

REALISTIC SIMULATION AND RENDERING OF CORRODED OBJECTS

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REALISTIC SIMULATION AND RENDERING OF CORRODED OBJECTS

by

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Certificate

This is to certify that the thesis titled **Realistic Simulation and Rendering of Corroded Objects** being submitted by **Nisha Jain** for the award of **Doctor of Philosophy** in Computer Science and Engineering is a record of bonafide work carried out by her under my guidance and supervision at the Department of Computer Science and Engineering, Indian Institute of Technology Delhi. The work presented in this thesis has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma.

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Abstract

Corrosion is a natural phenomena in which metal's exposure to environment results in structural degradation and aesthetic change in the surface of the exposed object. Metallic objects are ubiquitous in the real world. Simulation and rendering of material weathering is of great interest in computer graphics as it facilitates modeling of realistic objects in virtual scenes. Its application is across varied fields including civil engineering, aerospace, gaming, etc.

In this thesis we propose a generic framework for realistic simulation and rendering of corroded objects. We present a time-variant voxel-based model to simulate and render corrosion of different materials. We employ a physio-chemically based stochastic model to determine the deterioration level of different points on an object, given its material characteristics and the vigor of the environment. Our corrosion model leads to shape degradation. This shape degradation is then applied to the object in the form of surface displacements and weathered appearance. The shape degradations are captured in the form of depth map, specular map, weathering degree map and normal map.

The appearance degradation is challenging to physically model accurately due to its dependence on a large number of unknown parameters as well as its high sensitivity to errors in modeling them. Color degradation is particularly hard. Hence, we instead learn that directly from acquired images of corroded models. We employ a user-in-loop technique to learn color degradation from actual corroded samples. We present an efficient rendering algorithm that combines color, normal and depth textures to display the corrosion of any object of interest. This is an important step in linking the appearance to structural damage. We demonstrate our technique using several simulation results as well as different input photographs.

We also evaluate the fidelity of the simulation and rendering results in with respect to the input photographs as well as statistical data published in the corrosion literature. We also compare our rendered corroded objects with outcomes of already published results

of previous techniques used in the field of graphics. Our framework is generic and can be extended to a variety of corrosion scenarios. Ours is an important step towards predictive analysis of material loss and weathering phenomena for real objects.

Our framework allows for push, pull and guided simulation to control the spread of corrosion to achieve specific goals. The push approach aims at predicting the state of object, given a set of material properties and environmental conditions. On other hand, pull approach controls the spread of corrosion on a given object based on from real samples of corroded material. Corrosion is a complex process, influenced by multiple causal factors. We also equip our framework with a user-intervention module, which allows guided corrosion simulation to satisfy artistic demands and generate user specific outputs. The main contributions of this thesis are as follows:

- We have built a physio-chemically based stochastic model that predicts the holistic state of a corroded object after varying time periods.
- We develop a technique to determine the internal parameters of both simulation and rendering modules. In the stochastic model we capture the initiation and spread of the corrosion phenomena, which guides the pace and the distribution of corrosion. We learn the mapping of the diffuse color with the severity of corrosion decay from a sample image. This is enabled in the rendering module with the help of user guidance.
- Our simple and efficient rendering algorithm produces realistic corroded objects. We develop a comprehensive technique that combines roughness, normal variations and displacement maps generated from the stochastic model with the diffuse color map produced with the help of a sample image in order to obtain realistic rendering.
- Our simulation and rendering framework is modular in character. It comprises of relatively independent modules. This allows a combination of varied materials, external conditions and rendering methodologies to generate consistent results across

different forms of corrosion. We also provide an additional user interaction module, which allows the user to guide the corrosion phenomena to generate desired results.

- We demonstrate various validation techniques for different parts of the simulation and rendering modules to strengthen our confidence in the overall framework. This includes multiple validation strategies like statistical and visual comparison.

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