LEARNING SPATIAL DESIGN AND ANALYSIS CONCEPTS

Mark Shortis, Frank Leahy, Cliff Ogleby, Allison Kealy And Fiona Ellis
Department of Geomatics, University of Melbourne

Key words: learning, spatial geometry, design, simulation, web delivery

ABSTRACT

This paper describes the process and results of the transformation of the curriculum delivery of four different areas of the syllabus of the geomatics programs at the University of Melbourne. In each case the transformation addresses the teaching and learning problems associated with spatial relationships in two or three dimensions by providing a rich resource of theory material, animations of spatial concepts and, most importantly, visualisations or simulations of real world survey problems that provide immediate feedback. The visualisations and simulations allow students to investigate the design and analysis of spatial geometry and spatial relationships at their own pace, using immediate feedback to reinforce learning. The online material affords an enhancement of the learning experience for undergraduate students, both complementing and providing an alternative to the conventional teaching methods of lectures, tutorials and practice classes.

INTRODUCTION

Measurement science has always been a major component of surveying, spatial information and geomatics courses, and is typically taught across all years of the courses. At the University of Melbourne entry level measurement science contains curriculum material that is a generic introduction to all aspects of geomatics, whilst material presented in later years becomes increasingly specialised in sub-disciplines such as advanced plane surveying, geodesy, the cadastre, GIS and mapping.

In common with many geomatics programs at tertiary level, the proportion of the course devoted to measurement science has been shrinking in response to a number of factors. The first of these is pressure on the number of contact hours in engineering and science courses due to the wide perception of “over-teaching”. The second factor is the proliferation of combined degree courses, that allow students to graduate after five or six years with two degrees that, when taken separately, would require three to five years each. Although there is commonly some overlap of material between closely aligned disciplines, inevitably some geomatics material is removed from the combined degree program due to the pressure of time. The third primary factor is the change in emphasis in geomatics courses, such as the course at University of Melbourne, moving away from the more technical skills associated with measurement science toward higher level design and planning expertise associated with GPS, GIS and land management.

The Learning Problem

In concert with the contraction of the time available for measurement science material in courses, it is widely accepted that there is a learning problem associated with the spatial relationships embodied in measurement science. Unlike many of areas of tertiary education, measurement science is a relatively sudden acquisition of new knowledge and new practical skills due to unfamiliarity with the basic concepts of surveying and positioning. At entry level, students need to understand the geometry of and error propagation associated with, for example, surveys for large-scale mapping. At the advanced plane surveying level, students move on to the more demanding learning task of understanding survey network design, computations and analysis in 3D space. Students then progress to higher concepts of geodesy and GPS based on the ellipsoidal shape of the earth. The required synthesis of new knowledge and new skills, combined with the management and operation of complex survey equipment in the field and the design and operation of field surveys, is often overwhelming for students. In this environment the educational objectives can become completely obscured by the overload and the student does not learn the essential concepts of measurement science.

Further, a continuing difficulty with teaching measurement science in tertiary education is maintaining a clear connection between the mathematical processes, the surveying equipment and the field work techniques, whilst accommodating a variety of practical skill abilities and differing cultural backgrounds of students. The variety of student cohorts, and the associated different levels of mathematical skills, is a significant issue as measurement science is taught as core material to students in the geomatics programs, and as service courses to students in engineering, science and humanities courses. Students with relatively poor preparation in basic mathematics are clearly disadvantaged, and inevitably have much greater difficulty understanding design concepts that are based on principles derived from geometry and statistical theory.

A New Pedagogy

A potential solution to the combined problems of providing quality teaching over shorter time frames, and overcoming learning problems associated with poor synthesis of concepts and skills, is a dramatic change to the pedagogy of teaching measurement science. Rather than teach the basic skills (the bottom-up approach) which must be integrated to provide optimal learning outcomes, the teaching method can be changed to the challenge of problem solving (the top-down approach) with the emphasis on deep learning of design and analysis. This new approach has to be supported by a rich resource of online educational material that provides the details of field procedures and theoretical concepts. A problem based approach concentrates on design and analysis in lectures, de-emphasising issues such as the fine detail of instrument handling and field procedures.

