3D Transformation of 2D Captured Museum Objects at Risk

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Abstract. This paper presents a methodology for 2D to 3D object transformation, based on 2D captured museum assets (such as old photos, scans, or other 2D digitized content) for items with limited access due to their age, value or fragile nature. The technology simplifies 3D object generation in order to reduce cost of hardware or personnel for 3D production. It is applicable for improved display of valuable artefacts in 3D web-based virtual museums, galleries, educational games, *etc*.

Keywords: 2D-3D Transformation · 3D Design · 3D Virtualization · Museum Objects in Risk

1 Introduction

Digital technologies are introducing new solutions for museums, galleries and libraries and their new presentation in virtual space. Alluring solutions are offered by 3D technologies, but they come with challenges related to 3D design for content tinkering and making.

Technologies like 3D scanning and photogrammetry are usually used to create a 3D visualization. But those technologies require a large number of resources (specialized equipment, competencies, skills, time, *etc*.) and sometimes we cannot implement them due to various constraints or circumstances related to physical access to the target objects. This is usually the case for the most valuable museum items with limited access due to their bad condition (due to their age or fragile state), and risk of damage or destruction of the item, which makes them not suitable for displaying or makes the actual display difficult. Besides the artefacts, the museums store photos of valuable artefacts that are irretrievably lost for which solutions for 3D revival would be of most importance.

This paper presents a methodology for 2D to 3D object transformation, based on 2D captured museum assets (such as old photos, scans, or other 2D digitized content) for artefacts with limited access. The methodology offers a solution for simplifying 3D object generation including the usage of AI tools, reducing the need for expensive

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hardware and highly qualified personnel for 3D production, but applicable for improved display of valuable artefacts in 3D web-based virtual museums, galleries, educational games, *etc.*

The paper also offers an applicable framework for enhanced existing digital competencies and skills for 3D modelling (tinkering and making). Experiments have been realized with medals from Serbian history and in particular the war between Serbia and Turkey in 1912 and the suppression of the Timočka Rebellion in 1883. They were awarded to members of the Royal Serbian Army for proven service to the king and the fatherland or for exceptionally excellent and zealous service during peace, emergency or war.

2 Approach

2.1 Methodology for 2D to 3D Object Transformation

The presented methodology aims to show the basic steps for the creation of a simplified and web-optimized 3D object based on a limited number of 2D images of the corresponding object. It is suitable for objects having relatively standard geometry like coins, medals, vases, *etc.* Unlike other techniques like 3D scanning and photogrammetry the proposed one targets to create a low polygon object at the very beginning of the process, making it render-friendly for older or cheaper devices (PCs, mobile phones, tablets, SMART TVs, *etc.* devices with average graphic cards).

The process starts with just an image (Fig. 1) and the first step is to trace and vectorize the contour of the object for which we use Inkscape open-source vector graphics software [1].

The next step is to import the vectorized contour in a 3D modelling software (we use Blender [2]) and make a 3D mesh from the 2D vector graphic (Fig. 2) - for medals and coins, a solidify modifier is used (surface extrusion), for cylindrical objects (like vases) a lattice modifier can be used.

After the geometry of the objects is created, we need to define its materials and colors. Colors are usually defined using diffuse maps. A diffuse map is a standard bitmap image. The original 2D image of the object can be used as a diffuse map. There should be a relation between the original image and the created 3D geometry. This relation is called UV map. UV maps define how every polygon of the 3D geometry is positioned at the diffuse bitmap (Fig. 3).

One of the most important parts of 3D modelling (especially when we talk about presenting an object's small details) is normal mapping. The normal mapping defines the orientation of a surface toward a light source. Usually, a normal map is a matrix of RGB pixels mapped to the object according to the UV map. Every RGB pixel defines an XYZ vector (RGB colors are mapped as XYZ vectors). The normal vector is perpendicular to every part of the object's surface, so the light reflection changes accordingly and the 3D effect is achieved on a flat surface. This technique is very common in 3D graphics because it doesn't require more polygons for the objects and this is very important for the rendering process - the fewer polygons the faster is rendering and viewing the final 3D result [3].

Fig. 1. Source 2D images (first raw: Charter 1912, established by the Decree of October 31, 1913 after the victorious end of the war between Serbia and Turkey in 1912, Odin; second raw: Medal for Military Virtues, established after the suppression of the Timočka Rebellion in 1883, by the decree of King Milan Obrenović of December 21, 1883).

Generating a normal map from the object's picture is a task which may have many solutions. The most common solution is using the Sobel algorithm (or Scharr filter) which aims to detect the edges of the object and based on that to create a normal map after that.

A relatively new approach is the usage of neural network models which takes the picture of the object as input and generates a normal map as an output (Fig. 4). We have used a pre-trained model to show the result of such normal map generation [4].

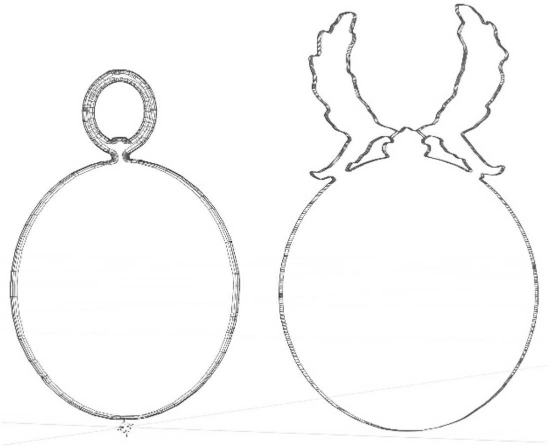

Fig. 2. A simple 3D model, created from the given 2D picture.

