Geoar, Integration Of Digital Elevation Models In Augmented Reality Environments

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ABSTRACT: Digital Elevation Models (DEM) are numerical data structures that represent the spatial distribution of elevation, providing quantitative and continuous information for the visualization of variables. On the other hand, Augmented Reality is a system that involves the user and complements the visualization of the real world through virtual elements. Linking Augmented Reality with Digital Elevation Models generates a great contribution for the visualization, interaction and understanding of phenomena. This article proposes a methodology that allows linking Digital Elevation Models with Augmented Reality environments, in such a way that it provides a positive impact on the ability to interpret the relief, satellite images, and even allow mobile applications development.

Keywords: AR, Augmented Reality, DEM, Digital Elevation Models, Geographic Information Systems, GIS, Mobile Electronic Learning.

Introduction

The fourth industrial revolution is not defined by a set of emerging technologies per se, but by the transition to new systems. Augmented Reality is an emerging technology that presents

a transition to new systems, among these, Geographic Information Systems, giving rise to Geospatial Augmented Reality or Geo AR.

This article shows in a practical way, a special link between Geographic Information Systems (GIS) and Augmented Reality (AR), through a functional and direct procedure to convert a Digital Elevation Model (DEM) into a 3D object that can be visualized in Augmented Reality, facilitating in an interactive and immersive way the topography or elevation of a surface, opening a great amount of possibilities for simulations, commerce, management, risk analysis, development plans and/or education.

The big difference between a visualization of a raster data (type of digital image represented in cells - Pixel) as a 3D object in Augmented Reality, versus a 2D or 3D visualization of a raster without processing, just using a Geographic Information Systems software, lies in the fact that the first, in contrast to the other forms of visualization, allows a more real interaction with this 3D dimensioning, improving its understanding and providing visual information for complex problems.
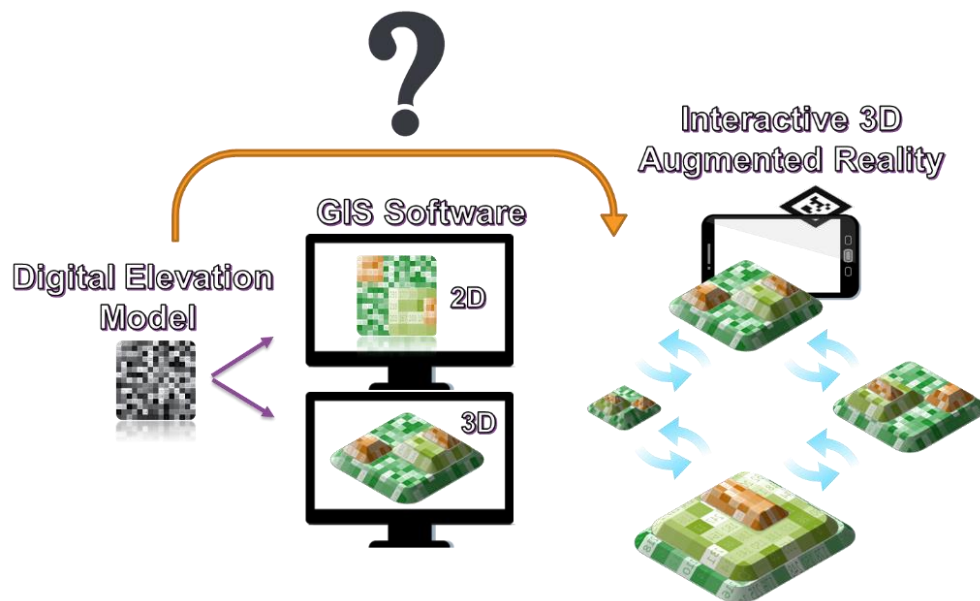

Figure 1. Visualization of raster data with AR, improving its interpretation and visualization.

Source: The author

A practical and functional procedure is proposed below, which, through the use of Open Data and easily accessible free tools, such as QGIS, Unity and Vuforia, allows the integration of formats with raster data, as is the case of Digital Elevation Models (DEM) in Augmented Reality (AR), enabling areas of study with a higher level of understanding and realism, as well as the generation of a related technological contribution.

Theoretical Framework

Augmented Reality – AR

It is unavoidable not to recognize the popularity that Augmented Reality (AR) has reached in the last decade, mainly due to the evolution of smartphones and the use of the technology in advertising. Augmented Reality provides a convincing, almost "magical" experience that captures the user's attention in a way that makes it easy to bring attention to the advertised message [1]. The spread of mobile devices and the improvement of their computing and communication capacity has generated a number of new technologies [2], allowing access to many types of sensors, such as GPS, gyroscopes, cameras, accelerometers, and others [3].

