Visualisation as a tool for understanding fibre network behavior

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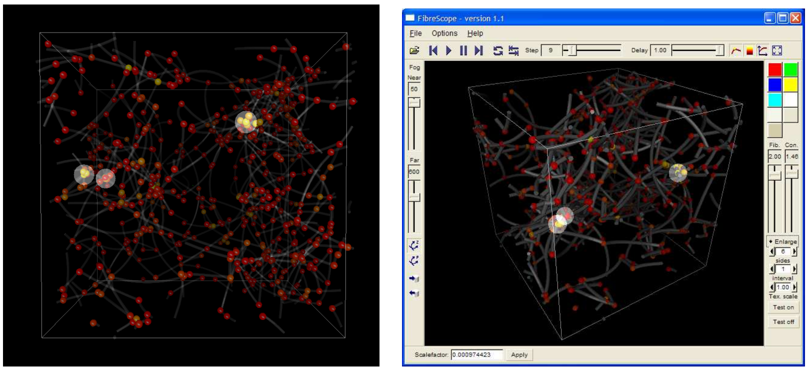

Figure 1: Connection breakage visualisation.

Abstract

Fibre networks are material with a structure consisting of fibres. At Structural Mechanics simulation methods for studying the behaviour of such networks has been developed. Because the behaviour of these materials are depends on three-dimensional interaction between fibres in the network it can be difficult to interpret the results without good visualisation tools and methods. The standard tools available are often designed with other materials and structures. To enable effective visualisation of these simulations custom tools and methods has been developed in parallel with the development of the simulation code, providing tools for better understanding the behavior of the simulations and to compare with real experiments.

Keywords: fibre networks, real-time, visualisation, finite element method

1 Introduction

Fibre network materials are materials with a structure consisting of fibres. Examples of such materials can be found in insulation material, diapers and paper. Structural Mechanics has during several years developed methods for studying the behaviour of different fibre network materials [Heyden 2000]. Visualising the results from the simulations been difficult using commonly found visualization software. This paper illustrates how visualisation can be used as an integral part in the development process of a new simulation code, enabling better understanding of simulation results as well as evaluating initial network configurations compared to real materials.

In earlier work [Lindemann and Dahlblom 2002], a texture based method was used to reduce the geometry complexity, enabling larger fibre networks to be visualised in real-time. This method is integrated in a fibre network post-processor, FibreScope.

2 Evaluation of simulation results

Results from a 3D fibre network simulation consist of ”snapshots” of the fibre network at different time steps in the calculation. In addition to this information on each fibre-to-fibre connection is also stored, so that fibre breakage can be studied. A simulated fibre network can consist of several thousand fibres and connection points. To evaluate the simulation results the visualisation tool must be able to visualise the deformation history of each fibre as well as highlighting connection point usage and breakage.

The common method of visualising fibres is to sweep a cross section over a spine (extrusion). This method is good when detail is needed, but generates a lot of geometry when the networks are large.

2.1 Visualisation of fibre structure and deformation

When the networks become larger, the extrusion based method become more and more costly in terms of real-time performance. To overcome this, a texture based method was developed and implemented in earlier work [Lindemann and Dahlblom 2002], reducing the geometry demands when visualising large networks.

The method renders the fibre as a simple band consisting of view-aligned quads (billboarding). A gradient texture is applied on the band giving it the illusion of a rounded fibre. Using this technique much larger networks can be visualised using similar hardware. Figure 2 shows the extrusion based fibre compared to the banded extruded fibre.

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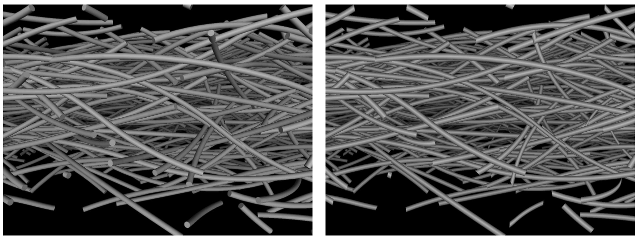

Figure 2: Fibres rendered with the extrusion based (left) and the texture based method (right)

2.2 Visualising connection point usage and breakage

An essential part in the simulation model is the connection point between fibres in the network. When the network is subjected to loading, these connection points will become stressed and eventually break. The simulation model [Heyden 2000] provides information about connection point usage. To be able to study how the behaviour of fibre network it important that the connection point usage is visualised in an intuitive way.

