Drone Based Urban Planning in Nepal

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Keywords: Spatial planning, UAVs, Low cost technology, Photogrammetry

SUMMARY:

The promulgation of new constitution in 2015, formation of local governments and execution of a new government system led to the emergence of 743 municipalities from 58 municipalities in 2017 in Nepal. Systematic planning was needed in a short time for which data of those local newly formed municipalities and towns are to be collected.

Urban planning and city modeling has become a buzz word especially in developing countries like Nepal where villages are transforming into towns and towns into cities. A well planned city is the ultimate answer to the increasing population and limited resources. But for planning cities, appropriate methods of survey, data collection and visualization is a must and this can be achieved by rapidly changing technology of UAVs or drones having potential uses in many aspects of urban life, including in the planning profession.

This study aims to assess the potentiality of UAV to achieve a superior low cost, adaptable and accurate data accumulating tool for planners and engineers. Presently, Gokarneshwor Municipality of Kathmandu valley is the first municipality in Nepal to formally use drones for capturing high resolution aerial images of the municipality for city planning, infrastructure development and project progress monitoring.

This article briefly describes the effective use of drones in urban planning of Gokarneshwor municipality. This municipality seeks to ameliorate random and unplanned urbanization triggered by accelerated growth of population and city, with the help of UAV Survey. The municipality plans to generate detailed GIS based maps of the municipal area which can further be used for clearly portraying detailed street network map and superintending the progress of infrastructural projects happening on the ground as it provides a unique viewing angle of ground details.

The city planners and engineers can remotely monitor what projects are happening along with their status. Aerial photographs can be created from exactly the same angle and exactly the same position at regular time intervals. This helps to document changes to the construction projects of any time and scale happening on the ground.

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1. BACKGROUND

The promulgation of new constitution of Nepal in 2015, formation 7 provincial governments, 743 of local governments and execution of a new government system led to the emergence of 293 municipalities from 58 municipalities and 460 Rural Municipalities in 2017 in Nepal. Systematic planning was needed in a short time for which data of those local newly formed municipalities and towns are to be collected. In this process, Gokarneshwor municipality took the initiative for properly implementing land use planning in its territory. Since the area was small, it is thought of drone survey as the best fit among the other aerial photogrammetry measures for data acquisition process. Hence, this project was commenced and got accomplished successfully as well. Survey Department Nepal is planning to complete land resources mapping at the scale of 1:10, 000 of Nepal in 2019/20 using 0.5m resolution satellite imagery and new LiDAR survey of Nepal also started in this fiscal year and expected to complete in 5 years.

2. INTRODUCTION

UAVs or Drones are refers to an unmanned aircraft or flying device capable of flying in the sky with a camera mounted on it and can be controlled in an autonomous, semi-autonomous or manual mode. Using camera mounted on drones, high resolution images of the grounds can be captured which can later be processed to generate accurate high resolution accurate maps. Maps generated in this manner include all the information provided by a traditional land survey. The total time required for mapping through drones is also lesser compared to traditional aerial survey methods. UAVs have been used in many other topographical and cadastral mapping surveys outside Nepal. UAVs are being widely used to construct accurate maps in a cost- effective and rapid way.

This chapter presents the background and motivation behind the project. We have also tried to show the relevance of UAV in the context of Nepal. The objective of the project and the scope of work are described.

3. METHODOLOGY

This chapter explains the working methodology to obtain the orthophoto, DTM, DSM from UAV captured images. The data obtained is used to prepare large scale Topographical with the better altimetric data which serves as the basic foundation for urban planning.

3.1 Project site

Project location is on the northeast side of Kathmandu. 8 wards of Gokarneshwor Municipality were chosen as our project site for evaluation. The extent of the project area is 27°42'38''N to 27°45'14''N and 85°22'06''E to 85°23'54''E and located at an altitude of about 1300m covering 10 sq. km. This project uses 15,420 images from 11 flight strips. The average ground sampling distance (GSD) of the image was 3.0 cm/pixel. It is shown on the Fig.1: Project Location Map below.

