

Studying shape semantics of an architectural moulding collection: classifying style based on shape analysis methods

Abstract—As technologies for 3D acquisition become widely available, it is expected that 3D content will become increasingly popular. Nevertheless, to provide access and enable the creative use of 3D content, it is necessary to address challenges such as the availability of open repositories dedicated to 3D content and the automatic enrichment of 3D content with suitable metadata so that content does not get lost. To address these challenges, this paper presents research on developing technologies to support the organisation and discoverability of 3D content. The main contributions of the paper include a suitable ontology for documenting 3D representations of decorative ornament using higher level concepts. This ontology is used along with developed shape analysis methods to improve the information that is automatically extracted from a 3D shape. These methods are tested on an architectural collection of Regency ornament mouldings used in domestic interiors. This content provides a rich dataset on which to explore issues such as design styles, patterns and motifs.

I. INTRODUCTION

The assimilation of 3D technologies over the last few years is an undeniable fact, as demonstrated by the growing adoption of 3D entertainment, augmented reality and 3D printing. Furthermore, as technologies for 3D acquisition become widely available, it is expected that 3D content will become increasingly popular. Thus, professionals and the public alike will be able to create and contribute 3D content documenting unique as well as everyday life objects. In turn, this will unleash opportunities for creative use of these assets; underpinning the development of industries which will take advantage of the richness and tangibility of this type of content for applications domains as diverse as entertainment, conservation, design and manufacturing.

Nevertheless, to achieve this vision it is necessary to address some challenges. Currently, one major problem is the lack of underpinning technologies which can ensure the automatic enrichment of 3D content with suitable metadata so that content does not get easily lost. To address this challenge, this paper presents research on developing technologies to support the organisation and discoverability of 3D content. Hence, the research contributes to address one of the major barriers for the ubiquitous use of 3D content, which is the access to 3D content at the right place and time. This is mainly caused by a lack of open repositories dedicated to 3D content. Most importantly, however, it is caused by shortcomings in existing technologies needed for the automatic analysis and enrichment of 3D content with its high level semantic meaning.

The research focuses on 3D content from the Cultural Heritage (CH) domain. Specifically, we use Regency ornament mouldings used in domestic interiors. This content provides a

rich dataset on which to explore issues such as design styles, patterns and motifs. It also provides a suitable application to the Cultural Heritage domain, where many artefacts and architectural elements are decorated using patterns and motifs relevant to a time period and place.

The main contributions of the paper include a suitable ontology for documenting 3D representations of decorative ornament using higher level concepts. This ontology is used along with developed shape analysis methods to improve the information that is automatically extracted from a 3D shape. This will allow a variety of users to interrogate a repository using the underlying semantic connections within the content, rather than its low level geometric information (e.g. name or size of a 3D mesh).

The paper is organised as follows. Section 1 presents a review of previous work on the area of semantic analysis of 3D content. Section 2 provides background information on the use of ornament to decorate architectural elements, in particular during the Regency period in Great Britain. Moreover, section 3 describe the main elements of an ontology to document an architectural moulding collection; and section 4 presents the shape analysis methods which are used to automatically enrich this collection with higher level semantic concepts. Section 5 describes the results of the current implementation. Finally, section 6 presents conclusions and further work.

II. PREVIOUS WORK

Once artefacts are digitised using 3D acquisition technologies, the resulting 3D content is usually kept stored in a computer, hard drive or uploaded into an online repository. The latter option is usually the less popular option as 3D repositories are still at its infancy and existing repositories have mainly resulted from research projects, including the Digital Shape Workbench [1], the Princeton University repository [2] and the 3D-COFORM repository [3].

Whatever the mechanism for storage, 3D content is at risk of being lost if there is no meaningful information associated with it. Although this problem is common to other content, such as text documents or images; 3D content has inherently richer semantic information associated with its shape than other content types. By information we mean the collection of facts about an object within a given domain.

Artefacts from the cultural heritage domain are described in a way that depends on the professional (e.g. curator, art historian) providing that description. As with other fields, different views on the object might be of particular interest in

order to convey its most important characteristics. According to Hudson [4], artworks are typically described in terms of their basic components (e.g. colour, shape, value, texture, space, time and motion, and sound and smell), principles of design (e.g. balance, unity and variety, proportion and scale, and rhythm), medium (e.g. physical material used in the work), and style (e.g. a particular period style). It is important to note that only a few of these elements can be automatically extracted from a digitised 3D shape; although it is possible that others can be inferred.

