New Possibilities in Surveying Education via the Use of Spreadsheet Software and Web Technology

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ABSTRACT

Least squares (LS) computations is a major topic in engineering surveying, and the traditional approach often requires much lecture time and prerequisite knowledge. There are also limitations on the extent to which students can be tested in an exam, since problems with programming must be overcome. As a remedy, a revolutionary method of computation has been constructed and introduced into a first-semester surveying course given at HKUST, making use of a powerful optimization package that resides within most spreadsheet programs. The reduction in time and software requirement also implies new possibilities of testing students' LS knowledge, since the problems no longer have to be taken home for programming and can be given as online quizzes. Working in collaboration with the Teaching Technologies Unit of the Center for Enhanced Learning and Teaching (CELT), a revolutionary approach for delivering tests on LS adjustment tasks is also proposed and implemented for Fall 2001.

TRADITIONAL APPROACH FOR TEACHING LEAST SQUARES AND ITS LIMITATIONS

The principle of least squares (LS) is the rigorous data analysis method for various types of survey figures (Wolf and Ghilani, 1997). Though a simple and elegant idea, learning and implementing LS traditionally requires probability, statistics, multi-variable calculus and programming a computer to perform iterations. Most popular texts such as Bannister and Raymond (1992), Cooper (1987), Davis et al. (1981), and research articles such as Smith and Varnes (1987) adopt this approach. The prerequisite knowledge may exceed what can be expected of first-semester freshmen and/or students from liberal-arts backgrounds, while the amount of material to be covered may cost too much lecture time for a one-semester surveying course, which is typical in civil engineering programs. Furthermore, homework assignments would require days to complete due to programming and debugging needs, while plagiarism also frequently occurs. It is also not possible to ask students to carry out an entire LS adjustment task in a paper exam due to limitations on time and computing resources. It seems that the only remedy is to abandon the concept of LS altogether and resort to non-rigorous adjustment methods, which are well summarized in Done (1982), and/or specialized survey software such as those provided by Wolf and Ghilani (1997), which only require entering all the data without any concept of LS. However, these computer programs may only handle specific problems without much flexibility or transparency, while they can also cause the "black box" syndrome (Gordon, 1985). Furthermore, LS is a useful tool for other areas of civil engineering such as hydrology and structural optimization, and students would benefit much by learning it early.

BETTER INSTRUCTIONAL DESIGN BY USING SOLVERS

According to Sweller (1999, Ch. 2), a good instructional design should

(i) minimize unnecessary burdens on students' working memory, and
(ii) maximize the chances of developing automated *schemas* in their long-term memory.

According to this theory, the working memory can only process very limited pieces of information (~ 7) for a short duration, while the long-term memory is practically infinite in capacity and stores "schemas" which can be brought down to working memory when necessary. Loosely speaking, a schema is a "problem identifier" in one's long-term memory that trims irrelevant complexities and allows one to recognize the "big picture" of the problem, and compare it to stored problem configurations to find a suitable solution strategy (Sweller, 1999). The best instructional designs should therefore refrain from extraneous activities that exhaust working memory resources while staying focused on the fundamental and simple principle(s) that will aid in schema acquisition. The implications for LS education are that (i) the long, error-prone, yet peripheral process of linearization, matrices assembly, and programming should be removed; while (ii) students should concentrate on the simple and straightforward LS principle rather than problem-specific details such as what is the derivative of an arctangent for a resection adjustment problem.

