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Conference Paper · October 2015

DOI: 10.1109/WEA.2015.7370154

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Development of a Mobile Application in Augmented Reality to Improve the Communication Field of Autistic Children at a Neurorehabilitar Clinic

Rincón M. Nubia; Garay R. Fabián; Rodríguez A. Wilson; Pérez B. Wilmer
Electronic Engineering
Distrital Francisco José de Caldas University
Bogotá, Colombia
nubiabioing@yahoo.es; fsgarayr@correo.udistrital.edu.co; wrodrigueza@correo.udistrital.edu.co;
wperezb@correo.udistrital.edu.co

Abstract—An augmented reality mobile application to improve the communication field in children whit autism from the Neurorehabilitar Clinic was developed, assessing the aspects to determine its functionality and use in cognitive therapies of perceptive identification. Range of physical variables were established through evaluating its performance in a variety of environments.

Keywords—Android; Unity; Blender; Augmented Reality; Marker; Vuforia; Script.

I. INTRODUCTION

This application uses the augmented reality through programming and linking of programming languages such as: C#, code editors and debuggers: Unity, 2D and 3D images design software such as Blender, all the mentioned items above are for the purpose of integrating realistic and virtual elements, which are features of augmented reality. With the use of representative pictograms and images of some clearly recognizable categories by people, such as animals, fruits, means of transport, among others; and matching them with characteristic sounds which are going to be reproduced by the mobile device: a tablet. A graphic interface can be observed, representing each module that the children can interact, based on the ABA method developed in the Neurorehabilitar Clinic.

Tests were performed in a sample of six patients, each one with the accompaniment of the therapist and the quality auditor. Different children reactions were observed and with the support of the Neurorehabilitar Clinic, these reactions were quantified as parameters in order to monitor if improvements exist in the communication field. Results will be shown below.

978-1-5090-0228-3/15/$31.00 ©2015 IEEE

II. SOFTWARE USED IN THE APPLICATION

A. Unity

Unity is an integrated tool, used for the development of interactive contents such as three-dimensional animations, architectonical elements, real-time animations and video games [6].

It is available for OS X and Windows operating systems. It has the advantage of allowing the development of applications and games for OS X, Windows, Linux, Xbox 360, Play Station 3, Android, Wii, Wii U, Ipad and IPhone platforms, among others.

B. Vuforia

Vuforia is a platform developed by Qualcomm Technologies, also known as Software Development Kit (SDK), this allows to create augmented reality (AR) applications and can be integrated with Unity in order to make them work in mobile devices with Android system. This platform makes an image recognition, based on informatics methods of first level. And thanks to the integration of native applications1, Vuforia can reach a lot, due to its compatibility with a wide variety of tablets and smartphones.

The performance of Vuforia is based on the image sensing trough using the camera device, this process is well known as tracking, where the most sensitive points of the image are known as "trackable" or markers. The Vuforia library offers the position and orientation of the markers through a 4x4 matrix, known as Pose.

C. Blender

Blender is a free software used to create three-dimensional objects. Under the General Public License (GNU), it was developed with the support of people who are part of the Blender Foundation. Its main features are modeling, sculpting, normal and UV texturing, rendering materials, nodes systems

[1]Native applications are designed to exploit the features of a mobile device.

for the textures, polymorphism, multi-texture, reflect, transparences or bump, bones systems, particles systems, oceans simulator, linear and non-linear animations, games development, composition, renderer engine, video edition, modifiers, camera tracking, among others.

As an open code project, it can be executed in many platforms that have C++ debugger and libraries of dynamic graphics, particles movement. Blender uses the SPH method to make the movement of fluids with particles, showing more accurate results in a physic point of view.

D. *Android*

Android is the operating system intended to mobile devices in the first instance, and others such as iOs[2], Symbian, Blackberry OS. The main difference of these mobile operating systems is that Android is based on Linux, a free multi-platform core and operating system. Android allows to program applications in a Java variation named Dalvik, also it provides all the interfaces to develop applications that can access to the device functions based on the Java programming language.

