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A Method of Searching Lithic Cores by Average Linkage Clustering

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***Abstract*—Stone tools are the main artifacts facilitating archaeological research of the Paleolithic era. The reassembly of stone tools is pretty meaningful for archaeological and anthropological research. According to the practice of reassembling stone tools, finding lithic cores is the best beginning part of reassembly. Meanwhile, for reassembly of mixed stone tools, the number of lithic cores determines the number of groups. However, several published reassembly methods are still hard to specify lithic cores automatically. Therefore, we propose a method for searching lithic cores automatically. Our method extracts features of stone tool models based on the segmented stone surfaces and geometric characteristics, and processes stone tool models by average group linkage clustering to search lithic core. The experiments conducted indicate that our method can find lithic cores successfully among mixed stone tool models.**

***Keywords*-lithic core; average group linkage; segmented surface; point cloud; bulbar scar.**

I. Introduction

In the Paleolithic era, a diversity of stone tools such as cutting tools or weapons were fabricated. To create a stone tool, a rock is struck repeatedly with a pebble, and flake pieces of various sizes are obtained. There are three principal types of tools appeared in the long Paleolithic Period, with substantial variations occurring within each type. The types are distinguished principally by workmanship but also vary in size and appearance and are known as core, flake, and blade tools[1]. In archaeology, classification and measurement play an important role. It is time-consuming to classify and measure manually for archaeologists.

At the same time, matching these flakes is also an important task for analysis and categorization of excavated relics. The reassembly of stone tools allows their manufacturing process to be understood easily. In archaeology, the reassembly of stone tools is the most important research work for analyzing human activities of that period. In recent decades, several methods have been presented to solve reassembly problems. But some methods are semi-automatically or still need to specify core tools manually.

Moreover, the process of searching lithic cores can actually be regarded as a process of classification. One group includes lithic cores, the other group includes other lithic tools. Clustering method is an effective way to deal with classification problems.

Based on these demands of finding lithic cores, this paper presents a new method of searching lithic cores. In our experiments, the imitations of lithic materials were examined to show the method can obtain core tools exactly.

II. Related Work

A. Core Tool

In Archaeology, a lithic core is a distinctive artifact that results from the practice of lithic reduction[2]. In this sense, a core is the scarred nucleus resulting from the detachment of one or more flakes from a lump of source material or tool stone, usually by using a hard hammer percussor such as a hammerstone[3]. Accordingly, the core is always marked with the negative scars of these flakes.

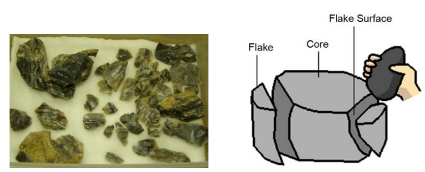

Figure 1. (a)Excavated stone tools (b)Stone tool fabrication

B. Related Reassembly Methods

In reassembly work, finding core tools is the best beginning of reassembly in accordance with the practice of reassembling stone tools. Likewise, for reassembly of mixed stone tools, the number of lithic cores determines the number of groups.

Admittedly, a variety of algorithms have already been published about object reassembly. [4] presented a system with good performance for automatic reassembly of broken 3D solids. [5] proposed a system for reassembling small objects such as fragments of wall paintings. However, these above systems are not suitable for mixture lithic materials without particular order of stone tool reassembly.

[6] proposed a method that reassembling mixture lithic materials by matching flake surfaces. This method starts reassembling from a specified core based on the time difference in generation of multiple flakes from a single

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core[1]. Nevertheless, the method still has to specify core tools manually.

C. Analysis of Clustering Methods

Clustering is the task of grouping or segmenting a collection of objects into subsets or clusters. The two most commonly used algorithms are k-means and hierarchical algorithm.

The k-means algorithm clusters data by trying to separate samples in N groups of equal variance, minimizing a criterion. It is top-down and efficiency. However, the algorithm requires the number of clusters to be specified. For stone tools, there are a variety of types. Therefore, it is hard to specify the number of clusters.

Hierarchical clustering is a bottom-up algorithm. Single linkage and complete linkage are the simplest methods of Hierarchical clustering. The defining feature of these linkage method is that distance between groups is defined as the distance between the closest or farthest pair of objects, where only pairs consisting of one object from each group are considered.

Compared with other clustering methods, the distance of average linkage clustering between two clusters is defined as the average of distances between all pairs of objects.

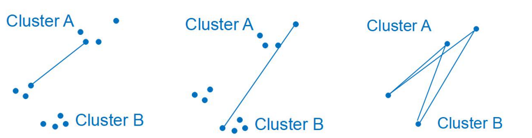

Figure 2. (a)Single linkage(b)Complete linkage(c)Average linkage

Average group linkage is one of average linkage that is between groups. It is more stable which considers an average of all members from the clusters whose distance is being calculated. Therefore, this method is less influenced by extreme values[7]. In this paper, average group linkage is chosen to be implemented in searching lithic cores.

