Creating a 3D terrain model for the territory of the Hasti-Imom ensemble in Tashkent, Uzbekistan

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Abstract. The purpose of this work is to create a three-dimensional model of the terrain on the territory of the Hasti-Imom ensemble of the city of Tashkent (Uzbekistan), using a Geoscan 401 multirotor unmanned aerial vehicle and a modern photogrammetric product Agisoft Metashape. Four flights were performed at this facility using a Geoscan 401 quadcopter. Aerial photography was carried out at different heights (from 40 m to 100 m) and with different inclinations of the aerial camera (45⁰, 60⁰, 90⁰) in order to display all elements of the ensemble in more detail. Aerial photography was carried out at a scale of 1:500 using a SonyDSC-RX1 digital aerial camera with a focal length of 50 mm. The longitudinal overlap of aerial photographs was from 70% to 80% and, accordingly, the transverse overlap was also from 70% to 80%. The number of aerial photographs at the site was 936 pieces. The length of all air routes was 65.9 km. The area of the filmed object was 14 hectares. The processing of unmanned aerial photography and the construction of a three-dimensional model of the terrain on the territory of the Hasti-Imom ensemble in Tashkent, Uzbekistan was carried out in the modern photogrammetric complex Agisoft Metashape.

1 Introduction

Not so long ago, drones, or unmanned aerial vehicles (UAVs), were rather relegated to the realm of science fiction. Today we are learning about ever wider possibilities for their application. UAV technologies have moved much further: the more capabilities radio electronics have, the more new materials for aircraft construction, the higher the development of global navigation systems, the wider the scope of application of “unmanned” aircraft. Considering that drones are much cheaper than manned airplanes and helicopters, this trend will only increase [1].

The prerequisites for the use of UAVs as a new photogrammetric tool are the shortcomings of two traditional methods of obtaining remote sensing data using space satellites (space photography) and manned aircraft (aerial photography). Traditional aerial photography, which is carried out using airplanes or helicopters, requires high economic costs for maintenance and refueling, which leads to an increase in the cost of the final product [2].

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Therefore, at the moment the whole world is focused on producing cartographic products using a fast and cheap method. But it became possible to obtain such a product only with the advent of unmanned aerial vehicles and corresponding software on the market, which can automatically create a digital orthomosaic and a three-dimensional terrain model.  

The relevance of this topic lies in the fact that just a few years ago all topographic and geodetic organizations were working on creating so-called flat 2D maps using the analogue method, using universal stereo topographic instruments. Now, in the age of digital technology, it is possible, having digital aerial cameras, unmanned aerial vehicles and accompanying software for processing unmanned aerial photography, digital photogrammetric stations, to create three-dimensional terrain models.  

The purpose of this work is to create a three-dimensional model of the terrain on the territory of the Hasti-Imam ensemble of the city of Tashkent (Uzbekistan), using the Geoscan 401 unmanned aerial vehicle and the modern photogrammetric product Agisoft Metashape.  

On the way to achieving this goal, the following tasks will be considered in the work:  
1. purpose of unmanned aerial vehicle type Geoscan401;  
2. purpose of the photogrammetric complex Agisoft Metashape;  
3. technology for creating a three-dimensional model of the territory of the Hasti-Imam ensemble.  

2 Materials and methods  

With the advent of unmanned aerial vehicles and software products on the world market that allow photogrammetric processing of unmanned aerial photography, the production of cartographic products has increased tenfold. The modern world today is actively engaged in the improvement and development of software products for creating three-dimensional terrain models that are photographic accurate and allow you to better imagine what a particular project will look like when brought to life and make certain adjustments.  

Thus, in this work, the technology for creating a 3D model for the territory of the Hasti-Imam ensemble, located in the ancient residential area of Tashkent, Sebzar, will be considered. The mosque was built in the best traditions characteristic of Central Asian architecture. Two colossal minarets, each 53 meters high, adorn the entrance to the mosque. The Hasti-Imam complex is an architectural ensemble that has been the main attraction of Uzbekistan for thousands of years. In addition to the buildings, there is a library of oriental manuscripts and the Koran of Caliph Uthman.  

To carry out the planned work, a Geoscan 401 multi-rotor unmanned aerial vehicle was used.  

Figure 1. Geoscan 401 quadcopter.
3 Results and discussion

The satellite image (Figure 2) captures the vast territory of the Hasti-Imam ensemble. This visual representation, derived from satellite technology, offers a bird's-eye view of the ensemble's geographical expanse. The image likely encompasses a wide area, showcasing not only the architectural elements but also the surrounding landscape, natural features, and the ensemble's integration into its environment.

Satellite imagery is a powerful tool for observing large-scale geographical contexts, offering valuable insights into the spatial relationships between the Hasti-Imam ensemble and its surroundings. The image may reveal the ensemble's proximity to water bodies, road networks, and other contextual elements that contribute to its overall setting. This comprehensive view aids in understanding the ensemble's position within the broader geographical and cultural landscape.

The satellite image serves various purposes, ranging from archaeological and historical research to urban planning and conservation efforts. Scholars can use it to study the evolution of the ensemble and its relationship with the surrounding environment.
of the ensemble over time, while urban planners may find it instrumental in assessing the ensemble’s impact on the surrounding urban fabric. Moreover, the image provides a visual resource for enthusiasts and the general public, offering a unique perspective on the Hasti-Imam ensemble and its relationship with the natural and built environment.

