
Teaching and Learning Discrete-Event Simulation & Modelling With WITNESS®

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At Oxford Brookes University the module Simulation & Modelling has been a feature of the Mathematical Sciences syllabus for a number of years. Students enrolled on this module are Statistics and Mathematics undergraduates in the second or third year of their degree course.

Teaching simulation modelling in the traditional way is not an easy task, especially if students have little or no programming skills. Visual Interactive Simulation Modelling systems (VISM) are ideal for addressing this problem. Fitzharris [1] gave an overview of how a VISM, such as ARENA, works.

At Oxford Brookes the simulation package WITNESS is taught as part of the course and used as a modelling tool for assignments and exercises. It offers large flexibility in modelling and enables the students to create a dynamic display of their model, and even interact with the running program [2].

In this article we are not intending to review the software, but to share our own and the students' positive experience with a WITNESS based group project. We use WITNESS Release 9.30, the Educational Version.

An overview of WITNESS

WITNESS is a VISM system [3] or *simulator* as Law & Kelton [4] call it. Produced by Lanner Group, it claims to be the world's leading software product in the field of visual interactive simulation. The version used for teaching is the educational version which has the full functionality of the proper version but is restricted to a smaller number of elements. Both discrete and continuous systems can be modelled, but our course is concerned with discrete systems only.

None or very little programming is involved which makes the learning of simulation more accessible for students with no computing experience. The main steps in building a model are creating elements and linking them together with rules.

The most commonly used discrete elements are "parts", "buffers" and "machines". They are displayed as dynamic icons and represent tangible entities in the real-life situation under study. "Parts" flow through the model and can represent, for example, people moving through a supermarket, products moving through a production line, or calls in a telephone exchange. "Buffers" are places where parts are held, such as people in a queue, parts awaiting an operation on a factory floor, or the space containing aircraft waiting to land. "Machines" represent anything that takes parts from somewhere, processes them and sends them to their next destination, for example a supermarket checkout or a machine tool.

Logical elements represent control and information aspects of the model and include attributes, variables, distributions and functions.

Parts are transferred between elements according to input and output rules which allow us to model complex decisions about the transfer of parts based on almost any criteria.

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Fig 1: A machine detail form

The software contains a library of icons to represent elements but the users have also the facility to create their own and this opportunity is taken up enthusiastically by most students.

After the elements are defined, displayed and detailed, the model can be run immediately and any logical errors can be located and corrected at this stage. The model can then be modified by adding, changing or deleting items, and then be run again to assess the impact of these changes.

The simulation can be run in different modes, from step-by-step (with full screen display) to a 'batched' time in the future (with no screen display). The element flow shows the movement of parts through the model.

Statistical reports are generated automatically. These reports can be used to help choose between alternative modelling scenarios. Standard reports comprise a collection of statistics for an element and can be exported in several formats.

There are many WITNESS features which aid analysis, including standard report tables and graphs (which list the basic mathematical behaviours of all elements in the model automatically). You can also create time series, pie charts, histograms and customised report tables and expressions in WITNESS.

The benefits of the WITNESS approach are that:

- students can work together as a team on creating and using WITNESS models.
- models can be built and tested in small incremental stages. This greatly simplifies model-building, provides the ability to identify errors in the logic and makes the model more reliable.

- the model can be changed at any time during its run. Changes are incorporated immediately, leading to faster model-building.

WITNESS at Brookes

At Oxford Brookes University a modular system is operated where each module is taught for a term with a weekly contact of a four-hour block (2 lectures and 2 PC-based practicals). The assessment of the Simulation & Modelling module is based on coursework only and one of several coursework tasks is a group project, which consists of modelling and simulating a real system using the WITNESS software. This assignment will be described in more detail.

The teaching consists of lectures where theoretical background for queueing models, input data fitting, output analysis, model verification and validation are provided to the students whereas the practicals are mainly dedicated to learning the use of WITNESS.

The students are introduced to the software from the second week of teaching, where they start running built-in demonstration models and looking at the output measure of performance such as average queue length, average waiting time, production per unit time etc. Steps that follow consist of bringing in some variation to the existing models, for example, decreasing the mean service time and observing the corresponding change in the average waiting time.

