PHOTOGRAMMETRIC METHODS USED TO CREATE ORTHOPHOTO PLANS IN THE CONTEXT OF TERRITORY ORGANIZATION

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Abstract. *A drone was used to map an area of 18.99 hectares with millimeter accuracy. The mapping process involved creating eight targets on the ground that were visible to the drone at a height of 60 meters. The coordinates of the targets were determined using GPS methods. Classical topographic methods have also been used to calibrate the drone's GPS for further correction and accuracy. A flight plan was created using DJI software, which determined the flight area, height, time, frame rate, camera tilt, battery level, direction of flight, wind speed, latitude, longitude, and flight speed. The flight plan was uploaded to the drone's memory, and the drone was flown according to the established parameters. This technology allows to make high-resolution digital maps (orthophotoplans), as well as 3D models of some objectives - historical monuments, buildings, land. A drone can be defined as an unmanned aircraft capable of autonomous navigation without external control using autopilot or that can be controlled by a remote control device. This technology allows the creation of high-resolution digital maps. With the help of UAV technology it is possible to provide topographic support for the revision of General Urban Plans (GUP), elaboration of Zonal Urban Plans (PUZ), feasibility studies for investment works, such as road infrastructure, railways, electrical networks. etc.*

Keywords*: uav, rtk,gps,drones,coordinates,gnss*

INTRODUCTION

Drones are classified into fixed-wing drones and multi-rotor drones. FIXED DRONES AND MULTI-ROTOR DRONES The most popular and widely used are unmanned aerial vehicles (UAVs). In this way, many risks to which human operators could be exposed are eliminated if they have to carry out inspections at various targets, such as wind power plants, nuclear power plants, hard-to-reach quarries, viaducts, high-capacity overhead power lines etc.), surface mining operations, hydrology, meteorology etc. In addition, the drone can be controlled via WI-FI, smartphones or tablets equipped with Android or iOS. In terms of use, drones are divided into the following categories: Unmanned aerial vehicle (UAV); Unmanned surface vehicle (USV); Unmanned underwater vehicle (UUV); Unmanned Ground Vehicle (UGV); High-altitude pseudo-satellites (HAPS).

Also, this technology allows to make high-resolution digital maps (orthophotoplans), as well as 3D models of some objectives - historical monuments, buildings, land. A drone can be defined as an unmanned aircraft capable of autonomous navigation without external control using autopilot or that can be controlled by a remote control device. This technology allows the creation of high-resolution digital maps. With the help of UAV technology it is possible to provide topographic support for the revision of General Urban Plans (GUP), elaboration of Zonal Urban Plans (PUZ), feasibility studies for investment works, such as road infrastructure, railways, electrical networks. etc.

Regardless of its use, the unmanned aerial vehicle runs on batteries or energy produced by its own photovoltaic cells. There are two types of electric motors for RC multirotor models: brush motors and brush motors. Drone technology is developing rapidly. In Romania, the implementation of UAV technology in various fields of activity is constantly increasing, due to the fact that in recent years this technology has become more affordable from a financial point of view.

MATERIAL AND METHODS

General notions about UAV systems

A drone can be defined as an unmanned aircraft capable of navigating autonomously, without being controlled from outside, using autopilot, or which can be controlled by a remote control device. In addition, the drone can be controlled via WI-FI, smartphones or tablets equipped with Android or iOS.

In terms of use, drones are divided into the following categories:

- Unmanned aerial vehicle (UAV);
- Unmanned surface vehicle (USV);
- Unmanned underwater vehicle (UUV);
- Unmanned Ground Vehicle (UGV);
- Pseudo High Altitude Satellites (HAPS).

Fixed-wing drones and multi-rotor drones

The most popular and most widely used are unmanned aerial vehicles (UAV). Regardless of its use, the unmanned aerial vehicle runs on batteries or energy produced by their own photovoltaic cells.

