Mobile application with augmented reality applied to programming learning

Aplicación móvil con realidad aumentada aplicada al aprendizaje de programación

SÁNCHEZ-JUÁREZ, Iván Rafael†*, PAREDES-XOCHIHUA, María Petra and MORALES-ZAMORA, Vianney

Tecnológico Nacional de México campus San Martín Texmelucan, México.

ID 1st Author: *Ivan Rafael, Sánchez-Juárez* / **ORC ID:** 0000-0001-8296-5532, **CVU CONACYT ID:** 493160

ID 1st Co-author: *Maria Petra, Paredes-Xochihua* / **ORC ID:** 0000-0003-1753-2313, **Researcher ID Thomson:** S-6991-2018, **CVU CONACYT ID:** 298117

ID 2nd Co-author: *Vianney, Morales-Zamora* / **ORC ID:** 0000-0002-1181-825X, **Researcher ID Thomson:** S-6627-2018, **CVU CONACYT ID:** 308547

Abstract

Augmented Reality (AR) is a technology that allows users to have interactive experiences between themselves, the physical world, and the virtual world through the use of digital devices that have a digital camera, such as smartphones, tablets, desktop computers, or laptops. AR has various applications such as entertainment, advertising and marketing, medicine, architecture, engineering, tourism, e-commerce, or education; in the latter, students can visualize different concepts of programming fundamentals or object-oriented programming. The objective of this project is to create a mobile application applying augmented reality to the fundamental concepts of programming so that students can improve their understanding and retention of syntax and examples of terms used in Java. The application is focused on control structures, conditionals, classes, methods, constructors, objects, and arrays. Searching for concepts on the internet, physical or electronic books, or even with classmates, can take up to 5 minutes, with this application, it is possible to see the structure and/or examples in a matter of seconds, besides having the advantage that it does not require internet connectivity.

Resumen

La realidad aumentada (AR) es una tecnología que permite a los usuarios tener experiencias de manera interactiva entre él, el mundo físico y el mundo virtual mediante la utilización de dispositivos digitales que cuenten con una cámara digital, tales como smartphones, tablets, computadoras de escritorio o laptops. La AR tiene diversas aplicaciones como entretenimiento, publicidad y marketing, medicina, arquitectura, ingeniería, turismo, comercio electrónico o educación; en esta última, los estudiantes pueden visualizar diferentes conceptos de fundamentos de programación o en la programación orientada a objetos. El objetivo de este proyecto es crear una aplicación móvil aplicando la realidad aumentada a los conceptos fundamentales de programación con la finalidad que los estudiantes puedan mejorar su comprensión y retención de sintaxis y ejemplos de los términos que se manejan en Java. La aplicación está enfocada a ciclos de control, condicionales, clases, métodos, constructores, objetos y arreglos. La búsqueda de los conceptos en internet, libros físicos o electrónicos, incluso con compañeros de clase, puede llegar a tardar hasta 5 minutos, con ésta aplicación es posible ver la estructura y/o ejemplos en cuestión de segundos, además de tener la ventaja que no necesita conectividad a internet.

Arrays, Augmented reality, Sintax   **Arrays, Realidad aumentada, Sintaxis**

---

* Correspondence of the Author (E-mail: ivan_r.sanchez@smartin.tecnm.mx)

† Researcher contributing as first author.

Introduction

In 2021, the National Survey on Availability and Use of Information Technologies in Households (ENDUTIH) was conducted, revealing that 91.7 million people have cell phone service, with 93.4% of them being internet users in the 18 to 24 age range, which includes university students. For this reason, the majority of university students have a smartphone that supports them in their school activities.

Around 226 out of 254 campuses of the Tecnológico Nacional de México offer the degree program in Computer Systems Engineering, where subjects such as Fundamentals of Programming and Object-Oriented Programming are taught. These subjects serve as the foundation for programming. However, many students struggle to understand the syntax of basic instructions in the Java programming language, such as the structure of a class, the for or while loop, among others.

To help them better comprehend these terms, a mobile application with augmented reality is created. When the marker is read within an editor like NetBeans, it will display the syntax of the instruction. This will save time that would otherwise be spent searching for it on various internet websites. Additionally, the application can display the syntax in a language other than Java, thus avoiding confusion. The application will be able to identify 16 different instructions and provide relevant information for each of them.

