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Automatic illustration of lithics from 3d scanned models

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Abstract. The manual drafting of lithics artefacts could be a very time-consuming work, and it could be cumbersome on the archaeological site. In this case, a 3D digital model of the object could be very useful. Nowadays, several digitizing technologies are available to easily acquire information about the shape of an object. Virtual models could be used to create a digital museum or to share information between researchers. On the other hand, the manual drafting of a lithic object contains information about the technologies used to realize it. Information about the core setup, types of chipping surfaces, detach sequence of supports, and much more. In this work a method to easily obtain a hand-made-like draft of lithic artefacts is proposed. The method is based on the 3D acquisition of the object with a structured-light based scanner and a sequence of digital processing of the acquired data.

1. Introduction

Recent developments in digital 3D acquisition technologies have allowed innovative applications for recording, conservation, reproduction, study and fruition of sculptural, architectural and archaeological artworks [1.]. Originally developed for industrial application, 3D imaging techniques have been successfully extended to the field of artworks acquisition. In lithic studies there are several researches oriented to use of digital models instead of manual drafting [2, 3]. Of human made artefacts in prehistorical era, only the stronger, made of stone or flint are enduring to our days. The lithic manufacturing could be subdivided in chipping stone manufacturing and the smoothing stone one. In this work the chipping stone were considered. Lithic artefacts could be obtained by chipping it with another object (percussion hammer) from a raw stone. Final product can derive from the stone so chopped (double-sided, chopper, etc..), from one of the obtained splinter or from machining one of the splinter obtained from the core. The artefacts arising from a detachment usually have a ventral-face (i.e. the one facing the original core) and spinal-face (i.e. the one that preserves the original surface of the stone or nucleus). Moreover, in all the artefacts a proximal end (i.e. the one that received the chipping stroke) and a distal end opposed to it, are always present. Usually, the faces with manufacturing signs are the ones drawn by technicians [4].

The purpose of the lithic illustration is to represent as close as possible the manual manufacture of the object [5, 6]. The illustration could be of three main type: 1) the typological drafting, that is very schematic and gives information about principal used instruments (Figure 1 a); 2) the technical drafting, that is used to show simplified technical data (i.e. morphology, type of re-touching)(Figure 1 b); 3) the technological drafting, that is the most realistic one, it reproduces both technical and morphological aspects (Figure 1 c).

To obtain a good lithic representation analytical study of the artefact is required. Stones can have different type of surfaces to depict with different type of graphical signs (natural fractures, artificial

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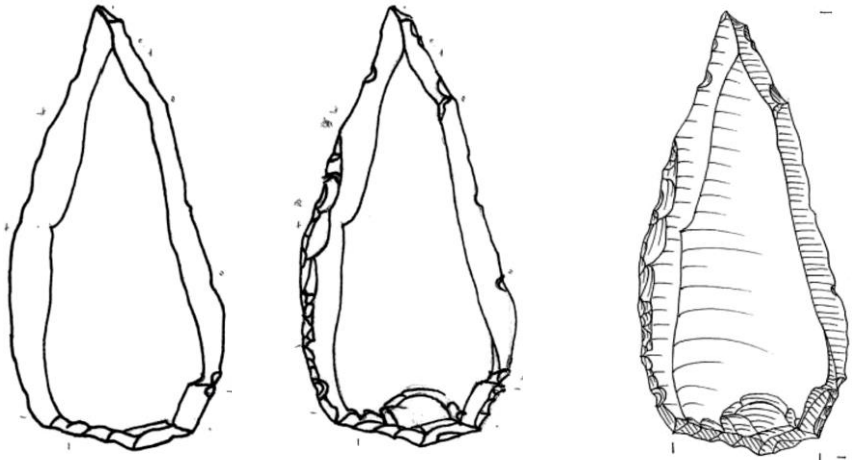
fractures, re-touching, pseudo re-touching, dorsal face, ventral face, …). Moreover, the orientation of the stone in the drafting is fundamental, also the reference system used has a technological meaning. The vertical axes should be the morphological one (the one with the main length of the piece), while the horizontal axes should be the principal chipping one, along the first fracture direction. Finally, also the light direction in the lithic drafting is very important. It should evidence, with the light and dark areas of the object, both its morphological and technical aspects. The light is usually placed in the top left spot of the artefact to be drawn.

