REALISTIC SIMULATION AND RENDERING OF CORRODED OBJECTS

NISHA JAIN

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
DECEMBER 2016

REALISTIC SIMULATION AND RENDERING OF CORRODED OBJECTS

by

NISHA JAIN

Department of Computer Science and Engineering

Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the

Indian Institute of Technology Delhi

DECEMBER 2016

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.

Prof. Prem Kalra
Department of Computer Science
and Engineering
Indian Institute of Technology Delhi
New Delhi, India 110 016

Dr. Subodh Kumar
Department of Computer Science
and Engineering
Indian Institute of Technology Delhi
New Delhi, India 110 016

Acknowledgments

During the last seven years, I have often wondered about the day when I would be writing the Acknowledgment Section of my PhD thesis. Now that the day has finally arrived, I sincerely hope I do not miss out on the name of any person who has been a part, in some way or the other, of this wonderful and exciting journey.

First and foremost, I would like to express my deepest gratitude to my supervisors Prof. Prem Kalra and Prof. Subodh Kumar, for providing me an opportunity to work under their precious guidance. It is my fortune to work with them. They have been enthusiastically guiding me at every stage of this work and encouraging me to achieve the targets set. Working with them was a great pleasure and vast learning experience. Their critical comments during the discussions enabled me to overcome my weaknesses and make valuable improvements. Thanks for your belief in my abilities and to channel my passion in the right direction.

I extend my gratitude to Tata Consultancy Services for supporting my entire PhD through the TCS Research Scholar Program Fellowship. A special thanks goes to Mr. Sachin Parkhi of TCS who has been instrumental in making sure that all logistic issues, be it monthly stipends or international travel funds, are managed seamlessly. I am grateful to IMPECS (Indo-German Max Planck Center for Computer Science) for supporting my visit to Max Planck Institut fuer Informatik, Saarbruecken, Germany (MPII).

A heartfelt thanks goes to Prof. Subhashis Banerjee, Prof. K.K. Biswas and Prof. Anoop Chawla for being kind enough to be on my Student Research Committee.

Surviving through a PhD tenure requires immense support from strong and motivated peers. I would like to thank folks of the graphics and vision group - Shantanu, Suvam, Nishant and Ayesha who were always ready to brainstorm on problems and ideas both on and off the research areas. Special thanks to Rohit, Yash and Rishit for helping me through in my research work. I met some of the most interesting and friendly individuals in these seven years. Thanks Namita, Shraddha, Syamantak, Deepak Ravi, Shibashis, Chinmay, Anamitra, Yamuna, Mona and Swati for the endless chats on research and life over coffee, lunch or dinner. It was only because of you guys that I could keep my head focused a midst all the work load. I would also like to thank Kaushik Sir, Negi Sir and Anil Sharma Sir for their timely assistance in lab related issues.

Outside the department, there are two people whose contribution to this thesis is more than I can express. The first one is Ritu, my closest friend whose house in I.P. has been my home in the last two years of my research work. Her enormous care and incredible cooking has been a strong driving force. Second is Vitesh, my best friend, who was always patient enough to listen to my problems and offer simple and comforting words of solution as well as encouragement.

Perhaps the most difficult task is to find words of gratitude for the four most important people in my life - my parents, my sister Ayushi and my husband Ayush. They are the reason for my achievements. Without their constant endeavor and encouragement, my PhD would have never happened. My mom has been like a pillar in my life. Whenever I was about to slip, I knew she would be there to hold on to. My sister has been my bundle of joy in all the tense situations. My husband has been my support system all throughout, he has constantly motivated, encouraged and guided me in infinite ways to achieve my dreams. A special thanks to my parents in law for being patient and supportive in my journey. This thesis is dedicated to mama, papa, babbo and Ayush.

Nisha Jain

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 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.

Contents

List of Figures

List of Tables