Chapter 1
Interactive Books in Augmented Reality for Mobile Devices:
A Case Study in the Learning of Geometric Figures

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ABSTRACT

One of the methods of teaching that has brought significant contributions to the field of education is augmented reality. This technology transformed learning into a more motivating, enjoyable, fun, and interesting activity. This chapter contributes an augmented reality application for mobile devices that complements and supports the learning of geometric figures. The application, called AGeRA, consists of a geometry book and software capable of reading special markers inserted into the book's content. When this book is placed in front of the camera of a mobile device, 3D objects, sounds, animations, and other interactive elements leap from book pages making learning more fun and exciting. Preliminary tests were made with teachers and students and showed good acceptance of the application to support the teaching of geometry.

INTRODUCTION

Evolution of mobile devices such as laptops, Personal Digital Assistants (PDAs), mobile phones and tablets led to emergence of a new field called Mobile Computing. According to Guan et al (2011), Mobile Computing is treated as a new computing paradigm that enables users to manipulate digital information remotely from anywhere and at any time. It is a concept that involves processing, mobility and communication through wireless network, which eliminates the need for users to be always connected to a fixed network structure.

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Mobile applications demand for support of these technologies. Therefore, new solutions and services have grown exponentially with development of devices. Currently it is possible to find a variety of applications in various areas of knowledge, eg, economics (Giridher et al, 2009), banking (Ciurea, 2012), medicine (Merdes; Laux, 2002), education (Kun et al, 2011), among others. In particular, in education, the use of mobile devices for teaching and learning has expanded the area of computer education creating a new concept called "Mobile Learning" or "M-Learning" (Wei, Liqiang, 2011). This new educational paradigm enables the learner to access content and interact with teachers and classmates from anywhere.

One main factor for the spread of mobile devices in education can be explained, in a first analysis, by the significant number of users in all age groups (Mishra, 2009), (GSMA, 2010). According to Benedek (2012, pp.17), it is estimated that in 2013 there will be 4.5 billion mobile phone users worldwide using entertainment services, community information and social networking. The low cost of the devices and mobile services, in comparison with the values of computers and Internet services, increased demand for applications to support teaching and learning (Lane et al, 2010). The teacher should look to expand his/her potential for teaching and learning, since such devices are meant for communication between users, i.e. send and receive calls and messages.

Besides the low cost, technological developments in mobile telephony has enabled the development of increasingly powerful mobile devices, with greater processing power, multimedia features and loads of sensors such as compasses, accelerometers and cameras (Lane et al, 2010). These device characteristics caused the spread, in large-scale, of augmented reality applications (Olsson; Salo, 2011). This technology makes it possible to integrate the real world with 3D virtual elements (Azuma et al, 2001); which can arouse the learner's curiosity and so makes the learning process more attractive, fun and motivating (Fotouhi-Ghazvini et al, 2009), (Balog et al, 2007), (Shelton, Hedley, 2002).

For all these reasons, this paper presents the research and development of an educational augmented reality application for mobile devices called AGeRA. This is an interactive book with augmented reality for teaching and learning of geometric figures. When looking at the book, it seems like other conventional books. However, when the book is placed in front of a camera on a mobile device, 3D objects, sounds, animations, textual explanations and other interactive elements, leap from its pages. These features added to the physical book can increase student interest and motivates them to explore the topics presented, thus enhancing learning.

Besides this introductory section, the chapter provides, in section 2, benefits of mobile learning, and discusses how mobile computing can be used as a teaching resource in the classroom. Section 3 presents the concepts and fundamentals of augmented reality technology and brings a study of papers that show the development of books created with augmented reality. In Section 4 we present the methodology of the AGeRA application development, detailing the choices of topic, target audience, functional requirements, interaction design, content covered in the book and the results of tests with users (students and teachers). Finally, in section 5, the main conclusions of this work and proposal to future works are presented.

MOBILE LEARNING

Use of mobile devices in education provided a new educational paradigm, called M-Learning, since no more learning occurs in formal locations like classroom (Wei; Liqiang, 2011). Particularly for children, it offers many opportunities for students to work their creativity, while at same time it becomes an element of motivation and collaboration.

This definition is consistent with the idea of pervasive learning "*In essence, pervasive learning* *concerns the use of a technology the apprentice has in his/her hands to create learning situations more meaningful and relevant, authored by student*"(Zanella et al, 2007, p.2). Furthermore, these types of devices utilize open platforms, allowing deployment of low cost educational applications with potential for expansion and replication in several places (Lane et al, 2010).

Vision of mobile computing is that of portable computation: rich interactivity, total connectivity and powerful processing, strong search capabilities, powerful support for effective learning and performance based assessment (Quinn, 2000). Its advantages is that a user can use it while on the move due to ubiquitous devices that makes mobile learning to be more considered as anytime, anywhere learning. The information can be accessed in any location; it is informal and formal learning. Mobile Learning ties the world together to encourage collaboration and communication.

Table 1 shows the evolution of mobile learning from the 19780's to 2000's. These include the telephony operation, generation and networks used in the mobile development. It really shows that mobile learning is upgrading and new technologies are invented.

Experts are concerned to provide a learning environment that always makes available to users the most current information possible. Thus, M-Learning emerges as an important alternative education and distance learning, where can be highlighted the following objectives (Marçal et al, 2005):

Table 1. Mobile development

	1980S	1990S	2000S
Telephony	Analog Calls	Mobile communication Simple messaging	Smart-phone's
Generation	1G-Analog Cellular telephony	2G-Digital Mobile communication	3G-wide-band Mobile communication
Networks	Cellular Networks	Digital networks	IP Data Networks

- Resources to improve student learning through task execution, ideas annotation, searching for information on Internet, record facts through digital camera, sound recording, access to podcasts of classes and lectures among other existing features.
- To provide access to educational content anywhere and anytime, according to device connectivity.
- To increase the possibilities of access to content, increasing and encouraging the use of services provided by an educational institution.
- To expand group of teachers and learning strategies available through new technologies that support classroom and distance learning.
- To provide means for developing innovative methods of teaching and training using new computing and mobility resources.

