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The use of UAV photogrammetry in modeling ancient structures: A case study of "Kanytellis"

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Abstract

Investigations of the Antiquity and Late Antiquity have been carried out numerous times by historians and archaeologists, and these researches continue intensely. Archaeological discoveries and historical ruins provide information about the enigmatic history of humanity. Studies on ancient cities contribute to the social, cultural, administrative and economic analysis of the period. Within the scope of this study, an ancient village house in Kanytellis, an example of these ancient cities, was modeled in 3D and digitally documented. The area and volume calculations of the building are also presented in the study by taking measurements on the 3D model of the ancient village house. Analyzes were conducted by two different software (Agisoft Metashape and Context Capture) and the results were presented comparatively in the results section of the study. According to the analysis made between the models, a difference of 1.32 cm was calculated. It is thought that the model reconstructed will contribute to the aims of transferring Turkey's historical and cultural heritage to future generations and playing a role in developing tourism activities.

1. Introduction

Humanity has started to actively change the environment in which it lives and move to a settled life in order to meet its needs from the hunter-gatherer order that it has been living in for 2.5 million years [1]. Ancient and late antiquity are the ages when examples of settled life are seen [2-5]. It is of great importance to examine the historical remains and artifacts in order to learn the details of the social, cultural, economic, political, administrative, religious, etc. experiences of the societies in the historical process [6]. Ancient cities are among the regions where historical ruins and findings are densely encountered. The ancient city of Kanytellis in Mersin province of Turkey is one of these examples. Kanytellis, which includes structures such as houses, tombs and churches, is dated to the Late Antiquity. The buildings are placed in terraces in accordance with the structure of the topography. The areas between them form streets, some of which narrow down to 1-2 meters. The relatively wider openings between the buildings were used as small squares and cisterns were placed in most of them. A main street starting from the Hellenistic tower continues northward along the western border of the sinkhole. This city axis, which was formed in Antiquity, was preserved in Late Antiquity, although a part of it was closed by a church and narrowed in the northern part [2].

Modeling and digital archiving of historical buildings and artifacts serve the purpose of transferring cultural heritage to future generations [7-10]. Numerous methods are used in modeling processes and photogrammetry is one of these methods that is frequently utilized [8].

In this study, an ancient village house in Kanytellis was modeled by photogrammetric method using an unmanned aerial vehicle. As a result of the analyzes conducted on the model obtained, values such as lengths, areas and volume of the building are presented. Analyzes were conducted by two different software (Agisoft Metashape and Context Capture) and the results were presented comparatively in the results section of the study. Coordinate and length measurements were carried out on the models obtained with both software and the results were presented comparatively. As a continuation of this study, it is planned to analyze the thermal performance of the ancient house.

The location of the ancient house is shown in Figure 1.

Figure 1. The location of the ancient house

2. Material and Method

This study is composed of two phases, namely field and office work. The steps of controlling the study area, preparing it for photographing and taking images of the ancient house by an unmanned aerial vehicle constitute the field study phase. When it comes to the office work phase, the steps of transferring the data received from the unmanned aerial vehicle to the computer environment, interpreting and processing were performed.

UAV photogrammetry has been used frequently in engineering projects in the last decade. Objects can be modelled without touching them using UAV [11-13]. Rockfall [14], landslide studies [15-16], pond volume [17], shoreline detection [18], village site modelling [19], material deterioration [20].

2.1. Field work

The field studies first started with the necessary permissions from the relevant museum directorate. The antique village house, which is an ancient artifact built in the 2nd century AD and located in the Kanlıdivane region of the Mersin province of Türkiye, has coordinates 36.526774, 34.177668. The ancient house is located in the northwest of the sinkhole.

Then, the flight altitudes at which images will be taken around the house were determined. Images were taken by Parrot Anafi HDR drone (Figure 2) by manually. The technical specifications of the unmanned aerial vehicle utilized are presented in Table 1. Some of the images of the antique village house are shown in Figure 3.

