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Review Article - 1

Analyzing the Effect of Distribution Pattern and Number of GCPs on Accuracy of UAV Surveys: A Review

1. Introduction

The pace of use of Unmanned Aerial Vehicles (UAVs) for aerial surveying, mapping, volume calculation and various other photogrammetric applications and feature modelling has increased significantly with the development and advent of this cutting-edge technology in surveying industry. Regardless of these aerial surveying technologies being economical and time saving, in comparison to results from traditional ground-based surveys like Auto Level and DGPS, the outcomes from UAV that relies on Global Positioning System (GPS) and Inertial Measurement Unit (IMU) technology for surveying and positioning, don't achieve the same level of accuracy. To sync with more accuracy, Ground Control Points (GCPs), the simple distributed marks on the survey site whose geographical locations are determined using DGPS, are used as a georeferencing points of the image during processing to obtain survey grade accuracies in final product. A review of the research (Awasthi et al., 2020) that is based on analyzing the obtained errors from varying GCP configuration to figure out the optimum number of GCPs and their distribution pattern is presented here.

2. Methodological Review

The research project was conducted on two different locations; one on a Corridor (Site 1) and other on an area with Undulation Terrain (Site 2) using a DJI Phantom 3 Advanced drone with 80% forward and 60% side overlap. The methodology adopted followed the sequential procedures of data preparation, data collection, data processing, result and analysis. Prior to the aerial survey, a static DGPS based ground survey was conducted to determine the geolocation of GCPs which were later used as the true value for the purpose of accuracy assessment. A total of 15 and 20 ground stations were established in Site 1 and Site 2 respectively. The aerial photographs were then taken varying the number and distribution configuration of GCPs on both project sites. During processing, each of the ground control locations were registered in the image and Orthomosaic and Digital Surface Model (DSM) were prepared for each of the sites having maximum number of GCPs for the analysis.

3. Discussions and Critiques

Used more often in the surveying industry, GCPs has greatly increased the global accuracy of drone mapping. Although they are not necessary in every situation, GCPs are a vital tool for precision mapping. Each drone mapping project is unique in a sense that the project varies as per location, nature of terrain, the area of project and accuracy required. Because of this, it is important to assess each project individually before deciding to take the extra step of placing the number and configuration of GCPs.

The original article has well-addressed the theme of the topic diving into its root. It, in a holistic approach, has placed the methodological and analytical discussions on the configuration and number of GCPs in different site. The RMSE was taken as a base for quantitative analysis and comparison of point cloud comparison with reference configuration for qualitative analysis to determine the best arrangement and number of GCPs.

In Site 1, the RMS Error determined for the quantitative analysis showed that the addition of GCPs along the length of the linear feature leads to decrement in RMSE defining the increment in accuracy of the product. The site having only a single turning on a corridor exhibited that the optimum number of GCP required is four along the feature. Furthermore, regarding the configuration, the alternating GCPs on each side of the linear feature separated by an offset distance along the feature was concluded as the most suitable arrangement.

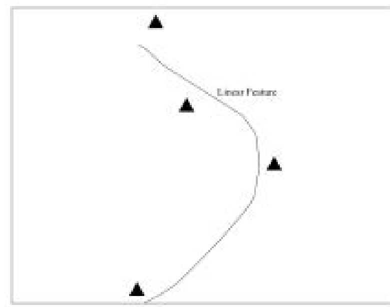


Figure 1. Optimum GCP Configuration in Corridor Site

However, the configuration was tested even by establishing the GCP in the middle of the river, which is not always possible. Moreover, the analysis of outcome by deriving RMS Error in X & Y and in X, Y & Z, separately for each GCP configuration, has exhibited the variation of errors in horizontal positioning and overall (horizontal and vertical) positioning. It clearly depicted the significant decrement in RMSE in Z with increment in number of GCPs. Nevertheless, there's an adequate number of GCPs required for a certain project beyond which, the decrement in error is very steady and more GCPs count is more financial burden. Additionally, in case of Site 1 which is a steady plane, only a single turning is located in a project site, that may not be the case in other sites. So, as per the outcome from this research, which shows that the four GCPs along the feature will be adequate for obtaining accuracy and generalizing it to conclude that, an additional GCP will be adequate in on-coming further turning might not always result in desired accuracy. This is because, along the change in length of corridor and its turning, the change in elevation might also be observed which might not be addressed by adding only a single GCP in turning point.

