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UA V AND MMS - MODERN, REMOTE TECHNOLOGIES, USED COMPLEMENTARY TO THE INVESTIGATION OF THE NATURAL ENVIRONMENT AND THE BUILT SPACE

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Abstract
The aim of this study was to demonstrate the applicability and opportunity of the means and methods of remote sensing (MMS) and photogrammetry (UAV) in rendering faithfully, with very high accuracy and precision, the components of geographical space, "remotely", without a direct contact with the investigated objective. As a case study, an immobile consisting of a construction and the related agricultural land, located in a rural locality, was chosen. To investigate the targeted immobile, a flight with UAV equipment (DJI Phantom 4RTK) and a "ground" scan with MMS equipment (Leica Pegasus Backpack) was performed. After the acquisition and separate processing, the data obtained through the two technologies (point clouds, orthophotoplans or images), were analyzed and processed in a "combined" way, in this case being obvious their complementarity relationship. As both the drone and the scanner have incorporated GNSS and INS equipment, the data obtained are "in coordinates" and therefore the use of control points and the georeferencing operation is excluded. By combining these "remote" measurements, the detailed topographic survey (with GPS and total station) is replaced and by 3D analysis all the details from the outside, but also from inside the plot are captured. By creating the orthophotoplan, the way of land use, aspects related to vegetation or the way of arrangement can be analyzed. The equipment used and the working methodology "experienced" in this study can be applied in any type of space or for any purpose.

Keywords: measurements, overlapping, remote sensing, scan.

1. INTRODUCTION
In recent years, the number of sensors and data collection systems has grown considerably. In addition to total stations and GPS systems, the most used topographic equipment, today, there are several options available for data collection, both topographic and for other fields of activity, from several different sources (Chatzistamatis et al., 2018).
Both UAV technology (Unmanned Aerial Vehicle) and MMS (Mobile Mapping System) are techniques with remarkable results in the measurement and mapping activity (Gruen et al., 2013). While UAV technology is constantly evolving, MMS technology is just beginning, especially in Romania, where the number of specific equipment is still very low.
Both internationally and in Romania, data acquired with drones are widely used in agriculture (Stafford, 2002; Zhang and Kovacs, 2012; Rokhmana, 2015; Tripicchio et al., 2015; Mahajan and Bundel, 2017; Puri et al., 2017; Shamshiri et al., 2018; Raparelli and Bajocco, 2019).
environmental monitoring, mapping or analysis of the evolution and prediction of phenomena (Sona et al., 2016; Themistocleus, 2017; Cohen et al., 2018; Sanches et al., 2018; Herrmann et al., 2020). In contrast, MMS technology addresses, in particular, the mapping and modeling of different components of geographical space, with remarkable results for architecture, design, geography or geodetic sciences (El-Sheimy and Schwarz, 1998; Pirotti et al., 2013; Guarnieri et al., 2015; Masiero et al., 2017; Nocerino et al., 2017; Simon et al., 2019).

With the help of drones, high quality aerial images can be collected for "modeling" the investigated areas using photogrammetric techniques (Simon et al., 2018). Because the whole process takes place in the air, there are difficulties in acquiring information about objects under trees or under the roofs of houses (Nex and Remondino, 2014). Instead, MMS collects information in the form of point clouds along with stereographic images, by scanning from the ground. Depending on the need, the “range” of the laser can be determined, but it cannot penetrate beyond solid obstacles or into another plane, for example for scanning the roofs of buildings (Tucci et al., 2017). The possibility to combine the data sets obtained by the two technologies, makes them complementary. The aim of this study was to demonstrate the applicability and appropriateness of the means and methods of remote sensing (MMS) and photogrammetry (UAV) in rendering faithfully, with very high accuracy and precision, the components of geographical space, "remotely", without a direct contact with the investigated objective.

2. MATERIALS AND METHODS
As a case study, a building consisting of a construction and the related agricultural land was chosen, located in Seitin locality from the southwest of the Arad Plain, in the Mures meadow.

The working methodology applied in the research involves several steps, summarized in Figure 1.