Although there are automated flight plans, the flights were made manually in order to get all the desired details on the structure. Every detail of the structure was tried to be captured by flying first at low altitude and then at high altitude. A total of 107 images were taken. Some of the images of the ancient house captured are shown in Figure 3.

Figure 2. Parrot Anafi HDR UAV

Table 1. The technical specifications of the UAV

	Feature	Value
Drone	Size folded	244x67x65 mm
	Size unfolded	175x240x65 mm
	Weight	320 g
	Max transmission range	4km with controller
	Max flight time	25 min
	Max horizontal speed	15 m/s
	Max vertical speed	4 m/s
	Max wind resistance	50 km/h
	Service ceiling	4500m above sea level
	Operating temperature	-10°C to 40°C
Lens	Sensor	1/2.4'' CMOS
	Aperture	f/2.4
	Focal length (35 mm eq.)	23-69 mm (photo)
	Depth of field	1.5 m - ∞
	ISO range	100-3200
	Digital zoom	up to 3x (4K Cinema, 4K UHD, FHD)
	Photo resolution	21MP (5344x4016) / 4:3 / 84° HFOV

Figure 3. Some images of the antique village house captured by UAV

2.2. Camera Calibration

The camera utilized should be calibrated beforehand so that the merging and overlay operations of the images can be of high accuracy. The unmanned aerial vehicle used in this research has a 5.92 mm sensor, as was indicated in the part before it. Images have a size of 4608x3456 pixels. Camera calibration was conducted in Context Capture software. The distortion parameters obtained as a result of camera calibration is shown in Table 2.

Table 2. Camera calibration parameters

	Focal Length [mm]	Focal Length (eq. 35) [mm]	Principal Point X [px]	Principal Point Y [px]	K1	K2	K3	P1	P2
Previous Values	3.74	22.75	2301.24	1754.28	-0.0015	0.0087	-0.0058	0.0022	0
Optimized Values	3.83	23.31	2325.78	1729.62	-0.0041	0.0142	-0.0112	0.0036	0.0003
Difference Previous / Optimized	0.09	0.57	24.54	-24.66	-0.0026	0.0055	-0.0054	0.0014	0.0003

2.3. Office work

After the completion of the image acquisition within the scope of the field work, the office work phase was initiated. Firstly, the data received from the flight were transferred to the computer environment. The total size of the image file acquired followed the flight was 517 MB. Data processing was conducted in Bentley's Context Capture, and Agisoft Metashape software as well. The office work, which was started after half a day of field work, was completed in two days. The positions of the images taken relative to the ancient house are presented in Figure 4.

Figure 4. The positions of the images taken by UAV

All the photos captured were utilized in the processes. Generic block type was chosen for the aerotriangulation process of the images based on experience from previous studies. No control point was used in this study. Positioning metadata of the images were utilized for rigid registration. High key points density option was selected. In the aerotriangulation process, 97377 tie points were formed in Agisoft, while 31390 tie points had been occurring in Context Capture software. Alignment steps of the images took 4 min 25s for Agisoft and 6 min 41s for Context Capture.

Reconstruction process was initiated by generic selection of matching pairs after aerotriangulation step. Extra geometric precision (tolerance of 0.5 pixel in input photos) option was implemented. In order not to deviate from the original geometry of the house, small hole-filling option was applied. Finally, in this step, the spatial frame is reduced, avoiding the modeling of unnecessary regions and the use of excessive computer power. After the aerotriangulation process, it took 1 hour and 28 minutes to recreate the 3D solid model. Computer used in processes has Intel(R) Core (TM) i7-7700HQ CPU @2.81GHz processor, 16 GB of RAM capacity and GeForce Nvidia 1050 Ti 4 GB graphics card.

The above operations were performed in Context Capture software and the same operations were repeated in Agisoft software. It took 1 hour and 13 minutes to obtain the 3D solid model of the ancient house.

Following the process of recreating 3D solid models, coordinate and length measurements were conducted on the model in both software. Obtained values are presented comparatively in the "Results" section.

