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(RESEARCH ARTICLE)

UAVs/drones for photogrammetry and remote sensing: Nineveh archaeological region as a case study

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Abstract

Unmanned Aerial Vehicle (UAV) is nowadays a valuable source of data for inspection, surveillance, mapping and 3D modeling issues. UAVs can be considered as a low cost alternative to the classical manned aerial photogrammetry, because they provide users with high spatial resolution images up to a centimeter limit. Following a typical photogrammetric workflow, 3D results like Digital Surface or Terrain Models (DTM/DSM), contours, textured 3D models, vector information, etc. can be produced, even on large areas. The paper reports the state of the art of UAV for Geomatics applications, giving an overview of different UAV platforms, applications and showing also the latest developments of UAV programs. The research presents the sequence of operations should be follow on the images taken with these aircraft for maximum use in remote sensing and air survey. Recent photographs were taken using the DJI Phantom 4 UAV (which was awarded to the Nineveh Department of Antiquities and Heritage by the Italian Mission) for the archaeological Nineveh region in Mosul city and use as a case study.

Keywords: UAVs; Drones; Remote Sensing; Photogrammetry; Environmental Monitoring; Nineveh archaeological region

1. Introduction

According to the International definition an Unmanned Aerial Vehicle (UAV) is a generic aircraft design to operate with no human pilot onboard. The simple term UAV is used commonly in the Geomatics community, but also other terms like Unmanned Vehicle System (UVS) or Drone are often used. UAV photogrammetry [1,2] indeed opens various new applications in the close-range aerial domain, introducing a low-cost alternative to the classical manned aerial photogrammetry and being a valid complementary solution to terrestrial acquisitions (Fig.1) [3].

Although conventional airborne remote sensing has still some advantages UAV platforms are a very important alternative and solution for studying and exploring our environment, it can provide dramatic illustrative photographs of sites, but can also be used to create metrically accurate records for survey and conservation work in particular for heritage locations or rapid response applications [4]. UAVs can carry a wide variety of sensors including cameras, multi/hyperspectral imaging units, and even laser scanners.

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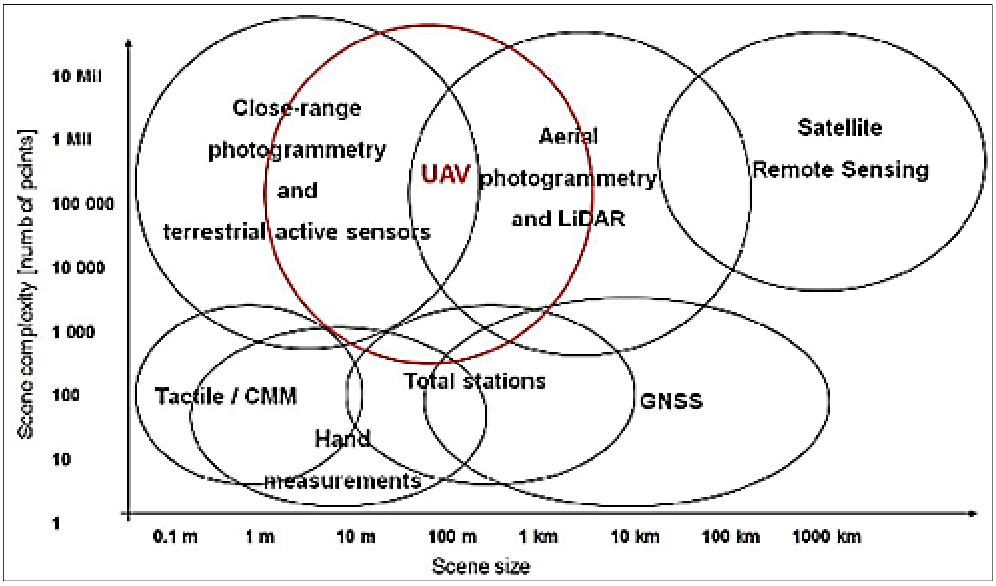

Figure 1 Available Geomatics techniques, sensors and platforms for 3D recording purposes, according to the scene' dimensions and complexity

Following the facilities provided by the American Federal Aviation Act in 2016, private companies are now investing and offering photogrammetric products from UAV-based aerial images as the possibility of using flying unmanned platforms with variable dimensions, small weight and high ground resolution allow to carry out flight operations at lower costs compared to the ones required by traditional aircrafts. Problems and limitations still exist, but UAVs are a really capable source of imaging data for a variety of applications [3].

