Artificial Video for Video Analysis.

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This paper discuses the use of video analysis software and computer generated animations for student activities. The use of artificial video affords the opportunity for students study phenomena for which a real video may not be easy or even possible to procure, using analysis software with which the students are already familiar. We will present three example activities: two lab activity "add ons" as well as a complete virtual laboratory exercise.

Video analysis has been proven a useful student activity for learning kinematics at the introductory level.[1,2,3] There are a variety of commercial and free applications that can be used for video analysis, including Videopoint[4] and Tracker.[5] The relevant technology has become inexpensive, video analysis has become a prevalent tool in introductory physics courses. There has also been an emergence of tools to create animations (in particular 3D animations) for use in physics instruction at reasonable cost and in reasonable time.[6,7] Thus we have new opportunities for creating novel curricular materials (artificial video) that students can analyze using familiar tools.

Our first example is a "What, if anything, is wrong" task following Hieggelke, Maloney, and O'Kuma's TIPERs (Tasks Inspired by Physics Education Research).[8] The students analyze a single video clip which shows four objects which are launched upward and "fall" back to the ground. A sample frame is shown in figure 1. The animation also includes a marker which can be used to set the video's length scale. Students are asked to identify which of the four objects do not follow our model for motion under the influence of gravity (i.e. constant acceleration downwards) and justify their answers based upon the results of their analysis. The video analysis software allows for curve fitting as well as plotting of velocity and acceleration based upon position data. Students most often use position data contrasted with a curve fit to a parabola to assess the motions of the objects. A composite graph for position versus time for typical data is shown in Figure 2. Students readily identify problems with the straight line trajectory of object C and the asymmetric curve of object D. The differences between the position curves for objects A and B are more subtle, but when the students look at the corresponding velocity graphs, such as in Figure 3, clearly only object B is undergoing motion with constant acceleration.

The students perform this brief exercise as part of our "gravity" lab which consists of 3 tasks: a measurement of the acceleration of gravity using a simple picket fence/photogate /computer experiment, measurement of the acceleration of gravity using video (some of which is created by the students using a simple digital camera in video mode) and finally our artificial video exercise. Students are asked to comment how well the motions of the objects in the first two exercises correspond to constant acceleration motion, using the computer generated graphs and curve fits created during those exercises the basis of their judgments. The final activity for the laboratory period is the analysis of the artificial video, which leads the students to consider more closely some the aspects of the model being investigated that day: motion under constant acceleration.

The second example involves projectile motion (motion in 2 dimensions with constant horizontal velocity and constant vertical acceleration) and is also a "What, if anything, is wrong" task. There are 4 separate videos each containing a single object following a two dimensional trajectory. Students are asked to identify which of the four objects best follows the model for projectile motion, and to identify a specific aspect of the motion of the other three objects which departs form that model. The trajectories

are designed so that students generally have to investigate more than one aspect of the motions to identify the problems with the deviant trajectories, that is, they can not easily deduce all the deviant trajectories by just examining the horizontal motions, or just examining the shape of the 2 dimensional shapes of the trajectories. In this series, object A follows the model for constant vertical acceleration. Object B's deviant trajectory is a circular arc traversed at constant speed. The remaining two deviant trajectories were crafted so that their trajectories do form parabolas in space; however the horizontal velocities are not constant. Plots of the trajectories are shown in Figure 4, while the horizontal and vertical components of displacement are shown in Figures 5 and 6 respectively.

The students perform this exercise as part of projectile motion lab which consists of 3 tasks: an analysis of a video created during the lab of an object tossed from one student to another, the artificial video analysis exercise and finally a conventional ballistic motion experiment with projectiles launched from spring powered launchers. The combination of exercises takes the students from an exploration of the model in the video exercises to extensively using the model to determine the launch speed of the projectile from the gun and predict landing distances in different launch configurations.

