MODELFIT: Fostering Student Understanding of Computerized Data Analysis

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Graphing and Data Analysis in Undergraduate Labs

- Display qualitative trends
- Determine whether (or NOT) data fit a particular mathematical model
- Extract fit coefficients from the modeling process

Student Understanding

- Do the data fit the particular functional model?
  - "by eyeball"
  - using reduced χ^2
- If so, what do the fit parameters (and their uncertainties) tell me about the physical system under investigation?

Data Analysis B.C. (Before Computers)

- Plot points
- Draw a “best” straight line
- Semi-log paper for exponential functions
- Log-log paper for power laws
- Slow, often tedious
- Students “interact” with the data
- “The whole world is a straight line.”

Data Analysis with Commercial Software

- Powerful, flexible (plotting, formatting and fitting)
- Expensive
- Difficult for students to use - steep learning curve
- Least-squares fitting interface not intuitive
- Uncertainties in both “dependent” and “independent” quantities not supported by fitting algorithms

MODELFIT Goals

- Simple plotting of laboratory data with essential labeling
- Interactive fitting process for basic model functions
- Full non-linear least-squares analysis
- Allow uncertainties in both “dependent” and “independent” variables

Model Functions Encountered in Introductory Physics

- Polynomial (linear, quadratic)
  - Freefall kinematics; Charles' Law
- Exponential
  - Nuclear decay; thermal conductivity
- Sinusoidal
  - Mass on a spring; pendulum; variable stars
- Power Laws ($1/r, 1/r^2$, etc.)
  - Boyle's law; Coulomb's law; Kepler's law

MODELFIT: The Program

- Easy graphing/fitting to common functions
- Fitting
  - Interactively, by hand - the “flexible ruler” idea
  - Full non-linear least-squares fitting with uncertainties in both variables
- Fit results
  - χ^2 or *S* factor
  - Values and uncertainties for all functional parameters

Sample Problem

From *An Introduction to Error Analysis*, by J. R. Taylor:

One way to measure the acceleration of a freely falling body is to measure its heights, y_i , at a succession of equally spaced times, t_i , and to find the best fit to the expected polynomial

$y = y_0 + v_o t - 1/2 g t^2$

Least-Squares Fitting

- Full non-linear (Marquardt-Levenberg) fits
- Equal or statistical ($\sqrt{N}$) errors for (x,y) data
- Error weighting for data (x,y,δy) or (x, δx,y, δy) data
  - see M. Lybanon, *Am. Journal of Physics*, Vol. 52 (1984) p. 22

MODELFIT Summary

- Easy to plot and fit to essential functions
- Students still “interact” with data
- Different uses at different levels
  - Simple graphing for qualitative trends
  - fitting “by hand” by eyeball
  - fitting “by hand” using χ^2
  - least-squares fitting
- Correctly incorporates uncertainties in both “dependent” and “independent” variables

Future Plans

- Y2K: Windows Version including hardcopy support (currently using Snag-It® from Techsmith Corp. to run in a DOS session)