AR is a system that allows the user to visualize the real world with virtual objects superimposed on it, complementing reality and giving the user the idea that virtual and real objects coexist in the same space [4]. Such spaces can be composed of objects, audio information or text with which the user can interact [5].

On the other hand, visualization is one of the options for making more effective the use of data. The goal of visualization is to represent data in a way that makes it perceptible and, hence, capable of engaging human sensory systems [6].

Since its inception, it has been adopted that any system that has the following three characteristics is considered AR: 1. it combines the real and the virtual, 2. it is interactive in real time, and 3. it is registered in three dimensions [4]. It is known that, although this technology is not new, it has recently become more accessible to the public. We know what it consists of, what it is and its emphasis on data visualization. But What is its usefulness? how to take advantage of its potential by displaying virtual information in the real world? The number of fields that have implemented Augmented reality is huge and is increasing even more.

The history of AR research and development can be divided into four phases [1], as follows: 1. Pre-1980: Early experimentation that helps to define the AR concept and shows the types of technology required. 2. 1980 - 1990, Basic Research: Research on possible technologies such as tracking, displays, and input devices. 3. 1990 - 2007, Tools, Applications: Use of AR technologies to develop applications and explore interaction, usability and design techniques. 4. 2007 - Present, Commercial Applications: AR available in various application areas such as games, medicine, mobile devices and marketing.

There are still several elements to develop and improve, the use of the cloud to implement web services or processing services for AR [5], facilitate browsing and accuracy in indoor environments, link it with new sectors or technologies or even access to holograms, which was already quite well seen with CNN's virtual presenter [7]. Likewise, as it has been

observed, the constant evolution of computational resources, both portable and mobile, has made it possible to access AR more and more easily, and to implement it in diverse fields and sectors.

Geospatial Augmented Reality – Geo AR

It is important to understand the adjective geospatial, defined by different sources as that which belongs to or relates to the relative position of things on the surface of the earth [8]. Related to the information that identifies where particular features are located on the surface of the earth, such as oceans and mountains [9]. Pertaining or related to the analysis of geographic data from multiple sources and technologies, using statistical methods and often resulting in computer visualization of locations under study [10]. Pertaining or relative to a geographic location, especially data [11].

The common denominator of each definition is: "pertaining to or related to the location of data or information about the earth's surface", even one definition talks about computer analysis and visualization. Therefore, and based on the initial definition of AR, GeoAR can be defined as a "system that allows the user to view the real world with overlaid virtual objects, objects that contain and/or represent data or information about the earth's surface, identifying where particular features are located". Fig. 2
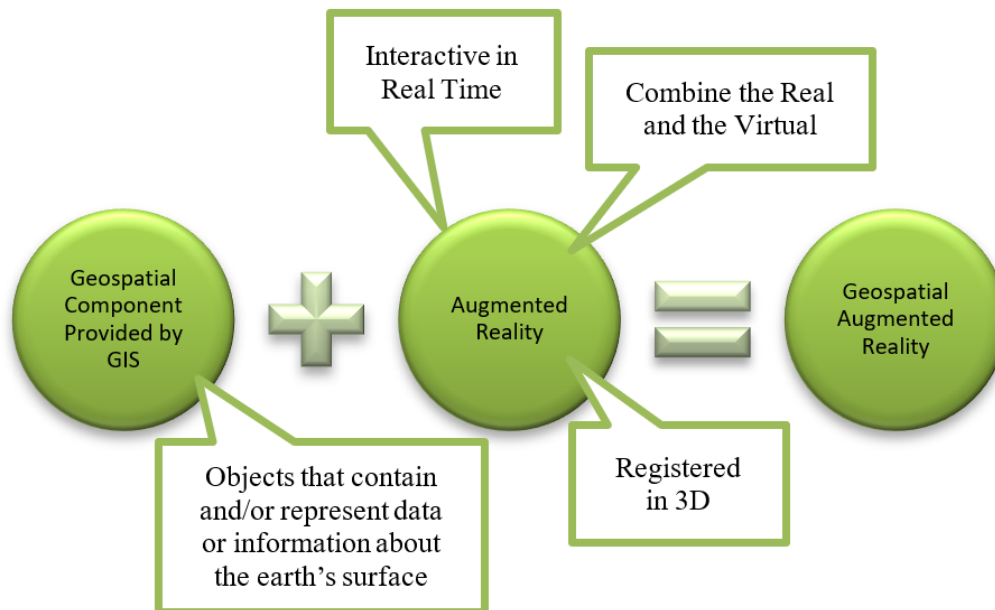
Figure 2. Decomposition of the Geo AR Term

Source: The author

Advanced interface technologies such as AR and the ways in which we interact with it, may change the way we acquire spatial knowledge, since these emerging technologies employ different mechanisms by which people visually interact and acquire knowledge [12].