Drones are classified into fixed-wing drones and multi-rotor drones. Multi-rotor ones, depending on the number of motors and their power, can be classified into tricopters, quadcopters, hexacopters, octocopters, etc.

In Romania, the implementation of UAV technology in various fields of activity is constantly increasing, due to the fact that in recent years this technology has become more affordable from a financial point of view. The professional use of drones tends to impose new requirements on practical and theoretical knowledge of new technologies, from the operation and maintenance of drones to the processing and use of the information obtained.

One of the main advantages conferred by UAV technology is that these platforms (drones) can move in hard-to-reach areas in a relatively short time, retrieving high-precision information. This eliminates many risks to which human operators might be exposed if they had to carry out inspections at various sites, such as wind power plants, nuclear power plants, hard-to-reach quarries, viaducts, high-capacity overhead power lines, etc.

With the help of UAV technology, topographic support can be achieved for the reambulation of General Urban Plans (GUP), elaboration of Zonal Urban Plans (PUZ), feasibility studies for investment works, such as road, railway infrastructure, electrical networks, etc.

In addition to the utility in the field of Geodetic Engineering, UAV technology can be successfully used in other fields, such as archaeology (for mapping and 3D modeling of archaeological sites), agriculture (for monitoring the health status of crops; determining the volume of biomass; applying treatments, etc.), forestry (reambulation of forest management plans; determination of wood volume, etc.), surface mining, hydrology, meteorology, etc.

The first drone was designed by Nikola Tesla in 1898. Later, this model was improved by engineer Charles F. Kettering, who attached an electronic device to the model, whereby the drone modifies its propellers to fall into enemy positions 2. A model more similar to the one used today was the AQM-34, created in 1948 and first tested in 1951. Drone technology is developing rapidly. Motorized devices are becoming more complex, with multiple functions, but much easier to control. Regardless of the type of drone, their most important characteristics are generally the following:

- maximum operating distance;
- duration of flight / trip;

- flight / travel speed;
-Connectivity;
- navigation system used;
- type and number of sensors;
- on-board GPS system;
- operating frequency;
-Weight.

Other performance characteristics of drones are as follows:

- availability to mount devices of different types, sizes and weights (cameras, video cameras, infrared cameras, radars, etc.);
- the ability to independently return to the take-off point (come-home option); ability to stay in a certain position (position hold);
- the ability to remain at a fixed altitude (elevation hold);
- small size - they are easy to handle and can pass through narrow spaces;
- methods of data transmission: through radio waves, through the Internet, data coming to PCs, tablets or smartphones;
- operating autonomy at which the battery can be charged from photovoltaic panels;
- shock resistance, so it can work regardless of weather conditions.

Applications of drones

Unmanned aerial vehicles can be used in various fields of activity: data acquisition activities in hard-to-reach areas, transport of objects, crop monitoring, national parks and wildlife, entertainment activities (videos), military applications, border control, control of aqueducts and dams and inspections of high-voltage power lines, etc. Depending on the field in which they are used, drones can be equipped with various devices: cameras, thermal imaging cameras, rangefinders, radar, sensors, GPS systems, remote data acquisition using tablets or smartphones. With the advent of new technologies, new applications for drones are being developed, especially in industrial applications, real-time image visualization, data acquisition and equipment control based on information transmitted through drones.

In Romania, the implementation of drone technology in various fields of activity is constantly increasing. The professional use of drones tends to impose new requirements on practical and theoretical knowledge of new technologies, from the operation and maintenance of drones to the processing and use of the information obtained. It is therefore necessary to create appropriate structures for the development of skills in the professional use of drones. An example of successful use of drone technology is in forestry; It is used to study areas affected by deforestation or fires and to plant trees. Hard-to-reach areas are scanned using drones to collect information and create 3D maps. Based on the data obtained, the most appropriate soil pattern is generated, called the seed plan. The drones used are equipped with specialized guidance and control software, software that allows seed distribution on the ground and monitoring tree growth.