In a real fibre network, the connection point is very small, so it is not possible visualise the actual connection point. In the previous work [Lindemann and Dahlblom 2002] colored spheres where used to indicate the connection points. Using a colour scale the sphere is coloured to indicate the connection point usage. When the connection point usage is over a certain value, it will break. To indicate breakage the sphere is scaled to produce a ”popping” effect, to make the user aware of breaking connection points. When evaluating this method proved less effective, because the scaled spheres where obscured by the fibre network and other spheres.

To enable the user to be aware of connection point breakage in the entire fibre network a different approach is taken. Instead of scaling the connection point representation an additional ”highlight sphere” is rendered on top of the connection point. To be able to see the highlight sphere even if the connection point is obscured by other spheres and geometry, it is rendered without depth buffer turned on (`glDisable(GL_DEPTH_BUFFER)`). To retain the visibility of the actual connection point indicator the sphere is also rendered using additive blending (`glBlendFunc(GL_ONE,GL_ONE)`).

Because breakage occurs at discrete moment in the simulation, and the behavior just before and after the breakage is important the developed highlighting method highlights the connection points when the exceed 95% usage or a user defined value. This enables the user to zoom-in on interesting events and see the breakage occuring, as seen in Figure 3.

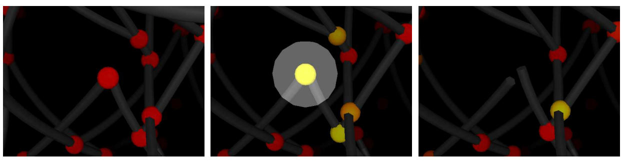

Figure 3: High usage, enlarged sphere, after break

Using this techniques the highlight for the connection point breakage will be visible at all viewpoints even if the real connection point is obscured by other geometry, as seen in Figure 4.

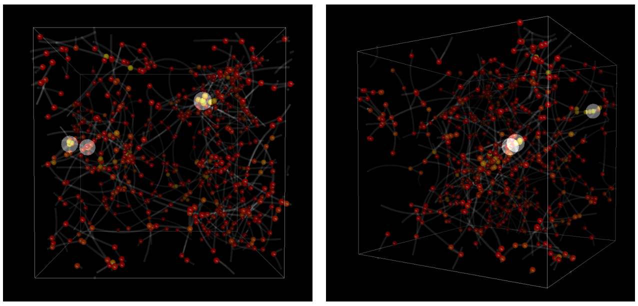

Figure 4: 3 connection breaks viewed from different viewpoints.

2.3 The tool: FibreScope

The methods described in the previous sections are all implemented in the post processing application FibreScope, see Figure 5, which initial development was done in previous work [Lindemann and Dahlblom 2002].

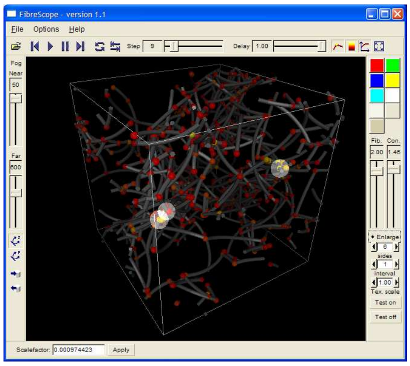

Figure 5: FibreScope post processor user interface

The main design concept of FibreScope is to implement a ”virtual” microscope that can be used to analyse the simulation results produced with the simulation code. The user can easily browse and animate the simulation time steps and in the same time rotate, pan and zoom. The user interface of is also designed to provide as much control as possible for the user, directly in the main window, eliminating the need for dialog windows. The user is encouraged to experiment with the different parameters for the visualization methods implemented. FibreScope has also been extended, so that active stereo equipment can be used, providing true depth perception.

FibreScope is a platform independent C++ application that can be run on Microsoft Windows, Mac OS X and Linux. 3D rendering is implemented using Ivf++ [Lindemann] a thin object-oriented library on top of OpenGL [Ope 2005]. The User interface is implemented using the Fast Light Toolkit (FLTK) [Spitzak 2005], to provide the necessary platform independence.