This type of problem based approach has proven to be effective in many disciplines, such as medicine [1] and economics [2]. The use of visualisations and simulations for teaching and learning is widespread, and simulated site visits often have a spatial nature, such as uses in architecture [3], mining [4] and geography [5]. [6] gives further examples of multimedia education resources with an emphasis on the spatial sciences.

A vital component of the new pedagogy is demonstration of the spatial relationships and field procedures through simulations and animations, in order to minimise the intimidating effects of complex survey designs and complicated field procedures. When presented with a field measurement problem, the outcome will be that the students will focus on the solution to the problem in terms of techniques, rather than being absorbed by acquiring the physiological skills of measurement processes with surveying instruments. Multimedia delivery of the curriculum material should also facilitate and encourage independent learning by students, which is often discouraged by "stand and deliver" methods. The availability of and encouragement to use online interactive material gives students feedback on their knowledge acquisition outside of formal contact with lecturing and tutorial staff during class times.

A disadvantage of this approach is that students have less time cultivating practical skills and therefore have less general experience with field surveys and handling of instruments. However, no matter how much field practice is included as a component of a geomatics course, new graduates who become field surveyors learn or re-learn many of their skills on the job. Further, many graduates of tertiary programs will never practice as field surveyors and typically will move into information systems or project management, so their need for the skills associated with measurement science is at a management level rather than practical level in any case.

FOUR MULTIMEDIA DEVELOPMENT PROJECTS

Each of the four projects described in the next sections are based around web sites that have been created to provide simulations or visualisations of spatial problems as a primary function. The spatial concepts are presented either as simulations of real world survey problems or visualisations of spatial relationships. In addition, some of the projects also include an equipment database, detailed simulations of survey equipment and animations of essential field procedures. All projects provide access to theory and practice material, such as lecture notes, tutorial guides and example data sets.

In all cases the theory material and equipment databases are straightforward web pages coded in HTML. The animations have been created by Macromedia Director and stored within the web pages as Shockwave applets. Visualisations are presented as VRML models [7] or rotating images, viewed using browser plug-ins such as CosmoPlayer [8] or LivePicture [9]. Some of the visualisations and animations required the use of CAD software to create the models and then generate image sequences that were exported to Director, or converted directly to VRML models. The problem simulations are coded in Java as separate modules and are linked to the web pages, or coded in C++ and loaded as a browser plug-in. The problem simulations utilise a survey analysis tool that processes simulated or actual field surveys and produces feedback such as the precisions of computed locations. The survey analysis tool is based on a survey network adjustment program [10] that is provided with correctly formatted data by the problem simulations. The advantage of the survey network adjustment program is that it can process virtually any data set and individually tailored solutions are not required.

In all four cases the multimedia material is or will be tightly integrated into the relevant courses. The web sites are used within lectures and tutorials to illustrate problems and theoretical material. Further, all subjects make use of tutorial and practical assignments, and many assignment tasks are oriented around the problems and visualisations included in the multimedia material. In some cases the students' solutions to the problem simulations are submitted as part of the assignment report.

Plane Surveying Concepts and Field Procedures

This project transformed the delivery of common, entry level material on plane surveying into a multimedia based, online curriculum for self paced learning and assessment. The plane surveying site has been used in the geomatics courses and service units since 1999 and is described in full in [11].

Briefly, the design of the web site is oriented around the metaphor of survey problems within the Melbourne Zoological Gardens. The use of the zoo environment was adopted principally because it is a familiar environment for the vast majority of students, and has the potential to create or adapt a variety of realistic plane surveying problems. Once selected, a particular field survey measurement task is introduced by a problem brief that outlines the environment, circumstance, the problem to be resolved, and is reinforced by feedback from the students in response to mandatory questions on the problem specifications.

