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MEDICAL EDUCATION AS A MODEL FOR SIMULATION EDUCATION

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ABSTRACT

Simulation professionals need to see themselves first as systems analysts, i.e., problem solvers, rather than just simulation users. As the networked digital economy develops, systems will become more complex, creating a robust market for experienced systems analysts who use simulation to solve operational problems and manage these complex systems. Physicians solve problems involving a complex biological system, i.e., the human body. The medical education system in the United States is examined and proposed as a model for an education structure for professional systems analysts. The objectives and requirements of simulation education are examined and a curriculum structure is proposed. It is also argued that certifying exams would do much to promote the profession and improve the educational environment.

1 INTRODUCTION

There are two broad classes of simulation practitioners: (1) simulation software developers and (2) problem solvers who use simulation. For the most part, people in the first category work for companies and institutions that create software products for others to use to develop and implement simulation models. They must have extensive knowledge of probability and statistics, and discrete event simulation methodology, as well as computing - algorithms, data structures, programming languages, database design and other areas. These people are specialists and generally prepare for their careers with a masters or doctoral degree in computer science, operations research or industrial engineering. We can call this the *research* model of simulation education.

This paper is concerned with the second group: persons who wish to be professional systems analysts and plan to use simulation as a part of a set of general problem-solving tools. We can call this the *practice* model of simulation education. It is widely recognized that simulation, especially discrete event simulation, along with linear programming are the two most frequently used tools in systems analysis. The reasons for this are that the models these tools use are quite robust and fit a large proportion of the problems that are encountered, and that software is readily available to solve the models. Thus, it is expected that simulation will be a frequently used tool. The question this paper seeks to address is: "What type of educational program will best prepare this person for a career as a systems analyst using simulation?"

Simulation professionals need to see themselves as problem solvers first. As academics, we are focussed on the methodology we teach. However, in the workplace, administrators and managers focus on the systems they are managing and the problems they encounter. Normally, these problems require a combination of methodologies and a variety of skills to solve. Since simulation is one of the most useful methodologies, it is often the modeling paradigm used to understand system behavior and evaluate decisions. But, the effective systems analyst must have a much wider range of skills.

The purpose of this paper is to put simulation in a larger context and to propose that simulation education should also be placed in this larger context. In this regard, medical practice and medical education provides a good model. This paper will review the characteristics of medical education in the United States that provide a useful conceptual foundation for simulation education and suggest a curriculum based upon this model. The changes involve not only a change in the design of curricula but also a change in the mindset of the profession.

2 MEDICAL EDUCATION AND MEDICAL PRACTICE

The practice of medicine has the final objective of solving health related problems and improving the quality of life. Physicians pursue their craft through a regimen of diagnosis followed by treatment. In addition to basic medical knowledge, they must develop skills and judgment to be able to deliver their services. To this end, most of their knowledge is gained at the bedside, not in the classroom. Moreover, their profession is multidisciplinary. They must deal with problems involving different systems of the body as well as social and public health issues. Decisions are multicriteria. Physicians must consider financial, operational, administrative and other issues as well as the patient's health and well being in making treatment decisions.

The objective of a medical education is to train students to provide medical care for the general population. A small number of students will go into medical research; a small proportion will go into administrative careers or other jobs not concerned directly with patient care; and some will go into very specialized areas of medicine with limited patient contact. However, most medical students go into some sort of clinical medical practice. In this practice, they must have a variety of skills:

- Communicate with the patient
- Communicate with other interested parties, e.g. the patient's family
- Examine the patient
- Diagnostic testing
- Disease diagnosis
- Treatment selection and administration
- Evaluation and follow-up

Additionally, the physician must be able to recognize problems that she cannot solve. These might be conditions that need to be referred to another medical specialist, or they might be medical conditions that cannot be treated effectively, as end-stage cancer, and therefore must go untreated.

To do these tasks, the physician must have extensive knowledge of anatomy and physiology, microbiology, virology, and other areas of medical science. However, he must also have background in law, sociology, computing, management and other areas not directly associated with medicine. In addition, he must have developed judgment and skills that cannot be taught in the classroom.

