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Video Analysis - A Multimedia Tool for Homework and Class Assignments

Video-based motion analysis is a popular tool that is often used in introductory physics laboratory courses but not so often in other settings. The LivePhoto Physics Project is producing homework and in-class assignments for teaching introductory physics using video analysis techniques. These span a typical year-long course, including electricity, heat engines and physical optics as well as mechanics. I will describe the project and the techniques we use for producing videos that are appropriate for students to analyze.

Introduction

The combination of video with computer display and analysis has led to a powerful and sophisticated tool based on visual information about real physical phenomena. A short video, just 20 to 30 frames in length, may contain the same images that are combined in a multiple-flash photograph. However, when digitized and displayed on a computer monitor, it becomes far more versatile than a photograph. Students can analyze digital videos in many settings including residence halls, computer classrooms, laboratories, or even under trees using laptop computers. Not still photographs, but too short to be considered movies, these “live photos” can be played on a computer monitor at any speed, backward or forward, at the will of the user.

Moreover, just as a ruler can be used to make measurements on a photograph, positions in a video frame can be measured by pointing a mouse and clicking. The position data that is generated can be graphed, analyzed in spreadsheets, compared to theoretical models, and even used to display vectors or points superimposed on the original video (Figure 1). Analysis tools include differentiation and integration as well as analytic mathematical modeling and least squares fitting. This use of the analysis of digital video as a learning tool in physics

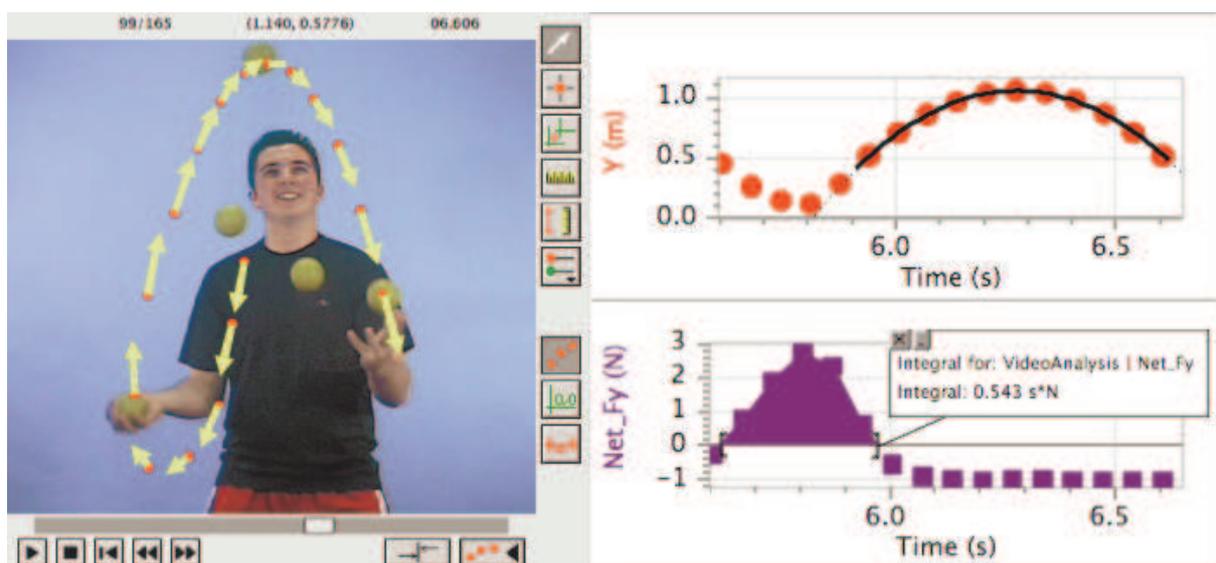


Figure 1. Analysis in LoggerPro of a ball caught and tossed by a juggler.

laboratory courses has become quite popular [1]. In practice, a student does the analysis with a computer program such as VideoPoint [2], Tracker [3], LoggerPro [4] or Coach [5].

In almost any area of physics instruction, video analysis can be used advantageously. The most obvious application is in the teaching laboratory, where students make measurements from videos of projectiles, cars, themselves and so on. As an extension of the teaching laboratory, students can do out-of-class projects in which they analyze movies they make themselves or that they obtain elsewhere. Another area is in the lecture, where teachers analyze videos of experiments as lecture demonstrations. If free or inexpensive software is used, video analysis can even be incorporated into homework assignments or distance learning.

The videos used in this technique are normally very short. They should be long enough to show a phenomenon completely, but compact enough for students to analyze with a reasonable effort. In making movies for use by introductory physics students, some things to keep in mind are:

- Use a high shutter speed to avoid motion blur (you need a brightly lighted scene).
- Turn off auto-focus!
- Align the camera axis perpendicular to the plane of motion.
- Include a length-calibration object in the plane of the motion.
- Other tips may be found at <http://www.millersville.edu/~pjcooney/making-movies/>

Examples of Video Analysis in Physics Teaching

The LivePhoto Physics Project has been producing videos and curricular materials since 2000. The project leaders are Robert Teese, RIT; Priscilla Laws, Dickinson College; Patrick Cooney, Millersville University; Edward F. Redish, University of Maryland; Ronald Thornton, Tufts University and Maxine Willis, Dickinson College. It is funded primarily by the US National Science Foundation. In addition to offering half-day, three-day and five-day workshops on video analysis for teachers, the project will publish a book of assignments along with a CD of videos during 2008 [6]. Some of these materials are available on the project website (<http://livephoto.physics.rit.edu>). The activities cover many of the topics usually found in a one-year physics course, including mechanics, thermodynamics, sound, waves, fluids, electricity, magnetism and optics.

