Proceedings of the 2001 Winter Simulation Conference
B. A. Peters, J. S. Smith, D. J. Medeiros, and M. W. Rohrer, eds.

WHY WE NEED TO OFFER A MODELING AND SIMULATION ENGINEERING CURRICULUM

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ABSTRACT

This paper describes some identifiable trends in the manufacturing industry regarding the increased use of simulation tools, especially by small- to medium-sized companies. These trends have resulted in the need for a new type of engineer, namely simulation engineer. This need prompted the University of Skövde to develop a B.Sc. simulation engineering study program. The contents and layout of the program, which started in Autumn 2000, are described. After receiving a firm foundation in manufacturing, logistics and mathematics in the first year, the main focus of the second year is on simulation. In the third year, which includes a substantial examination project, a specialization in manufacturing or in logistics is possible. Although simulation-related examination projects are already now carried out in other study programs, the simulation engineer will be able to cover a larger part of simulation projects and will have a broader overview of available simulation tools.

1 INTRODUCTION

The use of computer based simulation tools in product and production development has sharply increased in the past years. These tools, such as discrete event simulation and geometry simulation, can be used to analyze products and production systems, for instance to test and evaluate different concepts during the design stage. They can also be used for operator training and off-line programming. Companies have also started to use simulations as a tool for communication between different actors in supply chains, initially internally but increasingly between companies. This holds especially for discrete event simulation (e.g. production flow simulation) and geometry simulation (e.g. computer aided robotics), which are the main area of attention in this paper.

Given the importance that simulation tools have gained in industry, it is remarkable how little attention is being paid to the use of these tools in education. Whereas the use of simulation tools is fairly common in research, their use in undergraduate programs is usually restricted to a limited number of exercises in one or two course modules. As a result, graduates are relatively unfamiliar with the use of simulation tools. This can result in using these tools incorrectly or in not utilizing them to the full potential.

Recognizing this situation, the University of Skövde was the first Swedish university to develop an undergraduate study program that focuses on simulation engineering. This decision was based on identified industrial need for a new type of engineer, and on the results of a survey among school pupils that showed good potential for enrolment of students. It is envisaged that within about three years from now, the industrial demand for freshly graduated engineers with this background will have increased sharply, in particular the demand from small- to medium sized companies (SMEs). This expectation is based on the situation in Europe, in particular in Sweden, but a similar trend has been identified in the USA by Crosbie (2000).

2 TECHNOLOGY TRENDS AND POTENTIAL BENEFITS OF SIMULATION

Simulation of production systems is nowadays widely used. In the case of new production systems or production system modifications, often a thorough analysis with the use of simulation tools is carried out either by the user or by the supplier of the production system. Although a simulation or the availability of data (e.g., models and performance data of equipment) for simulations is currently still a selling argument for production system suppliers, this is rapidly becoming a prerequisite for selling production systems or production system components.

Similarly, suppliers of products or components are increasingly required to demonstrate the technical capabilities and output performance of their production facilities before they are granted an order. Even if this is not the case, many candidate suppliers carry out simulations in order to make sure that they do not accept orders that they will not be able to manage.

Shorter product life cycles mean that problems in production nowadays have more serious consequences than in the past. As an example, Owen and Steeple (1998) found in a survey that it was typical for SME automotive suppliers to struggle to meet customer expectations after the introduction of new products. Typically, what would happen is that after securing an order, there would be problems in the beginning of production. This is indicated in Figure 1 where the curve "P" indicates the customer's perception of quality and the line "E" indicates their expectation or demand. For the SME supplier, high costs are associated with the failure to meet product quality and delivery due dates. Contingency actions may include repair, tool modifications, premium time working, and increased logistic costs for expediting products. For the Original Equipment Manufacturer (OEM) client, costs can be a multitude, for instance missing a pre-arranged vehicle homologation test can seriously delay the launch date of new models

With shorter product life cycles, the costs for these contingency actions form a much higher percentage of the overall order costs. Furthermore, there is less time available to restore customer confidence in the supplier's ability. This makes the need to avoid potential quality defects and delivery problems paramount.