The final example is a virtual implementation of the Millikan Oil Drop Experiment. Silva and Mahendra have discussed the analysis of real video,[9] however the lack of apparatus locally precluded creating videos for student analysis. For the artificial video activity, students analyze several clips, each containing eight "oil drops".   The video view is taken form the vantage of looking through the microscope using a typical Millikan Oil Drop apparatus: a sample frame is shown in Figure 7. The simulation of the oil drop motion is based upon typical parameters found in typical student Millikan Oil Drop apparatus. Each video clip has a companion text file with the necessary physical parameters (such as oil density, air temperature, potential difference between plates, etc.) needed by the students to calculate the charge of the drops. A second companion text file intended for instructors also lists the actual quantization of the charges.

In the local implementation of this exercise, each student group works on a unique data set to determine the charge values; however each group assesses the quantization of charge from the collective data of all the groups. Although there are 360 frames for 18 seconds of video, only 5 or six measurements of drop position from video analysis are required to obtain very good determinations of the rising or falling velocities of the drops, allowing each group to obtain a substantial quantity of data, which in turn allows clearer portrayal of charge quantization.

Our implementation of the virtual Millikan Experiment has demonstrated the need for one caveat: it is possible to overestimate the level of detail that students can extract from a video. One semester the students were presented with "anomalous" videos, without any additional information as to what made the data different. These files were created to simulate charge quantized at the level of 1/3 e, presumably corresponding to the droplets containing bare quarks. The quantization when the instructor test drove the exercise was clear, however when the students performed this modified exercise, the additional error in their measurements was sufficiently greater so as to mask any charge quantization whatsoever. It was an interesting lesson in how, even with computer aided tools such as the video analysis software, some inexperience on the parts of students shows up as measurement noise.

These three exercises illustrate some of the potential for creative student activities made possible through the combination of computer generated videos and video analysis software. The use of artificial video allows the students to use familiar tools (the video analysis software) to study novel situations and the shallow learning curve of programs such as POV-Ray can provide instructors another avenue to be creative in developing curricular materials.
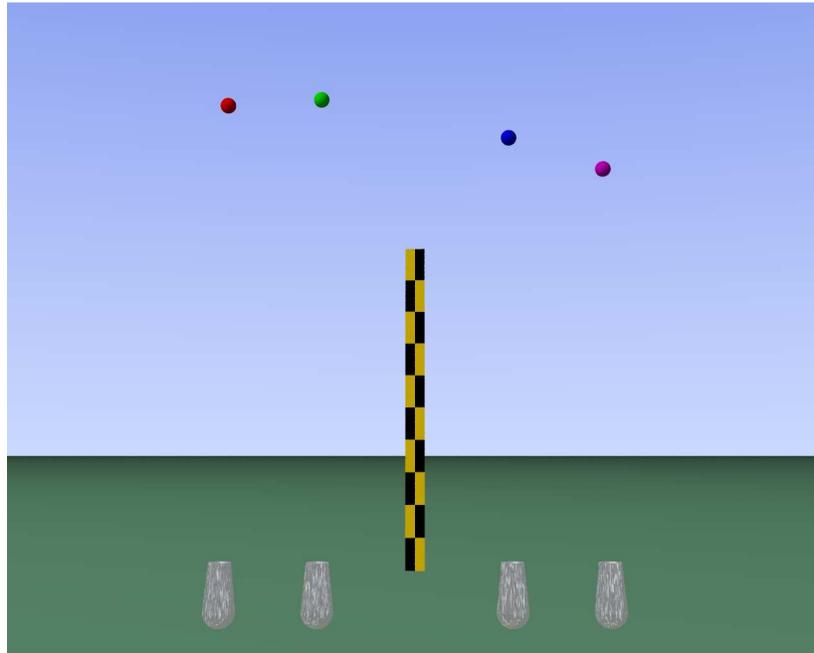
Figures

