

Realistic Rendering of Material Aging For Artwork Objects

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Abstract- *Material aging has a significant effect on the realistic rendering of artwork objects. Small deformations of the surface structure, color or texture variations contribute to the realistic look of artwork objects. These aging effects depend on material composition, object usage, weathering conditions, and a large number of other physical, biological, and chemical parameters. In this work we focus on local deformations due to corrosion/erosion and finally cracks mainly by modeling the behavior of displacements locally. Micro-profilometry provides the quantitative measurements of the surface texture and roughness at micro-metric level, which is used to obtain information about material changes over time in terms of its surface deformation. We present a method for deriving a model for simulating aging based on micro-profilometry measurements taken on material sample plates during an emulated aging process. Subsequently, we use this model for realistic rendering of aged artwork objects.*

Keywords- artificial aging, visualization, rendering, microprofilometry measurements, data analysis

I. INTRODUCTION

Material aging has a significant effect on the realistic rendering of cultural artifacts. Small deformations of the surface structure, color or texture variations contribute to a realistic look of artwork objects. The distinctive crack patterns observed in many materials arise due to small-scale interactions among elastic strain, plastic yielding, and material failure. Stress gradients can be very large near the crack tip where the stress field often approaches singularity. Modeling the effect of aging is a computationally intensive task. Therefore, tools are needed to expedite the aging simulation/emulation process. Several types of textures may be used to improve rendering. However, this process requires intensive user interaction which may not correctly capture subtle micro-deformations. Texture parameterization is a tedious task especially for non-genus-0 objects that may introduce triangle mesh distortions.

The aging process depends on material composition, object usage, weathering conditions, and a large number of other physical, biological, and chemical parameters. Weathering for example, over long periods of time results in cracking and peeling of layers such as paint. Material aging related visual

effects are important for capturing realistic effects in computer generated images. Simulating and rendering such phenomena results in images which have a much higher degree of realism. In this work we focus on local deformations due to corrosion/erosion and finally cracks mainly by modeling the behavior of displacement locally by studying the artificial aging process of sample plates.

Micro-profilometry, namely the acquisition of the surface at micron or sub-micron scales, is routinely used for materials inspection in the engineering field but it is a recent experimental application in Cultural Heritage. Surface metrology of artworks requires the design of a suitable device for in-situ non-destructive measurement together with reliable tools for effective analysis of non-engineered, i.e. complex and unknown, materials. Micro-profilometry provides the quantitative measurements of the surface texture and roughness at micro-metric level, which is used to obtain information about material changes over time in terms of its surface behavior. To this end, we introduce a method for modeling and rendering the aging process based on micro-profilometry measures taken on material sample plates during an artificial aging process. In each step of the emulated aging process microprofilometry measures are statistically analyzed and fitted by a normal (Gaussian) probability density function. Then used to determine regions where dents, bumps and cracks are plausible. Dents and bumps are approximated by radial basis functions parameterized to reflect material behavior.

Cracks are modeled by paths simulating surface singularities. These mesh deformations are modeled by directly altering mesh geometry or through displacement maps for rendering efficiently the aging effect on cultural artifacts.

II. RELATED WORK

Aging depends on material composition, object usage, and other physical, biological, and chemical parameters. Aging phenomena often play a key role in realistic rendering. Their absence results to non-realistic surfaces, looking too clean and smooth. Each specific aging process is considered according to as a challenging task in computer graphics, because of the often-complex underlying physics

involved and the need for providing designers with usable tools. Capturing aging in computer graphics is simulated by modeling object morphology changes such as cracks, fractures, patina, corrosion, erosion, burning, melting, decay, rotting and withering. Some approaches consider effects which influence the geometry of an entire object, instead of the surface appearance alone. In our work we propose a novel method for the modeling, prediction and rendering of small scale geometric deformations by studying the artificial aging effect on material sample plates. We employ a state of the art renderer for visualization. While the simulation of fracture physics has been studied in computer graphics, reproducing fracture patterns observed in real-world materials remains a difficult problem. In a high-poly mesh is dynamically produced locally to adaptively capture details wherever it is required by the simulation. Crack patterns observed in materials arise due to small-scale interactions between elastic strain, plastic yielding, and material failure. Stress gradients can be very large near the crack tip where the stress field often approaches singularity. In the surface of wood is defined by values assigned to tetrahedral mesh vertices. Changes in the surface are achieved by value changes. We build on this background to model cracks.

Demonstrates how a Bayesian optimization method can determine the parameters of a fracture model patterns based on examples. In our method we use statistical fitting to derive material behavior pertinent to local deformation. Hence no examples are needed to model, predict and render such aging effects. An important aging technique that simulates the deformation of an object caused by repetitive impacts over long periods of time is discussed in. The authors use adaptively refined meshes and mesh deformations to model aging due to heavy object usage. Another interesting approach describes the phenomenon of chemical aging in painting. Material aging is understood as changes of material properties with time, so usually observed as a gradual modification of some properties such as rigidity and strength. These approaches can be used in conjunction with our method to extend the repertoire of aging affects.