This paper reviews the most common UAV systems and latest UAV programs and data processing in the Geomatics field. A case study was taken about the Nineveh archaeological area inside the city of Mosul using DJI 4 Drone.

2. Other Drone Names

Drone is the alternative name for UAVs. The main idea naming it came from the buzzing sound of the bee flying.

Although UAV or Drone is the term most commonly used by the media and recognized by the public, other acronyms are these days used when referring to such low-level aerial platforms as including below (Fig 2):

A. Rotary Wing

- Quadcopter
- Multicopter
- Hexicopter
- Octorotor
- Hexarotor

B. Fixed Wing

(a)

(b)

Figure 2 Types of drones according to their shapes and type of wings. (a) Rotary Wing. (b) Fixed Wing

3. Different Drones applications

Drones technology has developed and prospered in the last few years. Individuals, commercial entities, and governments have come to realize that drones have multiple uses, which include [5]: (Fig3)

• Military uses • Gas detecting and mapping • Building safety inspections • Digital archaeology • Saving Heritage • Gathering information or supplying essentials for disaster management • Thermal sensor drones for search and rescue operations	• Geographic mapping of inaccessible terrain and locations • Agricultural analysis: Precision crop monitoring • Unmanned cargo transport • Law enforcement and border control surveillance • Aerial photography for journalism and film • Express shipping and delivery • Environmental analysis

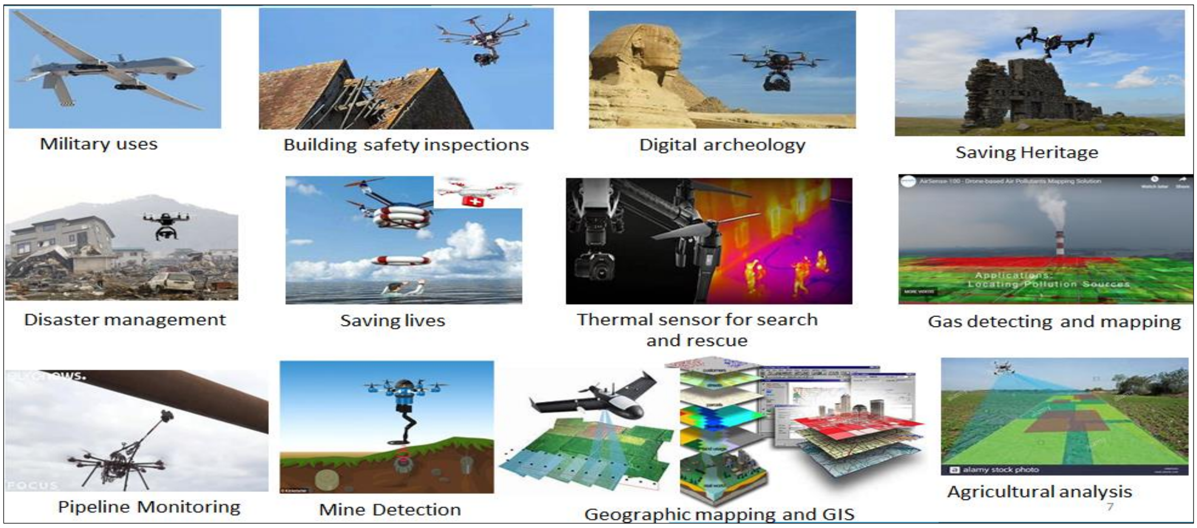

Figure 3 Different UAVs applications

4. Future Drones Technology

Drones technology is constantly evolving, so future drone tech is currently undergoing groundbreaking progressive improvement. According to the researcher, Drones technology has seven potential generations, and the majority of current technology sits in the fifth and sixth generations [5].

Here is the breakdown of the technology generations:

4.1.1. Generation 1

Basic remote control aircraft of all forms.

4.1.2. Generation 2

Static design, fixed camera mount, video recording and still photos, manual piloting control.