III. APPLICATION DEVELOPMENT

A. *Using Unity*

Unity, the software chosen, was the indicated for designing the augmented reality application, since it allows the interaction between real or virtual camera and environment designed in a virtual scene. Initially, a creation of a scene and a virtual camera (Main Camera) watching at the scene are assumed as a starting point of the project. Unity can automatically identify any file added in the "Assets" folder in the project folder, whether from the file explorer or dragging the file into the "Project" window in Unity.

This program supports not only the libraries and exclusive designed object, but also three-dimensional objects, images and audio files. The file extensions that are compatible with the software are mentioned bellow:

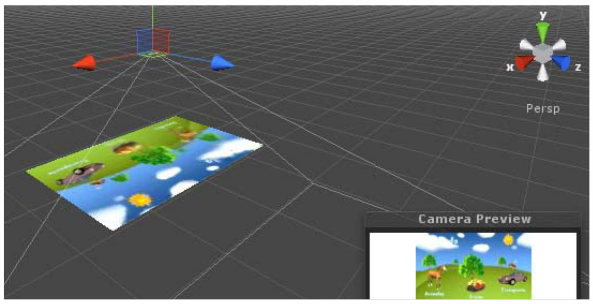

Fig. 1. Camera and cover the application in Unity.

B. *Scripts*

The scripts in Unity can be written in three different programming languages: Javascript, C# and Boo3. It is possible to combine those three languages not only in the same project, but also in the same object, however, there is some restrictions about cases when the methods can only be called in the same language the method is defined.

C. *Developing with the Vuforia library*

Integrating the Vuforia library in Unity is done through importing a package from the Vuforia official page, and the adding it to the project. A set of prefabricated objects are loaded, these content exclusive scripts to develop an application based on augmented reality. The Vuforia Software Development Kit (SDK) uses the mobile device screen as a receiver in an augmented environment where virtual and real objects are combined.

The application development in the Vuforia platform follows a process that consist of the integration of: Vuforia Engine, Target Management System that is stored in the Target Management, and optionally a physic storage space or a database stored on the cloud which contains references about the targets (Target Database).

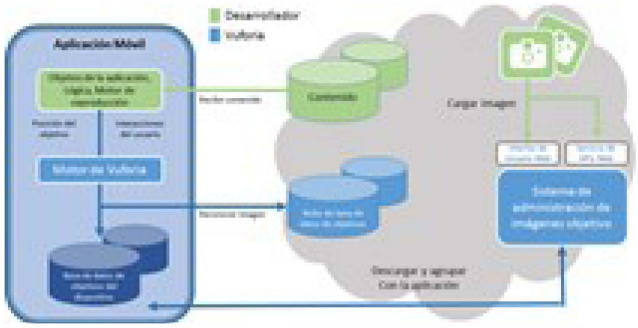

Fig. 2. Diagram of the process of application development platform Vuforia.

D. *Vuforia SDK Architecture*

The Vuforia library is a Software Develop Kit (SDK) for applications based on augmented reality, it is comprised of the core components mentioned bellow:

1. Camera: The camera component ensures that every frame can be captured and recognized in a suitable way by the tracker. The developer only has to initialize the camera in order to begin and stop the video capture. The camera frame is delivered by any device, the size and the image format can vary.
2. Image converter: The pixel format converter transforms the camera format (e.g. YUV12[4]) into a suitable format for the renderer OpenGl ES[7] and for inner tracking. This
   conversion also includes a sub-sampling to obtain different camera image resolutions, available in a set of converted frames.
3. Application Code: The application developers initialize every component and follow the key steps in the

2 iOS: Mobile operative system of the organization Apple Inc., formerly known as iPhone OS.