A new emerging area of AR application that supports the manipulation and emphasis of data within a geographic framework is GIS. Geo AR emerged mainly thanks to the integration of AR with GIS, since it provides the geospatial component and facilitates its manipulation and visualization.

A GIS enables the analysis of potential sites for new locations, for instance, business locations, which is currently known as Geo marketing. Such analysis could involve the visualization of demographic information with geographic information, "added" in an AR environment, where the user can not only make decisions in terms of demography, but can physically visualize the site in 3D supported by Geospatial Augmented Reality. This opens up many possibilities, such as, adding basic information about surrounding buildings, viewing site location and orientation, combining traffic data or building types. Not only will the user be able to visualize all this, but businessmen, financers, employees and consultants can also evaluate and examine the sites under consideration [6].

Furthermore, a GIS represents both entities (municipal boundaries) and surfaces where elevation is a common example. A DEM is often used to refer to any digital representation of a topographic surface, they are used to determine terrain attributes such as elevation at any point, slope and aspect. That is why, nowadays, GIS applications rely mainly on DEM [20].

Methodology

The proposed methodological process should conclude in obtaining 3D objects that represent the Colombian geography and relief, obtaining a model or simulation that allows to represent different variables in Geo AR, resulting in a visual and interactive improvement compared to a 2D representation.

The stages to perform a simulation study are defined as: system definition, model formulation, data collection, model implementation, validation, experimentation, interpretation and documentation [13]. Using these stages as a reference, the methodological process implemented here consists of 4 well-defined and differentiated stages: data collection, processing, use of scripts to convert DEMs to 3D objects and their use in Geo AR environments. Fig. 3
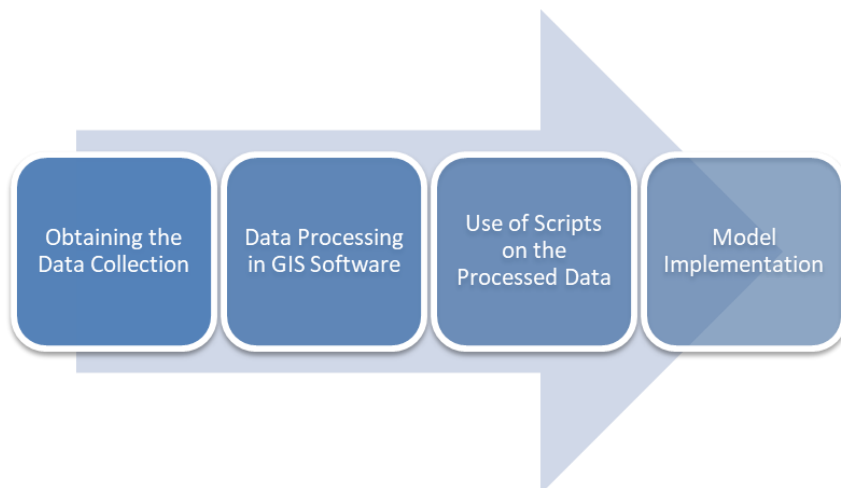
Figure 1. Methodologic Process

Source: The author

Obtaining the Data Collection

At this stage, the free GIS software QGIS is used to install the SRTM-Downloader plugin [14] Fig. 4. This is a plugin that allows downloading multiple DEMs without having to resort to individual downloads from the NASA website.
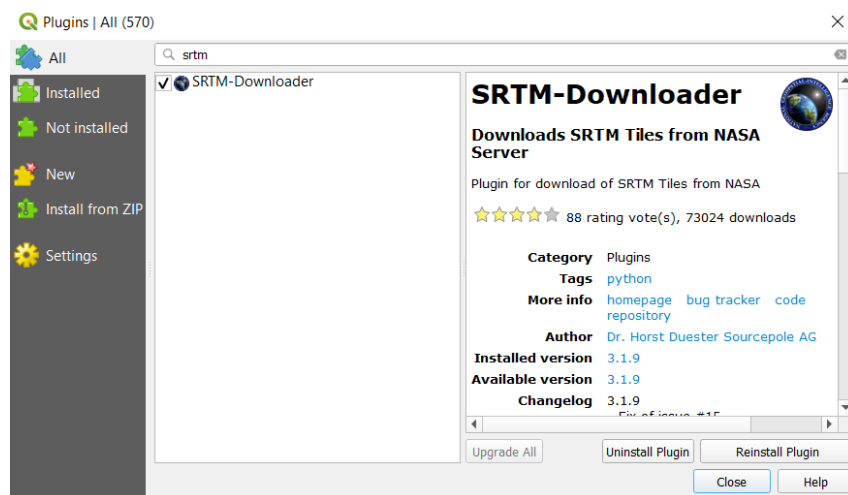

