Using Audiotape to Collect Data Outside the Lab: Kinematics of the Bicycle*

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ABSTRACT

Data collection and analysis in real-world situations has been enhanced by combining an electronic bicycle speedometer, audiotape for data storage and computer analysis. Using a computer distance, speed, acceleration and time results can be obtained from the audiotape. The system has been used effectively to improve learning and motivation while students are learning kinematics.

Keywords
Kinematics, bicycle, computer-based labs

PACS
01.50P; 01.50H; 01.76

Supported in part by the U.S. Fund for the Improvement of Post Secondary Education and the European Community.

Project Web site: http://www.science.uva.nl/research/amstel/bicycle/.

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Collecting data with computerized systems has become a very useful way to show students how the physics that they are learning in the classroom is related to real-life applications. The sensors used in computer data acquisition can easily collect data from situations that are somewhat complex and involve a variety of variables. Then, the students can use various computerized methods to concentrate on the variables in which they are interested. Further, if a measurement goes awry, they can quickly and easily take another one.

While the various sensors do allow for collection of data from experiments that are more realistic than the typical instructional laboratory experiments, they are, for the most part, limited to collecting data in a laboratory setting. Most commercially available interfacing equipment requires that the interface be connected to the computer while data are being collected. Thus, having students collect data while riding a bicycle or hiking in the woods is somewhat difficult.

Some manufacturers have addressed this problem in a limited way. Both the Pasco Science Workshop 500 and the Texas Instruments CBL have some internal memory and can operate on batteries. Thus, students can set up these systems for data collection, disconnect them from the computer, and collect data "in the field." Both systems are quite small, so they are portable.

The limitation is the amount of memory in the interface. This limitation became a factor in an experiment that we were completing. We wish to take advantage of students' interest in bicycling and create a series of activities in which they studied the kinematics of a moving bicycle. In particular, we wish to address the common student difficulty of not distinguishing well between velocity and acceleration by combining the kinesthetic experience of acceleration with analysis of data.

This type of data has been collected for short time periods by using digital video analysis.[1-3] With this procedure a bicycle is ridden across the field of view of a fixed video camera. Data may be collected by measuring distances on the screen knowing that the time between consecutive pictures is 1/30th second (in the North American and Japan) or 1/25th second (in the rest of the world). Alternately, the video can be digitized with a video capture board. Then by identifying the location of some part of the bicycle in each video frame, the students can collect distance versus time data and compute velocity and acceleration versus time. Collection of these data can be accomplished rather easily with any one of several data collection programs.[4,5]

In our application we wished to collect the data over an extended period of time. A long-term goal is to collect simultaneously data about the bicycle such as distance versus time and physiological data such as pulse or respiration rate about the rider. Such an effort would require recording a significant amount of data while the bicycle is in motion.

Measurement Techniques

Electronic bicycle speedometers (sometimes called bicycle computers) do collect the data in which we are interested. Unfortunately, bicycle computers do not have any readily available mechanism to read out the data which they are receiving. We decided to use the sensor of a bicycle speedometer and connect it directly to an interface device which could store the data.

The sensor placed on a bicycle wheel is a rather simple device involving a magnet and a reed switch. The magnet is attached to a spoke on the bicycle wheel while the reed switch is fixed on the frame of the bike. The bicycle speedometer supplies 1.5 volts (approximately) to the switch. When the magnet passes the switch, the switch closes, and the voltage drops momentarily to zero. Thus, the bicycle speedometer can "count" the number of revolutions of the bicycle wheel by counting the number of drops in the voltage. From this information the speedometer can calculate the distance travelled and speed of the bicycle.

