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Modelling Ozancık village (Aksaray) in computer environment using UAV photogrammetry

Hacı Murat Yılmaz[*1], **Nusret Aktan**[2], **Adem Çolak** [2], **Aydın Alptekin** [3]

[1]*Aksaray University, Geomatics Engineering Department, Türkiye*
[2]*Aksaray Special Provincial Administration, Aksaray, Türkiye*
[3]*Mersin University, Geological Engineering Department, Türkiye*

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Abstract

Modelling the terrain with high accuracy is vital to create modern settlement areas, and to find solutions that threaten the people. Traditional land surveying is a time-consuming and expensive method. Unmanned aerial vehicle (UAV) is a powered aerial vehicle without a human operator. UAV related case study publications have been increased since last two decades. Detailed three-dimensional (3D) information on the land surface can be obtained from high spatial resolution point clouds. Modelling the terrain requires up-to date information. UAV can provide high-resolution images with low cost in the order of centimeters. We can reconstruct the terrain in a 3D representation using photogrammetry. In this study, we model a village located in Aksaray city using UAV photogrammetry. We created the orthomosaic and Digital Surface Map (DSM) of the region to characterize the terrain in detail. The obtained model and maps will help us to generate modern living space.

1. Introduction

Remote sensing plays a significant role in modelling the terrain and disaster management. Satellite, unmanned aerial vehicle (UAV) and LiDAR are the most used remote sensing techniques. Satellite image resolution is not sufficient for detection of small changes in land. LİDAR is an expensive technology. UAV, high resolution, is a practical tool for modelling the terrain. Three-dimensional (3D) visualization of the study area can be easily performed.

In order to create healthy settlement areas, we need to see the environment with high resolution and accuracy. Unmanned Aerial Vehicle (UAV) has been used frequently to solve engineering problems since last decade. UAV photogrammetry enables us to model the environment in digital media. Therefore, engineers can find modern solutions in a practical way. Traditional land surveying is a time-consuming and dangerous method in many environments. UAV is a valuable tool to get information from terrain. High resolution point cloud can be obtained using a low-cost UAV in a practical way.

The land management planning of a city shows its development [1] such as location of main and intermediate roads, parking areas, shopping centers, school areas and administrative buildings. Mapping the terrain to prepare settlement areas is very important in today's context.

UAV has been frequently used in terrain modelling, natural hazards modelling, agricultural studies, mining, civil engineering applications and cultural heritage documentation.

Volume calculation [2-3], tree detection [4], shoreline detection [5], cultural heritage modelling [6-7], landslide site mapping [8-9], rockfall site mapping [10], energy line detection [11], coastal cliff mapping [12], road distress studies [13] and urban mapping [14] have been implemented using UAV point clouds in recent years. Moreover, Lucieer et al. [15] have determined horizontal displacements of a landslide using two DEMS with UAV. Rossi et al. 2018 have determined the volume and extent of the landslide, and the displacement along slope by comparing DTMs obtained using UAV.

* **Corresponding Author**

*(hmuraty@gmail.com) ORCID ID 0000-0002-9725-5792
(nusretaktan@hotmail.com) ORCID ID 0000-0003-2582-9395
(acolak68@hotmail.com) ORCID ID 0000-0003-2582-9395
(aydinalptekin@mersin.edu.tr ORCID ID 0000-0002-5605-0758

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2. UAV Technology

Photogrammetry is a branch of science that creates information about the object and its surrounding.

With the development of technology, it has become possible to obtain data from points that are not easy to reach. UAV provides new opportunities for mapping and monitoring of environment [15]. UAV is used to collect aerial photography. High resolution Digital Surface Map (DSM) and orthomosaic can be obtained in a short time. These products allow us to prepare land management strategies.

In general, there are three types of UAV which are rotary wing, fixed wing and VTOL. In this study, we used fixed wing rotary UAV. E-Bee (Figure 1) has been equipped with an optical camera, DSC-WX220_4.4_4896x3672 (RGB), and it has been used to perform photogrammetric data acquisition in an area. Technical specifications are given in Table 1.