Currently, most children grow handling different technologies. This ability allows these children access to an unlimited universe of knowledge and information. According to the Center for Research on Information Technology and Communication (CETIC 2012), in Brazil, about 47% of children and adolescents between 9 and 16 years old have access to Internet every day or almost every day. Around 45% have a mobile device, and of those, 21% have a mobile device with Internet access.

AUGMENTED REALITY

Augmented Reality is a technology that enables to mix virtual objects generated by computer with a real environment, generating a mixed environment that can be viewed through any technological device in real time (Azuma et al, 2001). The main characteristics of an Augmented Reality system are: a) real-time interactivity, b) use of 3D virtual elements, c) mix of virtual elements with real elements.

Augmented reality has emerged from research in virtual reality. According to Burdea and Coffet, (1994), virtual reality environments make possible total immersion in an artificial three-dimensional world. This way, the user can explore and manipulate imaginary virtual worlds as if it was being part of him. Images generated by computer seem to be natural size and scenery modifies starting from the user's interaction with the virtual world. If environment incorporates three-dimensional sounds, then user is convinced that the orientation sounds change naturally in agreement with his/her orientation inside the environment. The immersion in a virtual world can be provided through specific technology (Burdea; Coffet, 1994): head-mounted displays (HMD), devices of optical tracking, force-feedback data gloves and joysticks that allow the user to navigate inside a virtual world and to interact with virtual objects.

From the appearance of virtual reality, there was always a separation between real and virtual world. However, technological progress has made possible to mix real environment and virtual worlds (in real time) originating a new concept denominated mixed reality (Kirner & Tori, 2006b). Unlike virtual reality that transports the user inside of virtual world, mixed reality propitiates the incorporation of virtual elements in real environment (the user maintains the presence sense in real world) or it transports real elements for virtual environments complementing the environment. When there is predominance of real over virtual, the environment is characterized as augmented reality; therefore the real environment is enlarged ("augmented") with addition of three-dimensional objects. To the opposite, when there is predominance of virtual over real, the environment is characterized as augmented virtuality; therefore real physical objects are captured in real time and inserted in simulated environment by computer.

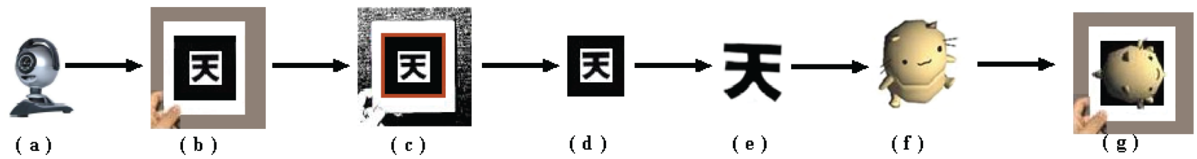
Augmented reality presents a great advantage on augmented virtuality: allows transport of virtual objects to the real world providing new interaction possibilities to individuals with serious problems of fine motricity (ability) and global motricity (agility). In this case, that the user can manipulate virtual objects happens in a natural way, dragging or touching an object with his/her hands or with his/her feet, without necessarily using devices of interaction or adapters. In case of augmented virtuality or even of virtual reality, training is necessary to use devices as mouse, keyboard, joystick or other technological devices. Many times, that need generates indifference, fear or even individual's incapacity in interacting with virtual environment.

Regarding the hardware of augmented reality, it's needed a common computer equipped with a display device (HMD, video monitor, screen or projector) and an image capture device (video camera or webcam). Ideal equipment for viewing the augmented reality environment is HMD with a processor, and navigation devices such as Global Positioning System (GPS), forming what could be understood as a helmet capable of capturing images, processing them and showing them to user in real time (Azuma et al, 2001). The helmet with these technologies is expensive and still with restrict use.

In relation to development software, it is necessary to use an Application Programming Interface (API) that uses augmented reality technology. The best known API is ARToolKit, but there are several other tools, such as NyARToolkit, ARTag, OSGART, Sudara, all based on ARToolKit. In this project we used NyARToolkit: an Object-Oriented Programming port aimed at Java 3D, JOGL, Android, SilverLight, C#, and C++.

Figure 1 shows the basic cycle of ARToolKit execution. Initially, the real world image is captured by a video input device (a). Captured real image (b) is transformed into binary image (c). This image is analyzed to find square regions (d). Then, ARToolkit calculates the position and orientation of camera relative to the square region seeking to identify specific figures, called markers (e). When the marker is recognized, ARToolkit verifies which virtual object is associated with it

Figure 1. Basic cicle of ARToolkit



(f). Finally, the ARToolkit calculates the exact point the virtual object must occupy in the real world and executes the superimposition of images returned to the user the visual combination of real world and virtual object (g).

In a simple application for Desktop, the user must point the marker to the camera so that it captures the image and transmits to the computer software. Software, in turn, will create the virtual object associated with this marker and show this virtual object on video monitor. While in a desktop application the user manipulates the marker; on a mobile device application the user manipulates the device itself with camera pointed at marker. Below there are some examples of the use of augmented reality with focus on Education.

