and so appears stuck on the square marker.
6. The final output is shown back in the handheld display, so when the user looks through the display they see graphics overlaid on the real world.

The Figure 4 summarizes these steps. This system is able to perform this camera tracking in real time, ensuring that the virtual objects always appear overlaid on the tracking markers.

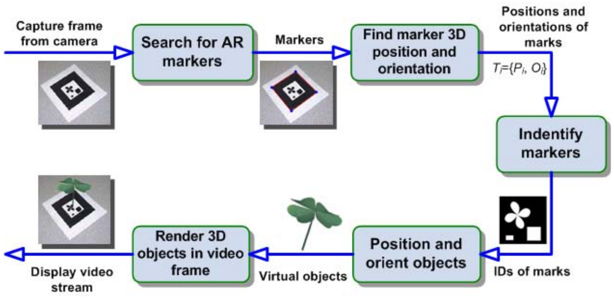


Fig. 4. The concept of ARFlora learning system.

In terms of system development and design, we divided it into two levels, namely User Layer and System Module. User Layer is responsible for devices used for operations or to accept messages, e.g. webcam, microphone, arduino clock and other input devices. Output device comprises of computer screen or projection equipment. For the integration of different media and hardware interface, Serproxy was used as a middleware to connect with the Arduino Clock. FLARToolKit was the main development module, with all interactive programming developed in ActionScript 3.0, and three-dimensional objects rendered and presented through Papervision3D. XML-based database was used to manage objects and media. Figure 5 shows the framework in detail.

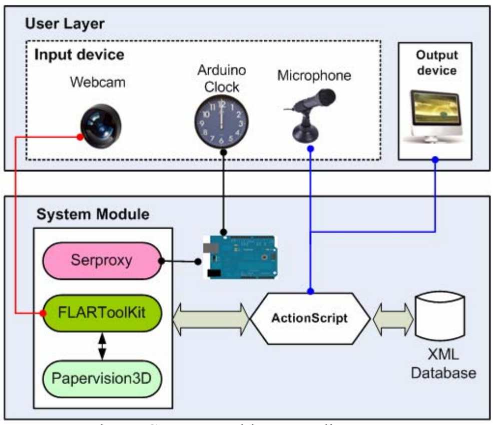
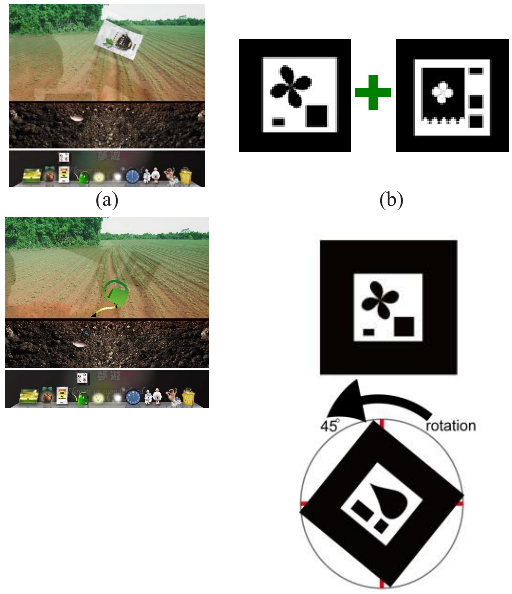


Fig. 5. System architecture diagram

## B. The User Experience

In order to enhance the realism and interactive nature of the system for the users to fully immerse in the learning content, the platform is designed to incorporate real-life conditions and physics for students to truly experience the virtual realism of AR. For example, in Figure 6, two AR markers are used, where the marker must be rotated 45$^{\circ}$ to carry out the process of watering. This technique exploits the analysis of the marker's Z-axis coordinates by FLARToolKit module; when the Z-axis is rotated 45 degrees, effects of water droplets for watering are produced.