A successful example of drone technology is the first unmanned aerial vehicle - the aircraft "HCUAV RX-1" built in 2016 in Greece. Its length reaches 4 meters, takes off at a speed of 2.8 meters per second and can develop a speed of 190 km per hour. It can transmit real-time, relevant and detailed information from a height of 2 km. The drone can help civil protection services and public safety by monitoring land and sea borders, protecting vital infrastructure, supporting rescue investigations, forest surveillance for firefighting, soil sampling, water and air pollution, road monitoring and aerial photography of areas of interest. In Greece, there is a lack of training centres to promote educational materials and certify drone users. Hellenic Drones and 3D AE are two of these, licensed by the Civil Aviation Authority. These are new unmanned academies in Attica and Thessaloniki, respectively, operating in Greece since September 2017. 1.3 How to build a drone Minimal knowledge of electronics and IT is required to build a drone. The first step in designing a drone is to know the components of the drones and the materials from which they will be made, depending on the field of use of the drones. A drone is made up of hardware and software components. Some components can be purchased, but some components can be made using a 3D printer.

The basic components of a drone are: frame, motors, regulators, ESC - speed regulators for brush motors, propellers, batteries, RC transmitter / receiver and other optional components (GPS modules, sensors, gyroscope, receiver, etc.). Frame - is the structure or skeleton of drones on which all other components of drones are mounted. Generally, frames are made of composite carbon fiber, aluminum, glass fiber, wood or PLA (3D printed prototyping materials), composites that are lightweight, robust and rigid to minimize vibration. Carbon fiber composites are the most widely used due to their strength, excellent rigidity and low weight.

. In general, propellers for a drone are not actually identical, some have different directions. This is due to the fact that some rotors rotate in opposite directions to each other. The flight controller is the brain of a drone and contains at least one microprocessor (CPU) and one sensor (IMU). The IMU is an electronic device that measures the speed, direction and acceleration of drones. The IMU usually contains a gyroscope (or Gyro) and an accelerometer (Acc). Batteries are the energy sources of drones. The performance characteristics of batteries are given by the rated voltage (number of cells, capacity and discharge rate.

After choosing the component elements, the following steps are taken to build drones:

- assembly of the drone frame;
- mounting electronic components on the frame;
- connection of electronic components;
- controller programming.

Step 1. Assemble the interior frame of the drones, for the construction variant in which the frame consists of several parts (the center of the frame with the drones and landing parts).

Step 2. The M1 (front-right), M2 (front-left), M3 (rear-right) and M4 (rear-left) engines are mounted on the frame so that they can rotate the propellers as shown in the figure below.

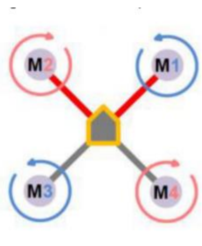

Figure 1. Direction of rotation of propellers

Step 3. Attach speed controllers (ESC) to the frame arms.

Step 4. The controller is glued using double-sided adhesive tape (or double-sided sponge for vibration damping) to the drone frame in the central area as far as possible in the drone's center of gravity, with the arrow on the upper surface pointing at the front drone.

Step 5. The battery, LED, receiver, voltage regulator and GPS module are mounted on a frame in the available areas so that the drone is balanced. Write the X, Y and Z coordinates of the point where the GPS module was mounted, relative to the center of gravity of the drones.

Step 6. Mount the propellers with the side on which the propeller is marked. On the flight controller the order is as follows: on the front arms, M1 - front right, M2 front left, M3 rear left, M 4 rear right. Thrusters shall be oriented so as to allow them to rotate as shown in figure 1.

Step 7. Connect drone components.

Step 8. The on-board software is downloaded from the Naga website and installed on your computer.

Step 9. Connect the radio receiver first and then connect the battery to the drone. Turn on the radio receiver, and then connect the controller to the computer. Step 10. Select the type of drone from the basic menu, Aircraft submenu.