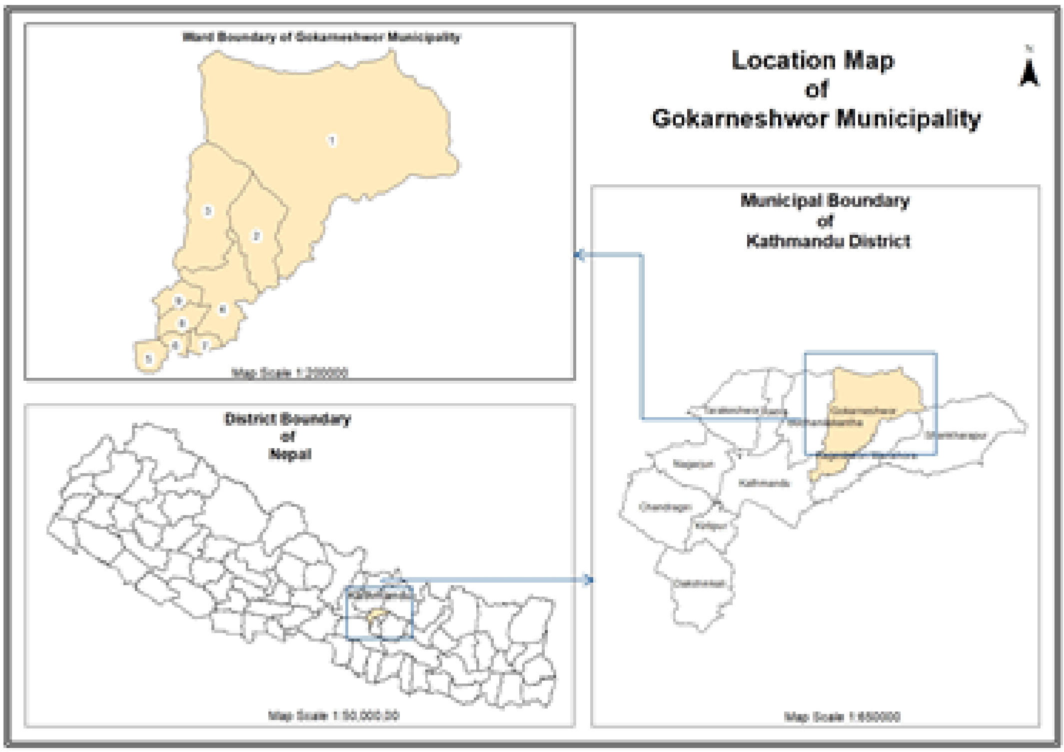

Fig1: Project Location Map

3.2 Materials Used

<u>3.2.1 Software</u>**:**

PIX4D Software was used for the purpose of generating Orthophoto, DEMs and 3D models by processing images. It is a commercial software product that uses photogrammetry and computer vision algorithms to transform both RGB and multispectral images into 3D maps and models. It is developed and supplied by the company Pix4D SA. It can convert thousands of terrestrial or aerial as well as oblique images captured by any type of camera or any platforms into different products like orthomosaic and DTM with cm level accuracy. The fully automated workflow handles all the image processing works. Furthermore it provides an interactive interface where users can annotate 3D objects, performs measurements on the surface models and even calculate their geometric properties like area, volume etc. of different surface properties. The salient feature of this software is that it allows optimization of the processing results by introducing ray cloud editor, an interactive 3D point cloud editing interface where users can edit the 3D point clouds and enhance the accuracy of the projects. As the images of this project were large in number, the whole area was splitted into different parts and proceeded.

3.2.2 Hardware:

There are many commercial drones. Among them, **DJI Phantom 4 Pro** was available for use in the company, which was used in this project. It is one of the best professional drones, it is engineered with intelligent flight support systems which include a dual satellite positioning system and enhanced vision position system. This provides a safer and more reliable flight experience both indoors and outdoors. It is fitted with a powerful camera capable of capturing 4K video at 30 frames per second. This creates impressive footage. The visionary intelligence elevated imagination feature makes the unit one of the smartest flying platforms. It is able to fly intelligently over or around obstacles and automatically creates seamless tracking shots with 30 minute flight time. It features a dual compass module and Inertial Measurement Unit (IMU) that greatly increases reliability.

3.3 UAV survey:

UAV for aerial survey allows us to obtain detailed data quickly and easily. Aerial imagery and precise mapping serves as a replacement for traditional 3D measurement tools and sensing tools. A survey drone is therefore much more versatile and efficient than the traditional tools individually. The general workflow of photogrammetric process.