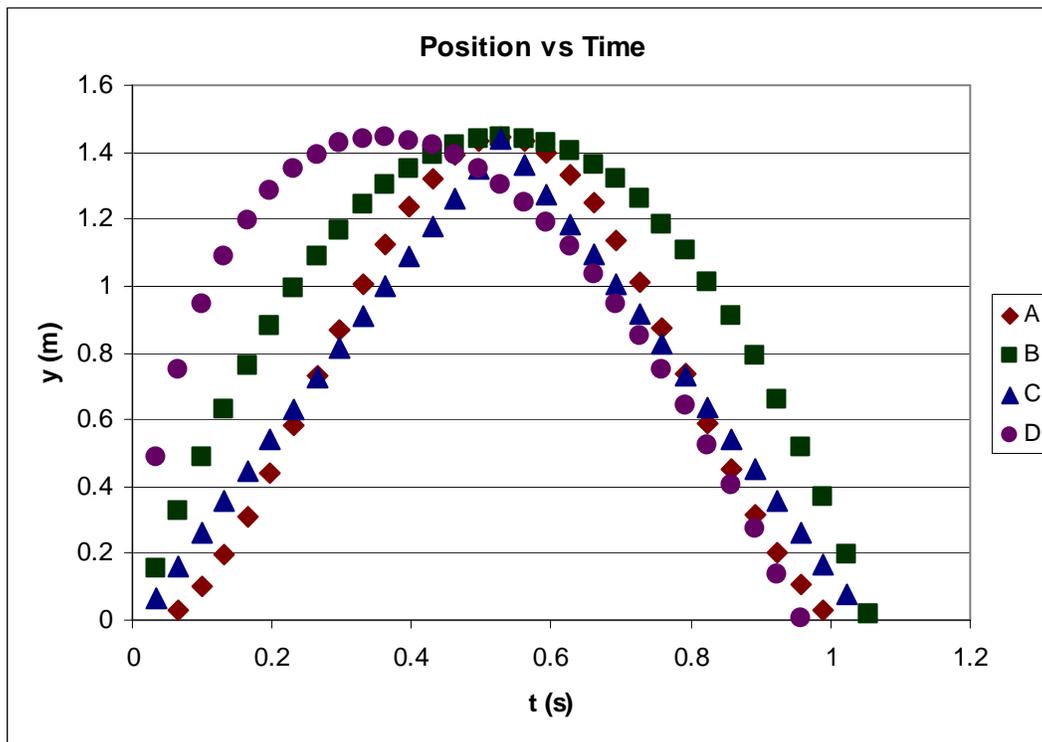*Figure 1: Sample Frame from Vertical Motion in 1D Video*

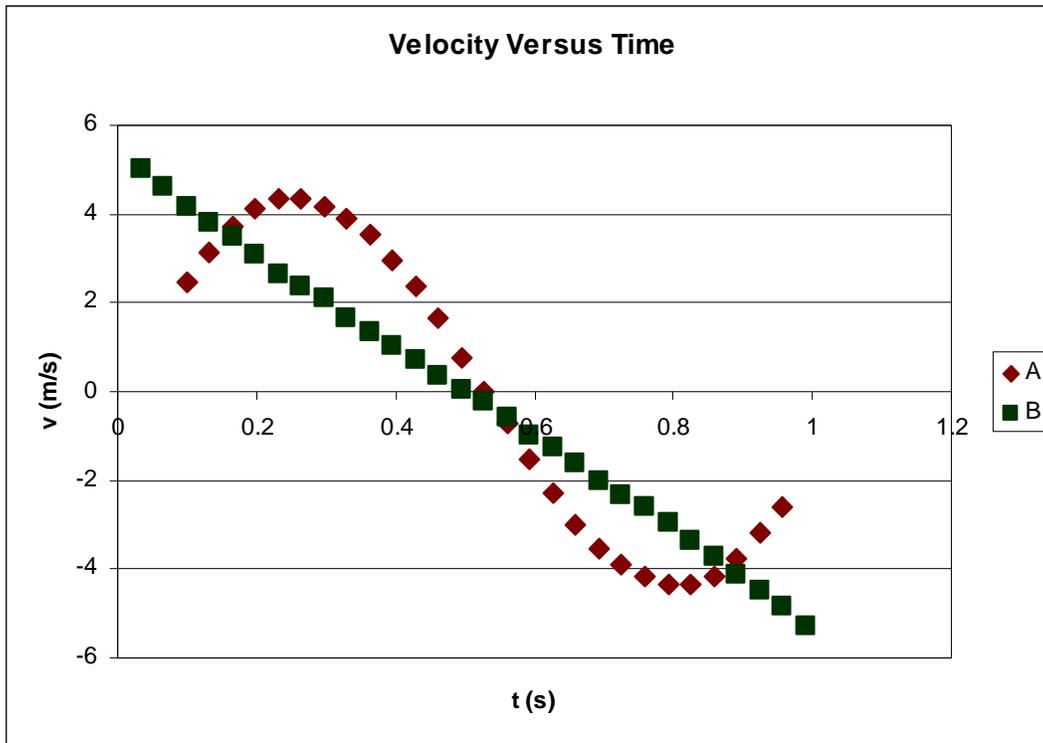*Figure 2: Position versus time data from 1-D motion artificial video*