They then learn to build the first simple model from scratch. The first WITNESS based assignment requires them to finish a partly built model, to use the model to optimise the efficiency of the system modelled and write individual reports about their findings.

By the fifth week of term students have gone through a steep learning curve, particularly those who had little previous contact with computers at all. They are now able to design, model and simulate their own system and ready to start the main project on the course which is described in the following.

One major point we observed during the term, was that the students were enthusiastic and highly motivated about learning and using the software package. Some tentative explanations for this are the range of varied activities involved in simulation, one of them being the chance to be visually creative, and the motivating power and satisfaction of the end product, the animated model on the screen, there for anybody to see.

A WITNESS assignment: Modelling a real life system

The brief for this assignment was the construction of a model and simulation of a simple system with no more than three or four interacting queues. Examples of suitable systems given were cafeterias, petrol stations, supermarkets, banks, or post offices. All aspects of the modelling process had to be demonstrated and would be assessed. WITNESS should be used to automate the model which, after being validated, should be used to test one or maybe two different innovations.

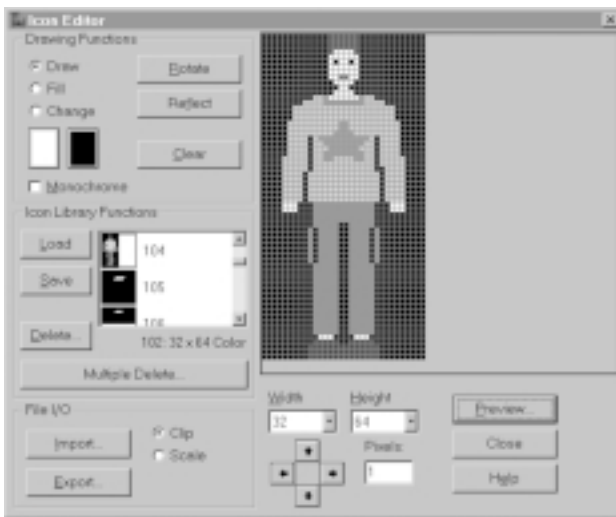


Fig 2: An icon designed by a student

The assignment had to be undertaken in groups of three or four people. As in most modelling projects management and cooperation of a team is a major part. The project was open ended and each team had to agree a plan and an agenda consistent with the amount of time they wished to devote to it. Tasks should be delegated and undertaken concurrently, e.g. once a rough model had been sketched out the data could be collected and the WITNESS model programmed at the same time. Reporting the results was a fundamental part of the project and sufficient time had to be scheduled to write up the aims, methods, results and conclusions of the study.

Some of the systems students have chosen in the past were cinema, post office, petrol station, the University library, the library's photocopier room, cafeteria, pub, swimming pool, train station, telephone switch board.

The models usually represent the various service points (tills, service desks, photocopiers, petrol pumps), the queues and the parts flowing through the system (customers, cars, phone calls, etc.). Reports include

analysis of queue length and waiting times in queues, average times in system, maybe profit, and typically suggestions for shortening the waiting times. One or more of these innovative schemes had to be implemented into the model and the results were analysed and compared, conclusions drawn and suggestions made.

Name	BWQueue	ColQueue
Total In	686	45
Total Out	671	44
Now In	15	1
Max	26	4
Min	0	0
Average Size	2.77	0.34
Average Time	1.66	3.09
Avg. Delay Count		
Avg. Delay Time		

Fig 3: A report form for queues

Verification and validation is an important part of the modelling process, and often students ask the manager of the system under study to confirm that their model behaves like the real system. Sometimes the managers in turn ask to see the final report and may review the performance of their queuing systems based on the findings of the teams.

Tutor support throughout the assignment was available in scheduled practical sessions as well as through email and personal contact. The standard of many of the finished projects was very high.

At the end of the term a session was organised where the students could present their projects and run their model in front of their colleagues who marked their presentation. The animated simulation is projected on a screen and each group presents their project as a team.

Example of a student project

The following is an example of one of the models that students developed for their project.

The library photocopier room contains five black and white copiers and two colour copiers. Students form two queues, one for black and white and one for colour copiers. Long queues tend to build up in the busy periods. The group suggested to simulate the current scenario and an alternative one, where one of the colour copiers was replaced by a black and white one.