In regard of Site 2, the most suitable arrangement of GCPs was found out to be a GCP at the central region of study area and other GCPs well distributed along the boundary. The qualitative analysis in which the point clouds obtained from all other configuration were compared with the reference configuration exhibited that, the arrangement of GCPs resulting the absence of referencing line in the project areas were more erroneous. This was accommodated by an additional GCP at the center and four others along the boundary (total 5 GCPs). The qualitative analysis suggested the importance of positioning of GCP more than that of number.

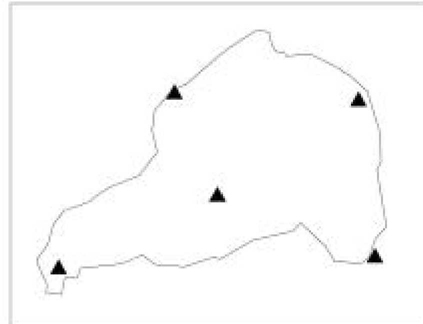


Figure 2. Optimum GCP Configuration in Undulating Terrain

4. Conclusion

From the review, it can be concluded that, it's not only number of GCPs that defines the accuracy of survey, simultaneously matters their configuration pattern. The case study exhibited the gradual increase in accuracy when the number if GCPs were added. However, the use of optimum number of GCPs is better economically and accuracy-wise. Though the number and pattern of arrangement of GCPs varies according to terrain, dimension of area to be surveyed and so on, the case study of corridor mapping showed higher accuracy for four GCPs, arranged along the feature. The finest accuracy for wide site with diversified topography was obtained with arrangement of GCPs in die shape, well distributed along the boundary, covering all elevations.

Review Article - 2

A Review on Existing UAV Regulations in Nepal

1. Introduction

UAV, an acronym for Unmanned Aerial Vehicle, also known as drone, is an emerging geospatial technology that can assist the data acquisition at various temporal and spatial scales. With the advent of this cutting-edge geospatial technology and its significant global applicability, its wider application is found to be growing in Nepal as well in different sectors like precision agriculture, forestry and topographical surveying, etc. Since the first known application of drone for military purpose in 1986, its wide application is found in forestry and agriculture, mineral exploration, to an effective tool in humanitarian response in present context. There is a correlation between efficient use of UAVs in these sectors and the legal frameworks that regulate the use of UAVs. A review of the research (Shrestha et al., 2019) that is based on providing holistic insights on existing legal regulations for UAVs in Nepal is presented here.

2. Methodological Framework Review

The criteria adopted in the framework for regulations study varies from operational to administrative aspect including governance aspect like ethics and the existing UAV regulations data for these aspects were collected based on workshop, namely, 'Flight for Purpose' and a single case study from aftermath of Nepal Earthquake 2015 and several government documents on UAVs regulations.

The criterion applicability refers to regulations based on purpose, weight of UAVs and characteristic of flight sight. According to the regulations of Civil Aviation Authority of Nepal (CAAN), drone weighting less than 2 kg, to operate below 200 ft. above ground within the premises of private property doesn't require permission from the Authority. Regarding the purpose and permission, for application of UAVs being applied for disaster relief activities, the operator must coordinate with local community such as Community Disaster Management Committee (CDMC) along with local people

Table 1. Analytical Framework based on (Stöcker et al., 2017)

Criteria	Factors
Applicability	Regulations according to purpose, Regulations based upon the weight of UAVs, Regulations based on the characteristic of the site for flight (Area, Land Use Types etc.)
Technical Requirements	Requirements to include instruments like parachutes, other special failure and safety instruments, Specific technical requirements like the material of the blades, GNSS device, Instruments to avoid collision path that is operated (BVLOS, BVLOS, and EVLOS)
Operational Limitations	No Fly zones Based on the horizontal distance: For e.g. restrictions to distance from airports/airstrips, army camps, distance from people, property, military areas, jails, industrial buildings, nuclear power plants, hospitals, government buildings, etc.), Flight Restriction based on the Vertical Height, Horizontal Distance based on VLOS, BVLOS, and EVLOS
Administrative Procedure	Registration of Platform, UAVs devices, Flight approval, Insurance policy
Human Resource Requirement	Technical skills/ Qualification of UAVs Pilots: Practical training, theoretical Knowledge, medical test, aeronautical test
Ethical constraints	Data Protection, privacy, data sharing policy

for flight. Additionally, non-settlement and open space area are categorized as low risk and government offices, religious/cultural sites, airport premises, military offices are endorsed as risk sensitive sites by the regulation of Ministry of Home Affairs (MoHA).

The criteria technical requirements refer to regulations based on requirement to include instruments like Parachute in case of special failure for safety. There are no such strict regulations regarding requirements to include the technical failure security instruments for risk minimization by CAAN. Only the restriction on the frequency of flying without interfering the telecommunication and security is mentioned, thus not addressing about incorporating technical equipment. However, UAV flight operators must be aware of harm to others.