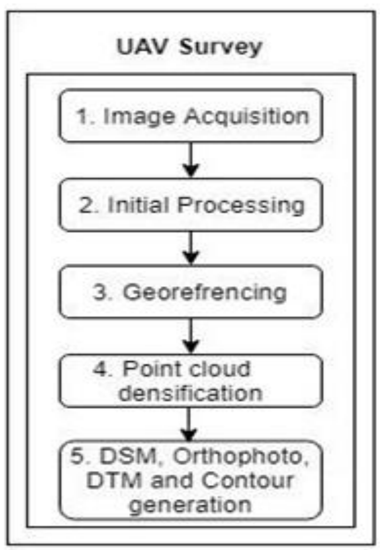

Fig2:General workflow of UAV Survey

3.3.1. Image Acquisition:

i. Initial Flight Planning: The flight was planned with the help of Google Earth imagery with terrain. This helped us to determine the tentative number of flights, flying height, time estimation, percentage of overlap between images, position of takeoff and general 3D perception of terrain. This also helped us to make accommodation and transportation plans.

ii. Reece and Monumentation: This is the stage where the reconnaissance survey (Recce) of the site was done by visiting the site. By visualizing the site, the locations of the control points to be established were determined. The distribution of the control points should be even and well distributed so as to get the better output with better accuracy throughout the project area. Also, the control points should be clearly visible from the nadir view of the Drone. After the location for control points were identified and finalized, they were marked or established. Then these points were covered by 60cm*60cm. red flags crossed with white enamel. These flags helped to identify the control points on the images taken by the drone. The center of this crossed white stripe is the control point. The image below shows the established control points on the ground.

Fig3:Marked control point

iii. DGPS Survey: The DGPS survey of the previously established national control network of control points should be done to transform the accurate position of those control points. The easting, northing and elevation of the control points were measured. It is considered that DGPS surveys can give a good(cm) level of accurate points. These control points were identified in the images and these coordinates were inserted at the time of image processing.

Fig4: Establishing control point

iv. Flight Planning: Before flight, flight plans need to be prepared over a basemap provided by the software. The final flight plan was prepared after visiting the site according to the site condition. At this stage we need to consider flying height according to the GSD required and area coverage according to the capacity of the battery of the UAV. The flying height was maintained 75m and forward and side overlap was maintained 85% and 65% respectively. Different flights were planned to cover the whole area from different heights. This stage is very important because wrongly planned flights can cause up to damage on the drone.

The image below shows an example of the flight plan.

Fig5: Flight plan in the software

v. Drone Flight: After the flight was planned to cover, the drone was taken off to capture the overlapped images. The flight plan can be more according to the image overlap, area to be covered, speed of UAV and the battery life. The image below shows the example of flight lines as planned before and the red dots represent the camera positions while capturing the image on flight.

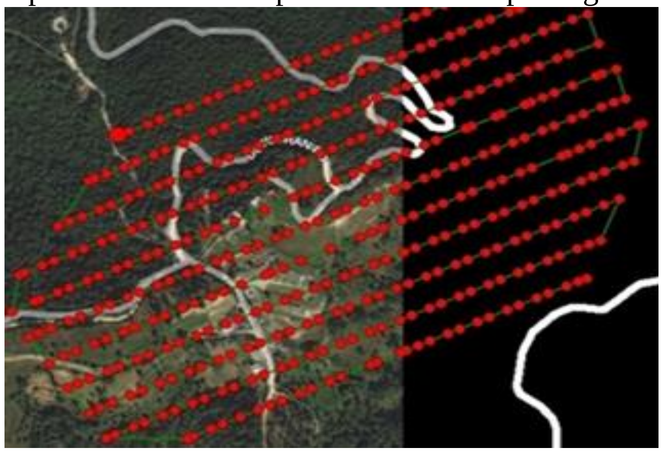

Fig6: Flight line and camera positions

<u>3.3.2 Image Processing:</u>

After the geotagged images were captured, they were processed to get the outputs like Orthophoto, contour lines, DTM, DSM, etc. The images were prepared before processing by removing unnecessary and tilted photographs. Then filtered/corrected images were added on the software for processing. Image Processing involves three major stages:

i. Initial Processing: The overlapped and geotagged images were processed utilizing the image matching algorithms like SIFT algorithm. The output of the initial processing is the tie points initially matched by this algorithm. These tie points are generated by matching the same feature within the overlapped images. If one feature inside an image is clear enough and a pixel of it is very sharp and separable, then this feature pixel is searched in other overlapped images and found out the x, y and z values of the point. The following image shows the camera locations while capturing the images.