Figure 1. Research methodology

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The equipment and software used according to the technical manuals are presented in Table 1.

| **Field stage** | **Office stage** |
|-----------------|------------------|
| - **Leica Viva GS14 GNSS receiver**: used as a Master Base to collect satellite observations at 1 Hz throughout the flight and ground scan, data acquired through the **Leica SmartWorx application**; |
| - **DJI Phantom 4 RTK drone**: for the acquisition of aerial images with the help of the **Pix4Dcapture application**; |
| - **Leica Pegasus Backpack mobile scanning system**: for collecting point clouds and stereographic images through the **MDA application - Mobile Data Acquisition** |
| **Leica Pegasus Backpack mobile scanning system**: for collecting point clouds and stereographic images through the **MDA application - Mobile Data Acquisition** |
| **Inertial Explorer program** - for correcting the trajectory and transforming the coordinates from the WGS84 system into the national STEREO’70 system, both for UAV data and for MMS data; |
| **Pix4Dmapper program** for UAV data processing; |
| **Pegasus Manager program** for MMS data processing; |
| **Leica Cyclone program**, for extracting and “modeling” information from the point cloud |
| **AutoCAD program** - for preparing the final documentation. |

3. RESULTS AND DISCUSSIONS

The methodology for acquiring UAV and MMS data was applied to obtain an extremely detailed and complete digital model (Eisenbeiss and Zhang, 2006). The traditional point cloud derived from terrestrial laser scanning was integrated with data obtained from a UAV photogrammetry campaign (Eltner et al., 2013).

**Data acquisition with UAV equipment**

The photogrammetric flight was made with a DJI Phantom 4 RTK drone that includes a Real Time Kinematic module that provides centimeter position information to obtain a very high absolute accuracy of the meta-information in the images. DJI Phantom 4 RTK is equipped with a DJI FC6310R camera that has a glass lens and not a plastic one, as is the case with DJI Phantom 4 Pro, equipment used in previous research (Simon et al. 2019). However, the camera specifications are identical to the camera on the DJI Phantom 4 Pro. The major difference between the two devices is the RTK module that allows us to acquire images without using ground control points for small areas (Peppa et al., 2019).

To obtain point clouds, in the case of drone flight, the working algorithm described in Figure 1 and Table 1 was applied.

**Data acquisition through MMS technology**

The terrestrial scan was performed with a very new equipment that appeared on the Romanian market, namely Leica Pegasus: Backpack. This equipment is the top solution in recording and capturing data about the surrounding reality, indoors, outdoors and underground. This equipment captures and combines image and point cloud data, even in locations where GNSS positioning is missing (Masiero et al., 2017).

Designed to capture the surrounding realities quickly and easily, the Leica Pegasus: Backpack makes progressive scanning a simple procedure. The equipment is a platform for sensors to capture reality. It has an extremely ergonomic design and combines five cameras that offer a fully calibrated 360-degree view and two LiDAR sensors. This unique mobile mapping solution is designed for fast and regular capture of reality (Leica Pegasus Backpack Wearable Mobile Mapping Solution).

Given that the scanning process results in millions of points that represent the exact position of all objects in the scanned area, the scanning process allows a better use of resources because in case of omission of details is not necessary another field visit.

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GNSS recordings that took place throughout the flight and scan were made with a Leica Viva GS14 GNSS antenna. This smart antenna is the universal GNSS tool for obtaining professional reliability when we need very high accuracy. The antenna was used as a reference station - Master Base, its location was made in an area without obstacles, with satellite visibility and minimal interference (away from buildings, trees, cars, power lines, etc.). The station collected L1 / L2 observations at 1 Hz and stored raw RINEX data (.20g, .20o and 20n files). These data were used in post-processing data obtained from photogrammetry and scanning.

**Planning the data acquisition mission**

In this study, the data acquisition mission was divided into three stages:
- In the first stage, the reference station was located and configured;
- In the second stage, a planned flight was performed using the Pix4Dcapture application;
- The last stage was mobile scanning, which in turn is divided into five phases:
  - static initialization, for 5 minutes; during this time the equipment remained motionless in the position in which it was placed to configure its GNSS Almanac and to establish the position; during this time the parameters for the cameras as well as the distance for the pictures were set;
  - dynamic initialization, for 2-3 minutes, during which the equipment was moved continuously to put the GPS / INS system into operation;
  - effective scanning; the area of interest is crossed with the equipment mobilized by the operator;
  - completion of the process - after taking over the data to complete the whole process in a correct and precise way, the initializations were done again, but this time in reverse order, first the dynamic initialization for 2-3 minutes, then static initialization for 5 minutes.

