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Comparative Study for Estimation of Realistic Generation of Surface Crack Patterns

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ABSTRACT: With the passage of time, deteriorating and object degrading is also one of the natural phenomena with various objects around, where 'degrading' means either 'physical disintegration' or it may be 'chemical decomposition' of objects.
In computer graphics field, to model complex and realistic shapes and structures, is, still, a challenging as well as a complex task. There are many techniques that have been evolved, with time, to render different 'aging and weathering' phenomena's. Though a great amount of work has been done, in the field of rendering 'deformed objects', 'aging processes' and, last but not the least, 'weathering processes' of different objects, for quite a long time but not much attention has been given to the area of problems, related to, 'crack and fracture modelling'.
Though there are some latest advancement in this area, but still there is so much to be done in this field. The work, which is done, provides various techniques, which addresses the problem of cracks and fracture generation, each, with some sort of limitation. These limitations are studied and future scopes are evaluated from them, which can be further advancements in the techniques, presently existing, and can help in more realistic rendering of the surface crack patterns.

KEYWORDS: Aging and weathering phenomena, Crack modelling, Simulation, Realistic rendering, BRDF, Fracture modelling, Textures, Surveys.

I. INTRODUCTION

In many fields, especially in computer graphics, fracture and crack pattern study and physically plausible objects deformation, are of central importance.
Even though, despite of the importance it has got, fracture and crack pattern study is, still, a very vast non-closed problem area, with so many issues clung to it, that are remaining, to be dealt with.
Many good reviews are there on deformation phenomena of objects, in computer graphics, and also, on all of the aging and weathering techniques, that just touches, on the topic of study of fracture and crack patterns. So, a great need is felt that a considerable amount of attention, for the current state-of-art of fracture and crack modeling technique, is required.
Though, so far, quite some work, in this field, has been done even and this can be categorized, according to several criteria.
To perform fracture and crack simulation, three categories of techniques are broadly defined and are mentioned below:

1. **Physical based models**
   Physical based models are known for following a simulation based approach. It computes the fracture opening, its propagation and also its appearance.

There is further sub classification of physical based models and they are as follows:

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a) Mass-Spring models:

In Mass-Spring models, an object is divided into finite number of masses. These are joined by springs, pair-wise. Each of it, is with its own defining parameters. The crack is shown with the breakage of the spring, joining the two masses, at a particular point.

b) Finite element method:

The object, in this method, is partitioned into set of disjoined elements, such as tetrahedron, joining at discrete points. In the next step, the problem, is then formulated, in terms of these points. Afterwards, the problem is converted into a set of simpler algebraic equations. These are then solved to establish the system's behavior.

c) Meshless method:

In this method, the approximation of object is done with a set of unconnected calculation points, which are simulated. If the value of any other point in the model is needed to be evaluated, it can be done with the help of interpolation.

We need numerical approximations to solve the equations, formulated for the modal or material. Physically based simulation is very effective for modelling and animating fractured objects, which tend to be having many degrees of freedom. These methods are very time consuming if we have to deal with large scenes, as lots of calculation is involved, which become very complex when applied to large scenes.

2. Procedural modals:

Procedural models are also known as Geometry-based models. These models are interested in seeking plausible patters and a physically accurate phenomena description is not their priority. Users are provided with more freedom and interactivity but a little compromise is done on the accuracy.

3. Example based models:

These models mimic real world fractures as they copy the behavior of the fractures in real phenomena. Using Computer Graphics techniques, the parameters of the fractures are extracted from the image and those parameters are used to generate fracture patterns [9].

Fig. 1 The real world image of a crack pattern **[13]**

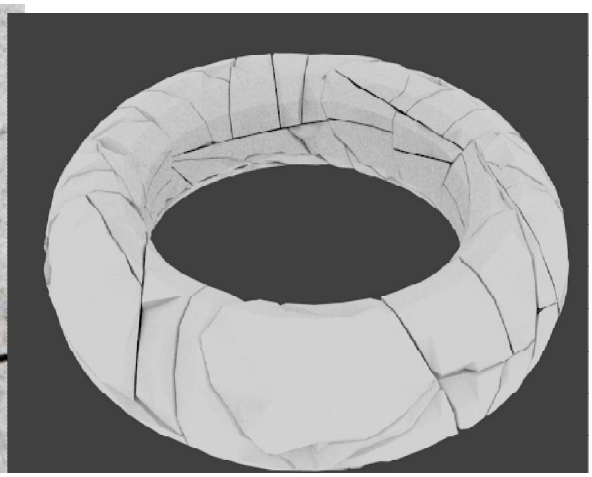

Fig. 2 Generated surface crack pattern [14]

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II. RELATED WORK

It starts from 1976, an animation of human face and hand, was developed by two researchers named, Ed Catmull and Fred Parke, at the university of Utah. A Swedish researcher, Hakan lans, further in 1979, applied for first patent in Computer Graphics **[1]**.