The main objective was to compare the queue lengths, wait times, total time in the copier room and number of students in the room over the busy lunchtime period. Data were collected during different times of the day and analysed to give distributions for use as service times for the copiers and interarrival times for the students. Service time was defined as the difference between the time when the copier card was inserted into the reader and the time when it was removed. Since students copy various numbers of pages it was decided to split the service times for copiers into two categories, less than 5 pages of copying and 5 or more pages. The proportion of students in each category was counted. Many visits were made to the copier room by the group. The proportion of students copying black and white and colour was also counted. The WITNESS model was developed.

Main elements were the part "student", the buffers representing the two queues, and machines representing the copiers. Icons were created for parts and machines, including status indicators for the copiers (busy or idle). Since the interarrival rates varied according to the time of day, it was represented by a function. Two timeseries graphs display the current queue lengths and time weighted mean time in each queue. The model was run for a simulated time of 24 hours, taking into account the closing times and the different arrival patterns during the day. The model was verified and statistical reports shown to the audio visual engineer in the library who confirmed that the model gave an accurate representation of the real system.



Fig 4: Screenshot of the example model

A day in the life of the copier room was simulated ten times, each time using a different set of random number streams for the distributions used. Mean values were calculated for the queue length, mean time in the queues, mean number of students in the system and mean time in the system. A Mann-Whitney test could have been used for validation at this stage, but the group did not have the time in this case. Machine utilisation was also considered, i.e. percentage of time the copiers are in use. The proposed changes were implemented in the model and reports generated as before and analysed and compared to the original model. As expected the mean queue length and wait times for the black and white copiers decreased, but this was at the expense of the colour copier queue. The conclusion was that it would be impractical to replace one of the colour copiers with a black and white copier.

Student feedback

A questionnaire was distributed to the students who took the module to seek a feedback about the overall course. The answers were ranked from 1 (most positive) to 5 (most negative). 92% of the questionnaires were returned. Figure 5 shows a box plot of the average ranking. The graph shows an average around 2.5 with an interquartile range of 0.94.

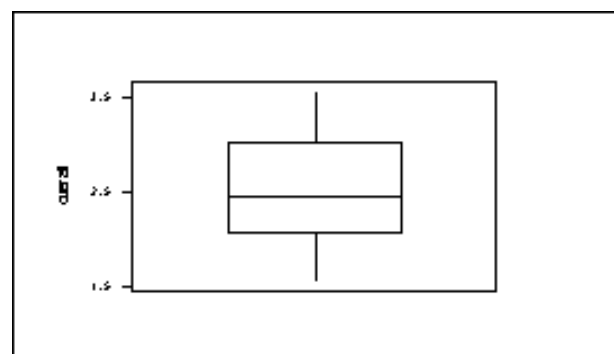


Fig 5: Boxplot of average ranks

Conclusions

Using WITNESS to teach simulation and modelling has proved to be a successful and popular choice. The approach seems highly motivating and makes simulation fun for a wider range of students, especially those with no or very little programming skills. Students gained considerable experience in modelling real world systems which for some will be an asset for their future professional career.

Acknowledgements

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Response from Tony Waller, WITNESS Product Manager, Lanner Group Ltd

Lanner are pleased that Oxford Brookes conclude that WITNESS has been a successful and popular choice for their simulation modelling course. WITNESS is used extensively by educational establishments throughout the world and the latest versions include a tutorial guide for student use. This is proving popular alongside course-specific case study and learning materials. We believe the key to fast learning with simulation software is ease of use and therefore we put much effort into providing a first class interface together with high functionality in the different model building blocks. Whilst WITNESS is easy to learn there are so many features : from links to spreadsheets to CAD imports to automatic optimisation to virtual reality graphics, etc that students cannot hope to master all the various facets that simulation modelling offers in the modern integrated world. However we are confident that courses as described in the article are popular, that they introduce successfully the concepts of simulation modelling and instil the basis for further development and use of simulation in the business world. This is good news, as simulation, especially with WITNESS, has much to offer industry to reduce risk and waste, and eliminate error.