Use of drone technology in agriculture

Among the most promising areas for commercial drone use is the agricultural sector, where drones offer the opportunity to address several challenges. Farmers are constantly confronted with problems related to irrigation, pests or diseases, which need to be addressed quickly to protect their crop and income.

Drones fly over the field and take high-resolution photos. The collected data is sent directly to the software and after that is available to customers. Thanks to this data, the user can select from the images all the necessary information, in order to make different prescription maps, depending on the operation that a farmer wants to perform in the field. The maps can then be uploaded to agricultural equipment which will adjust the amount of raw materials (seeds, fertilizers, pesticides) to be properly applied in the field.

The types of information farmers can get from drone images:

•Plant counting: plant size, plot statistics, number of stands, plots compromised, plant jump.

•Plant height: height and density of plants.

•Vegetation indices: leaf area, detection of abnormalities, treatment efficacy, infestations, phenology.

•Water needs: The drone ensures permanent monitoring of the crop in terms of the period and quantities of water that the field needs.

•Categorization of field areas:

(a) without intervention,

b) reduced intervention,

c) large intervention.

The spatial data of each area will guide the manufacturer to implement its strategy for each area.

The flight was performed with a DJI Matrice 300 RTK combo drone with the following technical characteristics:

- Weight (with a single gimbal down): about 3.6 kg (without batteries), and with drone-mounted batteries about 6.3 kg (with two TB60 batteries);
- Maximum take-off weight: 9kg;
- Operating frequency: 2.4000-2.4835 GHz, 5.725-5.850 GHz;
- Maximum angular velocity: Tilt: 300°/s, Dream: 100°/s;
- Maximum ascent speed: Mode S: 6 m/s, Mode P: 5 m/s;
- Maximum descent speed (vertical): Mode S: 5 m/s, Mode P: 4 m/s;

- Maximum descent speed (inclination): Mode S: 7 m/s;
- Maximum speed: Mode S: 23 m/s, Mode P: 17 m/s;
- Flight autonomy: 55 min. (only with FPV camera);
- Transmission distance: 15km; - Video: 1080p;
- Automatic transmission change: 2.4 / 5.8 GHz;
- Maximum distance from sea level: 7,000m;
- Maximum speed: 23m/s;
- Wind resistance: 15m/s;
- Main flight display;
- Collision sensors: 6 directions; - IP45 protection;
- Centimeter accuracy thanks to RTK positioning system;
- Operating temperature: -20°C to 50°C;
- UAV Health Management System;
- Self-heating battery;
- Anti-collision headlight;
- AirSense ADS-B receiver;
- External battery capacity: 4920 mAh;
- External battery voltage: 7.6V; - Charging time: 70 min. (15°C-45°C), 130 (0°C-15°C);
- Obstacle detection range: Forward/Backward/Left/Right: 0.7-40m, Up/Down: 0.6-30m;
- Operating environment: Surfaces with clear patterns and adequate lighting;
- Effective lighting distance: 5m;
- Camera resolution: 960p; - FOV: 160°;
- Frame rate: 30 fps.

Figure 2. Image of DJI Matrice 300 RTK drone

The characteristics of the GPS station for the drone are:

- Mobile station D-RTK 2,

- Centimeter accuracy The D-RTK 2 mobile station is a high-precision, high-speed GNSS receiver that supports all global satellite navigation systems, providing real-time differential corrections that generate centimeter-level positioning data for improved relative accuracy.

- Fully supports GPS, GLONASS, Beidou and GALILEO signals. The D-RTK 2 mobile station provides real-time differential data to achieve centimeter-level positioning accuracy. The built-in high-pitch antenna ensures better signal reception from multiple satellites even when there are obstacles.

- D-RTK 2 mobile station communicates via 4G, OcuSync, WiFi and LAN connections, ensuring uninterrupted and stable data transmission in any application scenario. Up to 5 remote control contacts can be connected simultaneously to the D-RTK 2 mobile station. This makes coordinated operations involving multiple drones a possibility, significantly improving efficiency.