The criteria operational limitations refer to restrictions in the flight based on horizontal distance and vertical height. CIAA doesn't mention the risk area quite evidently. However, MoHA has clearly demarcated the "No-fly Zone" above personal property, religious/cultural, archeological area, 5 km around airport, 1 km from main military and security offices and so on in its regulation. The maximum flight above ground level is 200ft and as per CAAN, flight must be conducted within Visible Line of Sight (VLOS).

The criterion administrative procedure refers to the application procedure for registration, flight approval and insurance policy to cover any harm by flight operation. There is no specific registration requirement regulation in Flight Operation Directives (FOD). However, at present the UAVs need to be registered for unique identification number (UIN). Furthermore, flight permission needs to be taken for each flight. The FOD clearly mentions about the requirement of security clearance from concerned authority prior to getting permission from CAAN. Drone flying Act 2019, regulates the

insurance aspect. Drones of category C and D must have third party insurance.

The criterion human resource requirement refers to technical skills and qualification of UAV pilot. CAAN didn't mention about specific qualification of UAV pilot. The FOD has mentioned that the remote pilot is responsible for the safety of flight. Whereas, MOHA has defined criteria like age limit of 18+ years old, technical knowledge about equipment and radiofrequency, etc. However, there is no provision of distribution license to the individual.

The criteria ethical constraints refer to regulations that protect use of information, its privacy and sharing policy, captured from UAVs. Though CAAN has endorsed the regulation prohibiting the filming and surveillance of personal privacy, the regulations don't spell regarding sharing, storage or deposition of collected data.

3. Discussions and Critiques

Along with the advancement of this aerial survey technology, its simultaneous practice in Nepal is jeopardizing. To review the associated regulations on this, it seems that the existing regulations in Nepal are somehow competent to the global framework. Nevertheless, their timely update and amendment is vital. In terms of applicability, the regulation needs to formulate in more detail to assist the execution of each project having different requirements and purpose. In case of technical requirements, there are no binding regulations to risk-minimizing and collision avoidance capabilities. Though, both the flight directives and aviation authority have mentioned about restriction zones in regard of operating requirements, but the MoHA endorses the law to restrict immediate operation after a disaster for humanitarian response, which might not be applicable in all cases. Furthermore, the regulation clearly mentions about the detail procedure for registration and obtaining flight permission as administrative procedure, but in case of aerial vehicles adopted as donation for various academic and humanitarian purposes, it is not always possible to fulfill the documents. Yet, one of the major strengths of Nepal UAVs regulation is the third-party insurance for Category C and D type UAVs. Moreover, the regulations have endorsed the minimum standard norms as human resource requirement applicable for general public. But, there is no provision for evaluating practical piloting skills which is a very important part. In a country, where advent of technology hasn't been long, the data privacy, storage and sharing policy is still very weak. Despite the regulations addressing that the flight shouldn't hamper the privacy of people or organizations, this ethical constraint isn't explicitly experienced.

Beside all these, there's still less awareness among the public regarding the regulations and aerial vehicle itself. Amending the existing regulations timely and implementing it in a very local level with proper awareness by the approach of participatory collaboration among government, private and civil society group is the most obligatory.

4. Conclusion

The article reviewed the existing UAV laws and regulations in Nepal residing on the original article that was based on illuminating the data on laws adopted from a workshop, a case study and several government documents. Inheriting on the framework of (Stöcker et al., 2017)*, that varies from operational to administrative aspect including governance aspect like ethics, existin

* Stöcker, E. C., Bennett, R., Nex, F., Gerke, M., & Zevenbergen, J. A. (2017). Review of the current state of UAV regulations. *Remote Sensing*, *9*(5), 459. https://doi.org/10.3390/rs9050459

regulations were presented. In technologically rising country like Nepal, the awareness about their existence and knowledge about proper exploitation, rooting on appropriate regulations is vital.

What is the current scenario of UAV photogrammetry in Nepal in context of survey & research?

Ans.→ Following the global trend and emerging practices, Nepal is making continuous progress in implementing cutting-edge technologies in geospatial field. The use of UAV photogrammetry as an advanced geospatial technology and its significant application is found to be growing in Nepal in survey and research along with many other sectors like precision agriculture, forestry and humanitarian response use cases. Though there was not much awareness among the public regarding this technology, with the endorsement of more systematic UAV regulations by the Ministry of Home Affairs in 2019, the application of this technology is becoming more prevalent across several sectors.