EVOLUTION OF AUGMENTED REALITY DEVICES

In 1968 Ivan Sutherland, an American computer scientist and Internet pioneer, said that "*the fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves*" (Suthterland, 1968). Based on this, there are four display techniques used for augmented reality applications:

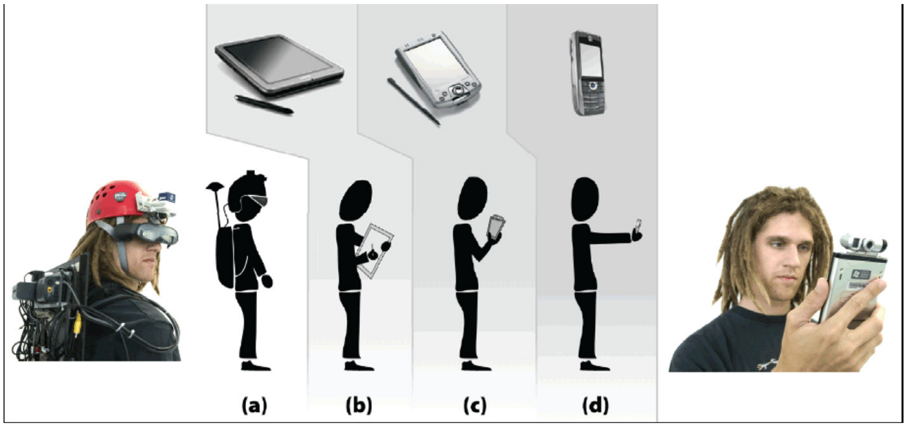
- Head-Mounted-Display (HMD).
- Personal Digital Assistants (PDAs).
- Tablet.
- Smartphone.

First of all the HMD, one might say as a archetype, was invented in 1966 by Sutherland himself. A HMD combines a helmet with a visor being, at least in part, paraboloid (Mostrom, 1975). The visor and a projection apparatus are fixed on the helmet (Mostrom, 1975). By means of a specific configuration of reflective surfaces any virtual object can be produced "*within the field of view of the person wearing the helmet*" (Mostrom, 1975). In a nutshell: HMDs obtain an enhanced view of the real environment by superimposing 3D computer generated objects into the real world view (Rolland; Fuchs, 2000). About 30 years after Sutherland's path breaking work in 1997, Azuma distinguishes between optical see-through and video see-through HMDs (Azuma, 1997). Optical see-through HMD's are based on optical combiners being placed in front of the user's eyes (Azuma, 1997). To avoid, that the users view is obstructed, these combiners are particial transmissive (Azuma, 1997). In contrast, video see-through HMDs capture the real world view with two cameras being mounted on the helmet (Emiliy et al, 1993). Until the images reaches the users eyes the virtual objects are placed electronically into the real worlds view (Rolland; Fuchs, 2000).

The second major technology used for augmented reality applications are handheld devices like tablet pcs, PDAs or mobile phones (Figure 4). In this paper we define handheld augmented reality just like Figure 2d.

Wagner (2007) does: "*We define handheld AR as a setup, where the user holds the mobile device actively in his hand*". Besides the fact that the screen containing the virtual content is handheld rather than head worn, which results in the great advantage of mobility, handheld AR differs from

Figure 2. Form factors of mobile augmented reality systems: (a) traditional "backpack" computer and HMD, (b) Tablet PC, (c) PDA, (d) Mobile phone (Wagner, 2007)



HMDs in several key distinctions. In contrast to the HMDs, handheld devices are ubiquitous and often abundant. The screen of a handheld device is directly connected to its input device (Billinghurst; Henrysson, 2006). Unlike HMDs, handheld devices "*are typically used only for short periods of intensive activity*" Billinghurst; Henrysson, 2006).

MULTIMEDIA INTERACTIVE BOOK WITH AUGMENTED REALITY TO LEARNING

Development of books potentiated with augmented reality is addressed in literature through reports of experiences, highlighting the work of: (Billinghurst et al, 2001), (Oliveira; Kirner, 2007), (Maier et al, 2009), (Costa; Kirner, 2010), (Gutierrez et al, 2010), (Okawa et al, 2010), (Kirner et al, 2012).

Billinghurst et al (2001) are pioneers in development of books potentiated with augmented reality . Authors created the Magic Book, where user can read the book content in the traditional way, flipping through its pages, without any additional technology. However, if you look through the pages with an augmented reality display (display connected to a hand held computer Desktop), users can view 3D objects coming out of the pages and enriching the contents presented. Just like the Magic Book, several other educational books potentiated with augmented reality were also created for desktop computers, they are:

- **LIRA (Oliveira; Kirner, 2007):** Helps to increase visual, audible and tactile capabilities of children with special needs. Traditional book was augmented with features capable of stimulating the senses of children through songs and animations issued by virtual three-dimensional objects.
- **Increased Chemical Reactions (Maier et al, 2009):** Proposes to help students to understand and learn chemistry, enabling to inspect molecules from different viewpoints, to control interaction between molecules and to observe chemical reactions.
- **LIPRA (Costa; Kirner, 2010):** Presents basic aspects of a game of chess as: names of parts, movements, catch and checkmates. Each of these topics is discussed in a separate topic in the book. At the end, book provides some exercises so that users can test their knowledge.

- **AR-Dehaes (Gutierrez et al, 2010):** Designed to help students to visualize, perform tasks and understand complex concepts of space engineering, such as surfaces, planes, corners, projections, etc.
- **SOLRA (Okawa et al, 2010):** Presents a solar system with interactive augmented reality using features of images, animations, sounds and interactions with multiple markers to facilitate knowledge acquisition in the context of the structure and behavior of the Solar System for educational use.
- **GeoAR (Kirner et al, 2012):** Designed for teaching and learning of geometric shapes, as recommended in the contents of elementary school mathematics. To use the book GeoAR, you must have a webcam connected to your computer and a video monitor. The content covered in the book GeoAR comprises the following topics related to geometry: rectangle, square, triangle, classification of the triangles according to their sides, classification of the triangles by their angles, trapezoid, pentagon and circle.

These innovative technological approaches allow a rich end user experience concerning sensorial stimuli, allowing for an enjoyable simultaneous interaction with the content (e.g. reading, hearing and display of static images and moving in 3D virtual models through augmented reality), thus enhancing the learning process.

The use of augmented reality applications mentioned so far are of use for desktops or notebooks which limits the user to a restricted space for the equipment. Multiple handsets and PDAs, tablets and iPads are capable of supporting a system based on augmented reality because they have a good processing power. This way you can use the camera's own device to capture the real environment and also use the display device itself with the virtual objects added. Researches on books potentiated with augmented reality for use with mobile devices are recent:

- **Children's Literature (Galvão; Zorzal, 2012):** Authors created a children's book of a Bible story. Stories are enriched with detection of rapprochement between two markers resulting in specific animations and sound effects, such as music, voices and storytelling.
- **Coloring Book (Clark et al, 2011):** Created for students to interact, to create and to express themselves through painting three-dimensional designs created by the user.

