# The application of deep learning in archaeology

12011528 Yiyan Zhang

12011526 Xun Sun

December 30, 2022

**Abstract**

***The long history of human civilization has resulted in a magnificent culture. In order to study the living customs and cultural rituals of previous generations, scholars have explored human sites and studied the antiquities left behind by ancient humans, and other important ways to know the way of life of previous generations and understand the culture and customs of that era. However, with the passage of time, many artifacts are weathered and it is difficult for scholars to analyze and compare them in bulk directly and quickly. In contrast, machine learning assists scholars to analyze antiquities, which seems more efficient and accurate in comparison, and mature machine learning models will become a powerful tool in archaeology to facilitate the archaeological work. In addition, analyzing and refining the characteristics of artifacts with the help of machine learning will help experts to discover the information carried by artifacts, perfect the history, and even identify artifacts that cannot be identified by relying on expert knowledge now[1]. And zooming in on our perspective, in addition to helping with artifact analysis and identification, deep learning can also assist with archaeological excavation work and the study of sites. For example, by analyzing map data, can help excavate archaeological sites, find sites, and reconstruct the historical landscape of sites. In general, the widespread use of deep learning in archaeology today has brought a new revolution in the field of archaeology, and this paper will briefly discuss the initial applications of deep learning models in archaeology.***

***Key words: Archaeology; Deep learning; Heritage Restoration; Site Detection; Site Reconstruction***

# 1 Introduction

## 1.1 Analysis of the difficulties encountered in archaeology

As people become more and more interested in the study of history, archaeological work is also in full swing.However, the deeper the archaeological work and related research, the more difficulties the researchers encountered.

Although historical researchers have a wide range of knowledge and rich experience, few of them can master all aspects of archaeological knowledge.What a pity it is when new antiquities are unearthed and no one is able to identify them.Many unearthed cultural relics cannot remain unchanged for a long time. If there is no correct interpretation and identification by experts and scholars within a certain period of time, the difficulty of this rare cultural treasure will disappear, and we will lose an opportunity to understand the ancient culture.

In addition, another important issue for researchers to consider when conducting archaeology is to determine how to excavate ancient sites.After an ancient site is discovered, researchers survey the surrounding terrain and discuss how to plan for excavation and development of the site. People want to do archaeological research with as little damage as possible.This is a difficult thing to do. It has been a long time since the ancient ruins were built until they were discovered today. The present topography has deviated from the time when they were built, and any careless excavation may cause irreparable damage to the ancient relics.How to do archaeological work on the premise of protecting the ancient relics and sites as much as possible is a thorny problem that archaeologists must face.

## 1.2 The development of deep learning in archaeology

Archaeology is a new and challenging field for deep learning.Deep learning first appeared in the 1940s. Some archaeologists have applied deep learning to archaeological work not long after the advent of deep learning technology.

In 2014, a research team from China Remote Sensing Earth Institute spent three years in Xinjiang to conduct archaeological work on the ancient Great Wall in Xinjiang. Using remote sensing and deep learning techniques to obtain weak information about ancient sites, researchers have "restored" the ancient Great Wall in Xinjiang, changing the long-held understanding that there is no Great Wall in Xinjiang, and inspiring the archaeological community.

In recent years, researchers from four institutions, including Pennsylvania State University in the United States and the University of Sydney in Australia, have published research showing the potential of deep learning algorithms for discovering ancient human remains. The results show that by using a deep learning algorithm, researchers have found several 3 000-5 000 years ago Native American survival relics - Shell Ring, the discovery of this relic will help to further understand the social and economic structure of Native Americans(Fig.1). It is worth mentioning that using deep learning to detect historic sites will not have a destructive effect on historic sites. It can accurately explore the historic site without causing spatial structural damage.

