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The NuragAI project: Artificial Intelligence-driven image analysis of Sardinia landscape, searching for unknown monuments

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Abstract

The NuragAI project aims at using an AI approach for image analysis of satellite imagery, in order to identify the nuraghi monuments (typical monuments of the Sardinia region, Italy, lasting from 1.8 to 0.7 ky BC), exploring the landscape and attempting a systematic survey of the Sardinia island. At the moment, a preliminary training has been performed, with an exceptionally positive result, and an earlier experiment of use. The satisfactory results are leading the authors towards a systematic analysis of the satellite imagery of the whole region, in order to check new monuments and open new perspectives for the use of AI in archaeological research.

CCS Concepts:

• *Applied Computing* → Arts and Humanities; • *Software and its engineering* → Software creation and management;

1. Introduction and research aims

Sardinia's most famous archaeological features, the *Nuraghi* (remains of the homonymous civilization, lasting about a thousand years, from around XVIII up to VII cent. BC) have been studied from many points of view [Lil88] [Lil06] [CPU18]. At the same time, the diffusion and high number of such monuments (over 8000 units), led to many attempts of systematic census [Mel67] [SP15] [Max]. Nevertheless, there has been no research based on AI applications to image analysis.

The authors tried to follow such an approach by preparing a test sample set of aerial images of positive (presence of nuraghe) and negative (absence) type and performing a training phase in order to reach an algorithm able to automatically recognize *nuraghe* items and obtaining a complete database of monuments for the whole region..

2. The case study

The Nuraghe Civilization represents a fascinating example of archaeological research. Since the XIX it was the subject of many studies. In the last decades, scholars agreed on approximately dating such a phenomenon between about XVIII and VII cent. BC [CPU18]. From a geographical point of view, the topic is strictly related to the Sardinia Island and its material manifestation, the nuraghe monuments, in fact, are typical constructions of this area, composed of one or more towers and a series of round shaped buildings around them (Fig.1,2). This kind of remains is typical of the Sardinia region and present all over the region, although with particular concentration in specific areas. Many attempts were carried out to complete a census of all monuments [Max] [SP15], the most remarkable being probably the one leading to the online archive of the SardegnArcheologica portal (https://sardegnarcheologica.it/text/1000/it). Relying on such data, at the moment, the registered ones are some 8-10k all over the island. Nevertheless, there seems not to have been an attempt to use AI in such a sense. Thus, the authors decided to set up a research project aimed to use an AI system to "learn" nuraghe features by a trial phase, in order to analyze the whole Sardinia region and check for this kind of monuments, to uncover the presence of unknown items and verify on the field the model reliability. The earliest step was to collect standardized aerial images of a series of positive (presence) and negative (absence) of nuraghe. a set of more than 2000 images has been collected and cataloged, representing the training set for the experiment, in its different phases.

3. The methodology

The process of building up the dataset firstly implied the extrapolation and arrangement of satellite images [AM10], which contained images of nuraghes, from the web-site *SardegnArcheologica*. The web-site has a database containing evidence of all nuraghes, classified from an architectural and archaeological point of view: corridor nuraghes, complex nuraghes, unclassified nuraghes, single tower nuraghes, mixed nuraghes and disappeared nuraghes. Once these satellite images were selected and downloaded from the database, these have been progressively divided into three main groups through an autopsic examination: positive cases (e.g.,

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Figure 1: *The "Arrubiu" Nuraghe, in Central Sardinia*

nuraghes found in environmental contexts, but easily recognized); uncertain cases (e.g., nuraghes found in environmental contexts, but hardly recognized); negative cases (e.g., nuraghes that were obliterated by subsequent structures).

For research purposes, only the positive cases have been taken into account, whereas the uncertain ones will be analyzed in a second phase. Once the image dataset will be substantial, we will proceed with the AI training.

Figure 2: *The "La Prisgiona" Nuraghe, in Northern Sardinia and the surrounding countryside from the top of the monument.*

4. The AI training

The proposed methodology involves a Deep Learning (DL) based strategy well-known in binary task classification. In particular, the proposal exploits an attention-based architecture, namely *Vision Transformer* ("ViT") [VSP*17] (see Figure 2), that is similar to a Recurrent Neural Network (RNN). It is an autoencoder with scaled dot-product attention units. The input is the RGB images collected from satellite images with their labels. The tests have been done using a 10-fold cross-validation scheme, thus averaging the results of 10 different tests. In each test the size of the training set is equal to the 90% of the total and the test set is composed of the remaining ones. The network has been trained on 100 epochs over 1000 positive and 1000 negative images in around 1 hour.

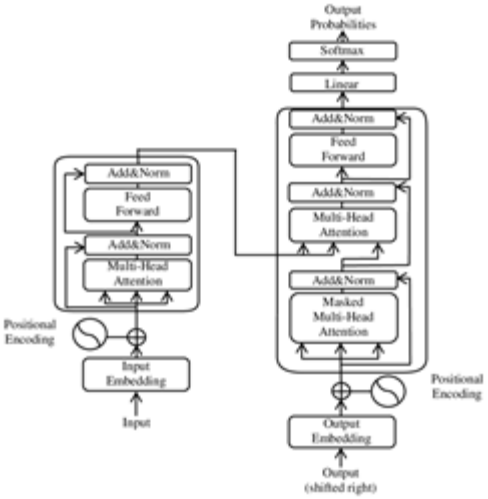

Figure 3: *Transformer's architecture.*

5. Conclusions and perspectives

The experiment gave an exceptionally interesting result: the system correctly recognizes 98,73% of aerial photos where a nuraghe is present, since its easiest phases. A deeper analysis revealed that the failures occurred when the surrounding is similar to the most common environments of positive samples: when there is a high similarity between a negative example terrain and a nuraghe surrounding one, the system could fail.

For the uncertain cases, the solutions we thought about are to increase the dataset size in the future and use heavier data augmentation techniques. The architecture seems robust due to its results with a dataset of only 2000 samples.

Such a goal pulled the authors to go forward in the use of the methodology for the systematic analysis and field research.

The next step will be the use of the algorithm on the whole Sardinia region, thanks to a dedicated script and the classification of all the results through a check of the existing literature and an on field survey. Moreover, the system is currently set for binary classification: nuraghe / not nuraghe. In the future we would like to classify structures more precisely

Beyond the creation of a truly inclusive list of the island nuraghi, which would be anyway a relevant milestone in the domain; the work may open various interesting research perspectives, such as the use of the same method for other areas characterized by architectural recurrent shapes, or the refining of the AI approach to try new ways of monument classification, beyond the traditional archaeologists' approaches; and so on.

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