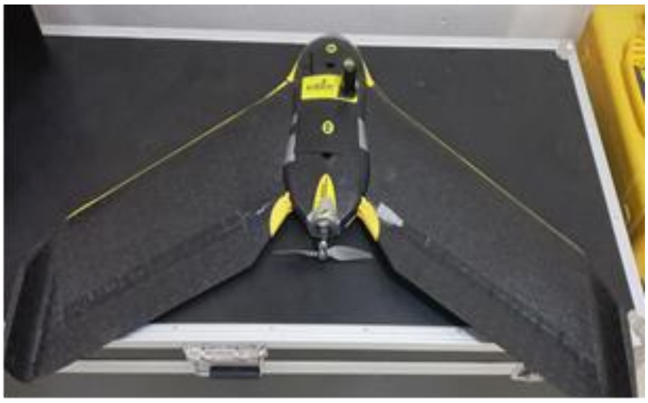


Figure 1. eBee SenseFly GZK UAV

Table 1. Technical specifications of EBee

Property	Value
Wingspan	116 cm
Weight	1.4 kg
Motor	Low-noise, brushless, electric
Radio link range	3 km nominal
Detachable wings	Yes
Camera options	senseFly S.O.D.A. 3D, senseFly Aeria X, senseFly Duet T, Parrot Sequoia+, senseFly S.O.D.A., senseFly Corridor, MicaSense RedEdge-MX
Flight & data management	eMotion
Cruise speed	40-110 km/h
Wind resistance	Up to 46 km/h
Max. flight time	59 minutes
Automatic landing	Yes
Landing type	Linear landing with Steep Landing technology
Ground Control Points (GCPs) required?	No, with included High-Precision on Demand (RTK/PPK)
Hand launched	Yes
Nominal coverage at 122 m	220 ha
Ground sampling distance at 122 m	2.5 cm/px
Absolute accuracy	Down to 3 cm

3. Study Area

In this study, we model Ozancık village located in Aksaray City, Turkey (Figure 2). The population of Ozancık village is decreasing each year. Ozancık village was founded in the 1700s.

Figure 2. Location map of the study area

UAV, E-Bee fixed wing, was used to obtain high quality pictures from field. UAV has taken 1227 pictures covering 3.97 km^2 area. Ground sampling Distance (GSD) was 4.24 cm.

Real time kinematics (RTK) is a surveying technique which can correct common errors in satellite navigation systems. RTK allows us not to use Ground Control Points (GCP). Relative position can be obtained with higher accuracy.

4. Modelling

In UAV photogrammetry, photographs of the region are taken with the flight plan prepared by taking into account the flight altitude, overlay ratio and flight speed parameters. The 3D model of the region is created by combining the pictures taken with the structure from motion method. Then DSM and orthophoto are produced.

Pictures taken from UAV has been imported into Pix4Dmapper software to adjustment, and ortomosaic (Figure 3a) and Digital Surface Map (Figure 3b) has been created. DSM, ortophoto and index details are shown in Table 2. Processing options are shown in Table 3. Error amounts after adjustment are shown in Table 4.

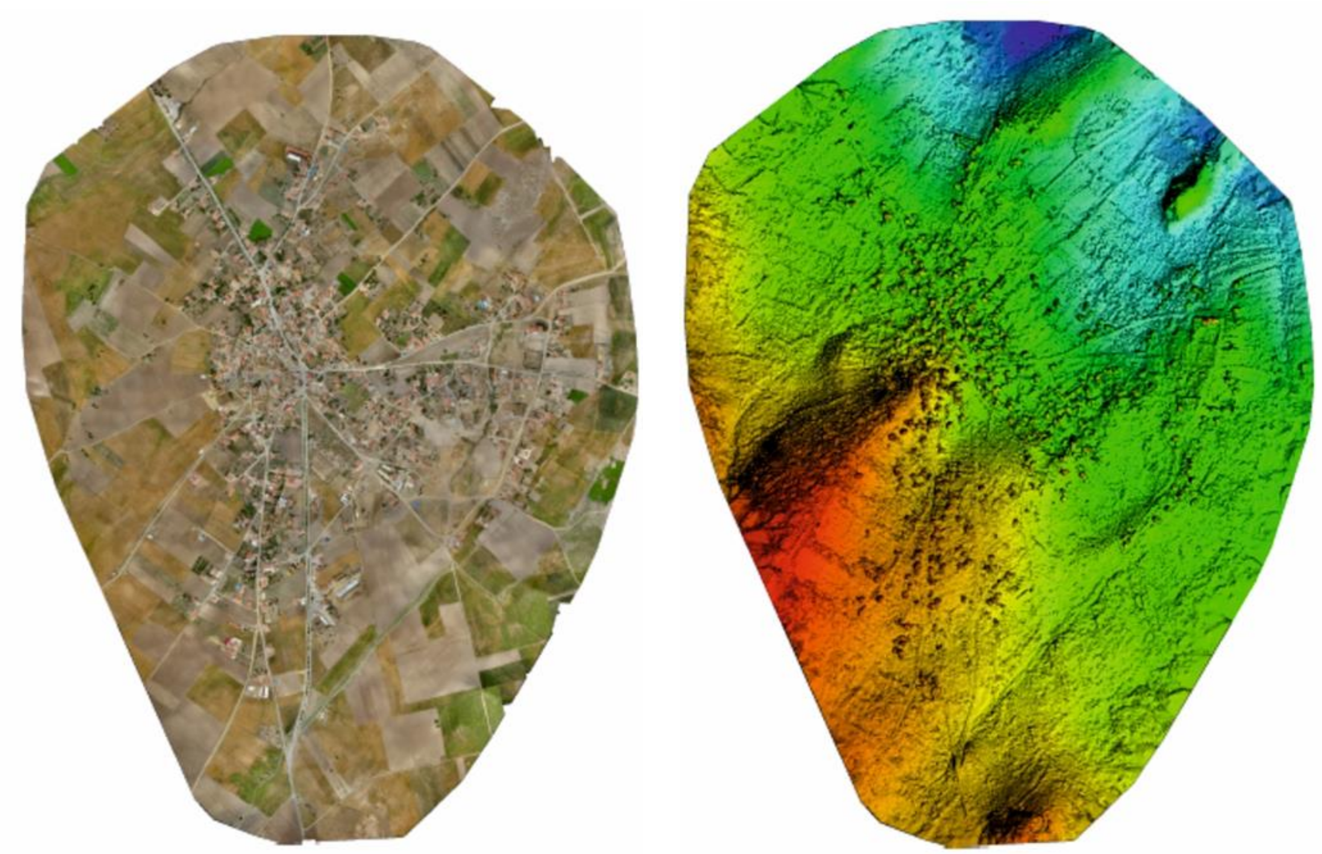
Pix4D mapper can transform aerial images to digital maps and 3D models. Mesh models, DSM, ortomosaic and index maps can be easily produced.