Figure 2. Plugin Installation Interface

Source: The author

Before running the plugin, it is important to define the study boundary area over which the DEMs will be automatically downloaded. In this case, a file representing the geographical extension of

Colombia was used to define this limit. In this way, the DEMs covering the extension of Colombia are obtained. Fig. 5. DEM provided by the SRTM, which have a spatial resolution of 30m.
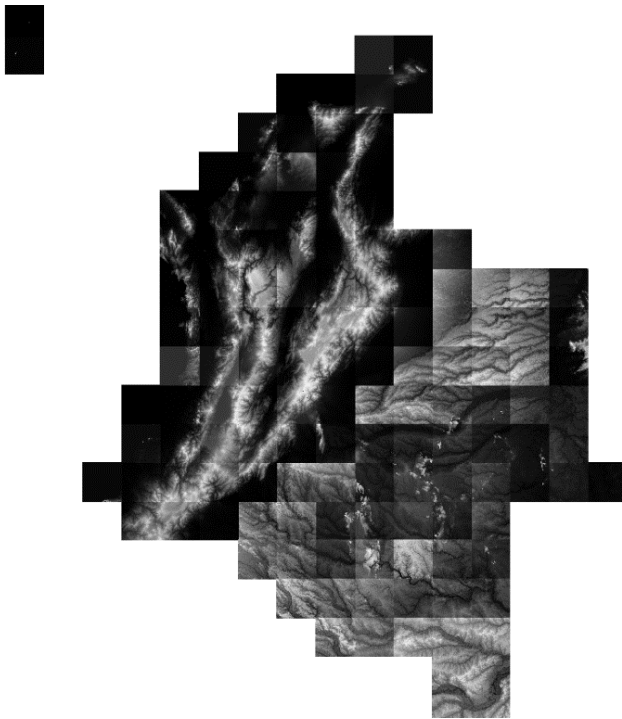

Figure 5. Digital Elevation Models covering the area of Colombia.

Source: The author

Data Processing in GIS Software

In the previous stage, 134 DEMs were obtained in HGT format, and to cover the same department it was necessary to have more than one DEM. Therefore, it was necessary to " join (MERGE geoprocessing)" and "cut (CLIP geoprocessing)" on these raster DEMs to obtain a single DEM per department (administrative division of Colombia).

The MERGE function represents a grouped or merged collection of raster images. It is used when having several raster that are wanted to be treated as a single element, for example, to calculate the same statistics, or when performing color balancing so that it does not have to be done on each image separately [15]. Once the 134 DEMs were processed in only 32 (one per department), the CLIP geoprocessing was used, clipping any raster by means of a vector mask layer [16], allowing to give the shape and silhouette of each department. Fig. 6. In this case, the objective was to obtain a DEM per department to be used as a basis for obtaining a 3D Object.
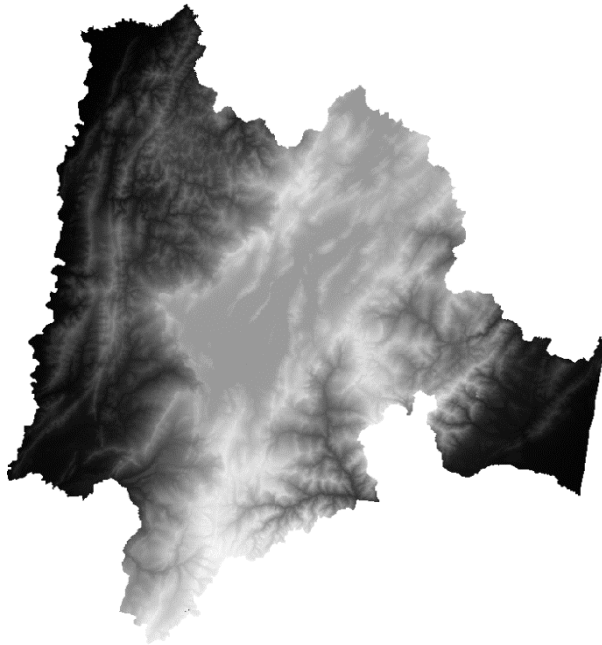
Figure 6. Cundinamarca Department, as a result of geoprocessing.