When the problem brief is completed, the 2D problem simulation is launched. The student is then required to place survey stations and measured positions to solve the problem. Immediate feedback is provided by error ellipses, to optimise the design of the survey, and the numerical data, to determine whether the survey is meeting required specifications.

Learning Design of Survey Networks

One of the fundamentals of the execution of field surveys is the effective and efficient design of survey networks. This combination of knowledge and design skill underlies much survey work, and is a strategic area of teaching for tertiary courses in surveying and geomatics. A weakness of the plane surveying project was the limitation to 2D representations of the survey problems. The greater complexity of advanced survey network design required realistic 3D virtual landscapes and real-time feedback on design outcomes. The survey networks site has been used in the geomatics courses since 2000 and is fully described in [12].

The pivotal component of the network design project is a web browser plug-in developed to allow the user to:

- Navigate around VRML models.
- Import and export files of survey station and measurement data.

- Occupy and sight to specific survey stations in the network.
- Add new survey stations and add or delete survey measurements.
- Compute the survey network solution in measurement or simulation modes.
- Display feedback from the survey analysis tool including error messages and error ellipsoids.

As part of the tutorial exercises associated with the course work, students are required to use the simulator to design a building monitoring survey and carry out a analysis of a dam deformation survey. Although the use of the simulator can not and was not intended to replace actual field surveys, it does allow students to practice their design and analysis skills in virtual environments with the benfits of visualisation and feedback.

Visualisation of Navigation and Positioning Problems

Students in the geomatics degree programs are required to have a fundamental understanding of navigation and positioning, both on and beneath the Earth's surface. The concepts associated with spatial relationships within a 3D world, and the ability to describe these relationships, are a common thread in the sub-disciplines of surveying, geodesy and mapping. A problem that is frequently encountered when discussing navigation and positioning is the inability of students to visualise the 3D spatial relationships. Conventional diagrams and figures represent these 3D relationships as a series of 2D views which often require a great deal of elaboration in order to explain the representation. The 2D views can often be very complex if the mathematical abstraction and the real world problem are to be shown in context with one another.

One solution to this learning difficulty is to present 3D navigation and positioning problems as 3D simulations that are realistic, layered and animated. Realistic VRML models can present 3D spatial relationships very clearly and the ability to rotate the models is critical, as interpreting the 3D geometry from apparent motion around the object is very often pivotal to students' ability to analyse the spatial relationships between vectors and surfaces. Scenarios can be created for many fundamental spatial relationship problems in surveying, geodesy and mapping. The impact of the visualisation and animation is much more critical for subtle and complex problems, such as the various definitions of 3D vector intersections and the shape characteristics of geodesics on the ellipsoidal Earth.

The web site created for the navigation and positioning project again presents the visualisations in the context of real world scenarios. Six examples are included or are under development and cover vectors in 3D space, vectors and lines, vectors and planes, vector intersections, spherical trigonometry and line intersections on the ellipsoidal Earth. Each scenario contains a tutorial that steps the student through the spatial relationships, a number of 3D models and images that can be viewed using plug-ins, a spreadsheet exercise and a spreadsheet template for the exercise.

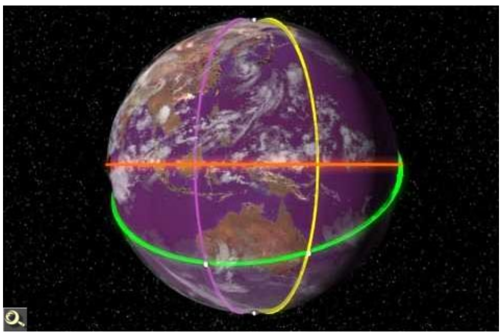

Figure 1. LiveImage model of spherical trigonometry.

