PalArch's Journal of Archaeology of Egypt / Egyptology

ASSISTANCE SYSTEM IN ARCHAEOLOGY FOR DETECTING CERAMIC ELEMENTS IN SAND USING ARTIFICIAL VISION

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Gonzalo Guillermo Moreno, César Augusto Peña, Elkin G. Flórez S. Assistance System In Archaeology For Detecting Ceramic Elements In Sand Using Artificial Vision-- Palarch's Journal Of Archaeology Of Egypt/Egyptology 19(3), 172-179. ISSN 1567-214x

Keywords: Archaeology, Artificial Vision, Ceramics, Sand, Conservation.

ABSTRACT

This article presents the advances in the development of an archaeology assistance system. The system applies artificial vision tools to detect ceramic elements immersed in sand. The system is being developed to work in parallel with a robot responsible for carefully removing the sand in archaeological excavations. The proposed algorithm is based on analysis techniques in the frequency domain that allow it to identify the remaining objects despite the significant similarities that they may have in terms of color with the sand. The results obtained show the excellent effectiveness of the algorithm in the segmentation of ceramic objects.

INTRODUCTION

One of the most common tasks in archaeology is searching for remnant elements to carry out studies of the past of ancient cultures. This is a complex task that requires a lot of time and patience, these characteristics being its main problem. Many of the archaeological finds occur by accident when carrying out the construction of civil works. In these cases, many interests against the archaeological study prevent the achievement of permits for recommended times. The pressure of time means that excavations are not treated with due care on many occasions, generating possible errors, among which the breakage of objects stands out. One of the most controversial cases in archaeology was the construction of the Aswan dam (Darwish & Pöllmann, 2015; Flaminio et al., 2021; Giegengack & Zaki, 2017; McCool, 2019; Raslan & Salama, 2015; Strzepek et al., 2008), which required the titanic task of speeding up many studies in a concise time to safeguard the most significant number of archaeological treasures of ancient Egypt (De Meyer & Vereecken, 2015).

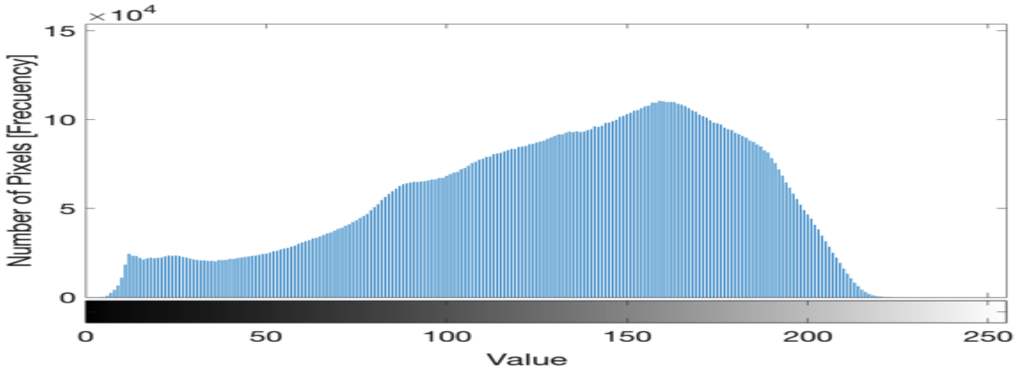
To provide archaeologists with technological tools that allow them to quickly execute repetitive tasks that require delicacy and precision, the development of search robots for remnants of ancient cultures is proposed. The main idea is to develop a device that allows sand to be gently removed from the excavation sites and to inspect the existence or not of the remaining elements. This objective is comprehensive and highly complex, so it is proposed to be carried out in stages. On the one hand, a robotic area removal system will be designed, and, on the other, an artificial vision system will be developed to search for archaeological objects. This article focuses on the advances obtained from this last system. This study has as limitations the search for ceramic elements only in soils made up of sand. In the same way, the use of algorithms contemplates lighting control as a requirement. Knowing the context, the problems and the limitations of the study, this work proposes to contribute to the solution of the following research question: Is it possible to detect archaeological elements of ceramic material in sandy soils?

The paper is structured as follow: First, the problem of finding ceramic elements in the sand is contextualized, then the proposed methodology is presented to solve the problem based on frequency and morphological analysis techniques. The following section presents the results obtained and their corresponding analysis. Finally, the main conclusions are presented.

