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APPLICATION OF HIGH-DEFINITION AERIAL DATA IN TRANSPORTATION ENGINEERING

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ABSTRACT

Transportation engineering is data dependent. Traditional methods of acquiring data are time consuming and resource intensive. Geometric and traffic data are usually collected through surveying, such as, reconnaissance survey, traffic survey, topograpghic survey, which may require skilled manpower. In urban areas with high population density and heavy traffic volume, such surveys may disrupt the usual traffic flow creating congestion and potential road safety concern. Even on high speed roadways having low traffic volume pose road safety hazards to the on-road survey personnel. Furthermore, in recent years the world has also experienced that a pandemic like COVID-19 may put someone's health at jeopardy if they come into contact with people in densely populated areas. Survey personnel might suffer from serious health risks in such circumstances. These issues demand alternative safe methods for such data collection. Fortunately, due to recent advancement in technologies, high definition aerial imaging process has become more accessible and require minimal skill than ever before. Drone technology has advanced to the point where it is now possible to perform photogrammetry survey over a moderate area with less effort and in shorter duration yet with higher accuracy. Artificial intelligence technology has also enabled realistic 3D modeling of the study area from aerial photography. Regarding traffic data, high definition video captured by drones are also deemed beneficial to understand broader perspectives than at-grade video captured by regular cameras. This paper aims to explore possible data extraction methods using high definition aerial imagery and video data captured with drone technology and their implementation in regular transportation engineering practices as an alternative to traditional survey methods. Safety, functionality and limitations of such methods are also taken into concern and discussed by authors.

Keywords: *Drone, aerial photography, high definition, remote sensing, survey*

1. INTRODUCTION

The use of aerial imagery in surveying predates world war era. The technology for aerial photogrammetry was still in an immature state until the Second World War (Collier, 2018). Aerial images were used mostly for military reconnaissance. Due to lack of technology and complexity of aerial photography in that period, photogrammetry could not be widely adapted into other survey methods where more accurate measurements of the topography were required. The conventional survey methods were still the choice to rely upon for precise measurements.

After the world war era, rapid developments in designs of both survey airplanes and special aerial survey cameras had transformed aerial photogrammetry surveying as a mainstream survey practice (“History of Photogrammetry,” 2008). Although the technology offered a rapid method to survey large areas, it was expensive and cumbersome for small areas to be surveyed with aerial imagery and creating a map using those images rather than using conventional survey methods.

It was only in the last couple of decades that the advanced innovations in unmanned aerial vehicle (UAV) took place and made UAV a viable widespread option for small scale remote sensing projects (Cracknell, 2018). Commercially available modern day UAVs, also known as drones, are equipped with high definition cameras and they are capable of capturing all the necessary data for high quality photogrammetry in an easier and satisfactory way more than ever before. Aerial imagery obtained from UAVs are in application for remote sensing in various scientific and technical fields and many others are still probing into possible opportunities of this technology.

Enormous sets of data are in high demand for transportation engineering. These datasets usually include information of road geometry, road furniture, vehicle profile, driver behaviour, visual obstacles, pavement conditions, land use, and many other relevant features. Traditionally these data are collected through various surveys, such as reconnaissance survey, traffic survey, topographic survey etc. Using various measuring tools such as measuring tapes, total stations, 3D scanners, cameras, GPS, RTK and many complex and expensive sensors and equipment are required in these surveys.

These survey works are also very demanding of skilled manpower, high expense and time. Also their operations are often very complex and may disrupt usual traffic flow while operating on road in a busy and densely populated urban area. Such disruption may cause traffic congestion or potential road safety concerns. Even on high speed roadways having relatively low traffic volume pose safety hazards to the on-road survey personnel. In recent years, another health safety concern has been risen regarding pandemic situations after COVID-19 has spread worldwide. In such pandemic situations, survey personnel's health might be in jeopardy if they come into human contact in densely populated areas as it has been observed that the risk of COVID-19 contraction is higher in densely populated area (Bhadra, Mukherjee, & Sarkar, 2021; Sy, White, & Nichols, 2021).

Alternative safe methods for data collection are needed to be explored in order to overcome the issues regarding traditional data collection methods. The authors had an assignment to survey around twenty locations inside Dhaka city within a short period. Initial data collection of road geometry was highly challenging due to high volume of traffic and the nature of traffic flow. Also the task was assigned in the midst of Covid-19 pandemic which was considered a high risk for the health of the survey team. Hence, the authors adopted drone survey method in order to expedite the survey process while maintaining accuracy and ensuring health safety. This paper will systematically discuss the benefits and limitations of drone survey methodology adopted by the authors.