The D-RTK 2 mobile station is compatible with Phantom 4 RTK, Phantom 4

Multispectral, MG-1P RTK, Agras T16, Agras T20, Array 210 V2, Array 300 RTK. It can be used as a continuous operation reference station (CORS), which provides high-precision positioning data within the base station roof radius, making it the ideal tool for surveying, aerial inspections, agriculture and other applications.

- GNSS RECEIVER: - GNSS frequency: Sumltane receptions: - GPS: L1 C/A, L2, L5 - BEIDOU: B1, B2, B3 - GLONASS: F1, F2 - Galileo: E1, E5A, E5B - Positioning accuracy: - Individual point - horizontal: 1.5 m (RMS) - vertical: 3.0 m (RMS) - RTK - horizontal1 cm + 1 ppm (RMS) - vertical2 cm + 1 ppm (RMS) - 1 ppm: For each increase in distance by 1 km, Accuracy will be 1 mm less.

For example, horizontal accuracy is 1.1 cm when the receiver is 1 km away from the base station.

- Positioning update rate: 1 Hz, 2 Hz, 5 Hz, 10 Hz and 20 Hz;
- Cold start: 45 s - Hot start: 10 s;
- Recapture time: 1 s;
- Initialization reliability: 99.9%;
- Data differential format: RTCM 2.X/3.X IMU: - 6-axis accelerometer accuracy;
- D-RTK 2 motion monitoring;
- Inclined measurements;
- Electronic bubble level DIMENSIONS: - (station body + extendable stand): 168 mm × 168 mm × 1708 mm;
- IP protection rate: IP65 COMMUNICATION AND DATA STORAGE;
- Communication distance: Operating mode 1/3, 2 km;
- Operating mode 4.5 km; Operating mode 5.6 km;
- Storage capacity: 16 GB ELECTRICAL CHARACTERISTICS;
- Power consumption: 12 W;
- Power supply: 16.5 – 58.8 VDC;
- Battery: Lithium-ion, 4920 mAh, 37.3 Wh;
- Autonomy: 2 h (WB37) OPERATING TEMPERATURE -20°.

Figure 3. DJI 300 RTK matrix with D-RTK 2 GNSS mobile station

The topography camera mounted on the DJI Matrice 300 RTK combo drone is a 54MP SONY camera with the following features:

- DJI Zenmuse P1 DJI ZENMUSE P1;
- Extraordinary efficiency: The P1 includes a full-frame, low-noise and high-sensitivity sensor that can capture a photo every 0.7s during flight and cover 3km² in a single flight. Outstanding precision: Equipped with a global mechanical trigger and a new TimeSync 2.0 system that synchronizes time between modules at the microsecond level, ZENMUSE P1

allows users to collect data with centimeter accuracy combined with real-time position and orientation compensation technology.

- Technical characteristics:
- 45Mpx full-frame sensor;
- Shutter speed 1/2000s;
- Supports 24/35/50mm lenses with DJI DL mounting;
- Video resolution: 4K@60FPS;
- Accuracy without GPC, 3cm horizontal / 5cm vertical;
- High efficiency: covers up to 2kmp in a single flight;
- 3-axis stabilization;
- Microsecond level synchronization.

Figure 4. Image of 54mp SONY camera mounted on DJI Matrice 300 RTK dorna

RESULTS AND DISCUSSIONS

In the first stage, a number of 8 targets were made on the ground, which were drawn with a phosphorescent color on the asphalt and at the interest of several streets to be visible from the drone during the flight. The height from which the flight was executed was 60m for maximum visibility. Image no.4 shows a target number 1, and visibility is very good.

Figure 5. Image with ground marking for GPS control determinations

The coordinates of the 8 targets executed on the ground and determined by GPS methods at millimeter precision are presented below.

