UAVs, Applications of Photogrammetry and Aerial Survey and Mapping in Drones

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Abstract

In the report, I will be highlighting few relevant information on UAVs in general, Photogammetry and it's application, Remote Sensing ,Aerial Survey and Mapping and lastly, Software/tools for Aerial Survey and Mapping/Photogammetry.

1. UAV

1.1. Introduction

Unmanned Aerial Vehicles (UAVs) / Drones are autonomous/remote controlled aircrafts that don't have a human pilot driving them.

1.2. Types

There are various types of UAVS, depending upon their functional use, aerodynamics,landing, weight and their altitude/range.

1.2.1 Based on Function

- Combat - For highly risky missions, UAVs can be used for attack purposes.
- Reconnaissance – Provides surveillance in areas difficult to reach/get information/intelligence from.
- Target and decoy – Helps to mimic enemy aircraft during training
- Logistics – Provides assistance in carrying goods like maybe food for calamity stricken countries or just simply used for transport of small objects during emergency situations.
- Civil and commercial UAVs – Used to support agriculture, urban land survey and map,unknown terrain map, etc.
- Research and development – Improving existing technologies in UAVs for better data capture, reducing distortions, improving details in mappings and reducing time.

1.2.2 Based on Aerodynamics

- Fixed-wing aircraft
  - The drones are simple but limited in designing and manufacturing.
  - The primary lift-generation is provided by the fixed wings
  - Requires higher initial speed and thrust to load ratio < 1 to being flight
  - Cannot hover in the same position and cannot maintain lower speeds.
  - Unstable during win conditions
- Flapping Wing
  - Inspired from insects
  - Very light-weighted wings inspired from birds feathers
  - Stable during wind conditions.
  - Easily mobile
- Ducted Fans
  - Drones where their 'thrusters' are enclosed within a duct.

- Can take off and land vertically as weel as hover and be controlled by two counter rotors and four control surfaces (vanes)

- Fixed/flapping-wing
  - Combining both fixed and flapping where lift generation is from fixed and propulsion is from the flapping wings.
  - Increases efficient and balance.

- Multirotor
  - Lifting and propelling comes from the thrust of the main blade.
  - They can do VTOL and hover at a position
  - Hovering and speed abilities makes them ideal for surveillance purpose and monitoring.
  - Need more power

1.2.3 Based on Landing

- Horizontal takeoff and landing (HTOL): They have high cruise speed and smooth landing
- Vertical takeoff and Landing (VTOL) They are great in vertical flying, landing and hovering, but not with cruise speed because of the the decline of retreating propellers.

1.2.4 Based on Weight

- Micro air vehicle (MAV) – Weigh less than 1g
- Miniature UAV – Weight approx. less than 25 kg
- Heavier UAVs. $>$ 500 kg

1.3. Advantages

1.3.1 Single-Rotor

- It's a VTOL flight
- it's a Hover flight
- It has a Heavy Payload
- It has a long endurance and large coverage

1.3.2 Multi-Rotor

- It's a VTOL flight
- It's a Hover flight
- It has great Mobility
- Can be used Indoors/Outdoors
- Can be used in Small and cluttered areas
- It has a simple design

1.3.3 Fixed-Wing

- It has a long endurance and large coverage
- It's flight speed is quick
- It has a Heavy Payload

1.3.4 Hybrid

- It has a long endurance and large coverage as well
- It's a VTOL flight

1.4. Disadvantages

1.4.1 Single-Rotor

- Area coverage is small
- It is more dangerous

1.4.2 Multi-Rotor

- Area coverage is small as well
- It has Limited payload
- It has shorter flight time

1.4.3 Fixed-Wing

- It needs a specific area for Launch-Landing
- It has no hover flight
- It requires forward velocity constantly to fly

1.4.4 Hybrid

- It is still under development
- It is a transition b/w hovering and forward flight

1.5. Limitations/Challenges

- Technology Challenges There is a great concern for payload endurance.
- Safety and security/Liability Accidents, injuries and interference with public and private freedom.
- Privacy Flying on private property
- Airspace interference Interfering with usual commercial airspace and breaching restricted regions

1.6. Recent Advances

1.6.1 Agriculture

- Helps in Precision Farming
- Helps control pesticide spraying and fertilisers.
- Aerial mapping and monitor of vegetation is built upon the spatial,temporal and spectral resolution of sensors onboard such as MODIS, OLI, and AVHRR
- UA drone used Microdrone MD4-200 with a team ADC lite digital CMOS camera with image resolution of 1200x1024 pixels to estimate nitrogen and aboveground biomass of soybeans, alfalfa and corn crops.
- A drone along with multispectral and thermal sensors to describe the spatial variability of water within a commercial rain-sustained vineyard.

