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Research Article

UAV Image-Based Plan Drawing Method in Submerged Terrestrial Archaeological Settlements: The case of Kibotos

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Abstract

Documentation with drawing and photography is one of the most important stages in archaeological excavations and surveys. It takes a long time to draw the walls of the structures, stone by stone, during the archaeological excavations. Carrying out these studies underwater is an activity that requires extra effort, time, and experience as it is a different environment. This article will examine the possibility of drawing the plans of the structures unearthed or detected during the underwater archaeological excavations and land surveys in shallow waters by using aerial photographs in a shorter time and with less effort. The research results show that photograph-based archaeological plan drawing is efficient for shallow water archaeological excavation and surveys. It reveals that it can save time and labour in archaeological surveys and rescue excavations where time is extremely limited.

Keywords: UAV, Orthophoto, Archaeological Drawing, GIS, Underwater Archaeology

Introduction

The history of archaeological excavations conducted for scientific purposes dates back to the 18th century (Renfrew and Bahn, 2016, p. 23). One of the basic requirements for archaeological investigations and excavations from the 18th century to the present is the documentation of archaeological finds. Written reports, including detailed drawings and photographic documentation of finds, are the most important components of archaeological studies (Drewett, 2001, p. 126; Sevin, 1995, p. 90). Photographic documentation and drawing methods in archaeological excavations are the principles that have changed the most in recent decades as digital development has rapidly increased. With competitive technologies offering less time-consuming and more accurate products, archaeological recording methods have evolved greatly. The development of spatial and visual technologies over the past quarter century has led to significant changes in archaeological excavation and survey techniques (Dell'Unto et al., 2016, p. 74). Photographic documentation has been the focus of archaeological studies since the mid-19th century (Shanks and Svabo, 2013, p. 89). In addition to cameras and remote sensing, unmanned aerial vehicles (UAVs) are now widely used for photographic documentation in archaeological research and excavations. In archaeological field studies, UAVs are mostly used to understand the plans of the identified structures more clearly, to produce orthophotos of the remains, and to document them in 3D. Today, the effective use of UAVs has become one of the indispensable tools in archaeological field research besides the cameras (Bilir, 2022; Dumankaya, 2018a, 2018b, 2019a, 2019b; Dündar and Rauh, 2017, p. 520; Erenoğlu and Erenoğlu, 219, p. 2018; Utlu et al., 2020, p.239; Şahin, 2022, p. 73; Sefercik et al., p.151)

Another important documentation method in archaeological excavations is drawing. Remains of new buildings unearthed during the excavation should be recorded seasonally and included in the plan created during the excavations of previous seasons. For many years, scaled architectural drawings in archaeological sites were drawn in the field with millimetre papers, rulers and meters. Later, scaled drawing became less time-consuming with the spread of terrestrial coordinating systems such as Total Station. Moreover, coordinating common points taken with Total Station to the manually drawn structures, which were scanned and digitized on drawing software such as AutoCAD, is one of the methods that is used widely. With this method, each wall is drawn one by one and processed into the plan. Thus, distance-induced deviations are minimized in the drawing of structures spreading a very large area. In archaeological excavations, at least three of the team members need to be allocated for drawing, and this process continues for weeks, depending on the width of the area.

Throughout the years, as unmanned aerial imaging systems are more cost-effective and accessible, manual drawing techniques have been replaced by drawings created through aerial photography.

UAV images can be scaled through the medium of a known object with known measurements on software such as Autocad. However, the further away from the object in the scaled image, the deviation between the actual length and the map length increases. In order to minimize this deviation, the orthophoto of the study area should be used as the basis for the drawing instead of aerial images. These orthophotos can be easily created today with software such as ArcGIS Pro, Agisoft Metashape and Pix4D. It is known that photographic mapping systems have been used, especially in archaeological excavations in deep waters, since the 1960s (Bass, 1970, p. 139; Martin and Martin, 2002, p. 137). When the underwater sites are at enough depth, photographs of the submerged structures can be taken at an angle of 90 degrees. The photographic plan of the excavation area is drawn by overlapping the images taken. However, this process has become much easier with the computer programs mentioned afore.

