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# Augmented Reality Applied To A Combination Of Spectral Bands And Digital Terrain Models

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## Abstract

*This article shows a different way of visualizing geospatial information through the interaction between Digital Terrain Models (DTM), satellite images and Augmented Reality (AR). In this case, using Unity, a platform for the creation of interactive content in real time, the DTMs together with the satellite images are converted into a 3D object that can be displayed in Augmented Reality. This procedure requires simple raster geoprocessing and a combination of spectral bands, which allow a better visualization and identification of the study area (municipality of El Carmen de Chucurí). At the end with the superposition of these integrated elements in augmented reality environments, we obtain a visualization of the area with 3D dimensioning. This link will have a positive impact on the interpretation of the relief with an interactive and immersive experience with models of natural phenomena, representing these real phenomena in a three-dimensional environment. Currently, to generate this type of procedure, proprietary tools and software must be available for this purpose, so the methodology implemented to go from a Digital Model of the Territory to a 3D object opens the possibility for many more researchers and even Users unrelated to programming or Geographic Information [1]Systems are interested in Geospatial Augmented Reality and can make use of a wide variety of resources and inputs to develop their own projects. Likewise, this methodology opens the doors to glimpse the possibility of implementing this methodology in other areas and integrating Geospatial Augmented Reality in other sectors and fields of research. Finally, this research and technical production provides the academic community and other interested parties with a model of the methodological process to obtain 3D Objects that represent geography and relief, specifically applied to the Colombian territory.*

***Keywords**: Augmented Reality, Digital Terrain Models, satellite images, DTM, AR.*

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## 1. Introduction

A Digital Terrain Model (DTM) is a continuous surface that, in addition to height values as a grid (known as a digital elevation model, DEM), also consists of other elements that describe the topographic surface, such as slope [1].

The term Digital Elevation Model (DEM) sometimes is used as a synonym for DTM, or as a general term to describe it. This term is not limited only to the visible terrain surface of the Earth, it is also applied in bathymetry (digital bathymetry models describing seafloor geometry), polar geodesy (digital bedrock models to describe the rock beneath ice sheets), and planetary sciences (digital elevation models of planetary surfaces), among many other areas of application [2].

The quality of these DTMs has increased significantly and especially due to three important factors [3]: first, the introduction and development of new methods for data acquisition, especially artificial satellites, and unmanned aerial vehicles (drones). The second factor is the increasing availability of additional data sources that are useful for the conformation of these models, such as aerial photographs and contour lines, sources that provide valuable information for the integrated production of DTMs. Thirdly, applications that use DTMs are now part of our everyday life, such as Google Earth (http://earth.google.com), Microsoft Virtual Earth (https://www.microsoft.com/en-us/maps), NASA World Wind (http://worldwind.arc.nasa.gov).

Consequently, the advancement in both Information Technology and computing power and graphical visualization capabilities have led to the rapid growth of the use of DTMs in fields such as, road engineering, landscaping, land surveying and mapping, mapping for military purposes, remote sensing, or Geographic Information Systems (GIS) [4]. These applications are also extended to some emerging technologies such as Augmented Reality (AR)

Azuma [5] defined AR as "3D virtual objects integrated into a real 3D environment in real time". This is a reflection of early research on the use of AR as a primarily graphical display. Currently, this definition is considered very limited. Nowadays the definition of AR has been broadened to include the fusion of any digital information with the configuration of the physical world, that is, being able to augment the immediate environment with electronic data or information in a variety of formats, including graphic-visual media, text, audio, video, and haptic overlays. According to FitzGerald, et al. [6]and David et al. [7], haptic systems allow touch, feel, and interact with an object that is in a virtual environment or in a remote type of environment.

This paper shows in a practical way a new approach to visualize specifically geospatial information, related to the relative position of things on the surface of the earth [8], data of our real world by implementing Augmented Reality.

The impact of AR technology shapes how digital terrain data (DTM), such as shape representation, slopes, mountains or elevations, are represented and interpreted. This overlay of DTM over augmented reality environments, displayed in a graphical user interface may be the future of how we analyze digital data; much like how 3D modeling improves the way flat maps are interpreted, with only 2D representations.