2. LITERATURE REVIEW

Aerial data in the form of image and video has been being used in transportation engineering for over a few decades. Agouris, Stefanidis, and Beard emphasised on benefits of digital photogrammetry in transportation engineering prospects of monitoring physical roadway, traffic within corridors, land use and other similar aspects (Agouris, Stefanidis, & Beard, 1997). Although data acquired by digital photogrammetry contain great details, use of this technic was very limited due to high expense and skills tied to it. In the last decade, advancement in UAV technology has made photogrammetry more accessible. Maintaining accuracy of position data was a big challenge for drone data collection systems in early years. Modern drones have proved themselves to be accurate enough in comparison with traditional methods to conduct road surveys (Babinec & Apeltauer, 2016; Barry & Coakley, 2013; Elkhrachy, 2021; Guido, Gallelli, Rogano, & Vitale, 2016; Zulkipli & Tahar, 2018). Dobson, Brooks, Roussi, & Colling used a high resolution DSLR camera and a Bergan Tazer 800 helicopter UAV to develop a road assessment system to be able to obtain sub-centimetre resolution data (Dobson, Brooks, Roussi, & Colling, 2013).

Transportation engineers and researcher are continuously searching for new opportunities to integrate UAV technology with transportation engineering applications. Congress, Puppala, Banerjee, and Patil used digital elevation model (DEM) from drone analysis to identify hazardous obstructions within an intersection (Congress, Puppala, Banerjee, & Patil, 2021). Kim collected pedestrian and bicycle data using drone video capturing method (Kim, 2020). Kaufmann, Kerner, Rehborn, Koller, and Klenov also used drone captured video in order to observe moving synchronised flow patterns of vehicles (Kaufmann, Kerner, Rehborn, Koller, & Klenov, 2018).

3. AERIAL DATA COLLECTION METHODOLOGY

Generally, using a drone camera, aerial data can be collected either as video format or as still image format. Image files captured by drone camera usually contain various useful information such as longitude, latitude, altitude, camera model information, camera settings and other details. Image or video data collection procedure can be executed in two different methods. As the first method, the drone can be operated manually and hover over a convenient vantage point or fly over the area of interest to capture image or video data. The second method is to operate the drone autonomously by executing predetermined flight missions with a programmed flight plan. The authors used a DJI Phantom 4 Pro V2 model drone with both methods.

3.1 Manually Capturing with Drone Camera

Figure 1: DJI GO 4 interface during a manual flight

The most basic method is to manually fly the drone to a convenient position and start recording video or capturing images. This method requires a skilled drone pilot to operate the drone. In this method, a drone pilot operates the drone remotely from a safe location. The pilot uses visual information shown in the remote controller's display to control drone navigation and camera orientation. Usually information is shown as GPS map, drone dynamics, drone camera feed, signal strengths and other details. The authors have used DJI GO 4 application for executing their manual flight missions. Fig. 1 shows the application interface with flight information displayed during a manual flight mission.

Manual flight is desired where there is possibility of presence of undetectable obstacles, such as electric wires, in the drone's flight path. This method works best for collecting video data of traffic dynamics from a hovering position or by flying over the area of interest. Also if satellite signal strength is not strong enough for autonomous photogrammetry flight mission to be executed, the mission might be executed in manual method although it will require much expertise and understanding of photogrammetry principles.

3.2 Autonomous Flight Missions

Drone flight missions can be automated using pre-programmed flight plans through various software packages. Currently for autonomous flight missions, some of the most used software packages are DroneDeploy, Pix4D, Litchi etc. These software packages offer fully automated data collection process which require no human input during the drone flight. Most of the time, full photogrammetry survey process can be executed within the scope of these software packages without having skills required for this types of survey. Image and video capture around a subject of interest, panoramic photo capture etc. can also be automated in their scope. The authors used DroneDeploy software platform which is a cloud based software package. All the flight planning, flight execution and data processing were done using the DroneDeploy software tools.

Usually the pilot or a surveyor set the boundary of the area to be surveyed in the software module. A flight plan is generated automatically covering the area inside the boundary. The attributes of the automatically generated flight plan can be customized according to certain preferences. Once all the conditions are satisfactory, the autonomous flight mission can be launched on command and it will be carried out autonomously from take-off to landing.

Figure 2: Autonomous flight mission settings in DroneDeploy

Autonomous flight missions are preferable when systemic photogrammetry survey over a medium to large area is required. It is also useful for taking images or videos from predetermined vantage points to cover large areas.