Simple manual tools, like caliper and compass, are used to measure the length, the depth and the width of the stone, which is placed in an ideal bounding box. Ventral and dorsal profiles are so manually traced on the sheet by contouring the stone with a pencil, while for the depth profile a contour gauge is used [7]. Finally, the projection of the heel, if it is present, is manually traced.



a) b) c)

Figure 1. Manual drafting of a lithic artefact: typological draft (a), technical draft (b), technological draft (c).

2. Materials and Methods

In this works a novel method to obtain manual-like illustrations from 3D scans of stones is proposed. The method is based on a semi-automatic segmentation of 3D data acquired by a structured light scanner. The segmentation is carried on by a cut algorithm based on the values of the crease angles between adjacent faces of the model, that is firstly decimated and smoothed.

2.1. High resolution 3D range camera system

To acquire the geometry of lithic artefacts a specifically developed 3D optical scanner was used. The device is a 3D range camera system composed of a DLP projector (1024 × 768 pixels) and one monochrome digital CCD camera (1280 × 960 pixels) (Figure 2). The acquisition method is based on a structured light approach, which uses binary patterns to capture 3D shapes. Projector is used as active device to scan the object with vertical striped light patterns. A calibration procedure is adopted to calculate distortion parameters and relative position of the optical devices. The projector is modeled like an inverse camera, and the calibration is exploited by using generated vertical and horizontal fringes [8]. A sequence of black and white vertical light stripes is projected onto the object (Figure 2). The crossing lines between black and white fringes define a pattern of planes that virtually slices the full object along a temporal sequence. Each pixel of the image acquired by the camera will be bright or dark depending on its location. A n-bit binary code could be assigned to each pixel, where n is the number of the projected stripe patterns, and values 0 and 1 are associated to the intensity levels, (i.e., 0 = black and 1 = white). The 3D coordinates of the measured points can then be computed by exploiting the intersection between optical rays from the camera with the projected planes. This

IOP Conf. Series: Materials Science and Engineering **364** (2018) 012017 doi:10.1088/1757-899X/364/1/012017

methodology could provide the horizontal resolution from the projector while the vertical resolution from the camera. A high-density range map is hence obtained in a matter of seconds.

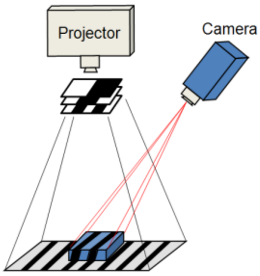
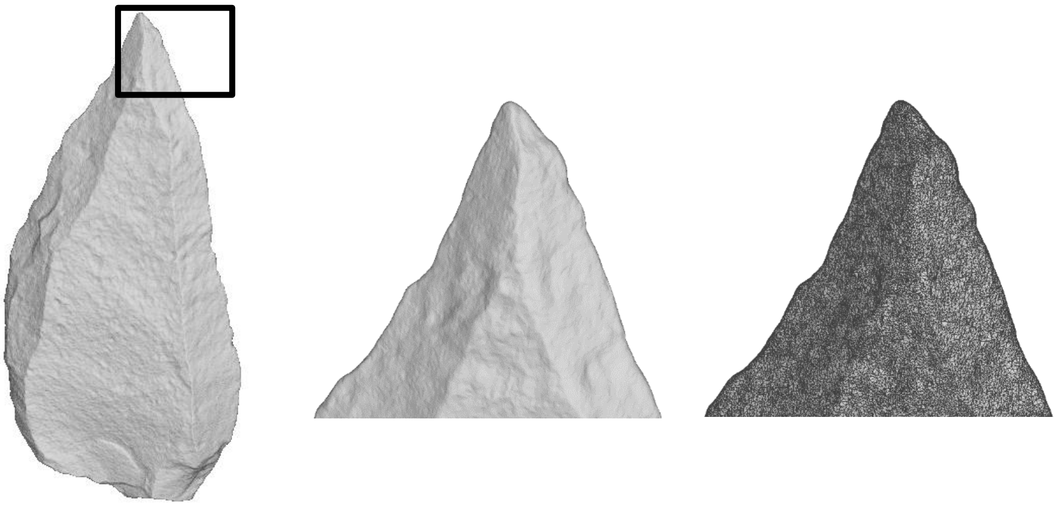


Figure 2. Scheme of the 3D range camera system.