Unlike tutorials, physical or electronic books, or websites, this application will be able to identify the marker (word) and display the syntax with information in less than 3 seconds. Furthermore, it does not require an internet connection.

Theoretical Framework

Augmented Reality (AR) enables the interaction between virtual environments and the physical world, allowing them to blend together through a technological device such as webcams, mobile phones (iOS or Android), tablets, among others.

In other words, AR inserts virtual objects into the physical context and presents them to the user using the interface of the real environment with the support of technology (Grapsas, T. 2019).

Augmented reality is classified into: Image recognition-based augmented reality: It does not require markers or patterns to activate the process. The images themselves serve as signals that trigger the method, where the virtual content is placed on top of them.

Geolocation-based augmented reality: It relies on the user's location being at a point of interest, and then visualizing relevant information on the device's screen.

Pattern recognition-based augmented reality: This type of augmented reality involves the use of markers (targets) to activate virtual content (KeepCoding Team. 2022).

For the implementation of this project, pattern recognition-based augmented reality (markers or targets) will be used. These markers will be images representing the instructions to be reviewed, such as "for," "if," "switch," or classes.

As expressed by ConversusTV in an interview with Dr. Jorge Toro González: "Education 4.0 (E4.0) applies Information and Communication Technologies to education in order to prepare people for the 4th Industrial Revolution (4IR); accessible to individuals at any educational level, to facilitate continuous learning and updating according to industrial, service, and business needs" (ConversusTV, 2019, 0m35s).

Augmented reality, like Education 4.0, is closely linked, allowing the integration of information and communication technologies with the visualization of three-dimensional objects in a real environment. This can lead to m-learning (mobile learning), which is learning based on mobile devices. The key characteristic is that educational applications can be installed on mobile phones and accessed anytime, making use of the time students have during their commute from home to school. As mentioned by García-Bullé (2019), m-learning content often promotes informal learning to acquire skills such as emotional intelligence or problem-solving. Therefore, using augmented reality in education will encourage student learning.

Methodology

The activities carried out for this project are: analysis of the elements to be generated, design of 3D elements, design of markers, creation of the Vuforia database, configuration of Vuforia with Unity, asset importation to Unity, application generation, and finally, testing. The Vuforia Target Manager is a web-based tool that enables you to create and manage target databases on Vuforia's developer portal. (Vuforia, 2023)

Analysis of the elements to be generated: A survey was conducted to determine which instructions students find most complex to understand in terms of their functionality or syntax. The survey also aimed to investigate the time it takes for students to search for the structure or example of programming instructions in Java, as well as the most common means they use to search for instruction structures.

Out of 16 instructions, the most complex syntax, ranked first, is the foreach loop with 57.1%. Matrices rank second with 46.4%, and methods, arrays, and lists share third place with 35.7%. 50% of the surveyed students take 2 to 5 minutes to search for instruction structures, 28.6% take over 10 minutes, 14.3% take 6 to 10 minutes, and only 7.1% take less than 1 minute to find the information. Finally, 82.1% search on web pages, 10.8% use PDF files, and 7.1% consult with a classmate. Figure 1 shows the results of the time it takes for students to search for an instruction.
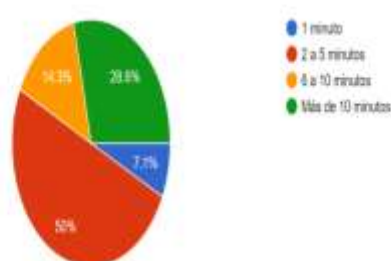

Figure 1 Search Time Results
Source: Own elaboration

Design of 3D elements:

The next stage is to design the various elements that will be displayed in 3D. These elements include: main, class, methods, constructor, for, foreach, while, do while, id, if...else, switch, vectors, matrices, lists, objects, and data types.