[3]Object-oriented language programming syntax is inspired by Python.
[4]YUV12: YUV color system in an amount of 12-bit data for one pixel.

application code. The state object is updated and the application rendering method is called for each one of the frames that have been processed.

4. Cloud Database: It can be created by using either the Target Manager or the Vuforia Web Services Application Programming Interface (API5). The required objects in the application execution time, use the recognizing feature proper of the Cloud Database, and make a visual search by using the camera images sent. Also, the Cloud Database can contain metadata for the targets, which are returned to make a search once again.
5. Target Words: The Vuforia SDK can recognize words in a manner similar to how it tracks the other types of targets. A word is recognized only if it belongs to a given list of words, this can be stored in the device and can be loaded by the application in the execution time.

A flow chart of the Vuforia Software Development kit environment is shown in the following figure. [6]

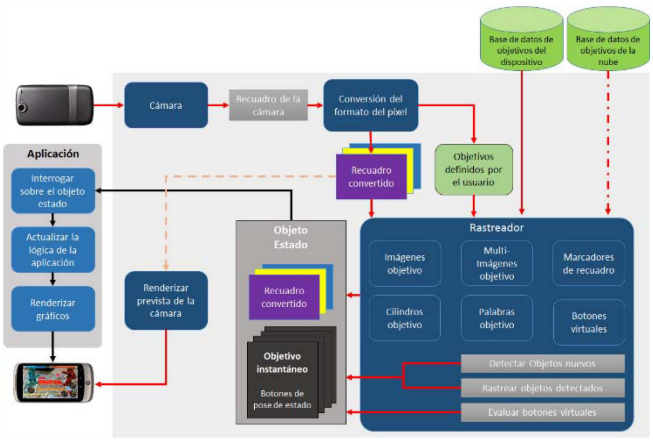

Fig. 3. Data Flow Diagram Vuforia SDK in the application environment.

E. Using Blender

It is necessary the use of three-dimensional objects in the application development, but there are some objects that cannot be created in the Unity software, because they have some complicated structures and require knowledge of design, this is why, with the use of the Blend Swap page, community of artists that share three-dimensional objects for commercial and personal purpose, great variety of three-dimensional models can be used only by signing up. However, it is necessary to design the animation, which it is needed to create joints and meshes of the separate parts of the model that needs to be animated.

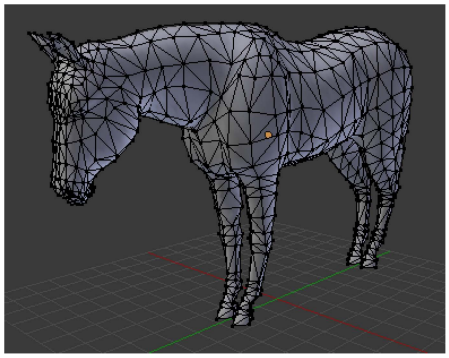

Fig. 4. Three-dimensional model developed in Blender.

F. Making the Augmented Reality Application

The application must have one scene per each category included in the augmented reality application, also it needs a main scene as home page, where the children can choose the category they want to enter. For these reasons, both the main scene designing and a study of what color is going to be used are assumed.

G. Colors Selection:

Studies show that the colors produce psychological effects on people, because they generate different sensations and reactions. It is believed that chromo therapy is a healing method for certain diseases through mixing and using colors.

H. Application Home Page:

It is considered that the scene must not have many elements because it can over-stimulate children and causes stress, the images related to nature can be a way to reassure children because green and blue colors have these effects on people. That is the reason why the scene must contain a very simple landscape with few elements.

I. Scenes:

Each one of the categories must be in a different scene, ensuring that the children can access and change between them through links in the Home Page, avoiding saturation. Each scene has an augmented reality camera, light elements, 5 objects that operate as markers and attached to them, the three-dimensional objects and their animations, the terrains, the audio sources and scripts, all the items mentioned must appear when the marker is identified. Also there must be a distance from the camera and the marker on the scene to make the augmented reality work.

