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Original article

Beyond manual drafting: a restoration-oriented system

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Abstract

The production of drawings is a basic activity in restoration, archeology and cultural heritage (CH) didactics. The manual production of technical drawings is a complex process, both in terms of time and skills required. In this paper we present a computer-aided methodology to produce technical drawings of CH artifacts. A pre-requisite of our methodology is the acquisition of an accurate digital 3D model of the artifact, which is now possible at affordable costs using 3D scanning technology. We discuss the specific needs that a drafting system oriented to the CH domain should satisfy and we present the design, features and performances of a computer-aided drafting system, called *Cavalieri*. *Cavalieri* allows to manage the huge digital models produced with 3D scanning devices and supports easy specification of orthographic drawings and cut-through sections, which are given in output as very high-resolution images (with user-selected reproduction scale and printer resolution). We conclude with some results of *Cavalieri*'s assessment in the framework of two restoration projects.

Keywords: Cultural heritage; Restoration; Technical drafting; 3D range scanning; 3D mesh visualization; Large print formats

1. Research aim

The research aim of this paper is to propose a semi-automatic drafting approach for the production of large formats prints of cultural heritage (CH) artifacts. The availability of 3D scanning devices allows to acquire very accurate digital models in sufficiently short times and with an affordable cost. The potential use of those digital models has to go beyond pure visualization. We propose to replace manual drafting (at least partially) with a flexible system which allows to produce large format prints from the available 3D model, making computer-aided drafting a very profitable instrument in the hands of restorers or archaeologists.

2. Introduction

CH artifacts are often the subject of an intensive drafting activity, especially in the framework of archeology or restoration. Technical drawing is produced, often in 1:1 scale, and together with photographs they make up the iconographic documentation of the restoration or archeological activity.

Drawing is still mainly a *manual process* in the CH domain. This can be considered a positive point, because the draftsman can often enrich and extend its product with *interpretations* or *reconstructions* coming from his experience and knowledge of the field. On the other hand, negative points of the manual approach are the *unknown precision*, the *long time* needed to make sufficiently accurate drawings of complex objects, and the *technical/artistic skills* required.

The overall goal of the project presented here is to reduce the gap between the potentialities of digitization technology for 3D objects (usually called 3D scanning [1]), able nowadays to produce highly accurate digital 3D models of CH artifacts, and the diffusion and real use of these models in CH applications.

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Most of the 3D digital models are used just to produce still images or [interactive] animations for *didactic* applications or *multimedia presentations*: the classical rendering-oriented applications are still predominant. On the other hand, people working in the CH field, initially satisfied by the simple images, are now asking for tools actually useful for their work.

In this project we focus our attention on one of these *day by day* activities—technical drafting—and we propose a new computer-assisted approach. The production of technical drawings is an ideal research focus because, on one side, we have a methodology that is time-expensive and heavily dependent on human contribution/skill while, on the other side, we could make a keen use of all the incredibly rich details and accuracy of the digital models produced with 3D scanning technology. The goal of this project is therefore the design of a semi-automatic drafting system for the reproduction of accurate technical drawings on large scale printing formats.

The paper starts with a brief introduction to technical drawing in CH applications, presenting the specific needs of this field and the pitfalls of the current manual techniques. Then a short overview on 3D scanning is provided to better focus the data acquisition technology us. Next we highlight some important needs and constraints of drafting in the CH domain. Those considerations are followed by a detailed description of the *Cavalieri* system, including functionalities provided and implementation details. Finally some experimental results of the use of *Cavalieri* system in the Minerva and Michelangelo's David restoration are presented.

3. Manual drafting in restoration

Let us introduce first why technical drawings are used in restoration and archeology. Technical drawings of archeological findings are produced with two main motivations: (a) to have a graphic documentation (more synthetical and rich of meta-information than photographs) of the shape and of the preservation conditions of the artifact, and (b) to be used in restoration to plan, design and document the actions to be done.

If we consider the first motivation, technical drawings are produced to give graphic evidence to the artifact shape, measures, lengths, morphological features, etc. All these information are often synthesized in the drawing and are needed to perform style comparisons, to determine the origin of the finding or to study the antique technologies used to mold/cast/sculpt it.

In the case of a restoration project, drawings are part of the basic documents (such as photographs, X-ray investigation, chemical analysis, etc.): they preserve memory of the condition of the finding before the restoration which might change in a significant manner the appearance of the artifact. Changes can affect the artifact chrominance (removal of patinas), the surface texture (polishing the surface from crusts or deposits), or even its shape (for example a bronze object, deformed by some accidents and brought back to its original shape during restoration).

Moreover, a second important reason for producing high quality technical drawings is to support the restorer with a permanent document on the original morphology of the artifact. Some examples which could clarify this need are as follows. An artifact can be discovered in damaged/incomplete conditions and documentation about the current state is needed. Another example is the case of highly fragmented objects with missing components (e.g. pottery). In this case drawings are produced to represent the available fragments, but also to place all of these fragments in the space according to the original shape, making at the same time some hypothesis on the structure and shape of the missing parts. This is probably the most complex task, where the experience and knowledge of the art historian or the archaeologist plays (and will also play in the future) a fundamental role. From the examples above, it is clear that *drafting* can encompass two very different activities: first, to produce an *accurate graphic representation* of the artifact shape (reproducing at a known scale and accuracy its dimensions, curvature, decorative elements or "stilema", etc.); second, to *draw some hypothesis* on its original shape or overall structure, according to an interpretation which heavily depends on the culture and experience of the human being in charge of the action. These two activities have to be clearly considered as two logically different stages. In the work described here we focused on the first task. While we consider the second stage as an exciting research topic, we do not think that current technology could give "sound solutions" to the latter problem.

Let us briefly introduce which are the requisite to produce useful and correct technical drawings, considering at this point just the requirements of the first task introduced above. Technical drawings used either for documentation purposes or as supporting material in a restoration project are in general done using the *orthographic projection*. This is because this type of projection allows to encode the metric attributes of the artifact in the drawing and to perform comparisons between either different cut-through sections of the same objects or different drawings. Given a three-dimensional cartesian space, the draftsman selects a set of views corresponding to the set of drawings he has to produce. The number of different views depends on the shape complexity of the artifact, its importance and the time and resources available to produce the drawings. In general, at most five or six views are used to build up the graphic representation of the artifact. A common approach is to select views which are aligned to each pair of cartesian axis (front, back, left and right side, top, bottom; see Fig. 1). Such a complete set of drawings is produced for valuable artifacts (for example a statue); since manual drawing is a costly task, just one or two drawings are usually made for less valuable findings. Moreover, a second basic manner to represent the shape of an artifact is to produce a set of cut-through sections (often, drafted over-imposed one to the other together with the top or bottom views; see Fig. 2). Due to the orthographic projection used, these drawings can be overlaid one on the other (using semi-transparent prints), for example to find the correspondence between features detected on the front and the corresponding areas on the back.