One example of a lecture demonstration from the LivePhoto book is Motion of Carts, which was adapted from *Interactive Lecture Demonstrations* [7]. The instructor first describes an experiment in which a low-friction cart with an electric fan mounted on it travels along a track. After the instructor shows a video of the experiment, the students are told to predict the position and velocity versus time graphs and discuss the predictions with their neighbors. The instructor then leads a class discussion of the predictions. After a few minutes of discussion, the students see the video again, but this time with a video analysis of the motion. They have a class discussion of the results. The process is repeated for other videos of the cart accelerating with various combinations of acceleration and initial velocity. Finally, videos of analogous situations (a cart on a ramp and ball tossed vertically upward) are shown and discussed. In each stage of the demonstration, according to the research-based protocol for *Interactive Lecture Demonstrations* [7], a video is shown without analysis, predictions are made, the video is analyzed, and then the students discuss the results.

Another example is an activity using a video of a variable capacitor (Figure 2). The capacitor is charged and its voltage is measured with an electrometer that is connected to a computer through a LabPro interface. As the capacitor spacing is changed by turning a knob, the voltage is recorded in a computer file. Students measure the capacitor spacing from the video and use the results to create a graph of voltage versus spacing in LoggerPro. From this and other measurements of the video, the students determine whether the instrument behaves as an ideal parallel-plate capacitor, what its capacitance is, and how much charge was deposited on it.

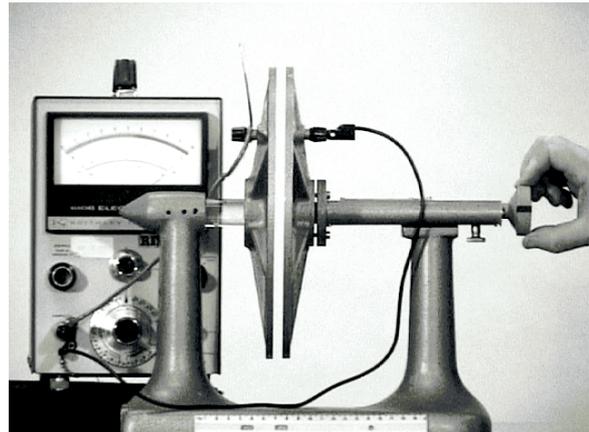


Figure 2. Variable capacitor video.

All of the LivePhoto activities are being created with two possible uses in mind: in class and homework. During an in-class activity, the students typically work in groups of two or three per computer. They carry out instructions on worksheets and fill in answers to numerical and short-answer questions. As homework, the students are given the worksheets to take home or to a computer lab. The videos and other computer files are made available either on a web server or CD. Because LoggerPro comes with a site license that allows departments to install the software in all their computers and allows students to install it on their personal computers, students are able to carry out the video analysis outside of class.

Research is underway at the University of Maryland on student learning and attitudes based on their use of video-based classroom, laboratory, and homework activities. During the next four years, research will also be carried out by LivePhoto workshop participants at their own institutions. This will include studies on (1) students' conceptual understanding of physics topics, (2) their understanding of the relationship between events, graphs and equations, and (3) their ability to use analytic mathematical modeling.

LivePhoto Videos

During the last seven years, the project has made many videos that have not yet been incorporated into written activities. They are available on the project website. Three examples are a video of moving-source water waves, a schlieren video of a firecracker explosion, and videos of soap bubbles in a wind tunnel.

A pair of videos of waves in a ripple tank is useful for studying the Doppler Effect. One video shows ripples from a stationary source that students can analyze to find the frequency and wavelength of the waves. Another video (Figure 3) shows the source moving at a constant velocity through the water. An analysis of this movie shows good agreement with the Doppler formula.

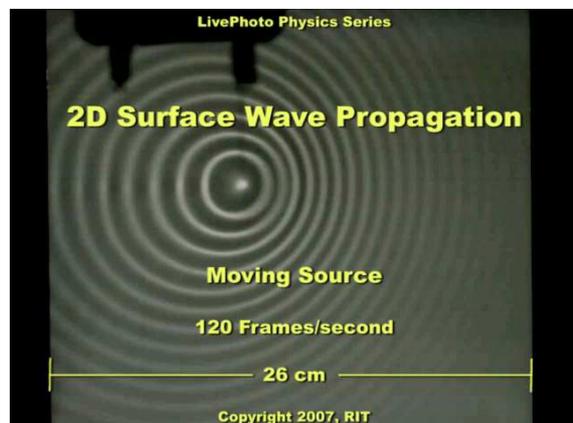


Figure 3. Ripple tank video.

Schlieren photography is a very old technique for visualizing gradients in the index of

refraction of transparent gas. The LivePhoto Physics Project has developed a simple method of making schlieren videos with digital video cameras [8]. A video on the project website shows the shock wave created by the explosion of a firecracker, along with reflections of the shock wave. The speed of the shock wave can be measured using video analysis.

Finally, a series of videos made with the Flotek 1440 wind tunnel in RIT's Department of Manufacturing and Mechanical Engineering Technology show air moving past an airfoil. Small (approx. 2-3 mm diameter) soap bubbles are in the air. They are neutrally buoyant, so their motion corresponds closely to the motion of the air around them. The movies were made at 500 frames/second with a shutter speed of 1990 microseconds. Each bubble appears as a short streak, and the length of the streak indicates how far the bubble moved in 1990 microseconds. An advantage of this video over lower-speed videos or a still photo is that each bubble's velocity can be measured at various points along its trajectory.

Video analysis is a useful tool for physics teachers. Videos and other materials available on the LivePhoto Physics website <http://livephoto.physics.rit.edu> can be used for homework as well as in-class activities.

Acknowledgments

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