One Photo, One Type. ArchAIDE, An Integrated System to Recognise Archaeological Pot-Sherds with Deep Learning

Francesca Anichini, Nachum Dershowitz, Gabriele Gattiglia, Barak Itkin, Lior Wolf, Holly Wright, Massimo Zallocco

Introduction

Today, characterisation and classification of ceramics are carried out manually, through the expertise of specialists and the use of analogue catalogues. While not seeking to replace the knowledge and expertise of specialists, the ArchAIDE project (www.archaide.eu) worked to optimise the identification process, developing a new system that streamlines the practice of pottery recognition in archaeology, using the latest automatic image recognition technology, with an innovative app for mobile devices and desktop where a single photo is enough for recognition. The ArchAIDE project was funded by the European Union's Horizon 2020 Research and Innovation Programme, with a consortium of partners which has representing both the academic and industry-led ICT domains, and the academic and development-led archaeology domains (Wright, Gattiglia 2018).

Methods and Materials

The collaborative work of the partners created a pipeline where potsherds are photographed, their characteristics compared against a trained neural network, and the results returned with suggested matches from a comparative collection with typical pottery types and characteristics. Once the correct type is identified, all relevant information for that type is linked to the new sherd and stored within a database that can be shared online. This goal has been implemented through the creation of:

- a digital comparative collection for multiple pottery types, incorporating existing digital collections, digitised paper catalogues and various photography campaigns;
- an automated-as-possible workflow to accurately digitise paper catalogues and improve the search and retrieval process;
- a multilingual thesaurus of descriptive pottery terms mapped to the Getty Art and Architecture Thesaurus;
- two distinct neural networks for appearance-based and shape-based recognition;
- an app using the digital comparative collections to support archaeologists in recognising potsherds during excavation and post-excavation analysis, with an easy-to-use interface and efficient image recognition algorithms for search and retrieval, based on either shape or decorative characteristics;
- a desktop application, which is a web-based, real-time data visualisation resource, to improve access to archaeological heritage and generate new understanding.

Results

The project developed two neural networks: one for appearance-based, and one for shape-based recognition. Two different classification systems were developed, one for appearance-based, and one for shape-based recognition. The appearance-based recognition tool is based on combining classic machine learning tools with neural networks, pre-trained on general image classification tasks. Features identified by the pre-trained neural network are used to feed another Neural Network, returning the classification into different classes. Furthermore, two dropout layers has been added. They made the model learn a more robust representation, and decrease the chances of overfitting to the training data. Moreover, to boost the application performance, we used the lighter ResNet-50 model (as opposed to ResNet-101 model). Training a neural network from scratch was not feasible, as we would have needed many more thousands of images, including those from rarest ceramics classes.

Random (multiplicative) fluctuations of luminosity, white balance and Red/Green/Blue channels were used to increase robustness to lighting/colour changes. The GrabCut algorithm for interactive foreground extraction has been integrated into the ArchAIDE application, in order to enable the users to reliably extract the foreground from most images.

For shape-based classification, given the very few (from a computational point of view) sherds available, we designed a system to produce synthetic sherds. To provide them, we started with the pottery profiles extracted from the catalogues. We used a direct method for generating synthetic sherd outlines, without the need to reconstruct a 3D model (Banterle et al. 2017). The process was based on the observation that every point rotated around the revolution axis, forms a circle in 3D, perpendicular to the rotation axis. To create a fracture, we generated a random 3D plane that intersects the model, where the angle between the plane and the z-axis is kept small, to simulate real-world fractures. We then computed the intersection of this plane with the circles, thus generating a 3D sherd in linear time. Each sherd had its primary fracture projected into 2D by placing a virtual camera at the same orientation an archaeologist would look at the fracture itself.

The neural network is based on an improved PointNet on which two important pieces of information have been added to each point : (1) annotation regarding side (inside/outside), and (2) the angle of the outline at that point. Moreover, we suggested a group-hot encoding approach for combining categorical and continuous values. We separated the branches of multi-layer perceptrons; one for the angle data and one for the location data. Both branches have the same shape. The outputs of these branches are then concatenated and fed into a single perceptron layer to obtain a feature vector of length 1024 per point. Max pooling is then performed over all the points to get the global feature vector of the same size and then followed by another multi-layer perceptron that delivers the output scores.

The average appearance-based recognition top-5 accuracy is 83.8%, and top-1 accuracy is 55.2%; the average shape-based recognition top-5 accuracy is 62.8%, and top-1 accuracy is 30.5%. Accuracy resulted as a process of improvement both of the neural network and in the general workflow.

Discussion

The solutions proposed for developing an efficient neural network for recognition of archaeological pottery's shape and decorations try to find a way for using algorithms which need a massive amount of data for training in a domain in which Big Data is not (yet) available. If the"ideal" solution (from an algorithmic standing point) would be to capture more data reflecting all the possible features, a "creative" approach allows exploring new methods that can be innovative both for archaeology and ICT.

References

1. Banterle, Francesco, Itkin, Barak, Dellepiane, Matteo, Wolf, Lior, Callieri, Marco, Dershowitz, Nachum, and Scopigno, Roberto. "VASESKETCH: Automatic 3D Representation of Pottery from Paper Catalog Drawings". *The 14th IAPR International Conference on Document Analysis and Recognition (ICDAR),* 2017: 683-690.

2. Wright, Holly and Gattiglia, Gabriele. "ArchAIDE: Archaeological Automatic Interpretation and Documentation of ceramics". In *Proceedings of the Workshop on Cultural Informatics Research and Applications,* co-located with the *International Conference on Digital Heritage,* Nicosia, Cyprus, November 3, 2018: 60-65.