A Multifragment Renderer for Material Aging Visualization

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Abstract

People involved in curatorial work and in preservation/conservation tasks need to understand exactly the nature of aging and to prevent it with minimal preservation work. In this scenario, it is of extreme importance to have tools to produce and visualize digital representations and models of visual surface appearance and material properties, to help the scientist understand how they evolve over time and under particular environmental conditions. We report on the development of a multifragment renderer for visualizing and combining the results of simulated aging of artwork objects. Several natural aging processes manifest themselves through change of color, fading, deformations or cracks. Furthermore, changes in the materials underneath the visible layers may be detected or simulated.

CCS Concepts

•***Computing methodologies*** → ***Rendering; Reflectance modeling;***

1. Introduction

The modeling, analysis and visualization of the aging process of various materials of cultural artifacts under a multitude of parameters within expanded time frames is an issue of key importance for curators and archaeologists. In this work we report on the development of a visualization tool for the aging process of objects that consist of several layers of materials. To this end, we employ state of the art multifragment rendering algorithms capable of visualizing multiple layers and properties of the materials throughout a simulated or emulated aging process.

Our visualization tool is built on top of a multifragment renderer using vertex and fragment shaders. The outcome is a fast user-friendly visualization tool that, given the scanned geometry and material model of an artwork piece, portrays the appearance of the artifact in the future when specific conditions and effects are applied.

The multifragment rendering tool is used to visualize, understand and analyze multiple sensor data. Therefore, the visualization tool may be used for investigating integration of: (i) low-resolution photogrammetry or laser scanner produced mesh, (ii) high resolution micro-profilometry surface measures, (iii) RTI for capturing surface shape/color and enabling the interactive re-lighting of the object and (iv) x-ray, ultrasound and ultraviolet light for detecting multiple material layers.

2. Related Work

Our work adapts and combines state of the art approaches from artificial material aging (aging emulation), aging simulation and multifragment rendering.

Artificial Aging. Some aging phenomena often play a key role in realistic rendering (except when the desired result is specifically a brand-new virtual object). Their absence results to non-realistic surfaces, looking too clean and too smooth. To solve these problems, artists either compose complex textures manually or through other techniques [MG08]. Aging also can describe a number of methods used in computer graphics to simulate object morphology changes due natural influences, such as cracks, fractures, patina, corrosion, erosion, burning, melting, decay, rotting and withering. Such approaches consider effects which influence the geometry of an entire object, instead of the surface appearance alone [FVG15].

Simulation Techniques. Physical, chemical, biological, environmental, and weathering effects produce a range of 3D model, shape, and appearance changes. To be able to visualize all these effects we need a novel simulation technique for geometrically and visually simulating these processes to create visually realistic scenes [Kid12].

Multifragment Rendering. A variety of algorithms ranging from photorealistic rendering, such as global illumination, order-independent transparency for forward, deferred, volumetric shading and shadowing to volume visualization and processing of flow, molecular, hair and solid geometry require accurate multifragment

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processing at interactive speeds. [VF13] presents a thorough survey and comparison of multifragment methods. In this work we have adapted S-buffer [VF12], a two-geometry-passes A-buffer implementation on the GPU, that overcomes the limitations of both linked-lists and fixed-array techniques by taking advantage of the fragment distribution and the sparsity of the pixel-space.

3. Developing a multifragment renderer for material aging visualization

In our visualization tool we render and combine data from (i) microprofilometry using normal and displacement maps (ii) photos and photogrammetry using detailed meshes and texture maps, (iii) RTI using albedo, specular and roughness maps (iv) infrared, x-rays, ultrasound and ultraviolet light using multiple layers. An example of gradually adding sensor data information is illustrated in Figure 1.

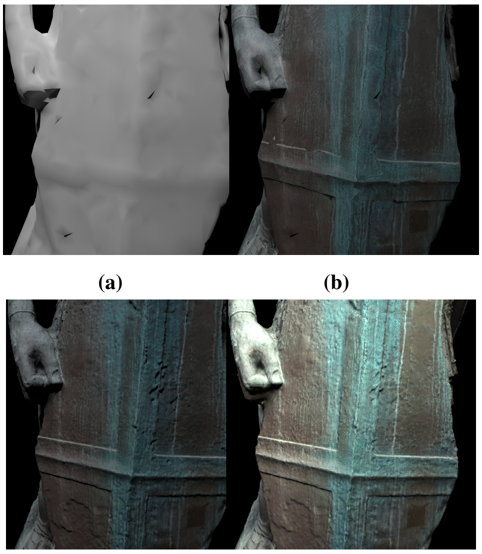
(a) (b) (c) (d)

Figure 1: *(a) low resolution, (b) low resolution with diffuse texture, (c) high res using normal maps an (d) incorporating RTI data.*

We have used a variation of S-buffer [VF12] (an improved implementation of A-buffer), to interactively visualize multiple layers of materials and of their properties and sensor data. Multiple layers are produced using either offsets of the original object or displacement maps. The layers are then rendered using a variation of the original alpha blending order independent transparency algorithm. For each pixel all fragments are stored and sorted by their depth. Then only the k nearest fragments that belong to alternating layers (from layer 1 through layer k) are rendered. The k nearest fragments correspond to the k material layers rendered by our visualization tool. The renderer works as follows. First, the user determines two parameters: the number of highlighted layers $d, d \leq k$ and a parameter $0 \leq v_\alpha \leq 1$ that specifies how visible the non highlighted layers will be. When $v_\alpha = 1$ only the highlighted layers are visible, when $v_\alpha = 0$ only the non highlighted layers are visible. The rgb color $col.rgb$ of each pixel is a weighted sum of the color of the fragments f_i of each layer as follows:

$$col.rgb = \sum_{i=1}^{k} col(f_i).\alpha * col(f_i).rgb), \; where \sum_{i=1}^{k} col(f_i).\alpha = 1$$

and

$$col(f_i).\alpha = \begin{cases} \frac{1}{d} v_\alpha, & \text{if } f_i \text{ is highlighted} \\ \frac{1}{k-d}(1 - v_\alpha), & \text{if } f_i \text{ is not highlighted} \end{cases}$$

The result of rendering a plate with 3 layers with the middle layer highlighted is shown in Figure 2.

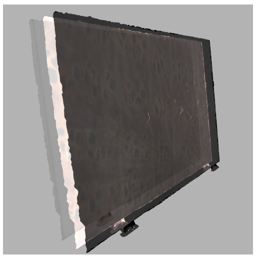

Figure 2: *The result of rendering 3 layers of a plate after aging with the middle layer highlighted.*

This renderer was developed using C++ and Qt 5.7 along with OpenGL core 4.4 and GLSL 4.6 in QtCreator 4.4.1 on a Windows 10 workstation equipped with Intel Core i7 4930K, NVIDIA GeForce GTX 760 4GB GDDR5 VRam and 32GB Ram.

4. Acknowledgements

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