Abstract
The Tracker video analysis program allows users to overlay simple dynamical models on a video clip. Video modeling offers advantages over both traditional video analysis and animation-only modeling. In traditional video analysis, for example, students measure "g" by tracking a dropped or tossed ball, constructing a position or velocity vs. time graph, and interpreting the graphs to obtain initial conditions and acceleration. In video modeling, by contrast, the students interactively construct theoretical force expressions and define initial conditions for a dynamical particle model that synchs with and draws itself on the video. The behavior of the model is thus compared directly with that of the real-world motion. Tracker uses the Open Source Physics code library so sophisticated models are possible. I will demonstrate and compare video modeling with video analysis and I will discuss the advantages of video modeling over animation-only modeling.

The Tracker video analysis program is available at: <http://www.cabrillo.edu/~dbrown/tracker/>.

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Introduction: definitions

1. Video Analysis: measure and/or analyze image features in a video
2. Simulation Modeling: construct and/or analyze interactive dynamical model simulations
3. Video Modeling: construct and/or analyze simulation models overlaid on a video

Video analysis

1. Most commonly used video analysis programs in US physics education: Tracker (free), VideoPoint & Logger Pro (commercial)
2. Tracker web site and features
   a. Free video analysis application
   b. Motion analysis: position-based data
   c. Image processing: RGB-based data
   d. Project of Open Source Physics (OSP)
   e. Uses Java, XML and QuickTime
   f. Exercises posted on BQ database
3. Typical tasks using Tracker (Ball Toss)
   a. Set up experiment
   b. Capture digital video
   c. Calibrate (set scale and reference frame)
   d. Mark points with mouse
   e. Motion vectors
   f. Plot y-t and vy-t
   g. Analyze with Data Tool (curve fit to y-t data)
   h. Compare with predictions
4. Simplifying options: use existing videos, pre-calibrate, pre-mark
5. Typical activities: lab experiments, independent/group activities, homework, interactive demonstrations
6. Advantages
   a. Built-in time base
   b. Videos are familiar (accepted as reality) and often of interest to students (friends, cars, sports, dancers, etc.)—especially if shot by the students themselves
   c. Videos widely available on-line
   d. Can be interactive: connects observations directly to kinematics graphs (move data point, see effect on plot)
   e. Results easily shared and reported
   f. Videos may show non-physical behaviors
7. Disadvantages
   a. Image is measured, not real object (calibration is prone to errors)
   b. Marking can be tedious
Simulation modeling

1. Many simulation packages are used in introductory physics education. Four examples: Physlets, PhET, EJS, spreadsheets

2. Typical tasks using ready-made models (images of Physlet, PhET)
   a. Predict behavior
   b. Measure behavior and compare with predictions
   c. Vary parameters
   d. Plot and analyze behavior in more detail

3. Additional tasks using student-constructed models (images of EJS)
   a. Define variables and parameters
   b. Define evolution equations and numerical ODE solvers
   c. Define view (animation) elements

4. Advantages
   a. Game-like and potentially interactive
   b. Widely available on-line
   c. Exploring parameters gives insight into equations
   d. Some ready-made models activities are like experiments with idealized data, and closely related to problem solving
   e. Student-defined models introduce the process of modeling (what science is all about!)
   f. May model non-physical behaviors
Video modeling

1. Typical tasks (Projectile model)
   a. Set up experiment and capture digital video
   b. Calibrate (set scale and reference frame)
   c. Define particle model force equations
   d. Vary parameters
   e. Plot and analyze data
   f. Compare with video images and/or data

2. Expression parser accepts all common mathematical functions

3. Simplifying options: use existing videos, pre-calibrate, pre-define

4. Advantages
   a. Video advantages but without tedium of marking points
   b. Simulation modeling advantages--like EJS but without complication of defining
      ODE methods and animation view elements
   c. Focus is on forces, not just on the motion itself
   d. Model is compared with video image rather than (or in addition to) data (minute
      differences between model and video are easily seen)
   e. Videos give models life, models give videos meaning
Video analysis: beyond basics
1. Motion diagram using ghost filter (Motion diagram)
2. Multiple and extended objects: center of mass (Puck collision)
   a. Tumbling hammer
   b. Human motion
   c. 2D collisions
3. Reference frames, cm reference frame (Puck collision)
4. Rotational motion
   a. Pennies on turntable lab
   b. Tumbling hammer: one end relative to other
   c. Pucks colliding/sticking: conservation of angular momentum
5. Spectra
   a. Image of experimental setup
   b. Thermal spectrum
   c. Color filter spectrum
   d. Helium spectrum
   e. Fluorescent tube spectrum
6. EM: electron beam
7. Thermal/statistical physics
   a. Linear expansion via single-slit interference
   b. Random walks
8. Nuclear physics: alpha tracks (images)

Video modeling: beyond basics
1. Friction, viscous and drag forces (Cupcake drag model)
2. Copy/paste to duplicate/compare models (Cupcake drag model)
3. Support functions to simplify expressions (Cart pendulum)
   a. Functions become available for other functions
4. Discontinuous forces: "if" statements (Bouncing cart)
5. Pendulum model: an x-y challenge! (Pendulum with drag)
6. Data analysis: compare with marked data
Fall 2007 student modeling projects

1. Open-ended assignment: “Identify a mechanical system for which the behavior of the system can be (a) captured on video and (b) modeled as a set of one or more particles. Construct models, capture videos and compare”.
   a. Multi-week project in both lab and drop-in center
   b. Despite earlier modeling exercises (viscous/drag forces on cupcake cups) some students still confused “modeling” with “problem solving.”
   c. All students eventually understood the modeling process
   d. More direction on choosing a system would be beneficial—many groups initially chose systems that were too complex.

2. Student models included
   a. “Spring wars” cart oscillations with friction (Spring wars)
   b. Coffee filter monkey/hunter (Coffee filter monkey)
   c. Cart bouncing from a spring on a tilted air track (Bouncing cart)
   d. Ball hanging from an accelerating cart (Cart pendulum)
   e. Large-amplitude pendulum (Pendulum)
   f. Mass-spring system in oil or water (Ball in oil)

3. Student presentations
   a. Discussed process, not just final products
   b. Identified and estimated forces by visually comparing model with video
   c. Student questions from the floor showed critical evaluation of others’ models
   d. Video clips of presentations are posted at www.youtube.com (search for Cabrillo modeling lab) (see part 2 “Spring wars” intro)

Conclusion

1. Video analysis is an attractive option for labs, lecture demonstrations and other learning activities across many topics in introductory physics
2. Video modeling offers a new way to use videos and new opportunities for students to learn about dynamic particle modeling and forces
References

Web sites
Tracker: http://www.cabrillo.edu/~dbrown/tracker/
VideoPoint: http://www.lsw.com/videopoint/
LivePhoto Physics: http://livephoto.rit.edu/
Easy Java Simulations (EJS): http://www.um.es/fem/Ejs/
Open Source Physics (OSP): http://www.opensourcephysics.org/
BQ database: http://www.bqlearning.org/
Physlets: http://webphysics.davidson.edu/Applets/Applets.html
PhET: http://phet.colorado.edu/
Fall 2007 video modeling assignment:
http://www.cabrillo.edu/~dbrown/labs/VideoModeling.html
YouTube videos of Fall 2007 video modeling student presentations:
http://www.youtube.com/  (search site for “Cabrillo modeling lab”)