3. Results

After the camera calibration, field and office work phases were complemented, a 3D solid model of the antique village house was obtained. The surface texture was produced by utilizing images to attach visuality to the obtained 3D solid model. Texture compression quality was selected as 100% quality and texture sharpening option was enabled. The three-dimensional models of ancient house are presented in Figure 5a and Figure 5b.

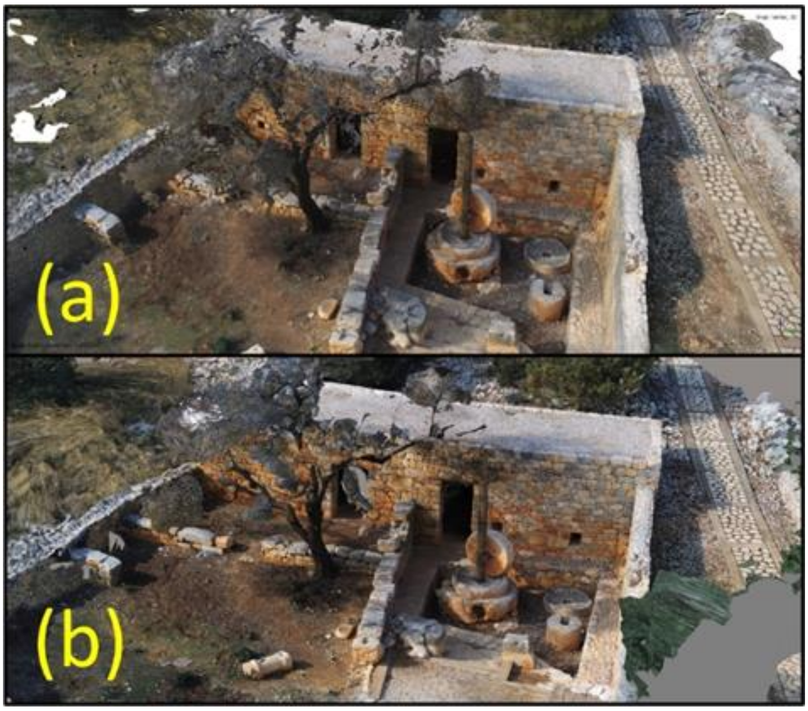

Figure 5. 3D models of the ancient house (a-Agisoft; b-Context Capture)

The final 3D models are in one-to-one scale with the real work. While length measurements can be taken on the model, area and volume calculations can be made at the same time. Examples of area and volume calculations on the building are presented in the Figures 6-7-8.

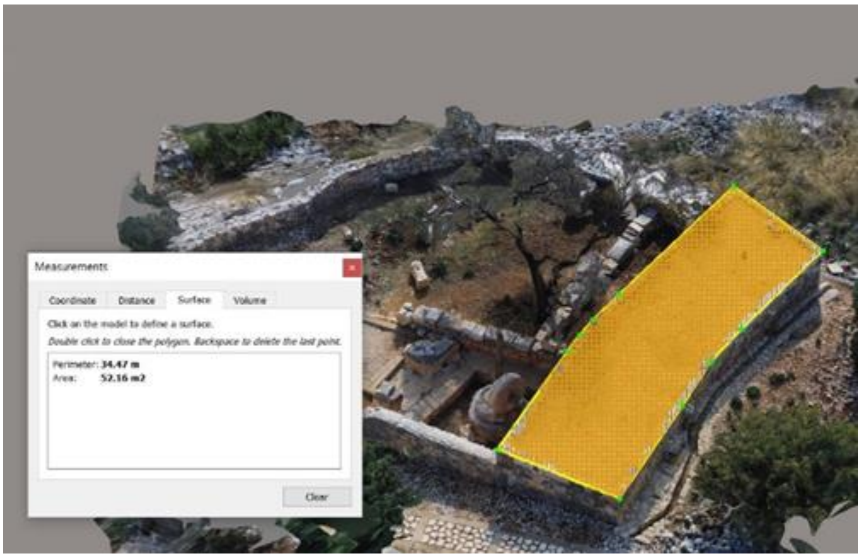

Figure 6. Floor area of the antique house

Figure 6 indicates the floor area of the ancient house, which is 52.16 m^2. In addition, the perimeter of the floor area was calculated as 34.47 m. The building height is 3.29 meters and as a result of multiplying this value by the floor area, the building volume is calculated as 171.6 cubic meters.