Some companies like Digital Tech Frontier and Sesame Workshop are combining augmented reality with toys and other children's books. These companies argue that the augmented reality helps children's learning, and at the same time keeping them entertained for longer time.

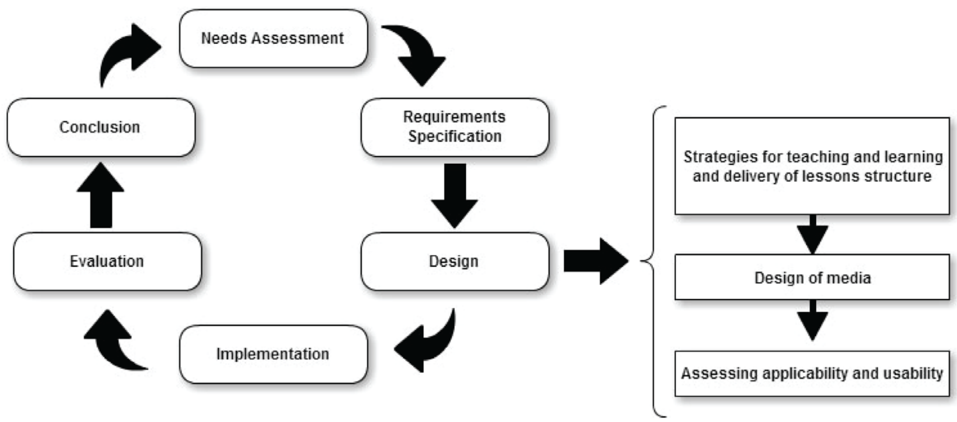
E-SPECIFICATION, DEVELOPMENT AND AVAILABILITY OF AGERA

To create AGeRA application, a specific development process was defined, compliant with principles of software engineering (Figure 3). The specifics of application and the technology of augmented reality were considered. Process follows a targeted approach to prototyping, where versions of the application are being constructed and evaluated, until a prototype that meets user requirements is obtained.

As shown in Figure 2, AGeRA application development comprises the following steps:

- In step Needs Assessment a research was carried out on teaching and learning methods of geometric figures geared for children.
- In Requirements Analysis phase a survey of requirements that needed to be developed was conducted . In this step were also defined the technologies used for develop-

Figure 3. AGeRA development methodology



ing AGeRA (environments and development libraries).

- In step Design a teaching and learning strategy of geometry was chosen and set a structure for implementing the lessons. Then, the design of printed media was created. Based on proposed activities in print, was made a planning application usability testing.
- In the stage Implementation use-case, class and sequence diagrams were created. With the complete conceptual modeling, a functional prototype was created to validate requirements.
- In step Evaluation a valuation methodology was defined, questionnaires were developed to collect data on users. These questionnaires were applied to students and teachers to assess applicability and usability of the application. After data collection, analyses of results were made.
- In step Conclusion final remarks on this work are made.

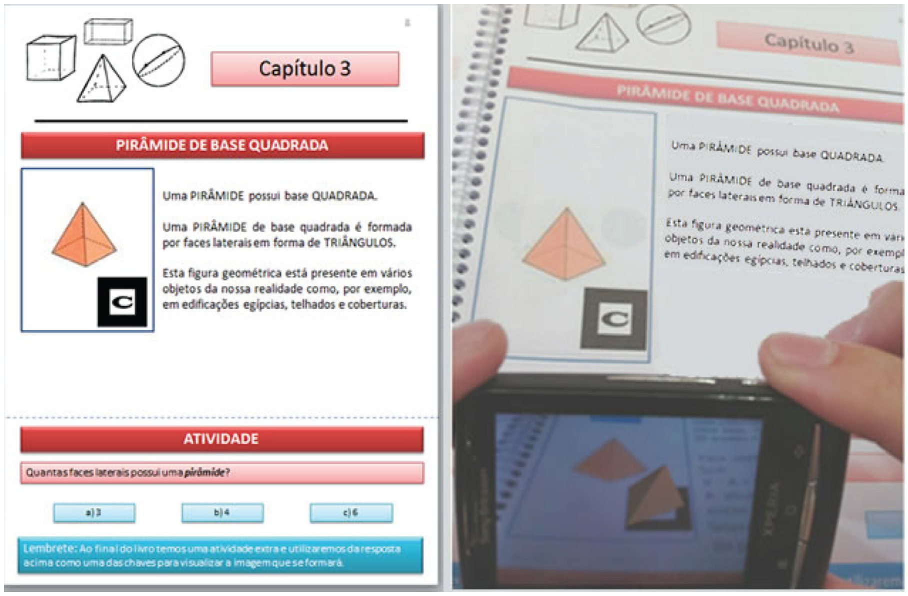
NEEDS ASSESSMENT

First the user profile was defined: elementary school students (1st to 5th year) that are learning matters pertaining to the sense of location, recognition of images, manipulation of geometric shapes, spatial representation and establishment of properties as specified by Parâmetros Curriculares Nacionais (PCNs). National Curriculum Parameters (Brasil, 1998) – specify how education should be conducted of Ministry of Education.

Then, a search was created to verify and analyze what are the difficulties that students of lower grades of elementary school have in the process of differentiation between spatial and planar geometries. We conducted a theoretical study about development of geometric thinking, considering the knowledge stage in which the child is, to be able to relate with practice in classroom (Fazza 2008).

