USING DRONE TO DELIVER THE DIGITAL TWIN OF ILHA DOS ARVOREDOS

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Abstract. *The main objective of this article is to present the progress of a GCSP project throughout the year, focusing on the theme of a topographic survey using drones, point clouds and digital terrain model (MDT). This report will address the case study of Ilha dos Arvoredos, an island located in Guarujá, SP, and the project aim is to conduct a topographic survey of the island using drones that are capable of capturing orthophotos, which, after processing, will become a digital terrain model. The goal of creating the digital terrain model is to eventually link it with the Digital Twin and, from there, model the island's infrastructure.*

Keywords: *Internet of Things, Sustainability, GCSP, Drone Aerial Photogrammetry, Point Cloud, Topography*

Introduction

According to Ribeiro *et al.* (2020), in the year of 1950, mechanical engineer and environmentalist Fernando Eduardo Lee also founded the "Instituição Fernando Lee", which is responsible for running Ilha dos Arvoredos since then. His vision was to create an open-air laboratory dedicated to the development of scientific research. Located in the coast of São Paulo, near Baia de Pernambuco in Guarujá, the island (Figure 1 (a)), approximately 36,000 square meters in size, is the setting for significant sustainable architectural projects, providing access to history, science, culture, and leisure. This unique combination of elements, coupled with the paradisiacal beauty of Ilha dos Arvoredos, makes the place truly special.

Figure 1 – (a) Photograph of Ilha dos Arvoredos (Portal Guarujá, 2023); (b) Model of the topography of the Island using Revit (Souza, 2021)

(a) (b)

Over the years, the island has suffered degradation caused by weather and the natural conditions of the environment. For this purpose, there was a need to make improvements to the Island, with the aim of preserving the history and the memory of Fernando Lee. As a result, students from the “Instituto Mauá de Tecnologia”, alongside Fernando Lee’s Institute, INMAR, and UNAERP, initiated a project to revitalize the space, which includes updating the island's projects and implementing other necessary improvements.

Nowadays, there is only an old and outdated model of the topography of Ilha dos Arvoredos, created years ago with limited instruments. There was an attempt to model the island's topography, as shown in Figure 1(b) above, but it is not possible to work with this model due to the lack of details and the inaccuracy of the site's topography.

Based on this, this project was developed with the main objective of conducting a topographic survey of the island, using drones that, when flying over the region, will capture orthophotos of its entire extent. Therefore, it is necessary to model the topography of the island to create a digital replica of the physical space. Subsequently, these images are processed, filtered, and transformed into a point cloud, where each point represents an X, Y, Z coordinate of the terrain model. Upon obtaining the point cloud, it is possible to convert it into a digital terrain model using appropriate software. Then, this digital terrain model can be imported into the island's modeling software. It is worth noting that this study is an integral part of a larger project, in which students from the Mauá Institute of Technology will develop a digital twin of Ilha dos Arvoredos.

Taking this into consideration, this study aims to contribute to the creation of the Digital Twin of the island by providing the island's topographic model.

Objectives

The primary objective of this study is to contribute to the development of a Digital Twin of Ilha dos Arvoredos, an initiative led by students from the Mauá Institute of Technology. To achieve this goal, a topographic survey will be conducted using drones to capture orthophotos. Subsequently, these images will be processed and transformed into point cloud data, giving rise to a digital terrain model. The integration of this model with the Digital Twin will also enable precise georeferencing of the buildings through BIM technology. This approach aims, in the future, to fully model the island's infrastructure, creating a virtual replica capable of monitoring building structures, anticipating natural phenomena such as rain, waves, and winds, and estimating related timelines.

Development

a) Methodology

It is known that the various methods for conducting topographic surveys are constantly evolving, and among the variety of equipment and techniques available, it is the responsibility of the engineer in charge of the project to decide which method is most suitable for each type of venture, by considering factors such as economic efficiency, quality of results, and desired productivity.

According to Silva (2023), aiming to encompass the historical context, it is known that humanity is increasingly seeking faster and more efficient methods to perform its services. With technological advancements, new options have emerged for conducting planimetric and altimetric surveys more quickly and with some advantages that stand out when compared to traditional methods. The use of Unmanned Aerial Vehicles (UAVs) is an example. Equipped with topographic sensors, these devices can fly over the study area and capture high-resolution terrain images, called orthophotos, obtaining precise information about the coordinates and altitudes of the measured points (Nery et al., 2021).

According to Fortunato (2018), using drones to perform altimetric measurements (Figure 2) in a specific area makes the entire process much faster and more dynamic. This is because the captured images are georeferenced, which simplifies the measurement in connecting points. Therefore, this optimization of work results in faster delivery of results with improved quality, generating data with more detail and greater precision, in addition to increasing productivity.

