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A 3D Pottery Database for Benchmarking Content Based Retrieval Mechanisms

A. Koutsoudis[1], G. Pavlidis[2], F. Arnaoutoglou[2], D. Tsiafakis[2], C. Chamzas[1]

[1]Department of Electrical and Computer Engineering, Democritus University of Thrace, Xanthi, Greece
[2]Cultural and Educational Technology Institute, Research Centre “Athena”, Xanthi, Greece

Abstract

The benchmarking of 3D content base retrieval mechanisms is usually performed on test bed datasets composed by 3D models. These usually cover several categories of objects such as ships, airplanes, animals, furniture, etc. In this paper, we attempted the generation of a ground truth database of 3D models that exhibit morphological characteristics similar to those found in ancient Greek pottery. We developed a software tool to model 3D vessels based on bitmap profile images, enhanced with the function to semi-automatically generate random 3D vessels accompanied by metadata. The metadata follow a proposed MPEG-7 compatible schema which covers the basic information required by an archaeologist to describe a vessel and the MPEG-7 3D Shape Spectrum Descriptor for allowing possible performance comparisons of novel descriptors against a standard.

Categories and Subject Descriptors: H.3.7 [**Digital Libraries**]: Collection; I.3.4 [**Graphics Utilities**]: Graphics editors

1. Introduction

Multimedia databases with 3D digitised cultural heritage content have become popular in recent years [GCJ*07] [PTK*06] [PTT*02] [SJC04] [TKP*02] [TPK*02]. Nowadays, museums and cultural institutes comprehend the importance of having their collections digitally archived. The digitisation process, which is still time consuming, has become cheaper as 3D scanning systems continuously evolve and at the same time the processing power of modern graphics cards is rapidly increased, allowing the efficient visualisation of complex 3D models. In fact, 3D scanning has already been applied in cultural heritage with great success [ABC04] [MKN*07] [KS*07] [BM02] [LPC*00] [SSF*06] [PTT*06]. Nevertheless, most of the data acquired have not been made available to the public for several reasons. The digital collection might contain unpublished findings which are not allowed to be made available in any format or protected by an online access control system or simply because no museum can afford a decrease in the number of visitors.

On the other hand, online 3D digital repositories of domains such as CAD-parts or visualisation models have gained more popularity and thus the development of content based retrieval mechanisms has become a very active research area [BKS*07][KYS*07][LSD*06]. This is due to that fact that content based retrieval mechanisms exploit the content richness provided by 3D models and although text based annotation is useful, only the former can discover geometric relationships. Although feature extraction is considered as the centre of content-based information retrieval [ZC02], present studies are focused apart from automating the feature extraction process to research areas such as high dimensional indexing, systems capable of active learning, ontology based searching and relevance feedback.

With this work, we present a first version of a synthetic 3D model repository that exhibit morphological characteristics similar to those found in certain ancient Greek pottery shape categories. The latter is a domain which shows particular requirements and restrictions that need to be considered in an efficient content based retrieval system. The 3D models have been dynamically produced using a random 3D vessel generator software tool. Additionally, the 3D models are accompanied by dynamically generated metadata that follow a proposed MPEG-7 [MSS02][MAR04] compatible schema. The paper is organised as follows: In section two we summarise some of the most significant datasets available in the web and discuss the selected pottery shapes included in our dataset. In section three, we outline the main points of the software application and its functionalities. Then, we continue by describing the proposed `ThreeDVDS` schema and the resulted dataset. Finally, we conclude in section four by giving some thoughts on the future development of the software and the evolution of the database.

2. Online 3D Model Repositories and Cultural Heritage

The number of 3D repositories on the web is growing dramatically as the demand for 3D models continuously increases. One could argue that 3D model retrieval over the Internet is one of the most important applications. Many recent research works have presented web based 3D search engines which allow *query-by-example* [VRA04] or *sketch-based-queries* [MCF02] since each type of objects is differently best described. For the evaluation of content-based retrieval mechanisms, researchers usually perform query tests on specific benchmarking datasets composed by 3D models from multiple or single domains. These domains usually involve 3D models for visualisation purposes such as cars, airplanes, plants, animals, insects, mechanical parts (CAD), etc. On the other hand, the number of cultural domain 3D repositories which are publicly available is very limited. Furthermore, the data types being used in most cases are polygonal meshes and volumetric object repositories are less common. *Texture mapped* models are less common than *vertex-coloured* models. The majority nevertheless, is without any textural or colour information. The table below summarises some of the freely available online 3D model repositories.

