Meridian, Parallels, and Map Projection:

Educational Application of Augmented Reality Technology

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ABSTRACT:

Augmented reality (AR) projects virtual objects into the real world and enables users to gather additional information from the scene. AR offers further learning through animations, audio files, and interactional games, each of which helps users to better understand complex concepts or see otherwise invisible scenes. Compared with 3D animation, AR offers enhanced interaction that engages users through hands-on experience. These characteristics make AR technology suitable for educational purposes. As AR technology continues to advance, academic research on AR education has also experienced growth. AR has been widely utilized in the disciplines of biology, geography, and Earth science. Within the field of geography, cartography is one of the optimal subjects for employing AR, as many cartographic concepts are perceived as abstract to students. This research aims to create an AR package for teaching and learning meridians, parallels, and map projection. Meridians, parallels, and map projection are considered among some of the most intangible concepts to high school students. Both graticule (latitude and longitude lines) and types of projection (such as cylindrical and conic) are difficult to illustrate from a solid sphere to a picture in a plane. With the understanding that AR can allow students to observe the transformation of a 3D globe to a plain map, we develop an AR system that demonstrates the various concepts of map projection. Integrating user interaction and dynamic illustrations, this system allows students to understand concepts of projection by playing with concrete images. We expect this application to help students learn geographic concepts more effectively.

1. INTRODUCTION

Just as virtual reality (VR) has gained popularity in recent years, augmented reality (AR) has also attracted mass appeal. In the field of education, there should be constant research and invention of new technology. Subsequently, these new technologies should be promoted to teachers and students once they achieve a degree of maturity. Although the potential of AR applications in education are widely acknowledged, the availability of AR educational products in the market is still limited. Compared with many K-12 school subjects, geography is especially suitable for adopting AR technology as part of the pedagogy because it involves many abstract concepts or phenomena. Applications of AR can allow students to understand complex concepts or see phenomena that may be otherwise invisible. Within the field of geography, map projection is one of the optimal subjects for employing AR because many cartographic concepts are perceived as abstract to students. This research aims to create an AR system for teaching and learning meridians, parallels, and map projection. Meridians, parallels, and map projection are considered among the most intangible concepts to most high school students. This paper will discuss the history, characteristics, and applications of AR. Furthermore, it will focus on the development of an AR educational system for high school students: 'Meridian, Parallels, and Map Projection'. Through this application, we look forward to spurring students' interest in geography.

2. AR SYSTEM

The concept of AR can be traced back to L. Frank Baum's novel "The Master Key" from 1901 (Grover, 2014). The first AR device, lvan E. Sutherland's head mounted display, dates back to 1968. This display projected 3D images visible to humans. In 1990, the Boeing Company became the first to employ AR in assembling, fixing, and operating complex machines in plane manufacturing (Lee, 2012).

AR is a stacking technology that amplifies virtual information into the real environment. Combining computer programs and a camera that can recognize images, the AR device displays virtual objects when the target is shown on the camera screen. Azuma et al. (2001) defined AR as the combination of virtual and real objects in a real environment; a system that aligns and registers virtual and real objects with each other and runs interactively in real time. Feiner (2002) referred to AR as computer displays that relay additional information to a user's sensory perceptions. Most AR research focuses on "see-through" devices, usually worn on the head, which overlay graphics and text on the user's view of his or her surroundings.

3. CHARACTERISTICS AND EDUCATIONAL FUNCTIONS OF AR

The main functions of AR are to provide real sensory experiences, timely interactions, information augmentation, and simulation operations, each which are described in detail below. Azuma (1997) suggested that AR allows users to see the real world with virtual objects that are superimposed upon or composited with the real world. Therefore, AR supplements reality rather than completely replacing it. It simulates a realistic sensory experience for users. The advantages of AR can be summarized as follows:

1. Real time interaction: Compared to 3D images or animations projected unidirectionally from TV or computer screens, AR focuses on bidirectional interaction with users in real time.
2. Information augmentation: Users can scan 2D markers of objects with AR devices and then gain additional related information of the objects. This feature help users learn and recognize more concepts.
3. Operation simulation: AR can simulate some risky operations in the real world, such as surgery, capsule, and military exercises, through simulation processes that avoid accidental risks and reduce operating costs, etc.

AR APPLICATIONS IN EDUCATION

AR is widely used in geography education to teach topics such as climate change, disaster prevention, basic geography knowledge, and more. Most students cannot observe and explore sites first hand, and textbooks oftentimes have difficulty explaining geographic concepts. AR, however, provides 3D animation and interactive games that explain abstract concepts, thus enhancing users' engagement with the subject matter and deepening students' impressions of the concepts.

