Models and Simulations: An example of using simulation-based data in an introductory geophysics course

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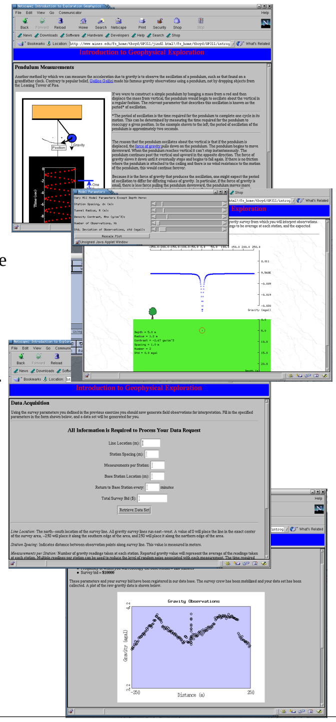
Introduction

Through the support of the Society of Exploration Geophysicists, we have designed and implemented a web-based learning environment for teaching introductory geophysics to non-geophysicists. Unlike many other web-based courses, ours entails much more than simply providing traditional course materials (e.g., syllabus, lecture notes, references, quizzes, etc.) in an electronic form. Rather, the relevant material is conveyed through the use of a generalization of the case-study approach we refer to as an interactive case study. Unlike a traditional case study, through the use of computer simulations students become engaged in an interactive case study by making all of the relevant decisions (i.e., survey design and cost decisions, data and interpretation decisions, etc.) regarding the case themselves. In completing an interactive case study, students not only develop an intuitive understanding of the nature of geophysical exploration, but also develop an appreciation for how geophysicists think and how to communicate with them, and a sense for what subsurface properties can and can not be constrained by geophysical investigations.

As described below, the case studies used in this course are couched in terms of a request for bid (RFB) that requires students to use a specific geophysical technique to address a geologic or engineering problem. In responding to this RFB, students write proposals, design geophysical surveys, collect data using these designs, interpret the resulting data, and report on their results. All of these activities are supported through interactive, web-based tools distributed as part of the learning environment. Everything described below is freely available at *http://www.mines.edu/fs_home/tboyd/GP311*.



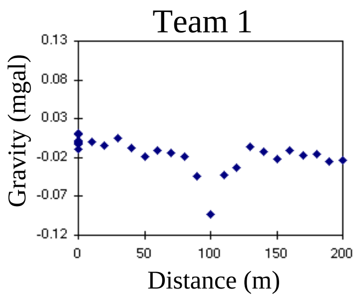
Description

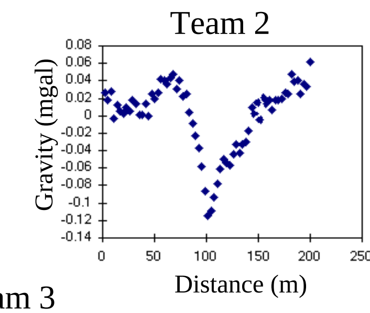
The introductory course is divided into four modules, one each on the use of gravity, magnetic, DC resistivity, and refraction seismic observations. Each module has two main subsections: lecture notes and the interactive case study.

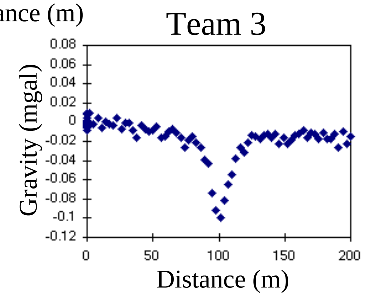
The interactive case study is framed around a specific request for bid (RFB). The RFB presents a problem to be addressed by a specific geophysical method. Students respond to the RFB by submitting a proposal that includes a geophysical survey design, a discussion of geophysical noise relevant to the particular survey, estimates of the geological sources of signal that would and would not be detected by the survey, and estimates of the cost of completing the field acquisition and data interpretation. Examples of student proposals are available on the web site.

To help complete the survey design, students are provided with Java-based programs that allow them to model the geophysical response over geologic structures relevant to the particular (RFB). The modeling programs generate synthetic observations over simple geological models. Using these forward modeling programs and cost estimates, students determine optimal survey parameters for the particular problem. Because the optimal survey is defined in terms of a cost/benefit tradeoff, different participants rarely base surveys on the same set of parameters. We encourage students to try surveys with different designs.

After designing the survey, students can enter their survey design parameters into a WWW page and immediately receive a data set that includes random and systematic noises unique to their survey design. Students are then guided through a data-reduction procedure using simple spreadsheet manipulations. Upon completing the data reduction, students can upload their reduced data into Java-based modeling programs that allow them to interpret their observations.







The data sets collected by the students are remarkably diverse. Although all are collected over the same geologic structure, each is obtained with a different set of survey design parameters. The figure above, and the table below show three example gravity data sets all collected over the same subsurface tunnel. In terms of cost computation, the relevant survey parameters include station spacing (Δx) and base station repeat time (Δt). In the top example, survey cost was minimized by using a relatively large station spacing. As a result, the gravity anomaly associated with the tunnel is poorly defined. In the middle example, survey cost was minimized by increasing the base-station repeat time. The resulting reduced data set is contaminated with tidal noise causing the observed anomaly to be highly asymmetric. The bottom data set represents what this particular class defined as the optimum survey design for this particular problem. Although more expensive surveys were designed (in this class one cost over $250,000), students readily discovered that, given the client's needs, the increase in information content did not justify increased survey costs once costs are larger than about $25,000.

	Team 1	Team 2	Team 3
Δx (m)	10	3	3
Δt (min)	120	180	120
Bid ($)	13,950	25,000	11,660
Cost ($)	6,320	16,800	22,320

Advantages of Current Implementation

- The use of interactive tools allows students to develop a conceptual understanding of the underlying physics at an intuitive level.
- The implementation that we use is inherently inquiry based.
- The interactive case study approach is one that inherently incorporates many aspects of game playing.
- Students to collect data over a known geologic structure many times. This allows students to assess the cost/benefit tradeoffs of geophysical investigations and to do quantitative error analysis of the results of a particular investigation.
- The use of interactive case studies also supports a systems-oriented approach to problem analysis and solving. This is facilitated in two ways. First, underlying the entire approach is student analysis of the needs.

Disadvantages of Current Implementation

- Students are not exposed to the mathematical underpinnings of the techniques they are employing.
- There is little field experience incorporated in the course.
- Because students spend virtually all their time exploring specific interactive case studies, they have little time – or incentive – to begin to generalize from these experiences.
- Finally, we should recognize that the physical sciences tend to work in a reductionist/constructivist mode. The interactive case study approach does not indoctrinate students into this mode of thinking.