It is known that geometry is present in various fields of human life, whether in civil constructions, nature elements or manipulable objects of everyday. School, as a formation agent, should give children access to this knowledge, in order that they understand and interact with the same world where they live. Therefore, Fazza (2008)

Figure 4. Sample page from AGeRA Book



recommends that teachers develop activities that provide the establishment of spatial relations in objects, like:

- Recognition of plane geometric figures (circle, triangle, square and rectangle) and their relationship with other objects present in every day.
- Recognition of non-planar geometries (spheres, pyramids, cubes and parallelepipeds) and their relationship with other objects present in every day.
- Perception of three-dimensionality in non-planar geometries, as well as the similarities and differences that exist between them.
- Classification of figures as plane or non-planar geometries based on criteria stipulated by students, explaining orally what are these criteria .
- Disclosure orally the relation and differences that exists between the plane and non-planar figures.

Smole et al (2003) present examples of activities that exploit the properties of objects:

- Conduct activities related to arm and disarm objects that help establish inverse relationships.
- Group objects by similarity and, at the same time establish differences relationships. Children should compare objects around them depending on its physical qualities. They may discover the same properties, such as color, texture, flavor, if used to eat, dress, among others. Manipulate objects of the same shape but different sizes, and verbalize what was made.

With the geometric objects (cylinder, cone, pyramid, prism, cube and sphere):

- Conduct exploratory activities and displacements.
- Plan activities so that the group works simultaneously with geometric and everyday objects that have the shape of the first.

Reports of teacher's experiences in early grades (Vasconcellos, 2008) indicate that students confuse plane and non-planar experiences, calling, for example, cube as square, parallelepiped as rectangle, as well not recognizing the same figures in different positions. Other experiments have shown that children identify packaging of a glue stick as a cylinder. However, they rarely recognize the cylinder in a coin, because of its small height.

REQUIREMENTS SPECIFICATION

Based on the needs assessment for learning Geometry and research involving educational systems with augmented reality, it was possible to establish the functional requirements of the AGeRA:

- Allow viewing and manipulation of geometric models in real time.
- Allow solving math challenges with issues related to geometric figures.
- Allow individual and collaborative work.
- Have low cost for dissemination in public schools.
- Have high availability to be easily acquired by students and teachers.
- Interface should be simple with minimal detail and easy to understand.
- Allow tangible and intuitive interaction.

As hardware requirements, AGeRA application needs a mobile device equipped with camera and Android OS.

INTERACTION DESIGN AND CONTENT ADDRESSED

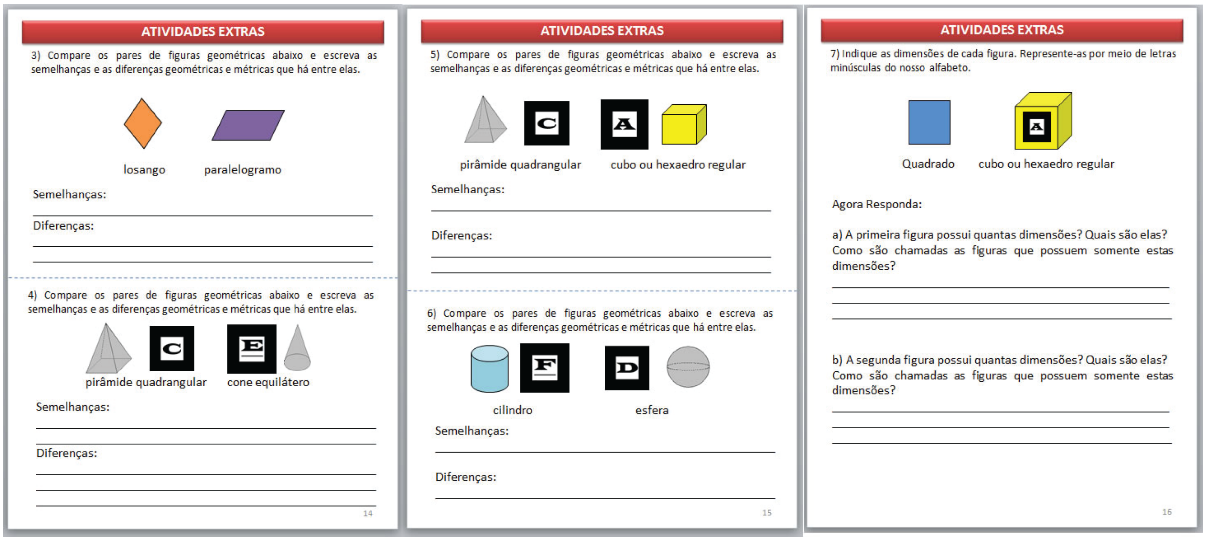
The stage of interaction design involved design of media (printed book prototype and augmented reality application) and study of teaching strategy. This strategy depends on the order and manner in which contents are exposed and treated. For this, we created a book, here called Print Media, with content on geometry, specifically about geometric figures.

Book is designed to be used together with augmented reality application (Digital Media) capable of reading the markers inserted into the book content. These markers generate three-dimensional geometric elements. This type of functionality, feature of books with interactive augmented reality represents a paradigm that maintains the use of books in their traditional form, along with the enrichment afforded by technology.

Figure 4 shows a page of book related to a quadrangular pyramid. This page contains information about pyramid: a) has a square base, b) side phases formed by triangles form, c) examples of similar objects of everyday life where the pyramid is present. At the end of the page, a question is posted to the user: how many sides has a pyramid? User must choose one of three response options. Book shows the 3D design pyramid drawn on 2D plane, but the user can use the mobile device to view 3D model of the pyramid. This enriches the learning.

Book has one marker to page. Each page presents a planar geometry as part of a non-planar geometric figure. For example, a cube is formed by squares; parallelepiped is formed by rectangles, prism is formed by triangles, and so on. The following geometric elements are treated: square-cube, rectangle-parallelepiped; triangle-prism, triangle-pyramid, triangle-cone, circle-sphere, cylinder-circle. Besides 3D models, animation and sound scripts were included to enhance interactivity. For example, when 3D object appears on screen, a sound effect is executed and, if user "touches" on 3D object, then it starts spinning on the screen. Each page has an activity for the user to choose a correct answer. Extra exercises were also created, where user can compare pairs of geometric figures and make a reflection on the similarities and differences between them (Figure 5). Moreover, there are also issues with open spaces so user can write what each question asks.