4. PROCESSING AERIAL DATA CAPTURED BY DRONE CAMERA

Aerial data captured in image and video format by drone camera is needed to be processed for analysis or proper meaningful interpretation. Various software packages offer multiple types of processed output from aerial images and videos. The authors processed their raw data using DroneDeploy software package. The raw images captured by drone camera are uploaded into its cloud computer through a DroneDeploy account dashboard. The software then processes the data and returns multiple types of files, naming orthomosaic 2D map, 3D model, point cloud, digital terrain model (DTM), digital elevation model (DEM), elevation contour dxf and shapefile, within few hours. The authors used orthomosaic 2D map image, 3D model and point cloud to conduct topographic survey of study areas. The authors also manually processed video data for tasks such as traffic volume count survey, traffic behaviour and pedestrian interaction observation and few other applications.

4.1 Point Cloud

Figure 3: Point cloud of a surveyed location

In most software packages, at first a dense point cloud is generated using multiple overlapping images. Usually a point cloud is comprised of millions of points with coordinates in three dimensional space. These points are generated by triangulating intersecting pixels from multiple overlapping images. Point cloud generated from images instead of Lidar can store colour information of each particular points which gives benefit for visualisations and other data processing. A demonstration of dense point cloud of a surveyed location is given in fig. 3.

4.2 3D Model

Figure 4: Photo-realistic 3D model of a surveyed location

Usually 3D models of surveyed locations are created using the point cloud generated from the images. A cluster of similar points located inside the point cloud are joined with a polygonal mesh object. A collection of these polygonal meshes then creates the full 3D model. Fig. 4 shows a photo-realistic 3D model of the same location displayed in fig. 3.

4.3 Orthomosaic 2D Map Image

An orthomosaic 2D map image is generated by stitching a collection of overlapping images together and correcting geometric distortions in the image so that the scale is uniform throughout the image. This image is free of perspectives meaning vertical faces remain orthogonal to the image. Orthomosaic images are as accurate as a map and dimensions from the image can be taken as true representative of the topography (Zulkipli & Tahar, 2018). Fig. 5 shows an orthomosaic 2D map image of the surveyed location presented in fig. 3 & 4.

Figure 5: Orthomosaic 2D map image of a surveyed location

4.4 Video Data Processing

Figure 6: Traffic observation from video data

Video data are usually used for analysing traffic dynamics of the study area. Usually simple analysis such as traffic count survey over a short period and area can be done by manually observing video data and recording the observed information. In order to conduct more complex analysis such as vehicle tracking and vehicle trajectory identification, often computer programs are used to automate the process.

Fig. 6 presents a screenshot of a video data that the authors used to determine traffic behaviour of a whole intersection at once. The authors manually counted traffic volume and observed vehicle path for their analysis.

5. ADVANTAGES AND DISADVANTAGES

5.1 Advantages

The application of aerial data has an overwhelmingly positive impact on transportation engineering aspects over other data collection methods. A few of the advantages of drone data collection method that the authors directly got benefited from have been discussed forward.

5.1.1 High-Definition Data

High-definition images and videos help identify very fine details of the surveyed location. Identification of small potholes, ditch, pavement depression, physical obstacles on footpath or roadways, damaged road structures are much convenient with drone survey.

5.1.2 Accuracy

With advancements in recent drone technologies, drone survey method has achieved desired level of accuracy and established itself a direct competitor to traditional survey methods. Also, automation in data collection has eliminated the chance of discrepancies in dataset incurred by human error. In the cases of 2D map generated by authors, average discrepancy of the maps were found to be less than 10 cm. Whereas, previously prepared maps from conventional topographic survey of the same locations were found to have discrepancy of more than few meters.

5.1.3 Time and Cost Efficiency

With automation of data collection by drone, it has been made possible to collect data of a large area with dramatically short period compared to other methods. Authors have observed that 1 acre of land survey for a road intersection generally requires about 10 minutes of flight time for drone survey whereas conventional method with a survey team of 6-8 personnel took about 2 to 3 hours to record sufficient amount of data. In terms of manpower and equipment, fewer resources are required for drone survey. Reduction in time and resources also help reduce the overall cost regarding the survey work.

5.1.4 Safe Operation

In conventional methods, for taking measurements on pavement, traffic has to be momentarily stopped in favour of the operational safety in few cases. The authors have experienced in the context of Dhaka city that, most of the drivers intend to disobey such stop signals and this creates the risk of getting run over for the survey personnel in busy intersections. In drone survey method, the drone itself or the drone pilot have little to no interaction with road traffic. Hence, it improves safety for both traffic and the survey personnel during conducting the survey.

5.1.5 Higher Safety of Survey Personnel

It is only possible in drone survey for the survey personnel to stay in a safe distance or far away from the actual survey location. This helps survey team to isolate themselves from crowd and thus reduce risk of Covid-19 or other similar contraction. In fig. 7, it can be seen that the survey team positioned themselves in a rooftop nearby the intersection to be surveyed.