3 Evaluation of generated networks

Initially the focus of this work was on visualising the results from fibre network simulations. Later on it was clear that the visualisation tools could also provide valuable feedback in the process of generating the initial fibre network configurations. That is to generate fibre networks resembling real fibre networks. A master thesis work [Edlind 2003] studied methods for generating fibre networks with specific properties, such as certain distribution of fibre orientations or fibre curvatures.

To compare the generated fibre networks with images of real fibre networks, 3D Studio MAX and FibreScope was used. FibreScope was used to quickly view a generated network, 3D Studio MAX was used to generate high resolution images for direct comparison with real images. Figure 6 shows a real fibre material compared to one generated material.

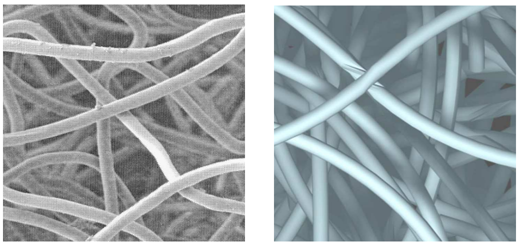

Figure 6: Real fibre material (left), Generated material rendered with 3D Studio MAX (right)

Because these generated networks have different properties in different directions, a special mode in FibreScope has been added to enable the user to study the depth complexity. This mode is implemented using a standard technique employed in many other visualisation applications. The basic idea is to render all objects with the depth buffer disabled and blending all objects using an adding function. By specifying colour components in a special way (red=0.2, green=0.1, blue=0.0), a colour scale will be produced where dark red represent low depth complexity and yellow colour represents high depth complexity. The colours must be calibrated for a specific depth complexity. Figure 7 shows a network with low complexity and figure 8 the same network from another angle now having a higher depth complexity.

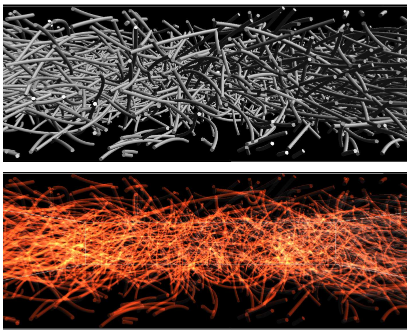

Figure 7: Network viewed in a direction having low depth complexity

To aid in the process of developing the generation methods FibreScope has been enhanced with routines for reading these generated networks. A full screen viewer was also implemented that could be used with the visualisation equipment and the Reflex RealityCenter at Lund University.

4 Conclusion

Fibre network simulations can consist of several thousands of fibres with snapshots of the simulation state stored at each time step. This produces a lot of data to analyse. Effective visualisation methods and tools are very important in this task. To aid in this task a banded texture approach was developed in previous work [Lindemann and Dahlblom 2002], to aid in the visualisation of large fibre networks.

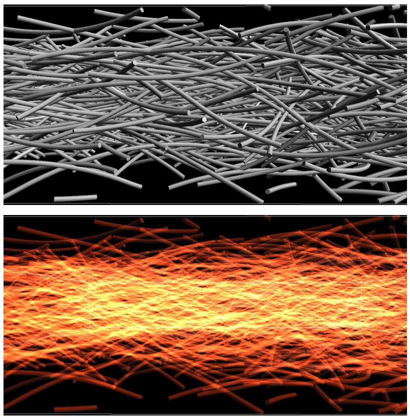

Figure 8: Network viewed in a direction having high depth complexity

Another important aspect in fibre network simulations is the connection point between fibres and how these break during load. This paper describes a enchanced method for highlighting connection point breakage, enabling the user to see connection point breakage even if the connection point is obscured by other geometry.

The tools developed has also been used to study methods for generating the initial fibre geometry, providing a rapid visualisation before more photo-realistic renderings are done in more advanced rendering packages, such as 3D Studio MAX.

This paper gives an overview how visualisation can be used as an integrated tool in the process of developing a simulation code. During the development of the simulation code developed by [Heyden 2000], tools for fibre network visualisation has been developed in parallel, providing important information about the behavior of the simulated networks. The FibreScope application is continually developed to integrate the developed methods into a easy to use user interface enabling the user to experiment with many parameters to achieve the desired results or findings.

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