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DESIGN OF AN INTERNET COURSE FOR TRAINING MEDICAL RESEARCHERS IN BAYESIAN STATISTICAL METHODS

Access to statistical information is at an all-time high, and the information age is fuelling this access at an extraordinary pace. This access increases the capacity for medical researchers to use statistics to guide decision making, yet few courses teach methods to do so. Rarely does statistics training include methods for incorporating statistical output into decision making. Mass education and educational reform is needed. Technological advances of the past decade make this goal possible, and allow us to dramatically change how we use, teach, and think about statistics. This paper covers the conceptual development of an Internet continuing-education course designed to teach the basics the Bayesian statistics to medical researchers. Two questions are discussed: Why the Internet, and why the Bayesian paradigm?

1. INTRODUCTION

Access to statistical information is at an all-time high, and the information age is fuelling this access at an extraordinary pace. Yet, the statistical literacy of the population, even in medical schools, is surprisingly low. A random selection of persons passing through the doors of a medical library would result in few persons that correctly define a significance level, and even the most respected medical journals have statistical mistakes and misinterpretations. And, although the importance of statistics to guide decision making is well recognised, few courses teach methods for incorporating statistical output into decision making.

These observations signal that mass education and educational reform are needed. Technological advances of the past decade make both goals possible, as the Internet increases accessibility to education while keeping costs low and computational advances make Bayesian decision-theoretic analysis possible. Together these advances can dramatically change how we think about, use, and teach statistics.

This paper covers the conceptual development of an Internet continuing-education course designed to teach the basics of the Bayesian statistical paradigm to medical researchers. Special attention is given to two questions: Why internet-based instruction, and why the Bayesian paradigm?

2. WHY INTERNET-BASED INSTRUCTION?

A reviewer recalls the introduction of several new technologies for teaching: filming great teachers, courses taught on television, VCR tapes, and CD discs. Each was supposed to revolutionise teaching and maybe even make the teacher unnecessary. Now the Internet has arrived. The reviewer asks: "Is the Internet different from the previous attempts and in what ways may it succeed where other technological attempts have basically failed?"

The chances that the Internet will succeed are greater than other attempts due to four interrelated reasons: Tempo of change, interactivity, access and flexibility.

> *"Not since the mainframe era has technology reached a level of relative stability before other discontinuous architectures entered the Instructional Technology (IT) environment. ..., IT planners barely have time to come to terms ... before the next 'paradigm' arrives."* (Gartner Group, 1998 c, p. 3)

The speed with which changes are coming prevents IT designers from developing a design process model by which they strategize, prototype, test, develop, and market a product. Products that cannot be updated and adapted quickly barely appear before they are abandoned. Because products offered via the Internet are adaptable rather than static objects, this technology is likely to survive where others have not.

The Internet also has other features that previous technologies lacked, the two most important being that rather than aiming to replace the teacher and textbook it improves upon both. The Internet can make the teacher more accessible and the textbook interactive.

The Internet allows people to come together across great distances without narrow temporal constraints. Via discussion and chat groups, students and faculty can interact across thousands of miles. Continuing education's traditional barriers of geographic proximity and job/family-compatible scheduling will disappear.

This communication medium will enable researchers to seek continuing education at distant universities with timing restricted to only their own availability. Students can work through courses at their own pace, in a convenient location, on their own time schedule. The Internet can make education more accessible, and more individualised.

The Internet can provide much more than a textbook on-line. (Puranen, 1998; Talbot et al., 1998) and multimedia software can provide interactive instruction (Cumming & Thomason, 1998; DiCiaccio, 1998; Giusti et al, 1998; MacRae 1998):

> *"Interactivity is the degree to which the user creates an individual experience with an application or body of content, ranging from "user as passive TV viewer" to "user as author."*
>
> *The critical differentiator in categorising "how interactive" an application is revolves around the degree to which the application can dynamically adapt to or change the user's needs in real time.*
>
> *Interactivity is often incorrectly correlated with media richness. Interactivity has two drawbacks: 1) The complexity and expense in content creation, delivery and the devises to experience it; and 2) the human-factor aspects of interactivity, i.e., how much a given audience can take, or how much time or inclination they have to embrace it. Interactive advertisements on TV sound great in principle, but with 30 seconds to complete the experience, most people will be overwhelmed"* (Gartner Group, 1998 a, p. 4).