For our first attempt to collect these data we used the Pasco Science Workshop 500. We connected two additional wires to the reed switch which were then plugged into one of the analog ports on the Science Workshop. The connection to the electronic speedometer was maintained so that it could provide the necessary voltage to the switch. After a little experimentation we discovered that the reed switch is closed for an extremely short time. To be sure that we obtained data for each revolution of the bicycle's wheel, we needed to set the sampling rate at about 200 Hertz. With this sampling rate, the Science Workshop memory filled within a few minutes. A similar situation was true for the Texas Instruments CBL. (A sample graph is shown in Figure 1.)

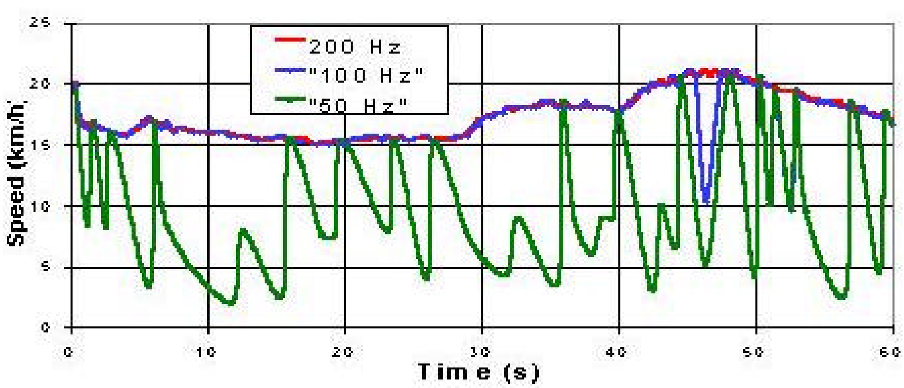

Figure 1: Data from the bicycle computer and Pasco Science Workshop 500 for different sampling rates.

To increase the time for which we could collect data we had two choices. We could design and build a circuit which converted the analog voltage information into time between pulses. Then, we would need to store only one data point, the time, for each revolution. This information then could be put into a digital port on one of the portable data collection devices. An alternative was to record the analog data in some other format so that it could be transferred to a computer later. We selected this alternative because it minimized the number of new devices or new components which needed to be built.

We have connected the output from the sensor to the input of a small portable audio recorder. Only an attenuating resistor has been added to the circuit. (See Figure 2) Each closing of the reed switch sensor is recorded as a click on the audiotape. With this system the time limitations are overcome. With standard audio cassettes the students can easily record up to two hours of data.

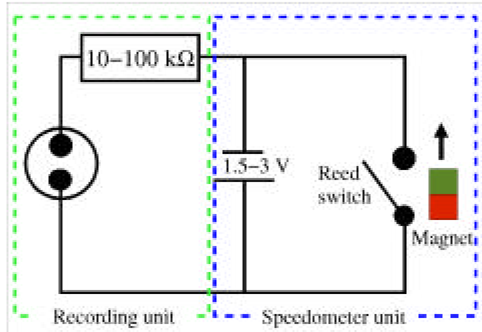

Figure 2: The circuit used to collect record data from the bicycle speedometer output to the audiotape

Digitizing the Data

The audio data are converted to digital form by using a standard soundboard which is available in most computers. The student connects the audio recorder to the computer's soundboard and captures the data as a .WAV file. By using one of several available programs the student can display the data as sound intensity versus time and can simultaneously play it through the computer speakers. These two methods of "displaying" the data can offer students some insight into velocity and acceleration. For example, they can see that equally spaced pulses indicate a constant velocity while changes in the times between pulses indicates acceleration. The audio playback of the file also seems useful. Constant time between clicks indicates a constant velocity with short times being a higher velocity than long times. Changing times between clicks indicates accelerations. This aural input provides a medium which is not normally available for the display of distance versus time data. Research into whether it helps students understand velocity and acceleration would be useful.