This article aims to present the documentation method used in the case study of Limnae/Kibotos underwater remains. The orthophoto created for drawing in the case study was created with the UAV, which is very efficient in underwater archaeological research in shallow waters. Within the scope of the study, images of the structures were taken with UAV and then processed on Agisoft Metashape Professional to obtain orthophotos. The deviations in the created orthophoto are matched with local coordinates on NetCAD, minimizing the difference between the length in the orthophoto and the actual length. Then, the architectural drawings of the structures are made with coordinated orthophotographs on NetCAD. Therefore, this study discusses the advantages of UAV photos in archaeological sites (Bayırhan and Gazioğlu, 2020, p.327)

Study Area:

The study area, underwater Limnae/Kibotos remains, is located on the eastern shore of the Hersek Delta within the boundaries borders of the Altınova district of Yalova province (Fig. 1). The Limnae/Kibotos site was discovered during the final last days of The Ancient Harbour and Underwater Survey of Yalova Province Coastline Research in 2019, and research began in 2020 (Gündüz et al., 2021; Gündüz and Akalan Gündüz, 2022). Limnae/Kibotos was a settlement/port/monastery that appeared on the scene of history between the 4th century AD and 1207 AD. Through the cleaning work carried out in 2020 and the underwater excavations carried out in 2021, it was understood that there are at least six different structures under the water, and the remains cover an area of about 3000 square metres (Gündüz and Akalan Gündüz, 2022).

Fig. 1: Location of Limnae/Kibotos (Author)

Equipment:

Ground Control Points in the study area were taken with the Leica TP 400 Total Station. The coordinates required for Total Station were determined by the TUSAGA-Aktif (Turkey National Fixed GNSS Network – Active) system with the Stonex S8N Plus GNSS receiver provided by Altınova Municipality. Aerial photographs of the remains were taken with a DJI Mavic Air. DJI Mavic Air has a 12 MP, 1/2.3” CMOS Sensor camera. A photogrammetric flight mission over the remains was carried out on the Pix4Dcapture app. Intel(R) Core (TM) i9-10980HK CPU @ 2.40GHz 3.10 GHz processor and 64GB RAM laptop and Agisoft Metashape Professional were used to create orthophotos from the aerial photos. The created orthophoto was calibrated with Ground Coordinate Points in NetCAD GIS 7. The drawing was carried out on the calibrated orthophoto.

Before taking aerial photographs of the study area, a flight plan was created on Pix4Dcapture. During the flight in August, an area of 43x50 meters was photographed from a height of 10 meters with a 90° camera angle. The flight lasted 8 minutes and 18 seconds, and 199 photographs were taken (Fig. 2). Resolution of the photos is 4056x3040, and the pixel size is 1.6 x 1.6 µm. Ground Resolution is 2.39 mm/pix, and the coverage area was 289 m2. In particular, the day and time zone was chosen when the weather was cloudless and the water surface was as calm as possible on the day of the flight. In UAV shots taken on different days, it was seen that the reflections of the clouds and the waves had a negative effect on the image quality.