III. ARTIFICIAL AGING DATA ANALYSIS

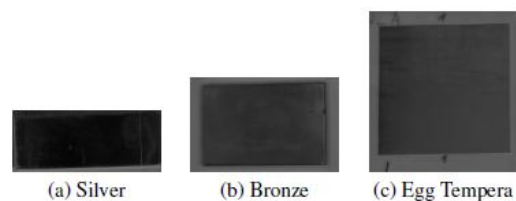
Micro-profilometry, namely the acquisition of surface structure at micron or sub-micron scales, is routinely used for material inspection in engineering but is recently used experimentally in the cultural heritage field. Surface metrology of artifacts requires the design of a suitable device for in-situ non-destructive measurement along with reliable tools for effective analysis of materials. So-called accelerated (artificial) aging tests are carried out for three major purposes. The first is to establish in a conveniently short time the

relative ranking of materials, or physical combinations of materials, with respect to their chemical stability or physical durability. The second is to estimate or predict long-term behavior of material systems under expected conditions of use. Thirdly, processes of deterioration are speeded up in the laboratory to elucidate the chemical reactions involved (the mechanism of the degradation) and the physical consequences thereof.

More specifically the aging process depends on material composition and can describe a number of methods used in computer graphics to simulate object morphology changes due to natural influences, such as cracks/fractures and local deformations. We will focus mainly on micro-profilometry data for our purpose. Areal micro-profilometry of the sample is obtained by raster scanning, i.e. collecting a set of line profiles along the scan direction and step by step along the sub-scan. The measurement of the sample is performed with the device placed in a vertical configuration, with the sample positioned perpendicularly to the laser beam of the probe. The sample is kept in a vertical position on a sample holder.

Micro-profilometry data consists of a sequence of distances between the lens and the target object, thus providing a digital representation of its surface through direct measurement of the surface heights. Several material features are detected by micro-profilometry such as surface cracks and other local deformations.

In this work we study the detection of such patterns within sets of data drawn from micro-profilometry measures taken on material samples such as silver, bronze or egg tempera coated copper plate during the process of artificial aging.



After each artificial aging process, we statistically analyze the microprofilometry measurements from each sample plate. We have used the maximum likelihood estimation (MLE) which is a method for estimating the parameters of a statistical model given observations, by finding the parameter values that maximize the likelihood of making the observations given a specific family of probability distribution functions. Given a statistical model (possibly multi-dimensional) we determine the set of values of the model parameters that maximize the likelihood function. This

process determines a probability distribution function that best fits a random set of input data.

The method of maximum likelihood is based on the likelihood function $L(\theta; x)$.

We are given a statistical model, i.e. a family of distributions $f(\cdot; \theta) | \theta \in \Theta$

The method defines a maximum likelihood estimate (MLE):

$$\theta \in \arg \theta \in \Theta \max L(\theta; x).$$

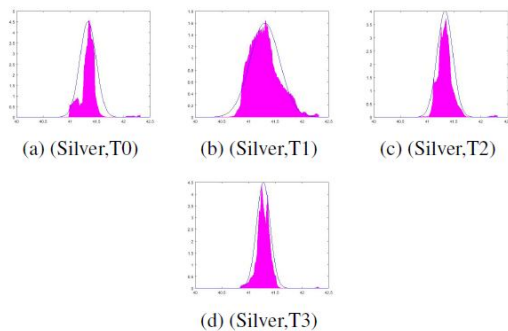


Fig. 2: Micro-profilometry measurements and pdf fitting for silver plate.

IV. AGING SIMULATION AND VISUALIZATION

Relating results from accelerated aging to those obtained in actual-use conditions is difficult because laboratory tests do not reproduce all the exposure stresses experienced by materials exposed in actual-environment conditions. Although artificial aging have been used as a research tool in the past decades. However, there are still several open problems regarding the significance and accuracy of the results. However, data from artificial aging of sample metal plates is sufficient to create a plausible realistic model intended for computer graphics applications.

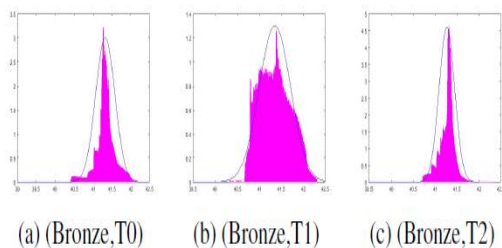


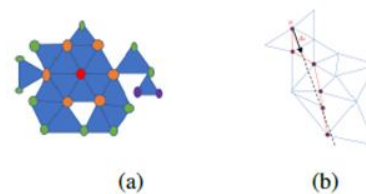
Fig. 3: Micro-profilometry measurements and pdf fitting for bronze plate.

In this section we further analyze the data from the artificial aging process and we use them to predict the occurrence of local deformations. Material failure in metals manifests itself mainly by local deformations. We distinguish

two types of such deformations: cracks and dents/bumps. We have studied (i) when and where such deformations come up, and (ii) their geometric structure and (iii) how we can represent such deformations in terms of surface mesh operations.

Next we study local deformations which are formed around a specific point of the surface, namely dents and bumps. By studying the data from micro-profilometry (MP) measurements we have observed the following:

- (i) Dents/bumps occur where large deviations from the mean value (distance from the metal plate plane) are obtained. Accordingly we can model the frequency of dents/bumps based on the standard deviation of the fitted distribution.
- (ii) Dents and bumps are created around a vertex and present themselves by translating the neighboring vertices of the mesh towards the normal vector direction.
- (iii) The attenuation of the displacement in the neighborhood follows an RBF function.



An example of vertex neighborhood & a crack path

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