1.6.2 Forestry, fisheries and wildlife protection

- A remotely controlled fixed wing UAV with thermal and hyperspectral sensors helped towards forest fire detection and monitoring
- UAV equipped with thermal sensors along with satellite are being approached for monitoring, tagging and counting of animals which help to wildlife conservation and curb poaching.

1.6.3 Defence

UAVs started off and still are used widely for war missions like intelligence, spying, reconnaissance vigilance and target detection.

1.6.4 Civil Applications

- Drones are being sought upon from electricity companies to the railway industry.
- Electrical companies are preferring drones for inspection of high tension lines with ease of risky task of climbs and power outages
- The Indian government is planning 3d mapping of thousands of kilometres long railway corridors and national highways.
- They are helpful during search and rescue operations of missing people during disasters.

2. GIS/Photogrammetry

2.1. Introduction

Photogrammetry is used to extract a model of a real-world object/scene by the principle of triangulation, which provides the 3-D real-world location/coordinates of the objects through the intersection of minimum two LOS (line-of-sight) rays, each originating from different perspective positions of the camera to the object points.

2.2. Usage/Application

2.2.1 Camera Location based Classification

- Aerial Photogrammetry: Aircraft is mounted with a camera on it's bottom, pointing vertically down towards the surface with a vertical or nearly vertical camera axis
- Terrestial Photogrammetry:

  The Photographs are taken from a fixed position on or near the ground and with a horizontal or nearly horizontal camera axis.
- Space Photogrammetry: Extraterrestrial photography with the camera may be on the earth, artificial satellite, or another planet.

2.2.2 Type-based Classification

- Interpretative Photogrammetry: This type of photogrammetry involves analysing and identifying objects through accurate interpretation of aerial photographs. It's also known now as remote sensing, and by remote aerial structures like satellites.
- Metric Photogrammetry: This helps to determine areas,volumes,distances,etc from precise measurements of photographs, thus being able to form maps as well. It's used by both aerial and terrestrial camera positions.

2.2.3 Type-based Classification of Aerial Photographs

- Vertical Photograph: When the optical axis of the camera is vertical or nearly vertical, the photograph taken is called a vertical photograph. Tilt must be less than 3 degrees
- Tilted Photograph: If the axis is tilted from the vertical, the photograph becomes a tilted photograph. Tilt is greater than 3 degrees
  - High Oblique photograph: When the Apparent Horizon appears
  - Low oblique Photograph: If the Apparent Horizon does not appear
- Angular Filed of View (FOV) Classification:
  - Normal Angle Photograph: FOV is between 50 to 75 degrees
  - Wide Angle Photograph: FOV is between 75 to 100 degrees
  - Super/Ultra wide angle Photograph: FOV is between 100 to 150 degrees

2.2.4 Lapping in Vertical Photography

- During vertical photography, the flight strip process is such that there is an overlap/duplication between successive photographs
- Stereoscopic overlap (End lap) is the overlapping area between successive adjacent pairs of photographs in the flight strip. It is usually 55% to 65%
- Side laps are from adjacent flight strips and are normally 25% to 30% Block of photographs are two or more side-lap strips.

3. Remote Sensing

Remote sensing is a state-of-the-art inspection technique that helps to map vital structural, environmental, terrain features using an aerial object like a UAV. It can be combined with Photogammetry and some automation to provide and monitor spatio-temporal changes over the area by converting raw data into 3D mappings. It is extremely useful as it helps to also decrease in-person work while at the same-time provide valuable information about dangerous and narrow terrains.

4. Drone/Aerial Survey Mapping

4.1. Algorithm

- Data Capture: A camera is mounted to the bottom of the drone and is pointing vertically down towards the surface. A large number of overlapping images are hence captured by the drone along the path
- Photogrammetry: A high resolution 3-D model/map is extracted through photogrammetry by projecting onto a orthophoto and all of them are mosaiced (Orthomosaic) after refinement of distortions by the photographs extracted by the drone The photographs extracted by the data capture are processed through stitching, preferably an automated method after which a high quality map is formed.

4.2. Industry Applications and Usage

They are used in many applications

- Police and Fire Departments:
  - Mapping highly frequented locations in cities, such as malls and schools:
  - Documenting crime scenes:
  - Mapping after disasters:
- Real Estate: Drone mapping, being of a higher quality than satellite images because of the lower altitude, can capture finer details of the estate for the interested costumer to view remotely. This

solves the commutation problems of ever-busy prospective clients, therby saving time.

