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A WEB-BASED VIRTUAL FACTORY AND SIMULATOR FOR INDUSTRIAL STATISTICS

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ABSTRACT

An educational web-based virtual factory and simulator environment is presented in this paper. It has been developed for university students to apply various statistical quality control techniques to explore the quality problems. The architecture of the simulator and methodologies for developing the website are discussed. Major benefits for both the students and lecturers are demonstrated.

1 INTRODUCTION

Management games are well-established techniques for improving the understanding and appreciation of realistic problems. Flight Simulators (Sterman 1992) where students "fly" a particular aspect of an enterprise are particularly rewarding. A web-based virtual factory and simulator platform for teaching industrial statistics and process improvement techniques has been developed. It provides students with experience of a "flight simulator" which allows them to practice effective decision-making and demonstrates the practical application of industrial statistics in a realistic environment.

2 THE PROJECT

The project aims to develop a virtual online factory within which, students can explore quality problems by controlling the machines within the factory. Students can manage the factory for either a period of one month, or the length specified by lecturers, with the factory running in real time. The main objective is to reduce quality problems and continuously improve the quality over a substantial period of time. Techniques such as control charts, process capability, experimental design and response surface methodology and their underlying statistics are explored. The simulator has the capability to generate the cost of production, the average throughput of products and process capabilities so that students can develop an appreciation of how quality strategies affect the productivity and cost of a factory's output. Thus a systems approach to managing the quality of a factory is encouraged.

The developed simulator creates a problem-based learning approach with relevant academic underpinning. It provides the student with the experience of applying theory to the practice of operating a factory in real-time. Students are able to "live" with the problem, research and develop solutions over a significant time period. It has always been a problem to teach effectively over the interface between two disciplines. This project addresses this problem and enhances the learning experience by providing a realistic scenario over an extended time frame.

The infrastructure of the system is based on the concepts developed by Wood and Kumar (1999). The simulator is interactively controlled over the Internet. Students and lecturers gain access through their group name and password. Each student group have their individual view of the factory under their control. The simulator is initialised with the same conditions by the lecturer. Individual students then access factories to inspect machine status. The lecturer can intervene by creating specific one-off conditions, for example unexpected failures, and obtain an overview of all the groups performances.

3 OVERALL STRUCTURE OF THE SYSTEM

The virtual factory platform consists of three machines as illustrated in Figure 1, representing three processes of a production line to manufacture components for the automotive industry. All components that do not meet the quality criteria (i.e. out of product specification) will be wasted, due to the nature of the process.In the early stages the factory is assumed to be running all the time without affecting the lead time and inventory. Before the factory starts, the system generates a certain amount of product data for students to download and analyse. As is the nature of web-based simulation, the simulator will stay static if it is not activated by any event. As the factory restarts, every time a group of students log in, the simulator will start running and record data into the database. The data will accumulate and be collected into the spreadsheets by downloading a server-generated Excel file. When the students log into the system, the data is calculated, and they will view the factory running continuously at the server side.

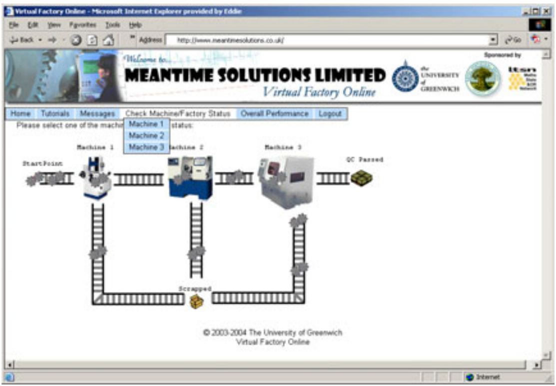

Figure 1: The Virtual Factory Workshop Layout

The students' task, as the newly appointed quality action team, is to control the system and improve quality within the factory making sure that there are minimal defects while also maximising the financial returns. Students need to log into the system regularly to check the status of the machines by downloading the control data into a database. Using the quality theory, they can generate control charts to analyse if the machines are in control. The control chart is the fundamental tool of statistical process control, as it indicates the range of variability that is built into a system (known as common cause variation) (e.g. Banks, Carson II, and Nelson 1996). Thus, it aids to determine whether or not a process is operated consistently or if a special cause has occurred to change the process mean or variance. If the students find the machine is out of control, they can deploy the control parameters on each machine to adjust its output. The students are not able to bring the machine into control unless they apply the appropriate quality theory and perform the calculations. By using experimental design, they can determine which parameters are affecting the quality of each machine's output. The simulation is designed so that the performance as well as financial returns deteriorate if the students try to 'guess' the parameter values.

The developed simulator platform comprises two main modules: a student module and an administrator module. The simulator tool contains interactive pages and links which teach the underlying statistics and solutions. It is configured by the lecturer/administrator so that data streaming from the system can be downloaded and analysed off-line, using software of the user's choice or online using tools such as control charts which are integrated into the system to streamline the analysis.

A dedicated messaging system works inside the simulator. Lecturers/Administrators are able to send individual or global messages to the students. The students can then reply or initiate messages to the lecturers. This facility enables more flexibility of communication between lecturers and students. For example, the lecturer can set up a malfunction on a certain machine, and then inform the groups that an event has happened. The students, as the quality control action team of the factory, need to provide timely dynamic decisions in order to make a profit.