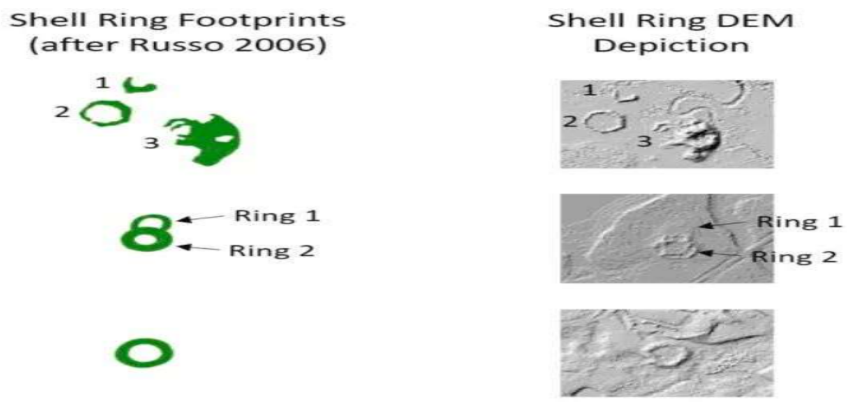


Figure 1: Shell Ring

# 2 Applications of deep learning models to archaeological processes

During the process of archaeological excavation, image information is necessary for the experts. Therefore, there are a lot of CNN's applications in archaeological processes. And now they can be divided into two categories. One is doing the detection and analysis tasks when the people are excavating a site, and the other is finding the potential sites by analyzing the high-precision scanning pictures, like satellite pictures. In the following sections, I'll discuss each of these two types of applications of CNN in archaeology.

## 2.1 CNN in internal structure scanning

Before excavations begin at an archaeological site, archaeologists need to explore the site's internal structure and make a plan according to the analysis result. In past years, people have used visualization techniques with airborne laser scanning (ALS) technology to explore the internal structure[2]. However, the representation of the characteristics of archaeological structures (e.g. size, shape, orientation, landscape context, topographic position) varies greatly among VTs, and the experts can't get very comprehensive information, which may influence the identification and characterization decisions[3].

But then The use of CNN enables a new breakthrough in exploratory imaging tasks. CNN can deal with complex images by dealing input data with several convolution layers and pooling layers. And after CNN processing, archaeologists can get a more accurate and comprehensive scan of the interior of the site (Fig.2).

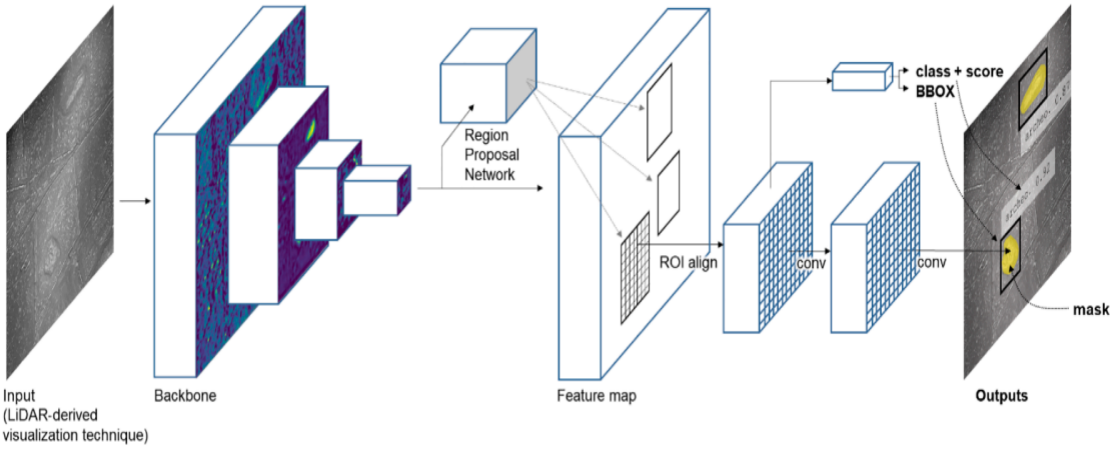


Figure 2: an example model of CNN. Data source: [3]

By applying different kernel filters to input images, the filters can intensify or weaken certain structures (edge information) in the training images[4]. Therefore, Using CNN can clear the details in scanning data and effectively remove noise interference in raw data, which means archaeologists can get information from the images more easily. With more comprehensive and clear scans, archaeologists can determine the location of artifacts at a site in advance. And prepare in advance during the excavation process, which can reduce the possibility of cultural relics being damaged during the excavation process.

