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Web-based Exploration of Semantically Rich 3D Decorative Ornament

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Abstract

The aim of this research is to document and provide easy access and exploration to 3D decorative ornament, in order to support its preservation and reuse in future products. The research focuses on the Regency style of ornamentation used to decorate different type of objects such as furniture, and, for example, in architecture. The ambition of the project is to bring this decorative art into the 21st Century by conducting research using the latest 3D access technologies as well as applying additive manufacturing technologies to its reproduction. Therefore, this paper will contribute information about the development of an accessible, web based, digital repository with semantically rich 3D ornamental shapes. This repository has the potential to make the content available to a variety of users, including art historians and designers.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1. Introduction

Meyer [Mey96] 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, by the ideas ruling at different periods and among different nations. Hence, decorative ornament is commonly perceived as a historical characteristic of heritage artefacts. In architecture, the post-1950s period witnessed a surge of interest in the conservation and preservation of ornamental shapes in buildings. Similarly, other industries are incorporating decorative ornament in their contemporary designs in order to transmit novel affects and sensations [MK16].

Nevertheless, the techniques for documenting, designing and producing decorative ornament, for instance in architecture and furniture design, have remained an artisan and manual activity. The invention of the printing press in the 15^{th} century brought novel ways of visualising decorative ornament in printed works which supported crafters in refabricating the historical forms while improving their manufacturing methods. By the 16^{th} century decorative ornament was increasingly documented on paper or printed by engravers and woodcutters making patterns for mass distribution.

Relevant sources are the work of Owen Jones, an English architect, and Franz Sales Meyer, a German professor of ornament, who are two of the most influential ornamental theorists. In 1856, Jones published his seminal design sourcebook, 'The Grammar of Ornament' [Jon86], containing over 100 coloured plates with patterns from around the world. In 1896, Meyer published the largest single-volume collection of classical art motifs ever compiled, 'A Handbook of Ornament' [Mey96], with over three thousand illustrations. Both of these publications have served as a source of inspiration to designers, by presenting geometrical elements and motifs as well as identifying the production rules of decorative ornament.

This research aims to transform this type of documentation by using the latest 3D technologies to record, document and provide easy access to the visual material. The main contribution of this paper extends the contribution described in [RS15] by creating a web based portal to a semantically enriched digital repository with 3D ornamental shapes.

The paper is organised as follows. Section 2 reviews the related work; while section 3 describes the requirements for the system and the software architecture and web environment which addresses these requirements. Conclusions and further work are described in Section 4.

2. Related Work

Decorative ornament is mainly a three-dimensional techniques as it often involves production techniques such as sculptural relief. The ornament aims to cast shadows on the object in order to create stylish and decorative effects. Currently, there are very few accessible databases that provide easy and quick access to this type of historical documentation.

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Unfortunately, most decorative ornaments are only digitised as 2D images in museums' websites and archives [†] or books. Even when the content is digitised in 2D and accessible over the web, access to the right content is not always easy. The problem is that the user needs to find the particular ornamental shape of interest. Although the ornamental shapes usually are classified according to the motifs they display, e.g. 'egg and dart', 'fret', 'acanthus', there might be hundreds of variations on each of these types. For instance, an 'egg and dart' pattern might display shells, flowers or acanthus as the 'egg' element of the pattern. It is also possible to find combinations of two patterns in the same ornament.

Encouraged by the Semantic Web initiative, the development of web based portals for the heritage sector has gained momentum. Heritage portals, such as Europeana [‡], allow users to access multi modal content along with metadata.

In addition, other research has produced web based access to repositories focused on 3D content, including the Digital Shape Workbench [VIS] and the 3D-COFORM repository [DTT*]. The ability to associate semantic metadata to 3D content in these repositories in an automatic or semi-automatic manner is a relevant research problem [LBS*11, RTG*12, ABV11, RS15]. The current research takes advantage of these approaches.

The main contribution of this research is a web based portal which enables easy access to 3D shapes in a repository. The access is supported by an architecture based on [DTT*] which enables the user to browse the content by exploring similar items. The similarity measures for 3D shapes have been described in [RS15].

The following chapters will explain the development of the web based portal of 3D decorative ornament.