The acquisition of a whole object requires several views of it from different directions. The alignment of the views could a cumbersome task and there are different methods that can be used. In this work a manual raw positioning of the object in front of the acquisition device has been used. The obtained range maps have been raw aligned by a 3-2-1 method and then processed with a standard pipeline to obtain the final model of the mesh (Figure 3).



a) b) c)

Figure 3. Sample of acquired 3D mesh of a lithic artefact (a), detail view of the top without (b) and with (c) visualization of the triangle edges.

2.2. *Automatic drafting from 3D model*

To obtain a manual like drafting from the acquired 3D model a novel methodology has been developed. The methodology is based on a sequence of mesh processing algorithms that enhances first the feature lines of the object and automatically extracts the drafting as projection of these lines.

2.2.1. Model Decimation. The first step of the processing phase is the decimation of the acquired model. Usually decimation is used in mesh processing to reduce the number of the faces with the aim at having light models (i.e. faster visualization and management). Several algorithms have been developed for decimation of triangular meshes. In vertex-based decimation, meshes are reduced by removing vertices from them. Usually vertices are treated one by one, and the resulting hole after each removal operation are closed by a re-triangulation process. In edge-base decimation the number of faces is reduced by removing edges from them. The removed edge is replaced with a single vertex and again a re-triangulation process is needed to obtain the final mesh. In triangle-based decimation, faces that are nearly co-planar with their neighbouring are replaced by one face (or in a minor number of faces). The co-planarity between triangles can be evaluated by analysing local curvatures or face normal. The purpose of this step in the proposed methodology is to reduce the number of faces, without decrease the accuracy and the resolution obtained in the acquisition step. Moreover, the topology of the resulting mesh should be optimized in order to facilitate the later steps towards the automatic drafting of the object. A quadric edge collapse decimation algorithm has been used to reduce the number of faces acquired by the system.

2.2.2. Enhancement of feature lines. In this step the acquired 3D models are processed to enhance features areas (i.e. object boundaries) while smoothing noisy ones (i.e. homogeneous regions). These features could be lost with classical isotropic denoising algorithm. Anisotropic smoothing techniques, instead, could be used with the aim at holding corners and ridges (i.e. sharp edges) of the lithics artefacts (i.e. the lines to put in the technical draft). Different forms of anisotropic diffusion filters have been developed and could be used on meshes [9]. In this work an algorithm based on second-order properties of the surface has been used. Indeed, in the case of an edge between two areas of a mesh, the minimum curvature is zero along the edge, while the maximum curvature is perpendicular to this edge. A weighted mean curvature flow has been computed, this operator allows to penalize faces that have a large ratio between their two principal curvatures. Features like sharp edges could be held while noise, more symmetric by nature, could be reduced. Results of such algorithm has been shown in Figure 4.