## 2.2 CNN in spatial relation analysis for a group of sites

In archaeology, some experts will want to understand historical contexts and landscapes. For example, to explore where are farms or settlements located, where is agricultural land located, where are the deceased buried, and how is the unsettled environment used. Up to now, only in some cases, researchers could verify that burial mounds were located near and directly related to pathways[4]. The difficulty is to find proof of whether routes were already used when nearby burial mounds were built. In general, pathways are difficult to date.

And CNN can't solve the problems directly, but it can help the experts in spatial relations between the sites. Give the trained CNN model an aerial view, and view all sites in the image as a point. And then make a circle for every point, and it means there are relics discovered in this range of circles. And then combining the information of relics, like the year of manufacture, the model can tell you which sites may be in the same generation and which sites can be a cluster. Although the result of CNN output is not explainable, experts can refer to the model's spatial relations in the analysis process. The experts can easily remove some wrong sites from their research and combine and analyze different sites' information.

### 2.3 CNN in the automated detection of archaeological sites[5]

CNN's powerful image feature processing ability can be used to detect archaeological sites by processing high-precision satellite images. The research (Bonhage et al., 2021) on detecting RCH sites shows the possibility of finding sites by satellite pictures. And Relict charcoal hearths (RCHs) are anthropogenic geomorphic features with an average diameter of 12 m found in many forests of Central Europe and in the eastern USA wherever pre-coal iron production took place or other industries demanded the production of charcoal[1]. They use the augmented image data to train a CNN model and get the result on the test set (part of result, Fig.3)

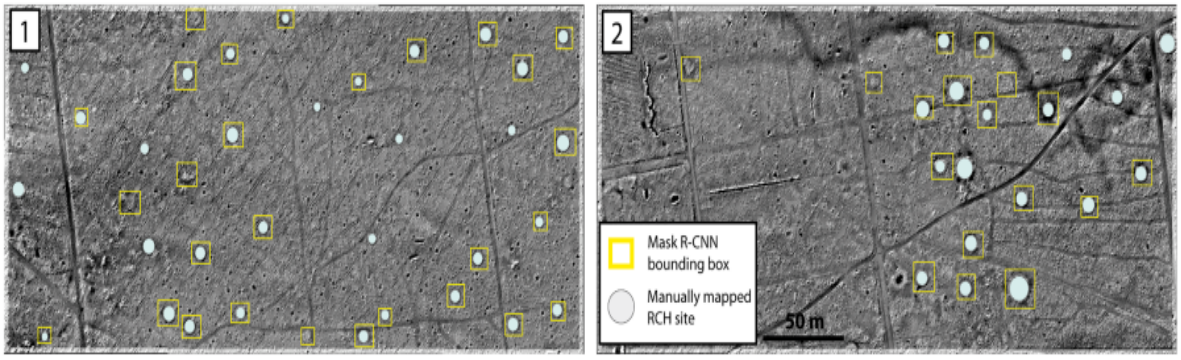


Figure 3: RCH detection by CNN. Data resource: [5]

In figure 3, the yellow rectangles are the position of RCHs given by the CNN model and the white points are the real RCHs. And we can see the result has high accuracy in figure 3, which is part of the test result.

According to Bonhage's report, the final result has high recall and high precision. It means the model has great accuracy and the result is reliable. Although the research just verified the ability of CNN in searching for potential RCHs, all archaeological sites are similar to RCH for CNN. We just need to use different characteristics to train different models to automate detecting archaeological sites with different characteristics. Moreover, we can finally gather the data and train a multiple-objects detection CNN model. Then we can efficiently detect the potential archaeological sites and excavate them.