The trend of use of UAV photogrammetry in Hydropower surveying in rural Nepal is accelerating. This surveying which requires comparatively more time and usually located in remote, hilly regions with undulating and difficult to access terrain, the procedure of detailed topographic survey, access road survey and geological survey using aerial-based surveys rather than ground-based surveys seems to be more economical and time saving. Topographical Surveying of Kalinchowk hydropower Station, Aerial Survey of Liping Khola Hydropower Station, Bhairabkunda Khola Small Hydropower Station, etc. are some on the major hydropower survey projects that adopted UAV photogrammetry.

Recently, a UAV based road mapping project was successfully completed. An aerial survey of 138 km road followed by developing a digital inventory of the road section was accomplished using small flying robots. The use case of UAV photogrammetry seems to be very effective in humanitarian response in Nepal, be it in an early response or recovery stage observation in the aftermath of Nepal Earthquake 2015 or the UAV surveillance in immediate aftermath of the Melamchi flood 2021. These cases of how drones can be deployed in future rapid disaster response and research in Nepal to assess damage, rush relief and immediate response seems to be effectively rising scenario of use of drones in Nepal.

Similarly, the UAV-based Survey of Glaciers in Himalayas are being carried out. A research based on UAV for glaciological and hydro-meteorological studies, to measure the rate of melting of glacier in Manang was one of the great milestones of explicit utilization this cutting-edge spatial technology.

To sum up, the UAV technology is in constant development and new applications are arriving over time. Simultaneously with the wide application of UAV globally, it’s wider application and scenario of trend of use is found to be growing in Nepal as well, in various surveying and research field.

How can you increase the accuracy of photogrammetric products?

Ans.→ The accuracy of products like Orthomosaic, DEM, etc. of photogrammetry ultimately depends upon the factors and constraints adopted during the initial aerial survey. It is crucial to regard the outcome to be generated and its accuracy from the initial stage. Some of the techniques to be adopted for increasing accuracy of photogrammetric products are highlighted below:

i) Ground Control Points: To achieve the global accuracy in mapping, the use of GCPs is vital. By creating a series of ground markers in the project area, whose positions are accurately determined by ground-based surveys, the model created from aerial surveying can be more accurately rectified to attain global accuracy. However, the number of GCPs to be used and their configuration pattern depends upon the nature of terrain to be surveyed. Nevertheless, not always increment in number of GCPs consequence the decrement in error. There's always an adequate number beyond which the decrement in error is steady.

ii) Consideration of flying height: The accuracy of products is highly affected by the resolution of the imagery. The higher resolution means the lower Ground Sampling Distance (GSD), and those smaller pixel consequences detailed features representation. All these are affected by flying height. Lower the flying height, more the resolution and ensuing better accuracy.

iii) Increase Overlap: Overlap refers to percentage of intersected portion between adjacent images. Though different literatures suggest different overlap margin, it is recommended to go for 80% forward and 60% side overlap for better accuracy. However, this factor can be adjusted by the surveyor as per the requirement and necessity of the outcome to be generated.

iv) Expanding capture area beyond study area limit: It is highly recommended to capture the images slightly beyond the extent of the area of interest. During the post processing and analysis, the reconstruction of individual overlapping images to for a single model might result in occlusions resulting erroneous output if the surveying is restricted on the boundary. So, this must be avoided to condense error and increase accuracy of the products.

These are the major factors influencing the accuracy of the photogrammetric products. Moreover, the accuracy is highly influence by the quality of camera and sensors to capture the imagery. Use of high-quality camera and sensor is preferred. The UAV technology is in constant development and new applications are arriving over time, resulting better accuracy in its products. Similar recent development is a UAV system with Real Time Kinematics (RTK) GPS which provides real-time corrections to location data as the drone is surveying and capturing images from a site. This helps in upholding accuracy w/o spending much time in postprocessing.

Prepare a proposal of a research using Photogrammetry on Environmental Study.

→ A Research Proposal on Assessment of Landmass Transformation on Landslide Susceptible Area using Photogrammetric Technique is presented below:

1. Introduction

1.1 Background

Natural calamities are inevitable, but with right decision and timely assessment of possible vulnerabilities, the cost of their aftermath could be minimized. With the arrival of monsoon, the hilly areas are prone to landslide and its occurrence is a common incident in Nepal as well. There are no any scientific researches and assessments regarding the land deformation caused by landslide. In this scenario, an approach for assessment of the landslide susceptible area in Pokhara is planned to be carried out. The sloppy hill beside the World Peace Pagoda (Figure) has been remarked as a landslide susceptible zone. A two phase of photogrammetric survey is proposed to be carried out before and after monsoon (in the extremities of June and September) to assess the impact of landmass transformation.