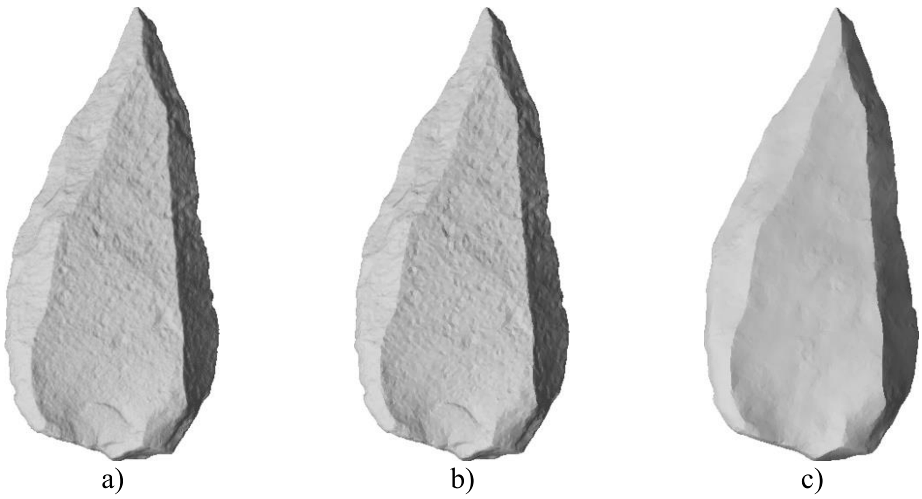
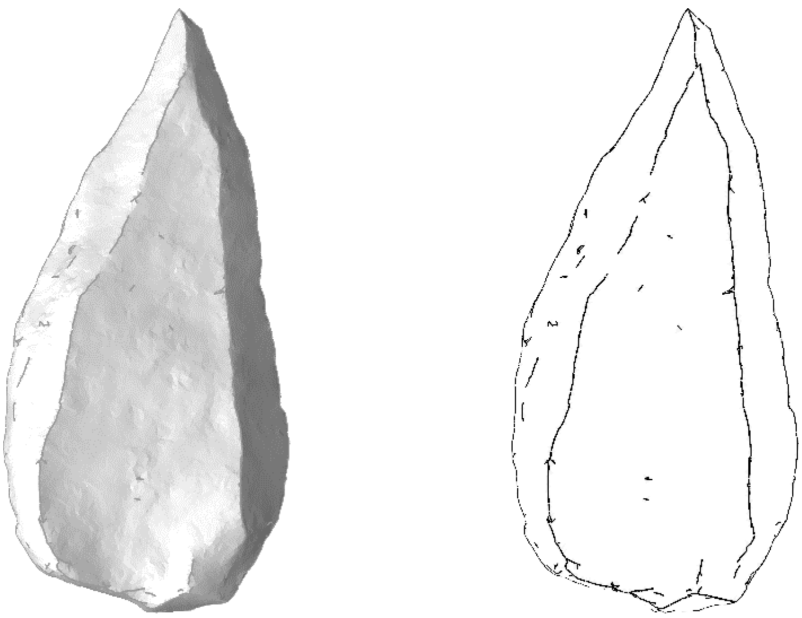


Figure 4. Decimation and smoothing of acquired 3D mesh of a lithic artefact: original mesh (a), 10% decimated mesh (b) and smoothed mesh (c).

2.2.3. Drafting creation. The last step of the proposed method is the automatic creation of the draft from the processed 3D model of the lithic artefact. This task consists of 3 main sub-steps: model positioning, mesh cutting and 2D projection of feature lines. The first step consists in the orientation of the model in order to obtain a 2D drafting as much as possible similar to the manual drafting. For this purpose, an initial guess orientation is based on the principal axis orientation of the model, in which the bounding box of the model is placed along the principal direction. From this position a manual adjustment could be performed to obtain the desired final position. The mesh cutting is performed to obtain the edge of the artefact. The cutting of the mesh is created where the angle between two adjacent faces (crease angle) is greater than a specific value. Once the edges are created they could be used to automatic draw the desired views of the artefact (Figure 5).



a) b)

Figure 5. Cutting step of the 3D model (a) and relative sharp edges view (b).

3. Results and discussion

Some lithic artefacts have been used to test the proposed methodology. In this works the result relative to one of the artefacts is presented. The artefact shown is a brown flint blade with heel's re-touches, obtained from a secondary chipping of a Palaeolithic detachment, with a height of 80 mm, a width of 30 mm and a depth of 10 mm (Figure 6). For the 3D acquisition of the artefacts 28 range maps (2.5M points) have been collected with a field of acquisition of 80x60 mm, a lateral resolution of 0.08 mm and an accuracy of 10 microns. The acquisition step along with registration phase and the data processing, has taken about two hours. The final model is a triangular mesh of 1.1 M triangles (Figure 7). The obtained model has been processed with the proposed methodologies and the obtained results are shown in Figure 8. The artefact has been also drafted by hand from a technician (Figure 9).