In the AR learning system, we designed an animated virtual clock resembling a real clock, which, through programming, allows the user control and experience the changes in plant growth. In order to display the variations during the plant growth and the time change in reality, a mechanical clock was taken apart to place in an Arduino chip and adjustable controller to produce a programmable Arduino clock. Figure 7 presents the Arduino control panel and the circuit for the clock. Time adjustment using the physical Arduino clock can be used to control the digital clock in the virtual scene. The results are the different responses of plants during the day or at night.



(a) (b)
(c) (d)

Fig. 6. The interactive screen. (a) planting flower seeds scene, (b) two AR markers, one is the "seed", anthers is "seed packet", (c) the watering scene, (d) two AR markers, one is the "seed", another is "watering" (rotation).

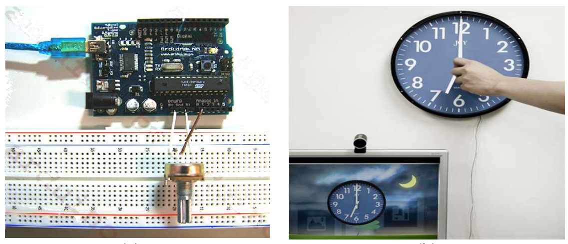

(a) (b)

Figure 7. The example of Arduino clock design. (a) the microcontroller board, (b) the Arduino chip and Clock.

## C. Experiment Results

In order to understand the learning effectiveness and practicality of this teaching platform in real classroom settings, we integrated this platform into a learning unit in an elementary school science class. A total of 20 grade 3 students (9-10 years old) participated in the experiment, where they were divided into 5 groups of four members. The main objective is to observe the students' acceptance level of this platform and their level of comprehension of the growth of plants after learning through this interactive learning mode. The experimental steps are summarized as follows.

Step 1: The teacher first describes the growth of plants, then, explains to the students how to use the learning platform and the meaning represented by each AR Marker.

Step 2: Students operate the learning platform in their designated groups and begin learning

Step 3: Students record their learning process and observations in a feedback survey.
Step 4: The teacher uses the feedback survey from students to conduct follow-up discussions, and performs satisfaction interviews with the students.

The findings showed that all 20 students liked this type of learning mode. From observing the virtual environment, 19 students made the observation of the growth of pants drawing nectar; 18 students showed clear understanding of the time needed for plants and photosynthesis. The experiment was conducted as shown in Fig. 8.

(a) (b)

Figure 8. The experiment (a) student's actual hands-on experience, (b) interaction scenario.

## V. CONCLUSION

This study incorporated an AR-based interactive e-learning platform to provide students studying science with the knowledge of plant growing cycle, guiding them to learn by doing. In this learning process, students are given the option to learn on their own or work with peers in a collaborative learning environment, thereby equipping them with the inquisitiveness merited in scientific research and problem solving skills. The findings from actual classroom implementation revealed that this multimedia and interactive digital learning platform incentivizes students to learn, and from the process of learning by doing, students gain hands-on experience so they are less likely to forget what they learn. According to the feedback survey after the experiment, most students enjoyed this type of learning, especially the process of hands-on operation that gives them a chance to try different things. On the other hand, in terms of curriculum design, teachers can timely incorporate this interactive learning platform and map out learning activities for various disciplines to expand the breadth of learning content, diversify the teaching materials, and consolidate interactive educational activities in the classroom, ultimately enhancing the overall teaching and learning efficacy.

To sum up, this study presents a new approach to learning through the interactive media e-learning platform. Knowledge and information on hard-copy book can be readily and interactively manipulated through images and 3D animation, in the form of markers. Having considered various physical phenomena, the system is designed to create a realistic virtual digital environment that reflects real-world experiences. In addition, this learning platform not only adopts multiple AR markers, but angle changes in AR markers can create different effects and real-life interactions. It can be expected that similar interactive learning platforms will see continuous developments in the future, making learning more interesting than ever in the digital age.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