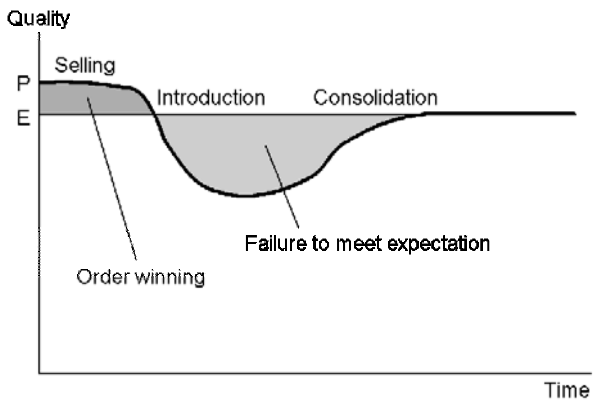

Figure 1: Potential Start-Up Problem in New Product Introduction, after Owen and Steeple (1998)

Through simulations of the production system, early detection of potential problems becomes much easier than by "gut feeling". Furthermore, alternative solutions for actual production can be explored against relatively modest costs. In addition to this, the simulations can be used to build customer confidence (by inviting the customer to a demonstration), or can be an aid to discuss proposed product modifications with the customer. These are some of the reasons for the increasing use of production simulation in industry, including SMEs.

3 THE NEED FOR SIMULATION ENGINEERS

Simulation is a powerful engineering tool, but only when it is used in a correct and systematic way. In the above-mentioned example of the assembly cell, a nominal simulation would not have revealed the problems associated with geometrical variations. Not recognizing the limitations of a nominal simulation could have resulted in taking an erroneous decision. In many cases, people have a tendency to ignore the limitations of a particular simulation run and jump to conclusions just because "they've seen it on the screen".

Another problem in many simulation projects is, that the goal and purpose of a simulation project is not always clear at the beginning. During many simulation projects, there tends to be a pressure to study more and more aspects of a production system, or to address 'what if' questions that the project was not supposed to give an answer to in the beginning. Not only can this result in the original goal not being achieved, it can for instance also result in detailed decisions being based on simulations carried out with the use of crude models or provisional input data which were initially intended for a concept study of a production system only.

One of the major problems, especially in discrete event simulation, is caused by the input data. Often, input data are incomplete and even if they are available, they may not always be correct. One example was encountered in a project in which data gathered over a number of years was used. The simulations did not give an accurate account of the actual situation because some stations in the production line were at the end of their technical life. In another project, storage/retrieval times in a warehouse had been measured during a period when production was low and the warehouse fairly empty. These were not representative at all for a full-production situation

Apart from these problems, an important issue is that many problems can be solved, or at least studied thoroughly, *without* simulation, as mentioned for instance by Karlsson and Samuelsson (2000) and by Sadowski and Grabau (2000). The mere availability of simulation tools is no excuse to use them in situations where other methods may be more appropriate. It is the simulation engineer's responsibility to use simulation tools in an appropriate way. Especially in SMEs, the simulation engineer may be the only person in a company who has the background and knowledge to judge the merits of particular simulation tools or to understand the validity of certain results.

4 EXAMPLES OF RECENT SIMULATION PROJECTS

In this section, some examples of examination projects in the more traditional study programs offered by the departments of Engineering Science and Industrial Management are given. Recent examples include:

[1] One examination project focused on developing a methodology for simulating production lines. A large customer for production systems wanted a structured work procedure where the machine and component suppliers for a line would supply models of their equipment at an early stage in production system development projects. The customer could then evaluate performance, layout, work schedules and so on, thus reducing the number of errors built into the line.

[2] Another type of examination projects focuses on the study of bottlenecks in existing production systems. One project concerned a problem of a freezer/refrigerator production system that consisted of one main line with several feeding lines. The problem was that congestion tended to occur after some hours of operation. The result of the simulation study was that implementing some simple queuing rules resulted in a considerably higher capacity.

[3] A variety of other projects study alternative layouts of production lines. Sometimes these lines can be fairly complex. A simple example regarded a line for automatic assembly of hydraulic valves. The study revealed that the production capacity of the initial layout was lower than required. It was suggested to double one assembly station. It was possibly to increase the production capacity even further but this was not justifiable from an economic point of view.

[4] Examination projects related to geometry simulation are still in the minority. One of these projects was the development of a software application for simulation and off-line programming of a robot-assisted pressbrake. The main problem in this project was to simulate the robot gripper position and orientation during sheet bending.

A difference between these examination projects and work that can be carried out by students and graduates from a simulation engineering programme is that the latter should have more experience with a variety of simulation tools and a broader understanding of simulation in general. Graduates from a simulation engineering programme should also have experience with discrete simulation as well as with continuous simulation, something that is considered to be rare, according to Crosbie (2000).

A typical simulation project could incorporate a number of phases as indicated in Figure 2. Naturally, these phases must not be treated as rigid sequential steps but must be seen as activities carried out in a concurrent way as pointed out by for instance Sadowski and Grabau (2000). The availability of data for instance influences the selection of methods as well as the definition of a realistic goal. Furthermore, time constraints need to be taken into account when defining a simulation project and this may mean that for instance that only a crude model can be built.