METHODOLOGY

Given the great variety of objects that can be found in an excavation as well as the diversity of soils, in this work it is proposed to address the search for ceramic elements in places where the primary substrate is sand, this being one of the most common in this type of archaeological studies.

In Figure 1a, one can see an image of a ceramic artifact embedded in the sand. These images are what the robot will provide when applying the sand removal technique by controlled injection of air in the excavation area. The robot must detect the artifact before continuing with its locomotion to avoid damage to the archaeological elements.



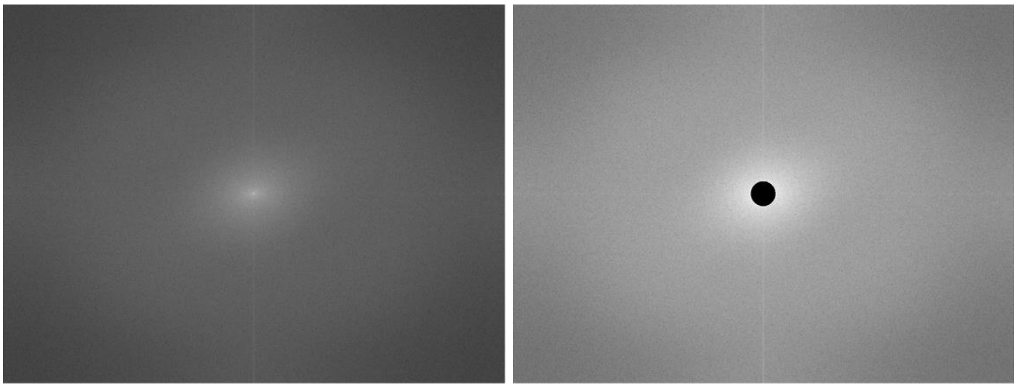
a) b)

Figure 1. Ceramic element covered with sand. a) Image. b) Histogram of red color

Identifying ceramic elements in the sand can be a complex problem if all the factors are considered. For instance, if it wanted to segment the object by color, the different shades of the pixels corresponding to the sand, combined with variations in the color of the ceramic elements, make it possible to overlap and confuse them. It can be seen when comparing the histograms of the image channels. In Figure 1b, it can see the histogram of the red color. Note that the pixels of the ceramic element are confused with the pixels of the sand; this is because each grain of sand contains different shades. This phenomenon increases with variations in lighting, humidity, and the accumulations of sand formed by the removal technique by controlled air injection. Figure 2 shows some shades of samples of ceramic elements. This diversity of colors can complicate or facilitate the identification of archaeological elements.

Figure 2. Samples of ceramic elements of different colors.

To avoid the problems corresponding to the overlapping of colors of the sand and the ceramic elements, it is proposed to carry out an artificial vision algorithm based fundamentally on frequency (Zeng et al., 2020; Zhang et al., 2021). In this order of ideas, the first is to convert the image from the RGB color space to grayscale. Subsequently, the fast Fourier transform is applied (two-dimensional case - discrete) (Li et al., 2021; Wang, 2020). Next, the amplitude spectrum is calculated (Asano et al., 2005; Durnyak et al., 2018; Merabet et al., 2019). It is locating the low-frequency components in the center of the image, as shown in Figure 3a. They are located in the center to eliminate them easily. In this way, only the high-frequency components are preserved, as shown in Figure 3b.

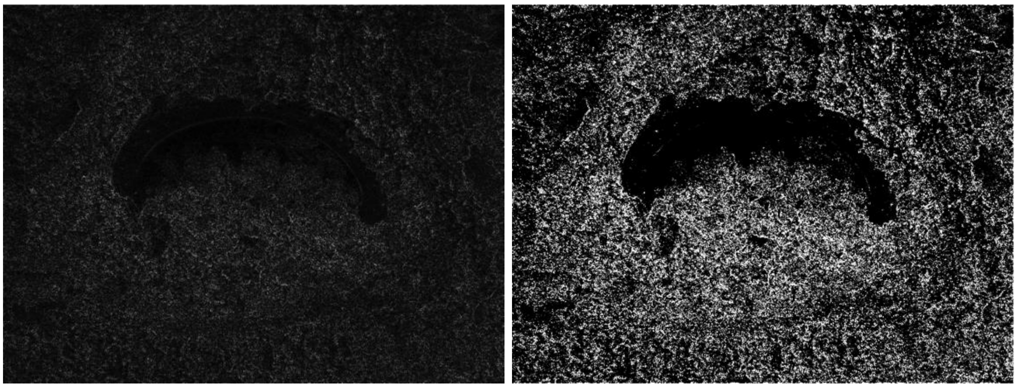


a) b)