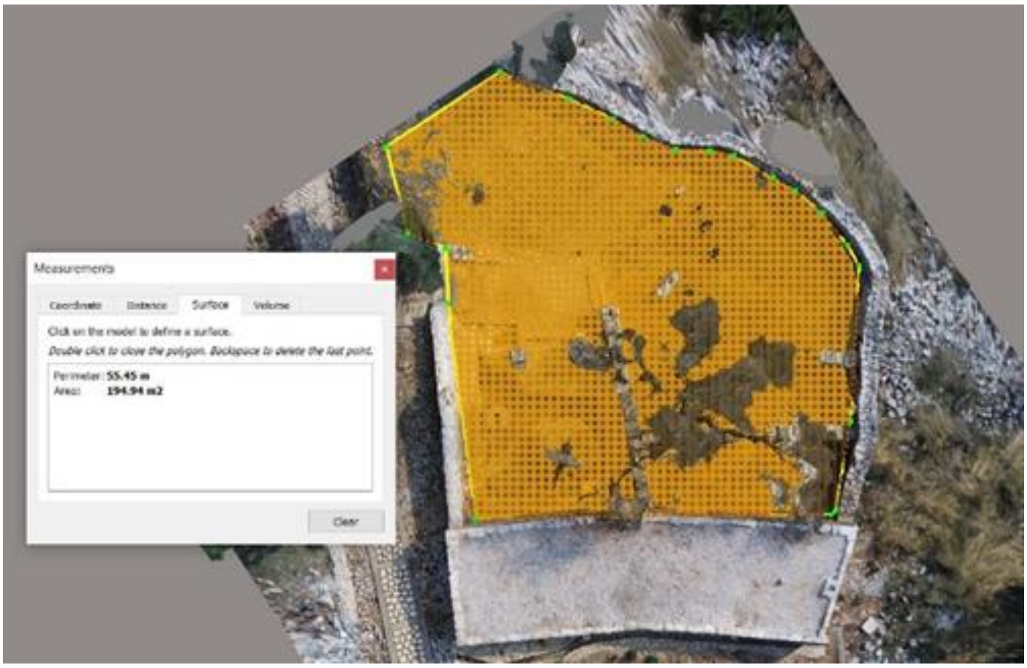

Figure 7. Garden area of the antique house

Figure 7 shows the garden area of the ancient house, which is about 195 m^2. Aside from that, the perimeter of the garden area was calculated as 55.45 meters. In order to calculate the usable garden area, the measurements were made from the inner border of the garden wall.