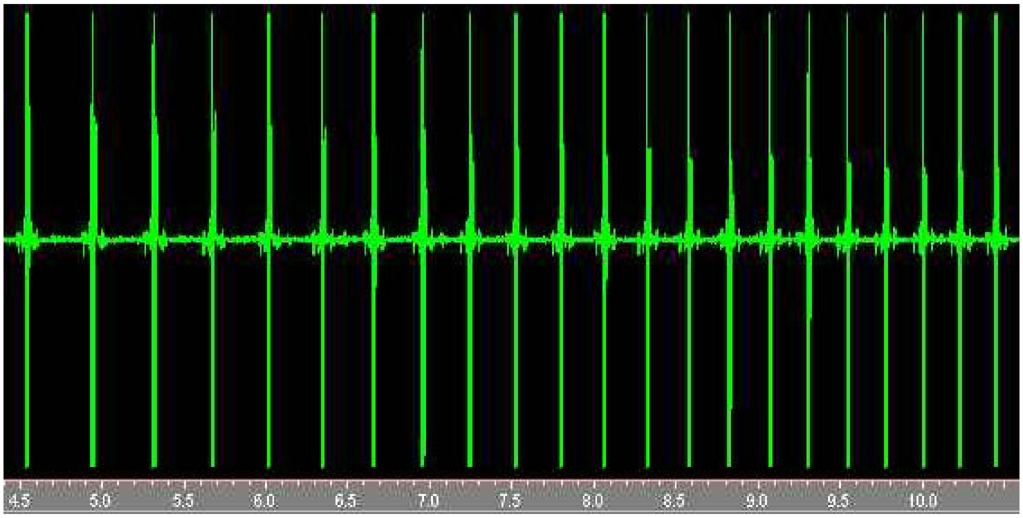

Figure 3: Intensity versus time for some sample data.

Figure 3 shows some sample data. The data at this point are not in a format which could be used for our analysis. Thus, we need to take two steps to convert the data into a file that can be read by other common data analysis programs. Several programs will convert a .WAV file into text information. For each of the sampling points in the .WAV file the program writes a number to indicate the relative intensity of sound at that time. The first step in our conversion process is to use this function. (We use Cool Edit for this purpose.[6])

This process creates a text file which is usually extremely large and contains much more information than we need. One of us (GB) has written a short program which reads through the text file and finds the times between the pulses. The program looks for high values in the text file and determines the times between consecutive pulses. The program also cleans the data in two ways. First, a threshold is set so that low-level noise, which can be seen in Figure 3, is not counted as pulses. Second, pulses which occur extremely close together are counted as a single pulse. Thus we remove spurious data which occur as a result of bouncing of the reed switch. By debouncing in software we have avoided the need for creating additional electronic circuitry. The program writes the time data to a comma delimited text file which can be imported into a spreadsheet or into the analysis component of programs such as Pasco's Science Workshop.

Analysis of Data

With the distance-time data the students can readily calculate the speed and acceleration for all times under investigation. Some sample curves are shown in Figure 4.

In addition to learning about the relationships among distance, time, speed and acceleration, students can also investigate some of the forces on the bicycle and its rider. For example, several different bicycles can be ridden at identical speeds and then allowed to coast to a stop. From the distance–time curve students can determine the acceleration. For the same bicycle and rider in several different configurations similar analyses can be made. By looking at