4.1.3. Generation 3

Static design, two-axis gimbals, HD video, basic safety models, assisted piloting.

4.1.4. Generation 4

Transformative designs, Three-axis gimbals, 1080P HD video or higher-value instrumentation, improved safety modes, autopilot modes.

4.1.5. Generation 5

Transformative designs, 360° gimbals, 4K video or higher-value instrumentation, intelligent piloting modes.

4.1.6. Generation 6

Commercial suitability, safety and regulatory standards based design, platform and payload adaptability, automated safety modes, intelligent piloting models and full autonomy, airspace awareness.

4.1.7. Generation 7

Complete commercial suitability, fully compliant safety and regulatory standards-based design, platform and payload interchangeability, automated safety modes, enhanced intelligent piloting models and full autonomy, full airspace awareness, auto action (takeoff, land, and mission execution).

The new function that company's added also to Drones can be summarized in Fig 4.

A. Return to Home Function used to send Drones back to the take-off position

B. Waypoint Navigation Drones flies to GPS points that you navigate on the drone's map.

C. Geofence GPS tells Drones to never go outside the GPS range that you navigated.

E. Using Oxygen and Hydrogen: to power Drones while flying and it's better than (litheome) batteries

D. foldable Drones (12/2018): Drones can fold to get through a small hole.

F. Electronic weapons: To hunt unauthorized Drones (Drones Shield).

Figure 4 The new function that company's added to Drones.

5. The Latest Drone Mapping Applications

It is common for people to fly drones now. They control the flying machine hovering above their heads with the traditional controller or the applications launched on devices. Therefore, this is a list of some of the best drone applications for Android and Tablets devices right now. The top three most popular drone mapping platforms out there are Pix4D, Drone Deploy, and Data Mapper.

5.1. Drone Deploy

This is the official app for popular drone vendor, DJI. DJI is undoubtedly a force to be reckoned with in the drone business so it is befitting that they own an app that measures up to its standard. The app makes provisions for standard flight planning and an automated control for the drone being flown. All a user has to do is set the coordinates and the drone hovers over the selected routes [6].

5.2. Pix4D

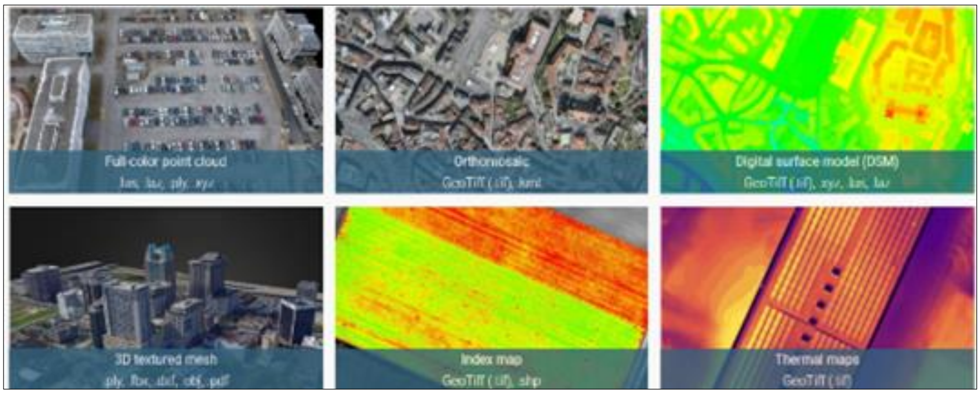

Figure 5 Pix4D program can gather RGB, thermal or multispectral images with any camera

A unique photogrammetry software suite for drone mapping, Measure from images offers several software offerings to help you get exactly what you need out of your drone mapping. Applications are available for specific uses, such as photorealistic 3D modeling and agricultural mapping, providing access to other key features such as CAD overlay, web sharing, NDVI mapping and DTM and DSM visualization. The package even offers high-tech mapping features such as thermography-making it a popular choice for everything from mining to forensics Fig 5 and 6. This allows you to perform such unique tasks as creating a 3D video fly through of the mapped area or comparing construction sites with design drawings to catch building errors [7].