The software used for the design is Blender 3.3.0. The files can be generated with the .blend or .dae (Collada, an exchange format for 3D applications and the format for 3D objects with textures) extensions. In this stage, colors, positions, sizes, or transformations are assigned to each object. COLLADA, which stands for COLLAborative Design Activity, is an open standard XML format for storing 3D models (ArcGis, s.f.). Figure 2 shows the design of the structure of a Java class.
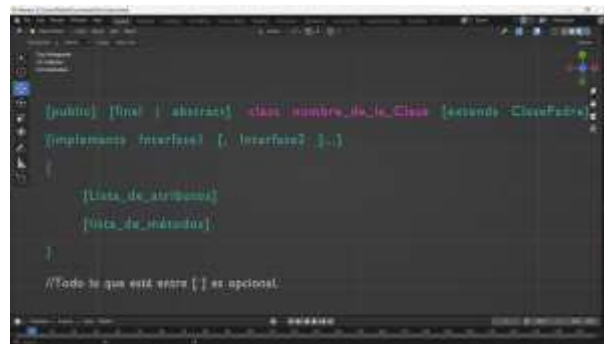

Figure 2 Class Structure Design
Source: Own elaboration

Marker design:

Augmented reality applications based on markers utilize target images (markers) to position objects in a specific space. These markers determine where the application will place the 3D digital content within the user's visual field.

Early-stage augmented reality technologies relied on markers (Softtek, 2022). To ensure good quality markers, the following characteristics must be met: grayscale images of 8-bit or RGB images of 24-bit in JPG or PNG file format are allowed. Failure to meet these characteristics will result in an error when uploading the markers (targets) to Vuforia.

Markers are detected based on their printing size and the distance given from the device's camera. It is recommended that the larger the marker's print size, the greater the distance from which the camera can detect the object. Table 1 shows the marker sizes and the detectable distances.

Size	Distance
16 * 16 cm.	1.9 m.
11 * 11 cm.	1.3 m.
7.5 * 7.5 cm.	1.0 m.
3.5 * 3.5 cm.	0.4 m.
1.3 * 1.3 cm.	0.16 m.

Table 1 Marker sizes and distance
Source: Adapted from Ministerio de Educación del Gobierno de la Ciudad de Buenos Aires (s.f.)

SÁNCHEZ-JUÁREZ, Iván Rafael, PAREDES-XOCHIHUA, María Petra and MORALES-ZAMORA, Vianney. Mobile application with augmented reality applied to programming learning. Journal of Technology and Education. 2023

Creating the Database in Vuforia: Vuforia Target Manager is a web-based tool that allows you to create and manage target databases on the Vuforia developer portal. Targets are assigned a star rating based on their quality. The star rating influences the robustness of the target in terms of detection and tracking.

The star rating can range from 0 to 5 stars. A higher rating is better because it indicates that the image target provides easier detection and more stable tracking. Vuforia Engine can only detect a target if it has a rating of at least 1 star. Targets with a rating of 0 stars cannot be used. If the database contains targets with 0 stars, they should not be selected when downloading the database. (Vuforia, 2023)

After generating the markers, it is necessary to create a database that contains all the targets. Each target in the database should have a rating of 3 to 5 stars, in addition to meeting the specified characteristics in the marker design phase. As shown in Figure 3, the targets are rated from 3 to 5 stars.
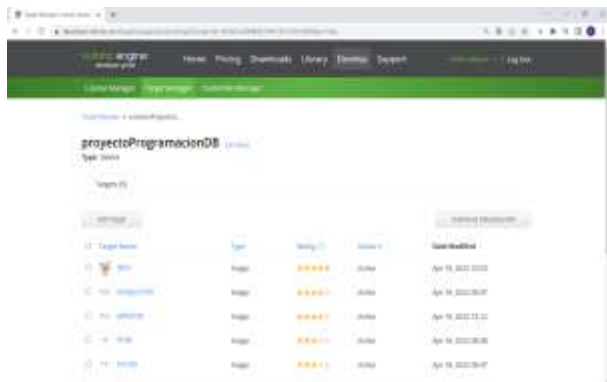

Figure 3 Target Ratings
Source: Own elaboration

Please refer to the table 2 below for the target ratings:

Target Rating	Description
1 star	Basic target quality
2 stars	Fair target quality
3 stars	Good target quality
4 stars	Very good target quality
5 stars	Excelent tagret quality

Table 2 Target ratings
Source: Own elaboration

Vuforia Configuration with Unity: Once the previous steps have been completed, a license key must be generated from the Vuforia website in order to enable Vuforia Engine features in the mobile application.