J. Camera-Marker Relationship:

Similarly, as the home page was elaborated, there must be a distance between the augmented reality camera and the marker. However, this distance is not relevant in determining a distance between the camera and the marker in real world when the application is executed in the device, since the

[5] API: "Application Programming Interface".
[6] Image from: "https://developer.vuforia.com/resources/dev-guide/vuforia-ar-architecture"

scripts of the camera read the real size of the marker and thereby overlay the attached object with a proportional to the marker size.

K. Marker-3D Object Relationship:

The three-dimensional objects are located over the Image Target in the Unity editor, considering the position of the marker. When the object is located over the marker, the process must be taken with care because both the marker and the object component, represent the position in the editor as in the device. Also, all the components can be moved, turned and scaled in Unity by using the tools in an appropriate manner.

L. Animating with Scripts:

The animation is key in the project, because all the three-dimensional objects not only must be quite close to the reality, but also must move and produce sounds in a real way. Also it is important to have an interaction between the application and the user, the therapist, the parent or the child. That is why the animations must be controlled with basic commands on the device, these commands are either tapping the screen or pressing a button. The animations are designed following the ideas mentioned before, so the functions "input" and screen functions are suitable.

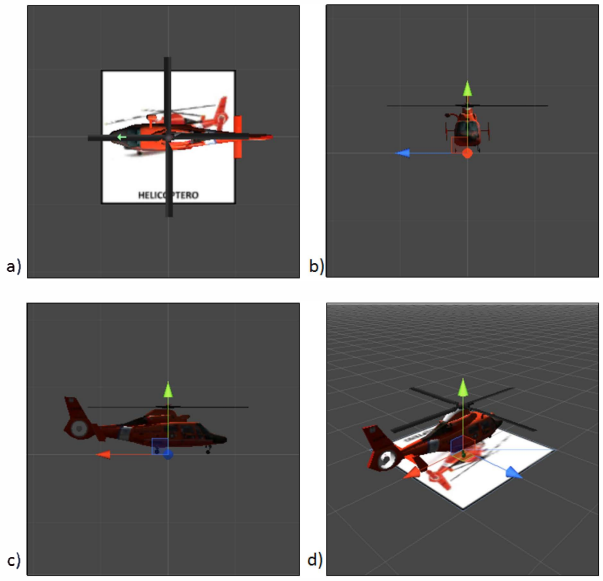

Fig. 5. Model of the application developed.

IV. RESULTS AND DISCUSSIONS

A. Illuminance

The minimum illumination necessary to ensure the application works is when the luxmeter show 21 lux, it tends to vary in 1.58 lux (±7.53 %). The maximum illumination necessary to ensure the application can work could not be determinate because the illuminance with natural light at midday was over 20 000 lux, and the application was functional at that illuminance. There is no scenery where the illuminance exceeds 20 000 lux in the Neurorehabilitar Clinic building.

B. Angle and Distance Results

The measurement of angle and distance were performed at midday, the luxmeter showed values between 19 700 lux and 20 000 lux. An experimental procedure were performed in order to find the minimum and maximum of both angle and distance, the application named Angle Alarm Protector allowed to control the angle while the distance between camera and marker was measured. All data were registered when the camera makes the first recognizing. The distance variances started at 2 cm when there was not recognizing, then increases were performed until the camera identified the marker. This procedure were repeated each 15° until 90°.

