Auffinden von Verzierungen auf bronzezeitlichen Keramiken zur Unterstützung der automatisierten Klassifikation

Finding Ornamentations on Bronze Age Vessels to Support the Automated Classification

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Zusammenfassung

Ein wichtiger Aufgabenbereich in der Archäologie ist das Klassifizieren von Fundstücken anhand verschiedener Merkmale. Ein signifikantes Merkmal stellt das Vorhandensein und die Art der Verzierungen dar. In dieser Arbeit werden Methoden vorgestellt, wie diese automatisch auf der Oberfläche von archäologischen Gefäßen aufgefunden und deren Attribute bestimmt werden. Als Ergebnis liefern diese Verfahren ein Maß für die Ähnlichkeit zweier Verzierungen. Dadurch ist es möglich, Verzierungen innerhalb der automatisierten Gefäßklassifikation zu berücksichtigen. Betrachtet werden einfache Eigenschaften wie Ausmaße, Planarität und Ausprägung, sowie komplexe Deskriptoren, die die Form der Verzierungen oder die Beschaffenheit der Oberflächen wiedergeben. Durch geeignete Ähnlichkeitsfunktionen kann die Abweichung zwischen zwei Deskriptoren bestimmt werden, wodurch ein Maß für die Ähnlichkeit zweier Verzierungen gegeben ist.

Abstract

Classification of archaeological finds based on different features is a principle task archaeologists have to cope with. The existence and the kind of ornamentation on the surface of a vessel can be used as a significant feature for classification. In this paper we introduce methods for automatic detection of ornamentation and determination of ornamentation's attributes. Furthermore, these methods provide a measure for the similarity of two ornamentations. Thus, it is possible to include ornamentations in an automated classification process. We consider simple features like dimension, planarity and intensity, as well as complex descriptors that express the shape of ornamentations and the character of the surface. Similarity of ornamentations is determined by computing the difference of descriptors using suitable similarity functions.

1. Introduction

In Saxony archaeologists excavate up to 750,000 artefacts per year. Only some of them are documented and used for classification. The classification process divides a set of archaeological vessels into groups and subgroups by considering resembling object features [1], [2]. The subgroups, which are also referred to as types and variants, are used to interpret the vessels to get information about the chronicle of settlement, the origin of the settlers or the tools, which were used for their production. For classification of an object it is necessary to determine its features. Important features are the main form of the vessel, the attributes of the vessel's segments like belly, shoulder, handle or rim as well as the ornamentations, which are in the focus of this paper. Since now this process has been done manually. This manual process is time consuming and its results are very subjective. It is our aim to automate this process. Thereby it is possible to achieve an obvious speed-up of the classification process. This is realised by an isolated determination of features and a computer-aided comparison of features to compute their similarity. In this article we exclusively focus on the complex task of comparing ornamentations. Several approaches for comparing 3D objects have been proposed [8], [9], [10], [11]. To our knowledge, ornamentations

have never been included in one of the existing approaches because it is an extremely difficult task to analyse them. Due to the variety of existing ornamentations this article exclusively focuses on decorations like grooves, incisions, bosses or impressions. In a pre-processing step the ceramics have to be digitalized. That is done by using a laser scanner, which captures the objects as point clouds. These clouds are processed to a 3D mesh utilizing appropriate software. In the next step the relevant features have to be extracted to identify classes of similar vessels. The exact proceeding was developed at the Chemnitz University of Technology in cooperation with the Saxony Office of Archaeology in Dresden and was already published in [1]. The similarity of two ceramics is determined by the weighted sum of similarities of the different object features.
The remaining part of the paper is divided into eight sections. In section 2 the extraction of ornamentations is described. In section 3, 4, and 5 we describe our methods for estimating features of ornamentations. Results are given in section 6 and 7. The paper concludes with an overview of unsolved problems in detecting ornamentations.

2. Localizing ornamentations on the surface

Before a classification based on ornamentations can be performed the ornamentations themselves have to be extracted. Therefore, we use the concept of ridges and valleys introduced in [3] and [4]. The ornamentations of Bronze Age vessels can be divided into convex and concave ornamentations. While grooves, channels, engraved lines and impressions are examples for convex ornamentations. Cordons, pointed lugs and bosses are examples for concave ornamentations. Hence, they can be represented well by ridges and valleys. In [5] this approach was adapted to handle archaeological vessels. Furthermore, we introduce different extensions to improve the quality of the results.
First we have to estimate all ridge and valley points of the mesh by analysing the curvature function. The curvature provides a measure for the indentation and convexity of an object's surface. While ridges correspond to local maxima of the curvature function, valleys correspond to local minima. After that we have to connect the detected points to feature lines. Neighbouring points are directly connected by the edges of the mesh. After the computation of the set of ornamentation lines it is necessary to remove dispensable lines by using appropriate filters. These lines result from the surface structure or from damages of the ceramic. The corresponding ridges and valleys to these faulty lines mostly have a lower curvature value as the ornamentations we are looking for so that they can be filtered out according to a threshold.

