Augmented reality sandbox: a platform for educative experiences

Sergio Álvarez Sánchez
Facultad de Educación
Universidad de Salamanca
seralsa@usal.es

Laura Delgado Martín
Dpto. Didáctica de la Matemática y de las CC. Experimentales
Universidad de Salamanca.
Paseo de Canalejas 169 -37008 Salamanca
laura@usal.es

Miguel Ángel Gimeno-González
MediaLab USAL Universidad de Salamanca Edificio I+D+i+34
923294500 Ext. 3286
gimeno@usal.es

Teresa Martín-Garcia
MediaLab USAL Universidad de Salamanca Edificio I+D+i+34
923294500 Ext. 3286
teresam@usal.es

Fernando Almaraz-Menéndez
Director of Digital Production and Innovation Universidad de SalamancaEdificio I+D+i+34
923294500 Ext. 3268
falmaraz@usal.es

Camilo Ruiz
Dpto. Didáctica de la Matemática y de las CC. Experimentales
Universidad de Salamanca.
Paseo de Canalejas 169 -37008 Salamanca
camilo@usal.es

ABSTRACT
In this paper, we describe the implementation of an Augmented Reality Sandbox as a platform for educative experiences. Usually,the traditional Augmented Reality experiences, where the interface is a screen of a mobile devices, here the interface is real sand. It can form real landscapes where a virtual layer of information is displayed. We constructed the Sandbox from open source software and with accessible hardware. In this paper we discuss the special features of this installation, we evaluate the bottlenecks toward its implementation in real classrooms and the contents that can be teach together with the expected benefits.

CCS Concepts
• Computing methodologies• Computer graphics • Graphics systems and interfaces • Mixed / augmented reality

Keywords
Augmented Reality; Education; ICT in education; earth sciences, mathematics education.

1. INTRODUCTION
Augmented Reality (AR) is a live direct or indirect view of a physical, real-world environment where a virtual layer of information is added by computer-generated sensory inputs. In the AR, the attributes of reality are augmented using different technologies, allowing a richer experience with real objects. The objective of AR is to provide one or more layers of virtual information to real objects to expand the information we can access or the ways we can interact with it [1-3].

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The explosion on the use of mobile and electronic devices has expanded the use and implementation of the AR in many areas including video games, learning and education.
The use of AR in education has been done leveraging the availability of mobile phones and tablets in schools all over the world. Most of the AR experiences until today are made using these type of devices which determines, in great length, the kind of experiences and the ways to interact with this augmented reality. These AR experiences using mobile devices can be broadly categorized in two types [4]: The first category include AR experiences which are location aware. The second category include those where the camera is the main sensor used to produce the experience.

In the first category, the extra layer of virtual information is linked to the location provided by the GPS, WIFI networks or other geolocalization method in the device. The information from these sensors is linked to a map providing the exact location of the user. Based on the location, different information or content is delivered to the user creating the virtual layer to the real world. The purpose is to make the student explore different locations learning more about the places he or she visits with the help of the mobile device [5].

The pokemonGo game, which became famous in the summer of 2016, is a very good example of experiences of this first category. It uses the location of the player to discover virtual creatures and motivates the exploration of the city. This game has brought the attention of the media due to large number of users (more than 500 million in September of 2016) and due to its very efficient way to engage users into that experience. More importantly, the game has drawn the attention of the public to the potential of the AR technology.

In the second category of experiences, the camera is used to add a virtual layer on top of the shape of real world objects. The camera is used to identify objects and the screen of the mobile device present the virtual layer which contains rich information or new ways to interact with the object [6]. Again, the fundamental idea is to use AR to help in the exploration of the surroundings in a real context.

In both of these categories, the main interface with this rich virtual information is the screen of the mobile device and therefore this interface determines the possibilities and limits of this type of AR.

The use of AR for educative experiences has become popular around 2010 and several studies have been performed [7]. Most of these studies are focused in the analysis of two important aspects of this technology.

The first one is the route to implementate in real school settings. Due to its nature, there are technical, financial and educational barriers towards the implementation in a class. The pros and cons of using this technology and the barriers toward its implementation have been discussed extensively in the literature.

The second aspect that has been analyzed extensively in the literature is the assessment of the impact of AR in the education. More specific in study of natural sciences or geology.

In this paper we present the AR Sandbox that uses a sand landscape as the main interface for the virtual layer. In this new type of AR experience there are no mobile devices or a screen carried by the student. Therefore, the constrains or possibilities in the AR experience is significantly different from those which have been discussed in the literature as educational AR experiences.