C. Discussions about result, compared to the traditional method

Tests were registered, first the traditional method results and the method using the application. The test was given to six children accompanied by the therapeutic team from Neurorehabilitar Clinic, the sample was made up of 5 boys and 1 girl, between the ages of 3 and 9. Three categories (Animals, fruits and means of transport), 5 elements each one were assessed. The elements given by the therapeutic team in order to determine if the application works compared to the traditional method were:

- Attention Process
- Appearance of verbal language
- Interaction

The traditional therapy has an established procedure for assessing the children progress, first, the pictogram is shown to the children; second, the therapist makes question in order to observe if the child recognizes the pictogram, the therapist accepts that the child recognizes the marker only when he or she makes sounds or movements related to the figure shown; third, the therapist gives instructions to the children, where the element shown can be involved, observing if the child follows the instructions. All of the results using the traditional method are registered, then the therapist makes the procedure by using the application, interacting with the device. The results are mentioned bellow.

C1. Attention Process:

The focus of attention on children was assessed in both the traditional therapy and the therapy with the application, the test consists of showing to the children the pictogram (traditional therapy) and then showing the three-dimensional

element on the tablet with its respective sounds, all the elements were shown.

The graphic 6 shows the comparison between therapies, the results are mentioned bellow:

- The category of animals reveals that there is an increase of 37% in the attention process when the therapy is applicate using the device, this is due to the children recognized the sounds of animals and then looked at the device while the elements were moving, trying to find the sound source. Animals like the hen and the horse have the most significant increase. Animals like the hen and the dog were attended by all the children.
- The category of means of transport reveals that there is an increase of 10% in the attention process when the therapy is applicate using the application, this is because the sounds and the animations were not so striking.
- The category of fruits reveals that there is not any increase when comparing the therapies. This is due to the animations of fruits are very simple and they do not make sounds. None of the items show progress in the attention process.

A bar graph was create, representing the number of times each patient shows attention process, so the maximum number is 6, which means the 6 children show attention process, and the minimum is 0, none of the children show attention process.

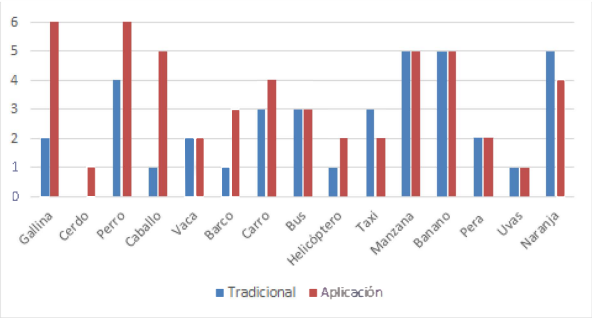

Fig. 6. Comparison of test results in the processes of care.

C2. Appearance of verbal language:

The appearance verbal language of children was assessed in both the traditional therapy and the therapy with the application, the test consists of verifying if the children recognize the pictogram and make any sound or movement, and then, showing the three-dimensional element on the tablet with its respective sounds, verifying if the children makes sounds of movement when the element is shown on the device, all the elements were shown.

The figure 7 shows the comparison between therapies, the results are mentioned bellow:

- The category of animals reveals that there is an increase of 17% in the appearance of verbal language when the therapy is applicate using the device, this is due to the children recognized the sounds of animals and then tried to imitate them. Animals like the hen and the dog have the most significant increase because their sounds are very common for people.
- The category of means of transport reveals that there is an increase of 10% in the appearance of verbal language when the therapy is applicate using the application, this is because the sounds of terrestrial means of transport are very common for the children.
- The category of fruits reveals that there is not any increase when comparing the therapies. This is due to the animations of fruits are very simple and they do not make sounds. None of the items show progress in the appearance of verbal language, when a child identifies a fruit, he or she does it with or without the application.

A bar graph was create, representing the number of times each patient shows appearance of verbal language, so the maximum number is 6, which means the 6 children show verbal language, and the minimum is 0, none of the children show any verbal language.

