Multimedia Statistical Labs & Toolkit (TILE)

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1. Introduction

The potential for multimedia to enhance the statistics curriculum is clear, but how to develop instructional materials that take advantage of the riches that multimedia has to offer is not as transparent. It requires more than a simple translation of textbooks into HTML and statistical software into Java in order to obtain a product that is functional, effective, and artful. Accepted definitions of good design and good educational paradigms do not necessarily hold in the new digital media. In this article we would like to consider ways in which multimedia can augment the statistics curriculum. We will provide examples drawn from our efforts to design instructional labs for use in teaching introductory statistics to university students who are non-science majors. We also describe a general collection of tools we have developed to build these types of labs. For further information on our project, *Tools for an Interactive Learning Environment (TILE)*, see `www.stat.berkeley.edu/users/nolan/TILE`.

2. Why Multimedia?

Multimedia differs from other forms of media such as print or film, because it is: *interactive*– information is exchanged between user and machine (in both directions); *dynamic*– information can be updated on the fly; *flexible*– the system can change according to user input; *nonlinear*– information can be organized in a complex hierarchy; *time-based*– users unfold the story at their own pace, in arbitrary order, and animations, video, audio have a time element.

In our work, we have found one of the most difficult aspects of designing a statistical lab is to determine how to integrate multimedia with the traditional role of the computer in order to convey statistical ideas in an interesting, useful, and fun way. One guideline we have followed is to find topical contexts to serve as natural metaphors in which to introduce statistical concepts. And we have attempted to combine these metaphors with adventures, puzzles, and simulations. A second guideline we have adopted is to create an organic learning environment for the student that promotes statistical thinking in context and that includes exercises, simulations, demos, and problem solving.

For example, an important element of statistical training is to learn how to interpret data. This training is ideally achieved through an apprenticeship, where students work with an instructor on case studies. In their work, they have the opportunity to analyze real-world data in order to answer important scientific questions. Multimedia seems well suited to assist with this training. With multimedia, we can offer students more than a calculator-like environment for performing statistical techniques. We can provide a context in which they are guided in their analysis of data, and where they can come up with individual solutions. Indeed, marrying easy-to-use statistical software with interactive exercises that are constructed by the instructor to demonstrate statistical concepts and that also have the capability of providing students individual and instant feedback on their work seems an ideal application of multimedia. And it is an application that adds a new element to the statistics curriculum.

In developing these labs, we discussed several designs for over a dozen labs with other instructors. This experience convinced us that different instructors have different pedagogical philosophies that could not be satisfied with a single set of labs. As a result, our project also focussed on providing a suite of tools to enable instructors to build and customize their own labs. Most simply, the instructor can easily change the context of a lab by providing text and image inputs. More ambitiously, an instructor can also program a new lab by building on the tools provided in the toolkit, including plotting, animation, window interface, and quiz tools. We present here a brief description of two of the labs that we have implemented and some of the tools available in the toolkit.

3. An example – Observational Studies

One lab we have developed is on the topic of Observational Studies. Observational studies are by nature complex. Important relationships may be observed between the response and other factors in a large health study, and these relationships need to be viewed with caution, as it is not a controlled experiment. Despite this limitation, observational studies have an important role in medical research. One of the goals of this lab is to assist students in understanding this role. We also want to help them learn how to read and interpret rates, read and compare bar charts, and control for a confounding factor by making comparisons within more homogeneous subgroups.

It is difficult to accomplish these goals through print. Most introductory statistics texts pay little attention to these issues. This deficiency may be attributed to the lack of space, which necessitates examples being short and with a single focus. Our goals are defeated if the study is reduced to predigested material with only two factors to examine. Some texts and courses use only data collected by the students in the course. These data are inherently toy-like, and lack a sense of the real-world import typically found in authentic observational studies.

Rather than over simplify the observational study, we try to pace the unraveling of the complex relationships and confounding. The model of an apprenticeship seems a suitable one for controlling this process. In this lab, we place the apprenticeship in an adventure. The student operates Fritz, a new hire at a hospital whose job is to investigate the incidence of low birth weight at the hospital. The data are 15,000 observations with 14 variables. The details of the investigation unravel as Fritz walks through the hospital; talks to various experts, docents, and visitors; and collects plots, documents, and dialogs in a binder. The analyses grow in complexity, and the student fills in reports at various stages in the investigation. Unlike when reading a text, the student is directly involved at all times, making decisions and controlling how the investigation unfolds. The student is immediately engaged in understanding the material.

By spreading the information throughout the hospital, the complex analysis is broken down into smaller pieces, interspersed with reading material and advice from experts and novices. Different from a text, the student *must* actively decide where to go next and take an active role in the investigation. Although we control the pace at which the investigation unfolds, we have avoided hiding information from the student. Also, to give the student more control, the lab activities are not modal and so can be interrupted at any time. To maintain consistency and avoid confusion, all of the lab components remain active throughout the activities, e.g. the binder is always available for looking up information.

The dialogs between the characters in the hospital and the student are used as a means to guide the student in the analysis. They help the students learn how to read the plots, address issues of causation, and set the stage for learning about confounding and controlling for it. Exchanges between Fritz and others in the hospital are not static. They may change according to whom Fritz has already spoken, what plots have been saved in the binder, or even how many times he has spoken with a person already. For example, if the student has already identified an important factor, the doctor will compare this factor with other potential factors. Otherwise, she will lead the student towards identifying a main factor. Similarly, the responses selected by the student to form Fritz's response can trigger different exchanges.