The medical curriculum is designed to provide this background. Most medical education programs in the United States consist of four years in medical school, divided into two years of primarily classroom study and two years of primarily clinical practice. The classroom study provides the theory - an understanding of how the human body is supposed to work and, when things go wrong, how they usually go wrong. It also provides knowledge in related areas such as psychology, law and so forth. The clinical practice provides the real-world application of these concepts under the watchful eye and direction of experienced clinicians. In clinic, the student deals with the messy, ambiguous realities of medicine. It is only here that the judgment and skill can be developed through experience.

Medical education does not end with medical school. All medical students are required to go through a one-year internship after the MD degree is awarded. Then, most students select one or more three-year residency programs. The purpose of internship and residency is to gradually increase the student's level of competence and responsibility in a controlled environment, until she is ready to practice medicine without supervision. Since physicians make critical decisions on a daily basis, it is important that the knowledge, judgment and skills be highly developed and monitored throughout the educational process. Thus, medical education is primarily a matter of managed "on the job training."

Once the formal education is completed, physicians are required by state law to take and pass board certification exams before they are given a license and allowed to practice on their own. Usually, individual study is needed before taking these exams, and in many cases they must be repeated periodically to assure that the physician's skills and knowledge are up to date. Continuing education programs are available to physicians, and they must complete a certain number of continuing education units annually to keep their license.

Thus, medical education is a carefully designed process that prepares the student to work independently in the practice of medicine, assures that they have not only the academic understanding but also the skills and knowledge to do the job under unpredictable circumstances, provides the knowledge to pass certification exams, and keeps the education up to date over their career. It is not a perfect system, but it has worked well to achieve the goals of developing a profession that is widely recognized, respected and highly valued, produce physicians that are generally competent over their entire careers, and provide the basis of a system to deliver high quality health care to the general population.

3 SIMULATION EDUCATION AND SIMULATION PRACTICE

Operations research, including simulation, is a much younger field than medicine. It was approximately 60 years ago that the first applications of what is now called operations research appeared in the context of World War II. Simulation did not take a prominent position in the field until the 1960's or early 1970's, when relatively "user friendly" software became widely available and many problems in manufacturing, logistics, communications and other areas were tackled. At the time, one needed an extensive background in mathematics, probability and statistics as well as computer programming to understand the modeling procedures and build the models. Students studying operations research planned careers as applied mathematicians and other specialized problem solvers, and many had intentions of pursuing a Ph.D. degree. This was the environment in which curricula in operations research developed. In other words, the curriculum was designed primarily by academicians for academicians, and virtually the same curriculum structure is used in most schools today.

In the United States, no graduate or undergraduate programs to my knowledge provide strictly simulation education. Instead, simulation is a methodology within programs in engineering, operations research, computer science, business and other areas. Some programs allow enough specialization in simulation and related technologies that the course of study basically becomes a simulation program. However, most of the programs of study, while requiring course work outside of simulation, focus on the methodology of simulation at the expense of practice. Most simulation education is delivered in the classroom and what practical experience is included consists of short projects and other "applications." Most persons who work in simulation, especially discrete event simulation, pursue a master's degree in either industrial engineering (or operations research), or business administration (MBA). Industrial engineering programs are generally more technically oriented and require more foundation courses in mathematics and statistics; MBA programs are more business application oriented and require background in accounting, marketing, economics, finance and other areas of business.

A typical IE/OR graduate program includes one to two years of courses in optimization, statistics, stochastic models and simulation, and provides electives in manufacturing, logistics, business systems and other areas. A thesis or project of some sort is generally required. IE/OR programs include a lot of statistical and simulation methodology as well as other OR methodology, but they have very little background in various areas of business management.

MBA programs, which require two years study, are designed to teach a broad view of business and focus on the traditional areas of business activity - marketing, finance, management, logistics, accounting, law, MIS. MBA programs include extensive course work on general business but lack depth in methodological areas such as statistics, operations research or simulation. Any study of simulation or other OR tools is usually provided in electives. Indeed, until the early 1990's, operations research was required in most MBA programs but has since been dropped as a requirement (Jordan et.al. 1999). For those students who elect to take a simulation course, it normally includes just classroom work with one small project.