Figure 2 – Topographic Surveys capturing orthophotos using Drone. One way to capture topographic data using drone (Mosaic, 2021)

Recently, the use of drones for mapping areas has become a technology that is increasingly being explored. This approach was chosen for conducting the topographic survey across the entire extent of Ilha dos Arvoredos. Therefore, the procedure essentially involves the drone flying over the entire expanse of Ilha dos Arvoredos, capturing orthophotos, which are subsequently processed for data analysis.

> “The significant advantage of Aerophotogrammetry, when compared to conventional topographic methods, includes a high density of points, a 3D point cloud, the generation of DEM – Digital Elevation Model, DTM – Digital Terrain Model, and high-precision volumetric calculations. Additionally, there is a differential in the presentation of the final product, as the result of a topographic survey is a vector drawing containing points, lines, and polygons, while the final product generated by Aerophotogrammetry is a high-resolution image and a 3D point cloud. In the latter, features and determined points are directly

> visualized in the image. Furthermore, financial advantages and timesaving should be considered, as this type of work allows for mapping a large area in a short period with a smaller team compared to a topographic team.” (Rodrigues & Gallardo, 2018)

According to Silva (2023), this data processing allows for the identification of altimetric variations between points, resulting in a point cloud that forms a three-dimensional representation of the surface, enabling the visualization of the area's topography through virtual reality.

b) Regularization

Regarding the use of the drone, all locations have clear rules that regulate drone flights. To carry out the overflight on the island, it is first necessary to hire a pilot who can operate the aircraft, meaning they have the expertise to control the drone and possess properly regulated equipment.

The agencies involved in the process of aircraft regularization are ANATEL (National Telecommunications Agency in Brazil), which is responsible for the homologation of the aircraft and the remote control. Additionally, it is essential to register the aircraft on the website of the National Civil Aviation Agency (ANAC). This procedure is mandatory for both recreational and professional use of aircrafts. After registering with ANAC, the pilot receives a certificate containing the characteristics of the aircraft, which must be always kept in possession.

Before starting the survey, the pilot needs to organize and register a flight plan. For this purpose, some companies have developed software capable of assisting in this process. Furthermore, to organize the flight plan, it is necessary to define the survey date and time, and provide information about the area and the altitude.

c) Drone Aerial Photogrammetry.

Performing area mapping using point clouds and drones is a modern and efficient method for conducting a rapid and accurate survey of large land areas. This process involves the use of specialized drones, such as those equipped with LiDAR (Light Detection and Ranging) technology, meaning unmanned vehicles with sensors and cameras that capture high-resolution aerial images of the area of interest.

The altimetric data generated by Drone Aerial Photogrammetry is similar to that generated by conventional topography, with the distinction that it creates a high-density 3D point cloud, allowing for a better delineation of the Earth's surface. The significant advantage of this working methodology lies in terms of operational safety when compared to the results derived from conventional topography. In this case, it is not necessary for the professionals on the team to be constantly moving in hazardous areas (Rodrigues & Gallardo, 2018).

Orthomosaic is a technique/method that involves creating a single image composed of multiple digital images of a specific area. After being processed and combined using software, these individual images are transformed into a single composite photograph. Using orthomosaics, it is possible to perform various tasks, such as creating detailed road maps or, in the case of the project in question, a detailed map of Ilha dos Arvoredos.

Additionally, photogrammetry enables the determination of geometric properties of objects and their reconstruction in 2D or 3D through the measurement and interpretation of photographic images. Terrestrial photogrammetry pertains to measurements of a fixed location on the Earth's surface, while aerial photogrammetry refers to measurements using unmanned vehicles (drones) (Kolecka, 2011).

d) Point Cloud

According to MELLO e BORTOLINI (2022), digital photogrammetry is a technique that allows the extraction of three-dimensional images of terrains, in addition to enabling the recording of data not captured through more traditional methods, such as colors, textures, and geometric variations. Through the processing of these digital photogrammetry's, using software like Autodesk´s Recap Photo, it is possible to transform them into a point cloud by automatically correlating homologous pixels in different photographs. This allows the verification of information in the generated point cloud, contributing to the creation of the 3D geometric model of the terrain.

The images obtained from UAVs are processed in dedicated computer programs, with the basic functions of digital photogrammetry to perform operations like photo triangulation and automatic measurement of points using advanced and efficient correlation and combination techniques.