Figure 6 Aero triangulated images and generated 3D point cloud using Pix4D App

5.3. Data Mapper

This app will turn your drone into a powerful mapping machine. DataMapper in-flight mobile app turns a drone into an advanced remote sensing tool that empowers businesses and consumers to gain actionable aerial data autonomously. This app features a highly-intuitive user interface to easily create flight plans that automatically guide the drone to capture aerial images for 2D/3D maps and advanced analysis [8].

Figure 7 The autopilot follows the routes identified after mapping the area on the map

6. Drones in the LiDAR Applications Sector

Light Detection and Ranging (LiDAR) by definition is a remote sensing method which uses pulsed laser light to measure ranges (variable or changing distances) to the Earth. LiDAR is a land surveying method that measures the distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor. The drone LiDAR sector is growing rapidly and especially over the past few years. In only a short period of time, manufacturers of the best aircraft LiDAR sensors have engineered LiDAR sensors for small drones [9]. LiDAR Drones will have a huge impact in all life sectors see Fig 8

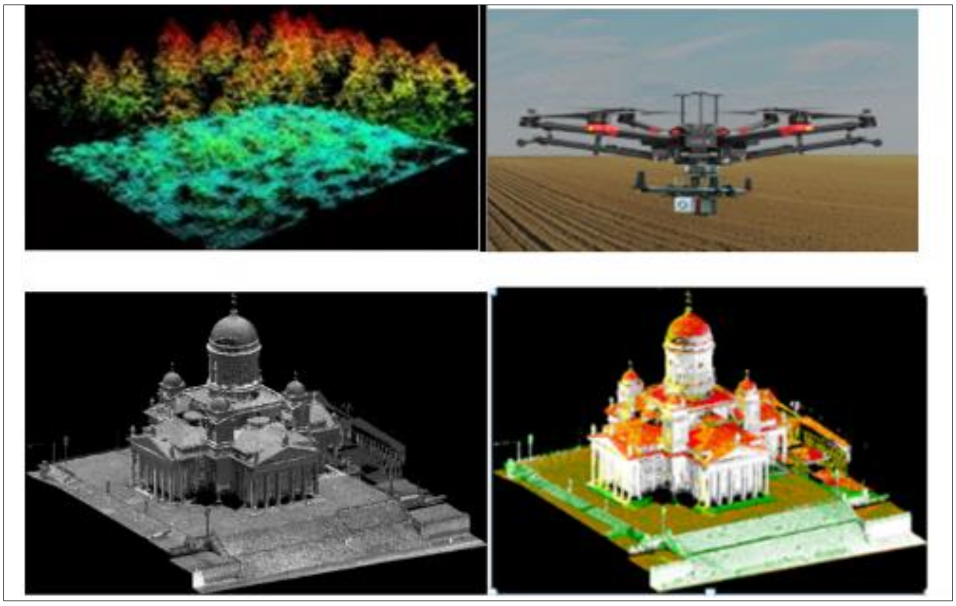

Figure 8 Outputs of LiDAR and Photogrammetry Surveys. Example of point cloud, before and after adding a color attributes

7. Examples

7.1. Heritage use of Drones

7.1.1. In England

Historic England has used Drone acquired imagery since 2008 and has built up long experience of using such platforms alongside other means of capturing low-level aerial imagery such as balloons, helicopters and planes. The imagery and data they capture can be used across multiple applications including monitoring, presentation, interpretative display, multimedia journalism, surveying, mapping and recording Fig 9.

Figure 9 Processing imagery captured by Drone to create 3D surface model for archaeological analysis. The blue rectangles represent the camera position for each individual shot used to create the model © Historic England

7.1.2. UNESCO

The United Nations Educational, Scientific and Cultural Organization UNESCO start using drones in most of its projects to preserve the world heritage. One of this examples are using drones to take pictures for the old city in Mosul after the recent war and to use it to build a three-dimensional model of the old area and the Al-Nori mosque to rely on reconstruction of the archaeological and heritage areas of this city (Fig 10) [10].