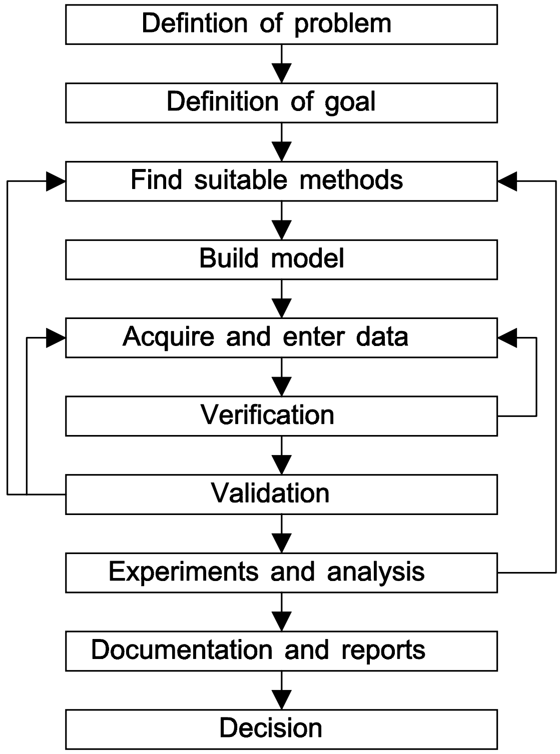

Figure 2: Typical Activities in a Simulation Project

When comparing current examination projects with envisaged examination projects for simulation engineers (or, for that matter, projects as they may carry out in their professional career), then a simulation engineer may (need to) address all the phases whereas currently, examination projects tend to cover only a number of them.

In the current situation, simulation is often part of examination projects in for instance the Automation Engineering programe. In these projects, the first three activities are usually already addressed by the company at the start of the project, or at least to a fairly large extent. Furthermore, the company usually has to supply input data that the students may use on an “as is” basis. Important steps such as verification and validation of models, and the early analysis of results can be enforced through supervision. Usually, the final interpretation of the simulation results that is the basis for instance for an investment decision is left to the company.

A simulation engineer will often be expected to cover a wider range of phases. It would also be expected from a simulation engineer to select the most promising approach(es) for a simulation project. Furthermore, the steps "verification, validation and timely analysis" should be like a second nature to the simulation engineer. In a professional setting, a simulation engineer will often also be held responsible for the correctness of input data and share final responsibility for capital and human resource investments. The need for engineers who can take care of a simulation project from the beginning to the end was one of the reasons to develop the Simulation Engineering programme at Skövde.

5 THE SIMULATION ENGINEERING PROGRAMME AT THE UNIVERSITY OF SKÖVDE

5.1 Subject Area and Size of the Study Programme

The subject area of the study programme can be described as "simulation of industrial manufacturing systems". This includes an overlapping area of Automation Engineering, Industrial Management and supporting/enabling disciplines (such as Computer Science and Mathematics). As Crosbie (2000) points out, finding the right balance between various skills is considered to be one of the key issues to be addressed when designing a simulation curriculum. Since SMEs usually recruit engineers up to BSc/BEng level, it was thought to be appropriate to develop a programme that leads to a Bachelor degree.

5.2 Skills and Tasks of a Simulation Engineer

Technical skills of a simulation engineer include computer programming, mathematics (in particular statistics), manufacturing technology, industrial automation, modeling and system design, data acquisition, logistics, production planning and production economics, and product data management (PDM). It should be stressed here that the simulation engineer will need to have a sound knowledge of manufacturing so as to be able to define projects, evaluate results and so on.

The ideal simulation engineer as industry would like to receive them straight from college is shown in Figure 3. This engineer is a combination of an engineer with a sound background in a number of traditional engineering disciplines and an engineer with state-of-the-art IT skills and knowledge in a broad range of disciplines, according to VSOP III (1998). Even though such expectations may not be completely realistic as also signaled by SME/AFFT (2001), it definitely poses a challenge for academia to try and meet these expectations as good as possible.

Social skills required from a simulation engineer include team-working skills, project based working, good communication skills with people from different backgrounds and at different levels in a company. Simulation and visualisation can be powerful communication tools, but different aspects of simulation results need to be highlighted for different audiences (e.g., machine operators or managing directors).