Repository Name	Model Domain	Total number of models	Data Types		URL
			Mesh	Voxels	
Princeton Shape Benchmark	Various	1,814	✓		http://shape.cs.princeton.edu/benchmark
The 3D Archive	Various	582	✓		http://www.the3darchive.com
Inria Gamma Group	Various	82,000	✓		http://www-c.inria.fr/gamma
McGill 3D Shape Benchmark	Various	505	✓	✓	http://www.cim.mcgill.ca/~shape/benchMark
NTU 3D Database	Various	10,911	✓		http://3d.csie.ntu.edu.tw/~dynamic/database/index.html
Signal Analysis and Machine Perception Lab.	Various	230	✓		http://sampl.ece.ohio-state.edu/data/3DDB/Models/index.htm
UK VR – SIG 3D Archive	Various	435	✓		http://www.martinreddy.net/ukvrsig
RC CAD Collection	Airplanes	700	✓		http://www.rccad.com/Gallery.htm
Avatara	Various	152	✓		http://www.avatara.com/avatars
Design Repository	Various	663	✓		http://www.designrepository.org
Shape Lab Database	Engineering Shapes	478	✓		http://shapelab.ecn.purdue.edu/Benchmark.aspx
Utrecht University 3D Shape Search Engine Database	Various	684	✓		http://www.cs.uu.nl/centers/give/multimedia/3Drecog
ITI 3D Models Database	Various	603	✓		http://3d-search.iti.gr/3DSearch
Télécom Paris Image-based Digitized 3D Models Archive	Various Digitised Cultural artefacts	68	✓		http://www.tsi.enst.fr/3dmodels
3DVIA Models Collection	Various	1559	✓		http://www.3dvia.com/3dmodels

Table 1: *List of online publicly available 3D model repositories*

The cultural heritage domain is represented by datasets such as the *Inria Gamma Group 3D Mesh Research Database*, the *Télécom Paris Image-based Digitized 3D Models Archive* and the *3DVIA Models Collection*. The proposed 3D pottery dataset, at its present form, aims towards a first attempt of enhancing the cultural heritage domain.

2.1. Selected Pottery Shape Categories

Although not immense, the number of shapes found in ancient Greek pottery is fairly large. Eligible for the project was a great range of shapes found commonly in ancient Greek pottery. An initial selection was made by using as key criteria the potentials offered until now by the software. The chosen shapes are: *Lebes/dinos* [BRO81], *psykter* [DRO75], and *phiale* [LUS39] which are related to one of the most characteristic activities of the ancient Greek life, the *symposion* (the male–only drinking gathering that followed dinner). Lebes/dinos was used for mixing wine and water, psykter was used for cooling wine while phiale was the drinking cup. Furthermore, *Kalathos* [MP86] [ST70] and *plemochoe/exaleiptron* [SCH64] are related to the daily life and female activities. Kalathos was a basket used to assist women in spinning but it was also used for cult purposes. As a perfume vase plemochoe/exaleiptron was close related with another aspect of the female world. *Alabastron* [ANG36][MAU85] was used by women as a perfume vase in domestic context but also for offerings at tombs. Finally, *Amphora* [KAN75] is a two-handled ceramic vessel with narrow neck used for storage.

3. A Random 3D Vessel Modeller

According to [STA99], a vessel can be projected to its planar outline. More specifically, 3D pots are described by revolving their profile curve in a certain distance around a vertical axis (This is a well known 3D modelling technique usually found into literature as *revolve* or *lathe*). Furthermore, the pot handles are generated using the *extrude-along-path* 3D modelling technique. The vessel's profile curve relies on parametric curves, also known as Hermite splines [FvDF*00][SPA99][MH02]. The application allows the rapid generation of similar models. The randomization of the geometry is controlled through a number of parameters which are set by the user. Once these parameters are set the user defines the total number of objects to be produced and then the application automatically generates the 3D models (VRML 2.0 format) and the accompanying metadata. At present, there are three randomisation modes:

- *Point Controlled Randomization* (PCR) mode: The coordinates of any control point of the profile curve are randomized within given limits (bounding boxes) which are defined by the user. Thus, the coordinates that a control point can acquire are limited in a rectangular area.
- *Leader-Followers Randomization* (LFR) mode: A control point plays the role of the *leader* and it is randomized again within the limits of a bounding box defined by the user. Additionally, a subset of the control points are characterised as *followers*. In each randomization phase, the system computes the spatial difference between the old and the new coordinates of the leader. Then, it applies this spatial difference to the coordinates of the followers. Thus, it allows a profile randomization

with the advantage of maintaining unaffected specific parts of the vessel's profile. This mode is useful in cases where there is a need to avoid deformations in specific parts of a profile. Such parts might be the rim, the neck or even the base of a vessel which might be required to remain fixed.

- *Height-Width Randomization* (HWR) mode: The final 3D model is randomly scaled according to maximum and minimum scaling limits defined by the user.

4. 3D Pottery Metadata

The proposed MPEG-7 compatible schema, named `ThreeDVDS`, can be adopted or extended by any MPEG-7 compatible database which contains 3D vessels. The schema is applicable to both computer generated and 3D digitised vessels. It is composed by a basic set of elements that can accompany a vessel and give adequate information about it. More specifically, the `attribution` element is referred to the artist or workshop to which the vase is attributed to, the `workshop` element is used to describe the name of the artist's or the city's workshop. The type of painting technique can be defined in the `technique` element while the `comments` element is used for any additional textual information that might be required. `Vessel-profile` contains the filename of the pot profile bitmap image and the `ThreeDVModel` is referred to the filename of the 3D model. `ThreeDVTriangles` and `ThreeDVVertices` are 3D model related elements. `ThreeDVHeight` and `ThreeDVWidth` hold the height and width of the pot. A filename of a thumbnail image which contains a render of the 3D model is hold in the `ThreeDVThumb` element. In the case of the vessel modeller this thumbnail is automatically generated. The filename of a vector graphics file corresponding to the pot profile is held in the `QPProfile`. The `date` element can be referred either to the date the model was build or scanned. Finally, `ThreeDVShapeDis` holds the MPEG-7 3D Shape Descriptor [ZP01] histogram (20 bins) of the model. This part of the metadata can be used for comparing the performance of a new descriptor against the MPEG-7 standard by using every model of the dataset as a *query object* and producing the *precision vs. recall* measure diagrams. The schema can be found at http://www.ipet.gr/~akoutsou/qp.

5. The 3D Pottery Dataset

A dataset was generated on an IBM compatible personal computer with an AMD Athlon 64 X2 4200+ processor and 2GB of RAM. The average model generation time was 11.66 seconds. For each of the shape categories described in section 2.1 a total of 50 models has been generated. The dataset is composed by a total of 350 models randomly generated and additional 60 models of various vessel shapes that were manually modelled using the application. At present, the models do not carry any texture information and the intra-class variability is limited as each model was derived from an initial profile deformation. Furthermore, in order to simulate incomplete pots with eventual defects and errors that are usually found in 3D scanned models (mesh noise, occluded areas, discontinuities, etc) we batched processed the produced models with a commercial 3D scanner data processing software (Geomagic Studio 9). Thus, a second dataset, based on the first one, was generated where the models carry defects such as geometry discontinuities and occlusions. Both datasets are available for downloading from the following URL: http://www.ipet.gr/~akoutsou/qp.

6. Conclusions

The availability of 3D data derived from the cultural heritage domain is still very limited on the web. Nevertheless, there is a great need to develop content based retrieval and classification systems for pottery as of all kinds of artefacts which may play a significant role in human history and life, ceramics are surely of the most important. Testbed 3D datasets is a prerequisite for the development of domain-specific descriptors. In this paper, we discussed the need of producing 3D datasets that exploit morphological characteristics similar to those found in the cultural heritage domain. We attempted a first version of such a repository which includes a limited set of 3D models that were semi-automatically generated by a software application. A second dataset, based on the first one, was also produced with the use of commercial 3D data processing software in order for the models to carry eventual defects and errors. In the near future, the dataset will be enriched with additional synthetic pots and royalty free 3D scanned vessels.

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