UAV AERIAL IMAGERY: MAPPING & 3D MODELLLING

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Abstract— Drones have recently enjoyed great success in a number of areas, most notably during the COVID-19 crisis, with applications in military and civic domains such as surveillance, agriculture, mapping, and monitoring. UAVs can create a variety of maps, including geographically accurate ortho-rectified two- dimensional maps, elevation models, thermal maps, and three- dimensional maps or models. CGA (Color Geolocation Approach), a new method for estimating the 3D world position of an object after detecting its 2D position in the captured image, is gaining popularity. The CGA technique is based on position encoding-decoding and employs the SRTM DEM (Digital Elevation Model) model to model the ground landscape (with a resolution of one arc second).

Keywords— UAV, 3D Mapping, CGA DEM, Mapping, 2DMapping, SRDM, GPS.

INTRODUCTION

Remote sensing mapping and three-dimensional (3D) earth modelling techniques have advanced significantly in terms of vehicles and sensors, as well as procedures and software. Thematic mapping with very high-resolution satellite imagery (0.5–0.3 cm) can be done easily and with good results from the vehicle side. The biggest barrier to mapping with very high-resolution satellite imaging data is the cost of data collecting, which is still fairly high, especially for mapping in a small area that requires more regular (daily or weekly) data repetitions. Unmanned aerial vehicles (UAVs) offer a low-cost, high-resolution option tothe concerns outlined above. They can be bought at any time with minimal limits for local-scale locations. The orthophotos created from numerous photos show the possibility of acquiring precise information about aterrain with a ground resolution of about 0.05 m, which is far greater than any current satellite imagery resolution. Multi-copters are a popular type of UAV that may be classified into several varieties based on the number of rotor arms. Traditional helicopters, hexa-copters (6propellers), octo-copters (8 propellers), and, of course, quadcopters with four propellers are all examples of multi- copters.

UAV is an unpiloted tiny aircraft that flies autonomously with on-board GPS, stabilizing on-board 3- axis gyro sensor and magnetometer in autopilot microchips, and tracking UAV telemetry at Ground Control Station (GSC). Navigation control, barometer, sonar, flight control, and an inertial navigation system are all includedin the UAV system. UAV photogrammetric refers to measuring systems that are autonomous, semiautonomous, or remotely operated. The UAV's flying height is between 100 and 300 metres above ground level, and it flies below cloud. To avoid image distortion, the right Earth-based flying height is required. The duration of flight is determined on the energy source. The maximum payload for a lightweight or micro-UAV launched by hand is only 1-2 kilos. The use of various power sources can have an impact on flight length and coverage area. For battery power, the aircraft takes two or three trips to cover a vast area. UAVs have been increasingly popular in the field of geomatics in recent years. Photogrammetric is a mapping technique that uses drones. Photogrammetric is the science of taking measurements from images. UAV photogrammetric combines close-range photogrammetric, airborne mosaic imaging, and terrestrial photogrammetry to create a novel measuring instrument for photogrammetric purposes.

LITREATURE SURVEY

A drone, or unmanned aerial vehicle, is an aircraft that does not have a human pilot on board and is a sort of unmanned vehicle. According to, the use of UAV drones for civilian purposes, particularly mapping, began in the mid-2006s, and included thematic mapping for agriculture, forestry, archaeology and architecture, environment, emergency management, and traffic monitoring, as well as project, regulation, classification, and UAV applications in the mapping domain. A ground vehicle and a mapping system are both components of a UAV system. A navigation device, an inertial measurement unit, a wheel odometer, cameras, and a Lidar make up the system. The primary benefit is that this navigation device provides direct platform georeferencing, allowing the MMS to identify all data and imagery acquired in a global reference datum. HD cameras are used to capture the visual view. Lidar is used to capture the geometry of the sceneries. Disadvantages include the requirement for an external carrier. It has ten HD cameras, is expensive, and has no top view. [1].

DJI Inspire 2 drones with Zenmuse X5S cameras and personal computers (PC) for data processing are the major hardware employed in the proposed UAV photogrammetry approach. With significant power support, the DJI Inspire 2has advantages in a wider range of domains. Only focused on one landcover object, mostly to test the accuracy of drone photographs.