- Construction: Maps can be used to generate 3-D models of the construction area. It can also be used to keep-track of progress of the project remotely with detailed picture of the raw-materials being used, hence, in real-time remotely, suggest changes/improvement.
- Conservation Drone mappings help to keep track of the increasing levels of poaching. It also helps keep track of withered away trees, forest fires, etc.
- Agriculture This field has one of the most bigger chances of making an impact as it helps farmers keep track of irrigation details, and figure out poor regions without traversing along the whole field everytime, saving their energy and time. Some help in precision irrigation, which helps their yield even more.

4.3. Terminologies

4.3.1 Orthomosaic

An Orthomosaic map is a detailed, accurate photo representation of an area, created out of many photos that have been stitched together and geometrically corrected (“orthorectified”) so that it is as accurate as a map.

4.3.2 Topographical Mapping

Topographical Mapping is the mapping of the 3-D layout of the ground (terrain,buildings,vehicles,etc) to a 2-D surface using Photogrammetry.

4.3.3 DEM-Digital Terrain Model (DTM)

- DTM contains terrain only
- Buildings,roads, vegetation,vehicles,etc are not included

4.3.4 Digital Elevation Model (DEM))-Digital Surface Model (DSM)

- DSM contains terrain information as well as buildings,roads, vegetation,vehicles,etc, ie, any objects above surface.
- Creation of an Orthomosaic map/ single Orthophoto requires DSM, since better detail means better 3-D point cloud/mesh.
- Highly detailed
- Each pixel contains (X, Y, Z) where (X, Y) is the 2D information (Z) is the altitude of the highest point for this position.

4.3.5 Point Clouds

Point clouds is the fine-grained collection of points taken from the triangulation of the position of an object (photogrammetry) plotted in 3-D space

4.3.6 3d textured mesh

3D Textured Mesh is a culmination of meshes whose vertices,edges,faces and texture are the refined points from the point cloud

4.3.7 Contour Lines

Contour lines are created from either of the Digital Elevation Models (DSM/DTM) through contour intervals.

4.3.8 Advantages of Aerial Survey by Photogammetry

- High spatial resolution (influenced by correcting/optimizing camera parameters)

4.4. Data Captured by Drone

- Orthomosaic Maps
- 3D Point Cloud
- Digital Elevation Models
  - Digital Surface Model (DSM)
  - Digital Terrain Model (DTM)
- 3-D Textured Mesh
- Contour Lines

4.5. Advantages/Importance of Aerial Survey

- Reduced time and costs: Topographical mapping using a drone facilitates fewer manpower and is much more quicker than the former. Also with geo-tagging, multiple surveyors need not be present, hence saving resources and time, is faster and reduces cost.

- Provide accurate and exhaustive data:A single drone flight produces thousands of measurements, which can be exported in multiple formats (orthomosaic, point cloud, DTM, DSM, contour lines, etc), with each pixel containing important 3D information.

- Mapping otherwise inaccessible areas: The drone can map dangerous terrain, steep slopes which prove difficult to survey through original means. Saves lives, money and time.

4.6. Disadvantages of Aerial Survey

- Can sometimes cause difficulty in identifying objects due to obscuring.

- Has many distortions like geometric, height.

- Mapping restrictions due to wind

- Risk of equipment failure

- Data management issues of larger areas.

4.7. Available Software/Tools for Aerial Survey Mapping

4.7.1 DroneDeploy

They help create accurate, high-resolution maps , 3D models, live-maps. They are Cost-Effective and compatible with third-party UAV.

4.7.2 Pix4D

Pix4D is a Swiss company that offers a suite of photogrammetry applications. It plans UAV flight, creates orthomosaics, point clouds and professional 3D models. It gives maximum accuracy and efficiency when a drone is compatible. It also provides NDVI video in real-time while in air.

4.7.3 Photo Mod

It contains all photogrammetric products like DEM, dDSM, 2D and 3Dvectors and orthomosaics

4.7.4 Agisoft

It's is a Russian tech company that started in 2006. Their software does photogrammetry, 3D modeling, panorama stitching, and support for fisheye lenses.It's a cost-effective all-in one software suite with a full range of image sensors

4.7.5 Sensefly eMotion

It's used for drone flight planning and data management.

4.8. Disadvantage of above Available Software/Tools for Aerial Survey Mapping

4.8.1 DroneDeploy

It's surface resolution of structures like buildings is a bit poorer when compared to Agisoft and Pix4D for

4.8.2 Pix4D

Unfortunately topographical maps can only be created manually.

4.8.3 Photo Mod

It doesn't contain camera self- calibration facility (as opposed to pix4D)

4.8.4 Agisoft

It has less functionality compared to Pix4D and requires a single license per computer.

4.8.5 Sensefly eMotion

It has no real time NDVI processing despite having a very advanced software.