Hence, semantic meaning of a cultural heritage artefact might be intrinsic or extrinsic to the shape itself. For instance, style is used as a descriptor to classify an artefact within a specific time period, place, art movement or school. As such, style is related to the visual appearance of the artefact and can relate an artefact to others in the same style. However, the required knowledge to determine the style of an artefact is usually stored in the head of experts who are trained to observe the shape of artefacts as well as ornament patterns and motifs used across history to decorate artefacts.

Solutions for understanding and interacting with the semantic-less 3D content rely on shape analysis methods, including segmentation, labelling, classification, matching, recognition and retrieval methods. Instead of making use of the original 3D content, shape analysis methods firstly compute an alternative characterisation of the 3D shape. This is done by extracting representative features and computing descriptors for these using shape segmentation techniques.

Shamir [5] and Lavouev [6] present surveys of existing shape segmentation techniques. One of these is the part-type segmentation techniques which aim to decompose the 3D shape morphologically. Existing solutions for semantic enrichment provide manual or semi-automatic mechanisms for understanding the semantic meaning of shapes ([7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17]). Most solutions rely on different shape segmentation approaches as well as labelling or manually connecting the shape (or part of it) to a semantic network with relevant information on the knowledge domain. Most solutions attempt to understand what a shape represents, rather than study the shape to extract other relevant information which might help for its classification.

Leslie et al. [18] describe research in automating the annotation of digitised paintings using an ontology of semantic information, such as artist and painting style, by analysing the painting's colour distribution and brushwork. To our knowledge, there is no equivalent research for 3D shapes, such as artworks. It is evident that the semantic enrichment of 3D content remains an active area of research, where different challenges need to be solved to fully support an automatic pipeline. These include modelling semantic information and knowledge related to the shape; automatically linking it to the 3D shape; and using standards to store and interoperate the resulting semantic network.

Of relevance to this work is the research of Buglio et al. [17] who propose a bottom up approach to characterise the features of a column based on the analysis of the low level geometric properties of a collection of instances. Our approach also looks at architectural elements of historic domestic interiors. However, the approach focus on studying their decoration

to extract semantic meaning of the 3D shape. Hence, the proposed automatic methods classify the 3D content according to artistic period and likely production methods.

The following section will describe essential background on the use of ornament to decorate domestic interior, in particular focusing on the Regency period in the United Kingdom.

III. ARCHITECTURAL ORNAMENT FOR THE DECORATION OF HISTORIC DOMESTIC INTERIORS

Meyer [19] defines the term decoration as the art of applying ornament to beautify objects. The style of decoration is usually determined by the aim and material of the object to be decorated and, secondly, by the ideas ruling at different periods and among different nations. Phillips and Bunce [20] trace patterns used in ornament from ancient and classical times through to the Gothic and Victorian periods, and culminating in high-tech computer-aided designs of today. Jones [21] presents a comprehensive history of ornament along different periods and nations from antiquity to the medieval and the Renaissance in Europe, India, China, Pacific islands and the Islamic world. In this work, Jones define style in architecture as the peculiar form that expression takes under the influence of climate and materials at command.

Furthermore, *pattern* used in ornament is defined as a design composed of one or more motifs, multiplied and arranged in an orderly sequence [20]. Meyer [19] supports this definition by stating that decoration is produced by arranging and joining dots and lines, or by combining and dividing geometrical figures, in accordance with the laws of rhythm, regularity, symmetry. Moreover, Liu et al. [22] describe the four distinct atomic transformations in 1D (frieze) and two-dimensional (2D) Euclidean space that can be used to create ornament by repeating the base motif: translation, rotation, reflection and glide-reflection.

Motif is defined as a unit with which the designer composes a pattern by repeating it at regular intervals over a surface [20]. Meyer [19] makes a further distinction between organic (e.g. natural foliage, animals, human figures) and inorganic (e.g. geometrical elements) motifs.

According to definitions above, ornament can be classified as follows:

- By their historical and cultural origin
- By the type of imagery used for the elements of the motifs
- By the organisation of the motifs that form the structure of the patterns

This research focuses in particular on ornament used to decorate interior of buildings during the Regency period and others trying to emulate this style. Regency Britain was a marvellous period for the visual arts. This period is known as the time in which George IV acted as Regent (starting in 1811), in place of George III who was seriously ill. In 1820, George IV was proclaimed king of Great Britain. However, the Regency period is not constrained by these political events. Experts can trace Regency style expressions from as early as 1780 until 1840, when the Victorian style starts to be identified. Regency

is also a unique style which was exported to the United States having a substantial influence on American design at the time of the Federal and Empire eras of architecture and decoration [23].