Figure 5. Example exercises of AGeRA book



At the end of book it's provided a set of puzzles involving some geometric figures discussed in book. Goal is to analyze images of everyday objects and try to identify geometric figures studied are present in those figures. For this, book has a page containing a set of card markers used in previous activities. Each letter present inside the marker corresponds to a geometry studied. This page can be detached from the book and the user must cut cards to form small pieces. This activity is divided into three steps: 1) cut the cards to form parts markers, b) analyze the pictures of the book with everyday objects, c) paste cards on grid answers in correct sequence (Figure 6).

If the assembly of puzzle is correct, the image of Android mascot in 3D is shown to user. Mascot is animated at sound of a really fun soundtrack (Figure 7). Answers of the exercises in book, including open questions, are available on the last page of book.

DEVELOPMENT AND TECHNOLOGIES

Figure 8 shows the relationship between technologies used in development of AGeRA.

Below is a brief description of these technologies:

- **Eclipse:** Development environment used to develop applications in Java programming language.
- **Java Development Kit (JDK):** A set of utilities that let create systems for Java platform. It contains the entire necessary environment for creation and execution of Java applications, including Java Virtual Machine (JVM), Java compiler, Java APIs and other utility tools.
- **Android Software Development Kit (SDK):** Is the process by which new applications are created for the Android Operating System. Includes a comprehensive set of development tools, debugger, libraries, a handset emulator based on QEMU, documentation, sample code, and tutorials.

Figure 6. End exercise of AGeRA book

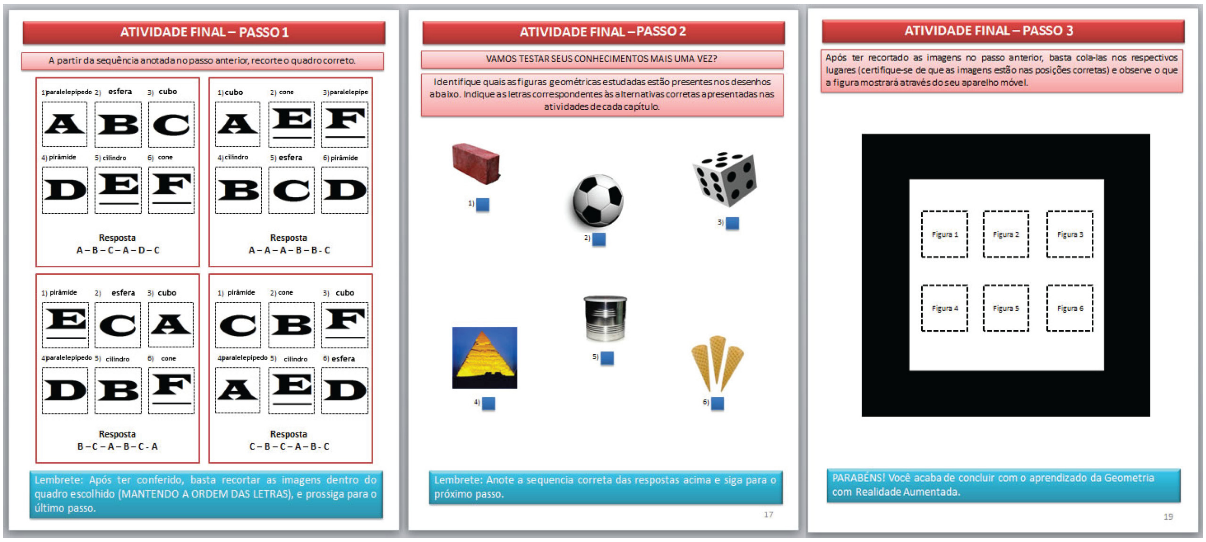
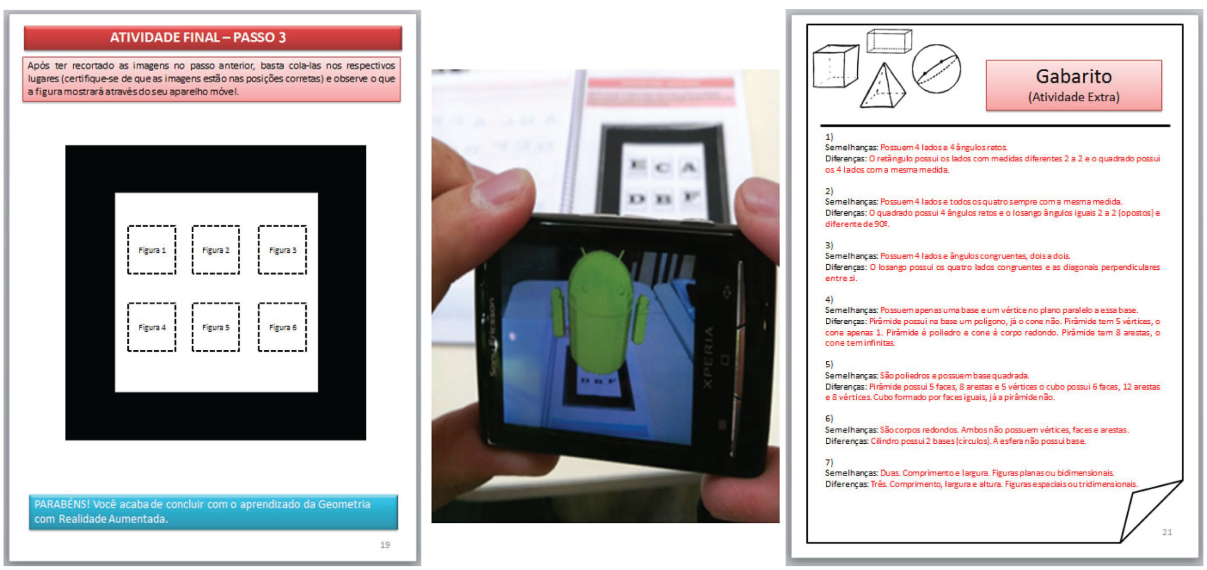
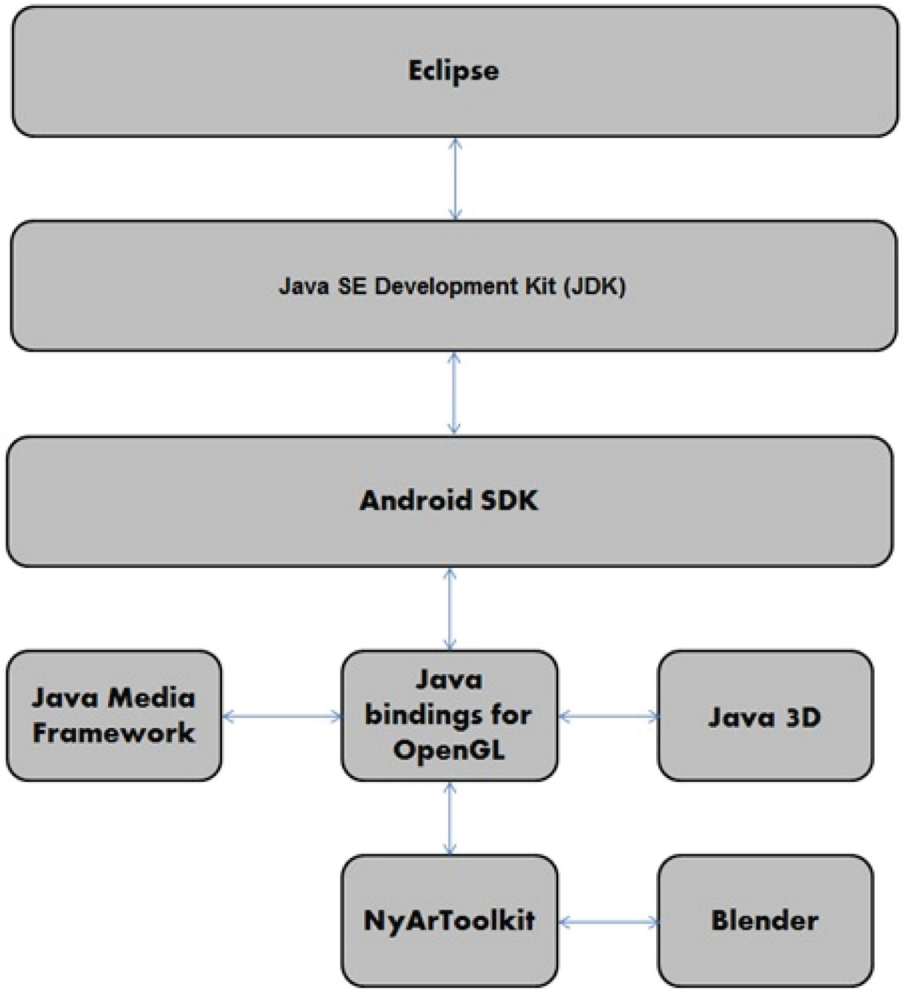


