Connor Lord

Computer Graphics I

Literature Review 3

Date: 4/17/18

As with the previous literature reviews, for this assignment, we were instructed to read two academic articles, and then create a summary of these two papers. The primary paper that we had to pick, had to be from a proper source as outlined by the assignment, and the second paper had to be from those cited in the bibliography of the primary paper. The review of these two papers must have attention paid to how these two papers related to each other. Like the last literature review, I had made sure that I found a pair of articles that were both in the provided library sources.

The assignment states that it is best to describe the secondary paper first, as it will be easier to compare it to the primary paper that cites the secondary one. The secondary paper that was chosen for this assignment was ‘Super-Helices for Predicting the Dynamics of Natural Hair’ written by Florence Bertails, Basile Audoly, Marie-PauleCani, Bernard Querleux, Frederic Leroy, and Jean-Luc Leveque. The computer graphics matter that this paper discusses to great length is three dimensional object rendering for the purpose of animation; specifically, simulating human hair.

The goal of the paper, is to show that the Kirchhoff equations for dynamic, inextensible elastic rods can be used for accurately predicting hair motion. A novel model for solving the Kirchhoff equations is introduced, and each strand of simulated hair is represented by a super helix, i.e. a piecewise helical rod which is animated using the principles of Lagrangian mechanics. Large time steps are allowed due to resulting in a realistic and stable simulation. Then the paper goes on to discuss an in-depth validation of the super helix model, carried out through a series of experiments based on the comparison of real and simulated hair motions. A high level of realism from the simulated model is shown with a wide range of hair types. This paper issues the problem of accurately modeling hair dynamics while keeping the computational costs of such a model reasonable. The model in this paper is set up using studies from the field of cosmetics on the physical properties of real hair. This allows for realistic simulations to be yielded.

For the purpose of hair rendering, this model relies on the structural and mechanical features of real hair to achieve realism. This is achieved by looking towards the Kirchhoff equations for dynamic rods, which are integrated in time thanks to a new deformable model that is named, super helices. A hair strand is modeled as a continuous, piecewise helical rod, with an oval to circular cross section. This paper uses the degrees of freedom of this inextensible rod model as generalized coordinates, and derives the equations of motion by Lagrangian mechanics. Due to this, the deformable model used here is able to handle a wide range of natural hair types. While the computaions of such a model are no more expensive than those of recent hair models presented in computer graphics.

The paper then goes on to discuss the model being simulated for the use animating realistic three dimensional hair, super helices. These models have a tunable number of degrees of freedom, and are built upon the Cosserat and Kirchhoff theories of rods. A rod is defined as an elastic material that is effectively one dimensional, its length is much larger than the size of its cross section. Simulating a full head of hair using a mass of super helices to represent the individual hairs, requires an efficient and accurate scheme for handling hair to hair and hair to body interactions. Detection of these is efficiently processed by exploiting temporal coherence. Contact between hair volumes, or super helix volumes, are handled by dissipative penalty forces. The super helix model is used to animate sparse strands that define global hair motion, and a new scheme is proposed for convincingly modeling a hair assembly from this sparse set of strands. Then this model was compared against examples of experiments on real hair, to demonstrate that the super helix model accurately simulates the motion of hair.

Super helices are concluded to take into account important hair features such as the natural curvature and twist of hair strands, as well as the oval shape of their cross section. A rigorous validation of their model was presented to stress on the powerful representation of moving hair by super helices; which is supported by a series of comparative experiments on real hair. It is also noted that Super-Helices are able to achieve realistic motions at a very reasonable computational cost.

This article was a source used by my primary paper for this literature review, 'Real-Time Interactive Tree Animation' written by Ed Quigley, Yue Yu, Jingwei Huang, Winnie Lin, and Ronald Fedkiw. In this article a novel method for posing and animating botanical tree models interactively in real time is presented. Whereas other methods of animated trees models produce trees that are overly flexible, the approach displayed here allows for arbitrarily high stiffness while still maintaining real-time frame rates without spurious artifacts, even on quite large trees. This is done by using an articulated rigid body model with as-stiff-as-desired rotational springs in conjunction with our newly proposed simulation technique, which is motivated both by position based dynamics and the typical O(N) algorithms for articulated rigid bodies. This method is amenable enough for the incorporation of a large variety of desirable effects such as, wind, leaves, or collisions.