Figure 3. Amplitude diagram after Fourier transform. a) the Whole b) Removed the central amplitude.

The application of this algorithm is based on the fact that the pixels corresponding to the sand tend to act in the same way as visual noise. There are many lighting changes around each grain of sand. Therefore, it oversees locating the sand, and the empty areas are studied to identify possible ceramic objects.

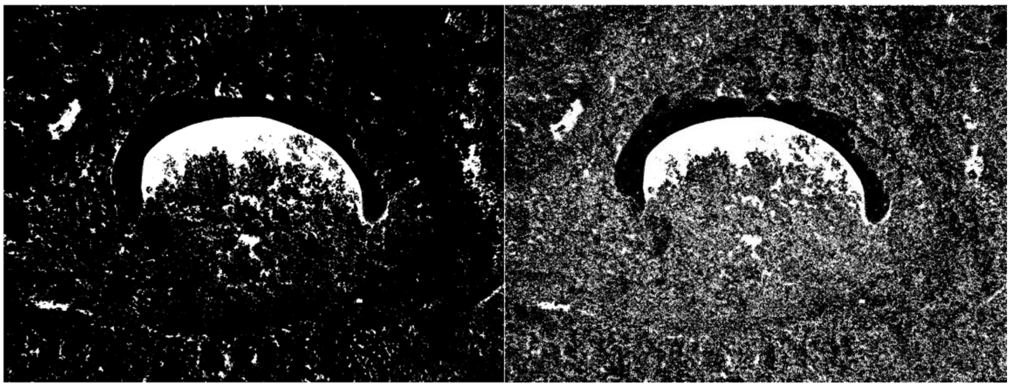
Once the low-frequency elements in the image spectrum are removed, it is restored through the inverse Fourier transform. This result can be seen in Figure 4a. Subsequently, the image is binarized by a Threshold of 15% to highlight the high-frequency elements, as shown in Figure 4b. Note that the ceramic element can be seen in the central part of the image, represented by the color black.



a) b)

Figure 4. High-frequency image was obtained by applying the inverse Fourier transform with the modified amplitude diagram. a) grayscale. b) binarized image with a threshold of 15%.

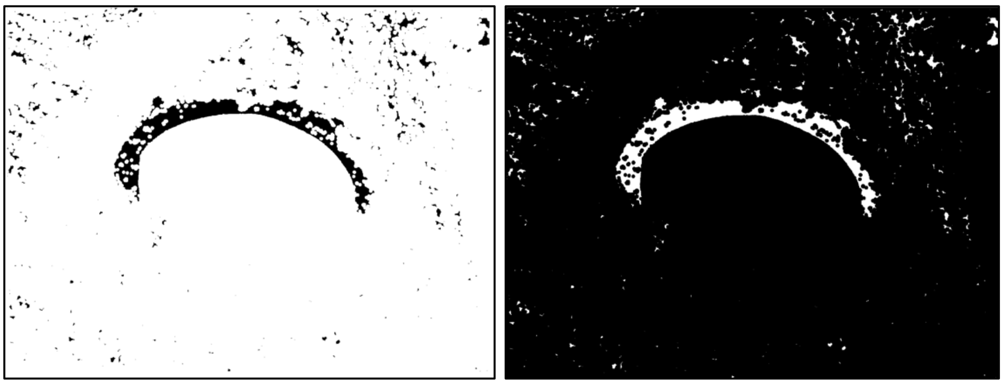
When analyzing the image in detail, the shadows and the dark areas of the image can be seen as part of the low-frequency areas. To take these pixels into account, a binary image is generated from the original image, thresholding at 20% and inverting the image. This result can be seen in Figure 5a. Subsequently, the union operation is applied between the previously obtained high-frequency image with the image of the shadows and dark areas, obtaining the image in Figure 5b.



a) b)

Figure 5. Segmentation of shadows and dark areas. a) Binary image of shadows and dark areas. b) Union of the high-frequency image with the image of shadows and dark areas.