3. System Architecture

The resulting web based portal can be accessed at `http://www.ornament3d.org/3ddataset`. Its requirements included the need for a cross-platform interface to a repository of 3D decorative ornament [RS15]. An important requirement was the need to support the exploration of the 3D shapes by automatically suggesting similar decorative ornaments.

The system was designed with a three tier architecture, as shown in Figure 1, with the presentation tier being a web based user interface. The following subsections will describe the development of the database storage and logical data amalgamation layers of the system.

3.1. Database Storage Layer

The database storage layer is based on the 3D-COFORM infrastructure described in [DTT*]. This layer includes an Object Repository (OR), a Metadata Repository (MR) and a shape similarity index database. We define an OR as a large store of objects with properties that can be queried. Several Object Repositories can be distributed in different locations in order to support the distribution of data amongst heritage organisations. The Metadata Repository is a centralised RDF triple store with the semantic metadata, including legacy and provenance metadata based on the CIDOC-CRM [DT11] and the CIDOC-CRM dig [DT11] extensions. Each 3D shape has users' permissions so the models are protected against unauthorised download. The MR contains a querying service, creating a bridge between the user interface and the repository. Furthermore, the shape similarity index database keeps an up-to-date ordered scoring system representing the similarities between the 3D shapes.

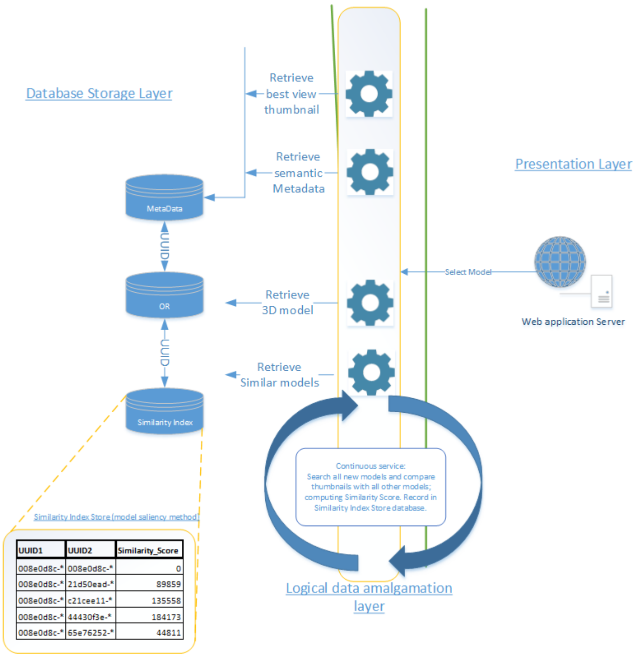

Figure 1: *System architecture of web based application to visualise 3D content from repository.*

A script was developed using the repository API to automatically extract the 3D shapes' file attributes and ingest them into the repository. This API includes the ability to ingest and update the 3D shape, their metadata as well as the file attributes such as number of vertices and file size. The 3D shapes were automatically simplified (decreasing their polygon count, whilst maintaining their structure) using MeshLab Server [Mes16] to make them suitable for web viewing. Each 3D shape original size ranged from approximately 100MB to over 1GB in size. After simplification the 3D shapes were approximately 1.5MB.

The architecture ensures that the 3D models are linked to their relevant metadata, such as legacy data and provenance. For this, the 3D models' Universally Unique Identifier (UUID) provide a unified identifier amongst all layers and services. This UUID is generated at the time of ingestion of the 3D content.

The script also generates a best view 2D thumbnail for the 3D

[†] http://collections.vam.ac.uk/, last accessed July 2016
http://www.metmuseum.org/collection/the-collection-online, last accessed July 2016
http://vads.ac.uk, last accessed July 2016
[‡] http://www.europeana.eu, last accessed July 2016