## 3 Simulation of antiquities identification by deep learning model

### 3.1 Transfer learning on automatic recognition and classification of stone image

Transfer learning is a machine learning method. It uses the similarity between data, tasks, or models to apply the learned or trained models in the old fields to the new fields.Rock and jade are very important

[1]definition comes from www.sciencedirect.com/science/article/abs/pii/S034181622030446X

parts of archaeological work, and they can provide important information to researchers.But how to identify and classify a large number of jade or ore is a difficult problem for archaeologists.If we apply in-depth learning to jade identification, it may be possible to solve this problem.

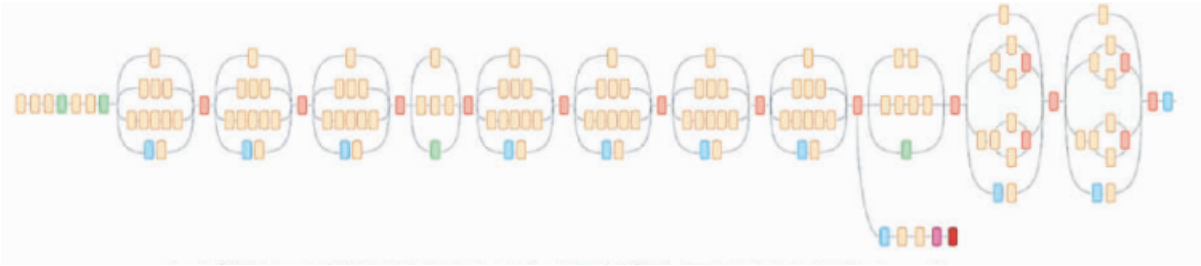

Figure 4: Inception-v3

[6]

Researchers use Google convolutional neural network Inception-v3 module. As a pre training model, the original dataset contains 1.2 million images, divided into more than 1000 Categories.Inception v3 model can extract effective information from images.First, input and process a rock image in the feature extraction model, and the feature extraction model is the convolution layer and pooling layer in the Inception v3 model; The convolution layer and pooling layer in the model are used to calculate the image characteristics of the rock image.The structure system of the whole network starts from the input end. First, three roll up layers are set to connect one pooling layer; Set 2 more roll up layers, connect 1 pooling layer, and finally connect 11 hybrid layers.

The rock image samples used in the experiment are collected by different means such as photos, rock database and network search. Granite, phyllite and breccia are mainly selected for testing, identification and analysis. The rock type is mainly composed of three kinds of images: laboratory rock specimen, on-site rock specimen and on-site large scale rock. In general, granite images are mostly of granular texture, phyllite images show phyllitic structure, and breccia images show porphyritic structure.

In general, from the classification and recognition results, there are two images of granite with poor classification effect, one image of breccia with poor classification effect, and phyllite with good classification effect. The reason for poor classification effect may be that the training set is limited, and there are few or no rock images similar to the test set, leading to the failure to extract the rock features in the image.

Based on Inception-v3's rock image depth learning migration model, the effective recognition of granite, phyllite and breccia is realized, and the recognition probability can reach more than 0.8, and some results can even reach more than 0.95; The model extracts features by searching image pixels without manual operation, which reduces the influence of subjective factors. Moreover, the training process has low requirements on the size, imaging distance and light intensity of rock images. In addition, by adding the cut rock image to the training set for re training, it shows that continuous

learning of rich training sets is an important factor affecting the model recognition ability.

### 3.2 Deep learning in authentication of ancient paintings

Traditional Chinese painting is not only a creative form of ancient painting art, but also a form of expression of traditional Chinese culture. The identification of traditional Chinese painting is conducive to the appreciation and protection of traditional Chinese culture.But there are two problems[7].The first is that in the Internet era, digital traditional Chinese painting has become popular due to its advantages of easy preservation, fast retrieval, etc. However, in the authenticity verification task, experts cannot quickly locate the category of painters when facing the unsigned digital traditional Chinese painting images of different styles, which affects the efficiency of verification.

The second is that with the development of the times, the form of painting forgery is no longer just the traditional methods of imitation, copying, and painting. The use of a new generation of information technology to imitate the artist's style makes it difficult to identify the authenticity of the generated paintings. However, the traditional identification methods, which mainly rely on expert experience, are subjective and vulnerable to interference, affecting the identification accuracy. Therefore, in the identification of digital traditional Chinese painting, an objective and quantifiable reference index is particularly necessary.