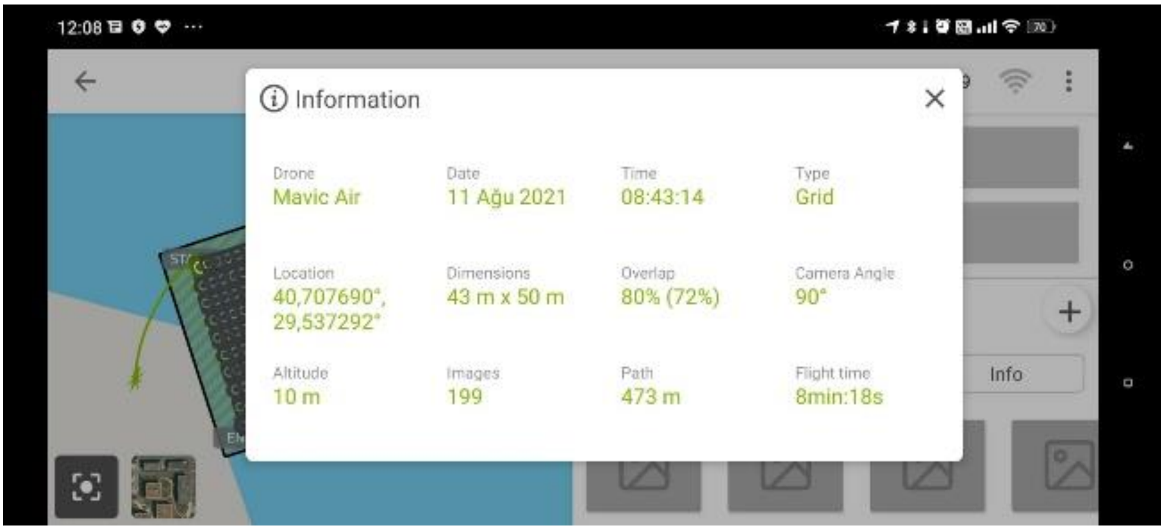

Fig. 2: Flight Information in Pix4Dcapture

DJI Mavic Air and Pix4Dcapture perform automatic flight from a minimum height of 10 meters. Since every detail and every centimetre matters in this study, the flight was performed from the lowest feasible height. After the flight, the images of the round-planed structure were selected for the drawing, and an orthophoto was created on Agisoft Metashape Pro. This choice is due to the fact that the entire orthophoto includes a larger area than the structure to be drawn. Large areas and high resolution slow down the workflow of the operation when working on Agisoft and NetCAD (Fig. 3).

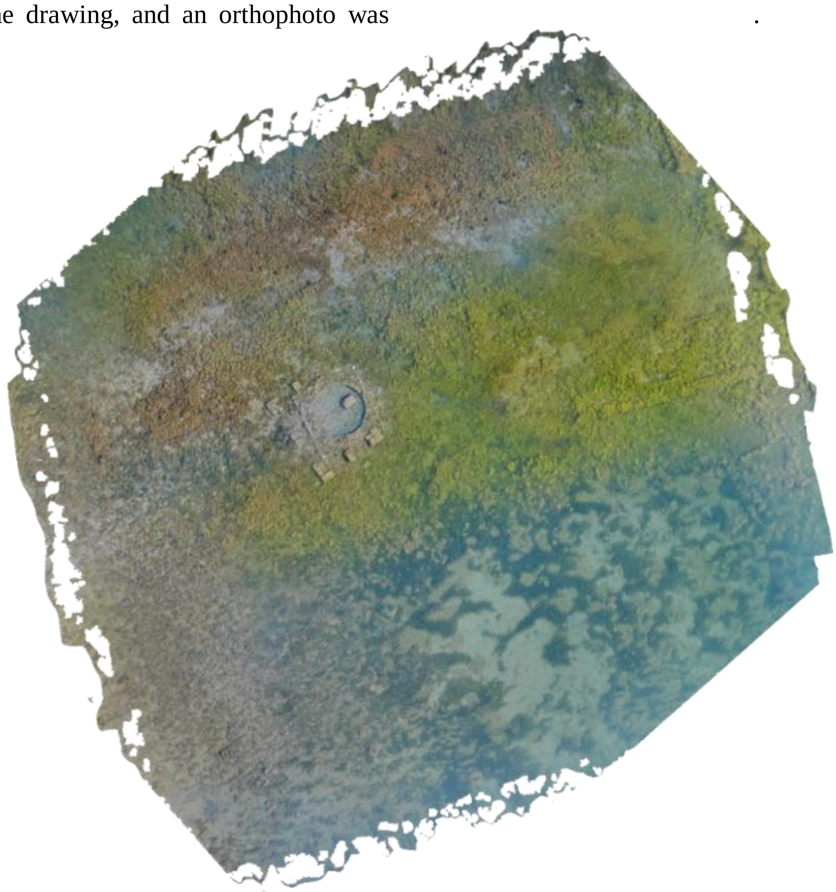
Fig. 3: The Orthophoto of the Area

The orthophoto used for the drawing was created with 57 photos containing the images of the round-planned structure. Point cloud, digital elevation model (DEM) and orthophoto of the area were produced on Agisoft Metashape Pro (Fig. 4). 78,956,566 points were generated during the cloud process. Generated DEM models' size is 9,917 x 10,252, and the resolution is 2.39mm/pix and 17.5 points/cm^2.