III. Proposed Method

A. Overview

In this paper, we put forward to a method based on average group linkage clustering. The input of our method is several groups of stone models from point cloud. And two main features of stone models are extracted. One is the number of segmented surfaces, another one is the number of surfaces with negative bulb. Based on these features, core tools are searched by average linkage clustering.

B. Data Acquisition

Our data are obtained from a 3D surface reconstruction technique using four-directional measurement machine developed by Iwate University and LANG Co. Ltd.[8][9]. Hundreds of stone tools can be scanned simultaneously and

Figure 3. Scanning Device

Figure 4. Segmented Surfaces

the surface features are intact preserved from the highest 0.1 mm precision of laser scanner. These lithic materials range from several centimeters to tens of centimeters in size. Hereby, the 0.1 mm precision is sufficient for obtaining stone models.

C. Segmentation

In the process of making stone tools, the lithic core would be peeled the most times. The most of the surfaces are smooth and closed to flat since the original stone can be divided sharply[1]. According to this property, a standard region growing algorithm is implemented for obtaining flake surfaces.

D. Definition of Negative Bulb

In archaeology, negative bulb refers to a small depression on a core below the striking platform, produced by the force that detached a flake[2]. As the Figure 5 shows, the negative bulb is below the striking platform. In the Figure 6, a negative bulb can be observed on a stone tool model.

Because core tools are detached many times, they would have more negative bulbs than flakes. Based on this kind of phenomenon, we can regard the number of negative bulbs as one feature for clustering.

E. Judgement of Negative Bulb

In order to detect negative bulbs, the concave and convex of segmented surfaces have to be calculated. Hereby, an effective way to detect the concave and convex is proposed. First, calculate the major axes of segmented surfaces by PCA. Second, obtain the bounding-box and determine the baseline between maximum length. Then, the baseline is divided into 100 equal pieces. Since equal-distance points P_b are obtained, calculate the distance $d(P_i)$ between the points P_i and their neighbor sphere region points within

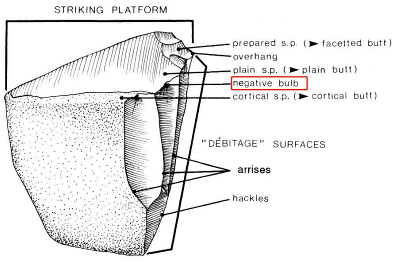

Figure 5. Negative Bulb[2]

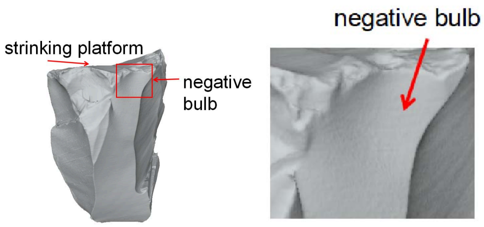

Figure 6. a. Negative bulb of 3D model b. Zoom-in view

radius R by equation(1). Next, calculate sum of distances as D by equation(2). D is regarded as the concave and convex of the point P_b on the baseline. To illustrate, baseline of segmented surface is the green line shown in the Figure 7 and the calculating method is shown in the Figure 8.

$$d(P_i) = |P_i - P_b| \tag{1}$$

$$D = \sum^{d<=R} d(P_i) \tag{2}$$

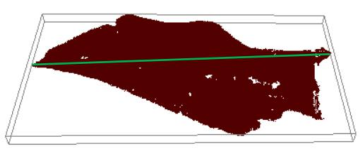

Figure 7. Baseline

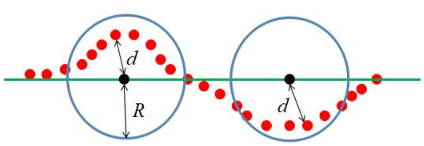

Figure 8. Calculation of distance

If the distance is larger than 0, this part of surface is regarded as convex surface. Otherwise, the distance is smaller than 0, the part of surface is regarded as concave surface. The distances indicate the concave and the convex. According to the description of negative bulb, the negative bulb is upon which the striking platform. That is to say, it is always on the ends of surfaces. To illustrate, by analysing the Figure 9, from 86 to 99, more than 10 points are consecutive concave, and other points are not evident concave. As a result, the part from 86 to 99 can be regarded as a negative bulb.