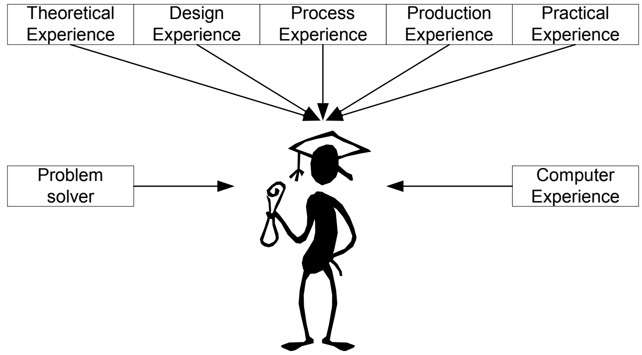

Figure 3: The "Ideal" Simulation Engineer

The industrial simulation engineer will most likely work project based during the first years of their professional life. This can be as internal or external consultant, simulation application developer (the latter would probably require some continued studies or additional courses), modeling of manufacturing systems. Other roles can be production manager, a coordinating role in production and logistics, or roles related to production economics.

5.3 General Layout of the Study Programme

The first year contains only one specific simulation course, 'introduction to production flow simulation'. This may seem remarkable but it is a consequence of the fact that one has to have a deeper understanding of manufacturing before one is able to simulate manufacturing systems adequately. Therefore, the studies in the first year provide a solid basis in amongst others manufacturing, logistics, mathematics and programming skills (Figure 4). An additional advantage of this approach is that it is relatively easy for students to switch between study programs within automation engineering or industrial management. In this phase of the studies, the emphasize is on giving students a broad but relatively deep understanding of manufacturing and related topics.

In the second year, over 50% of the study effort is related to simulation engineering. This includes courses in modeling of manufacturing systems, discrete event simulation, computer aided robotics (geometry simulation), and a simulation project based on a real-life industrial problem. In addition to this, the students read a number of engineering and production management courses, as well as ergonomics and psychology of work. In this phase, the students improve their IT-skills and become acquainted with the latest management philosophy and simulation tools.

Year 1	Year 2	Year 3	
Foundation: Manufacturing, Logistics, Mathematics, Programming	Simulation and continued studies in logistics and manufacturing	variant Logist.	Exam. project
		variant Manuf.	Exam. project

Figure 4: General Layout of the Study Program

In the first half of the third year, students can chose between two variants, namely a package of courses with a focus on manufacturing engineering, and a package related to logistics and management. In this phase, the students continue to build their knowledge and expertise in a selected area of manufacturing topics. Normally (but not automatically), this means that the students specialize either in discrete event simulation or in geometry simulation. In the second half of the third year, they carry out a substantial examination project, normally within industry and sometimes within one of the research projects of the Centre for Intelligent Automation.

5.4 Master Level Studies

Currently, there are no plans for a new Master level study programme in simulation engineering. The existing Master level programs (Mechatronics, Computer Integrated Manufacture, and Manufacturing Management) already provide the possibility for Master level studies with a substantial focus on simulation engineering. Furthermore, the main lack of simulation engineers was found to be on B.Sc. level. Graduates from the Simulation Engineering programme qualify for the above-mentioned Master programs. It is currently more likely that the existing programs will be modified or extended with alternative streams than that a completely new Masters programme will be developed.

5.5 Current Status

The first group of students for the new programme started in Autumn 2000. This means that the academic year 2000/2001 is a pilot year. It was decided to start with a small group of eight students. Although this is relatively ineffective from a financial point of view, it makes the development of new course modules easier. In addition to this, the students form a close group that is actively involved in the evaluation of the programme.

Within the programme, a number of simulation tools are used, but mainly Quest and Igrip. The Centre for Intelligent Automation has some software licenses available that can be used by students doing an examination project in industry. This is particularly helpful when a project is carried out at an SME as these smaller companies do not always can make a license available to the students. Thus, such projects also provide an excellent opportunity for SMEs to become familiar with the use and potential costs and benefits of simulation tools.

6 CONCLUSIONS

From an increased use of simulation tools in industry and an increased number of examination projects related to simulation, the need for a new type of engineer has been identified. This has resulted in the development of a B.Sc. programme in simulation engineering at the University of Skövde, Sweden. The programme as a whole is characterized by a relatively high percentage project related study effort. The first phase is characterized by studies in the field of manufacturing, logistics and supporting disciplines in order to create a firm engineering basis. During the second phase, the focus shifts towards simulation engineering. The third phase starts with a specialization in logistics or in manufacturing engineering and is completed with a substantial examination project. The first graduates are expected in 2003, by which time it is expected that the demand for simulation engineers will be even larger than today. An evaluation of the overall programme can be expected around 2004.

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