The whole mission was completed in about 30 minutes, much shorter compared to other technologies in the field. A very large amount of data resulted without affecting the integrity of the scanned objects.

**Data processing**

The data were processed in dedicated software, presented in the research methodology and exported in the form of a point cloud in .las files in order to be integrated together. Due to the GNSS and INS systems integrated in these equipments and the data collected by the reference station, both data sets were obtained in the same coordinate system and with the same precision. The overlap of the two data sets (Figure 2) was done perfectly, without the need to correct any data set. So I got a faithful copy of reality in digital format, without omitting any information.

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Based on this complex data set, different analyzes can be made, 3D models or 2D plans can be built. For studies on land use, both built space and agricultural land we have developed a Digital Terrain Model (DTM) which is the 3D digital representation of the area. For the realization of this DTM on the whole investigated area, points were automatically placed at the base of the terrain so that the points are not found on the building, vegetation or other high elements. All these points were joined by a network of triangles on the basis of which we obtained the digital model of the terrain. For a better investigation of the area, we also built the level curves (Figure 3).

![Digital Terrain Model (DTM) and contours](image1.png)

**Figure 3. Digital Terrain Model (DTM) and contours**

To create a 2D plan it was necessary to prepare the area through horizontal sections at various heights (Figure 4). These sections have the role of eliminating the information we do not need, but they are also useful for determining the ground footprint of the construction and the fence.

![Horizontal sections in the area of interest](image2.png)

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Information extraction and processing

Once the area is ready, the information is extracted. The advantage of using combined data obtained by UAV and MMS technology is their complementarity. For example: when drawing the ground footprint of the building, very large errors appear from the UAV data because, following the aerial overflight, the projection on the ground is blocked by the roof (Figure 5), but from the data obtained with MMS equipment can be extracted very detailed, from the outside of the building, more precisely everything we can see from the ground. In this way, by using both data sets, the "gaps" are filled in and all the details in the field are captured, regardless of the representation plan.

The lack of a compact fence allows the laser to penetrate inside the analyzed perimeter, but the information is incomplete in some places. The combination with the data obtained with the UAV equipment offers us the possibility to complete the data, especially in the areas inside the analyzed perimeter and in the upper part of the construction.

Another objective of the study, achievable by combining the two technologies, UAV and MMS, is to create a situation plan of the studied perimeter, detailed topographic plan, which contains information in the Stereographic 1970 reference system (Figure 6).

The following information can be extracted from the situation plan:
- length of the fence - 68.43 m on one side and 68.72 m on the other side;
- width of the fence - 32.24 m on one side and 33.02 m on the other side;
- the surface of the studied area - 2236 sqm;
- the ground surface of the construction - 148 sqm;

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- average land elevation - 94.35 m.
Due to the fact that all the data brought in the 2D plan are in a coordinate system, it can be used in the design and arrangement activity (Figure 7).

Figure 7. Proposal for landscaping of agricultural areas

The proposed arrangement example can be materialized in the future and aims at planting fruit trees, but also a space for vegetable growing, given the location of the building in the rural area.

4. CONCLUSIONS
The results of the study demonstrate the compatibility and complementarity of the data acquired by two means specific to remote sensing and photogrammetry.
By combining the data sets obtained "remotely", by UAV and MMS technology, the topographic survey of detail (with GPS and total station) is replaced, and by 3D analysis all the details from the outside, but also from inside the investigated objective are captured. By creating the orthophotoplan, the way of land use, aspects related to vegetation or the way of arrangement can be analyzed.
As both the drone and the scanner have incorporated GNSS and INS equipment, the data obtained are "coordinated" and therefore the use of control points and georeferencing operation is excluded, which means a significant reduction in working time and operator effort.
The equipment used and the working methodology "experienced" in this study can be applied in any type of space or for any purpose.

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