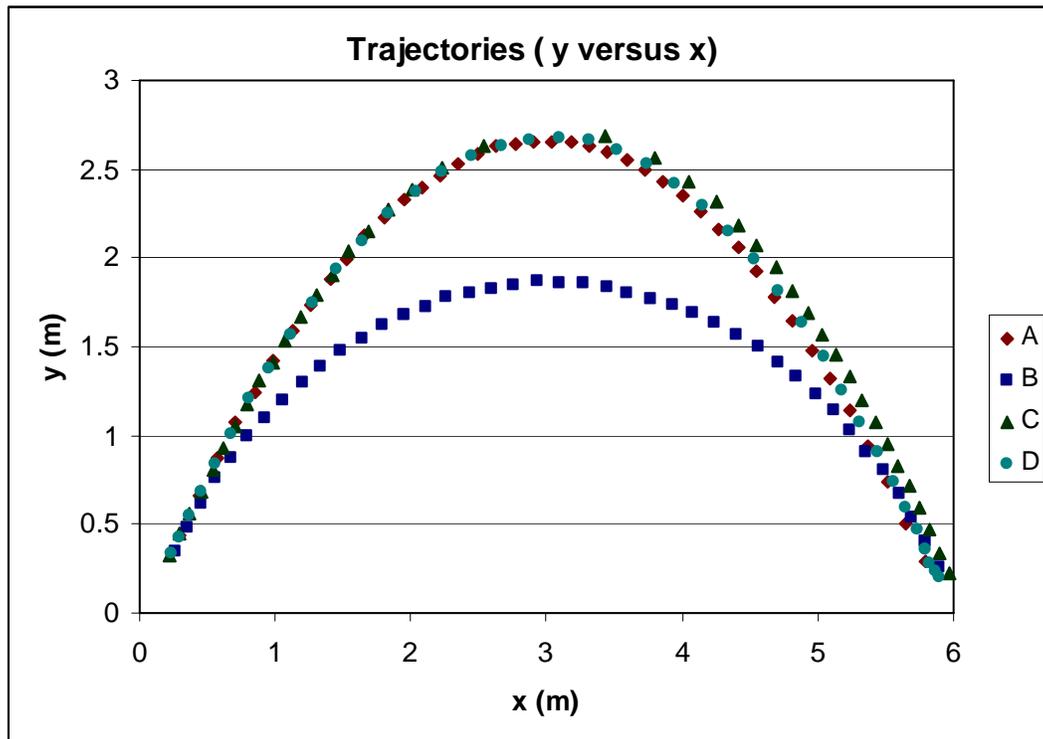*Figure 3: Velocity versus time data from 1-D motion artificial video*

