CSCI 5611 Instr.: Guy

Project 2: Physically-Based Animation with PDEs

Project Due: Fri., Oct 20

Overview. This assignment focuses on using numerical integration to simulate physical systems that follow well-known rules. Our focus will be on phenomena that are well described by simple Differential Equations (ODE & PDEs), such as physically-based models of rope, cloth, and water.

You may work with a partner, just one project turn-in needed per pair. You cannot repeat your partner from Project 1.

Part 1: Rope/Cloth Simulation [up to 90 points undergrad / up to 100 points grad]
You will need to write a rope/cloth simulation of multiple threads interacting with their environment in a smooth and natural fashion. Choose from the below features to receive full credit; required components are indicated with a star (*).

Multiple Ropes (at least 2D)* (up to 45 points).
Extend the rope implementation shown in class to support multiple independent ropes, which all hang and swing freely. The ropes need to support one-way interaction with an obstacle (e.g., a circle) by falling naturally onto the obstacle. To achieve all of these requirements, your implementation must produce smooth, natural-looking swinging behavior. Obtaining this desired behavior will require tuning your simulation parameters carefully, so be sure to allocate time for this step!

Cloth Simulation (up to 20 points).
Extend your rope simulation to include horizontal springs that bind ropes to each other in order to create a complete cloth simulation. The cloth should be able to interact with an obstacle (e.g., a ball) in a one-way manner by naturally falling onto the obstacle. To achieve all of these requirements, your implementation must generate smooth, realistic swinging behavior. Tuning your simulation parameters will be necessary to obtain this desired behavior, so please allocate time for this step. *[This will also count as multiple ropes, meaning cloth sim totals up to 65 points.]*

3D Simulation (up to 10 points).
Update your rope or cloth simulation to be in 3D. To earn full points, your simulation should have smooth 3D motion and a natural camera that allows the user to navigate around the scene from different angles and positions.

High-quality Rendering (up to 5 points).
Use a high-quality 3D rendering with a natural camera that allows the user to navigate around the scene from different angles and positions. For full credit, you must use texturing and 3D lighting to create a compelling rendering.

Air Drag for Cloth (up to 10 points).
Include an air drag and wind terms in your cloth simulation using the method discussed in class. Show video results comparing the simulation with and without drag to demonstrate the effect drag has on the motion. Also, show video results demonstrating varying amounts of wind.

User Interaction (up to 5 points).
These points come from allowing the user to interact directly with the simulation itself (not from controlling the camera). To receive full points, the user should have a clear, smooth, and natural way to interact with the ropes/cloth. Discrete interactions, such as toggling some behavior on/off, will only receive a couple of points. Look for continuous interaction, such as allowing the user to move an obstacle with the mouse.
[If you simulate additional systems (such as fluid or rigid bodies) you can implement the user interaction on those simulations instead.]

Realistic Speed (up to 5 points).
Match your simulation to a reference video of your choice (e.g., hold one end of a thread and time how long it takes for the other end to drop). If your simulation moves as quickly as real threads or cloth, you'll get full credit. Slightly slower simulations will receive partial credit. *Note, this is challenging for cloth!*
[If you simulate additional systems (such as fluid or rigid bodies) you can demonstrate realistic simulation speeds on those simulations instead.]

Ripping/Tearing (up to 10 points).
Rip or tear the cloth/rope when the forces get too large. Note: this looks very cool, you should try it. =)

Self-Collisions (up to 10 points for cloth, 5 points for rope)
Detect and respond to self-collisions between different parts of a single piece of cloth or rope.

Rope-rope Collision (5 points)
Detect and respond to collisions between multiple different ropes (or multiple separate pieces of cloth).

Part 2 - Challenge: Additional Simulation
An additional challenge simulation is required if you are a graduate student, and it is optional for undergraduates. If you complete the challenge, you will receive a 72-hour extension on the project. For the challenge simulation, you must complete an additional physically-based simulation (apart from cloth/ropes). Three options are:

Continuum Fluid Simulation (up to 30 points (grad), 20 points (undergrad)).
Using a continuum, PDE-based fluid simulation method, such as the Shallow Water Equation or Stable Fluids, to create a 1D or 2D water simulation. For full points, the

fluid in the simulation should flow smoothly, execute in real-time, and be rendered to look like actual fluid. Additionally, the fluid simulation should be placed in some context, such as a larger scene, or interact with other objects.