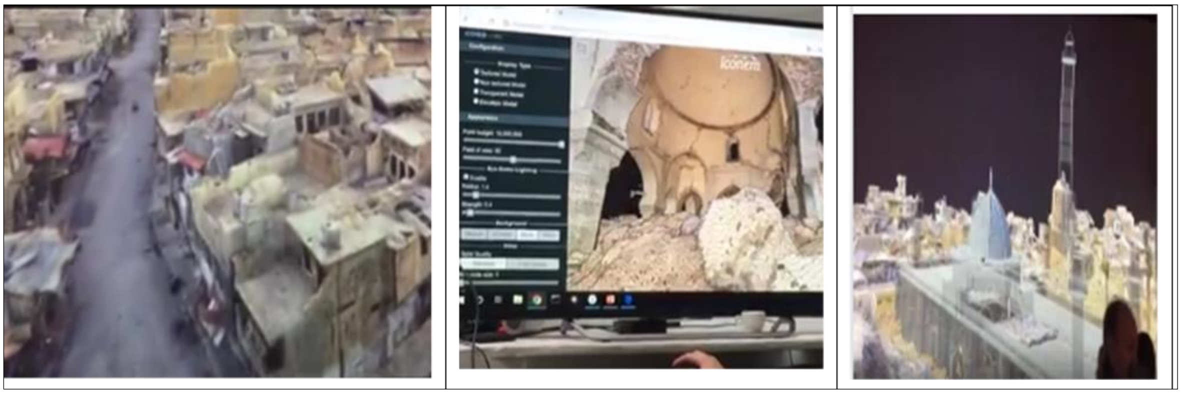

Figure 10 UNESCO: Using Drones to Documentation of the Old City and Al-Nori mosque in Mosul and presented in 3D old age cities exhibition in France

8. Drones data acquisition and processing

The traditional image-based aerial survey using Drones requires flight planning and ground control (GCP) for geo-reference purposes. After acquisitions, images can be used to manufacture mosaics [11], or can be introduced into the imaging process. In this case, camera calibration and image triangulation are done initially, in order to generate a digital surface model (DSM) or digital terrain model (DTM), respectively. These products can eventually be used to produce 3D modeling images or applications or to extract more measurement information using photogrammetry science [3,12]. In Fig 11, the general workflows are displayed and are followed through a case study in the following sections.

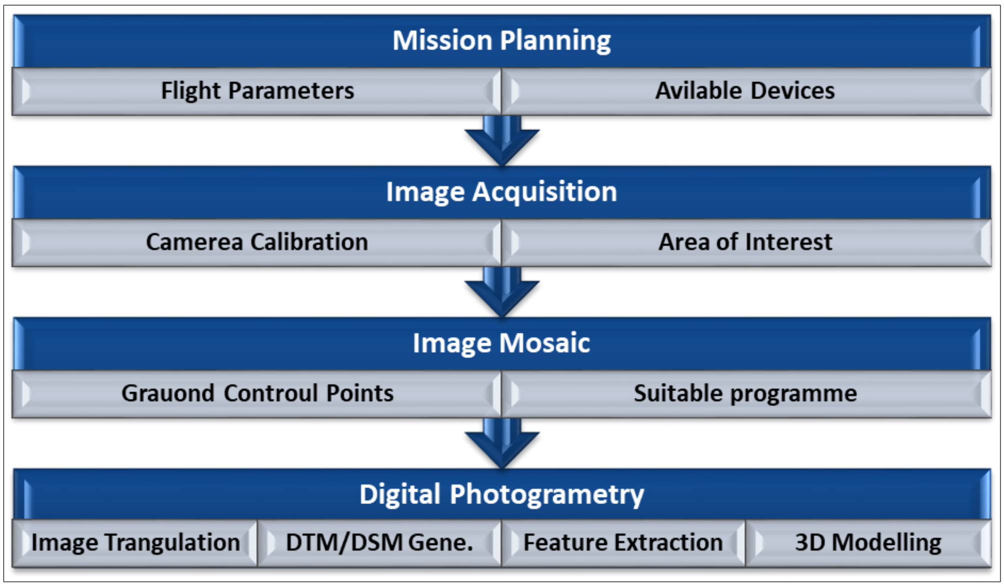

Figure 11 Typical acquisition and processing pipeline for Drone images

9. Case study: Nineveh archaeological area in Mosul city/Iraq

The images taken using the DJI 4 Pro Drone were donated by the Italian expedition to the Nineveh Antiquities and Heritage office in November 2018 [13]. Images which were selected for use in the preparation and configured for use in digital processing, and photogrammetry.