Likewise, the "add-vuforia-package-10-10-2.unitypackage" file must be downloaded to implement the tools that support augmented reality with Vuforia in Unity, including AR-Camera and Image Target. After adding the AR-Camera to the Unity scene, the license key must be added in the Vuforia Engine configuration section. Finally, the database containing all the targets should be downloaded from Vuforia, and it will have the .unitypackage extension, allowing it to be imported into the Unity project. Figure 4 shows the Unity scene with targets and the Vuforia key.
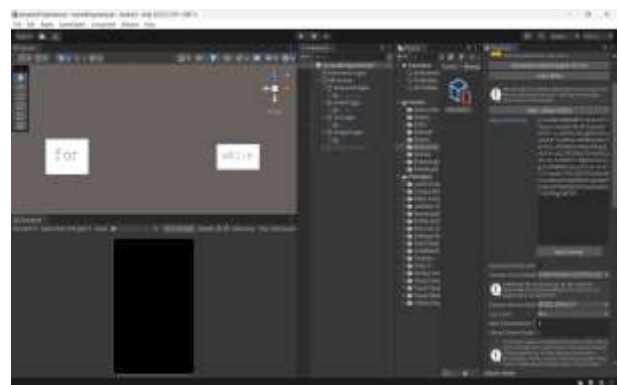

Figure 4 Vuforia configuration with unity
Source: Own elaboration

Importing Assets to Unity: With the AR Camera and the database ready, the image targets were added to the scene. Each image target must be associated with an image that serves as the previously designed marker. When this marker is placed in front of the device's camera, it allows the visualization of the 3D object. Once each target is ready, the assets, which are the elements created in Blender, are added. Each element is overlaid on the corresponding image target where it should appear. Figure 5 shows the inclusion of the "for" loop asset within its image target, which is located within the AR Camera.

Figure 5 "For" loop asset in Unity
Source: Own elaboration

Generating the application: Once the Unity scene is finalized, it's time to generate the application file for the mobile device. The following parameters need to be configured: company name, product name, version, default icon, and setting the Minimum API Level to Android 9.0 'Pie' (API Level 28). When performing the application build, the application name is set and saved on the phone for execution. Figure 6 shows the Player settings configuration of the application to generate the APK file that will be installed on the smartphone or tablet.
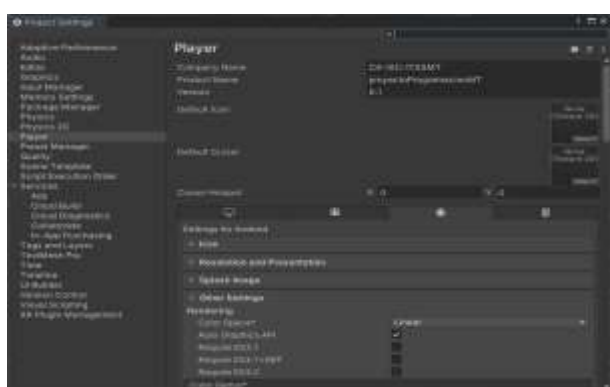

Figure 6 Player settings configuration
Source: Own elaboration

Results

At the end of the project stages, the application was installed on the smartphones of students and teachers. Tests were conducted with the programming instructions mentioned in the "Design of 3D Elements" stage. Figure 7 shows an example with the syntax of the conditional statement "if". The application detects the "if" marker, which can be read in the NetBeans 8.2 IDE. In the example, the boolean condition and the code block are highlighted if the condition is met.

Figure 7 AR applied to the "if" statement in Java
Source: Own elaboration

Another marker that it detects is for the "for" loop, it will show the way to initialize the loop, the stop condition, and the increment, followed by the code block to be executed. Figure 8 shows the execution of marker detection.
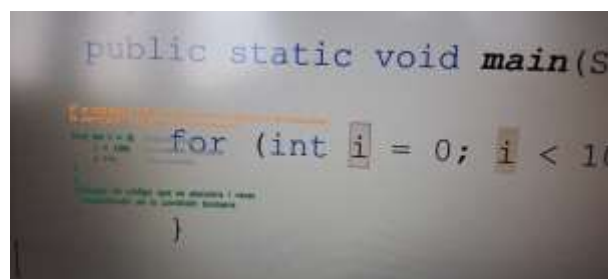