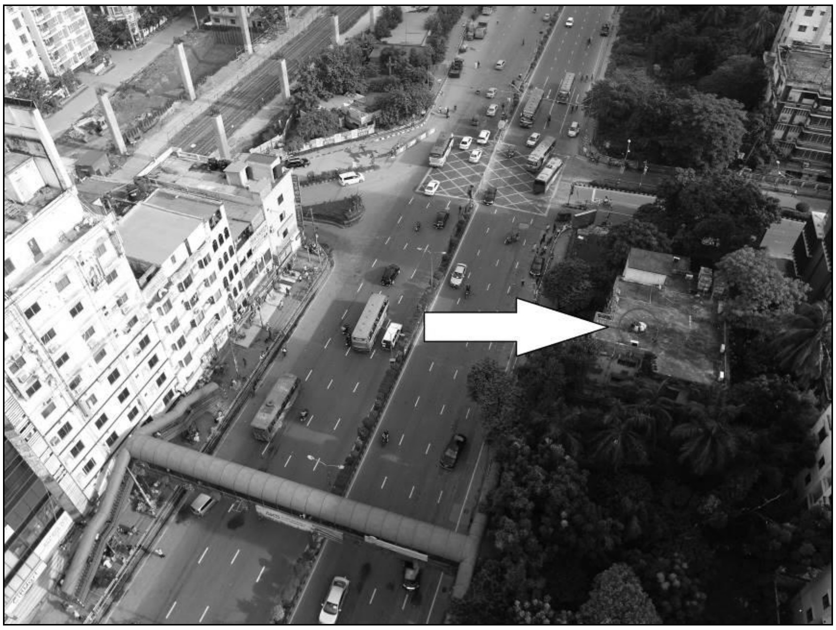

Figure 7: Survey team (pointed) positioned in a safe location

5.2 Disadvantages

Just like any other methods, drone survey has their own set of disadvantages. A few disadvantages that the authors have faced has been discussed in the followings.

5.2.1 Limitations

Drones have their limited boundary of accessibility. Generally, airports, sensitive zones of national security, military defence establishment etc. does not allow flying drones in their vicinity. Within 3km radius of airport runway it is prohibited to fly drones and marked as no fly zone. Though special authorization can be granted to fly drones in such zone, it may pose risk to other aircrafts.

Also, in locations with foliage of big trees covering large area creates blind spots for drone camera. To overcome this, drone operator or surveyor has to carefully identify those blind spots and take sufficient data of the covered area in addition to the original dataset.

5.2.2 Risk of Crash Landing

Drones can easily crash when get hit by an obstacle if obstacle detection system fails during an autonomous flight mode. Often tree branches, electric wires, etc. do not get detected by obstacle detection system. Also it is common for predatory birds to attack drones and causing a crash landing. If the drone is operated from a great distance, there is a risk of the drone getting lost if it crashes.

5.2.3 Limited Flight Time

The most prominent disadvantage of drone survey till date is that the flight time is very short due to drone battery charge capacity. The authors have experienced that, with full charge DJI Phantom 4 Pro V2 can give only a flight time of 20-25 minutes. Having few extra battery might help to cover large area though swapping batteries mid mission might increase the mission time. Hopefully in future with more innovation in battery technology this problem will be solved.

6. CONCLUSIONS

The authors have applied drone survey method in various locations. Though personnel safety and protection from Covid-19 spreading were main concern at the time of survey, this method has been proven to be beneficial in other aspects too. However, some difficulties were also faced while conducting the survey operations.

Firstly, the quality of collected data has been significantly improved. The top view from drone helped identifying finer details which were very likely to be missed from a viewpoint at ground. High definition camera helped capturing large amount of data in a very short time. Also video data of traffic movement from a high viewpoint gave a broader perspective and helped analysing the scenario as a whole.

Secondly, survey personnel had an increased sense of safety as direct interaction with traffic and pedestrians were eliminated. Also it allowed them to maintain social distancing which was advocated during Covid-19 pandemic uprising.

Thirdly, the whole survey process was greatly expedited by using a drone. This method helped saving great expense and resources. The authors believe this method can save great resources in other projects also and thus developing countries like Bangladesh can be benefited by reducing project expenses.

Furthermore, there are also few limitations for the use of UAVs as a survey tool in certain scenarios. Extensive knowledge of drone operations, flight restrictions, probable obstructions in survey area, sufficient power source in terms of battery coverage or charging power outlets are needed to be considered in pre-survey planning phase.

Drone survey is a novel practice in Bangladesh. High-definition aerial data from drone might help solving transportation engineering problems by analysing them from a new perspective. Further research might unveil easier or novel ways of data collection and analysis of complex problems by taking advantages of the drone technology. Combination of drone technology and machine learning programs might bring more automation and accuracy in due processes. Despite its limitations which might be overcome with further technological advancements, drone technology will hopefully become an important and prevalent tool in transportation engineering research.

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