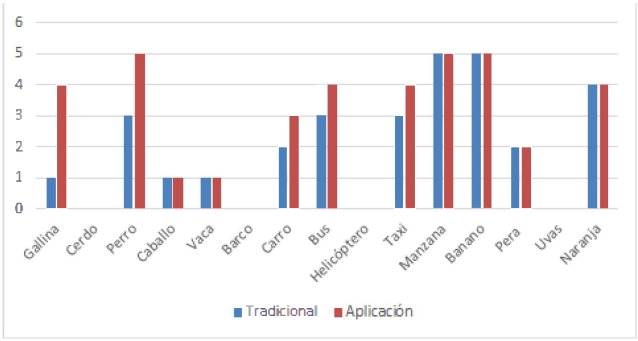

Fig. 7. Comparison of results in the emergence of language.

C3 Interaction:

The interaction in children was assessed in both the traditional therapy and the therapy with the application, the test consists of verifying if the children attends the instruction made by the therapist, all the elements were shown. The test of interaction reveals that there is not any pattern that can relate the interaction between therapies, since they respond in different ways to the same instruction made. The patient number 6 shows more interaction than the other patients that is because the child has a mobile device and the child is used to using technology. Social interaction proved to be a unquantifiable parameter due to changes in the behavior of children performing traditional test and after

with the application, is why it is not a concept that can validate the functionality of the application as a tool that improve communication.

Tests and interviews with the speech therapists who participated in the supervision of the same, shows that the application works as an alternative tool for identifying semantic therapies where children need to recognize items in different categories; one of this is the area of speech therapy, as therapists stimulate oral and expressive language by imitating sounds; children may reject the device as well as to the rest of all objects used in therapy so it's just a matter of adaptation.

The performance of three-dimensional elements helps the children to internalize what the therapist is trying to teach. Using real sounds help children to focus on the device, this improves their attention process when there is a lack of concentration. This also motivates the imitation done by the children, another one important area on phono audiology, applied to children. The category of animals is the most eye-catching for the children because of the sounds and movements.

V. CONCLUSIONS

- Requirements made by Speech therapist from Neurorehabilitar Clinic in Bogota as well as previous questionnaire for evaluation of learning mood, made possible the development of a augmented reality mobile app, which was used by six autistic children, who attend to rehab in Neurorehabilitar Clinic. The test shown an improvement in the learning field compared with the results obtained using the traditional methods. Test shown an increase in the attention process of 14% and a 9% in appearance of verbal language.
- Augmented reality mobile app functions as an alternative tool for semantical identification therapies as it presented an stimulation of oral and expressive language by playing onomatopoeias and representative sound of the elements, this is reflected in an increase of 9% in the verbal language apparition contrasted with the traditional method. Final task for evaluation made to the main speech therapist reaffirm the improvement observed.
- Social interaction is not a validation parameter of the mobile app by not being a quantifiable variable due to continuous changes in children's behavior. This was proved in the tasks made, where answers of autistic children were different with the same elements alternating traditional method and mobile app method.
- Characteristics sounds of the elements caused bother to 1 of the 6 children who made part of the study, once testified the rejection it was observed that it depended from the auditory sensitivity of the child, as it was informed by the speech therapist present along the therapy. However, by reducing the sound level of intensity the patient could accept the mobile app.
- 21 luxes minimum value of illumination was found, which guaranteed functionality of the app, forecasting unfavorable light conditions that could happen in the Neurorehabilitar clinic facilities. At the same time it was verified that the app fully functional under lightning values of 20 000 luxes, similar to environment produced in the shadow by a midday natural light. This parameter do not affect the first reconnaissance of the marks when camera's angle of incidence or distance between mark and device. Neurorehabilitar Clinic counts with necessary lightning conditions to assure minimum values of illuminance.
- Identified the characteristic equations of minimum and maximum lengths in which the application is functional when the angle varies found that the maximum value of the error between the characteristic equation and the experimental measured value, is when the incidence angle is 60 °, the measured value is 12 cm while the result of the characteristic equation is 13.23 cm , this shows an error of the 10.23% which is equivalent to 1.2 cm representing a minimum variation, comparing it to the dimensions of the marker of 11.5 cm square and the mobile device of 10.1 inches.

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