Using An Interactive Simulation To Teach Centripetal Force

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A Virtual Environment

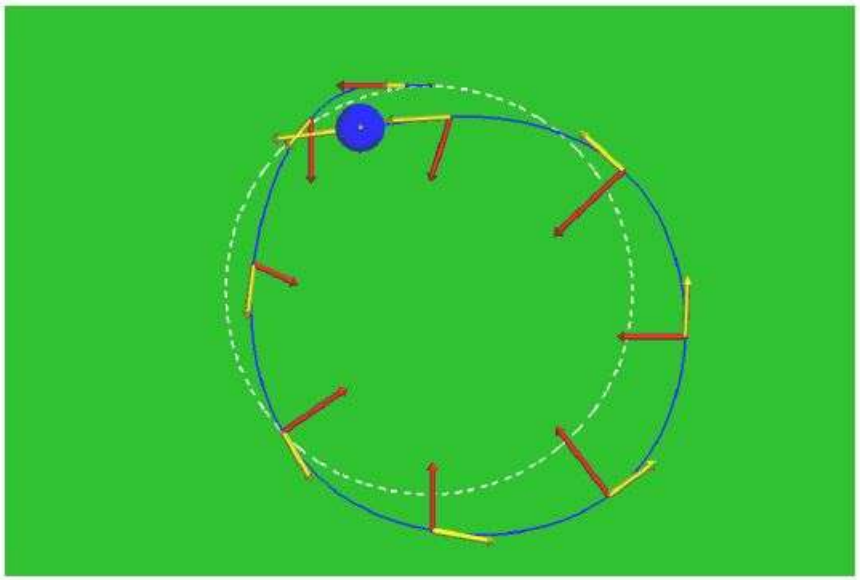
- We are developing a number of physics simulations using 3D graphics.
  - support for stereoscopic 3D viewing
  - movable “camera” in the Virtual Environment (VE)
  - multiple input options, including joystick
  - flow of time can be slowed down, sped up
  - dynamic interaction with simulated objects in real time
  - physical properties of simulated objects are easily changed

Exploring the Virtual Environment

- Our simulations are designed to allow students to explore and discover physical phenomena, rather than serving as demonstrations of externally asserted rules.
  - basic physics is programmed in but students can, for example, apply whatever forces they wish at any time
- In associated curriculum, we ask students a question and they are free to see what works and what doesn't.
  - because of the openness of the VE, they will be able to look for answers in an active “doing” mode instead of a passive “watching” mode
  - when they expect something to work, but it doesn't, they will experience cognitive conflict and, hopefully, learn

Circular Motion Simulation

- Motion in a horizontal plane. External force (magnitude and direction) is applied with the joystick.
  - realtime interaction with the joystick and the sensation of "pushing" is what makes this simulation engaging
- Displays a "trail" showing path and applied forces.
  - upon success, the "central force" idea is clearly seen



First Trial: A Lecture Demo

- This simulation was presented to a calculus-based intro class as a lecture demonstration.
  - lecturer did an example run, during which the force vectors were turned off so as to not give away the answer
  - class was polled for ideas: how to move it along a circle?
  - two volunteers with opposing ideas went to the front of the room to test them, and the class chose a "champion"
- Student response and interest during the demo was excellent. They laughed, cheered, etc..
- In their weekly survey, most students said the sim. was helpful, and that they would like to see more.

Classroom Implementation

- For the spring term, we designed three new labs which make use of our VR simulations.
  - two were modifications of existing labs
  - the circular motion lab was designed from scratch
- The course is the first term (mechanics) in our standard Calculus-based intro sequence. (N ~ 240)
- Evaluation for the new labs was based on answers to relevant FCI questions, a set of in-house diagnostic questions being developed for this project, and an open-ended survey. The in-house diagnostic emphasizes the sensations of force *felt by the student* during everyday or imaginary experiences of motion.

Circular Motion Lab

- All the VR labs involve parallel or analogous experiments in both the virtual setting and with real equipment in the lab room.
- As a real-world analogue to the simulated ball with perfect force-at-a-distance, we used metal bearings and “pucks” made out of checkers for the low and high friction cases.
- Students investigate zero, low, and high friction cases in an attempt to bridge abstract physics knowledge (“central force”) to real world experiences where the applied force needs a forward component to maintain a circular path.

Results

- Although some effects were seen in diagnostic scores for the 1-D Motion lab, for the most part we were unable to detect any unusual changes in conceptual understanding. Some contributing factors:
  - the intervention was small; the Circular Motion lab was written to fill a “spare” half-lab period
  - the number of diagnostic questions was small; only one FCI question was directly relevant, and only three additional questions for this topic were ready in time for testing; further, one of these questions had unforeseen complications regarding static vs rotating reference frames

Results, cont.

- In surveys, students ranked the VR labs fairly highly.
- 62% of respondents felt that use of the joystick helped them to understand the role of force in motion.
  - 13 students volunteered unsolicited comments that the circular motion lab was “especially” helpful

Future Work

- We are continuing to develop curriculum for the existing simulations, as well as additional simulations.
- A second full-scale implementation in a lab course is planned for late in the coming school year.
- We are also refining and expanding our in-house diagnostic in order to better address students' experiences with force.