The AR Sandbox offers a unique way to experiment and observe different natural phenomena in real time. In this paper we will discuss the possibilities it offers.

Similar to previous studies of AR, we will focus in the pathway to implementation. From the institutional point of view we describe the role of the MediaLab USAL and the unique opportunities it provides for projects like this. From the technical point of view we will describe how it works and how its nature solve several of the more serious bottlenecks towards its implementation in a school environment. We discuss about the advantages that this experience brings and how we can use it to teach some specific content related to natural sciences.

Finally we talk about the possibilities of using the AR Sandbox as a platform for development and how it can be exploited in the future.

2. TECHNICAL AND INSTITUTIONAL IMPLEMENTATION

Oliver Kreylos, a computer scientist studying 3D scientific visualizations and computational geosciences at UC Davis designed and programmed the AR sandbox software [8]. He was inspired by a prototype of an interactive sandbox visualization made in the Czech Republic (goo.gl/H3fHua). Several installations of this kind have been made in institutions and science museums around the globe.

The AR sandbox is made of a table with a box full of sand. The surface of the sand is recorded with the IR camera of a kinetic for Xbox videogame console. The camera is placed on top of the sandbox as it is shown in Figure 1. The kinetic records the coordinates of the surface created by the sand and produce a detailed 3D map of the surface in real time. This information is transferred to the computer for processing. The computer uses this information and produce a real time video output to a beamer which projects on the surface onto the sand. Figure 1 shows the schematics of the installation and how the different elements are arranged.

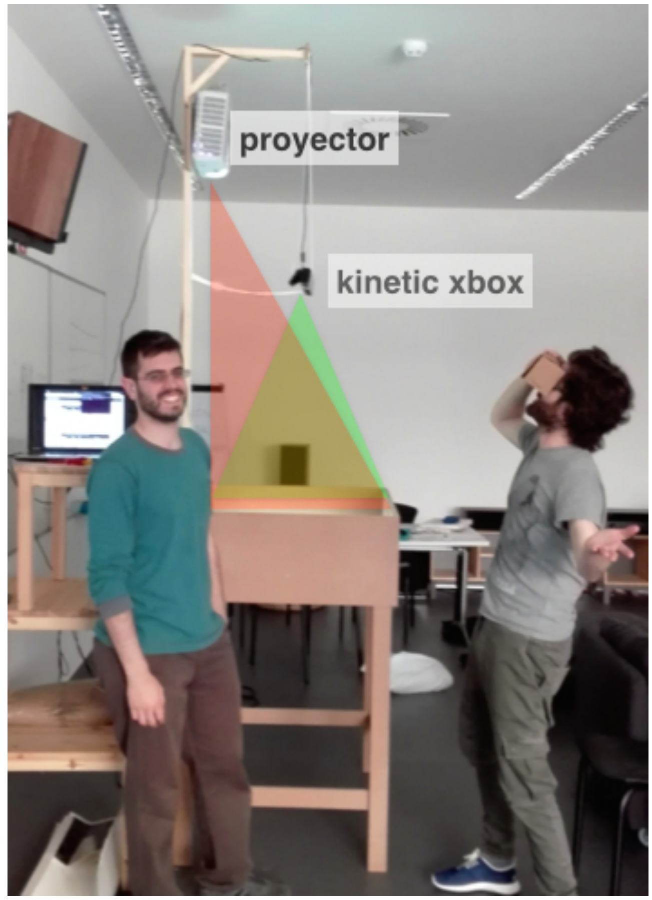

Figure 1. Schematics of the AR Sandbox. The Kinetic camera reads the surface while the beamer add the virtual digital layer

The kinetic camera emits an IR pulse that is reflected by the surface of the sand and is recorded back in the camera to produce a map of the height of the sand at each point in the table. This information is extracted with the software (The Kinect 3D Video Capture Project). The software produces a topographic map with contour lines. This information is displayed onto the surface and allows seeing the different heights of the terrain with the same colour.

The system has also the possibility of produce rain. By placing the hand or another object in front of the camera, the system projects water. Depending on the time that the hand stays in front of the camera the water level rise accumulating according to the details of the terrain. The water flow simulation solves the Navier Stokes equations on real time according to the boundary condition imposed by the surface of the sand. Therefore it can produce rivers and bodies of water with great detail and realism.