Figure 7. Mascot of AGeRA book



- **Java Bindings for OpenGL (JOGL):** Used for loading and rendering 3D objects. Uses Java 3D to create a 3D virtual world by means of functions that let load 3D models into the application. It is necessary to use the library Java Media Framework (JMF) to enable and build multimedia applications.
- **NyARToolkit:** Is the port of ARToolkit in Java. It is used to create augmented reality application: find a video capture device, makes the capture of frames, does all the processing of images for recognition markers, uses JOGL libraries for manipulating 3D objects and mix them with the real world.

Figure 8. Technologies used in development of AGeRA



- **Blender:** Tool used for creating 3D models.

Initially a study about installation and configuration of NyARToolkit library in a conventional computer was done. It was necessary to study and understand the characteristics of major classes of NyARToolkitAndroidActivity.java file. In this file is located InitScene() method where you can make the object instance that defines Animation-Object3d control frames, position and scale of geometric objects. NyARToolkit supports up to three types of 3D file formats: a) OBJ (Geometric Object), b) MAX_3DS (3D Studio Max) and MD2 (Model Format). In this project we used the md2 file format due to familiarity with Blender tool that supports import and export files in this format. 3D models were placed within the folder res/draw of NyARToolkit to be loaded into the application by manipulating the class InitScene(). Textures of 3D model were separated and placed in the folder res/drawable of NyARToolkit.

Files relating to markers were created and pasted into folder res\raw so that the NyARToolkit also be loaded into the application. Marker relative to the cube, for example, has been renamed pattcubo. Each marker is associated with a 3D object. It uses a list where there is an association identifier marker with the identifier of 3D model. When the application is started, the NyARToolkit reads the markers being used and loads 3D objects associated with them.

AGeRA is designed for Android 2.1 mobile phone, as this is a version supported by Smartphone Sony Xperia device used in this work.