SPH Fluid Simulation (up to 30 points (grad), 20 points (undergrad)).
Using an SPH-based method, create a 2D water simulation. For full points, the fluid in the simulation should flow smoothly and execute in real time. Your SPH simulation can be rendered as large points or spheres, rather than a continuous fluid surface. For full points, the simulation should be well-tuned to move like fluid. Additionally, the fluid simulation should either be placed in some context, such as a larger scene or interact with other objects.

2D Rigid Body Simulation (up to 30 points (grad), 20 points (undergrad)).
Rigid body simulations of multiple boxes/rectangles interacting through collisions with each other and the ground. For full points, the simulated boxes should move smoothly, interact naturally, execute in real time, and not excessively jitter. Additionally, the objects in the simulation should be placed in some context that provides meaning beyond an abstract simulation.

Extra credit will be provided for well-working 2D shallow water, SPH that has two-way coupling interaction with obstacles, 3D rigid body simulation, or simulations that combine fluid dynamics with cloth or rigid bodies in an interesting way.

Note: All three of the challenge simulation options are hard! Do you best, and just try to start by getting some of the basics working. It's okay to turn in a simulation that doesn't work very robustly, you'll still get partial credit.

Art Contest
If you generate a pretty image (even by accident), save it to submit to the class art contest. A pool of honorable mentions will be given 2 points, and the grand winner gets 5 points. All winners will be chosen *completely subjectively*.

Project Report & Video* (10 points).
Your submission must be in the form of webpage with:

- Images of your physical simulations
- A brief description of the features of your implementation and timestamp of where they occur in your video(s).
- Code you wrote
- List of the tools/library you used
- Brief write-up explaining difficulties you encountered
- One or more videos showcasing features of your simulation
- Submission for the art contest (optional)

These 10 points for the submission itself will be based on the clarity of expression of the report, and to the degree which it quickly communicates what you tried, what worked well, and what didn't. Be sure to use full sentences in your report.

Additionally, each feature you expect to get credit for must be documented in your submission videos in a way which clearly shows the resulting behavior. If you do not show a feature in your submission video(s) you will not receive credit for it.

Grading Criteria
Simulations must animate well and look convincing to get full credit. Partially implemented features will receive partial credit. Points past those needed for full credit will count as extra credit, though at a discounted rate (see Scoring below). If you do other things that you think are cool and worth credit let me know beforehand and be sure to document them in the report.

Use of other code and tools
Anything you are getting credit for must be code you wrote for this course. You must write the code for the simulation yourself! External libraries may be used for aspects that are not related to simulation (e.g., rendering, camera motion, video capture) just be sure to document that you used these.

Partners & Groups
You are strongly encouraged to work in pairs for the project. Each pair should turn in only one assignment. Both people will be given the same grade. You cannot repeat the same partner from a previous project.

Project Scoring
Undergrads need 100 points for full credit (e.g., 90 form part 1 + 10 from the report, or 70 from part 1 + 20 from part 2/challenge + 10 from the report), though you may choose to submit up to 120 points of work, subject to the following limits:
90 for part 1 (rope/cloth)
20 for part 2/challenge
10 for the report
… if you submit more than the limit, we will grade a random subset.

Graduate students need 120 points for full credit, though you may choose to submit up to 140 points of work, subject to the following limits:
100 for part 1 (rope/cloth)
30 for part 2/challenge
10 for the report
… if you submit more than the limit, we will grade a random subset.

Partial credit will be given. Scores computed as follows (points above 100 possible):
-*Undergraduate*: Grade is √(totalPoints * 100) [e.g., 100 points will be full credit]
-*Grad students*: Grade is √(totalPoints * 84) [e.g., 120 points will be full credit]

*Extra credit will only be given to assignments with at least an A- on the required features.