Fig. 3. UV map - polygons mapped to image

Figure 5 shows the final rendering with applied normal maps and using advanced lighting (a spotlight is added in front of the objects).

Fig. 4. A normal map (left side is Sobel algorithm generated, right sight is AI generated).

2.2 Used Technologies

The tools we used for the creation of 3D objects from 2D images include open source software - Inkscape - in order to trace the image contours, Blender - for all of the 3D modelling.

The following GitHub projects were used in order to create the normal maps:

- Normal generator using Sobel or Scharr algorithms [5].
- A normal map generator based on pre-trained AI models [4].

For the web presentation of the final results, the following technologies were used:

- THREE.JS - a powerful javascript library for rendering 3D environments on the web [6].
- glTF - a lightful format for storing three-dimensional data using JSON and binary data [7].

Fig. 5. 3D objects final rendering.

3 Virtual Demonstration of Created 3D Museum Objects

3.1 In Holographic Pyramid

Presenting 3D objects using holographic pyramids (also known as fake holograms) is an impressive way of visualization of artificially created objects in real space. The objects are projected, in fact, on a display (phone, tablet or another horizontally positioned screen) and the pyramid, which is built from tinted glass materials, reflects the projection [8]. Figure 6, Fig. 7 and [9] present screenshots and demo of the final results. The object can be observed from all 4 sides of the pyramid thus making this approach suitable for spaces where viewers are all around.

3.2 In Inclined Plane Projection System

The created 3D museum objects could be presented also in the inclined plane projection system, which is specifically designed technical solution for the virtual storytelling for museum objects during exhibits [10]. This system consists of two synchronized video presentations that are displayed one above the other on separate projection surfaces

Fig. 6. A tablet presenting the four sides of an object.

Fig. 7. A holographic pyramid placed on the tablet.

[11]. The upper projection surface is an inclined plane realized as a see-through display designed for the presentation of 3D museum objects. The projection is made on the semi-transparent glass to achieve the simulation of a holographic effect similar to a holographic pyramid. The bottom surface is the horizontal plane with special projection foil used for video presentation projected from a projector hidden in the box of the system. This video presentation is used to provide additional and more detailed information about 3D museum objects projected on an inclined plane. Currently, the solution is used in the Digital Museum located in Fortress of Niš to display stories and digital reconstructions of objects from different historical periods of the city of Niš. This relates to the presentations

such as the archaeological site Mediana, Serbian houses that existed in the Ottoman period and details about Niš as a war capital. The presented medals from Serbian military history will enrich the current digital collections.

3.3 In Universal Electronic Museum Guide

Another platform which is suitable for the presentation of the created 3D objects is the universal electronic museum guide, a mobile application that could be adapted for various museum exhibitions [12]. This electronic museum guide is realized as a more advanced solution compared to classical museum audio guides. The developed modules can display various multimedia formats such as text, image, audio, video or 3D objects. This gives visitors the choice of familiarize themselves with the information about the display in the museum in their preferred format. The engaging feature of this guide is achieved with the integration of VR and AR technologies where 3D museum objects can be visualized in an appealing way.

3.4 Possible Usage of the 3D Created Museum Objects for Educational Purposes

The created 3D museum objects could be used for educational purposes, especially in supporting VR/AR presentations of the reconstructed objects in serious educational games or other interactive learning materials. More precisely, students can examine the symbols in the above medals given for bravery, dedication and proven service to the king and the fatherland in interactive educational resource for historic events from the Serbian history. Similarly, as the national symbols (coat-of-arms and flag) the medals hold their symbolism, which is rarely recognized and understood by the current generation. In that way this precious knowledge about the national memory can be passed on in understandable and easy way to the students.

Some of the presented approaches and some test objects, mainly coins, weapons of war (swords, sabers, *etc.*) were experimentally embedded in our current development, the Aquae Calidae serious game [13, 14]. Students can explore the multilayered archeological excavations in the town of Aquae Calidae, situated in the Burgas mineral baths region in Bulgaria. Through immersing in the 3D reality of the ancient complex, and playing intuitive educational mini-games, students improve their knowledge and understanding of the ancient civilizations on the Balkan peninsula. The player, for example, visits a hall with artefacts of Thracian treasures, and, in gaming mode, explores 3D transformed objects in detail and perceives crucial aspects of the Thracian culture and civilization [15].

4 Conclusions and Future Work

In this paper a methodology for 2D to 3D object transformation, based on 2D captured museum assets is proposed. It represents a symbiosis between traditional methods and algorithms for 3D modelling and advanced technologies based on artificial intelligence. Possible applications of the reconstructed 3D objects could be the representation of ancient artifacts, treasures and valuables in a more realistic way, enlarged, voluminous, and in all around view. Moreover, in order to present more complete content, complex scenes can be created using combinations of real and artificial 3D objects, specific animations and transitions. As a next step, we plan to optimize and improve the offered framework towards maximum use of generative AI for creative co-creation of immersive and authentic 3D applications.

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