The mission (flight and data acquisition) was planned in the lab with dedicated software, starting from the knowledge of the region of interest, and the required ground sample distance. The drone images were used, represent the Nineveh archaeological region, do not contain any geographical references.

For the purpose of matching, the method of engineering-visual matching (registration image-to-image) has been used to unify the geometric characteristics of one of these images on the assumption that one of the two image is the reference [14]. This method will be used to correcting the geometric characteristics of the drone images, depending on World View satellite data taken in 2016. As the drone data considered as the test data that is intended to convert their properties to the engineering characteristics of reference World View image.

The geometric matching was applied by selection of 12 points of symmetrical control point between the two images using Erdas Imagen program after making the mosaic process. The corresponding control points were determined by selecting the permanent characteristics, ie, do not change with a time and spectral characteristics, for example (the confluence of the valleys, the buildings' corner) as in Fig 12. The root mean square error was (0.1) witch considered as a very good accuracy and indicates the high matching of the data. ArcMap program was then used to make sure that the drone images have received geographical coordinates with all the other engineering reference as shone in Fig 13,14.

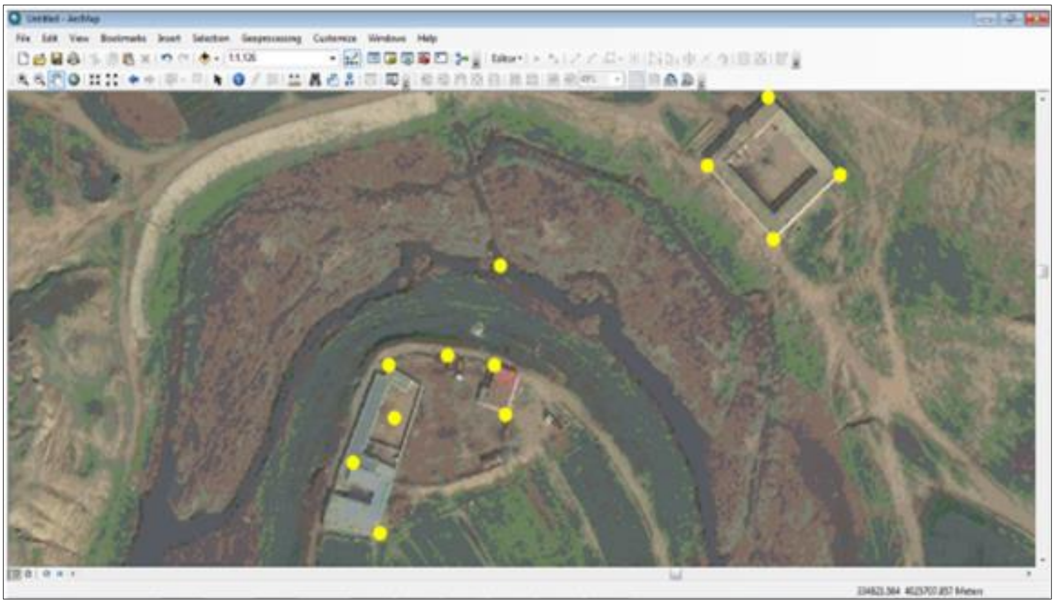

Figure 12 World View satellite image: Using 12 GCP to Mach between satellite and drone data