Source: The author

Use of Scripts on the Processed Data

From the previous step, 32 DEMs were obtained, one for each department in .TIF format (stores images and bitmap graphics). As the purpose of these DEMs is to show them in Augmented Reality environments, it is necessary to use a modeling and development software for this type of environments. For this purpose, we use Unity, a platform for creating interactive content.

The Unity software provides two scripts to perform the desired procedure. Fig. 7, these are: Heightmap From Texture, a plugin developed in JavaScript [17] by Eric Haines and transcribed to C# [18] by "lesmasamuray". The other script is the Terrain Obj Exporter [19] plugin developed in JavaScript by Eric Haines and transcribed to C# by Yun Kyu Choi.

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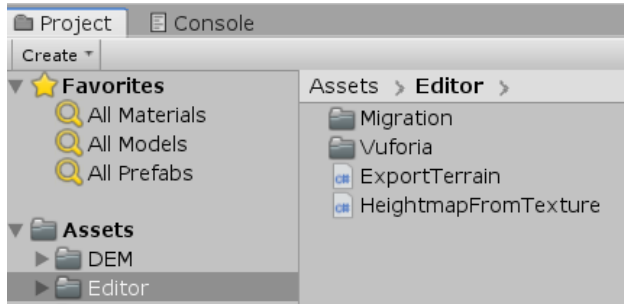
Figure 3. Implemented Plugins in Unity

Source: The author

In the Unity platform, the plugins were imported and implemented, as well as the 32 DEMs previously processed. There, a TERRAIN element was created and the Heightmap From Texture script was executed on it. Fig. 8. This script molds the TERRAIN and gives it the shape of the selected DEM with an extrusion process (vertical expansion process of a flat 2D shape to generate a 3D object).
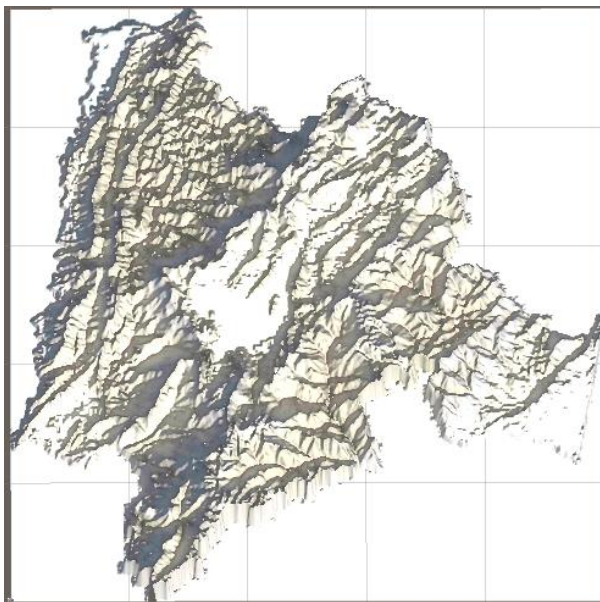

Figure 8. Result obtained with the Heightmap From Texture script

Source: The author

Model Implementation

Once a TERRAIN with the shape of the DEM is obtained, it is exported as a 3D object. For this, the second script, Terrain Obj Exporter, is used. This generates a new file with 3D format to be executed directly in Windows, used in modeling software or implemented in

Augmented Reality environments. Fig. 9. This procedure was performed with the 32 DEMs representing the departments of Colombia.
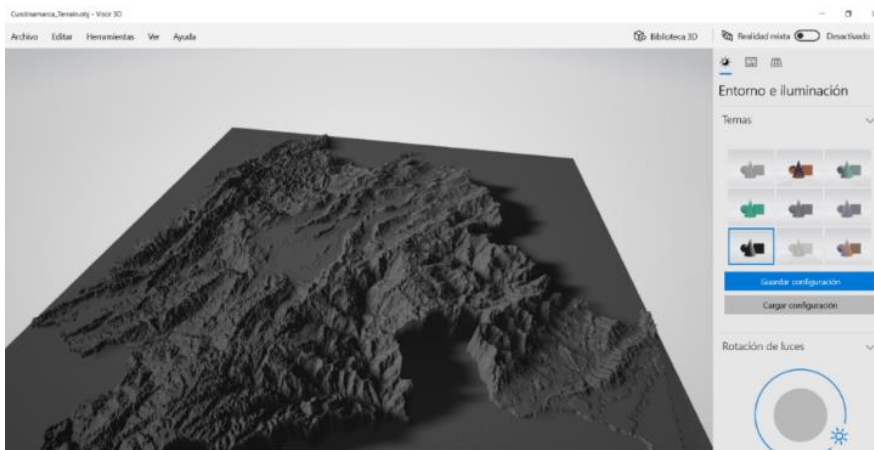