> A point cloud is simply a set of data points in space. The point cloud of a scene is the set of 3D points around the surfaces of the objects in the scene. In its simplest form, 3D point cloud data are represented by the XYZ coordinates of the points, or these may include additional features such as surface normals and RGB values. Point cloud data represent a very convenient format for representing the 3D world. Point clouds are commonly used as a data format in several disciplines such as geomatics/surveying (mobile mapping); architecture, engineering, and construction (AEC); and Building Information Modelling (BIM). Point clouds have a range of applications in different areas such as robotics, autonomous driving, augmented and virtual reality, manufacturing and building rendering, etc. (Bello et al., 2020, p. 2)

The use of the BIM system and its information exchange, given that surfaces generated in Recap can be transferred to modeling software such as Revit and AutoCAD Civil 3D, both produced by Autodesk, enables the survey of existing buildings or constructions, as well as vacant land slated for new constructions. There is also the possibility of analyzing earth movements (cut and fill) and surface runoff (Almeida Neto and Ramos, 2018).

Mapping land using point clouds and drones offers many advantages compared to traditional land surveying methods. First, it allows for the rapid coverage of large areas, saving time and resources. Second, it provides high-resolution data with accuracy down to a few centimeters, which is extremely valuable for various applications. Finally, this method can be conducted without the need for physical access to the site, making it particularly useful in remote or hard-to-reach areas.

e) Processing using Recap to convert to Revit

In her article on As-Is BIM Modeling of a Commercial Project through Point Cloud Data Obtained via Laser Scanner Survey, (Silva, 2023) explained the data processing stage after the topographic survey. Therefore, right after collecting the aerial photographs obtained from the drone topographic survey, the RISCAN PRO software is used to process and filter the point cloud, which is then transformed into a .rcp file format using the RECAP software. Subsequently, the file is converted into the Revit software, and a three-dimensional model of Ilha dos Arvoredos in BIM is created.

Results and Discussions

The utilization of drones for capturing orthophotos of the entire terrain has demonstrated its efficiency as a superior approach in comparison to other topographic survey methods. This is attributed to the agility and speed with which altimetric data can be obtained.

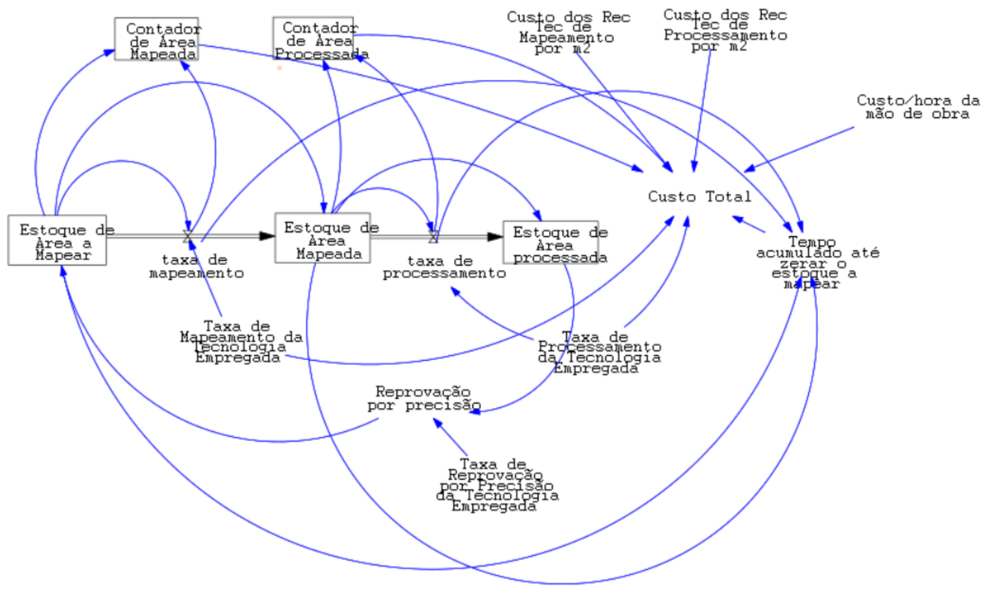
As noted by Rodrigues and Gallardo (2018), the data derived from topographic surveys utilizing drone-captured aero photographs exhibited high quality and precision. This is due to the substantial level of detail provided by the voluminous amount of data collected by this equipment. Furthermore, this method offers substantial advantages over traditional topographic survey methods, eliminating the necessity for professionals to expose themselves to risky areas.

The operational efficiency of data acquisition through drones is noteworthy not only for its speed in covering large areas but also for the cost savings compared to conventional methods. The ability to map extensive areas of the island in a short period with a reduced team is a significant advantage in terms of both time and cost.

In addition to the drone-based approach, an extracurricular class conducted in the first semester of 2023 focused on dynamic systems analysis using VenSim (Figure 3). In this class, a study was undertaken to develop a dynamic system that aimed to compare three distinct topographic survey methods available on the market: GPS, drone flyovers, and the local station method.