4 SYSTEM SCENARIOS

Through their own group name and password, the students are able to access their own factory. The simulation engine handles individual scenarios for each group. Therefore they operate the factory without affecting other groups. The students can also access the other groups' overall performance to see their ranking among all the groups.

The students can access the factory floor, choose certain machines, change the parameters and download product output data, read messages set by the lecturers, read tutorials and access the overall groups' performance ranking list, as illustrated in Figure 2. Lecturers or administrators have full control of the online simulator. They can set up

Figure 2: Interfaces and Screenshots from the Virtual Factory

the initial scenario, develop their own story or using the ready-made templates, set the factory start and finish times and send messages to the student groups. They are also able to view the student registration information, the groups overall performance and the operations carried out by each group.

This web-based virtual factory has been based on discrete-event simulation theory. The simulation engine employs a Gaussian random number generator on which special causes such as trends and freaks are added to simulate out of control conditions. The slide bars determine the condition of the control chart data in terms of special and common cause variation. The students need to find out for themselves how to use the parameters provided to control the quality output.

The current scenario used in the virtual factory is composed of three stages as shown in Figure 3. In the first stage, students find that one of the machines is out of control, so they need to bring the control chart in control and eliminate the special causes. Once in control, the students find that another machine is producing products outside specification requirements. Students therefore need to apply design of experiments to determine which parameters affect the variation.

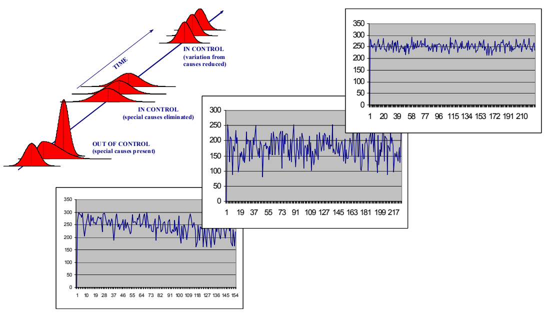

Figure 3: Three Stages of the Online Competition

5 SYSTEM IMPLEMENTATION AND BENEFITS

This Internet based simulator is platform independent because of its ability to run fully at the server side. As long as the lecturers or students have Internet access and a web browser, they can manage the virtual factory anywhere, anytime. One of the main advantages of using this approach is that the students are able to develop a methodology for quality improvement techniques rather than just an appreciation of the individual tools. Therefore one of the challenges of developing the simulation is to ensure, for example that students are not able to improve a process through experimental design unless they have first got the system in statistical control. The project will offer students an opportunity to interact with a realistic scenario over an extended period. This is particularly important to both engineering students who sometimes find it difficult to appreciate the practical relevance of statistics, and statistics students who may find it difficult to appreciate the practical application of their discipline (Spedding 2001).

The tangible benefits to lecturers in higher education are the provision of a realistic environment to practice the application of statistics. The simulation is managed by the university administrators so that teachers do not have to concern the administration of the environment. The project will help teachers of engineers to illustrate the power of statistics in solving real engineering problems by providing a virtual simulation which is both physically and dynamically a realistic replication of the industrial environment. The website will also be useful to industries as a training tool for quality improvement.

The web site uses server-side technology, and is fully documented and programmed in modules so that the suite can be developed further. A combination of Active Server Pages (ASP), Java technology, and a Microsoft Access database has been chosen to develop the proposed system.

The infrastructure of the database is designed to ensure that in the future, as the system is used in a multi-user environment, it can be extended to a large scale database such as SQL Server or Oracle. These can provide more stable service and better security features to the online system. The system will be able to serve different groups from different courses or institutes without affecting each other’s performance. Groups from the same course are able to compare their outcome, balance and performance statistics in real-time while their factories are running.

There are several benefits of using server-side technology to run the virtual factory through the Internet. It provides a common interface to all students, while they have their own settings for their machines. As it is controlled online, students do not have the ability to turn the simulator on or off. Therefore it forces students to look after the factory in turns, even over-night to monitor its performance, and adjust parameters in order to produce the maximum outcome. The ability to let students download the data in real-time enables them to analyse the data, using statistical tools to generate control charts. The other advantage of an online simulator is that it is much easier to maintain and update - there is no need to distribute CD-ROMs or patches if any maintenance is required. A single update on the server will be sufficient.

6 CONCLUSIONS

An interactive web-based virtual factory and simulator platform is discussed in this paper. The system has been tested and validated by masters students studying on a Quality Engineering course at the University of Greenwich, UK. During a two week period, 16 groups logged into the factory more that 5,300 times to monitor their own factory. It has been demonstrated that the students had significant interest and motivation for such an online competition. The simulator provided very positive feedback, including recommendations by several part time students to use it as a training aid for their companies.

The second phase of the project will focus on the development of more sophisticated and flexible control parameters, both for students and for lecturers so that a more realistic enterprise environment can be simulated. Software agents offer a convenient way of modelling processes that are distributed over space and time. Therefore, an agent-based approach will be developed and implemented in the developed system. Further work is currently being undertaken to include other areas such as the service sector by developing templates that can be over-laid to provide different scenarios.

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