Figure 4. . Result obtained with the Terrain Obj Exporter script

Source: The author

To obtain a better representation of the DEM, a symbology is created in the GIS software and exported to Unity. Fig. 10 and Fig. 11.
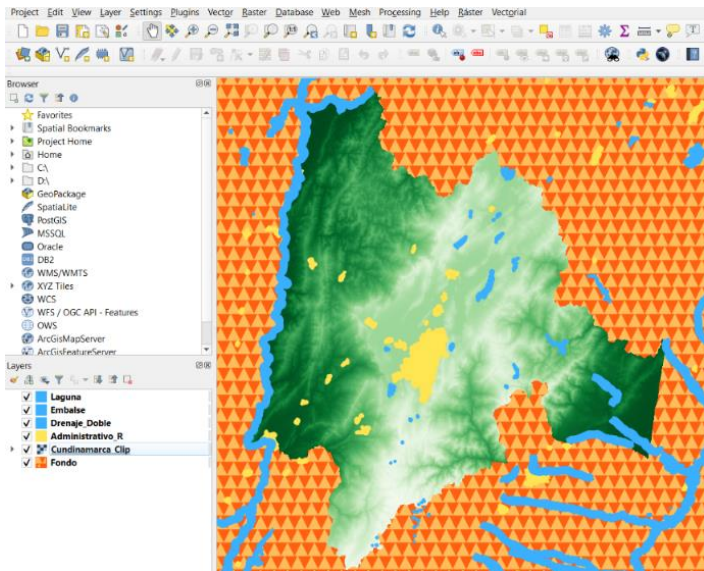

Figure 10. Symbology assigned to the DEM and additional elements in QGIS
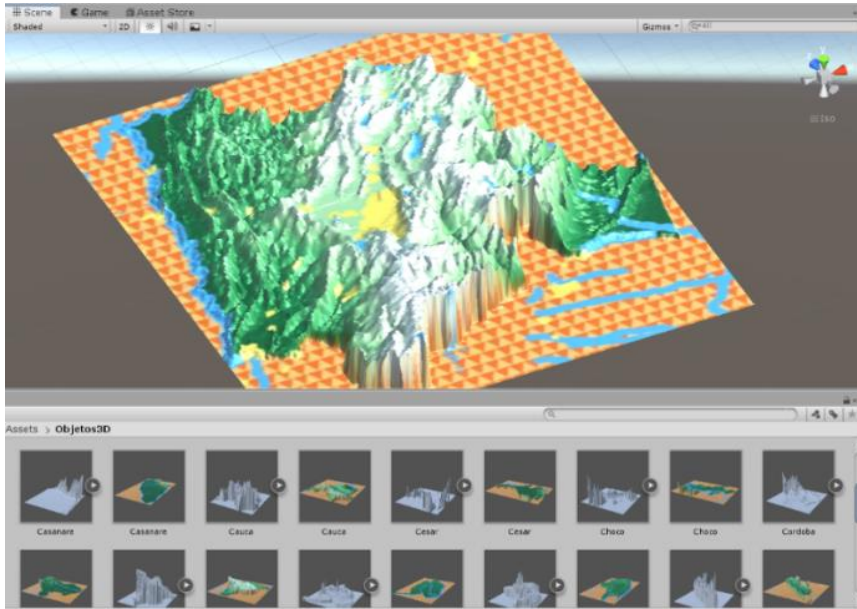
Source: The author