## 2. Methodology

The proposed methodological process will result in a 3D product, an object representing a continuous surface of elements describing the topographic surface, a simulated model of the shape, which allows representing different geospatial elements with a visual improvement and interaction regarding a 2D representation

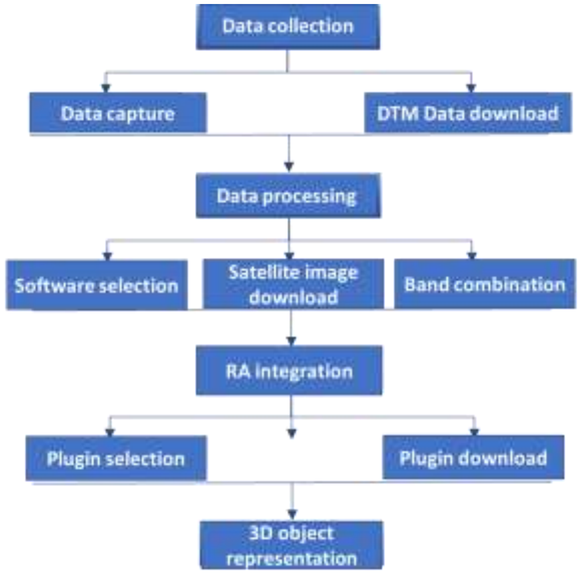



Figure 1. Methodologic process

Source: the author

## 2.1 Data Collection

As can be expected, the procedure for obtaining and downloading the DTM will be based on the selection of a territorial area. In this case, we will use ALOS PALSAR (https://search.asf.alaska.edu/), one of the many freely available mapping resources (from the Japan Aerospace Exploration Agency (JAXA). This DTM resource has a resolution of 12.5 meters resampled globally and in a multitemporal way.

Likewise, instead of adding a customized symbology to the DTM, combinations of spectral bands of satellite images will be used in order to perform a visual and exploratory analysis in Augmented Reality by combining these with the DTM and obtaining a final 3D product.

The satellite image of the area of interest was provided by the Worldview 3 satellite, which has a spatial resolution of 4m in SWR (Short Wave Infrared), 1.2m in multispectral and 50 cm in panchromatic. The area corresponds to the Colombian municipality of El Carmen de Chucurí, located in the department of Santander, 178 km from the departmental capital, Bucaramanga.

Figure 2. Visualization of the Municipio El Carmen de Chucurí in the GIS software free QGIS. Source: Authors

The different band combinations of this satellite image provide information to analyze different types of coverages and spatial phenomena.

### 2.2 Data Processing

A satellite image represents the different objects on the surface of our planet in real time. Satellite imaging is the scanning of the Earth by satellite to obtain information about it. Currently, there are many satellites and for different purposes that scan the Earth, using different types of sensors to collect electromagnetic radiation (in different windows or spectra) reflected by different objects from the Earth [9]; in other words, satellites extract information from the energy that interacts with the Earth's surface [10].

All colors in a satellite image are made up of a combination of red, green and blue or RGB for short. The satellite sensors that capture the images record grayscale images; each pixel (the smallest "dot" that makes up a satellite image and basically determines how detailed it is) is assigned a value in red, green or blue, which show the brightness of each of these colors (brightness on a scale of 0 to 255, where black is 0, white is 255). Shades of gray are in the middle). When we combine the three values, we get an image with new information [11].

Therefore, a frequently used method for extracting information from satellite imagery is to match classes of information to spectral ranges or a combination of spectral ranges, that is, to organize them in such a way as to extract new and unique information [12].

Some of the combinations that can be made with these multispectral (multiple spectra) images are: combination 863 (NIR2 - Red Edge - Green): Enhanced Infrared; combination 841 (NIR2 - Yellow - Coastal Blue): Vegetation Analysis; combination 321 (Green - Blue - Coastal Blue): Bathymetry; or combination 753 (NIR1- Red - Green): False Color Standard.

Within the proposed methodology, the following relationship is established with the different combinations of bands as follows:

1. The ALOS PALSAR DTM of 12m spatial resolution was downloaded. In this case, it is not necessary any type of treatment to the DTM and the algorithms be applied directly; obtaining a 3D object that represents the relief of the study area in grayscale.
2. Combination of bands are made with a GIS software tool to obtain the different tonalities. These are exported so that they can be used as textures on the 3D object.
3. The different layers of information, MTD and Image Combinations are overlapped with the Augmented Reality implementation in Unity and Vuforia.
4. The different 3D objects are visualized, applying different combinations of the satellite image.