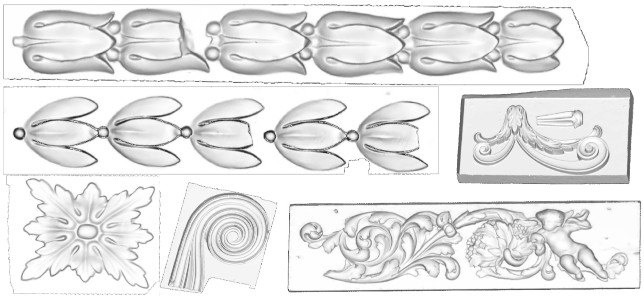

Figure 2: *Examples of thumbnails generated by the system to be displayed in the web interface.*

shape which is ingested alongside its corresponding 3D shape. The 2D thumbnail of each 3D shape is generated by using the method reported in [RS15]. The method first detects the saliency of a 3D shape which measures its regional importance. Then the saliency information is combined with the visibility measure to find the best 2D view of the 3D shape which maximises both the saliency and visibility when compared to other views. Thereafter, the best 2D view is saved as a JPG to serve as a thumbnail of the 3D shape as shown in Figure 2.

3.2. Logical Data Amalgamation Layer

The purpose of this layer is to have services which process all queries of the portal interface. These queries include i) retrieving the 3D shapes from the repository infrastructure; ii) retreiving the 3D shapes' metadata (including automatically generated thumbnails); iii) amalgamating the retrieved data to be presented via the web interface; and iv) finding 3D shapes similar to a given 3D shape in order to facilitate finding related content.

PHP, JavaScript and WebGL technologies were used to build the web based portal. The interface was built as a module of the Drupal Content Management System. Drupal [dru]. The 3D Heritage Online Presenter (3DHOP) [PCD*15] was used as the 3D model presentation layer for rendering the 3D shapes. 3DHOP is a framework for the creation of advanced web-based visual presentations of high-resolution 3D content. It uses the WebGL (Web Graphics Library) [Gro] API for rendering the 3D shapes on the browser.

Furthermore, the Similarity Indexing service runs continuously. This service is implemented using C++. Its purpose is to locate all new 3D shapes in the repository. Since the thumbnails contain rich visual information, the Similarity Indexing service uses them as shape descriptors representing the original 3D shape. Hence, a similarity score is computed by comparing the best 2D view of a 3D shape newly added into the repository to that of each existent 3D shape in the repository. The comparison which outputs a dissimilarity score is implemented based on the SIFT flow algorithm [CP84]. The results of the comparison are stored in the Similarity Index database by using the pair of 3D models' UUIDs. This database provides a real time SQL query service to present to the user similar 3D shapes to a given 3D shape.

The Drupal module communicates with the repository using user authentication credentials which are entered into the module configuration page. After successful initial authentication, an authentication token received from the repository is used thereafter by the Drupal module to query the repository by using the 3D shapes' UUID to retrieve relevant information.

