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Fracture of geometric bone models. Multiscale simulation issues

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ABSTRACT

Fracturing of osseous models is a field that allows to obtain advances in computer-assisted medical simulations, as well as to prototype fragile objects as is the case of bones. This field of study includes the use of physical features of bones. Not all fracturing methods are valid with osseous models, due to the importance of considering the hierarchical structure of the bones. In this work, we focus on the study of bone fractures at the macroscale level and on obtaining fractures with a realistic appearance. Therefore, a tool has been developed that allows the fracture of osseous models, obtained through a 3D scanning process, by the use of patterns and physics. The different approaches for the fracturing of osseous models are also shown, and discussed the need to obtain more information about the fracturing process.

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Bone model; bone fragments; fracture pattern; fracture methods; geometry; hierarchical structure of bone; interactive tool; physical simulation

1. Introduction

The advantages provided by the fracture and deformation of geometric models, in fields such as architecture or medicine, have made it a topic of reference in computer graphics in recent years. In the field of traumatology, technological advances appoint new frontiers in the simulation and prototyping of fragile objects, as osseous tissue, as well as the evaluation of resistance and resilience studies by using geometric models (Muguercia et al. 2014).

A fracture can be defined as a phenomenon resulting in the breakage of a solid object as a result of a blow, force or traction exceeding its limit of elasticity. A fracture provides a great deal of information about the properties of a material and its relationship to other elements. The fracture of an osseous model also implies that the fragments have been obtained through a physical simulation applied to a heterogeneous material such as bone. This material is composed of a series of hierarchical structures that influence the entire fracturing process.

A tool for fracturing a bone model has been developed at a macroscale level using patterns. In addition to obtaining fractures with great detail, it is possible to extend the algorithm so that new types of patterns can be included, thus increasing the detail and information about the fracture zone, enabling real-time fracturation and performing fractures based on forces or physics. The purpose of this work is to obtain fractured models that can be used as input models for more detailed physical simulations, as prefractured bones, with a realistic appearance, using patterns obtained through the study of real fractures. These patterns will allow the creation of a large data set of realistic-fractured bone models. In the future, we could use these fractured models obtained by physical simulation and compare them with real fractures. We could also consider the effect of different physical phenomena, as well as the training of intelligent systems for the automatic generation of fractures, so that advances could be achieved in the modelling and study of bone fractures.

The summary of this article is as follows. In section 2 the different fracture methods applicable to bone models are analysed, as well as the different scales in which they can be classified and the factors that affect the fracture process. In the next section the methodology used to obtain the fractured models has been described. After this description, the results obtained with the tool developed are presented. After this description, the results obtained with the tool developed are presented. This section is complemented by the following one which discusses the results obtained and examines the advantages and deficiencies of the tool. Finally, the conclusions summarise the objectives of this tool and propose the work to be developed in the future.

2. Previous work

There is a wide range of techniques to simulate the fracture of geometric models. Muguercia et al. (2014) classify methods for fracture simulation of geometric models into three approaches:

- Based on geometry: it focuses on the generation of suitable patterns, for the simulation of geometric fractures, obtaining a high degree of control over the fracture in aspects such as the size or shape of the different fragments. This approach does not focus on the physical description of the fracture phenomenon (Muguercia et al. 2014). This type of fracture is faster to simulate than other approaches, although its main drawback is the loss of information and the difficulty of simulating the fracture in real time. The latest advances in this type of fracture suggest, by different authors (Oh et al. 2012; Müller et al. 2013; Pacevič et al. 2015), focus on the decomposition of the model being fractured into different fragments connected through a hierarchy of nodes. These nodes have established a series of connections and resistances and the simulation of the use of a force in a determined zone produces the

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the fracture zone to be obtained.

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