The software is open source and can be modified accordingly. This is very important in order to use this installation as a platform to further developments.

The AR Sandbox was conceived as a Master thesis in the MSc in Teaching Education (Secondary) with Qualified Teacher Status (QTS) at the Universidad de Salamanca. It was made in the MediaLab at the Salamanca University thanks to the unique facilities it provides. The MediaLab of the University of Salamanca is a new interdisciplinary and collaborative learning space. A meeting point of Art, Technology, Science and Society to experiment with emerging technologies and their possible artistic, social and educational applications. It is, therefore, a permanent place of the university dedicated to the exploration of technological innovations. A project of this nature requires expertise from many different fields such as Education, software, hardware, installations and new technologies.

The scope of this project is normally outside of the projects that can be achieved in a department or an institute because these structures are specialized in a very well defined topic and it is very hard to establish mechanism to produce projects with complementary experts. The MediaLab at Salamanca addresses this problem and has allowed us to carry this project by providing experts in this technology and resources to implement it.

In order to explore the possibilities of these technologies it is fundamental to establish collaboration spaces where experts from different areas can collaborate. A successful implementation of AR experiences must be well implemented in all its aspects: The technical, the hardware and the educational dimension.

2.1 Viability

The use of AR in education has been reviewed extensively in the literature, most of the implementations involve the use of mobile devices such as tablets or mobile phones and the interface to interact with the AR layer is almost always the screen of the device. This installation is different. In this case the interface is the sand and apparently, there is not an especific installation to be used, it is very simple: no instructions and interact so the experience is very rich.

Before describing the benefits of this technology in the education of science and the specific topics that can be teach with this AR Sandbox it is important to evaluate how realistic is to implement this installation in the setting of a normal school with limited resources.

Similar installations are commercially available and they are used mostly in science museums of exhibitions. Nevertheless, these are very expensive installation and cannot be modified in the hardware or the software. The AR sandbox has several advantages for its implementation.

- Cheap and accessible hardware: The kinetic is a sensor sold with the Xbox videoconsole that is cheap and affordable. The beamer needs some specifications but any general-purpose beamer can be used for the project.
- Open software: the full software for the installation is open source which means there is no fee or payment to use it and the most important thing is that the code is open and therefore can be modified to the needs of the user.
- A community around it. As the installation has been performed in several places, a community has been created which is helpful to obtain resources and help the installation. Also, the community improves the software and implementation constantly to produce a better experience.

These characteristics of the installation provide a better route to the implementation of these experiences in the classroom. The table and the box for the installation are also easy to implement and not expensive.

3. ADVANTAGES OF THE AR FOR THE TEACHING OF THE SCIENCE IN HIGH SCHOOL

The teaching of sciences in high school can be implemented using Information and Communications Technologies (ICT) to produce a better education experience for the students. There is a wide range of resources that have demonstrated that these technologies can help to engage the student in the experimentation more efficiently [7] or become more involved in the learning process [1,2]. Methods involving the use of the ICT have been reported to help in the engagement of sciences [3] and to help to better understand abstract concepts [2] through advance methods of visualization.

In particular, methods of teaching with AR have demonstrated to help in the teaching of complex science or mathematical subjects [1-3].

One interesting application of this AR Sandbox is the illustration of mathematical abstract concepts such as topographic maps and contour lines. While the geometrical concepts of 'mathematical locus' defined as all point on a surface with the same height are not easy to illustrate in class with traditional methods. The AR Sandbox is a perfect implementation of this concept. Furthermore, varying the surface on the sand, the student can observe that this definition is general and how this concept of isosurface or contour line evolves as the surface changes.

The students can experiment by changing the shape of the sand with theirs hands and experimenting the changes in the topographic map. The computation of contour lines is made in real time and the evolution of the map is continuous which help to relate the changes in the map to changes in the surface.

As the sand is the interface, the experience is much richer than that of the screen where the possibilities are reduced a small area. In the case of the AR Sandbox several students can interact with the sand and the installation is reactive to all of the changes in the surface.