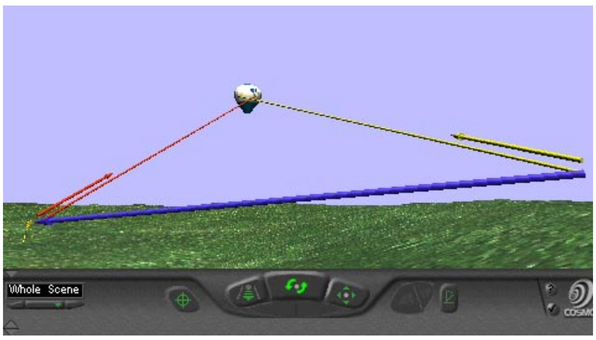

Figure 2. VRML model of vector intersection.

Each scenario includes a LivePicture display (Figure 1) for "constrained" investigation of the spatial relationships and a VRML model (Figure 2) for "free" investigation of the spatial relationships. The LivePicture model allows students to rotate the object about one axis to allow an important view aspect to be presented. The VRML of the 3D object allows complete freedom of movement around and within the model. It is easy to get spatially or intellectually "lost" within the 3D model, so in each case pre-defined views are provided to illustrate the most important aspects of the geometry.

The scenarios are once more strongly integrated into the course work for the undergraduate students, as the tutorial exercises are an assessed component of the course. The web site was used for the first time in 2001 and initial feedback from the students was very positive. In particular the students found that the flexible access to the tutorials and models very useful in understanding the spatial relationships

Integrated Systems in Geomatics

The newest multimedia project, under development in 2001/2002, is focussed on preparation of students to use GPS technology in the field and to provide students with virtual experience of the measurement processes and technology of integrated systems. Students will be able to visualise the limitations and capabilities of different data acquisition techniques and the different methodologies that can be combined into feasible solutions for contemporary measurement problems. Integration will be demonstrated using case studies and will be pivotal to the understanding of design and analysis of positioning and navigation systems.

A further rationale for this project is the unavoidable limitations on access by students to state of the art equipment. Tertiary education institutions inevitably have restrictions on the resources that can be made available to teaching programs, and the provision of a broad range of current field survey equipment is simply not feasible. It is often the case that a small number of geodetic class GPS receivers, for example, must be shared amongst a large number of students. Virtual access to equipment is not a replacement for actual experience, however virtual access is better than no access, and a simulated GPS receiver does allow students to have some preparation and familiarity with field equipment and therefore make efficient use of the equipment when it is available. Use of virtual equipment becomes an essential enhancement of the student learning process to facilitate very effective access to state of the art equipment.

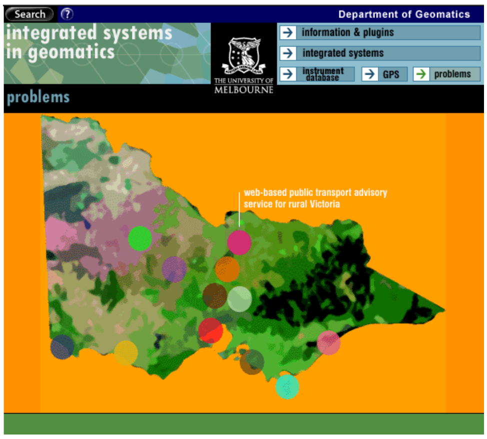

Figure 3. Presentation of case studies.

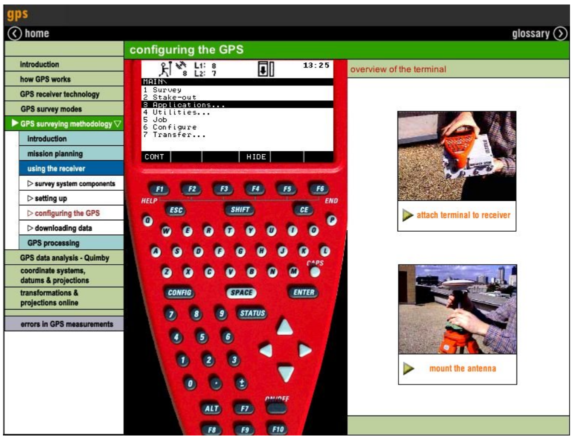

Figure 4. Simulated GPS receiver.