While interactivity has also been available via CD ROM technology (Watson, 1998) and other computer based resources (Morris & Le Voi, 1998), products offered via the Internet can be adapted and updated with much less hassle. Authors have greater flexibility and control over changes to their work. The Internet also provides the opportunity to link with related sites and can potentially make education more interactive and more flexible.

3. CURRENT STATE OF INTERNET BASED STATISTICS EDUCATION

The current state of internet-based education suffers from the 'textbook on a computer' syndrome. This means that sites look like a poorly formatted textbook, rather than being coherently mapped, layered and linked. Sites vary greatly in their use of multimedia, an advantage that the Internet offers over textbooks.

There are many interactive simulation demonstrations (see Galmacci, 2001), but rather few that focus on strong case-style applications. Many sites are overwhelming in detail, making the reader want to turn and run and most are beginning bits and pieces rather than a complete work. Few keep their links updated, and few are far enough along in design to foster conceptual learning. Most of us are still learning the tools, tools that change by the minute and we are still realising that publishing on the Web is very different from traditional publication methods (Korpela, 1997). Our Internet products are not yet of professional quality, but this is changing very quickly as universities allocate resources to instructional technology and educators' team up with graphic artists and professional designers.

4. DESIGNING AN INTERNET COURSE

According to Gartner Group (1998, b) to capitalise on the advantages of the Internet requires processes and technologies that make it possible to highly automate content creation, assembly, and production functions. This requires changes and poses challenges to architecture/technologies, products, and organisational procedures. An instructional architecture must be defined and integrated with the enterprise at large. The cut-and-paste tools on the desktop must be replaced with content-aware intelligent products that can process all information resources, not just document elements.

Designing an Internet course requires several steps:

1. Software decisions;
2. Slide development that simulates teacher/student interaction;
3. Script development;
4. Testing;
5. Implementation;
6. Updating.

Deciding on software includes answering questions such as:

- Which software for slide production?
- What type of audio/video will be used?
- What quality is required?
- Will access be via modem or high-speed connection?
- What plug-ins are required?

In deciding upon software, one must remember that resources must be provided at the lowest common denominator among current users. Compromise between using 'state-of-the-art' and 'state-of-the-masses' is requires. While video clips are now easy to incorporate into presentations, if it takes the student two hours to download, they won't use it. You will only reach students whose computing resources easily support everything you use.

Although the public's resources and skills are changing rapidly, make sure that students have the hardware and software to support your product and include training for how to use it. Use multimedia sparingly and keep files small. Make sure multi-media clips enhance comprehension rather than replace something that is more effective.

Test clips on different computers and use compression. Assume the user has a system one-quarter the size and speed of your own. Make sure things are user friendly. Always have a backup-plan if a student has problems. It is naïve to think glitches won't be common.

In developing slides one must think continually about content, structure, and delivery. It requires a sequential process of *Strategize, Prototype, Test, Develop, Test,* and *Enable,* that will ensure projects meet users' needs and are sustainable over the long run (Gartner Group, 1998 b).

Systematically define the scope of the content and the units in which information will be developed. Keep units short and modular. One advantage of the Internet is that material presentation need not be linear. Yet the structure, the mapping, layering and linking of material will be overwhelming if not meticulously planned.

Develop a structure that determines how units will be mapped, layered and linked for easy navigation. Determine how aggregated information will be disseminated for efficient delivery. Make sure materials can be easily searched, retrieved and discovered. Remember different browsers display differently.

Careful attention to page layout, including sizes, colour, and positioning can make your product look great on your own monitor-browser combination and horrible on someone else's. Keep each slide simple and uncluttered. Keep slide organisation simple, systematic, and easy to navigate.

Be sure to abide by copyright laws. Xeroxed material for teaching in the classroom is not the same as putting copies on the Internet. Make sure you don't put things on the Internet that you do not own. Copyright laws do not allow you to put other's materials on the web without express permission. Also realise that making your own materials available on the web will make them quite easy for others to use, with or without your permission. Use password protection intelligently.

Making your presentation interesting requires a lively script. This is as important as including multimedia clips and interactive exercises. A well written and delivered script is more difficult than the slide content and organisation. You must develop the script in a way that gives the student a feeling you are in the room talking with them. Your speaking performance on the Internet will be compared against public television's best program narrators rather than your university's faculty lecturers. Listen to the pro's and learn from them.