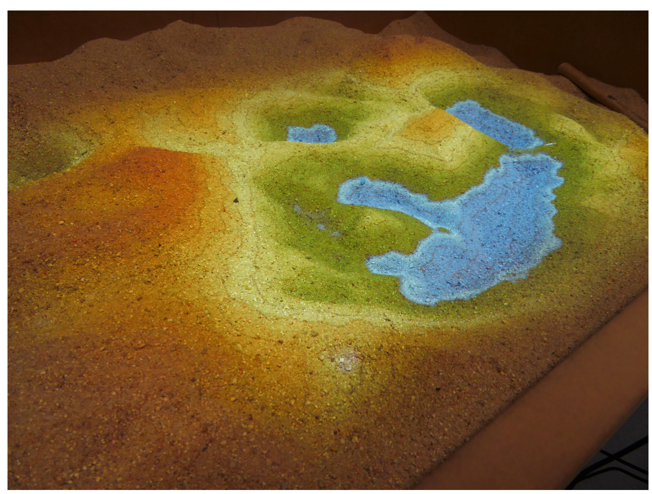

Figure 2. Contour lines are drawn on top of the sand according to the details of the landscape. The water fills the deep zones of the terrain

4. NATURAL SCIENCE CONTENTS

The AR Sandbox is specially suited to teach contents related to Geology and earth sciences. The AR Sandbox can be used as an educational tool to explore the importance of water, erosion or mountains in the evolution of the landscape as a topic of hydrology, earth science, and environmental studies.

The possibility to create water from 'rain' or to form bodies of water can be used to teach the students the importance of water in the shaping of the landscapes. One of the main concepts in Geology is that the shape of the terrains that we observe was created by a variety of processes such as erosion, tectonics, and glaciation. The location of lakes, rivers, subterranean bodies and the whole movement of water in the earth is based on the shape of landforms. This distribution of water determines the type and distribution of ecosystems around the world.

These concepts can be taught using this AR Sandbox installation. While experiments in Geology are hard to perform (it is obvious that it is not possible to place a mountain anywhere), this tool can be used a playground to experiment basic principles of Geology. A similar experience could also be taught with computer simulation but they are required complex settings and intensive training to perform simple experiments while this tool needs too little instruction and can be used in a classroom.

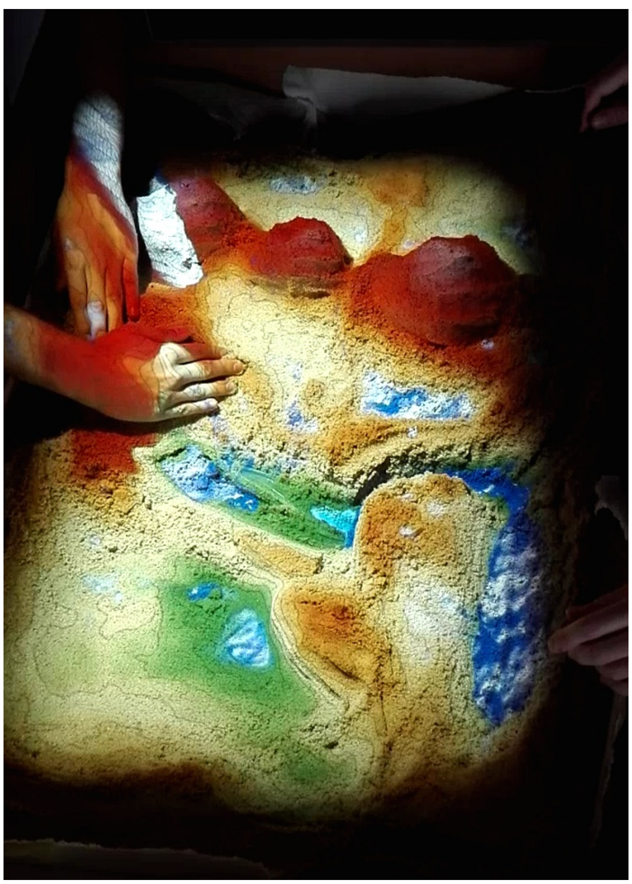

Figure 3. Water bodies are simulated through the fluid equations of Navier Stokes. The movements of the water follows the structure of the terrain and determines the conditions of the ecosystems

These are some of the potential of this installation and how it can be used to teach complex mathematical concepts or earth science concepts.

5. CONCLUSIONS AND OUTLOOK

We have built an AR Sandbox installation based on a design by the USC California, open software and accessible hardware. This installation can be used as an educational resource for mathematics and natural sciences. We have highlighted the unique possibilities it has and discuss the barriers toward implementation in a real classroom. We also discuss the topics that can be covered using this tool and the benefits to the educational experience that it can provide. This installation can be used as a development platform for new AR experiences. The nature of its construction and the open source software are perfect opportunities to try new ideas as use the installation as a platform to develop new ideas.

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