The main components of the web site are:

- A series of local case studies that illustrate the range of measurement solutions provided by integration of technologies such as GPS, GIS, remote sensing and conventional surveying (see Figure 3).

- A comprehensive and detailed tutorial on GPS technology, including animations of GPS survey methodologies and a simulated geodetic GPS receiver (Figure 4).
- A Java utility for the conversion and transformation of geodetic coordinates and datums.
- Links to other resources such as GPS mission planning, reduction and analysis software.

The case studies are used as an assessed component of coursework and are presented as a tender situation in which student teams present a proposed solution to the client. The student response to the tender indicates the team skills and integrated systems approach to accomplishing the task, including project management and costings. Whilst components of the web site were used in 2001, the first comprehensive use of the web site will occur in semester 2, 2002.

CONCLUSIONS

In summary, the multimedia projects described in this paper provide rich resources of information and visualisation or simulation of spatial concepts, measurement fundamentals, survey instruments and field processes. The presentation of comprehensive simulations of the field work processes, including instrument handling, prior to the students taking equipment into the field, leads to more efficient and effective use of the equipment. This enables students to concentrate on the correct implementation of measurement processes, rather than contending with the lack of skills in equipment use. The multimedia material reiterates and augments the spatial concepts presented in formal lectures, utilising the dual mechanisms of presenting simulations in lectures and self-paced review by students.

Feedback and evaluation from students has in general been positive and encourages expansion of the current projects and further development in other areas of measurement science. However, as stated at the outset, the online material is an enhancement of the learning experience for undergraduate students, both complementing and providing an alternative to the conventional teaching methods of lectures, tutorials and practice classes.

REFERENCES

1. Finucane, P. M., Johnson, S. J. and Prideaux, D. J., Problem based learning: its rationale and efficacy, *Medical Journal of Australia*, 168: 445-448 (1998)
2. Johnston, C., James, R., Lye, J., and McDonald, I. An evaluation of the introduction of Collaborative Problem Solving for Learning Economics. *Journal of Economic Education*, 31, 13-29 (2002)
3. Newton, C., Simulated site visits, *International Conference on Computer and Visualization and Graphics*, IEEE Computer Society, London, England, pp.62-66 (1999)
4. Russ, K. and Wetherelt, A., Large scale mine visualisation using VRML. *IEEE Computer Graphics and Applications*, 19 (2): 39-44 (1999)
5. University of Leicester, Virtual field course, Department of Geography, www.geog.le.ac.uk/vfc/ (2002)
6. Shortis, M. R., and Cartwright, W. E., An overview of curriculum transformation and multimedia delivery. Proceedings, *Trans Tasman Surveyors Conference 2000*, Queenstown, New Zealand, pp 37-49 (2000)
7. Web3D, Virtual Reality Markup Language, Web 3D Consortium, www.web3d.org/vrml/vrml.htm (2002)
8. Cosmo Software, CosmoPlayer, www.cai.com/cosmo/home.htm (2002)
9. MGI, LivePicture plug-in, www.mgisoft.com (2002)
10. Shortis, M. R. and Seager, J. W., 1994. The use of geographic and map coordinate systems for geodetic network adjustments, *Survey Review*, 32 (254) : 495-511
11. Shortis, M. R., Ogleby, C. L. and Kealy, A., Self-paced learning of plane surveying concepts and field procedures, *International IT Conference on Geo-spatial Education*, Hong Kong Polytechnic University, Hong Kong, pp 171-180 (2000)
12. Shortis, M. R. and Woodhouse, N., Learning design concepts from a three dimensional survey network simulator. *Australasian Association for Engineering Education 12th Annual Conference*, Queensland University of Technology, Australia, pp 34-39 (2001)