In the authenticity identification task, experts cannot quickly locate the artist category in the face of unsigned digital traditional Chinese painting images of different styles, which affects the identification efficiency. Therefore, the researchers used the traditional Chinese painting painters only classification algorithm based on multi branch attention mechanism network.

First, the image is divided into blocks, and the image contrast is calculated to remove the code blocks with low contrast, that is, less feature information; Secondly, according to the characteristics of traditional Chinese painting, it uses multi-dimensional features such as strokes, textures, colors, etc. to intelligently classify painters, and uses edge detection, local binary mode, and color moment calculation to completely pre generate features[8].Then, a multi branch attention mechanism network is designed to achieve the fusion of pre generated stroke features, texture features and color features to achieve accurate classification. Finally, the proposed algorithm is proved to be effective by parameter setting experiments and comparison experiments.

## 4 The comparison between intelligent archaeology and traditional archaeology

Compared with traditional archaeology, intelligent archaeology uses deep learning technology. And deep learning can comprehensively analyze the hidden information under the complex data compared with the people. In traditional archaeology, the experts' ability is limited and they can't conclude and analyze the data of all aspects. So some potential information always can't be found and some

conclusions may not be as correct as they think. However, the addition of deep learning models allows for more sophisticated curation by subject experts who would be relieved of the burden of rote processing[9]. And In the intelligent archaeology generation, experts can use more powerful tools to do the research. For example, multi-label classification, multi-task classification, unsupervised image clustering, and explainability.

The replacement of traditional archaeological methods by intelligent archaeology is also an inevitable change brought about by the changes in The Times. In the digital generation, more and more detection technologies are created so that archaeologists also have more methods to excavate the sites and do some research. However, the tendency also means a more large number of data collected and analyzed. Traditional archaeology doesn't have the ability to deal with this order of magnitude of data. Therefore, as new detection techniques are applied, new analysis methods, like using CNN, have to follow.

Although deep learning models are so powerful and convenient, traditional archaeological methods are still necessary. As nowadays the combination of archaeology and deep learning is not perfect, the models are often limited by the small datasets of archaeology[10]. And 90 percent of archaeology's datasets can be seen as small datasets for the deep learning model[11]. What's more, the output of the model is always unexplainable, and the experts can't know how the model calculates the result. Therefore, we still need to use traditional archaeological methods to check out the validity of the results. And the work of excavating the history behind cultural relics cannot be performed by computers, and experts still need to analyze and summarize it. At present, the application of intelligent archaeology to learning models is still in the stage of a simple application. Most contributions are in the development of visual or textual features which form the input to the model as a pre-processing step[12]. And few works have used advanced models of clustering and classification.

## 5 Future insights in intelligent archaeology

In conclusion, deep learning has gone into the field of archaeology and plays an important role. This transformation is shifting both academic and cultural resource management inquiry. Many of its applications are evolutionary, greatly improving the types, scale, and complexity of analytic tools that archaeologists already use.

With the deep learning model, the experts can remodel some defective cultural relics, like ancient papyrus[13], and get more accurate structure information by combining advanced detection technologies and deep learning model, like sites' structure analysis[4]. And according to our survey, we think intelligent archaeology still has a long path to explore. As I mentioned above, the use of deep learning models in intelligent archaeology is still in its infancy. And if it can use some more advanced models and methods, this field will get a technological revolution again. And some problems that existed in the application, like the accuracy of auto identification caused by low data[14], will be solved. Moreover, I think intelligent archaeology will generate more subjects that analyze historical information

from different perspectives utilizing the ability of deep learning models. And now there are some new research subjects, for example, Molecular Archaeology[15].