Table 1

Coordinates of control points determined on the ground by GPS methods

X	Y	Z
X1 : x = 468185.552;	y = 177669.256;	z = 79.327m;
X2 : x = 467880.201;	y = 177153.128;	z = 79.775m;
X3 : x = 467727.594;	y = 177273.736;	z = 80.398m;
X4 : x = 467556,669;	y = 177411.467;	z = 80.077m;
X5 : x = 467472,329;	y = 176977.498;	z = 80.458m;
X6 : x = 467607.835;	y = 176866.165;	z = 78.974m;
X7 : x = 467316.817;	y = 176683.746;	z = 78.568m;
X8 : x = 466978.125;	y = 176815.202;	z = 79.312m;

After determining the points by classical topographic methods, before executing the flight with the help of the drone, for the established sector, a calibration of the RTK GPS drone from DJI was made to ensure additional corrections and better accuracy. The correction system is shown in the following figure, with the mention that the point where the drone's GPS was placed on a classic tripod, the coordinates were also determined by classical topographic methods and manually entered into the drone's GPS. All data measured within the sector were in STEREO 70 coordinates.

Figure 6. DJI 300 RTK matrix with D-RTK 2 GNSS mobile station

After determining GPS points by classical topofrafic methods, the flight plan was made, which was made with the help of software developed by DJI directly in the drone's field book.

By carrying out the flight plan, the following characteristics were determined:

-Flight area in Ha in our case of 18.99ha;

-Flight height (60m);

-Flight time in this case 22 minutes;

-Number of photograms with an overlap of 60% horizontally and 70% vertically in this case 402 images;

-Tilt of the camera which for the case presented was nadir;

-Camera resolution;

-Time level for batteries;

-Direction of flight and wind speed at the time of take-off;

-Latitude and longitude for the measured sector;

-The flight speed that in that project was 5.9m / s.

The flight plan is loaded into the drone's memory and at take-off the parameters established by the flight program are ob

