Overview

- A brief introduction to CS 277 @ Stanford
- Core topics in haptic rendering
- Use of the CHAI3D framework
- Development of homework assignments
- Haptic rendering course projects
CS 277
Experimental Haptics
2002-2012 @ Stanford
CS 277: Experimental Haptics

- Really a haptic rendering course
- Has its roots in the computer science department, but we get a good mix of students
- Workload is 4 programming assignments plus open-ended course project
- Students usually design a game, but other projects, including mechanisms, are encouraged
THE FOUNDERS

F. Conti  
J. K. Salisbury

AND THE TORCH BEARERS

F. Barbagli  
C. Sewell  
D. Morris  
S. Chan  
A. Leeper
Core Topics
in Haptic Rendering
Teaching Haptic Rendering

- Identify key computational algorithms and data structures required for haptic rendering
- Present the algorithms in a progressive, coherent, and consistent style
- We’ve settled on a syllabus that roughly follows historic progression
Proxy-Based Rendering

- God object & proxy rendering algorithms
- Implicit surface representations
Haptic Rendering « Tricks »

- Surface properties
- Friction
- Texture
- Underactuated rendering
- Device workspace management
Collision Detection

- Intersection tests for primitives
- Spatial partitioning
- Bounding volume hierarchies
Dynamics Simulation

* Laws of motion
* Time integration
* Mass-spring models
* Modelling dynamic & deformable bodies
Six Degrees of Freedom

- Penalty force / dynamic proxy methods
- Constraint-based methods (6-DOF god object)
Event-Based Haptics

- Human vs. device bandwidth
- Open-loop playback
- Synthesized and sampled transients
A Course Text?

- We distribute key papers as readings
- Lin & Otaduy appear to agree with our selection of core topics
- Text is a collection of many seminal papers
- Is it mature enough?
The end!

CHAI 3D

www.chai3d.org
Excellent Teaching Aid

- CHAI3D was developed at Stanford in conjunction with CS 277
- Both platform and device agnostic
- Reduces image/geometry manipulation and graphical rendering burden
- Can be a double-edged sword!
CHAI3D can do a lot...

- Implements direct rendering, god-object, force shading, friction, surface effects, mesh structures, collision detection, mass-spring simulation, etc.
...but has its drawbacks

- Can be difficult for someone not versed in object-oriented programming in C++ to ramp up
- Code internals could be much more pedagogical
- It already implements most of the concepts we’re trying to teach!
To use or not to use?

- One solution is to distribute a reduced CHAI3D
  - Device communication and basic graphics

- Alternatively, design assignments that exercise key concepts but are not implemented in CHAI3D
  - Can be difficult! (and gets trickier every year...)
Pedagogical Exercises

- Use it or lose it!
- We converged on 1-2 week assignments
- Covers a good cross-section of haptic rendering
- Challenge: CHAI3D already has implementations of all the key algorithms!
  - Extensions to CHAI3D?
The Novint Falcon

- A huge boon for teaching our course!
- Every student takes one home on loan for the quarter
- Inexpensive and virtually indestructible
Potential Fields

- Force field rendering
- Experience pop-through problems
- Attractive fields
- Identify stability limitations
Proxy-Based Rendering

- Implicit surface rendering algorithm
- 3-DOF planar constraint tracking
- Virtual spring
- Coulomb friction effect
Surface Effects

- Force shading
- Barycentric normal interpolation
- Texture-mapped surface effects
- Image gradients for normal modulation
Collision Detection

- Point cloud scene representation
- Metaball implicit surface
- k-D Tree to find points within support radius
Deformable Objects

- Mass-spring system
- Penalty force model
- Time integration
- Stiffness vs. stability
One device for each hand makes the game more displayed for each haptic device, and each device turning it into a 2-handed game. One avatar is for each of the drums drop into view. When a

Every time the avatar hits the top of one of the notes are played, the higher the score. Almost which simulate playing an instrument. Notes Rhythm games are a popular genre of games all rhythm games available currently require a

The haptic tool position is locked into place until a determined that at least one of the points of the saw has voxels arranged into the shape of a cylinder. When it is haptic rendering library and a Novint Falcon haptic

Overview

Fig 2. A momentum pulse, illustrated in blue, is "Visuohaptic Simulation of Bone Surgery for Training and Evaluation", D. M.D. Tsai, Y.D. Yeh, Oct. 2005

"An amputation simulator with bone sawing haptic interaction", M.S. Hsieh, using voxels also allows for easy rendering of the tree and the distance by which the saw moves after size. Pressing 1 and 2 will increase and decrease the tree and the distance by which the saw moves after strength of each voxel in the tree, making the tree harder

Pressing 3 and 4 will increase and decrease the point quad. In addition to simulating the visual and haptic aspects of sound

Implementation: Sound

pitch and volume of each incremental sawing sound are

tree  and  the  distance  by  which  the  saw  moves  after

stabilization

In addition to simulating the visual and haptic aspects of

Realistic Slicing Sensations using Haptics

The goal of my project is to accurately model the forces involved when slicing through various deformable objects using a knife. The feeling of

The technique we encountered, and got a lot of experience with the problems that haptics researchers often experience. Although I didn't get as realistic an

unstable. A lot of my effort went into attempting getting the objects to be simulated well took some effort, but addressing stability and the since the cylinders are stacked vertically there are different forces act on the tool

difficult objects like oranges and eggs. The player

Player battle for galactic domination! Using his sinister

Client handles the haptics loop and object about new objects to all players. Since every play.

