

Automated Creation of Unique Editable Textures for Three-Dimensional Models of Archaeological Artefacts

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Abstract. The article is devoted to the description of the algorithm for obtaining a complete model from a colourless model of a stone and its prototype image with a material that allows you to manually make changes for greater detalization. Since it is often necessary to make some manual changes in the tasks of modelling archaeological objects, which necessarily requires special skills in working with complex software, as well as considerable time costs, the task was to implement an algorithm that facilitates this process. First, using an image of the object, PBR maps are created. After that, the UV map of the object is formed, and at the end, a unique PBR texture of the object is created. The algorithm was tested on a number of colourless models of stones and various images. At the output, we get an object wrapped in a texture obtained from the original image. Also, an extension for professional free software was created, allowing to make any additional changes in its texture if needed and get the desired result for the minimum number of user actions.

Keywords: Modelling · Archaeology · Photogrammetry · Object reconstruction

1 Introduction

One of the most important tasks of 3D-modelling is the creation of three-dimensional models of artefacts, taking into account their size, materials and shape [16]. In addition to single items, an actual task is the reconstruction of monuments and buildings [3]. In this process, high accuracy is absolutely necessary to make these objects look natural. This way we can easily ensure access to cultural heritage objects, including those carefully protected, to a wide range of users [13,14]. Creating such models shows us to solve two main problems of preserving unique artefacts:

– interaction with an electronic object does not damage it, while the original object can deteriorate even from light and climatic conditions of local exposure;

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– scientists from all around the world can conduct their research without direct contact with the artifact [2,4,12].

Some other opportunities offered by digital three-dimensional copies can be noted such as:

– demonstration of elements of scientific collections with the possibility of examining objects from all sides [19];
– visualization of artefacts in context of reconstruction of the historical scene [11,17];
– placement of an unlimited number of items in the limited space of the museum;
– the possibility of forming various expositions and stands, modelling and animation of events;
– making hard copies of any museum objects and their distribution, including in the form of souvenirs [1].

As a result of archaeological research, an array of information and documentation about the state of cultural and historical monuments is formed. To carry out reconstruction and research of objects in the context of archaeology, tools of automated modelling are necessary [7]. However, the data which you can work with is often very limited, and the process itself is very laborious and time-consuming. Some developments in this field are reconstructing:

– stones from pairs of sketches;
– walls from recreated stones with user's instructions [8];
– surfaces from video taken with a camera from above;
– continuous textures from pictures [9].

Modern technologies allow us to recreate the texture of the image, but it is often necessary to make any changes manually. Therefore, special skills to work with complex software are necessary. In this work, we set a goal to facilitate the task of 3D-modelling of archaeological finds and provide artists with the opportunity to influence the final result of the textures of objects obtained earlier in an automated way.

2 Problem Definition

Let us consider the situation when we have a prepared colourless model of a stone and its real image. The problem is to solve the problem of obtaining a 3D-model of a stone, visually as close as possible to its prototype. In addition to form, it becomes particularly important to solve the problem of obtaining realistic Physically-Based Rendering (PBR) textures [18] in which the artist could make changes.



Fig. 1. Input image

3 Solution Method

For input, the algorithm receives a colourless model of the object and one two-dimensional image of its prototype - a photo or a drawing (Fig. 1).

The algorithm can be divided into four steps:

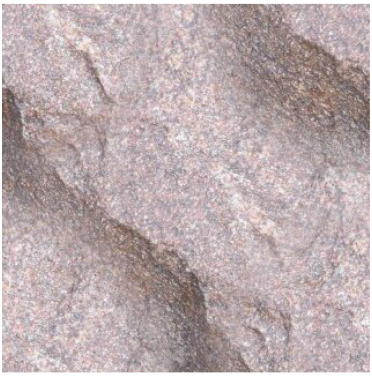
I. Creating a scalable PBR material from the image.
II. Forming a UV map of an object sweep to represent it on a surface.
III. Making a PBR texture specific to the current object.
IV. Exporting the resulting object to Unity.

The first stage is performed with Python 'scikit-image' library using the 'bitmap2material' algorithm. At the output we obtain the following images (Fig. 2):

Now we can proceed to the procedure of creating a UV map of an object sweep. We will execute the algorithm in Blender 3D-editor [5,6,15], one of the most popular, rapidly developing software for modelling nowadays. To begin with, we need to load the object and change its size in order to display it correctly in the editor. After that, we can begin the process of creating a UV-scan.