AR Scanning Globe

Kickstarter's "Orboot: An Educational Augmented Reality Globe" allows children to scan icons on a 3D globe through an AR app. Orboot can show the names of continents and identify animals, plants and famous landmarks such as the Eiffel Tower. AR expounds upon invisible information on the globe, allowing children to learn more about geography and the world, as shown in Figure 3-1.

Figure 3-1 Orboot: an Educational Augmented Reality Globe (Kickstarter.com)

AR Coloring Globe

Quiver is a coloring AR app that allows users to fill in the colors of various map templates, which may subsequently be rendered as a 3D image. As shown in the following examples shown in Figures 3-2 to 3-4, a 3D sphere appears on the screen after users scan a map that they draw.

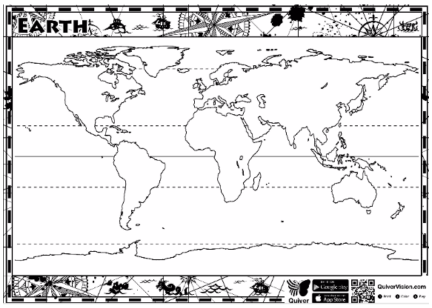

Figure 3-2 the original template

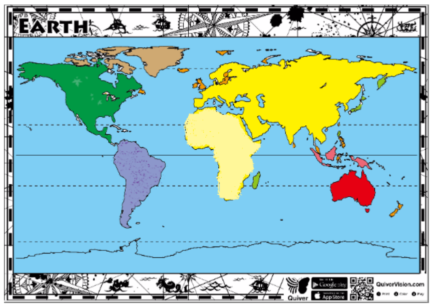

Figure 3-3 the colored template

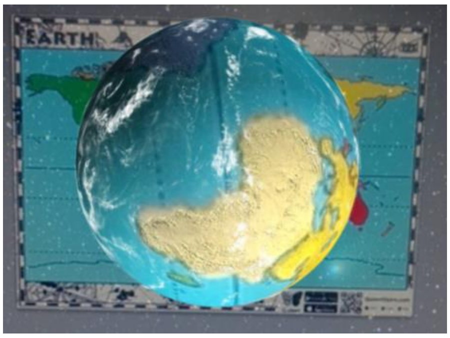

Figure 3-4

AR Theme Map

As shown in Figure 3-5 and 3-6, AR can be combined with a topographic map overlay that features contours, colors, and surface buildings. For instance, Craig (2009) applied it to the thematic map of wind power. Through color identification technology, variations in height and color convey data of the thematic map to the user.

Figure 3-5

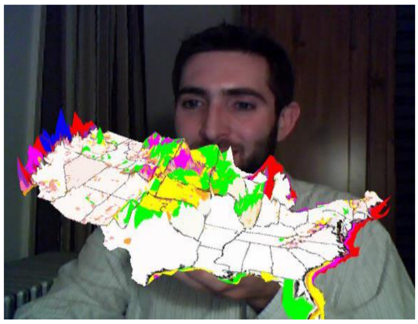

Figure 3-6

AR Sandbox

The AR Sandbox, developed by several research laboratories at UC Davis, allows users to dynamically shape versatile terrain features with sand while projecting contours and color tinting on the sandbox (Snow, 2015). For instance, users can build mountains, valleys, plains, or basins, and create artificial rain when pressing their hands on the mountains, as shown in Figure 3-6. The AR Sandbox system is equipped with a sensor that detects the heights of sand surfaces and subsequently calculates the contours and hypsometry of the terrain surface created by the user. Through the contour and color tint layer, the user can understand the relationship between terrain surface and contours, which is typically regarded as a difficult concept in traditional map reading.

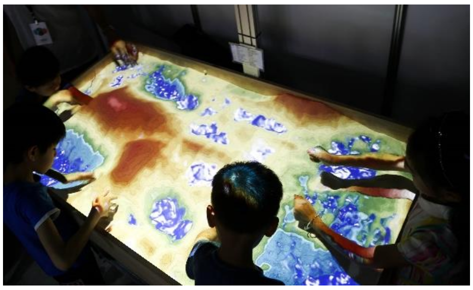

Figure 3-6 AR Sandbox

4. RESEARCH QUESTIONS AND METHODOLOGY

Research Purpose

As concepts of map projection are difficult for most students to grasp, this research aims to develop an AR system that can more effectively teach map projections. The purpose of this research is as follows:

1. To cultivate the operating skills of AR educational applications by experiencing the process of research and product development, confronting and overcoming various obstacles, and utilizing technology and tools.
2. To offer a teaching resource for map projects and to draw distinctions between AR products and other traditional teaching materials.
3. To compare and research the practical benefits of AR and other teaching materials used for educational purposes.