### 2.3 Augmented Reality Environment Integration

Once the DTM is obtained, the information is stored in a .TIFF format (Tagged Image File Format, a digital file format for storing bitmap images). The purpose of the DTM is to be able to superimpose it in an Augmented Reality environment, it is necessary to implement a modeling and development software for AR environments. In this case, we will use Unity, a platform for creating interactive content in real time.

This software tool provides two scripts (see Figure 3) that allow performing the expected procedure. On one side, we have HeightmapFromTexture, plugin developed in JavaScript [13] by Eric Haines and transcribed to C# [14] by "lesmasamuray". The other script is the TerrainObjExporter [15] plugin developed in JavaScript by Eric Haines and transcribed to C# by Yun Kyu Choi.

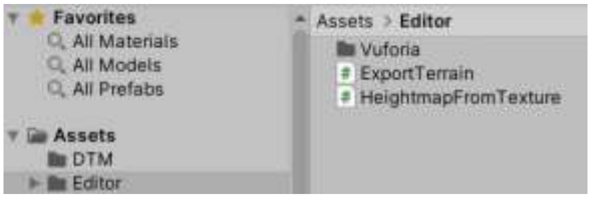



Figure 3. Implemented plugins in Unity
Source: The Authors

In the Unity platform, the plugins were imported and implemented, just like a DTM. There, a TERRAIN element is created and the HeightmapFromTexture script is executed on it (see figure 4). This script molds the Terrain and gives it the shape of the selected DTM with an extrusion process (vertical expansion process of a flat 2D shape to generate a 3D object).

Figure 4. Obtained results with script HeightmapFromTexture
Source: The Authors

Once the Terrain with the DTM shape is obtained, it is exported as a 3D object, implementing the second script, TerrainObjExporter. This generates a new 3D format file to be executed directly in Windows, used in modeling software or implemented in Augmented Reality environments (see figure 4).

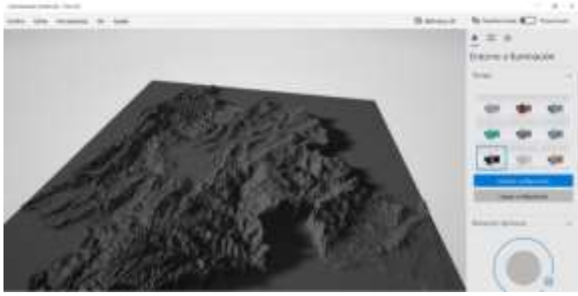


Figure 5. Obtained results with script TerrainObjExporter
Source: The Authors

### 2.4 3D Data Representation

Nowadays, there are a variety of platforms for Augmented Reality environments, however, and taking into account the academic-research focus of this process, we use the Vuforia tool (see Figure 6 and Figure 7). Vuforia allows using Augmented Reality for free, visualizing 3D objects, although with certain consumption limitations.


Figure 6. Use of Vuforia to implement AR using processed DEM
Source: The Authors

Figure 7. View of the processed DEM and then converted into a 3D object in AR
Source: The Authors

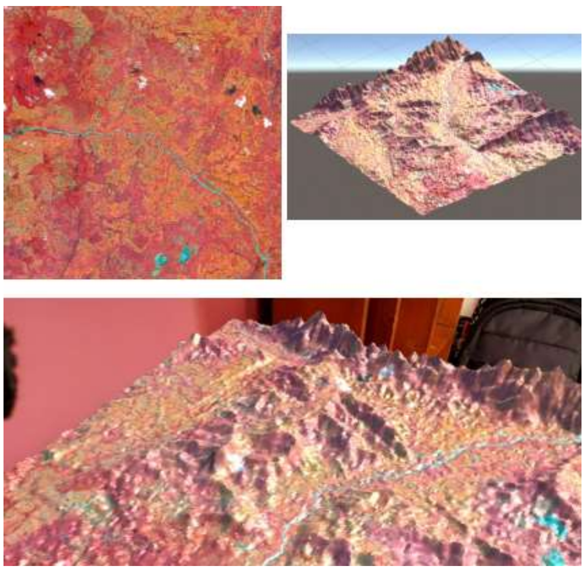
## 3. Results and Analysis

In the end, this procedure is shown as a contribution to the analysis and visual interpretation of satellite images supported by a DTM and views in Augmented Reality environments, environments that do not require GIS software and facilitate interaction within the real world.