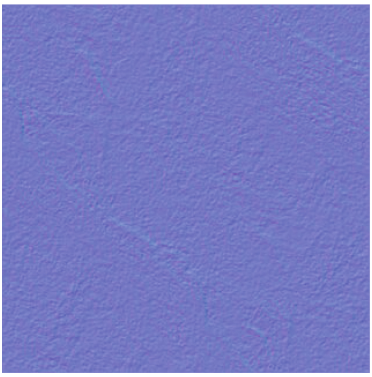
The following method allows us to create a 2D image from a 3D mesh that almost completely retains crucial characteristics of the object, such as shape, size and connectivity [10]:

1. Cluster faces of the object into groups using their normal vectors as basis. It should be noted that we do not consider how these faces are connected.
2. Compute average normal vector for each group. After that, derive the orthogonal projection to convert 3D faces into 2D plane. Weighting coefficients proportional to their sizes are used to average the normal vectors. Therefore,

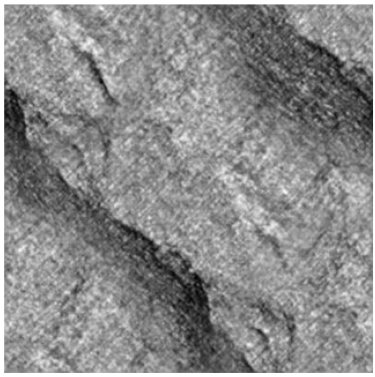


(a) Diffuse map

(b) Occlusion map



(c) Normal map



(d) Bump map

Fig. 2. Generated PBR maps

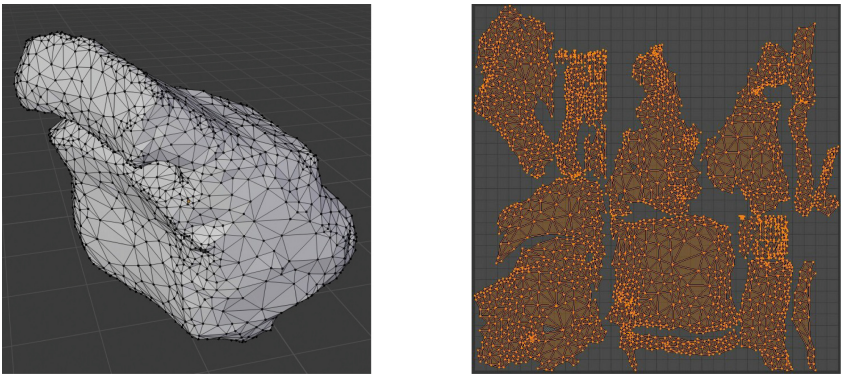
vectors of larger faces are prioritized. This way we can transform polygons from 3D to 2D and mostly preserve their size and shape.

3. Merge every cluster's neighbouring member faces to created 2D islands.
4. Place generated islands to a rectangular area. It should be done as compactly as possible in order to obtain a correct UV unwrapping of the object. In this case 'UV' means two-dimensional coordinate system.

Figure 3 illustrates the result of UV unwrapping of imported object using Blender smart UV project. Here "Unwrapping" means transformation from a 3D mesh surface to a 2D rectangular map. "UV" is referred to as texture coordinates of the surface texture.

The third stage - the creation of the material. It can be divided into several steps:

1. Create material for the object;



(a) Marked object (b) UV map

Fig. 3. 2D unwrapping

2. Enable use of graphic schemes (nodes);
3. Create a texture map;
4. Load the generated maps and correctly connect them in the diagram (Fig. 4). In this stage, we will need already generated maps obtained in phase I.

And the last step - exporting the model. Now that the object is ready, it is time to transfer it into some other 3D renderer (Fig. 5). If we do this, we will be able to make our model look even more natural using advanced functions of other applications. In our case, we chose a cross-platform real-time engine Unity because it has useful features that can do much more complicated manipulations with models.