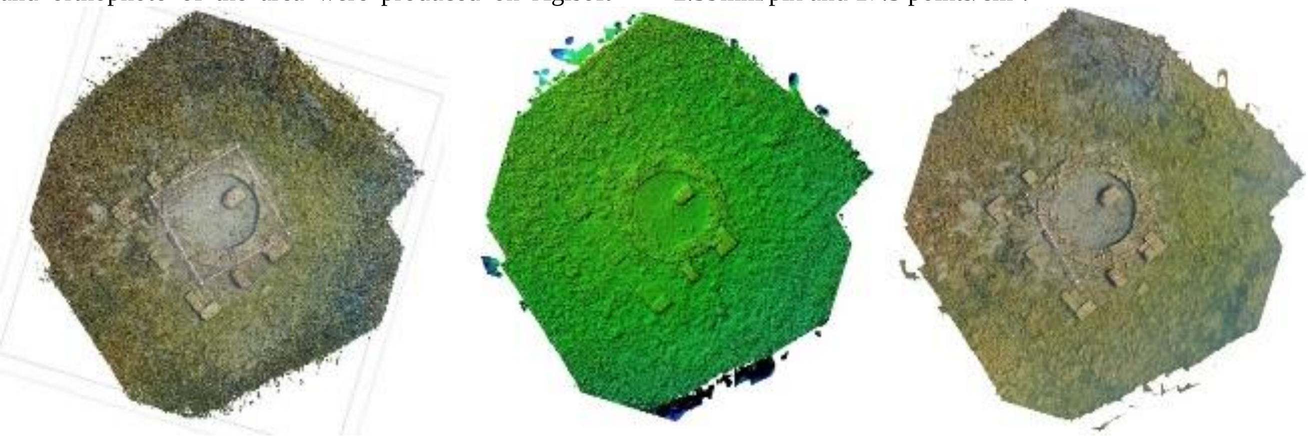

Fig. 4 Point Cloud, Digital Elevation Model (DEM) and Orthography of the Round Plan Building

When creating the orthophoto and DEM data, TUREF/TM30(EPSG:5254) was chosen as the output coordinate system. While checking the dimensions on the orthophoto, it was understood that the length of the edge of the trench, which should have been 5 metres, was 5.12 metres (Fig. 5). Although the average camera location xy error is 56.8314 cm, the dimensions of the building appear to be 12 centimetres longer than itself. The possible reason for this 12 cm may be that the structure is under the water, and the water acts as a lens which makes things appear bigger. This 12 cm difference shows that the drawing made directly on the orthophoto would not be correct and cannot be used as a base.