Figure 11. Symbology Exported and Used as Texture in the 3D Object

Source: The author

Use of 3D Objects in Geospatial Augmented Reality

Currently there are several platforms to implement Augmented Reality, however, taking into account the academic and research approach, Vuforia is used. Fig. 12 and Fig. 13. Vuforia allows the use of Augmented Reality for free, although with certain consumption limitations.
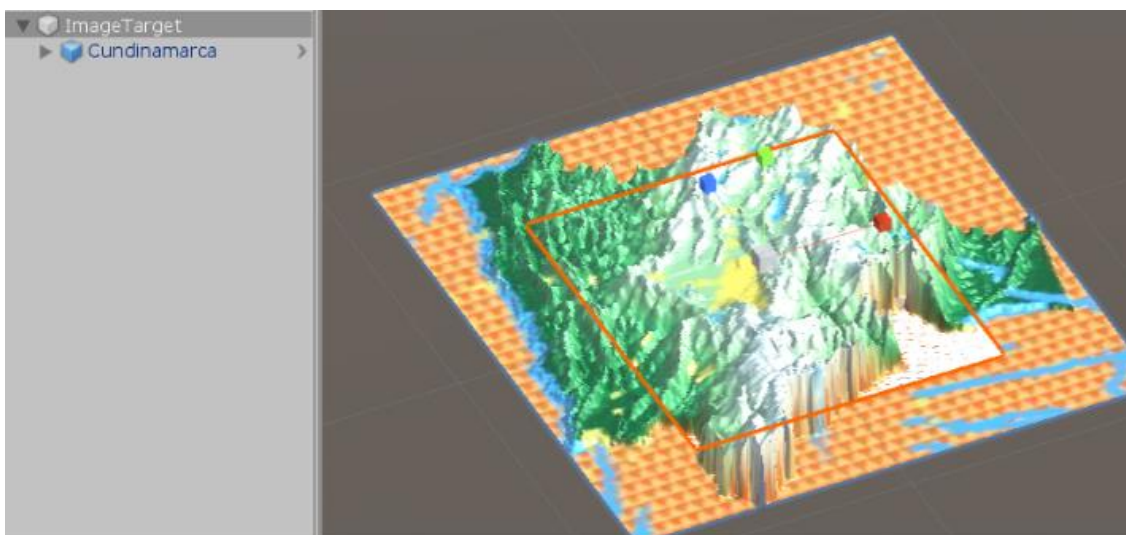

Figure 12. Using Vuforia to implement AR using the processed DEMs.

Source: The author

Figure 13. View of the DEM Processed and Converted to 3D Object in AR

Source: The author

Results

Analysis

Actually, the proposed methodology is quite flexible and allows to generate 3D products that work as an input in Augmented Reality environments. However, is it possible to use other types of data? perhaps DEM or satellite images with a different format or higher resolution? is it possible to add user interaction? Beyond suggesting or implementing a methodology, the idea is that this procedure opens the doors to a wide range of possibilities where DEMs can be linked in Augmented Reality environments with different uses and purposes, whether education, research, or analysis in the field of what is called Geo AR.

Testing

Augmented Reality Interaction

Since the proposed methodology generates a 3D DEM Object with a personalized texture, it opens the possibility of adding interaction with that Object. Elements that display messages when selecting or clicking on them, animations, sounds or multimedia elements. Generating a wide range of possibilities in educational topics.