3. Simple ornamentation features

In order to compare ornamentations we initially have to extract and analyse their features. Features of ornamentations like size, extension, planarity and intensity can be determined easily. Analysing these features makes it possible to perform a rough classification of ornamentations. To compute the size of an ornamentation we have to choose a suitable projection method. Relatively planar ornamentations are mapped onto a plane. Otherwise we project them onto the superficies surface of a cylinder. After it we can determine the length and width of the projected ornamentation, which represent the dimension of an ornamentation.
A suitable projection method can be chosen manually or automatically. Normal variance, which is a measure for the planarity of an ornamentation, is used to choose the suitable projection method automatically. Therefore, we determine the deviation of the normal vectors of the single vertices to the average normal of the ornamentation and compute the sum of differences. This procedure is illustrated in figure 1. On the basis of this mean value we can decide whether an ornamentation spreads over a small part of the surface and so it is relatively planar or if it is distributed over the whole vessel. The expressiveness of the normal variance is illustrated in figure 2. When we use a small threshold only the grooves on the belly of the can are detected. The horizontal lines have a higher normal variance so that they are filtered out. This ornamentation feature enables us to find the suitable projection method that minimizes the loss of information generated by the projection.

Another simple feature is the curvature gradient, which includes the curvature values of the vertices of an ornamentation. Deviation of two ornamentations is determined by comparing the

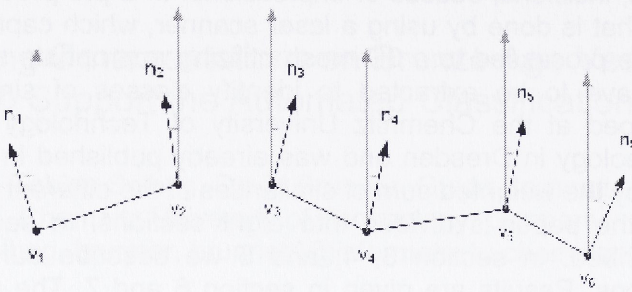

Fig. 1: Normal variance is the deviation of the vertex normals to the average normal (gray).

difference of curvature values on regularly distributed samples. The sum of differences conforms to the similarity of two ornamentations. If the value is smaller than a given threshold value the feature

Fig. 2: Detected ornamentations, which have a normal variance lower than a given threshold. The threshold value is increasing from second to the fifth figure. The leftmost figure shows the object with all its detected ornamentations.

lines are declared as similar. However the curvature gradient only gives information about the intensity and is just applicable for a rough classification.

4. Vertex-based descriptors

The first approach for a more complex description of ornamentation features defines a descriptor for each vertex of the ornamentation. Such a vertex descriptor is the so-called Curvature Map, which was introduced by Gatzke et al. in [6]. Such a map describes the curvature function of the surface region, which surrounds the considered vertex. Gatzke et al. defined two kinds of Curvature Maps. The 1D Curvature Map considers the curvature depending on the distance to the vertex. The 2D Curvature Map additionally considers the orientation of vertices, so that they correspond to a sampling of the surface based on the structure displayed in figure 3. In contrast to the approach of Gatzke et al. we do not only want to compare vertices but also ornamentations in terms of sets of vertices.

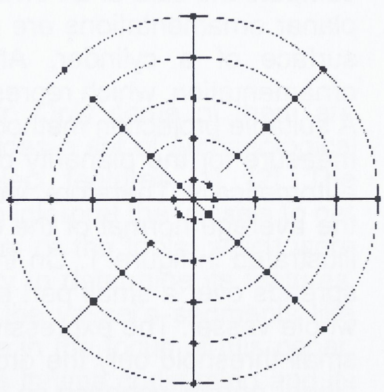

Fig. 3: Geodesic Fan

Therefore, we developed two methods to compare these sets. The first approach maps the ornamentation lines, which should be compared, on the same interval and performs a sampling over it. Finally the differences of the curvature maps at the chosen samples are summed up. This measure represents the similarity of the compared ornamentations. The second procedure to determine the similarity of two ornamentations compares subsets of the sets of vertices. For each vertex of the first ornamentation we compute the difference to a set of vertices of the second ornamentation. After this we sum up the single deviations. This value enables us to decide whether the two ornamentations are similar or not.