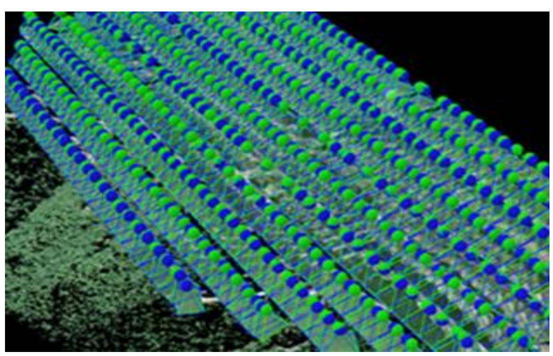

Fig7: Camera positions

In this step the images and GCPs will be used to do the following tasks:

- Key Points extraction: The algorithm of the software identifies the specific features ask key points in the images.
- Key points matching: The images which have the same key points are matched together.
- Camera model optimization: Calibrate the internal (focal length) and external parameters (orientation) of the camera.
- Geolocation GPS/GCP: Locate the model using the provided geolocation information.

The result of the initial processing is the sparse point cloud with few points representing the surface. The following is the sparse point cloud generated through initial processing.

Fig8: Sparse point clouds

ii. Point Cloud and Mesh: The initial processing result is the point clouds with less density. Now, another algorithm generates millions of 3D textured point clouds that look exactly like the ground itself. The image below shows the dense point clouds which look like the model. This step will build on the Automatic Tie Points with:

Point Densification: The additional Tie Points are created by triangulating automatic tie Points that results in a Densified Point Cloud.

3D Textured Mesh: Based on the Densified Point Cloud 3D Textured Mesh can be created. The following image shows the dense point cloud which looks like real ground.

Fig9: Densified point cloud

iii. DSM, Orthomosaic and Index: This step enables the creation of:
Digital Surface Model (DSM): Finally the DSM was generated using 3D mesh. The creation of the DSM will enable the computation of Volumes, Orth mosaics and Reflectance Maps. The output accuracy of the DSM can be modified as x *Ground Sampling Distance (GSD). Where x is the multiplier and GSD is distance between the centers of the pixel in the photo. DTM can be generated as per the need. The contours can also be generated and that are based on DTM. These contours have been utilized in the preparation of topographic maps.
Orth mosaic: The georeferenced orthophoto has been generated based on orthorectification. The orthophoto stands for the ground observed from a nadir view from a certain point from a certain

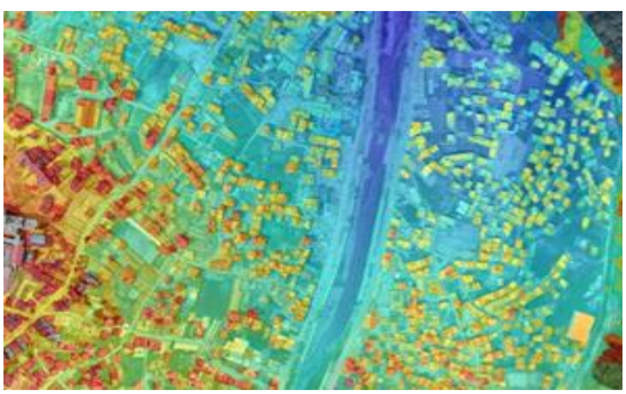

Fig10: Digital Surface Model (DSM)

Fig11: Orth mosaic

4. RESULT AND DISCUSSION

4.1 Accuracy assessment

The accuracy assessment of the drone based topographical survey was done during the processing of the captured images. There are three types of Control Points to improve and check the accuracy of the model:

4.1.1 Manual tie points (MTPs):

There are automatic tie points that are calculated by itself. But if the software doesn't find any tie points that are common in overlapping images or it fails to find sufficient tie points, we have to manually identify the points that are distinct in more than one image to match the images properly and those distinct points are called the Manual Tie Points. As the accuracy and number of points generated as output directly depends on the number of matches in the images, MTPs can play a significant role in enhancing the accuracy of the model. The image below shows the manual tie point that has been identified and marked in multiple images:

