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Damage Detection of Guqin in CT Images Based on Deep Neural Network

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Abstract: Guqin is the treasure of Chinese heritage culture and the top listed musical instrument. Among the Guqin collected in the Palace Museum, the most famous Guqin named Jiuxiao Huanpei was made by Lei Wei in the Tang Dynasty, which was regarded as an invaluable treasure and ranked first in the Palace Museum. There is a very rare situation in its internal structure where in the Dragon Pool, we saw a round ditch with a width of 2 cm and a depth of 1 cm, there is no such groove in the belly of an ordinary Guqin. This structure has led many well-known modern musical instrument makers to deliberately design their Guqin like this, because they believe that this is the exquisite design of the ancient master, which can make the sound performance better. Few people have questioned it for hundreds of years. Nowadays, the artificial intelligence technology in the world is developing very fast, among which the model used for object detection has gradually improved its accuracy. This paper applies the YOLO model in deep learning to train with 7803 CT slices of Guqin, and then tests the Jiuxiao Huanpei Guqin in the Forbidden City and several other Guqins. The conclusion is that this Guqin was not intended to be designed to that model, it was likely damaged, and like the Emperor's New Clothes, no one except AI can tell the truth. The purpose of this paper is to arouse people's attention to the establishment of digital scientific analysis for cultural heritage.

Keywords: Guqin, CT, 3D, Deep Neural Network, YOLO

1. Introduction

Among all the Guqin collected in China today, the most famous one is the "Jiuxiao Huanpei" from the Tang Dynasty. According to Chinese tradition, the number "nine (Jiu)" can be described as extreme, meaning "supreme", so it is often associated with imperial power and mercy. The "Nine Clouds (Jiuxiao)" in the name of Guqin also refers to the extremely high sky and celestial world; "Huanpei" is a jade ornament worn on the waist by ancient Chinese people, which can make a sweet jingle when colliding with each other. All of the legends have made this "Jiuxiao Huanpei" Guqin a world-famous, priceless national treasure. It was made by Lei Wei, the first generation of Lei, a family who made Guqin in Sichuan during the Kaiyuan period of the Tang Dynasty. It was used in the ceremony of the King's third son's succession in 756 AD. Its sound is warm, pure, and perfect, and it has been admired by Guqin artists since the late Qing Dynasty, and it is regarded as a "famous Tang thing" and a "fairy product" [1]. Lei Wei has greatly improved the manufacturing of Guqin. Its technology is superior, and it has won an unprecedented reputation. At present, there are four Guqins named Jiuxiao Huanpei that have been confirmed to be authentic, one for each collection at the Beijing Palace Museum [Figure 1], the China History Museum, and Liaoning Provincial Museum, and one for Mr. He Zuoru in the 2023 Guardian auction.

Figure 1. *Jiu Xiao Huan Pei [2].*

In the Dragon Pool, we saw a round ditch with a width of 2 cm and a depth of 1 cm [Figure 2]. This is very rare. There is no such groove in the belly of an ordinary Guqin [Figure 3].

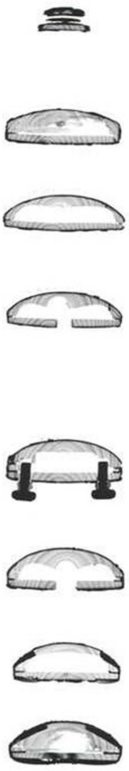

Figure 2. *CT picture of Jiu Xiao Huan Pei [2].*

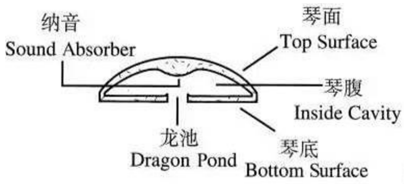

Figure 3. *Common Structure of Guqin [1].*

Clear Records of the Dongtian Qinglu (Song Dynasty) by Zhao Xihu. During King Li's period of the Southern Song Dynasty, he said that "Lei and Zhang, there's a trick to making the belly of a Guqin. At the bottom of the instrument, I know that the depression is like a tile [Figure 4]. I made an experiment to prove that with one Guqin and explored it with my finger in the pond." [3].

Figure 4. *Traditional Chinese Tile.*

Su Shi, a Guqin enthusiast, is not only a famous writer, calligrapher, and painter in the Northern Song Dynasty, but also a Guqin performance artist. He was not only good at playing the Guqin, but also at collecting Guqin. In order to explore the mystery of Lei Wei's Guqin making, Su Shi actually cut the belly of a Guqin from Lei Wei, which was made in the 10th year of Kaiyuan in the Tang Dynasty (722), to find out. Later, Su Shi finally discovered the secret that Lei Wei's Guqin: "The sound of the instrument comes from two pools, and its back is slightly uplifted. It is like the leaf of scallion, the sound will come out and pass, but it won't go away. It's the best thing to pass on." Interpreted by China Archives [4], Su Shi found that the "Sound absorber (Nayin)" is like the leaves of small garlic with a shallow groove in the middle. Please pay attention to the translation explanation of this ancient prose, which is not found in the original words of Su Shi, so the translation is ambiguous. [Figure 5].