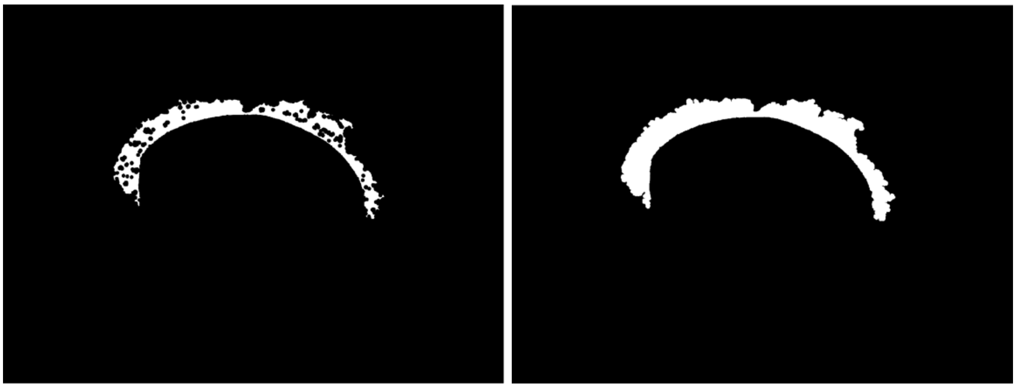
Although Figure 5b shows how the ceramic element begins to be identified more clearly, mathematically, it can become complex due to the number of black pixels that are blurred throughout the entire image. For this reason, some morphological operations were carried out (Cooksey & Withers, 2008; (Mokhtari et al., 2019; Panguluri & Mohan, 2021; Rashid et al., 2018; Rebhi et al., 2016; Shi-Gang et al., 2018) that help the segmentation of the ceramic element. First, the dilation operation was applied using a 15-pixel-radius disk as a structuring element. This operation causes the pixels surrounding the high-frequency elements to be much broader as they attempt to cover most of the arena, as seen in Figure 6a. Subsequently, the image is inverted, obtaining Figure 6b.



a) b)

Figure 6. Image subjected to a morphological dilation operation. a) Original image. b) Inverted image.

In Figure 6b, it can be seen that there are still several sets of pixels in the background of the image, so the area of these sets begins to be calculated, and the groups that do not exceed a pre-set size of 100,000 pixels are eliminated. The result can be seen in Figure 7a. Due to the various applications implemented in the algorithm, some of the pixels corresponding to the ceramic element were affected; this is mainly due to the noise and dirt it presents. For this reason, the holes were filled, and the dilation operation was applied to the segmented element. Figure 7b shows the result, where a localized ceramic object is clearly observed.



a) b)

Figure 7. Segmentation of the ceramic element. a) Elimination of pixels sets with small sizes. b) morphological restoration through filling and dilation operations.

RESULTS

When analyzing the results obtained by the proposed algorithm, it was possible to show that the algorithm locates the ceramic elements with reasonable effectiveness, despite the variety of inconveniences generated by the presence of sand in the image. The algorithm takes this weakness and turns it into a strength since the first thing it does is locate this same sand and restrict the search zones to the zones where it is not present. The average execution time of the algorithm is only 14.7 seconds. To use it in real-time, it is proposed as future work to implement the algorithm in an embedded card that allows parallel processing. Figure 8 shows the final result of the algorithm, where it incorporates a rectangle and a title on the ceramic object identified in the scene.

Figure 8. Location of the ceramic element on the original image.

CONCLUSION

The advances of the proposed algorithm allowed us to endorse the feasibility of detecting objects in the sand even though their colors can be confused with it. This algorithm was developed thanks to apply techniques in the frequency domain.

The inclusion of the analysis of shadows and dark areas in the image was very relevant for the development of the algorithm, considering that these areas are identified by being modeled as low frequencies.

It is presumed that the proposed algorithm can be implemented in other types of applications, such as augmented reality applications. These applications will make it easier for archaeologists to search for excavation remnants.

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