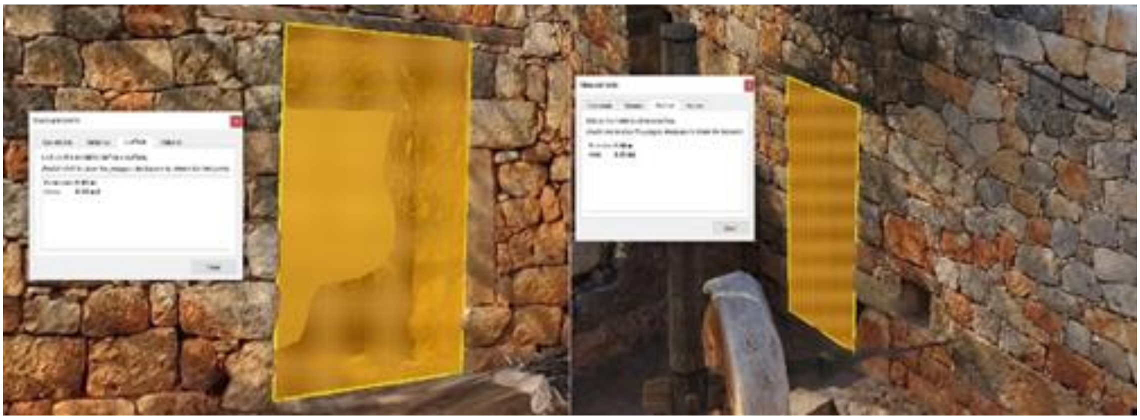

Figure 8. Measurements of building entrance doors

Figure 8 displays the measurements of the building entrance doors. There are 2 entrance doors to the building, and the first of these doors has an area of 2.11 square meters and the second one has an area of 1.85 square meters. The door on the side where the olive oil production workshop is located is the smaller one. There is a mechanism in the garden for olive oil production in the ancient village house and it covers an area of approximately 15.5 square meters.

In the last step of the study, the length and coordinate measurements of the models obtained with both software are presented comparatively in Table 3. The length and points used in the comparison are presented in the Figure 9 and 10.

Table 3 indicates the point coordinates acquired from Agisoft Metashape software. Table 4 shows the point coordinates obtained from Context Capture software. Table 5 and 6 presents the root mean square error (RMSE) calculations of the North and East coordinates. Table 7 indicates the RMSE calculation of the points' elevation values.

Figure 9. The points used in the comparison

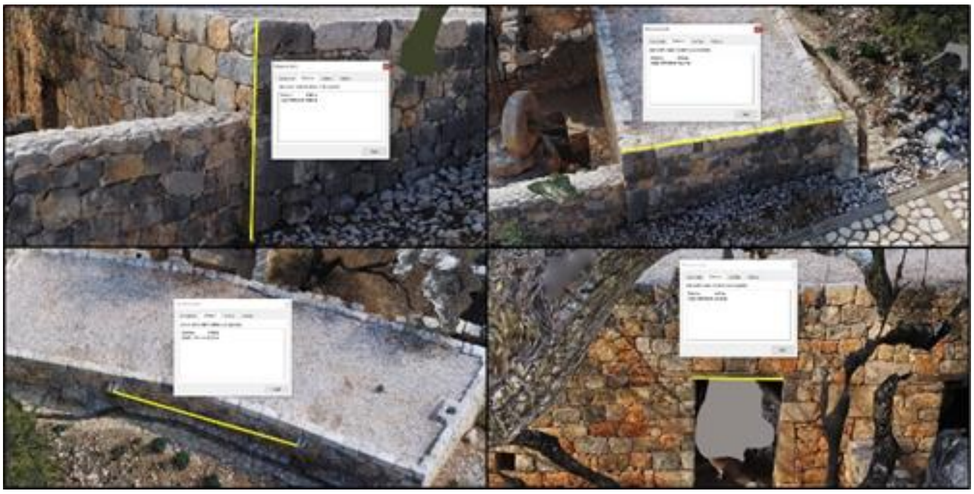

Figure 10. The lengths used in comparison

Table 3. The point coordinates (from Agisoft)

	North	East	Elevation
1	36.526776	34.177573	250.066
2	36.526881	34.177659	249.706
3	36.526898	34.177620	249.627
4	36.526805	34.177544	250.014
5	36.526810	34.177607	248.790
6	36.526834	34.177628	246.698
7	36.526865	34.177595	249.427
8	36.526828	34.177568	249.378

Table 4. The point coordinates (from Context Capture)

	North	East	Elevation
1	36.5267758	34.1775732	250.100
2	36.5268813	34.1776587	249.720
3	36.5268980	34.1776204	249.630
4	36.5268045	34.1775444	250.010
5	36.5268103	34.1776067	248.790
6	36.5268342	34.1776280	246.700
7	36.5268646	34.1775948	249.430
8	36.5268279	34.1775677	249.380

Table 5. RMSE calculation of the North coordinates [deg]