Geographic information system software will be used for processing and modelling. AgiSoft Metashape from AgiSoft LLC was utilised, as well as ArcMap 10.3 from Esri Inc. Flight route planning and GCP determination, drone picture collection, DEM creation, 3D modelling, contour generation, and scenario map creation [2]

The goal of this project is to create an object detection algorithm based on CNN and 3d lidar placed on a UAV. Data preprocessing, postprocessing, and human categorization is the three primary components of the technique discussed here. Objects in this paper were divided into two categories: human and nonhuman. The classification was done by employing occupancy grid mapping to project the 3D point cloud onto a sequence of 2D planes. Supervised CNNs use single view and multiview image channels to classify images. The fundamental benefit of deploying lidar onboard a UAV is that data can be acquired rapidly and accurately over a variety of terrains. The main disadvantages are the high cost, difficulty to determine distance in heavy rain, and snow.[3] A rotating UAV with a high-quality medium format camera with a 55 mm focal length was used to record 3 cm GSD (ground sampling distance) photos while flying at a height of 300 metres. To maximise the visibility of more landscape elements for stereo-mapping, the photos were captured with an 80 percent end-lap and side-lap. Pix4Dmapper and ORIMA software were utilised. To eliminate shadows and maximise visibility of objects and landmarks, the waypoints were designed with an 80 percent side-lap and end-lap. The disadvantage of this approach is that the altitude and ground solution have already been determined, thus it can only be utilised for this range..[4]

I. APPROACH AND IMPLEMENTATION

Effective catastrophe management is one of the most pressing issues facing the world today. One of the biggest impediments to disaster management is the inaccessibility of broad areas of terrain, despite the urgent need for assistance immediately after a disaster. Unmanned aerial project, regulation, classification, and UAV applications inthe mapping domain.

A ground vehicle and a mapping system are both components of a UAV system. A navigation device, an inertial measurement unit, a wheel odometer, cameras, and a Lidar make up the system. The primary benefit is that this navigation device provides direct platform georeferencing, allowing the MMS to identify all data and imagery acquired in a global reference datum. HD cameras are used to capture the visual view. Lidar is used to capture the geometry of the sceneries. Disadvantages include the requirement for an external carrier. It has ten HD cameras, is expensive, and has no top view. [1].

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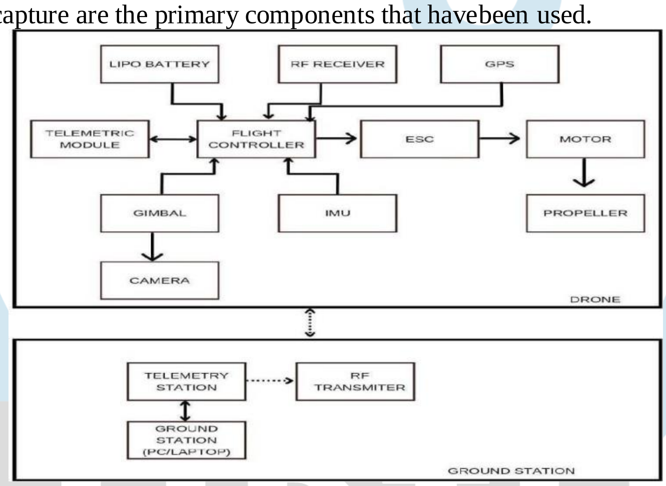
II. APPROACH AND IMPLEMENTATION

Effective catastrophe management is one of the most pressing issues facing the world today. One of the biggest impediments to disaster management is the inaccessibility of broad areas of terrain, despite the urgent need for assistance immediately after a disaster. Unmanned aerial vehicles (UAVs) have been increasingly popular in recent years as a means of assisting in numerous disaster management tasks and enhancing disaster response effectiveness. The project's main goal is to create an unmanned aerial vehicle (UAV) capable of mapping and 3D modelling of the target regions. They aid with SAR (search and rescue) operations, surveillance, and other types of monitoring. It cuts the time and number of searches needed to find and rescue an injured person. The system proposed is The CGA (Color Geolocation Approach) is a new approach for UAV aerial photogrammetry (mapping and 3D modelling). Our CGA method is based on location encoding and decoding, and it models the ground landscape using the SRTM DEM (Digital Elevation Model) model. Based on a known 2D position of the item identified on the image, this function estimates the position of a target on the ground. Our method entails creating a 3D model using the OpenGL APIand modelling the ground terrain mesh with the SRTM model.

Each triangle of the terrain mesh has its relative position to the STRM tile encoded in its colour. The camera mounted on a gimbal and an IMU mounted on the camera are the essential components The GNSS/GPS connected to the drone autopilot is located on top of the camera. The key challenge that was attempted to tackle was the accurate location of the drone and the current orientation of the camera. After detecting the 2D position of the object in the acquired image, we estimate its 3D world position. Our CGA method is based on position encoding-decoding and employs the SRTM DEM (Digital Elevation Model) model to model the ground terrain. It involves encoding the world locations of each point with a unique colour and then decoding it to recover the world position. The 2D position of the target recognised in the taken image, the altitude, and the UAV's GNSS/GPS location are the input data. and the camera's height, which is determined by an IMU mounted on top of the camera. This is accomplished by using the OpenGL API to implement CGA in a 3D engine environment. The camera on a gimbal, an IMU on top of the camera, the GNSS/GPS coupled to the drone autopilot location of the drone itself, and the orientation of the camera when capture are the primary components that havebeen used.