The proposed study describes a system that begins with the delineation of an area to be mapped, using a mapping rate related to the variation of the area to be mapped over time. The resulting inventory represents the already mapped area, connected to a counter that relates square meters to the total cost of the operation. Subsequently, point geoprocessing is performed with a rate related to the variation of the mapped area, resulting in an inventory of processed area. Variables such as mapping and processing rates of the employed technology are crucial, as well as the error percentage represented by the precision rejection box.

Figure 3 – Dynamic Analyse of different methods of topographic surveys



The final cost is calculated considering the cost per square meter for the survey, technological resources for mapping and processing, labor, and time. The system allows simulating different processes with various technologies, facilitating the integrated analysis of the variables involved.

At the end of the study, it was possible to conclude that each topographic survey method has advantages and disadvantages, making it crucial to choose the most suitable technology for different situations. For example, the use of drones may not be advisable in densely wooded areas due to the difficulty of object identification. Meanwhile, GPS, although fast and user-friendly, can be expensive and less precise, making it inadvisable for areas with significant signal interference.

Thus, the comparative analysis among total stations, drones, and GPS emphasizes the importance of considering their characteristics. Total stations provide high precision, ideal for detailed work. Drones are efficient for large areas but may have limitations in complex environments. GPS is fast but comes with a high cost and is susceptible to interference. Choosing the appropriate technology for civil engineering topographic surveys impacts efficiency, precision, and cost, proving essential for the development of this field.

a) Studies on the use of drones for Engineering solutions in Brazil

Over the years, there has been a growing interest in the use of drones in the civil context. This is due to the ease of operation of these aircrafts and their ability to fly in hard-to-reach locations. The application of drones spans a wide range of uses, playing a significant role in civil engineering. More recently, there is exploration into using drones as an alternative to manual labor in the construction industry. The purpose is to prevent accidents and reduce costs associated with constructions.

Among the national research on the subject is the use of drones for inspecting pathological manifestations on building facades. (Ballesteros & Lordsleem Junior, 2021).

Evaluation of the use of UAVs for 3D mapping of buildings and construction sites.

> In aiding construction management activities, it improves the layout and logistics of the construction site, monitors and tracks the progress of construction activities, and also allows visualization in hard-to-reach locations, assisting in inspection processes and, consequently, reducing risks to human life. This was observed in the Union Bridge, which integrates the road interchange in the state of Pará, where drones were used for structural monitoring and monitoring of work fronts, thus assisting in project management (Alvares *et al.* 2016).

Conclusion

As observed throughout this study, Arvoredo´s Island serves as a model for various projects in the sustainability and science fields. As a means of preserving this location and the memory of the engineer and environmentalist Fernando Lee, students from the Mauá Institute of Technology, together with INMAR, UNAERP, and the Fernando Lee Institute, are implementing improvements on the site. The Digital Twin is one such improvement, going beyond simply offering a three-dimensional model of the area, more than that, it constitutes a representation that incorporates essential information to anticipate and address potential complications on the site. Additionally, with the creation of a Digital Twin, it becomes feasible to predict natural phenomena, analyze building structures, estimate values for future maintenance, and improvements.

Knowing this, it was essential for the Digital Twin project to generate the model of the island's topography. Therefore, this study has the central motivation to conduct a topographic survey of the island as a contribution to a portion of the digital twin. This method involves capturing terrain orthophotos using drones, which, after being filtered, processed, and transformed into a point cloud, will result in a digital terrain model. This not only ensures a precise representation of the local topography but also includes the georeferencing of elements on the island, giving the model an accurate position in the real world.

The choice of using drones for the topographic survey was based on the various advantages that this method provides. First of all, the favorable cost-benefit ratio compared to other surveying methods, such as the local station method, which requires more manpower and consumes more time is something to consider. Additionally, drones have the ability to access hard-to-reach areas, simplifying and facilitating the work process.

The next step in this research will be to visit the island to conduct a field study. In collaboration with the responsible pilot, a topographic survey will be conducted and orthophotos will be taken. Consequently, these images will undergo a treatment process, culminating in the transformation into a digital terrain model.

The digital model of the island's topography directly contributes to the development of the Digital Twin, which represents an innovation in the visualization of the island and is also essential for predicting and addressing future challenges, significantly contributing to the improvement of the local environment.

In conclusion, the use of drones in the topographic survey of the island, with the utilization of point cloud technology for the generation of the digital terrain model, represents an advancement in mapping and in terrain analysis practices. By adopting this technology, it is possible to optimize the collection of topographic information. The resulting point cloud not only provides a true representation of the island's topography but also serves as the basis for creating a three-dimensional digital model and, consequently, for the development of digital twins.

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