Research Process and Methodology

The development process of this AR system is as follows:

1. Determining the target customers and the goals of the product.
2. Defining the concepts and skills of map projection employed in the system.
3. Designing a full lesson plan.
4. Setting the functions and structures of the system.
5. Designing the user interface and visual arts and effects.
6. Developing the AR system using various software packages (Unity and Adobe Photoshop).
7. Testing the primary version of system.
8. User testing.
9. System modification and testing.
10. Completing the system and releasing product announcement.

The entire system development process is carried out through the collaboration of cartographers, educators, product designers, and research and development engineers. Steps 1 to 4 are executed by cartographers and educators and steps 5 to 10 are executed by product designers and research and development engineers.

5. EXECUTION AND RESULTS

Background

When the Earth, represented in the form of a 3D sphere, is projected onto a 2D map, its 3D coordinate system is converted to a 2D coordinate system. Depending on the purpose, there are multiple types of projections that may be used. Compared to the original 3D sphere, every map projection in 2D will inevitably result in some degree of distortion. Moreover, each map projection method has its pros and cons (Shyu and Liu, 1996).

In this study, we design the functions and user interfaces of an AR mobile application (APP) for learning geography. The reason why we choose mobile phones is that they are the most widely used form of electronic device these days. Binks (2009) considered handheld devices as perhaps the fastest growing platform of AR and the most likely to first adopt common AR systems. Apple iOS and Google Android have been widely noted for their extensive use of AR technology.

This APP's target audiences are grade 10-12 senior high school students as well as teachers of relevant courses. As mentioned earlier, map projection is an essential skill taught in 10^{th} grade geography textbooks in Taiwan, although it remains a relatively abstract concept for most students.. For years, senior high school students and teachers have considered this subject to be very difficult to learn and teach, respectively. In order to help students to enhance their understanding of the concept of map projection and map transformation, this APP focuses heavily on map projection. In this APP, there are two modes accessible from the main menu: portrait projection or map projection.

Portrait Projection

In portrait projection mode, this APP allows a user to take a portrait in selfie mode and then overlay it on a globe in order to better understand the transformation of map projection. The user can see his or her portrait on a solid globe in addition to a map projection of the portrait on a 2D map below the globe. In portrait projection mode, a total of 13 types of map projection methods allow the user to observe the differences of their transformation. The instructions are as follows:

(1) Camera mode: When the user turns on the app, the following portrait interface shown in Figure 5-1 will be presented. The user can take photos with a phone, after which a circular perspective grid will allow users to align the center of the lens. When the user presses the lower camera button to shoot, the screenshot as seen in Figure 5-2 will appear.

Figure 5-1 Portrait interface for shooting

(2) Home screen: The screen will project the user's portrait on both a 3D globe and a 2D map below the globe. The 2D map will show a user's portrait transformed or distorted by one of 13 kinds of map projection methods. The user can tap the map projection icons to change from one to another. This will show the transformation of the user's portrait in the form of the type of map projection in real time. There are 13 common kinds of map projection methods in this app: Mercator Cylindrical, Equirectangular, Lambert Cylindrical Equal-Area, Lambert Conformal Conic, Lambert Azimuthal Equal-Area, Azimuth Gnomonic, Azimuthal Equidistant, Azimuthal Stereographic, Robinson, Sinusoidal, Mollweide, Goode Homolosine, and Bonne.

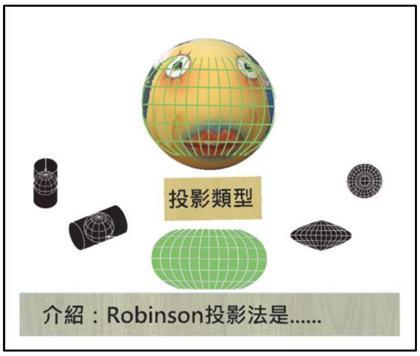

Figure 5-2 Portrait interface with different types of map projections

(3) User operation: After the transformation is generated, the user can slide the portrait left or right on the 2D map and observe the distortion and transformation of the portrait on the left or right side, as shown in Figure 5-3.