A. WORKING

a. Drones use rotors to propel and controlthemselves vertically. Air is pushed down by spinning blades. All forces are equal in magnitude, thus as the rotor pulls down on the air, the air pushes up on the rotor. As a result, the drone rises, which is achieved by managing the upward and downward forces. The more the lift, the faster the rotors spin, and vice versa.

b. In the vertical plane, a drone has three options:hover, climb, or plummet. To hover, the drone's net thrust from its four rotors must equal the gravitational force dragging it down. Increase the thrust (speed) of the four rotors so that an upward force greater than the weight exists. After that, we may reduce the thrust slightly, but the drone is now subjected to three forces: weight, thrust, and air drag. As a result, the thrusterswill still need to be larger than for a simple hover. Reduce the rotor thrust (speed) so that the net force is downward when descending. Turning (Rotating): The opposing pair of rotors rotates counterclockwise, while the others rotate clockwise. The total angular momentum is 0 when the two sets of rotors rotate in opposing directions. The moment of inertia is calculated by multiplying the angular velocity by it. The angular momentum is determined by the rotational speed of the rotors. If no torque is applied to the system (in this case, the drone), the total angular momentum must remain constant (zero in this case). If one pair of rotors has positive angular momentum and the other pair has negative angular momentum, the total angular momentum is zero.

However, reducing the spin of rotor 1 caused the drone to rotate, but it also reduced the thrust produced by rotor 1. The drone lowers as the net upward force no longer equals the gravitational pull. Worse, the thrust forces aren't balanced, thus the drone tips downhill toward rotor

1. Reduce the spin of rotors 1 and 3 and increase the spin of rotors 2 and 4 to rotate the drone. Because the rotors' angular momentum does not equal zero, the drone body must rotate. However, because the overall force equals the gravitational force, the drone continues to hover. The drone can keep balanced since the lower thrust rotors are diagonally opposite each other.

Forwards and Sideways: Because the drone is symmetrical, travelling ahead also means moving back or to either side. It requires a forward component of thrust from the rotors to fly forward. A drone travelling at a steady speed is shown in this side view (with forces). We could speed up the rotation of rotors 3 and 4 (the back ones) while slowing down the spinning of rotors 1 and 2. Because the overall thrust power is equal to the weight, the drone will maintain its upright position. Furthermore, because one of the rear rotors spins counterclockwise while the other spins clockwise, the increased rotation of those rotors will yield zero angular momentum. The front rotors are the same way, therefore the drone does not rotate. The drone will lean forward due to the larger force in the back. A small increase in thrust for all rotors will result in a net thrust force that includes a weight-balance component as well as a forward motion component.

Flight control CPUs can use data on the attitude, velocity, location, and heading of the UAV to direct the flight and operation of the vehicle according to the parameters defined by the user by integrating an array of sensors including gyros, magnetometers, and accelerometers with a GPS.

Ground Control Stations: Ground control stations for unmanned aircraft systems (UAS) autopilots are designed to be as user-friendly as possible, allowing users to simply construct flight plans and alter them in the air, adding waypoints and making modifications as needed. Many control units have mission simulators and safety pilot modes, which allow operators to take manual control of the UAV in the event of an emergency. Video receiving, mapping functions, payload control, and simultaneous vehicle control are examples of other ground control station features.

3D modeling

After recognizing the 2D position of the object in the acquired image, the UAV system calculates the object's 3D world position. To simulate the ground landscape, we use a position encoding-decoding method. The 2D position of the target recognized in the acquired image, the UAV's altitude and GNSS/GPS location, and the camera altitude using an IMU mounted on top of the camera are used as input data. Lidar range finders are typically employed to detect target objects on the ground, but their volume, mass, and power needs make them impractical for small drones. Through the camera's external shutter release, a UAV flight control computer was linked. The camera was triggered to acquire photographs and store them according to the flight plan when the UAV arrived at the test area. On the drone, an AHRS (attitude and heading reference system) was mounted, which was combined with GPS signals. When each shot was triggered, the flight control computer captured the camera position using GPS and AHRS data for later UAV aerial photogrammetric processing. Following target detection, the 3D engine camera is oriented using the IMU readings from the gimballed camera. Decoding the colour of the pixel at the intersection of the ray that passes from the object position at the image plane and the terrain mesh yields the target/object geolocation. The terrain has been modelled using the SRTM DEM. If the SRTM file is visualised in 2D, the first step is to load it into memory. Then, utilising the loaded elevations, we generate a 3D terrain mesh model. At the time of terrain mesh production, the colouring strategy entails encoding the position of each point of the terrain with a unique colour. Use the OpenGL readPixel functionality to read the current vertex buffer and extract the colour at a specific 2D position on the camera window once an object is detected on the image.