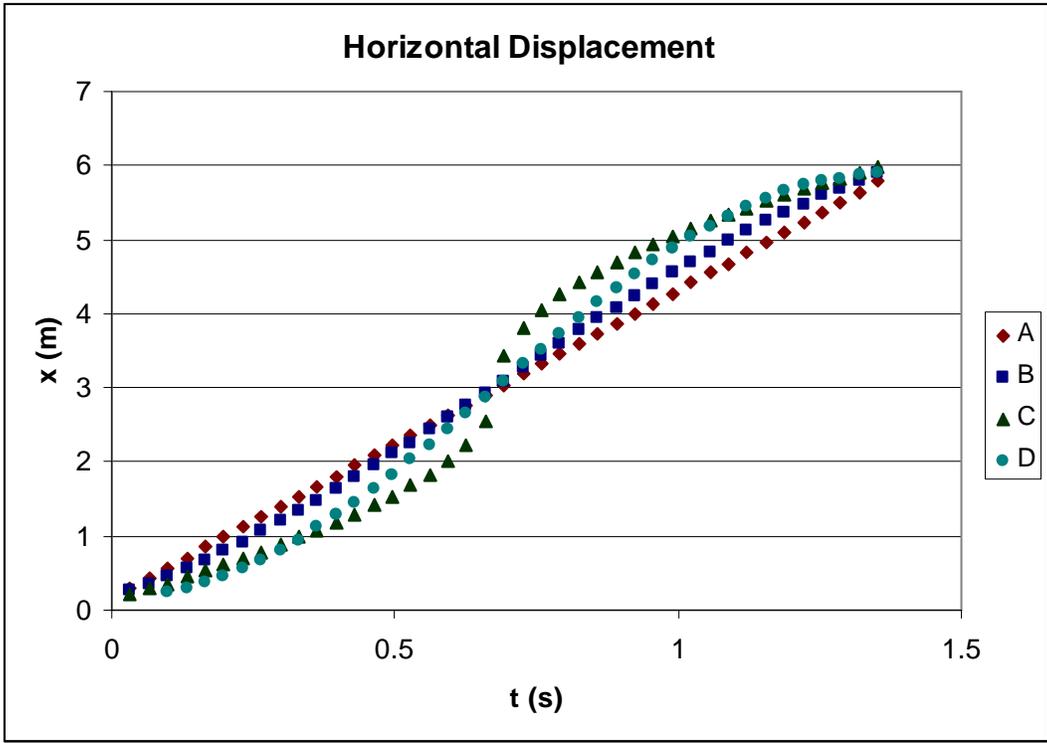*Figure 4: Trajectory data from 2-D motion artificial video*

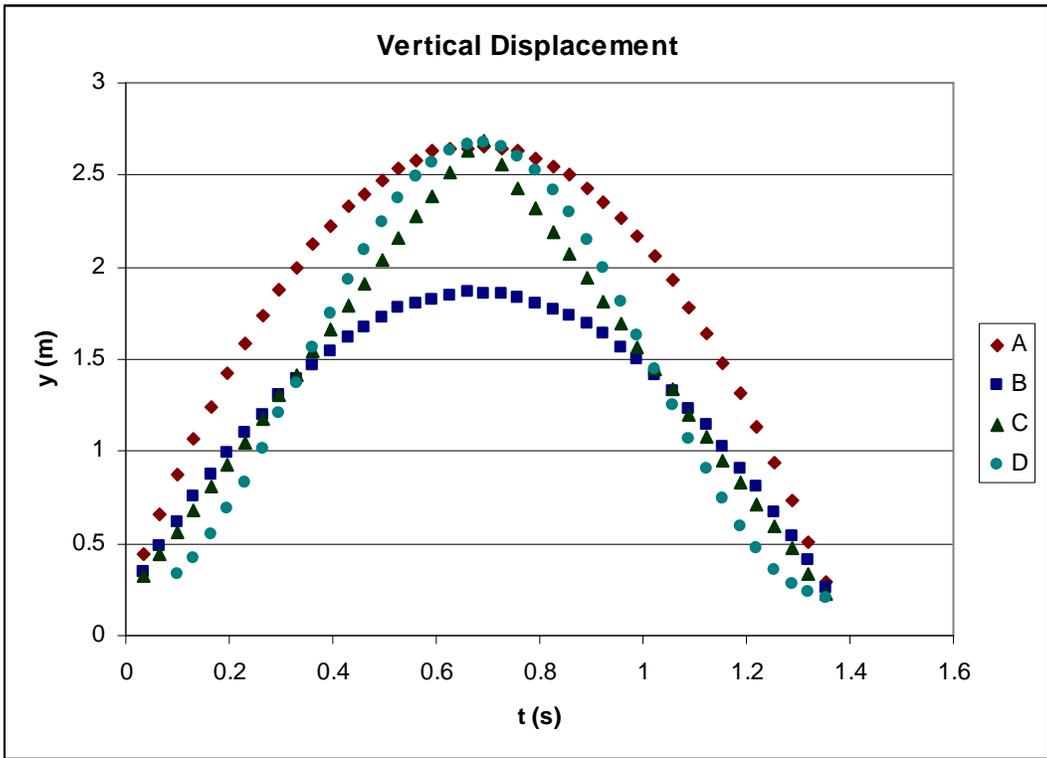*Figure 5: Horizontal Displacement from 2-D motion artificial video*