Figure 7. Flight plan for the sector to be measured

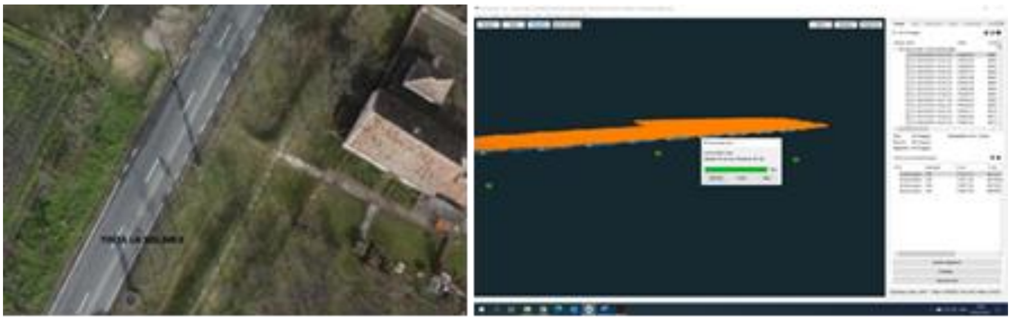

Figure 8. Ground Point Control and processing the images taken from the drone

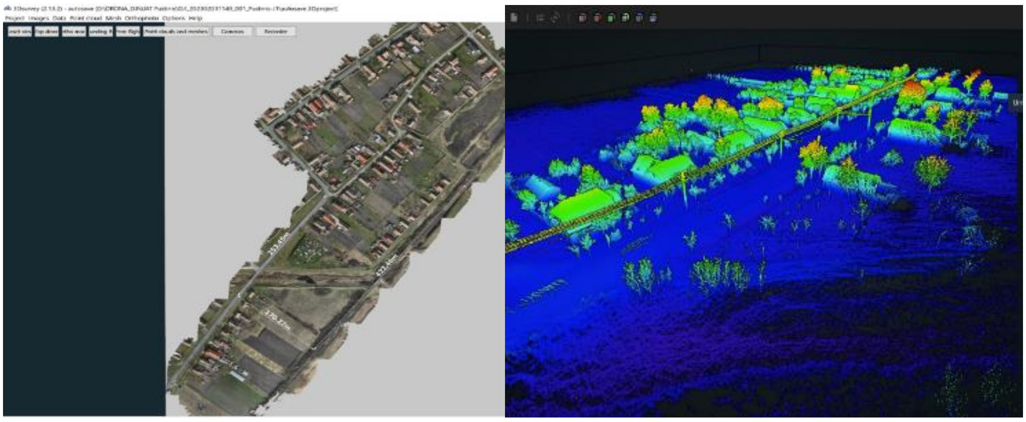

Figure 9. The point cloud resulting from image processing and the digital terrain model

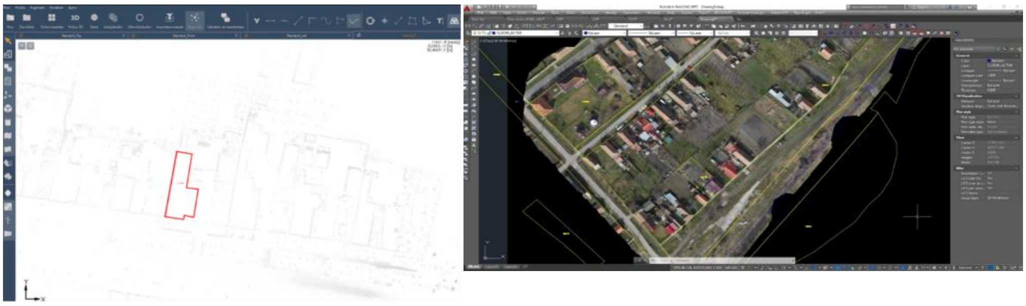

Figure10. Cadastral sector and property limits superimposed on the orthophoto plan

CONCLUSIONS

The use of UAV (Unmanned Aerial Vehicle) technology in creating orthophotoplans offers numerous advantages in the fields of cartography, topography, urban planning, and more. Here are some of the most important uses of UAV technology in this context:

Efficient mapping: UAVs can quickly and efficiently cover large and hard-to-reach areas, enabling the collection of geospatial data with extensive coverage in a short amount of time.

High resolution and accuracy: UAVs can be equipped with high-resolution cameras and GNSS (Global Navigation Satellite System) sensors, allowing them to produce orthophotoplans with very good accuracy and detailed resolutions.

Rapid updates: With UAV technology, it's possible to rapidly update orthophotoplans to reflect changes in the field, such as urban development, changes in infrastructure, or natural events.

Cost-effectiveness: The use of UAVs can significantly reduce the costs associated with creating orthophotoplans compared to traditional methods like manned aircraft or helicopters.

Personnel safety: Using UAVs eliminates the need to send personnel into dangerous or hard-to-access areas, such as disaster-stricken zones or high terrains.

Land change monitoring: UAV technology can be used for continuous monitoring of changes in the landscape, which is valuable in natural resource management, urban planning, and other applications.

Urban planning and development: Orthophotoplans created with UAVs are useful in the urban planning process, including infrastructure placement, transportation planning, and urban development. Precision agriculture: Modern agriculture benefits from precise land data obtained with UAV technology for efficient crop management, irrigation, and fertilization.

Environmental monitoring and natural resource conservation: The use of UAVs in cartography is valuable in environmental monitoring and natural resource conservation, such as assessing deforestation, identifying endangered species, and monitoring protected areas.

Disaster management: UAV technology is useful in emergency situations, such as natural disasters or accidents, for quickly assessing damages and coordinating rescue teams.

The use of UAV technology in creating orthophotoplans highlights versatility, efficiency, and accuracy, with a positive impact on various fields, including cartography, urban planning, agriculture, the environment, and more.

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