Fig12: Manual Tie Points

4.1.2 Ground Control Points (GCPs):

UAV/Drone has its inbuilt GPS on the system but the accuracy of the GPS is about 5 to 10 m similar to handheld GPS. If the desired accuracy falls under this category, then only the geotagged images obtained will be sufficient for generating the quality output. But if the desired accuracy is less than a meter or centimeters then we have to do extra survey to establish the control points by any means that gives this kind of accuracy such as Total Station Survey, DGPS (Differential GPS) survey etc. In this case, DGPS survey has been chosen and placed DGPS Machine in each Ground Control Points established at site. The accuracy of the DGPS survey is up to millimeter level accuracy. Those established control points later will be made distinct (by any means such as red cloth with white cross) while capturing images to identify them while processing images. The model can be adjusted using these ground control points while processing the images and obtaining the final output. The distribution of the GCPs over the model also plays a significant role in the accuracy of the model. The more even distribution, the more accurate the model will be in each part. Those obtained Control points from DGPS Survey can be used as either Ground Control Points (GCPs) or

Check Points (CPs). While maintaining the distribution over the model, some points can be used as CPs to check the accuracy of the model. The image below shows the Distribution of the Control points over the project area.

4.1.3 Checkpoints (CPs):

Checkpoints are the control points collected at the field and are used to check the accuracy of the model. These are the same as GCPs but these points are not used while processing of the images but after the model is generated the accuracy of model is calculated as follows:

Ac = X1 – X2

Where, Ac = Accuracy of the model

X1 = Actual position of CP X2 = Position of the CP in the model.

In this case two control points BM1 and BM2 were taken from one of the parts as checkpoints and other points as GCPs. The error in the position of GCP and CP are as follows:

Error in BM1 in meter:	**Error in BM2 in meter:**
Error in X: 0.083	Error in X: 0.022
Error in Y: -0.077	Error in Y: 0.036
Error in Z: 0.144	Error in Z: 0.186

Manual Tie Points and Ground Control Points were used to improve the accuracy of the model whereas the Check Points were used to check the model accuracy.

5. CONCLUSION AND RECOMMENDATION

The concept of traditional aerial photogrammetry occupied a broader field for the preparation of topographical maps from the earlier time till now. However, it has somehow been outdated at present while compared to other modern photogrammetric tools and technologies like the use of drones. The mapping features of drones like ortho rectification, cloud coverage, feature extraction, etc. are quite advanced for map production unlike traditional photogrammetry and remote sensing techniques. Thus, with the use of UAV photogrammetry, it can produce high resolution orthophoto, better altimetric data and large scale topographical map with low cost and human resources than that of traditional photogrammetry. Most importantly, it is a convenient tool for surveying over small areas with tolerable accuracy and under a reasonable budget. From this project we recommend that the UAV flights must be carried out in clear weather conditions for better result and altimetric accuracy, UAV flight with optical sensor is not recommended in dense vegetation. However, there are other types of sensors like LIDAR technology that can be used to accurately map those kinds of areas. Also, the manual point cloud classification must be carried out properly to get the more accurate result.

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BIOGRAPHICAL NOTES

Mr. Pravin Lamsal (Co-Founder, Dronepal) is a Geomatic Engineer graduated from Himalayan College of Geomatic Engineering and Land Resource Management (Purbanchal University), Kathmandu, Nepal and currently works as CTO at DroNepal, the first Drone Service Company in Nepal (2016), with four years of drone flying experience and worked as team lead for various surveying and mapping projects.

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Mr. Punya Prasad Oli is a former **Director General** of **Nepal Survey Department**, and presently active as a **chairman** of **ERMC Pvt Ltd**, and **President** of Nepal Institution of Chartered Surveyors.

ACKNOWLEDGEMENTS

We would like to express our heartfelt appreciation to the Department of Survey, Gokarneshwor municipality (http://www.gokarneshwormun.gov.np/en), Environment and Resource Management Consultant Pvt. Ltd., Dronepal Pvt. Ltd and Naxa Pvt Ltd for providing information and data sources for this research.

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