The above (i) and (ii) may seem to be conflicting goals in traditional LS education. The solution was discovered accidentally from seemingly unrelated academic fields: in structural mechanics, there is a mathematically similar problem of reliability calculation, which traditionally also requires iteration methods (Ang and Tang, 1984). A recent breakthrough was the introduction of spreadsheet approaches for rapid reliability computations (Low and Tang, 1997), which has now found tremendous applications in surveying computations. When spreadsheet Solvers are properly used, LS data analysis can be made significantly more efficient and requires nothing more than the LS principle itself, without calculus on the part of the user. Such rapid methods of computation are important to researchers in their own right, and have been recently applied to triangulation adjustment problems (Hu and Tang, 2001), LS coordinate transformation with redundancy (Hu, 2001), and traverse adjustments (Hu et al. 2002). In a sense, the spreadsheet acts as an extension of one's working memory, allowing (i) and (ii) to be satisfied simultaneously, as evident in Hu and Tang's (2001) approach in solving triangulation problems. In the old days, such a direct approach to handling nonlinear equations in LS adjustment (but without the Solver) was viewed as "very complex and is rarely done" [Davis et al. (1981), Appendix B.9]. The new approach will hopefully help educators and practitioners abandon the use of non-rigorous methods and view the rigorous LS method as the norm. It is noted that the use of spreadsheets is only mentioned sparingly in the surveying literature, and only for routine work (e.g., in Wolf and Ghilani, 1997).

NEW MODES OF EXAMINATION ENABLED BY SOLVER AND THE INTERNET

Overview

The new methods of computation are adopted in a surveying course (CIVL 102) taught at HKUST. Since this new approach shortens the amount of time required to perform typical LS tasks from days to hours or less, while the only software required is a spreadsheet, a new way of testing becomes available. Online quizzes on LS are created; the question data as well as correct answers are prepared in advance and randomized, so that no two students would get the same quiz. The problems are then placed on the Internet, and students may take the tests online at specified times. Grades are determined automatically and released to the student once s/he completes the quiz, while the time needed to complete the quizzes is also recorded as part of the basis for grading. The preparation of the quizzes and the Web-implementation involve ingenious applications of Excel VBA programming and the Solver, and various Internet tools such as Java Script, etc.

System Architecture

The quiz system is deployed on an Apache Web server. It is developed primarily in PHP with MySQL database. Questions are coded in PHP scripts, while standard answers and student's submitted answers are stored in the database. Client-side Javascript is used for answer format validation. The client requirement is a common browser such as Internet Explorer. In preparing a quiz, Excel VBA macro is used to generate random numbers for input as parameters to formulae that will calculate answers. These answers as well as the parameters set are then loaded into the MySQL database.

To provide an accurate and secure testing environment, session variables are used on the server side to keep track of the student's activities in the quiz. The server clock is used as the only timing equipment. The IP address for each student is recorded by the Web server, so that any student not taking the quiz at the designated venue can be easily identified.

Further Development

With the latest Internet technologies, spreadsheets will be able to communicate directly to a server. This has two beneficial implications: on the usability aspect, students are not required to manipulate data to and from the web browser. On the technical side, the direct communication between spreadsheet and server can simplify the system complexity since the intermediate component (i.e., the web browser) is no longer needed.

CONCLUSION

A revolutionary method for LS computations has been developed and implemented in CIVL 102, a first semester surveying course, and a system of online quizzes has been created for this class. Not only can much more material be covered in a first course, but the audience can also be extended to include students from non-calculus backgrounds. This is important because, for example, the Polytechnic University's LSGI department admits freshmen from non-science streams, while surveying is also taught at various technical institutes, and, without the new computation methods, many important topics in data adjustment would be inaccessible to those less equipped students/ practitioners.

A paradigm shift is likely to take place once the spreadsheet method is made popular, and the new modes of computation and testing will also lead to a series of questions to be considered by educators in surveying and other fields. What are the appropriate software skills to be acquired by civil/surveying engineering students (Frank, 1985) as well as instructors? What should be taught in mathematics and computer courses at university and secondary levels; should we delete some of the programming material (e.g., PASCAL), and introduce some advanced spreadsheet skills to all secondary students before they go on to universities? Should we draw a clearer line between mathematicians and engineers in terms of what they have to learn in school and be able to do in their careers? Some partial answers to such questions can be found in Frank (1985), Harvey (1994), Langley (1987), and Verderber (1992), among others. However, answers to such questions will inevitably change with time, as new technologies such as those introduced in this thesis emerge.

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