Utilizing Low-Altitude Imagery and Weak Learner Algorithms for the Detection of Archaeological Surface Ceramics: The Kophinou case study

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Introduction

In recent years, the application of remote sensing in archaeological research has grown significantly [1,2]. This study builds upon a 2021 case study conducted in Kophinou village, Cyprus, with a focus on improving the detection of archaeological surface ceramics using low-altitude imagery. The initial approach successfully identified scattered archaeological objects, even when they exhibited high spectral similarity to the surrounding surface [3]. This study further explores the potential of cost-effective, low-altitude sensor data and machine learning (ML) algorithms to accurately detect and map archaeological surface ceramics. However, challenges were encountered in accurately detecting ceramics, particularly due to the issue of imbalanced data. To address this problem, a new methodology was developed to enhance the detection of surface ceramics. The aim of this research is to address this gap in the literature by incorporating AI methodologies to manage non-uniformly distributed classes, using weak learner algorithms to provide a more efficient approach in terms of both time and accuracy. The methodology presented here has practical applications for improving archaeological foot surveys.

Methods and materials

We employed two different platforms of unmanned aerial vehicles (UAVs) and sensors to acquire high-resolution centimeter resolution imageries over the case study area. In particular we employed aDJI Phantom 4 Pro and a DJI Mavic 3 Multispectral platforms. Fligh height was set at an altitude of approximately 15 meters above ground level, capturing orthophotos with a spatial resolution of a couple of centimeters. The subsequent step involved standard photogrammetric processing for the production of the orthophoto-mosaic. Finally, we employed two supervised pixel-based classifiers, namely the Random Forest (RF) and the Support Vector Machine (SVM) methods. Additionally, pixels with similar spectral characteristics were grouped together into segments, creating objects via an image segmentation process. Overall accuracy was assessed by using randomly distributed ground truth data to evaluate the detection (classification) performance..

The process is illustrated in diagram 1 below.

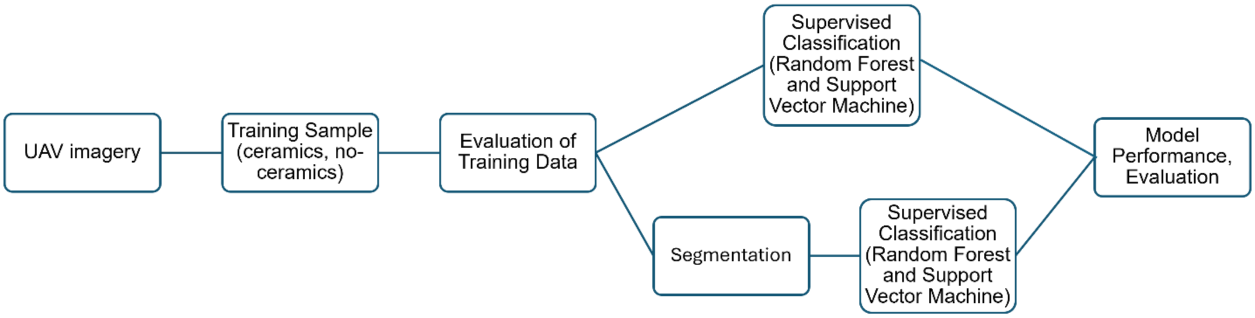

Diagram 1: Research methodology.

Results

Our training model involved two classes: 'ceramics' and 'no-ceramics', and therefoe was considered as a binary classification problem The results of the ceramics class varied in accuracy, with both RGB and multispectral images ranging from 7% to 16%, while with segmentation images provided slightly better results with an accuracy ranging from 22% - 46%.

The low success detection rate, can be explained as the majority of standard classifier learning algorithms are designed with the assumption of an equal class distribution and misclassification costs. Nevertheless, these algorithms may provide poor results when dealing with imbalanced data sets. In the context of archaeological surface ceramics, accurate modeling is challenging due to small sample sizes, separability, and sub-concepts. Existing literature suggests solutions such as rebalancing class distribution and modifying learning algorithms. In 1995, researchers [4, 5] developed a boosting algorithm to enhance the classification performance of other learning algorithms, especially designed for imbalance datasets. Adaboost algorithm is widely adopted method of boosting that enhances prediction capabilities for imbalanced data by giving an increased weight to challenging examples and combining weak rules through majority voting (Diagram 2). This algorithm has significantly improved our prediction accuracy compared to using only a decision tree.

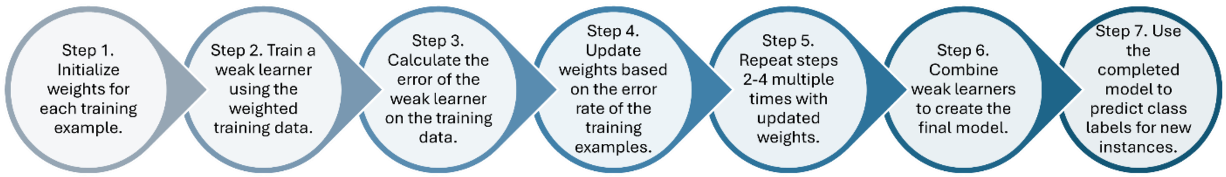

Diagram 2: Framework of the boosting algorithm processing steps.

Discussion

This study emphasizes the potential of using low-altitude sensor data and weak learner algorithms to accurately detect and map archaeological surface ceramics in a non-invasive manner. The findings indicate that these techniques show promise for advancing archaeological research by providing reliable and precise results. To ensure statistically significant spectral separability among the ceramics, lab-based spectral measurements will be conducted during the same flight. Additionally, further drone surveys are planned to improve data for algorithm training and outcome assessment. The future goal is to reduce noise, enhance the distinction between classes, and analyze imbalanced ceramics data using evaluation metrics such as the F-measure, G-mean, and ROC analysis.

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