The game supports up to 16 players in network play with your friends!

'仲' finished pot can be selected by pressing 'a', and

and

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different sounds for the rotating

Different tools we

HAPTIC RENDERING COURSE PROJECTS

A SMALL SAMPLE FROM 2008-2011
Fair Warning

- Open-ended projects require extremely heavy guidance from the instructors!
- Most students learn just enough to get into trouble, but not enough to get out...
- This selective sample of excludes many a misguided project
Crosscut Saw Simulation

Implementation: Graphics

Collision detection and rendering of the tree were implemented using voxels and point quads.

Implementation: Sound

Sawing sounds are played depending on the location the saw gets stuck in the tree and the distance by which the saw moves after penetrating the surface of the tree, a set of points representing the tip of each blade on the saw were defined relative to the position of the haptic tool in the graphical environment. To allow fast collision detection between the saw points and the tree, a set of voxels arranged into the shape of a cylinder. When it is determined that at least one of the points of the saw has penetrated the surface of the tree, the projected point of the saw is moved in the direction of the number of voxels intersected by the points of the saw. If the projected point is moved far enough, it is considered to be through the tree, and the resulting value is larger than some predefined voxel strength of each voxel in the tree, making the tree harder to saw. The cuts made to the tree can be reset by pressing P.

User Input

Pressing 1 and 2 will increase and decrease the pitch and volume of each incremental sawing sound are randomly tweaked from the source sound file. Destroying a set of voxels. To vary the sawing sound, the portion of the forward or backward sound tracks were played depending on the location the saw gets stuck in the tree.

Implementation: Haptics

User forces are determined by the distance of the tool from the haptic tool position is locked into place until a significant enough force is applied to the haptic device to destroy the voxels intersected by the projected point. To determine when the user has applied enough force to destroy the voxels intersected by the projected point of the saw. To determine when the user has penetrated the surface of the tree, the projected point of the saw is moved in the direction of the number of voxels intersected by the points of the saw. If the projected point is moved far enough, it is considered to be through the tree, and the resulting value is larger than some predefined voxel strength of each voxel in the tree, making the tree harder to saw. The cuts made to the tree can be reset by pressing P.

References:


"Visuohaptic Simulation of Bone Surgery for Training and Evaluation", D. M.D. Tsai, Y.D. Yeh, Oct. 2005


John Jessen

11 March 2010
Haptic Pottery

Pottery is made by deforming clay into objects of different shapes. We have implemented three different tools they can use to curve out different shapes. Starting with cylindrical mount of clay, the player tries to shape it similar to real pottery. There are various uses the falcon to touch the surface of clay and the point tool to select the level. The game mechanics challenge the player to achieve that using the cylindrical tool curves out larger area easily and makes very narrow groove in the pottery. We simulate pottery by using the falcon to haptically interact with the clay on the pottery wheel. A variety of sound effects add more realism to the graphic experience.

Techniques

The Cylindrical Element Method (by Han, et al.) is used to simulate the electric motor under the background. We also use SDL sound library to use to render the pottery and its background environment. The score measure is always played in the background. The sound effects add more realism to the graphic experience. The haptic pottery has a free form mode and a game mode experience. The haptic pottery is a single person game for pottery enthusiasts to get "hands on" with the art of pottery making. Players use the falcon to haptically interact with the clay on the pottery wheel. A variety of sound effects add more realism to the graphic experience. The haptic pottery has a free form mode and a game mode experience.
Haptic Toothbrushing

Explicit Euler Integration is performed.

from the bristles (F<br
Law, given the two forces applied on it: the force<br
step, the position of the brush is updated by Hooke<br
with a damping component (Figure 2). In each time<br
brush (center of mass) and the real device position<br
A virtual coupling spring is added between the virt<br
2.

I extended CHAI3D<br
1.

Algorithms behind the Brush<br
the teeth. User can rotate the device as they like.<br
brush realistically turn and bend as they interact<br
Novint Falcon! The body and bristles of the tooth<br
brushing the virtual teeth with our favorite device<br
Haptic Toothbrush offers the exciting experience<br
and the force from the coupling spring<br
exerted on it: one resulted from F<br
every time step, from the sum of the two torque

The orientation of the toothbrush is updated, in<br
updates the proxy, and computes the contact force.<br
algorithm detects if the bristle penetrates the too<br
represent the end points of each bristle. God-objec<br
toothbrush mesh with 6 3dofPointers attached which

Virtual Coupling Force & Torque

Multiple Interacting Points (god-object)

\[ F_{\text{bristle}} = r \times F_{\text{brush}} \text{, and the other} \]

\[ F_{\text{attachment}} + F_{\text{spring}} \]

\[ F_{\text{surface}} = k_b (L - L_0) - b_p V. \]

Reference:
[1] CHAI3D
[2] DAB: Interactive Haptic Painting with 3D Virtua

SAMMY LONG
Lock Picking Simulation
Summary

- Identified core topics in haptic rendering
- Discussed use of CHAI3D for teaching
- Examined pedagogical haptic rendering exercises
- Reviewed a sample of course projects
Thank You!

Questions?
http://cs277.stanford.edu