4. An example – Descriptive Statistics

In a lab on descriptive statistics, we aim to teach students how to use simple summary statistics to describe data. In terms of its pedagogical design, it is the simplest of all the labs we have developed. We present the student with several questions on different topics. Each question essentially asks the student to compare two distributions, e.g. the heights of young and middle-age men, the salaries of baseball players in 1987 and 1997, the GRE scores of male and female students. An instructor can easily add topics to this lab by providing additional data sets and questions, and topics can be randomly selected for each student.

For each topic, the student is presented with a single work area consisting of three parts: quiz, data table, and statistical workplace. The quiz guides the student through the analysis and interpretation of the data, and these questions are designed to aid the student in comparing and interpreting the distributions. The questions are broken up into separate pages to help pace the unraveling of the investigation, to build questions that are dependent on answers to previous questions, and to keep from revealing too much of the future direction. Responses to a page of questions are checked immediately and feedback is provided to the student. The feedback comes in a variety of formats. If the student has not performed an adequate analysis of the data then the page may not be graded and the student is encouraged to do more analysis before proceeding. If some critical questions are answered incorrectly, the student may be provided with a special page of questions to address the problem. If the work is acceptable then the answers are provided along with individualized feedback on the student's responses.

The student is given a variety of simple descriptive statistics tools that can be applied to the data, including mean, median, SD, IQR, histogram and box plot. The student is free to perform any type of analysis on the data in order to answer the questions. The results of the analysis are kept in a transcript or work sheet, and the student may edit the work sheet to remove and move statistics already calculated. There are also a number of interactive editing features available. A student may change the number of bins in a histogram, compute arbitrary percentiles, or find the areas under a section of a histogram. One interesting feature is the ability to annotate a histogram with statistical information. For example: the mean or inter-quartile range of the variable can be added to its histogram; for the purpose of comparison, summary statistics from another variable or data set could be added; or a subset of the histogram bars could be shaded to indicate a region of interest. Color plays an important role in these annotations, for it serves to convey information, not simply to prettify the histogram.

5. Technical design

To implement these labs, we have constructed a full-featured Java toolkit. The philosophy of the toolkit is to allow the components to be easily connected together to form labs. While the connectivity is supported at the Java programming level, more importantly the elements can be customized and controlled using a scripting language ($\widehat{\Omega}$) or via named properties contained in ASCII files. Many of the inputs are in the form of SGML (a general HTML) where we use special tags and attributes to communicate with the Java code. We describe 3 of the modules of the toolkit here, those for the main work window, quizzes, and plots.

The interface where the human user meets the machine is a critical part of multimedia design. The user meets the multimedia application through the visual appearance, interactivity, navigation and sense of location. To maintain consistency across labs, we settled on a single interface for all labs. The student operates in one main work window. The interface uses the common layout of many software applications. Always available are quit-and-save, print, and font-size options, as well as an HTML help system (which brings up its own window), a status bar for displaying messages, and a worker who supplies hints upon request. Messages in the status bar result from user actions and from requests for help from the worker, and they may have links to the help system.

In order to provide personalized dialogs, questions, and feedback to the student based on what the student has done up to that point in the lab, we have created several special SGML scripting languages. We sketch how the scripting languages for the dialogs works. A dialog consists of several potential exchanges. Each exchange consists of one round of the initiator (the person that Fritz talks to) speaking, a thought being chosen for Fritz by the student, and Fritz speaking. Exchanges are designated through a `section` tag, which includes four sub-tags: `initiator, thought, spoken`, and `next`. The `initiator` tag provides the text for the person with whom Fritz speaks. The `thought` tag contains a list of possible thoughts from which the student selects one. Fritz's reply is in the `spoken` tag, and the `next` tag determines which dialog exchange, if any, appears next. All of these tags support the `script` attribute with which the instructor can specify arbitrary commands including the text to be displayed or the name of the next section to display. This attribute can also be used to display a plot or document within a dialog. The commands have access to the Java variables used in the lab and thus provides a simple way for an instructor to control the lab.

Finally, all plots can be optionally made interactive and support facilities for: identifying data elements by clicking and rubber banding; stretching axes; annotating; etc. From an instructor's point of view, a useful feature of the plotting tools is the ability to specify attributes in input files. The plotting tools understand a common set of attributes such as background color, axes ranges, and fonts for labels. Also each tool understands attributes that have meaning just for it, such as number of bins or bin widths for a histogram. In addition, data can be added incrementally – a feature used in animations to show histograms and scatter plots being constructed dynamically.

RÉSUMÉ

Nous décrivons des méthodes d'enseignement 'multimedia' pour améliorer les cours de statistique. Nous donnons des exemples issus de nos efforts de planification des séances d'exercices pour des cours d'introduction à la statistique destinés aux étudiants s'orientant vers des disciplines non-scientifiques. Voir `www.stat.berkeley.edu/users/nolan/TILE` *pour obtenir des informations sur Tools for an Interactive Learning Environment (TILE).*