Figure 2. Satellite image of the territory of the Hasti-Imam ensemble

Figure 3 provides a detailed snapshot of the Hasti-Imam ensemble’s territorial layout, showcasing a specific fragment on a scale of 1:2000. This scale offers a comprehensive view of the architectural and spatial elements within the ensemble, allowing for a detailed examination of the site. The fragment depicted in the figure likely highlights key features, such as the arrangement of buildings, pathways, green spaces, and other significant landmarks within the ensemble.

The 1:2000 scale indicates that each unit of measurement on the map corresponds to 2000 units in the actual environment, providing a balanced representation that balances detail and comprehensibility. This level of precision is particularly useful for urban planning, architectural analysis, and understanding the overall organization of the Hasti-Imam ensemble.
By examining Figure 3, one can gain insights into the spatial relationships between different components of the ensemble, discerning the overall layout and design principles that contribute to the cultural and architectural significance of Hasti-Imam. This detailed territorial plan serves as a valuable tool for scholars, urban planners, and enthusiasts seeking a deeper understanding of the ensemble's structure and historical context.

Figure 4 presents a diagram illustrating four distinct flights that were conducted at the Hasti-Imam site. The diagram likely depicts the trajectory and key parameters of these flights, providing crucial information about the airborne activities carried out in the vicinity of the Hasti-Imam location. This kind of diagram is essential for understanding the spatial coverage, altitude variations, and flight paths during these aerial operations.

Each flight's trajectory may be delineated in the diagram, indicating the specific areas covered and the altitudes achieved during each phase. Flight paths could be color-coded or annotated to differentiate between the four flights, allowing for a clear and concise representation of the aerial survey or reconnaissance conducted at the Hasti-Imam site.

Such diagrams are invaluable tools in fields such as aerial photography, surveying, and archaeological research. They enable researchers to visualize and analyze the scope of the flights, helping to identify patterns, areas of interest, and potential archaeological features. Moreover, these diagrams contribute to the documentation and planning of further research activities, aiding in the interpretation of aerial data collected over the Hasti-Imam site (Table 1).

<table>
<thead>
<tr>
<th>Flight No.</th>
<th>Route length (km)</th>
<th>Evaluation time (min)</th>
<th>Area of aerial photography (sq. km.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.8</td>
<td>27</td>
<td>0.22</td>
</tr>
<tr>
<td>2</td>
<td>15.9</td>
<td>32</td>
<td>0.22</td>
</tr>
<tr>
<td>3</td>
<td>19.0</td>
<td>38</td>
<td>0.11</td>
</tr>
<tr>
<td>4</td>
<td>17.2</td>
<td>34</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Figure 5 shows aerial routes that were carried out at different heights and with different inclinations of the aerial chamber. The tilt of the camera was changed in order to provide a detailed image of all elements of a given territory. During the first flight mission, the drone ICECAE 2024 flew at a specific altitude and orientation to capture high-resolution images.
manages to complete two cross routes at an altitude of 90 meters. On the second flight mission, the drone also manages to complete two cross routes at an altitude of 60 meters, but with the airmeter tilted at 60 degrees. On the third flight mission, Geoscan 401 does not have time to complete two cross routes (due to battery discharge), so the fourth flight mission is carried out, which involves performing an aerial flight at an altitude of 40 meters perpendicular to the third route.

Fig. 5. Image of aerial routes that were carried out at different altitudes and with different inclinations of the aerocamera

The process of generating a three-dimensional representation of the Hasti Imam site involves several key steps, as evidenced by Figures 6, 7, and 8. In Figure 6, the point cloud construction using the Agisoft Metashape program is depicted. This point cloud serves as a detailed and accurate digital representation of the surface, capturing the spatial coordinates of numerous points across the site. It provides a foundational dataset for subsequent analyses and visualizations.

Fig. 6. Cloud of points on the territory of the Hasti Imam ensemble

Following the point cloud construction, Figure 7 illustrates the creation of a height map. This map, likely derived from the point cloud data, visualizes variations in elevation across the Hasti Imam site. The height map is instrumental in identifying topographical features, terrain undulations, and structural elevations, contributing to a comprehensive understanding of the site’s morphology.
Building upon the height map, Figure 8 showcases the culmination of these efforts—a three-dimensional image. This immersive representation offers a lifelike portrayal of the Hasti Imam site, providing depth and spatial context to its architectural and environmental elements. The three-dimensional image facilitates detailed examinations of the site's topography, allowing researchers, archaeologists, and planners to explore and analyze the space virtually.
The integration of these three figures underscores the power of modern technology, particularly photogrammetry and 3D modeling, in archaeological and geographical research. The comprehensive visual data generated through these processes enhances our ability to study and preserve cultural heritage sites like Hasti Imam, offering insights into its physical characteristics and historical significance.

4 Conclusions

From the analysis of the work done, we can conclude that the use of Geoscan UAV as an aerial survey platform has great prospects when shooting small-scale area objects, and the accompanying Agisoft Metashape software allows you to process the resulting aerial photographs in a short time. Data from UAVs makes it possible to obtain high-quality cartographic materials with a resolution sufficient to obtain a map at a scale of at least 1:2000. A distinctive feature of all GeoScan complexes is a high degree of automation of all stages of work from preparing a flight mission to automatic landing at a given point and ease of use.

At the moment, 3D modeling is very popular, especially after 3D printing became available to people. Thanks to the advent and popularization of 3D printing, three-dimensional modeling has moved to a new level and has become more in demand than ever. A 3D terrain model has much greater capabilities than its two-dimensional counterpart.

References

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