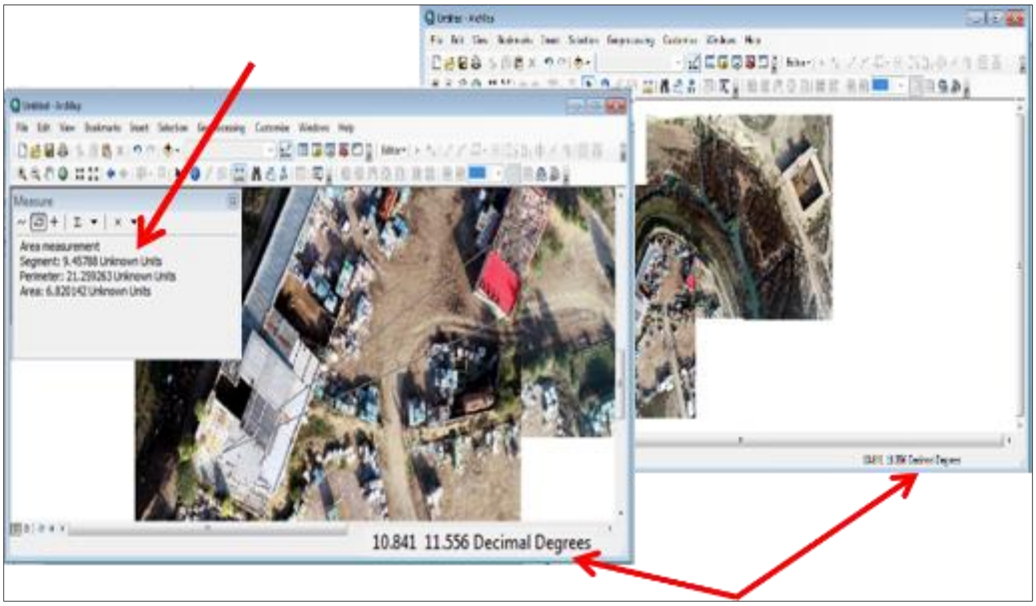

Figure 13 Drone image after the Mosaic process: The images have only the Screen Pixels coordinates

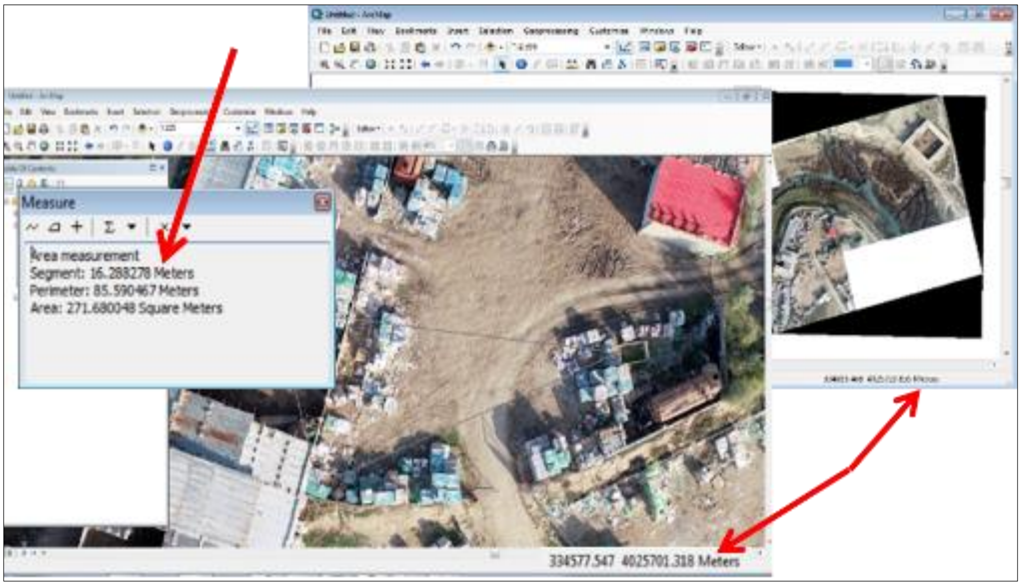

Figure 14 Drone image after the processing: The images have the Georeferencing coordinates

10. Conclusion

Drones represent one of the emerging technologies in photogrammetry. This technology is suitable to innumerable applications such as saving the historic building, heritage preserve and the maintenance of cities infrastructures. There are also many uses for surveillance and control vast areas, as well as surveying the topography or individual architectural constructions.

The article provides an overview of existing Drone systems and applications with particular attention to the geomatics field. Drones can be used in high-risk situations and inaccessible areas. High resolution images can be derived, generally at the centimeter level and are used for texture mapping purposes on existing 3D data, for mapping and generation or 3D modeling construction. Compared with conventional airborne platforms, Drones reduce operational costs and reduce the risk of access to harsh environments, while maintaining high-precision capabilities. As a model this paper prepares the drone images to use from GIS and Photogrammetry experts.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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