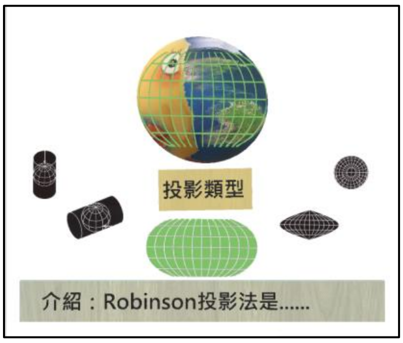

Figure 5-3 Moving portrait on the left and right side

Portrait projection is expected to enhance users' cognition and understanding of the common types of map projection by demonstrating the transformation of the map in real time. Meanwhile, by manipulating his or her selfie, the user can more intimately sense the distortion and transformation of the map projection.

Map Projection

In this mode, a user can click buttons to control an AR globe and see the process of map projection. At the beginning, a tutorial will show the user how to use the app. At the end of the tutorial, the map projection interface will appear.

(1) Tutorial: The first time a user selects this theme, he or she will be directed to the tutorial mode that shows step by step directions, as shown in Figure 5-4. The user may skip the tutorial and proceed directly to the map projection interface.

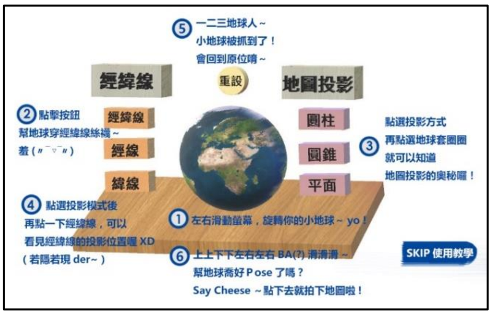

Figure 5-4 Operating instructions

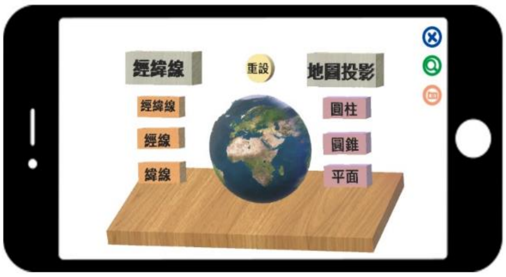

Figure 5-5 Map projection interface

(2) Map projection interface: As shown in Figure 5-5, at the end of the tutorial the user will be shown an AR globe in the center of the screen, surrounded by three groups of buttons: latitude and longitude buttons, map projection buttons, and a reset button. The functions of each of these respective buttons will be described in detail below.

(3) Latitudes and Longitudes buttons: There are three buttons for users to choose: the latitude and longitude button, the latitude button, and the longitude button. After clicking on one of them, the user will see an AR rendering of Earth that displays latitudes and longitudes, or only one of them, every 15 degrees a warp, every 10 degrees a weft, for a total of 20 warps and 18 wefts (including two poles). These renderings are shown in Figures 5-6 to 5-8.

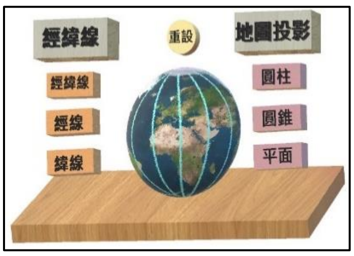

Figure 5-6 Figure 5-7 Figure 5-8

(4) Map Projection buttons: When the user clicks on the Map Projection button, a 3D geometric rendering of the map projection either as a cylinder, cone, or plane will be displayed above the image of Earth. When the user slides the cylinder, cone, or plane to fit the Earth, the image on the Earth's surface will be projected onto the plane of the map projection. It will then generate an animation of the process of map projection and the 3D rendering will be flattened into a map. Figures 5-9 to 5-11 demonstrate this process.

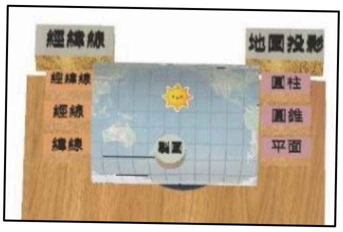

Figure 5-9

Figure 5-10

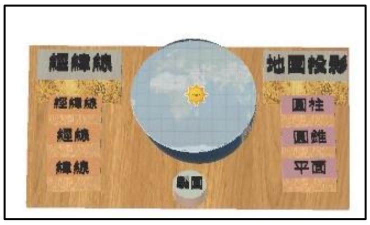

Figure 5-11

(5) Reset button: The reset button can adjust the globe into the default setting. That is, it will go back to the setting as shown in Figure 5-5 and the user can repeat the above steps with a different geometry.

In map projection mode, we expect the user to have a basic understanding of graticule (latitude and longitude lines) and the plane of map projections as introduced in the first edition of geography textbooks for high school students. This includes the rationale of choosing between the three different planes (cylinder, cone, and plane) and manipulating the system that converts a 3D globe to a 2D map, each of which allow students to explore in-depth the abstract process of map projection.

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