Once your presentation is ready for students, implementation hurdles must be jumped. These hurdles include making sure students have the software they need and know how to use it. Student access is the first and biggest hurdle:

> *"The availability and speed of network access remain a gating factor. The move to untethered (wireless) computing will allow users to obtain real-time information when and where they need it"* (Gartner Group, 1998 c, p. 7).

It will not be long until this gating factor is not an issue, but until then access issues must be addressed. Other hurdles include keeping links current, keeping up with student communications and setting clear communication boundaries. Throughout the implementation phase it is important to get as much feedback as possible about your product and to respond to students with the same level of receptiveness that you give in the classroom.

5. WHY THE BAYESIAN PARADIGM?

The statistical training of medical researchers usually begins with an introductory undergraduate statistics course, which is perhaps followed by a course or two in research and statistical methods while in nursing, graduate or medical school. Any other statistical education comes from 'on-the-job' training and continuing- education courses.

Laake (1998) and Phillips et al (1998) discuss teaching statistics to professionals in health-related sciences. Typically courses cover a mixture of statistical analysis and research design, while nearly all courses cover hypothesis testing, and few courses address the use of statistics directly in decision making.

The call for a stronger link between statistical analysis and decision making is not a new one, but work answering this call is a rarity. Twenty-five years ago leaders in our field were urging statisticians to take greater leadership in decision-making. Rice (1977) reported that, at the 1975 ASA meeting, Sir Claus Moser made this suggestion:

> *"Foremost responsibility (of the statistician) is to contribute to more enlightened and efficient 'decision making' ... through the fullest possible exploitation of our skills in analysing and interpreting the data."* (Rice, 1977, p. 104)

In 1977, Dorothy P. Rice, then director of the National Center for Health Statistics, stated:

> *"As in other areas of social policy, health statisticians and health data are increasingly expected to provide keys to rational decision making. To accomplish this goal, the statistician and decision maker need to interact to an increasing degree."* (Rice, 1977, p. 101).

While these quotes were all made nearly 25 years ago, very little has happened since then with respect to the role that statisticians play in decision making. Pleas for change (Tukey, 1976; Stangl, 1995; Paltiel & Stinnett, 1996; Rice, 1977; Lindley 1997, 1998; Tan & Smith, 1998) and theoretical decision-making books (DeGroot, 1970; Berger, 1985; Lindley, 1985) are available, practical applications are rare.

The most important gap in current methodology follows from the fact that while decision-making is the incentive for most research efforts, the decision process usually remains informal and ad hoc.

The statistician's role has been to provide statistical synthesis and has not typically included promoting formalised decision-theoretic techniques. The disjuncture between statistical synthesis and decision making is an unnatural and undesirable one, because it undermines the impact of quantitative information.

Adopting a Bayesian perspective provides a natural bridge for this gap. But how does one teach Bayesian methods to persons with little mathematical training? There has been discussion of main didactical problems in teaching Bayesian inference at the undergraduate level, in particular, students' difficulties and misconceptions (Albert, 1997; Berry, 1997; Moore, 1997).

David Moore argues that it is, at best, premature to teach the ideas and methods of Bayesian inference in a first statistics course for general students. He argues that:

1. Bayesian techniques are little used;
2. Bayesians have not yet agreed on standard approaches to standard problem settings;
3. Bayesian reasoning requires a grasp of conditional probability, a concept confusing to beginners; and
4. An emphasis on Bayesian inference might impede the trend toward experience with real data and a better balance among data analysis, data production, and inference in first statistics courses.

Similar arguments could be given for not teaching medical researchers Bayesian inference; however, these arguments are equally specious (Stangl, 1998) for medical researcher education as for undergraduate education. It is my own belief that hiding from our students and research colleagues the fact that there is more than one interpretation of probability, and the fact that there is no universal solution to the problem of inductive inference, is irresponsible.

Also, based on my own teaching of Duke undergraduates and medical researchers, students find it much more difficult to understand sampling distributions and significance levels than they do Bayes theorem and predictive distributions. Distributions for future outcomes of interest are much more easily understood than distributions for test statistics. Empirical research to test these impressions is in the planning stages. Another author, Iversen (2001), also addresses these issues in this volume.

6. SPECIFIC FEATURES OF THE INTERNET COURSE

Many authors have proposed the use of case studies and course maps (Barnes et al., 1994; Bryant & Smith, 1995; Chaterjee et al., 1995; Bradstreet, 1996; Schau & Mattern, 1997; Par & Smith, 1998; Nolan & Speed, 1999). This course will use both.