3.3. Presentation Layer

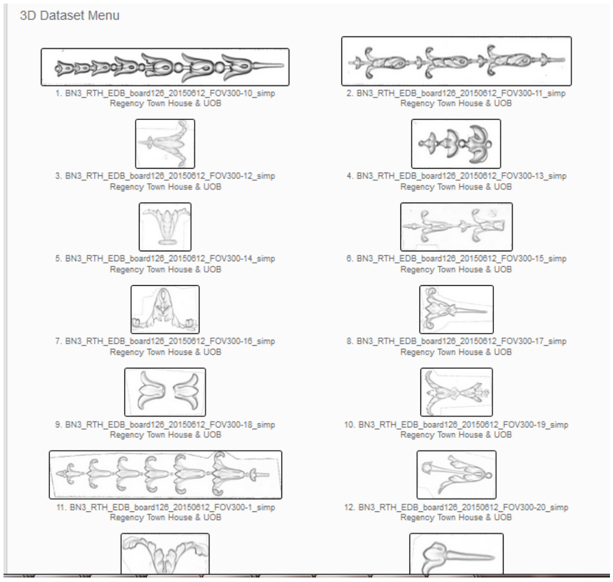

Figure 3: *Menu with 3D decorative ornament ordered by similarity*

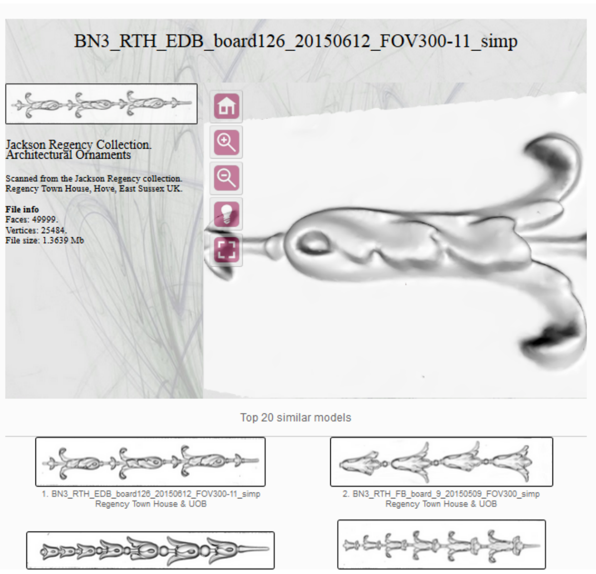

Figure 4: *3D Visualisation of decorative ornament along with basic metadata*

The main menu in the portal is shown in Figure 3. This menu displays a list of all the 3D shapes available in the repository based on the similarity index to the first model included in the page.

Once the user finds a 3D shape of interest, the user can select the 3D shape's thumbnail and the 3D model is then displayed in a separate web page (see Figure 4). The 3D shape is displayed alongside some basic metadata including provenance and file information. We are currently in the process of making available legacy metadata of the 3D shapes.

Furthermore, the page also contains a list of the 20 most similar shapes in the collection as shown in Figure 5. These top 20 shapes are extracted automatically from the Similarity Index database.

Each 3D shape in the PLY format can be downloaded by clicking on the 'Download Model' button. In this research, we have released all 3D shapes under the Creative Commons Attribution-NonCommercial 3.0 Unported license.

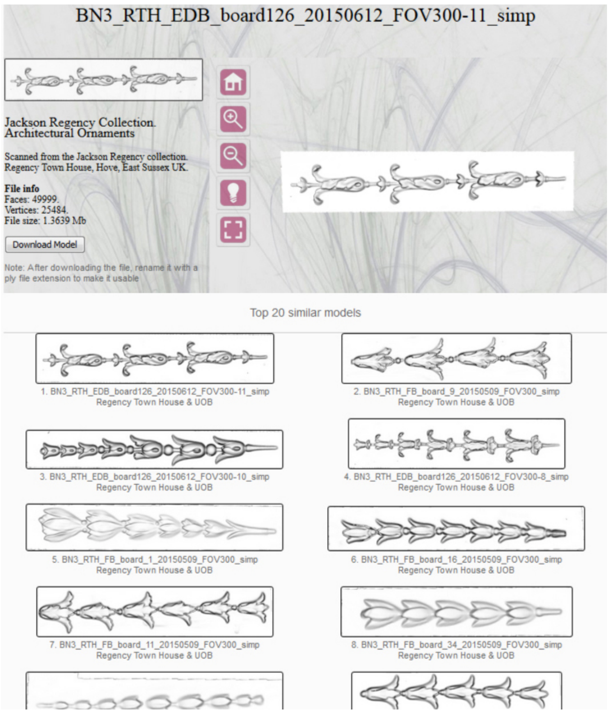

Figure 5: *A screenshot of the visualised 3D model and its most similar models ordered based on the computed similarity*

4. Conclusion and Further Work

This paper has presented a web based portal based on a repository infrastructure for documenting and providing easy access to 3D decorative ornament. The repository stores and manages the 3D shapes and semantic metadata including legacy as well as the provenance metadata of the digitisation process. The resulting web based portal provides a suitable mechanism for users to browse the 3D shapes and find other relevant content based on their similarity.

One of the potential uses for 3D decorative ornament is the preservation and restoration of heritage buildings. This has been demonstrated in [RSFS16] where Digital Fabrication technologies, including graphic algorithms and additive manufacturing technologies, are used to enable the design and fabrication of customisable ornamental mouldings. Other envisaged uses include supporting the design and fabrication of other objects including furniture, jewellery and other everyday objects.

Further work of this research includes enriching the dataset with more legacy metadata, testing the system and improving the navigation by learning from the user interaction to provide better suggestions.

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