The contributors to this paper designed a new method for efficiently solving articulated rigid body systems where joints can be arbitrarily stiff as they are in the case of trees, especially those with thick trunks and branches. Using the analytic solutions to the spring dynamics equations in order to model rotations about joints this method is realized. This new proposed approach for the simulation of trees as systems of rigid bodies articulated by stiff joints via approximations that permit an analytic treatment of joint springs is discussed with how it is effected by various factors, as well as this approaches utility of efficiently simulating tree models with many degrees of freedom.

As various parts of a tree are modeled as a series of conical frustums obtaining a piecewise linear approximation of the curved branch, a leaf is represented by a thin triangular prism allowing us to approximate it as a triangle for interactions with the wind. Fruits are treated as spheres in order to utilize efficient collision detection techniques. For each rigid body that makes up this model, we compute external forces and torques due to gravity, user mouse input, collision penalty forces, wind forces, etc. This algorithm makes use of composite rigid bodies, which are defined for each rigid body by rigidifying the entire outboard subtree emanating from that body inclusive of the body itself. In addition to outer forces such as wind, another variable that needs to be taken into account is collisions with other objects. For example, when the torque on a fruit’s joint exceeds a certain threshold, the joint is broken and allows the fruit to fall away from its branch as a non-articulated rigid body.

For this approach to by reliable, it needs to work in real time animation; it does this by having a posing system. One of the major benefits of real-time simulation is the ability to quickly, iteratively tune parameters in order to obtain desirable motions for the many degrees of freedom. This tree modeling approach lends itself well to such an approach. This approach works so well that it was incorporated into the Unity game engine and could be run interactively on a low budget tablet. An interactive interface was created that allows for the manipulation of spline curves via control points in order to set the stiffness and damping values for the parent joint of a tree branch based on the branch’s radius. Editing these splines let a user alter the extent of bending and other movement in response to external stimuli. While this interface can run in real time for trees with ten thousand branches, this system is also useful for the interactive tuning of trees that are too big to be simulated in real time.

The two articles that I chose to cover are related in the fact that both of them make use of approaches that simulate the movement of complex 3d models using realistic physics to make realistic animations of what they are modeling. My primary article shows an approach of how to animate models of trees that appropriately demonstrate how trees realistically move. My secondary article shows an approach of how to animate human hair that appropriately demonstrate how a head of hair can realistically move.

Sources Cited

Real-Time Interactive Tree Animation


```
@ARTICLE{7836345,
author={E. Quigley and Y. Yu and J. Huang and W. Lin and R. Fedkiw},
journal={IEEE Transactions on Visualization and Computer Graphics},
title={Real-Time Interactive Tree Animation},
year={2018},
volume={24},
number={5},
pages={1717-1727},
keywords={Computational modeling;Deformable models;Heuristic algorithms;Mathematical
model;Real-time systems;Springs;Vegetation;Computer graphics;botanical tree;physically-based
modeling},
doi={10.1109/TVCG.2017.2661308},
ISSN={1077-2626},
month={May},}
```


Super-helices for predicting the dynamics of natural hair


```
@article{Bertails:2006:SPD:1141911.1142012,
 author = {Bertails, Florence and Audoly, Basile and Cani, Marie-Paule and Querleux, Bernard
and Leroy, Fr{\'e}d{\'e}ric and L{\'e}v\^{e}que, Jean-Luc},
 title = {Super-helices for Predicting the Dynamics of Natural Hair},
 journal = {ACM Trans. Graph.},
 issue_date = {July 2006},
 volume = {25},
 number = {3},
 month = jul,
 year = {2006},
 issn = {0730-0301},
 pages = {1180--1187},
 numpages = {8},
 url = {http://doi.acm.org.umasslowell.idm.oclc.org/10.1145/1141911.1142012},
 doi = {10.1145/1141911.1142012},
 acmid = {1142012},
 publisher = {ACM},
 address = {New York, NY, USA},
 keywords = {Cosserat model, Lagrangian dynamics, hair modeling, physically-based
simulation},
}
```