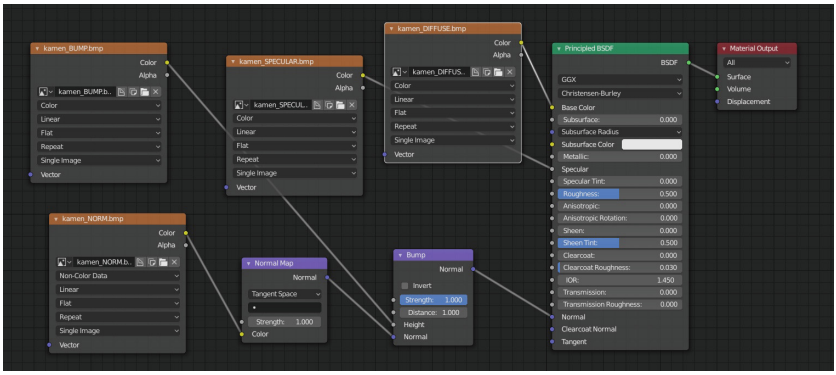


Fig. 4. Node graph

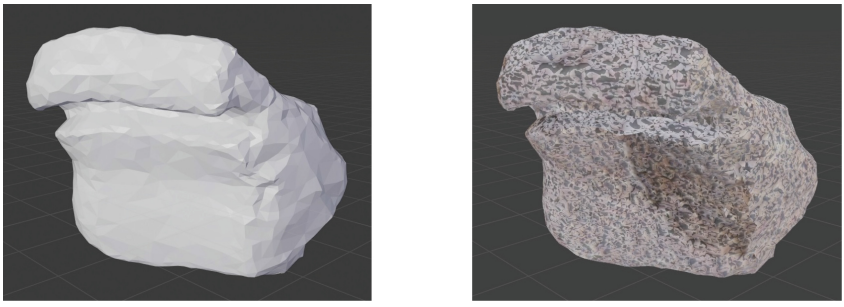


(a) Clean object (b) Object with texture

Fig. 5. Model exported to Unity 3D

4 Experiments

The algorithm was tested on a number of colourless models of stones and various images (Figs. 6, 7, 8 and 9). As a result, we get an object wrapped in a texture obtained from the original image. In this case, it is possible to make any artistic changes in this texture if needed.

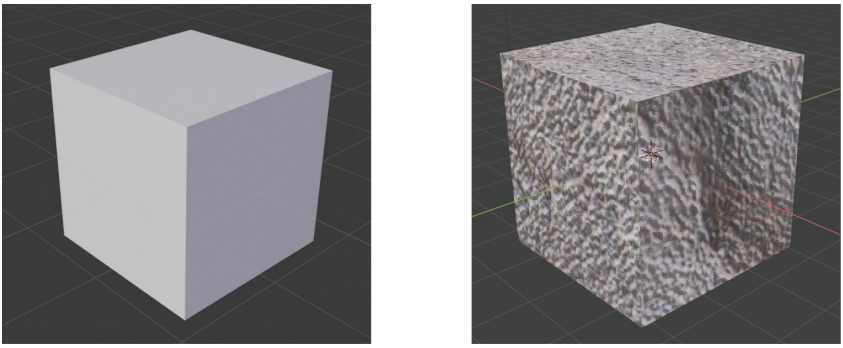


(a) Clean object (b) Object with texture

Fig. 6. Stone

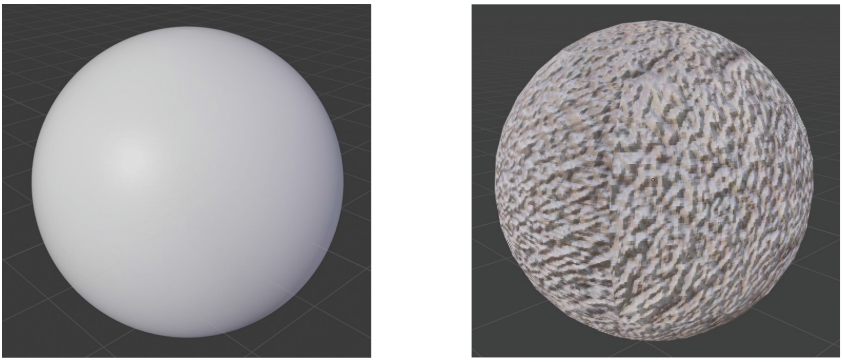
The execution time of the algorithm for different models:

1. Actual stone model: 0.3 s.
2. Standard Blender cube: 0.1 s.
3. Standard Blender sphere: 0.1 s.
4. Subdivisioned Blender sphere: 3.1 s.
5. Bunny model: 1.3 s.



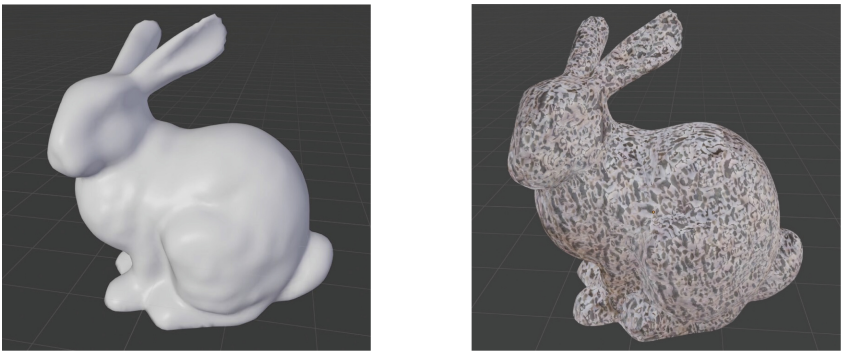
(a) Clean object (b) Object with texture

Fig. 7. Cube



(a) Clean object (b) Object with texture

Fig. 8. Sphere



(a) Clean object (b) Object with texture

Fig. 9. Bunny

5 Conclusion

An algorithm was presented that allows obtaining a model with material from a colourless model of a stone and its prototype image, which allows manual changes to be made for detail. An extension has been created for professional software Blender that allows you to get the desired result for the minimum number of user actions. The implementation of the algorithm showed good results in terms of execution time and the quality of the object received at the output. In the future, it is planned to integrate the program into the web-service format and use tools for automatic texture styling.

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