SOFTWARE DESCRIPTION

Arduopilot

ArduPilot is an open source autopilot system that supports a wide range of vehicle types, including multicopter aircraft, traditional helicopters, fixed-wing aircraft, boats, submarines, rovers, and more. A huge community of professionals and enthusiasts work on the source code. The ArduPilot software suite includes ground station controlling software such as Mission Planner, APM Planner, QGroundControl, MavProxy, Tower, and others, as well as navigation software (typically referred to as firmware when it is compiled to binary form for microcontroller hardware targets) running on the vehicle. With nearly 400 total contributors, ArduPilot source code is stored and managed on GitHub. The software suite is built nightly, with Travis CI providing continuous integration and unit testing, and a build and compiling environment that includes the GNU cross-platform compiler and Waf. Users can acquire pre-compiled binaries for a variety of hardware platforms from ArduPilot's sub-websites ArduPilot has a variety of features, including the ones that are common to all vehicles:

- Flight modes include fully automated, semi- autonomous, and fully manual, as well as programmable missions with 3D waypoints and optional geofencing.
- Options for stabilisation to eliminate the requirement for a third-party co-pilot.
- ArduPilot SITL and other simulators are used for simulation.
- Several versions of RTK GPSs, classic L1 GPSs, barometers, magnetometers, laser and sonar rangefinders,

optical flow, ADS-B transponder, infrared, airspeed, sensors, and computer vision/motion capture devices are all supported.

• SPI, I2C, CAN Bus, Serial communication, and SMBus areall options for sensor communication.

• Failsafes for radio contact loss, GPS failure, and breaking a predetermined boundary, as well as a minimum battery power level.

• Vision-based positioning, optical flow, SLAM, and Ultra Wide Band positioning support navigation in GPS-deficient situations.

Pix4Dmapper

Pix4Dmapper is a photogrammetry software market leader. The images were first imported into the applications, then combined. The Initial Processing tool and Agisoft Photoscan - Align Photos are used by Pix4D. In both cases, the image size to which the similarity points (characteristic, base) were searched may be specified. Three levels of precision were chosen:

- low - 1/4 resolution is considered,
- medium - 1/2 resolution is considered, and
- high - a full resolution photograph is considered.

The parameters of the images' internal and external orientation are pre-determined by these functions. As a result, there were clouds of points with no spatial reference. The coordinates of three places from a photogrammetric matrix were loaded to provide georeference. The photogrammetric retroreflection rule requires a minimum of three sites with known coordinates. The identical spots were selected and marked on the same location on the photos in both applications. Points were made and marked on the photographs in their true location using Create Markers (Agisoft) and GCP (Ground Control Points) / MTP (Manual Tie Points) Manager (Pix4D). The internal and external orientation characteristics of the images were optimised at the end of the point determination phase. The point's coordinates weredetermined in this manner.

The image acquisition strategy is determined by:

Reconstruction of a terrain or an object. GSD (Ground Sampling Distance): The distance (flight height) at which the photographs must be taken will be determined by the GSD required by the project specifications. A GSD of 5 cm, for example, means that each pixel in the image corresponds to 5 cm on the ground (5*5 = 25 square centimetres).

Overlap: The rate at which the photos must be captured is determined by the type of terrain being mapped and the overlap.

A poor image acquisition strategy will result in erroneous results or processing failure, necessitating the acquisition of new photos.

In most cases In most circumstances, acquiring photos with a consistent grid pattern is recommended. At least 75 percent frontal overlap (in relation to the flight direction)

and at least 60 percent side overlap are recommended (between flying tracks). To achieve the ideal GSD, the camera should be kept at a constant height over the landscape / object as much as feasible.

Depending on the topography, the overlap and flying height must be adjusted. At least 80% frontal and side overlap is suggested for flat farm areas. Increase the overlap to at least 85 percent frontal and side overlap and fly higher in forest, dense vegetation areas to make it simpler to find similarities between overlapping photos.