5. Descriptors based on projection

The second strategy to estimate the ornamentation features is based on the idea of projecting ornamentations from 3D to 2D. So the most important step of this approach is the projection, which could be performed in different ways. We analysed the projection of ornamentations in a local or global plane and the projection on the girthed area of a cylinder, which is aligned to the y-axis and the complete mesh. The projection in a plane is suitable for relatively planar objects like shards, plates or flat dishes. Cylindrical ceramics like cans and pots should be mapped onto a cylinder.
After the choice of the projection method it has to be assigned, which information is saved in the map. On the one hand we use the shape of ornamentations and project it in a so-called Shape Map and on the other hand we map the curvature in a Curvature Map. A Shape Map is generated by discretizing the shape of ornamentations in the map. So the overlaid grid cells get the value one and the rest are set to zero. By the application of the Gaussian Blur filter the received lines are smoothed and an additional tolerance region surrounding the ornamentation is created. This involves a greater area for the estimation of the similarity of ornamentations.
To compare two ornamentations it is necessary to compute the deviation of the associated maps. Shape or Curvature Maps are overlaid in their barycentre and the difference of the overlapping parts is summed up. The values of the remaining cells are directly added to the deviation so that it induces a lower similarity. In addition to the direct comparison there exists the possibility to detect a single pattern in an ornamentation. Furthermore it can be determined whether an ornamentation is part of another or if certain elements appear several times in an ornamentation. Therefore the whole map of the considered ornamentation is passed through and on each position the deviation to the pattern we are looking for is estimated. If the minimum of the single differences is lower than a given threshold the ornamentation contains the pattern we are looking for.

6. Results

In the following section we illustrate the quality of the described methods by presenting different examples of classified ornamentations. The first example is the can in figure 4. It demonstrates the difference between the results of the curvature gradient and the results of the 2D Curvature Maps. The results demonstrates that the usage of single curvature values does not possess sufficient expressiveness because there were also found some ornamentations, which have no similarity toward the angular lines on the belly of the can. All these ornamentations have a similar intensity, so that it is not possible to distinguish them. In contrast to the curvature gradient 2D Curvature Maps take the vertex environment of the ornamentations, we were looking for into account. This is much more convenient.

Fig. 4: Detecting grooves on the belly of a can (1. 3D mesh, 2. Valleys, 3. Results generated by curvature gradient, 4. Results generated by 2DCurvature Maps)

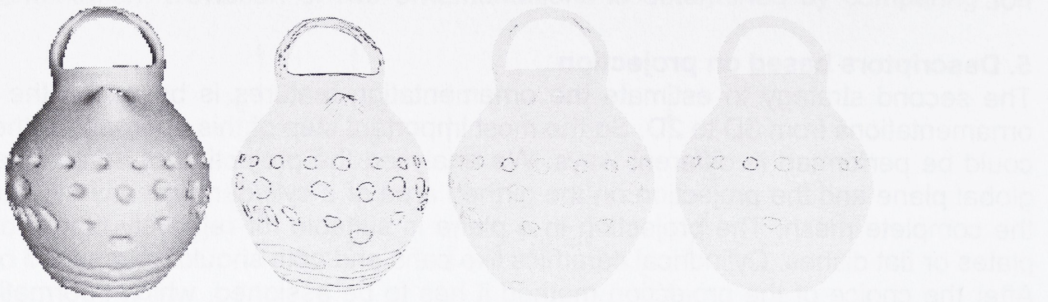

Fig. 5: Results for finding circular impressions on a can (1. 3D mesh, 2. Valleys, 3. Results for 2D Curvature Maps, 4. Results for Curvature Maps for each ornamentation)

The second example (figure 5) illustrates the gain of information by the usage of Curvature Maps for the complete ornamentation and not only for the corresponding vertices. The vertex-based method identifies ornamentations, which are not similar to the circular impressions we were looking for. The second approach eliminates these wrongly classified ornaments. The improved results appear because the form and orientation of ornamentations are considered. In the case of vertex based descriptors form and orientation are not taken into account.
The examples pictured in figure 6 show that the presented algorithms are applicable for a great range of archaeological vessels to derive the classes of ornamentations from the set of ridges and valleys. First of all, the quality of classification strongly depends on the quality of the 3D scans. The surface structure has great influence on the curvature function and generates dispensable ornamentation lines or prohibits the detection of ornamentations. Furthermore, the results for incomplete ceramics are less accurate because only segments of ornamentations can be extracted there.