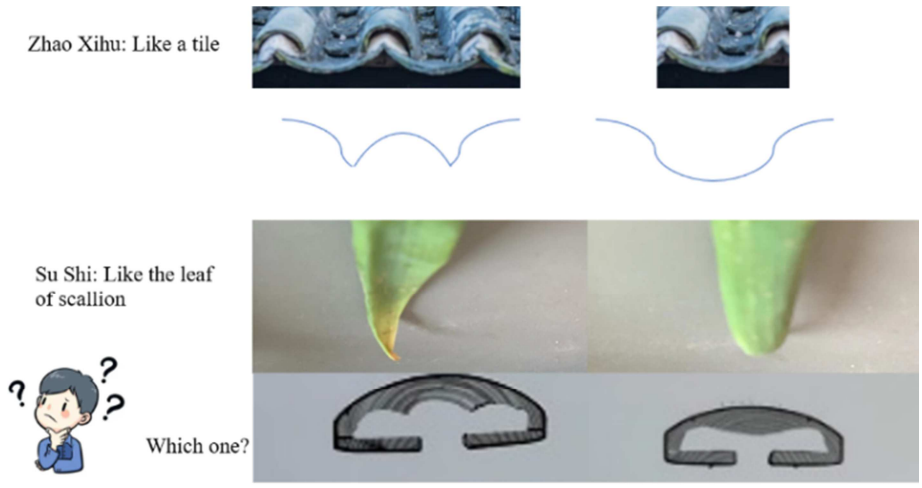

Figure 5. *Confused.*

Many contemporary Guqin gurus imitate the translated text recorded in this ancient text and deliberately design their own Guqin to have a groove in the middle of the sound, for example, as shown in the picture [Figure 6].

Figure 6. *A Documentary about the production of ancient Guqin in Xihe Guqin Manufactory Studio [5].*

In addition, even the Guqin made by Master Zeng, a top 10 famous contemporary artist, can see the shadow of design reference. It can be seen that Lei Wei's works are important for future generations.

Figure 7. *Master Zeng's Guqin [1].*

However, is it deliberately and carefully designed or is there some other reason? We use AI technology to unveil the answer.

2. Method

In recent years, deep learning has developed rapidly, and great progress has been made in the fields of object detection [6], intelligent robots [7] etc. Deep learning is a deep neural network structure with multiple convolution layers. By learning the features of input data, the lower-level features are formed into more abstract high-level features to represent the attribute categories or features of training data, and the data are expressed by vectors and feature maps [8], so as to improve the effect of the deep learning model. Based on the strong learning ability and feature extraction ability of deep learning in a large amount of data, many researchers try to apply deep learning technology to product defect detection to improve product quality [9], mainly including: Product defect detection technology based on convolutional neural network (CNN) [10]; Product defect detection technology based on autoencoders [11]; Product defect detection technology based on deep residual neural network (DRN) [12]; Fully convolutional neural network (CNN) [13]; Convolutional neural network (CNN) [14].

Because all kinds of objects have different appearances, shapes, and postures, and because of the interference of illumination, occlusion, and other factors during imaging, object detection has always been the most challenging problem in the field of computer vision. In addition to the detection of these common targets, many fields also need to detect targets that they are interested in.

For example, defect detection of material surfaces, hard-brushed circuit board surfaces, etc. Object detection technology is also needed for surface defect detection and crop surface pest identification in agriculture [15]. Before the appearance of Deep Convolutional Neural Network (DCNN or DNN) [16], Deformable part model (DPM) [17] has been the best algorithm in the field of target detection. After the application of DNN in target detection, it has made rapid progress, greatly improved the accuracy of the model, and promoted this technology as being practical.