The 3D virtual relief represents a DTM, which, by means of buttons, the user can change its tonalities to visualize different combinations of satellite image bands. The user can select any of the buttons on the right side to have such interaction.

The obtained 3D object and the different textures corresponding to the band combinations are displayed below.

Some of these band compositions were used to test the proposed methodology, as follows:



Result 3D object seen in AR with Image Combination 841 as proof of the process.
Source: The Authors

Result 3D object seen in AR with Image Combination 863 as proof of the process.
Source: The Authors

The application offers a visualization and interaction in 3D of Digital Models of the territory that represents, in this case, the area of El Carmen del Chucurí. Once the user enters the application, he must focus a preset image with the camera of his mobile device. In this way, a virtual element will be displayed on the real image that represents the relief in 3D together with the points of interest that the user can select to display the information related to said point in a pop-up window. The zoom and navigation of each DEM can be done by the user when moving the mobile device

Figure 8. View of the processed DEM and then converted into a 3D object in AR with the 753 combination, fake standard color. Band Combination: Each button describes a combination of satellite imagery bands (multispectral and SWIR). Click on the buttons to view it.
Source: The Authors

The Geospatial Augmented Reality application offers a 3D visualization and interaction of a Digital Elevation Model. Using buttons, it changes its color to represent different combinations of satellite image bands without the need for Geographic Information Systems software. Once the user enters the application, he must focus a preset image with the camera of his mobile device. In this way, a virtual element that represents the 3D relief will be displayed on the real image together with combinations of satellite image bands that the user can change by pressing each of the buttons.

Figure 9. DEM symbology change based on band combinations. Band Combination: Each button describes a combination of satellite imagery bands (multispectral and SWIR). Click on the buttons to view it.
Source: The Authors

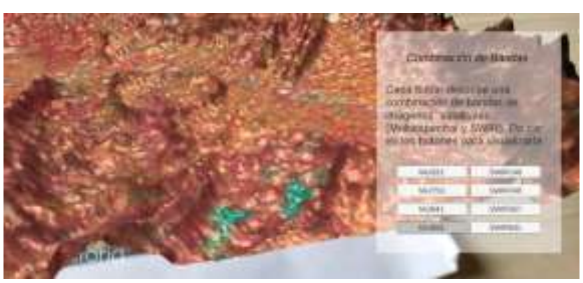


Figure 10. View of the processed DEM and then converted into a 3D object in AR, with the combination 861con la combination improved infrared. Band Combination: Each button describes a combination of satellite imagery bands (multispectral and SWIR). Click on the buttons to view it.
Source: The Authors

Figure 11. View of the processed DEM and then converted into a 3D object in AR, with the combination 248. Band Combination: Each button describes a combination of satellite imagery bands (multispectral and SWIR). Click on the buttons to view it.
Source: The Authors

## 4. Conclusions

The proposed methodology allows converting Digital Terrain Models (DTM), with or without GIS software processing, to 3D objects and add to them simbology 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 AR environments with geospatial information, positively affecting the representation and interpretation of relief. It can also provide base models for other studies and areas, since by generating a real representation of the relief and territory; it will allow exploratory analysis of satellite images in different environments.

The scripts used in this work use the concept of extrusion to "stretch" the terrain according to the value of each pixel independently, this generates 3D models that are not smooth or with a pixelated display in some cases. Improving the scripts could optimize the resolution of the 3D Object or render it in a smoother way taking into account the relationship between the pixel values.

These 3D objects used in educational applications can represent and visualize different variables and information in an interactive and immersive way, favorably affecting the teaching-learning processes. The active search for new information with a different perspective generates a new way of learning, an immersive learning.

It should be noted that the resolution of the final product is somewhat limited because the algorithms used make an approximation to the DEM and the texture has a single display scale, unlike the display of satellite images in GIS software in which each scale has its own rendering. This limitation may be a starting point for future research.

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