For this case, slight tests were performed by adding virtual "buttons" on top of the DEM so that each one would display different messages depending on the user's interaction. Two spheres were added at the ends of the Tolima department with different colors, so when the user selects them, they will display different messages. Fig. 14.
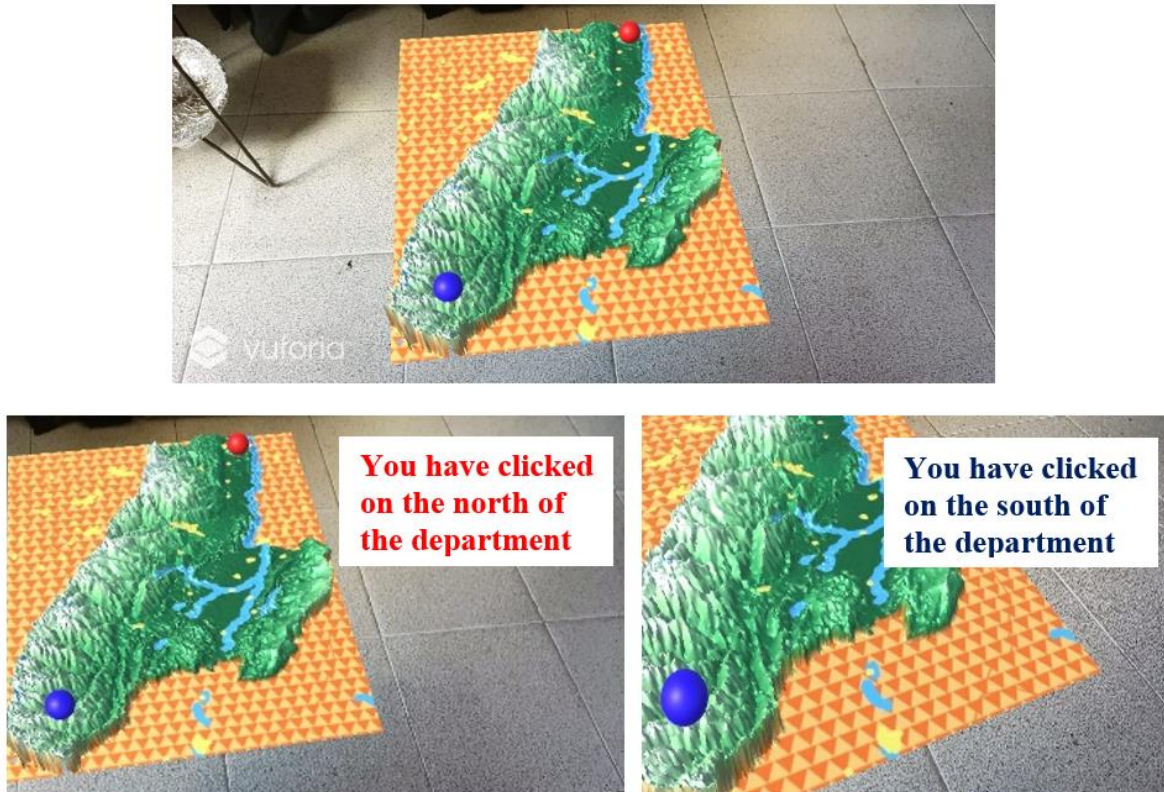

Figure 14. Interaction with the DEM in AR, Department of Tolima.

Source: The author

This demonstrates the easy integration of the 3D object obtained and the possibilities that open up with the development of applications where the main input is Geo AR elements. Fig 15.
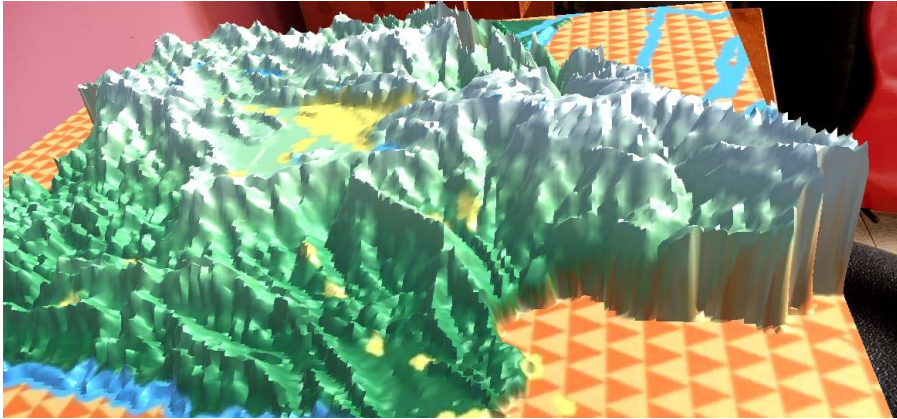
Figure 15. It is Possible to Zoom In, Zoom Out or Move Around the Processed DEM.

Source: The author

Conclusions

The proposed methodology allows converting DEM - Digital Elevation Models, with or without GIS software processing, to 3D objects. Add to it symbology derived from satellite images and interactive elements such as buttons or pop-up messages. Therefore, it is possible to visualize raster-like elements without using GIS software, generate an immersive visualization and use these models as input in other applications.

Having a 3D object that models elevation will facilitate the implementation of Geo AR environments and will have a positive impact on the ability to interpret relief. It can also provide base models for environmental studies, since it has a real representation of the relief and territory on a national scale, and will allow exploratory analysis of satellite images, among other possible applications.

Identifying, knowing and making use of software tools with greater accessibility, allow the implementation of Geo AR in different sectors, as well as the customization of these products and even the improvement of current workflows. The proposed methodology is flexible and allows the adaptation of different data and information sources.

It should be noted that the resolution of the final product is somehow limited, because the algorithms used make an approximation to the DEM and the texture has a single scale of visualization, unlike the visualization of satellite images in a GIS software in which each scale has its own rendering.

The way ahead would be to improve the implemented scripts, to optimize the resolution of the 3D object, to generate a better correspondence using coordinates between the DEM and the texture or even to develop new Geo AR applications where its applicability is enhanced.

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