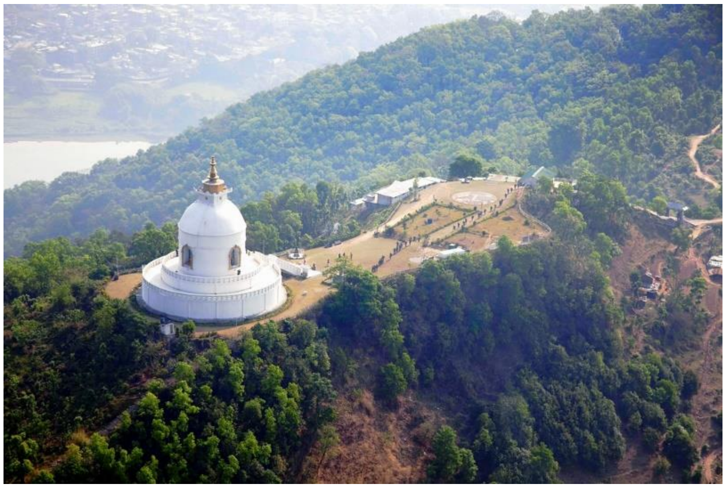


Figure 1. World Peace Pagoda, Pokhara

1.2 Objectives

The key objective of this project is

- To develop a 3D model of area to assess the impact of landslide.

The secondary objective that will be accomplished throughout the exertion for achieving primary is:

- Generation of high-resolution Digital Elevation Model (DEM), aspect model, slope model and digital orthophoto.

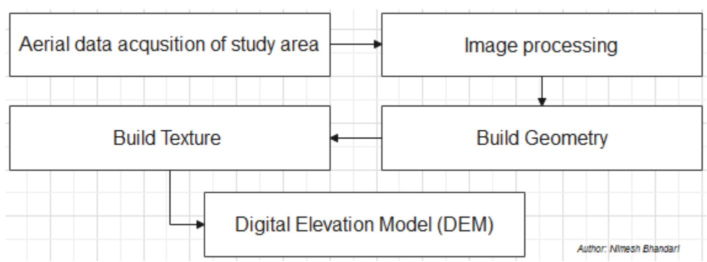
2. Methodology

2.1 Theoretical Framework

Landslides are quite frequent along the tectonically active Himalayan region and result in enormous casualties and huge economic losses every year. The mapping and assessment of these areas is of utmost importance. In recent times, utilization of aerial photographs and have also been used to map the landslides as well as depth and volume estimation of landslides (Martha et al., 2010a). Many researchers; (Patwary & Parvaiz, 2009; Martha et al., 2010b; Ghosh et al., 2012; Kumar et al., 2017) have acclaimed regarding the extensive application of aerial photographs for extraction and mapping of landslide and its assessment.

2.2 Study Method

The methodology to be adopted for this approach of study is charted below:



A) Flight Planning and Data Acquisition:

The Pagoda site is selected as study area because it is remarked as a vulnerable site with appropriate slope degree for the study. Before carrying out data acquisition, flight planning is to be considered. In order to obtain high quality images in flight, planning certain requirements such as image overlap of 80/60, flight height 50m, in a DJI Air 2S will be managed. For global accuracy, 6 GCPs will be established in the site at varying elevation points whose control locations will be established by static DGPS survey. With these settings, consecutive stereo pair imagery data will be acquired via aerial imagery.

B) Image processing and Outcomes

The acquired image in both timeframes (in extremities of month June and September) will be processed in a commercial photogrammetric software, Pix4DMapper. The registration of GCPs will be carried out followed by developing the Orthomosaic and Digital Surface Model (DSM). Uploading thus obtained outcomes in ArcGIS software and postprocessing in its components like ArcMap and ArcScene, slope model, aspect model and finally, 3D model of the terrain will be generated.

C) Analysis Procedure

The digital products of photogrammetry have the great power to demonstrate various things for further analysis and proper decision making. The 3D model generated from studies at two different times will be compared with each other and investigated. The 3D model will help us in finding the physical movement of landmass and changes in surface, primarily via volumetric analysis, if any occurs in the site during monsoon. Overall, the difference of the terrain changes together with volume changes variations between two sets of data could be calculated during the measurement.

3. Conclusion

With the rising trend of using photogrammetric techniques in varying forms of environmental studies, it is equally useful in disaster forecasting and its aftermath surveillance as a part of environmental research. This study with the use of cutting-edge technology will obviously saves a lot of time, economy and human resources for the quick and effective analysis of the change in landmass from the 3D model and leads to proper decision-making for emergency preparedness.

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