According to Parissen [23] the historical events of this era reflected on the choice of materials and processes to be used for the architectural detailing of the Regency home. During this period, plaster and composition plaster became a popular choice for decorating the interior of buildings and households. In addition, there is usually a distinction made between i) mouldings defined by a cross section; and ii) plaster mouldings defined by patterns of ornament. This distinction is made by the type of production method which is used to produce the ornament.



Fig. 1. Plaster cornice and ceiling rose at Regency style building

For this research we had access to the prestigious Jackson ornament collection provided by our partner the Regency Town House [24]. This collection comprises of architectural plaster and composition mouldings used for decorating wall and ceiling spaces. This included architectural elements such as coving, ceiling roses, corbels or panelling. Figure 1 shows an example of a plaster cornice and ceiling rose with a Regency style. The collection includes reverse cut and positive hardwood and soft wood blocks. It was assembled by the ornamental firm George Jackson and Sons through the 19th and 20th centuries.

The firm Jackson and Sons, founded in 1780 was key in revolutionising the way in which relief decoration was created. They introduced the use of composition plaster into England. Composition plaster differs from traditional plaster as it is produced by a mixture of ingredients, such as chalk, glue, linseed oil and resin [25]. The composition mouldings were formed by using wooden moulds which were carved with extraordinary delicacy and precision (as shown in figure 2). The use of wooden moulds meant that the plaster could be prefabricated as opposed to created on site.

The vocabulary of motifs and patterns of Regency plasterers was influenced by Neo-Classical motifs. The more important the room, the heavier and more profuse the moulded ornamentation was. Figure 3 illustrates some commonly used patterns, including:



Fig. 2. Example of wooden moulds for plaster and composite plaster mouldings from the Jackson architectural ornament collection.

- Anthemion and palmette moulding: pattern comprising alternating palmette and anthemion motifs. The term anthemion comes from the Greek term for *flower*. The palmette is a motif resembling a stylized erect leaf divided into lobes, in the form of a fan or palm leaf, often supported by spirals.
- Egg and dart moulding: pattern of egg-shaped motif alternating with dartlike motif.
- Bead and reel moulding: pattern with disks alternating singly or in pairs with oblong beads.
- Fret moulding: Patterns consisting of repeated, linear, geometrical shapes, usually angular, in a continuous band.

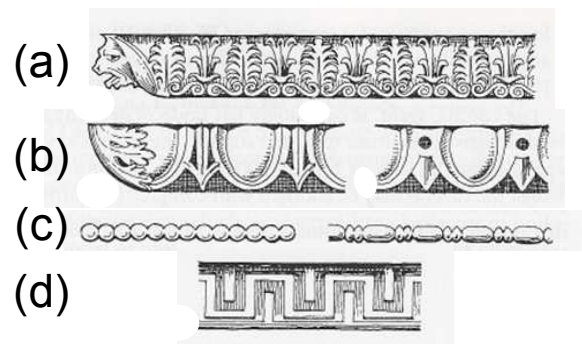


Fig. 3. Patterns commonly used in Regency style mouldings in household interiors. a) pattern with anthemion and palmette motif; b) egg and dart; c) bead and reel; and d) fret pattern [26]

The use of ornament declined after the 1920s following the Modernist Movement. This movement dictated the omission of any superfluous decorations on architectural elements; instead form following only functional requirements. However, towards the end of 1960s there was a resurgence of interest on the conservation and preservation of historical buildings. This interest has continued until today, in particular in areas where there is a large concentration of architecture with a particular historical style decorated with ornament. The seafront area of the city of Brighton and Hove, in the South East of the England, is an example of an area with a distinctive Regency style of buildings (see figure 2). Hence, the interest in the use of plaster mouldings to decorate architectural elements both in interior and exterior of buildings remains high. It should be noted that the production of plaster mouldings for these purposes has remained mainly an artisan activity

where methods developed by Jackson and Sons and other contemporaries are still in use today.

The Jackson collection is complemented by an existent database (?) with basic information such as.

IV. DESIGN OF ONTOLOGY TO DOCUMENT ARCHITECTURAL MOULDING COLLECTION

include data we have to describe the current mouldings (based in CIDOC-CRM and Getty AAT thesarus).

V. SHAPE ANALYSIS METHOD

Describing Ran's implemented method

VI. RESULTS AND TESTING

Testing on current scanned shapes

VII. CONCLUSIONS AND FURTHER WORK

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