Using a Microcomputer for Graphing Practice

Students learn graphing when they compare a computer-drawn least squares fit with their hand-drawn version of the same graph.

Robert J. Beichner

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Most physics lab courses require some form of graphing. Unfortunately, these laboratories are often the first experience students have with actually taking data, plotting a graph, and interpreting the results. Their introduction to graphing often involves an experimental study of Hooke's Law. It is fairly simple to collect the data, graph it, and relate the slope of the line to the strength of a spring. Unfortunately, in my Architectural Physics class, elasticity is covered later in the semester. The Hooke's Law lab is more appropriate then.

I developed this laboratory exercise to introduce students to graphing. It requires no apparatus except the computer. This makes it a perfect "independent study" project to be completed before the first real lab experiment, allowing the new physics student to concentrate on graphing techniques. It avoids possible confusion resulting from learning how to take data and relate it to a real physical situation with equipment calibration and malfunction, error analysis, and similar complications. Once the proper mathematical techniques have been mastered, students are free to study physical phenomena in the rest of the semester's lab exercises.

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Generating the Data

The students begin this exercise by running a program called SNAIL DATA. The computer simulates an experiment testing the effects of sound intensity on the crawling speed of a snail. It prints out a set of linear data with some random "scatter" for the students to examine. When the lab was initially developed, all the students received one common set of data. They soon discovered that they could get all the information they needed by looking over someone else's shoulder. Having each student run the SNAIL DATA program eliminated this problem.

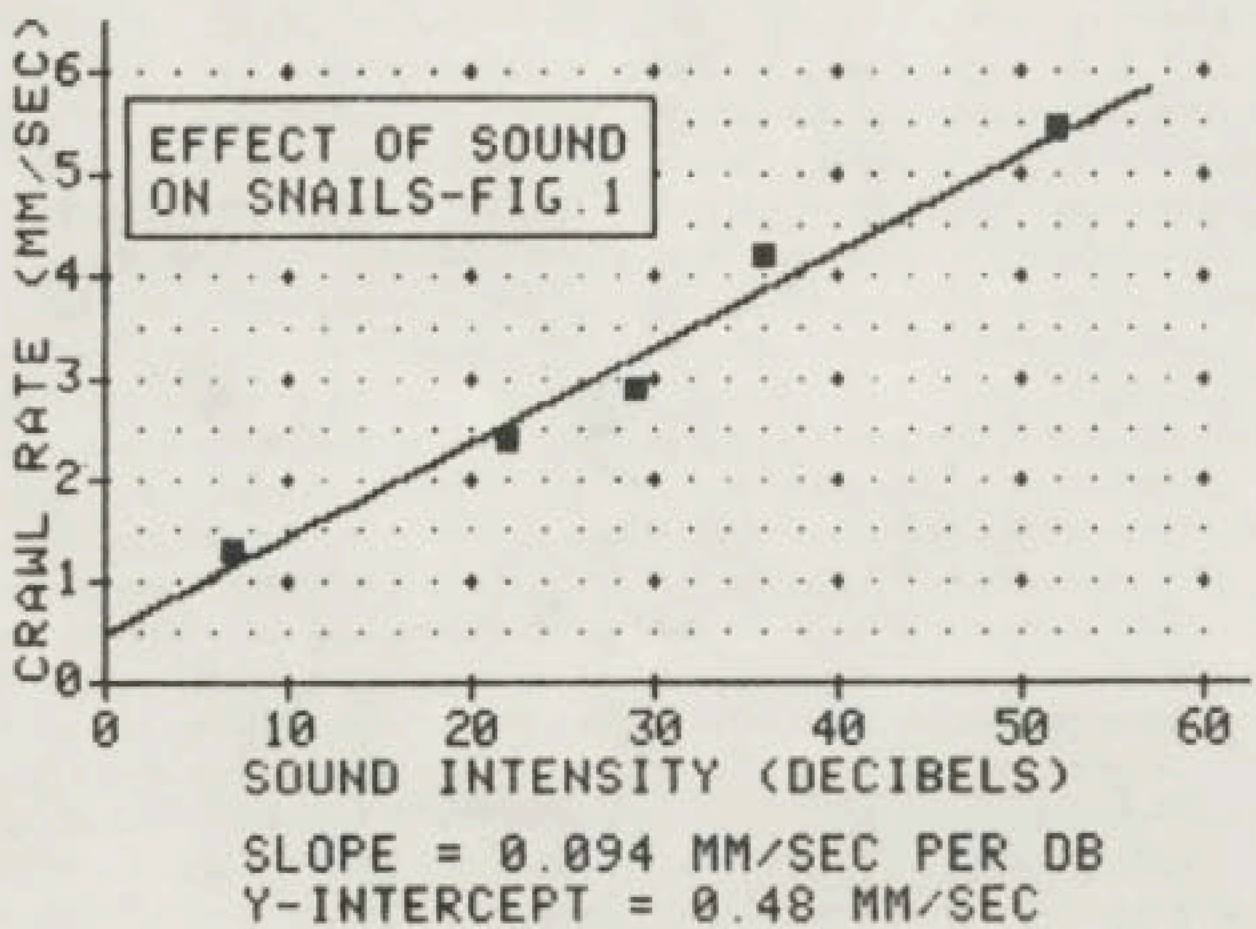
The program starts out with a simple FOR . . . NEXT loop, which produces sound intensity values to be plotted along the x axis. Corresponding speed values are calculated using the equation for a straight line, $y = mx + b$. Change this equation and the computer will produce any kind of data relationship you like. Students can practice making exponential or logarithmic graphs, study inverse relationships, and so on. The fairly simple subroutine that actually makes the "scatter" is listed in Table 1. It was written in Applesoft BASIC, but could be adapted to other languages. The complete SNAIL DATA and graphing program set is available from the author at no charge.