The high-resolution DSMs and orthophotos allowed the detection and the monitoring of fissures and small-scale changes of the surface.

DSM, geospatial feature, shows elevation values of environment. It includes both natural and artificial features.

Orthomosaic is a map that shows true location. It is a geometrically corrected map and represents Earth's surface.

Sfm can produce 3D model from 2D images using tie points. SfM method is cost-effective and practical tool.



(a) (b)

Figure 3. Ortomosaic and DSM

Table 2. DSM, Orthomosaic and Index Details

DSM and Orthomosaic Resolution	1 x GSD (4.24 [cm/pixel])
DSM Filters	Noise Filtering: yes Surface Smoothing: yes, Type: Sharp
Raster DSM	Generated: yes Method: Inverse Distance Weighting Merge Tiles: yes
Orthomosaic	Generated: yes Merge Tiles: yes GeoTIFF Without Transparency: no Google Maps Tiles and KML: yes
Grid DSM	Generated: yes, Spacing [cm]: 100
Time for DSM Generation	01h:30m:41s
Time for Orthomosaic Generation	04h:11m:57s

Table 3. Processing options

Image Scale	multiscale, 1/2 (Half image size, Default)
Point Density	Optimal
Minimum Number of Matches	3
3D Textured Mesh Generation	yes
3D Textured Mesh Settings:	Resolution: Medium Resolution (default) Color Balancing: no
LOD	Generated: no
Advanced: 3D Textured Mesh Settings	Sample Density Divider: 1
Advanced: Image Groups	group1
Advanced: Use Processing Area	yes
Advanced: Use Annotations	yes
Time for Point Cloud Densification	03h:27m:02s
Time for 3D Textured Mesh Generation	40m:18s

Table 4. Error amounts

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-0.11	0.00	0.00	18.42
-0.11	-0.09	0.00	0.00	5.46
-0.09	-0.07	0.00	0.00	4.81
-0.07	-0.04	0.16	0.41	5.70
-0.04	-0.02	3.42	3.26	7.50
-0.02	0.00	46.62	44.50	6.36
0.00	0.02	45.88	47.19	6.76
0.02	0.04	3.75	3.99	7.25
0.04	0.07	0.16	0.65	5.87
0.07	0.09	0.00	0.00	6.03
0.09	0.11	0.00	0.00	6.19
0.11	-	0.00	0.00	19.64
Mean [m]		-0.000015	0.000581	-0.002184
Sigma [m]		0.012165	0.012794	0.128967
RMS Error [m]		0.012165	0.012807	0.128986

5. Discussion

There are some limitations in using UAV. Weather conditions, flight area and presence of high trees. Proper weather conditions play important role. Weather forecast has to be checked properly.

Although the spatial resolution of satellite imagery has significantly improved in the last decade, the data collected is still not sufficient for medium to small coastal changes (centimetric accuracy).

Environment management requires up to date information [12]. Small changes are not distinguishable at the spatial resolutions obtained using manned aircraft and satellite systems. We used Pix4D mapper because it automates the SfM pipeline in a user-friendly workflow.

Georeferenced orthophotos and DSM s are used to measure small changes.

Models can be used flow-direction studies, power line corridors and project managements.

UAV enables to produce maps in a short time. UAV offers the opportunity to fly close to the object [16].

Many villages are located in mountainous region. Mapping those terrain will not be possible sometimes. UAV will be very useful for those terrain.

6. Conclusion

In this study, products that can offer the opportunity to work in many professional disciplines have been produced. UAV photogrammetry helped us to map the terrain with high accuracy and resolution in an easy way. This research has demonstrated us successful mapping has been achieved. The obtained model and maps will help land management. These maps can be used as base maps for many engineering projects. This study has shown that all public institutions can easily obtain a model of the desired terrain with UAV photogrammetry.

Author contributions

Hacı Murat Yılmaz: Conceptualization, Methodology, Software **Nusret Aktan:** Data curation, Writing-Original draft preparation, Software, Validation. **Adem Çolak:** Visualization, Investigation. **Aydın Alptekin:** Writing-Reviewing and Editing

Conflicts of interest

The authors declare no conflicts of interest.

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