And in the future, intelligent archaeologists need to try to use deep learning models more flexibly. And utilizing some models to explore the potential that draws upon an ever-improving and ever-expanding library of data, which can deal with a big problem in intelligent archaeology that lacks sufficient datasets. The revolution will be in integrating these outcomes into both academic and cultural resource management frameworks, which is a significant challenge given that archaeologists will have to become competent in managing this much richer and more diverse information[16]. And the experts in this field also need to actively explore the work pattern. The deep learning models are generated by the statistics so that some rare cultural relics can't be identified and analyzed correctly by the model. Therefore, the experts need to explore how to arrange the work of experts and models in the workflow to minimize the amount of experts' work and not miss rare cultural relics.

# References


[1] L. M. Pawlowicz and C. E. Downum, "Applications of deep learning to decorated ceramic typology and classification: A case study using tusayan white ware from northeast arizona," *Journal of Archaeological Science*, vol. 130, p. 105375, 2021.

[2] B. Kazimi, F. Thiemann, K. Malek, and M. Sester, "Archaeological object detection in airborne laser scanning data using convolutional neural networks," 03 2018.

[3] A. Guyot, M. Lennon, and L. Hubert-Moy, "Objective comparison of relief visualization techniques with deep cnn for archaeology," *Journal of archaeological science, reports*, vol. 38, pp. 103027–, 2021.

[4] M. F. Meyer-Heß, I. Pfeffer, and C. Juergens, "Application of convolutional neural networks on digital terrain models for analyzing spatial relations in archaeology," *Remote. Sens.*, vol. 14, no. 11, p. 2535, 2022.

[5] A. Bonhage, M. Eltaher, T. Raab, M. Breuß, A. Raab, and A. Schneider, "A modified mask region-based convolutional neural network approach for the automated detection of archaeological sites on high-resolution light detection and ranging-derived digital elevation models in the north german lowland," *Archaeological prospection*, vol. 28, no. 2, pp. 177–186, 2021.

[6] A. M. Hilal, M. A. Alohali, F. N. Al-Wesabi, N. Nemri, H. J. Alyamani, and D. Gupta, "Enhancing quality of experience in mobile edge computing using deep learning based data offloading and cyberattack detection technique," *Cluster Computing*, pp. 1–12, 2021.

[7] K. Browne, "Who (or what) is an ai artist?," *Leonardo*, vol. 55, no. 2, pp. 130–134, 2022.

[8] X. Wu, Y. Niu, S. Gao, Z. Zhao, B. Xu, R. Ma, H. Liu, and Y. Zhang, "Identification of antioxidants in edible oil by two-dimensional correlation spectroscopy combined with deep learning," *LWT*, vol. 162, p. 113436, 2022.

[9] K. Karterouli and Y. Batsaki, "AI and cultural heritage image collections: Opportunities and challenges," in *Electronic Visualisation and the Arts, EVA 2021, London, UK, July 5-9, 2021* (J. Weinel, J. P. Bowen, A. Borda, and G. Diprose, eds.), Workshops in Computing, BCS, 2021.

[10] S. H. Bickler, "Machine learning arrives in archaeology," *Advances in Archaeological Practice*, vol. 9, no. 2, p. 186–191, 2021.

[11] C. Heitman, W. Martin, and S. Plog, "Innovation through large-scale integration of legacy records: Assessing the "value added" in cultural heritage resources," *J. Comput. Cult. Herit.*, vol. 10, jul 2017.

[12] M. Fiorucci, M. Khoroshiltseva, M. Pontil, A. Traviglia, A. D. Bue, and S. James, "Machine learning for cultural heritage: A survey," *Pattern Recognit. Lett.*, vol. 133, pp. 102–108, 2020.

[13] R. Abitbol, I. Shimshoni, and J. Ben-Dov, "Machine learning based assembly of fragments of ancient papyrus," vol. 14, jul 2021.

[14] M. L. Gualandi, G. Gattiglia, and F. Anichini, "An open system for collection and automatic recognition of pottery through neural network algorithms," *Heritage*, vol. 4, no. 1, pp. 140–159, 2021.

[15] P. Hunter, "Molecular archaeology and machine learning," *EMBO reports*, vol. 23, 2022.

[16] B. Jones and S. Bickler, "High resolution lidar data for landscape archaeology in new zealand," *Archaeology in New Zealand*, vol. 60, pp. 35–44, 09 2017.