Agisoft	Context	Difference	Difference²
36.526776	36.5267758	2E-07	4E-14
36.526881	36.5268813	3E-07	9E-14
36.526898	36.5268980	0	0
36.526805	36.5268045	5E-07	2.5E-13
36.526810	36.5268103	3E-07	9E-14
36.526834	36.5268342	2E-07	4E-14
36.526865	36.5268646	4E-07	1.6E-13
36.526828	36.5268279	1E-07	1E-14
	RMSE		**2.91548E-07 deg**

Table 6. RMSE calculation of the East coordinates [deg]

Agisoft	Context	Difference	Difference²
34.177573	34.1775732	2E-07	4E-14
34.177659	34.1776587	3E-07	9E-14
34.177620	34.1776204	4E-07	1.6E-13
34.177544	34.1775444	4E-07	1.6E-13
34.177607	34.1776067	3E-07	9E-14
34.177628	34.1776280	0	0
34.177595	34.1775948	2E-07	4E-14
34.177568	34.1775677	3E-07	9E-14
	RMSE		**2.89396E-07 deg**

Table 7. RMSE calculation of the Z values [m]

Agisoft	Context	Difference	Difference²
250.066	250.100	0.034	0.001156
249.706	249.720	0.014	0.000196
249.627	249.630	0.003	9E-06
250.014	250.010	0.004	1.6E-05
248.790	248.790	0	0
246.698	246.700	0.002	4E-06
249.427	249.430	0.003	9E-06
249.378	249.380	0.002	4E-06
	RMSE		**0.0132 m**

Table 8. RMSE calculation of the lengths on the 3D solid models [m]

Agisoft	Context	Difference	Difference²
1.58	1.60	0.02	0.0004
3.93	3.93	0	0
4.92	4.90	0.02	0.0004
1.16	1.17	0.01	0.0001
0.92	0.92	0.0009	8.1E-07
1.88	1.88	0	0
6.31	6.30	0.01	1E-04
4.73	4.75	0.02	0.0004
	RMSE		**0.013233 m**

4. Discussion and Conclusion

When the obtained models are examined, although Context Capture gives better results visually, Agisoft gave better results in terms of mesh smoothness. According to Figures 6-7-8, it is seen that detailed measurements can be made on the models acquired. As a matter of fact, within the scope of this study, coordinate, length, area and volume measurements of the ancient house were conducted.

When it comes to consistency of results and comparison of software, the measurements made on the obtained models were examined. As indicated by Table 5-6, the consistency between the measured coordinate values is quite high because the RMSE value is low. Moreover, the fact that the RMSE values of the North and East coordinate data are almost the same among themselves strengthens the results.

As verified by Table 7, the elevation values of the points have a low RMSE value of 1.32 cm. For a building with a floor area of 52.16 square meters, the average error of 1.32 cm is considered to be at an acceptable level. When Table 8 is examined, the fact that the calculated difference value is the same as Table 7 reflects the consistency of the results in a way.

In a previously published and similar study, an ancient mausoleum was modeled and these analyzes were conducted [4]. In this study, the calculated difference value between both coordinate and length values was more consistent than the previous study. The reason why the results are more consistent is thought to be the higher quality of the photo processing operation.

The high consistency of the results obtained with two different software proves the accuracy and usability of the models recreated. The 3D models received can be used in future studies such as restoration, modification and improvement. Furthermore, the 3D models acquired can be utilized by historians and archaeologists, as well as by local governments in advertising activities to improve tourism activities.

To summarize the study, digital documentation of an ancient village house located in the Ancient City of Olba in the Kanlıdivane region of Mersin province was carried out. Photogrammetric modeling was conducted by flying around the ancient village house via UAV. The modeling process was carried out with two separate software and the consistency of the results was presented comparatively. The fact that the calculated RMSE values were very small compared to the building size documented the consistency and usability of the results.

As a continuation of this research, it is planned to examine the thermal performance of the ancient village house.

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Author contributions

Engin Kanun: Conceptualization, Methodology, Software, Writing-Original draft **Aydın Alptekin:** Data curation, Writing-Original draft preparation, Software, Validation. **Lale Karataş:** Visualization, Investigation, Writing-Reviewing and Editing. **Murat Yakar:** Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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