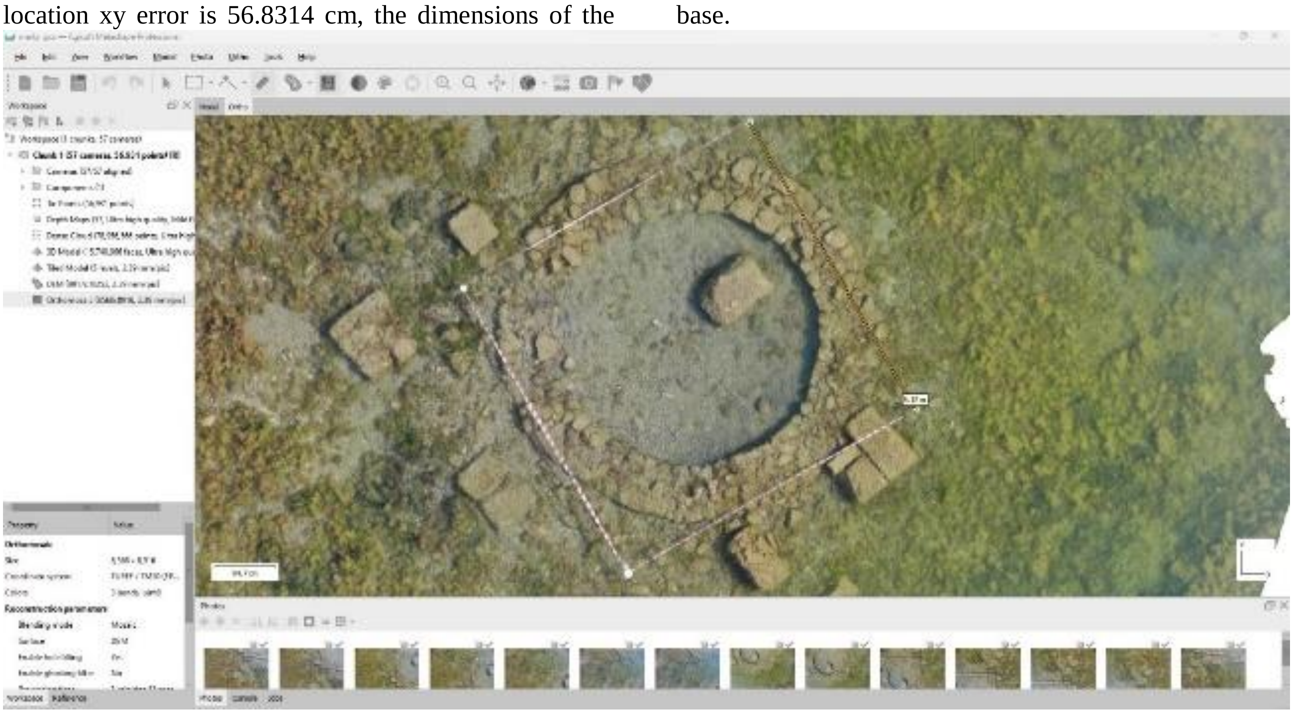

Fig. 5: Measurement on Agisoft Metashape Professional

The corners of the trench were created for the excavations of the round planed structure surrounding the building on all four sides. For this reason, the existing trench corners were determined as Terrestrial Coordinate Points before they were photographed with the UAV. Using the Total Station installed at the points determined by the TUSAGA-Aktif CORS system with the Stonex S8N Plus GNSS receiver, the underwater trench corners were recorded and transferred to NetCAD as a .ncn file (Fig. 6). The coordinate projection of NetCAD was chosen as Universal Transverse Mercator (UTM) 3, Datum; ITRF96 (International Terretrial Teference Frame 1996), and zone 30.

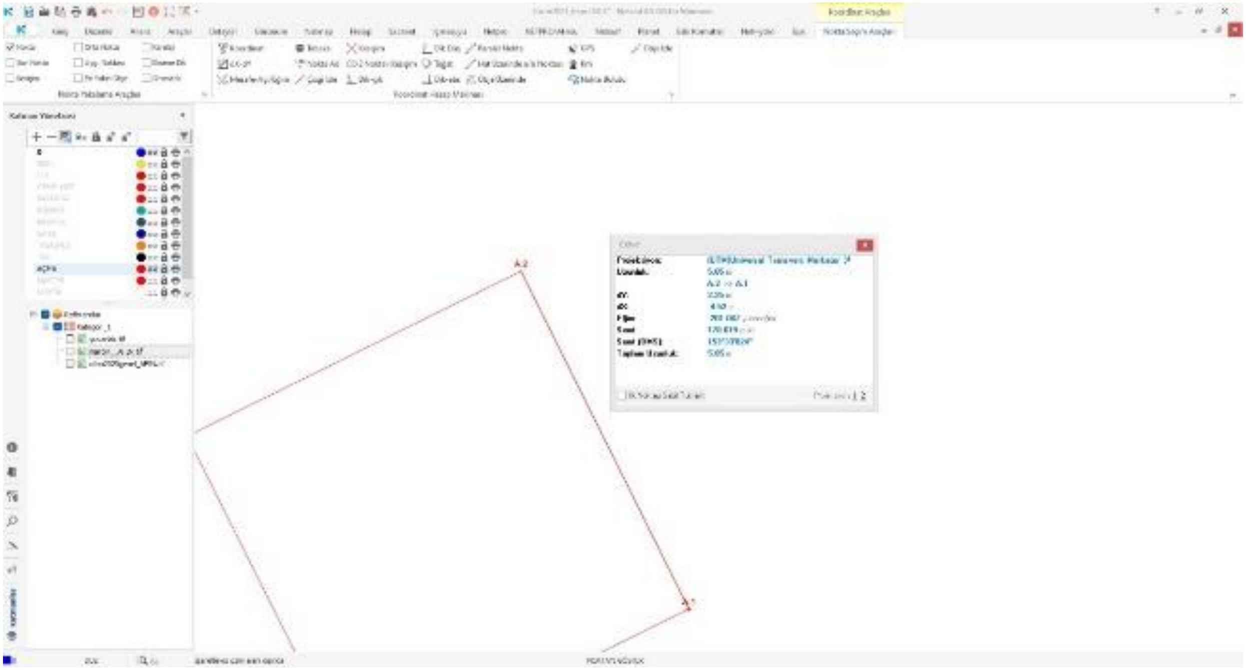

Fig. 6. Trench Corners in NetCAD

Points taken with Total Station were placed on the orthophoto created as a raster on NetCAD. Although the UAV has a built-in GPS, it does not have an accurate positioning system as the CORS system. For this reason, no match was achieved when the two data were overlapped on the computer (Fig. 7).