A first arguments for case studies is that cases require complex problem solving and this translates into longer retention of statistical concepts. Second, because students like cases, they become engaged in learning and are willing to take self-responsibility for their learning. And third, cases impart reality, since cases send the message that data analysis is process rather than a static numerical exercise, and cases more effectively communicate the need for statistical methods in the 'real' world. Students report increased confidence in their ability to use statistical methods in working with case studies.

A primary strength of this Internet resource will be the use of several health-related case studies. One such case is built around the GUSTO study (GUSTO investigators, 1993; Brophy & Joseph, 1995; Hively, 1996), a controversial study that has been analysed from both frequentist and Bayesian perspectives. It clearly highlights the differences between the paradigms, and the differences in answers to research questions that can arise when using different approaches.

The cases will be more in-depth than the examples provided in the general explanatory materials, will raise scientific and/or policy questions, provide rich relevant background material, contain data sets, and present analyses for addressing questions. The goal is to encourage and develop quantitative inductive and deductive reasoning skills within the context of health-related research.

The premise for course mapping is that understanding the relationships among statistical concepts is a prerequisite for effective statistical reasoning and problem solving. The model assumes that to be accessible from long-term memory, knowledge must be organised (or structured) and the relationships between different concepts clear and explicit. Teaching via the Web mandates organisation and explicit linkage. Because the teacher has less control over the student's navigational choices, the site's organisation is critical.

This course will use the concept of course mapping at multiple levels of resolution. At the lowest resolution general concepts will be linked with no technical detail. This level of resolution will be aimed at someone who wants the 'big picture' differences between Bayesian and frequentist inference. Bayes theorem will be presented not as a mathematical formula, but instead in words as a way to learn from data. Prediction and decision-making will also be presented as general concepts without mathematical formula.

A middle level of resolution will add some technical detail. Some probability and simple mathematics will be presented, but knowledge of calculus will not be assumed, and where calculus is used, it will be explained. This level of resolution will be aimed at the user who wants to be able to work textbook-level problems, and very simple real-world applications. It will demonstrate Bayes Theorem for discrete spaces and conjugate set-ups.

At the highest level of resolution there will be a great deal of technical grit, and knowledge of calculus will be assumed. This highest level of resolution will be aimed at the researcher who not only wants to understand the concepts behind Bayesian inference, but who also wants to be able to implement it in realistically complex applications.

7. COURSE CONTENT

The topics covered in this Internet course are the same as those covered in my 'live' courses except that time constraints are reduced on the Internet, and I can offer the student more choice in terms of technical detail.

At an introductory level, my teaching philosophy is much like that of Freedman, Pisani and Purvis (1998). I want deep thought without being too technical. My course is very applied and I teach mostly by example. In this particular course, examples will include clinical trials and observational studies from a wide variety of medical topics. A general outline of the topics covered follows:

1. Distinguish the conceptual differences between the Bayesian and frequentist paradigms of statistics including the definition of probability and the likelihood principle (Berger & Berry, 1988);
2. Explain Bayes theorem and examine each of the components of a Bayesian model, including prior, posterior, and predictive distributions, and likelihood and utility functions;
3. Introduce approaches to the elicitation of prior distributions;
4. Teach how to calculate posterior and predictive distributions for simple conjugate distributions, and demonstrate techniques for calculating posterior and predictive distributions for more complex cases;
5. Teach how to use predictive distributions within a decision-theoretic framework;
6. Teach sensitivity analysis for prior distributions and utilities;
7. Present case studies of published health-related research that use Bayesian methods;
8. Demonstrate software useful for Bayesian analysis and explain how to gain access to this software.

8. EXPERIENCES TO DATE

This paper discusses my own conceptual thoughts and others' expert wisdom on designing an internet course for teaching Bayesian methods to medical researchers. It is based on my teaching experiences with diverse students including undergraduate premed students at Duke, applied biostatisticians and non-statisticians taking LearnStat courses through the American Statistical Association, and medical researchers at Duke University Medical School.

While the middle resolution content (slides and script) are ready, this summer will be my first chance to focus on structure. This will include pulling things together, mapping and linking. By the end of the summer I will begin piloting the project, and I will discuss marketing with the American Statistical Association. During the coming year I will focus on developing lower and higher levels of resolution to broaden the market of appeal.

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