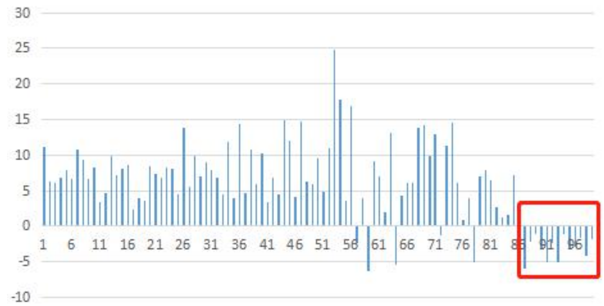

Figure 9. Concave and convex of surface

F. Clustering by average group linkage

In our method, two features such as the number of segmented surfaces, the number of negative bulbs are applied in average group linkage. Based on these features, average distance between every two groups can be calculated by using squared Euclidean distance. Then, the clusters with the smallest average distance are merged into one cluster. Finally, two main clusters are obtained, one cluster includes lithic cores, and another one includes other kinds of lithic materials.

IV. Results

We implemented our proposed method using the C++ programming language on a PC with an Intel Core i7-6700 CPU and 8.00GB memory. The data of 35 lithic materials were examined in our experiment. No.01 and No.20 shown in the Figure 10 with red thick boxes are the lithic cores. We conducted experiments in independent groups and mixture groups. The results indicate that our method can search lithic cores effectively. Figure 11 is the first group, there are 19 stone tools, we can found the lithic core is the No.1, and Figure 12 is the second group, there are 15 stone tools, we can found the No.20 is the lithic core. For mixture test, we can pick up No.1 and No.20 are lithic cores among 35 stone tools as shown in the Figure 13.

V. Conclusion

In this paper, we proposed a new method of searching lithic cores by average group linkage clustering. Segmented surfaces and several geometry characteristics are used for clustering. The experiment results could show that our new method could find lithic cores among mixture lithic materials. In the future work, we will study more on features of lithic cores to make the method can be applied in a wide

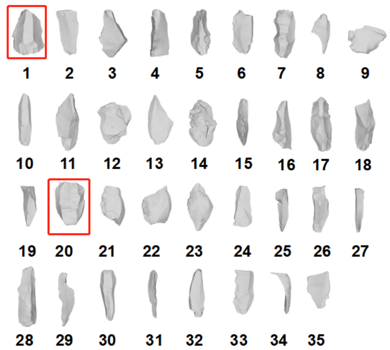

Figure 10. Experiment data

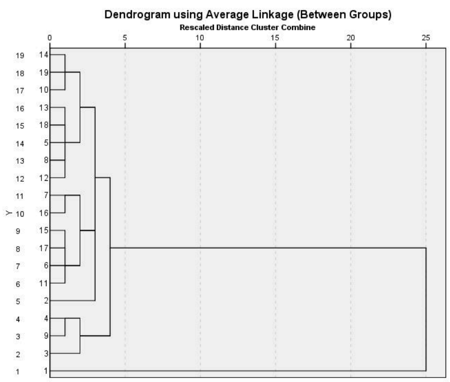

Figure 11. Result of group 1

arrange of lithic materials. Moreover, we hope our research could contribute to classification and auto-reassembly of lithic materials.

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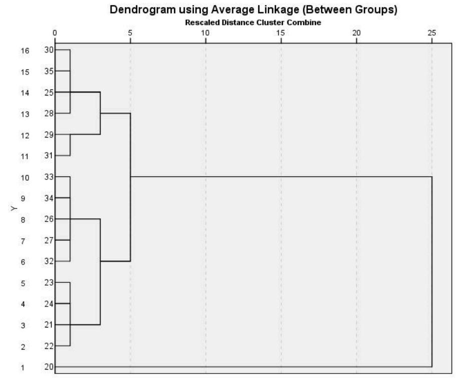

Figure 12. Result of group 2

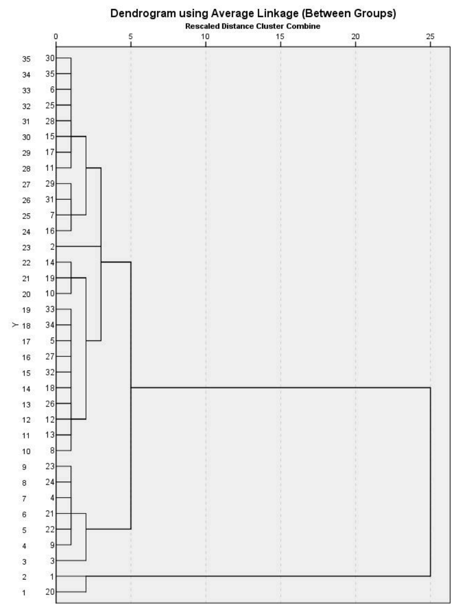

Figure 13. Result of group 1 and group 2

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