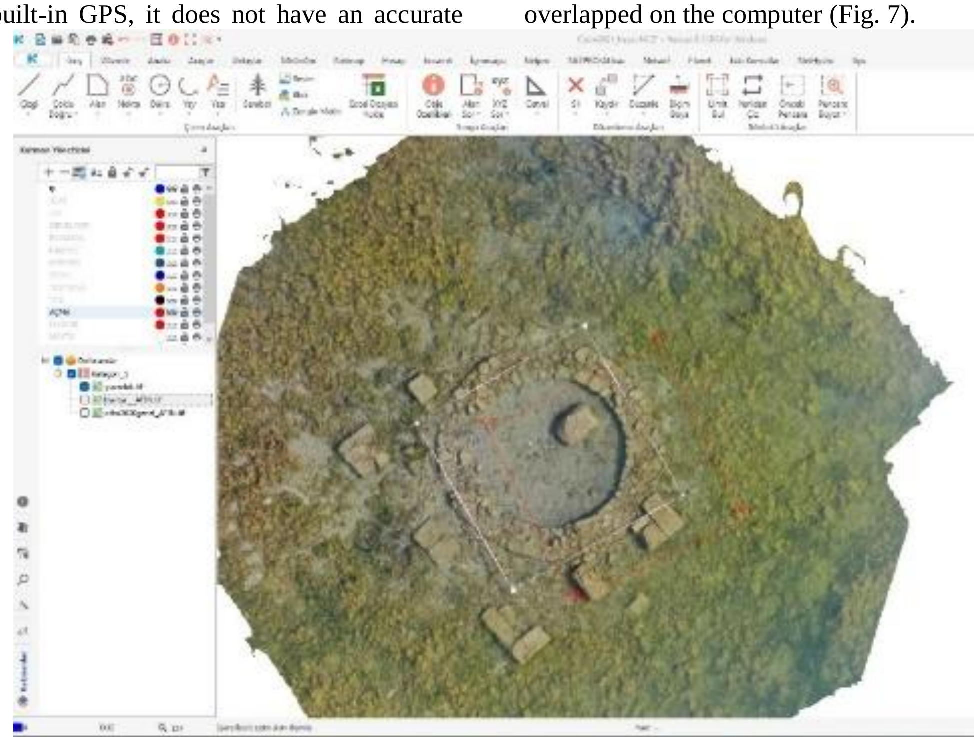

Fig. 7: Orthophoto–Trench Limits

There is a deviation between the orthophoto points and coordinated points because the dimensions in the produced orthophoto differ from the actual length and GPS deviation. Raster conversion to the image was made on NetCAD to bring the dimensions of the orthophoto to real dimensions and its real position on earth. This transformation can be done by matching the four trench corners on the orthophoto with the four points taken with the Total Station. After completing the transformation, it is possible to draw the architectural plan of the building with a few hours of work on the computer (Fig. 8).

Fig. 8: Prepared Orthophoto and Drawing of Rounded Planned Structure.

Discussion and Conclusion

Documentation is one of the most important steps of archaeological studies. Architectural remains unearthed as a result of excavations or detected during the survey are documented visually with scaled drawings. In this study, the importance of this tool was presented at Kibotos underwater site. In the Kibotos case study, two of the most important documentation techniques of archaeology were used together. As a result of this study, the coordinated aerial photograph and the architectural drawing of the building were obtained. In archaeological studies, drawing is a team effort. While at least two people take measurements in the field, one person must also draw. With the method mentioned in the article, drawing has ceased to be teamwork and become a work that can even be undertaken by a single person. This means less crew, less expense, and less time for very tight-budgeted research such as surveys. In future, with the automatization of image processing, this kind of work will even take a shorter time to execute.

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