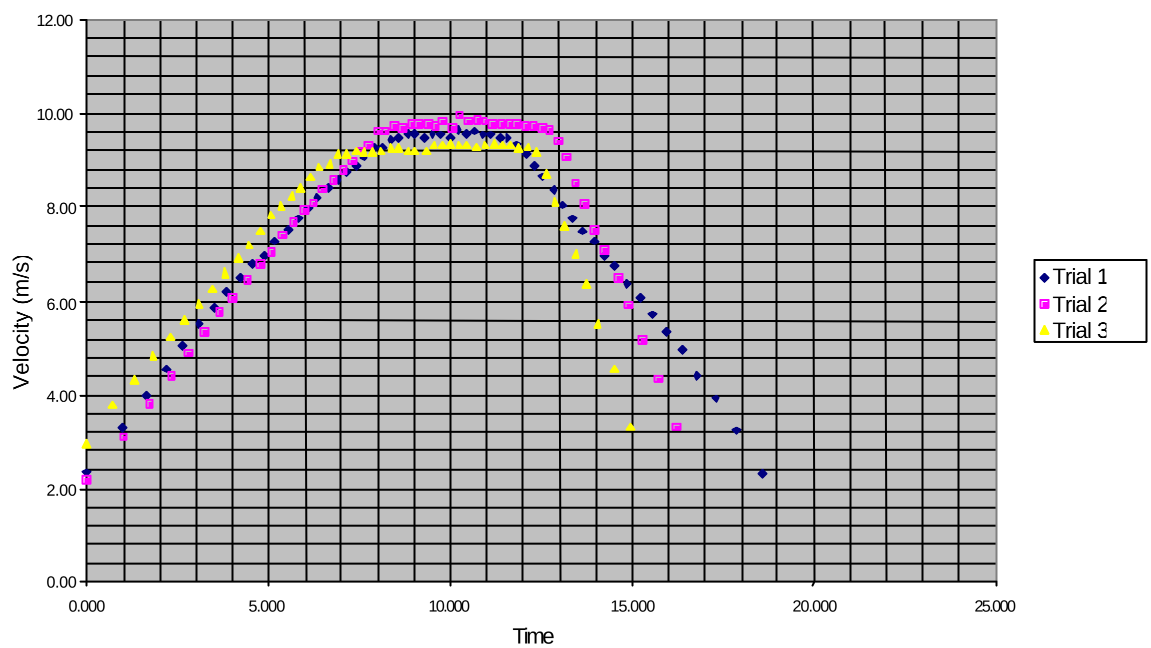

Figure 4: Typical velocity-time data collected by students

the acceleration curve for this situation the students can calculate the force of friction being applied to the bicycle in these and other situations. They can complete further analysis for different types of bicycles and for varying road conditions. Likewise, the students can look at the ways various conditions affect the increase or decrease in speed when they are attempting to go from zero to some maximum speed. Figure 4 shows one representative set of data for bicycles that are accelerating.

Extensions

As stated at the beginning of this paper we would like to combine the kinematic bicycle data with some physiological data of the rider. Early in our investigation we attempted to record pulse data using one of the devices which is placed on a finger and uses a photocell. The data were not satisfactory because of the large amount of noise induced in the system as the bicycle moved. We also tried PASCO's EKG. These data were even worse. We have not yet attempted to utilize a device marketed by Vernier which straps around a jogger's chest and emits an electron pulse for each heartbeat. However, to correlate these data with the kinematics data we would need a stereo tape recorder. While small portable stereo recorders are now available, they are somewhat expensive.

Another possibility would be to correlate video and audio data collection. One could use a wireless microphone or a very long wire to collect pulses on the audio track of a videotape. Simultaneously, video of the bike's motion can be recorded. Students can then compare four representations – audio, video, numerical and graphical – of the kinematic data.

Conclusions

In one sense collecting data on audiotape seems rather old fashioned. It was the method of choice before floppy disks became available for personal computers. However, our application attempts to take advantage of the ability of contemporary personal computers to capture and analyze sound. We believe that the system could be used in a variety of situations where students would collect data in the field. The costs in addition to components that are readily available in an instructional laboratory are minimal. Thus, it should be easy and inexpensive to implement data collection in the field in a variety of teaching situations.

More information (in German) about the use of these techniques with secondary school students and copies of the program written for data conversion may be found at http://planet.ipn.uni-kiel.de/projekte1999/braune/. This development effort is part of the International Bicycle Project which is supported in part by the U.S. Fund for the Improvement of Post Secondary Education and the European Community. For more information about the overall project, see http://www.science.uva.nl/research/amstel/bicycle/.

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