Terzopoulos et al. **[1988]** research played an important part implying that fracture modelling has been an essential part of physically based animation. They modeled tearing sheets of cloth-like material by using a finite differencing scheme. In elastically deformable modals were proposed for use in computer graphics, and simulated three principle in elastic behaviors---viscoelasticity, plasticity, and fracture**[2]**.

Norton et al. **[1991]** also suggested that generating surface crack patterns is an important part of computer animation. He exhibited a presentation of breaking objects using physical simulation as he used a mass spring system which modelled the breaking of a teapot. The model included three principle features i.e. a breakage model, a collision-detection/response scheme, and a geometric modeling method. **[3]**.

O'Brien et al. **[1999]** and **O'Brien** et al. **[2002]** used finite element method to produce or simulate britte and ductile fracture. In 1999O'Brien and his collaborators augmented existing techniques, so that models for crack initiation and propagation can be included for simulating flexible objects in three dimensional volumes.**[4]**, **[5]**.

S. Merillou et al. **[2008]** proposed a survey of aging and weathering phenomena in computer graphics. The paper provided vast number of surveys or techniques which allowed, the user, to represent a wide range of aging and weathering phenomena of objects in computer graphics. It depended on the process involved that whether it is erosion, aging, cracks or growth of organic material over the surface **[6]**.

Iben et al. in **[2009]** exhibited a method which generated surface crack patterns appearing on materials such as mud, glass, ceramic glaze etc. They used existing physically based methods and their algorithm generated cracks from a stress field, which was defined heuristically over a triangle discretization of the surface **[7]**.

Lien Muguercia et al. **[2014]** proposed how to model fractures in computer graphics. It presents a brief survey, having a special focus on the latest advancements in the field of generation of surface crack and fracture patterns. Also a careful analysis has been done of the open issues in this area with several new avenues for further research **[8]**.

L. Glondu et al. **[2012]** proposed Example-Based Fractured Appearances. It is a new approach and it includes example-based modelling which creates surface crack patterns or fracture patterns on synthetic objects. It matches the statistics of cracks and fracture patterns from the real world image of a crack patterns to the fracture patterns generated by the model in computer graphics **[9]**.

H. Shin et al. **[2010]** proposed analyzing of Fracture Patterns in Theran Wall Paintings. Here fractures and cracks in a wall painting were analyzed which was destroyed, first in a volcanic eruption and then in an earthquake. Interactive programs were used which traced detailed fragment boundaries of the crack pattern. Then, geometric analysis algorithms were ran which calculated the statistical parameters of those fragmented boundaries such as fragment adjacency, area of fragments, length of edges, angles etc **[10]**.

Loeiz Gloudu et al. **[2012]** proposed Real-Time Simulation of Brittle Fractures. A physically based approach has been proposed, in this paper, which simulated realistic brittle fractures. It also computed the contact durations and the contact forces. It efficiently produces fracture patterns and their geometric surfaces **[11]**.

Katalin Csillery et al**. [2010]** proposed a simulation process to estimate the evolution in biology and ecology **[12]**.

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III. CONCLUSION AND FUTURE WORK

Creating realistic generations in computer graphics is very challenging because it is a complex task in terms of rendering. Here, a particular problem of realistic generation of cracks and fractures, is being addressed and most relevant techniques, related to this problem area, have been review in literatures mentioned above.
The conclusion is that no single generic solution is able to cover all cases well because each material, on which crack patterns are being generated, behaves in a different way and if we discuss different methods of simulating crack patterns, no technique, whether Physical, Procedural or Example based, is solely capable for the realistic crack patterns generation.
However **[9]** proposed the mixed approach of two techniques i.e. Physically based method and Example based methods, and it is first kind of work in itself, in this field. As this is first step, lots of work is still needed to be done regarding the accuracy and efficiency of this technique. Further work can be done in the field of enhancing the accuracy and realistic representation of a crack pattern by manipulating its statistical parameters and evaluating that which parameters contributes most for the realistic generation of the crack patterns.

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