4. Conclusion

Even if there are several standards in manual drafting of lithic artefacts, the result could be variable because of the involved factors [2]. Indeed, the archaeological technician could evidence different characteristics of the stone based on his experience and on the purpose of the drafting [10, 11]. Moreover, when pictures are used instead of the technological drafting, these could not underline the most important details (e.g. due to colour or light reflection). 3D acquired models have been introduced in the last years in technical documentation of the artefacts and it could be of high potentialities in the archaeological field. The model could be used over time for looking at the object from different viewpoints or could be zoomed in to looking for specific details. Moreover, 3D model could be used to produce a replica by additive manufacturing techniques. Anyway, 2D technological drafting could be very useful, especially when printed documentation is needed, because of the additional information included.

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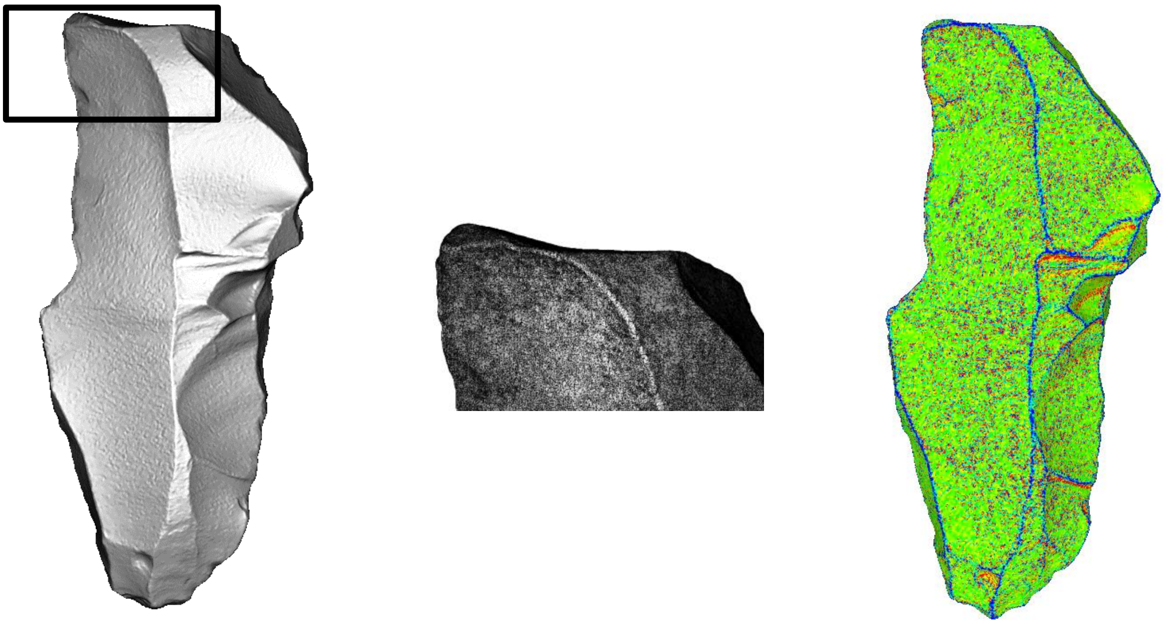
a) b)

Figure 6. Picture of the lithic artefact: frontal view (a) and rear (view (b).



a) b) c)

Figure 7. Acquired 3D model of the lithic artefact: frontal view (a), detail view (b), curvature maps of the frontal view (c).

In this work 3D scanned data has been used to automatic create manual-like lithic technological drafting. The method is based on the processing of acquired data by algorithms of mesh decimation and smoothing. The obtained results show high potentialities of the proposed solution, especially for the technical drafting. Some little details miss from the drafting, anyway it is very interesting the mixed representation that could be easily obtained from 3D model. This, for example, could be used as a base from the technician for easily add technological details. From archaeological point of view, the typological and the technical drafting, digitally obtained from the proposed solution, are of higher accuracy with respect to the manual ones and, of course, faster.