The flight planning programme Pix4Dcapture, which is available on Android and iOS, can automatically fly all of the flight plans shown below. There should be overlapbetween the different flights in projects with many flights, and the conditions (sun direction, weather conditions, no new structures, etc.) should be similar.

Procedures for processing

1. Initial preparation
   - Extraction of keypoints: Identify certain aspects inthe photos as keypoints.
   - Matching keypoints: Determine which images have the same keypoints and pair them together.
   - Model optimization for cameras: Calibrate the camera's internal (focal length,...) and external (orientation,...) characteristics.
   - If geolocation information is available, locate the model using GPS/GCP.
2. Mesh and point cloud
   - Point Densification: Based on the Automatic Tie Points, additional Tie Points are constructed, resulting in a Densified Point Cloud.
   - 3D Textured Mesh: A 3D Textured Mesh can be constructed using the Densified Point Cloud.
3. Orthomosaic, DSM, and index
   - The construction of the Digital Surface Model (DSM) will enable the computation of Volumes, Orthomosaics, and Reflectance Maps.
   - Orthomosaic: Orthorectification is used to create the Orthomosaic. The perspective distortions in the photographs are removed using this procedure.
   - The goal is to create a map in which the value of each pixel accurately represents the object's reflectance.
   - Create an Index Map in which the colour of each pixel is calculated using a formula that blends the Reflectance Map's distinct bands (s).

III. RESULT AND OBSERVATION

There were 3 field experiments for 3D mapping altogether. In order to determine the minimal hardware requirements needed to execute the 3D models with high quality, a laptop computer with various system requirements were employed for processing. The initial laptop has an Intel ® Core TM i5 -420QM CPU clocked at 1.60 GHz and 2.30 GHz, with 8.00 GB of RAM. In order to determine which file type can yield the greatest results with 3D mapping, many file formats, such as P4D or JPG, were generated during the data processing step. A P4D file with geolocation data saved in the EXIF data is created when one flight mission and 3D mapping processes are successfully finished.

Depending on how the visual asset was gathered, the image processing technique may change. The 3D models from the field tests have a quality for the construction of buildings and terrain, agriculture, search and rescue operations, etc. A 3D mapping with a higher point density than one with an ideal point density is more accurate based on processing settings. Higher point density means more accuracy because there are more point features surrounding each output raster cell. Compared to an image format without geo-location information, the P4D file performed better (Still image). Additionally, multi-scale photos provided better 3D mapping accuracy than smaller image scale, although processing took considerably longer due to the larger number of key-points in multi-scale images compared to smaller image scale. This enables more precise image matching throughout the registration procedure. This makes it possible for the registration process to match the photos more

Fig: 2D image captured by camera & 3D modeled image

A. ADVANTAGES, LIMITATIONS AND FUTUREPERSPECTIVES

The ability of actual UAV systems to transmit high temporal and spatial resolution image information fast and allow a speedy response in a variety of critical scenarios when immediate access to 3D geoinformation is needed is a significant benefit. Indeed, UAVs have real-time data collecting, transmission, and possibly processing capabilities. Because rotary wing UAV platforms can take off and land vertically, there is no need for a runway. UAVscan supplement or replace terrestrial acquisition in small- scale applications (images or range data). The resulting high-resolution images can be utilised for texture mapping on existing 3D data, as well as mosaic, map, and drawing generation, in addition to geometric modelling. When compared to typical aerial platforms, they lower operational expenses and the risk of access in hostile environments while maintaining excellent accuracy. However, in order to attain the same picture coverage at a comparable quality, compact or medium format cameras, which are commonly used, especially on low-cost and small payload systems, demand the acquisition of a higher number of photos. The stability and endurance of low-cost and light platforms, particularly in windy places, is also a concern, though camera and platform stabilisers can help mitigate weather dependence. A disadvantage could be the requirement of at least two people for system manoeuvres and transportation. The acquisition of image blocks with acceptable geometry for the photogrammetric process remains a key issue, particularly for large-scale projects and nonflat objects (e.g. buildings, towers, rock faces, etc.). While flight planning is simple when employing nadiral views, it becomes much more difficult when dealing with 3D objects that require convergent images and, maybe, verticalstrips. Future work will focus on developing tools to make this effort easier. Despite the fact that automated image processing is already achievable with fairly dependable and exact results, there is still room for progress in the near future. Advanced DSM generation algorithms may give surface models in a quick time thanks to GPU programming, while high-end navigation sensors like DGPS and costly INS would allow direct georeferencing of the captured photos on location. Advanced SLAM methods could be used to produce real-time picture orientation in low-end navigation systems.

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