Table 1. Scatter Subroutine

```
1000 REM INTRODUCE RANDOM SCATTER
1010 FOR I = 1 TO N :
     REM N IS THE NUMBER OF DATA POINTS GENERATED
1020 XERR(I) = INT(10 * RND(I)) / 10 : IF X > 0.4 THEN 1020 :
     REM IF "ERROR" IS TOO BIG, FIND ANOTHER ERROR
1030 IF RND (1) > 0.5 THEN XERR(I) = -XERR(I) :
     REM RANDOMIZE ERROR LEFT OR RIGHT OF PERFECT DATA
1040 YERR(I) = INT(10 * RND(I)) / 10 : IF Y > 0.4 THEN 1040 :
     REM SIMILAR TO LINE 1020
1050 IF RND (1) > 0.5 THEN YERR(I) = -YERR(I) :
     REM RANDOMIZE ERROR ABOVE OR BELOW PERFECT DATA
1060 NEXT I
1070 REM RESULTS FROM THIS ROUTINE ARE ADDED TO THE PREVIOUSLY
     GENERATED X AND Y VALUES TO SIMULATE SCATTER IN THE DATA
```

Sample Output of SNAIL DATA program:

dB	Speed (mm/s)	db	Speed (mm/s)
7	1.3	14	1.2
22	2.4	24	1.8
29	2.9	28	3.3
36	4.2	40	4.3
52	5.4	52	5.0



By looking at the results of two RUNs, you can see that each student gets a unique set of data. However, the subroutine keeps the randomness of the data within close limits so that something reasonably close to a straight line appears when they graph the data. The random scatter from a true straight line is limited to ±0.4 mm per second on the vertical axis and ±4 dB on the horizontal axis. These limits can easily be changed.

Working with the Data

The students take their individual data sets and first make a tiny graph—no larger than two inches by two inches. They seem to enjoy making small graphs. Once they have strained their eyes on this project, they repeat their efforts on a more reasonably-sized graph. By comparing the small-graph results to those from a graph filling a full sheet of graph paper, the students will learn to make their graphs on a fairly large scale. For both graphs the students are to draw the "best fit" line, calculate its slope, and find the y-intercept.

Probably the most valuable aspect of this exercise is the chance for students to compare their "best line" to the linear least squares fit. They often have difficulty in deciding where to draw the line representing the trend in the data; sometimes they just "connect the dots." By comparing what they have drawn to what is mathematically correct, they can learn from their mistakes. Once they are comfortable using graphing as an analytical tool, they can get more out of their laboratory experience. □