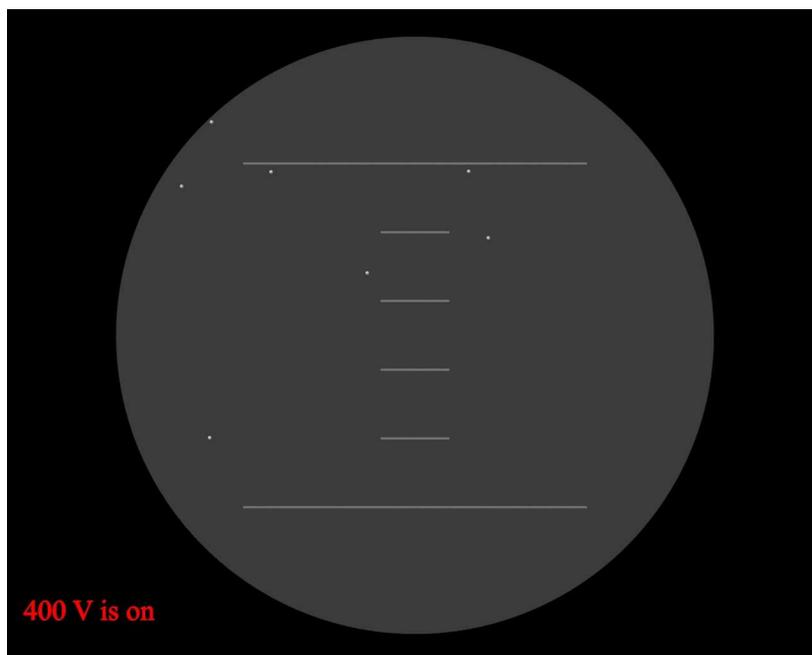*Figure 6: Horizontal Displacement from 2-D motion artificial video*

Figure 7: Frame of artificial Millikan Oil Drop video

References

1   Laws, P., Pfister, H. (1998). Using Digital Video Analysis in Introductory Mechanics Projects. The Physics Teacher, 36, 282–287.
2   R. J. Beichner, "The impact of video motion analysis on kinematics graph interpretation skills," Am. J. Phys. 64, 1272–1277 (1996).
3   Rodrigues, S., Pearce, J. M. and Livett, M. 2001. Using video analysis and dataloggers during practical work in first year physics. Educational Studies , Volume 27, No. 1.
4   http://www.lsw.com/videopoint/
5   http://www.cabrillo.edu/~dbrown/tracker/
6   Gallis, M.R., Wang, P. "Animations for Introductory Courses" Proceedings for 2004 ASEE Annual Conference & Exposition June 20-23, 2004 Salt Palace Convention Center, Salt Lake City, Utah
7   Bensky, TJ Illustrating Physics with Ray-Traced Computer Graphics, The Physics Teacher 44, 369 (2006)].
8   For more information about the TIPERs, please visit http://tycphysics.org/tipers.htm.
9   Silva, Kenneth J.; Mahendra, Jacquelyn C. (2005). "Digital video microscopy in the Millikan oil-drop experiment" Am. J. Phys. 73, 789-792