7. Summary

In this paper we introduced and analysed new methods for detecting ornamentations and estimating features of those ornamentation on surfaces of Bronze Age vessels. Using our algorithms it is possible to compute a measure for the similarity of ornamentations. So ornamentations can be used in the context of classification of archaeological vessels. Using our methods we are able to detect similar ornamentations on the object's surface and objects with similar ornamentations. Furthermore we are able to estimate the number of these similar ornamentations. Therefore, we analysed different attributes like size, intensity, form, distribution or orientation and developed suitable descriptors that return these information. Based on suitable comparing functions the required similarity values could be estimated.

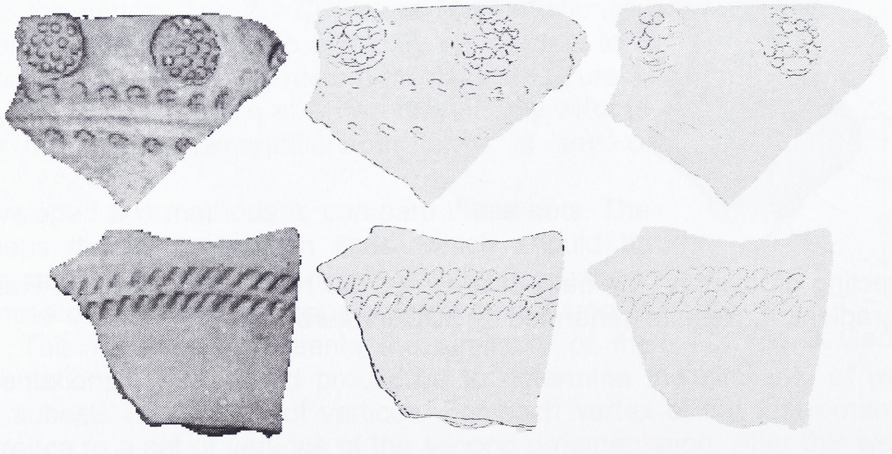

Fig. 6: The examples show similar ornamentations detected by the use of Curvature Maps.

The application of the explained methods on different examples shows that we achieved good results in extracting the existing ornamentations and subdividing them into classes. But there are still some problems which strongly depend on quality of the 3D models. Especially noisy scans, which result from the surface structure and inauspicious reflection properties of the surface, and incomplete ceramics with missing shards influence the results negatively. Due to these problems it seems to be advantageous to perform the error-prone extraction of ornamentations semi-automatically with user interaction or as a complete manual process. However the classification could be realised fully automatically.

8. Future work

In the previous sections different descriptors were introduced to distinguish ornamentations. These methods produce the desired results. However the extraction could be improved. The arising problems depend on the quality of archaeological scanner data. Furthermore, ornamentations with multiple, independent and disconnected parts shown in figure 7 could not be detected. Only the separated ornamentation lines could be detected. This example illustrates the necessity of determining relations and hierarchies, which offer much more information about ornamentations. So it will be possible to consider ornamentations as it is done by archaeologists. If ornamentations are similar relations between them exist. This could be estimated by analysing different suitable criteria like form, orientation, intensity or size by using the introduced ornamentation comparing methods. The hierarchies define whether related ornamentations should be combined to a more complex ornamentation resulting from their similarity and location or not. But this is a relative different task or partly not realizable task because these attributes do not always allow a unique statement about their relation and existing hierarchies. The two cans in figure 8 illustrate this issue. The grooves are adjacent and have a similar form but they should not be grouped as one ornamentation.

So we suggest that this process should be supported by the user. Different possibilities to manipulate and control the detection of ornamentations are conceivable. Firstly it is useful to remove or correct wrongly detected ornamentations already in the extraction process. Furthermore, it should be possible to group related feature lines. Otherwise the software could display suggestions for related ornamentations and the user has to confirm or correct these