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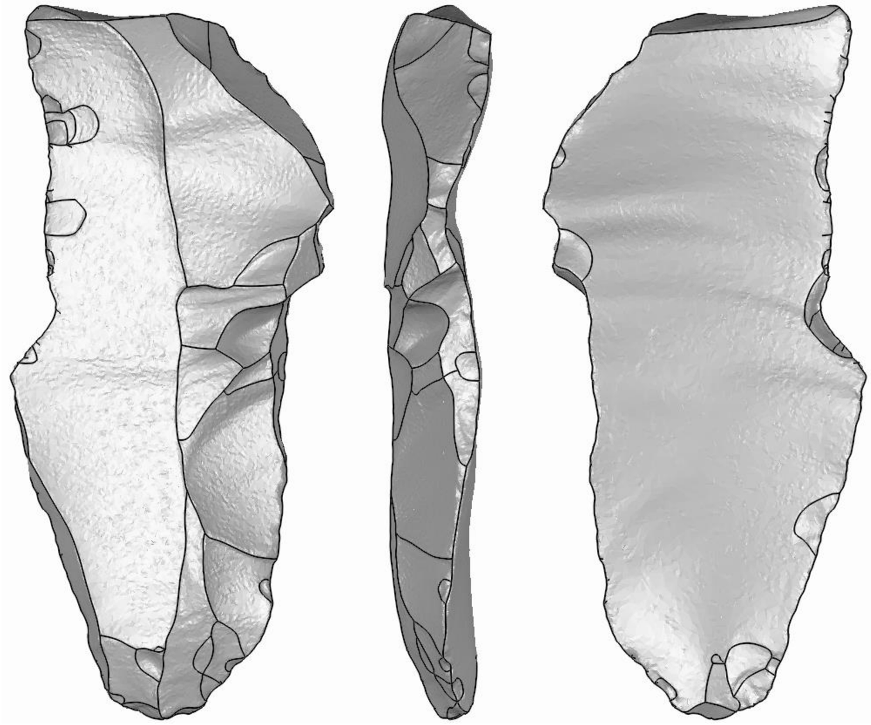

Figure 8. Automatic draft obtained for the lithic artefact.

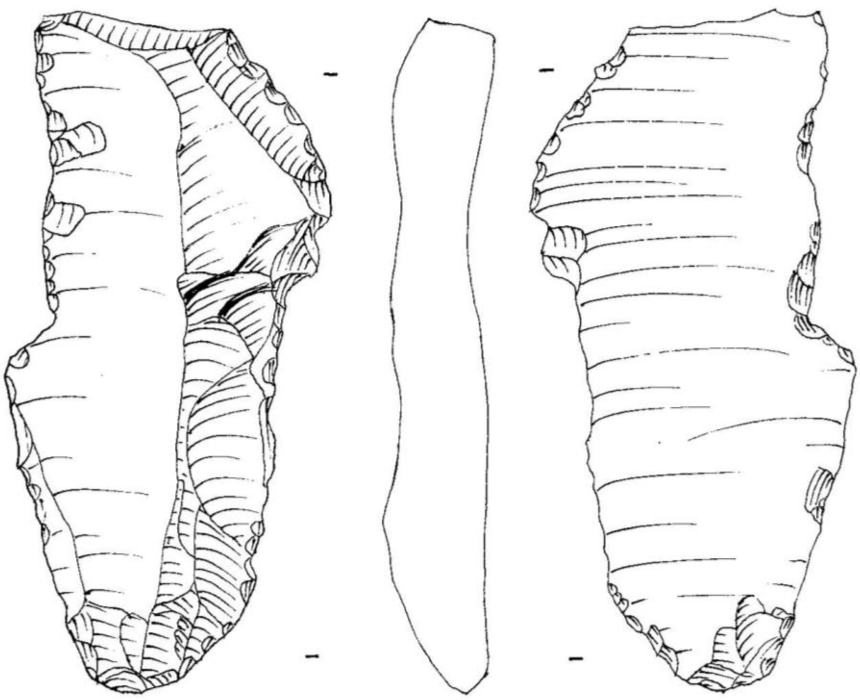

Figure 9. Hand-made draft of the lithic artefact.

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