TESTES OF AGERA WITH TEACHERS AND STUDENTS

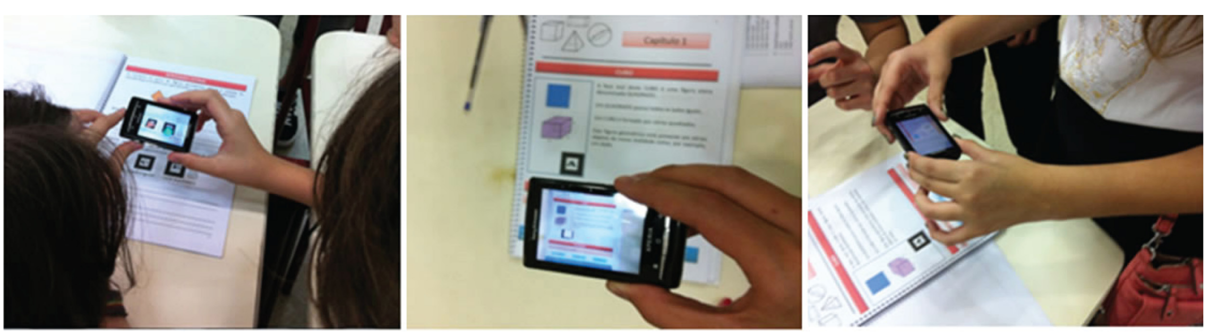
Tests with AGeRA were made with six teachers and five elementary students. Tests are important for measuring the level of acceptability of a software and detect usability problems. For tests two satisfaction questionnaires were designed to assess the applicability and usability of AGeRA. In the tests we used these materials: a mini Sony Xperia mobile device with AGeRA application installed, and printed book. Initially a demonstration of application use was made so students could meet the augmented reality technology. Figure 9 shows tests performed with students.

A questionnaire for students was built based on QUIS method (Questionnaire for User Interface and Satisfaction), designed to probe the interaction of satisfaction and usability aspects. The questionnaire for teachers was built based on Likert scale, with statements made by the respondent. It measured the degree of agreement and disagreement regarding the questions of questionnaire. Respondents chose among five options that best demonstrate their degree of agreement with what has been exposed. In addition to objective questions, text had spaces for participants to write their opinions.

For data collection, it was necessary to identify items that need to be investigated (user profile), the items that need to be observed (efficiency and usefulness) and items that need to be evaluated by the participants during testing (expectation about the result):

- **Survey of Student Profile:** Age, gender, grade level, use of camera phone, Internet access and services most used on mobile.
- **Usability Observation:**
    - **Effectiveness:** Completed the task.
    - **Efficiency (User Effort):** Understood the task.
    - **Utility:** Can be used to learn geometry.
- **Satisfaction Evaluation (expectations about the results):** Fun (amused), interest (would use again), attractiveness (aroused curiosity when the instructor was presenting the augmented reality technology), aesthetically appreciable interface (nice), pleasure (is happy, angry or frustrated), easy (easy use and easy to learn how to use).

Figure 9. Tests of AGeRA with teachers and students



RESULTS OF EVALUATIONS WITH TEACHERS

Mean age, 35 years of which 3 are women and 2 are men, 100% have a camera phone and Internet access. Among the most used services on mobile, beyond phone calls, include: access to social networks and posting photos on the Internet. 100% of teachers completed the task without interference from instructor. 100% of teachers agreed that AGeRA is suitable for use in teaching Geometry. 80% of teachers agreed that the interaction with virtual objects enhances the activity and allows students to feel motivated and challenged to solve the problems posed. 100% found the book attractive to work with students, 80% agreed that the AGeRA is easy to use and easy to learn to use. In the open questions, some teachers said the AGeRA has potential for use in other disciplines such as Arts and Physical.

RESULTS OF EVALUATIONS WITH STUDENTS

Mean age, 12 years of which 3 are boys and 3 are girls. 83,33% do not have their own cell phone, but they use their parents' and already carry a cell phone to school. 100% have used camera phone to take pictures and play. 80% completed the task without intervention from the instructor. Just game was needed to help the instructor to clarify the aim of puzzle game. 100% found fun to learn geometry with application AGeRA. 83,33% of students would use it again on other occasions to show colleagues and brothers. 66,67% liked the design of printed book. 100% said they were satisfied with use of AGeRA, 66,67% found it easy to learn geometry with the AGeRA.

FUTURE RESEARCH DIRECTIONS

We intend to increase the content of geometry subject discussed in the book, for example, include formulas to calculate the area and volume of solids. We are developing an evaluating AGeRA´s contribution to the process of teaching students, by following them in classroom with the help of a teacher of the area. This review could be performed from random separation of students into two groups: one group would have lessons with the help of AGeRA and the other group would have the same classes, but without the aid of AGeRA. After this step, the two groups were assessed for knowledge obtained from the classes. Finally, with the support of specialists, a study was done to identify whether there was some progress in the students who used the system as a support tool during lectures.

For this, we are reshaping the questionnaires and raising hypotheses to be investigated. From the hypotheses we will elaborate issues and define a scale of assessment to be used. We intend to offer the app for free in the Androids App Store.

CONCLUSION

Computer graphics have become much more sophisticated, looking all too real. In the near future the researchers plan to make the graphics on the TV screen or computer display and integrate them into real world settings. This new technology called augmented reality, further blur the line between reality and what is computer generated, improving what we see, hear, feel and smell.

Augmented reality has a vast field of exploration in various areas of knowledge, contributing significantly in education. It´s provides a great potential in the creation of interactive books, allowing an interaction intuitive and easy to adapt. It allows users to have a vision and expanded the enriched environment. It´s possible to enrich the information conveyed by the author of book with use of multimedia and three-dimensional objects. In this context, this work presents the development of AGeRA, an interactive book in augmented reality for mobile devices capable of supporting and supplementing learning geometry, especially of geometrical figures.

A preliminary usability evaluation of AGeRA was carried out with six teachers and five elementary students. They were exposed to a simple task to interact with AGeRA, content in augmented reality context, and they answered a satisfaction questionnaire related to the task. We have concluded that the AGeRA enhanced features impact on learning process:

- Adding visualization to a standard text book about Geometry will enhance its value as an educational material.
- Visualized text is easier to understand, and thus learning process will be fostered.
- Audio-visual content is more attractive and fun than standard text books.
- Adding visualization features to a standard text book creates a new media concept and possibilities, resulting in completely new educational instruments.
- A very intuitive and easy to use authoring tool will allow for unlimited creativity during educational material preparation.

Summarizing, AGeRA can bring benefits to teaching and learning of geometry, it provides greater interest and curiosity on part of students. Besides the fun, the AGeRA has provided digital inclusion, given that none of the users had previously interacted with augmented reality technologies. It was observed that the tests with augmented reality had great acceptance for educational use in mobile devices.

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