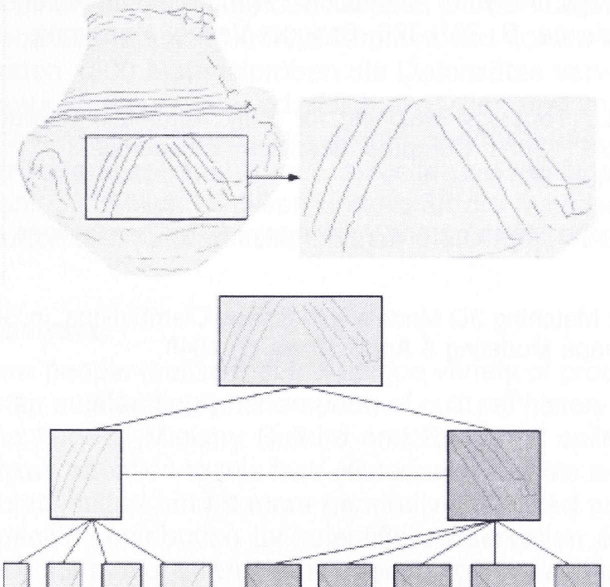

Fig. 7: A complex ornamentation split into its single feature lines. The graph shows the relations and hierarchies between the separated lines.

Fig. 8: Examples with relatively similar ornamentations, which should not be grouped by an automatic relation detecting algorithm

relations. Of course the complete process for detecting ornamentations could be done manually and only the classification could be performed automatically. However, the automatic computation of ridges and valleys ensures a great time saving so that it should be constituted.
Another feature, which should be considered in the classification process of ornamentations is the position on the surface of the vessel. Therefore the archaeological objects have to be segmented. An appropriate procedure was already presented in [7]. For example this additional information gives us the possibility to distinguish ornamentations located on the belly and shoulder.

Literatur

[1] Brunner D.; Brunnett G.; Oexle J.: Concept for an application-oriented automated classification system for Bronze Age vessels. EVA 2006 London Conference Proceedings, EVA 2006 London Conference, EVA Conference International ECI, 2006, S. 16.1-16.12, ISBN 0-9543146-7-0.

[2] Hörr C.; Brunner D.; Brunnett G.: Primärklassifikation archäologischer Gefäße mit Multiresolutional Reeb Graphs. Tagungsband der 3D-NordOst, 8. Anwendungsbezogener Workshop zur Erfassung, Modellierung, Verarbeitung und Auswertung von 3D-Daten, 2005, S. 125-132, ISBN 3-9809212-5-5.

[3] Interrante V. ; Fuchs H. ; Pizer S.: Enhancing Transparent Skin Surfaces with Ridge and Valley Lines. S. 221–228, IEEE Visualization 1995, 1995.

[4] Ohtake Y. ; Belyaev A. ; Seidel H.-P.: Ridge-Valley Lines on Meshes via Implicit Surface Fitting. In: ACM Trans. Graph. 23 (2004), Nr. 3, S. 609–612. – ISSN 0730-0301.

[5] Solbrig T.: Automatisierte Generierung von skizzenhaften Darstellungen archäologischer Gefäße. (2005). – Studienarbeit, Fakultät für Informatik, Technische Universität Chemnitz.

[6] Gatzke T. ; Zelinka, S. ; Grimm, C. ; Garland, M.: Curvature Maps for Local Shape Comparison. In: Shape Modeling International (2005), Juni, S. 244–256.

[7] Hörr C.: Segmentierung und hierarchische Klassifikation archäologischer Gefäße, Fakultät für Informatik, Technische Universität Chemnitz, Diplomarbeit, 2006.

[8] Ankerst M.; Kastenmüller G.; Kriegel H.-P.; Seidl T.: 3D Shape Histograms for Similarity Search and Classification in Spatial Databases, SSD '99: Proceedings of the 6th International Symposium on Advances in Spatial Databases, Lecture Notes In Computer Science, S. 207–226, Springer-Verlag, Hongkong, Juli 1999.

[9] Hilaga M.; Shinagawa Y.; Komura T.; Kunii T. L.: Topology Matching for Fully Automatic Similarity Estimation of 3D Shapes, Proceedings of ACM SIGGRAPH 2001, Computer Graphics Proceedings, Annual Conference Series, S. 203–212, Los Angeles, Aug. 2001.

[10] Kazhdan M.; Funkhouser T.; Rusinkiewicz S.: Shape Matching and Anisotropy, ACM Transactions on Graphics (SIGGRAPH 2004), Aug. 2004.

[11] Osada R.; Funkhouser T.; Chazelle B.; Dobkin D.: Matching 3D Models with Shape Distributions, in SMI '01: Proceedings of the International Conference on Shape Modeling & Applications, S. 154ff, IEEE Computer Society Press, Washington, DC, 2001.