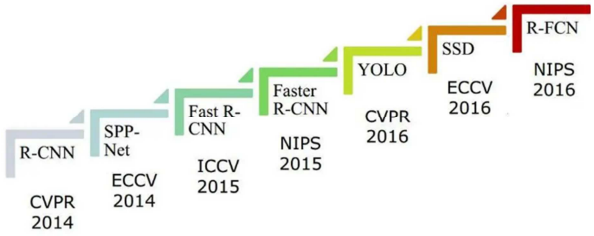

Figure 8. *Historical Development of Object Detection [18].*

In 2015, with the emergence of YOLO [19], Deep Learning (DL) object detection model started to improve continually. Different from the two-step detection model represented by the R-CNN series, YOLO omits the candidate frame extraction branch (proposal stage), and directly completes feature extraction, object frame regression and classification in the same convolution network, which makes the network structure simple, and the detection speed nearly 10 times faster than that of Faster R-CNN. This makes the deep learning object detection model begin to meet the needs of real-time detection tasks under the current computing power. On the basis of YOLOv2, YOLOv3 [20] uses the newly designed Darknet53 residual network and combines the FPN network structure. After sampling the last two characteristic maps of the network, it aggregates the characteristic maps of the corresponding size in the early stage of the network, and then gets the prediction result from the convolution network. These improvements make YOLOv3 achieve the same accuracy as SSD in one third of the time. YOLOv3's model is much more complicated than the previous version, and the speed and accuracy can be improved by changing the size of the model structure. There are several improvement points in YOLOv3, such as multiscale prediction (FPN), a better backbone network (Darknet53 Residual Network), and classification loss that uses a binary cross-entropy loss function instead of a Softmax loss function. [20].

In addition, there are other detection models, such as MegDet [21] submitted by face++. Their scheme does not optimize the detection model too much (ResNet50+FPN is adopted), but optimizes the scale of parallel training.

One of the difficulties in modeling a musical instrument is

that it is not an easily definable engineering structure. The Computed Tomography (CT) scanner presents itself as a useful tool for reverse engineering a musical instrument [22]. I use the data set with 7803 Guqin CT pictures [Figure 9], and select the YOLOv3 model according to the computer's calculation capabilities.

Figure 9. *Train Data Set: CT picture of Guqin from different years.*

3. Experimental Results

The experiment show that this ancient instrument was not intended to be designed to that model, it was high probability damaged.

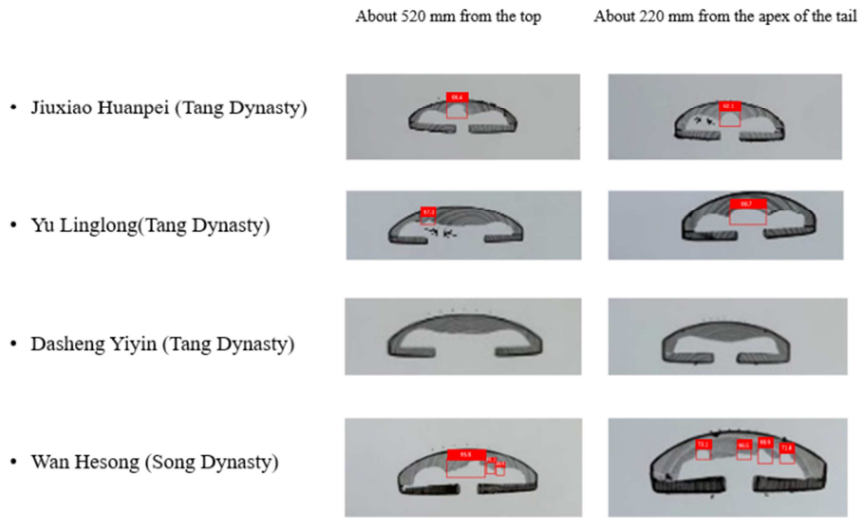

Figure 10. *Object Detection Outcome.*

We speculate that according to the grain direction of the annual rings, the whole piece of wood is peeling off because of its age. The very tiny residual irregular shape observed by computer vision further illustrates this inference. The second Yu Linglong Guqin tested in the Forbidden City confirmed this inference even more obviously. Only the lower part of it was damaged, but the upper part was not damaged.

Previous studies on damage detection have focused on

industrial applications mainly. However, no one has ever used DNN to study Guqin before. Our research is pioneering in the field of Guqin, AI can be applied to damage detection of cultural heritage based on CT images recognition.

4. Conclusion

Through DNN analysis, it is found that the inheritance of Chinese Guqin flourished in the Tang Dynasty, but because of the inability to quantitatively analyze it, gradually declined, and its descendants could hardly reach the state of its heyday.

When reading and translating ancient Chinese prose, people were misled by mistakes, and some famous artists misunderstood the meaning of tiles. However, no one points out this mistake openly, like the King's new cloth, no one except AI tells the truth.

We should stop spreading false information and imitating others. In the next step, scientific analysis of data should be established to carry on cultural inheritance.

It is a pity that although some researchers used CT to study Guqin in the previous studies, there was never a case of using AI computer vision model to study the image recognition and damage detection of Guqin. Our study opened a new window, allowing the research of artificial intelligence to be applied to Guqin for the first time, thus activating the cultural heritage.

This research project has reached the National Final of "Exploring Original Plan" 2022 - Exploring the New Era of Cultural Heritage Digital Activation Award Selection. Host by the China Cultural Relics Protection Technology Association, Tencent Digital Culture Laboratory, Tencent Research Institute, Tencent Sustainable Social Value Organization and the Creative Industry Technology Research Institute of Renmin University of China. A series of studies on the application of artificial intelligence in cultural heritage have led universities to make useful attempts in science and technology innovation education.

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