Figure 8 AR applied to the "for" statement in Java
Source: Own elaboration

Similarly, when reading the "while" loop instruction within the NetBeans editor, the application displays its structure and a practical example. Figure 9 shows the detection of the marker and the augmented reality for the "while" loop.
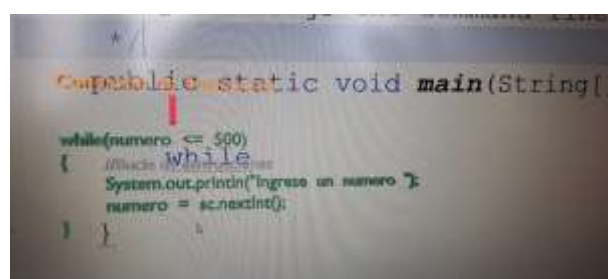

Figura 9 AR applied to the "while" statement in Java
Source: Own elaboration

Finally, the detection of the word (marker) "ArrayList" is shown, along with an example of how to create a generic ArrayList and add elements of different data types to it. The declaration of an ArrayList specifying its data type, such as Integer or String, is also demonstrated. Figure 10 shows the application in execution with the detection of the ArrayList.
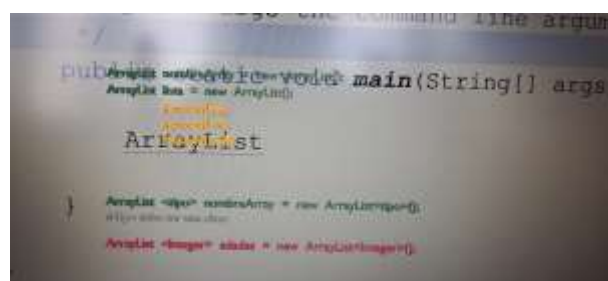

Figura 10 AR applied to the "ArrayList" instruction in Java
Source: Own elaboration

The application detects the markers within a range of 3 to 5 seconds and displays the desired information based on the selected instruction, significantly reducing the time spent searching through websites or electronic files.

Tests were conducted with students from the 2nd and 4th semesters of the Computer Systems Engineering program. For the application to work properly, it is recommended to have a phone with a camera resolution of at least 8 megapixels.

Acknowledgment

Financing

Conclusions

By using this application, it becomes easier for students studying Computer Systems Engineering or related fields to search for the most common programming instructions. It saves search time, eliminates the need for internet access, and detects various programming instructions in a matter of seconds within a single application.

As a future work, the application can be uploaded to the virtual store so that any student in the country can have access to it, taking advantage of the benefits offered by mobile-based education (m-learning).

References

i.   ArcGis. (s.f.). Una vista general del conjunto de herramientas A Collada. https://pro.arcgis.com/es/pro-app/latest/tool-reference/conversion/an-overview-of-the-to-collada-toolset.htm#:~:text=COLLADA%2C%20que%20significa%20COLLAborative%20Design,textura%20almacenados%20dentro%20de%20KML.

ii.   ConversusTV. (5 de abril de 2019). Educación 4.0. [Archivo de video]. Youtube. https://www.youtube.com/watch?v=JGfo3SsumKQ

iii. Grapsas, T. (2019). Conoce la realidad aumentada y las posibilidades de interacción que la hacen sobresalir en el mundo digital. https://rockcontent.com/es/blog/realidad-aumentada/

iv.   García-Bullé, S. Observatorio del Instituto para el Futuro de la Educación. (2019). ¿Qué es el m-learning? ¿Es una opción viable para la educación del siglo XXI?. https://observatorio.tec.mx/edu-news/que-es-mobile-learning/

v.   KeepCoding Team. (2022). Tipos de realidad aumentada. https://keepcoding.io/blog/tipos-de-realidad-aumentada/

vi.   Ministerio de Educación del Gobierno de la Ciudad de Buenos Aires. (s.f.). Creación de Marcadores para Realidad Aumentada. https://biblioteca-digital.bue.edu.ar/descargar/c0c191-tutorial-marcadores-realidad-aumentada.pdf

vii. Softtek (2022). ¿Cuáles son los diferentes tipos de Realidad Aumentada?. https://blog.softtek.com/es/cuales-son-los-diferentes-tipos-de-realidad-aumentada

viii. Vuforia. (2023). Vuforia Target Manager. https://library.vuforia.com/getting-started/vuforia-target-manager.