Neither type of curriculum includes extensive practice in solving "real-world" problems. Simulation courses include some practice problems and often require the student to complete a project that involves developing a simulation model of a "real system." However, "real systems" are usually very simple systems. The semester does not provide enough time to work on larger models. The expectation is that these problems are scalable. Thus, if the student can solve a problem involving a single-server queue, then he can scale it up to solve a problem involving an emergency room or a freight terminal.

Thus, the objective of most master's degree programs has not been to prepare students to solve real-world problems. Over the past few decades, simulation software has been rather arcane and difficult to use. Specialists had to be trained to use and develop the software. Indeed, the level of knowledge required to use the software was almost the same as the knowledge needed to develop it. For this reason, there was not a need for a "professional" master's degree in simulation or operations research.

Now that simulation software has become visual and graphical, analysts with little or no computer programming skill can build complex models more easily and with fewer errors and problems than before. This has allowed the analysts to focus on system modeling and actual problem solving instead of the details of simulation programming. In turn, this has created a growing market for professionals who specialize in using simulation (and other) software to solve problems in various industries. This new professional class of analytical problem solvers is the group that the new curriculum needs to target. They serve a role for organizations that parallels the role physicians serve for individual people. To create a curriculum for professional systems analysts, we must discard the legacy (i.e., research) model. The education of these problem solvers should consist of instruction in solving certain classes of problems along with instruction in specific methodologies. The curriculum should follow classroom instruction with a lengthy period of supervised learning through solving real problems.

4 A SYSTEMS ANALYSIS CURRICULUM

Now that we have examined the basics of medical and simulation education, let's look more carefully at simulation practice. What types of problems are the graduates expected to model and solve? What other tasks are they expected to be able to do in the context of problem solving? I believe the market is for general problem solvers rather than simulation experts, and that problems are usually in some area of management, whether they be in health care, logistics, finance or other fields. Business, industry and government systems have grown much more complex and this trend will continue and accelerate in the networked digital economy. This is creating a demand for professional systems analysts who can understand the intricacies of these systems and develop models to help decision makers manage them. These considerations require that the modeler have a general background in organizational management as well as specific training in the problem area(s) in which he wishes to work. Moreover, the person must be able to work as an effective team member and team leader because organizations in the future will be much flatter and work will be done by teams. For a view of such organizations, see (Tapscott, 1995). The demand for professional systems analysts is just getting started, but with the right curriculum in place and the right direction from the professional operations research and simulation community, it will grow.

In designing a simulation curriculum, it is tempting to think narrowly about the minimal skills a systems analyst would need in a staff or consulting position. Instead, consider the needs of a person who does for organizations what physicians do for individual people - solve (operational) problems. Some things this analyst would need to do are: Interview the organization and gather data. We are assuming that the problem is thought to be in an area that the analyst can be helpful in dealing with. Once the information has been gathered, she would use it to diagnose the problem, likely with the help of other employees and professionals. Once the problem is diagnosed, an appropriate solution is devised and tested, often but not necessarily with the use of a simulation model. The model, once developed, then remains available to be updated and reused if other related problems arise. We can think of the model as both a diagnostic instrument and a part of the patient's chart. It documents the problem and provides recommendations on treatment. The analyst would also be responsible for monitoring the treatment, i.e., comparing the effects of changes and updating the models as needed.

Simulation practice involves much more than just simulation methodology. Not only do small models not scale well, but the problems one must deal with in practice do not lend themselves to cookie cutter solutions. Instead, they require insight and creative thinking. Consider the following scenario based on the author's experience modeling an emergency department: Although this scenario takes place in a health care system, a similar scenario could apply to any system in manufacturing, logistics, government or other area. The hospital administration had built a new "urgent care" facility close to the emergency room with the expectation that most patients would present to the urgent care facility and the most serious cases would be referred to the emergency department. Management was concerned about the capacity of the entire system and wanted guidance regarding optimal staffing levels and ways to minimize patient waiting time.

The consulting group was retained by hospital management, but without the knowledge or consent of the medical director of the emergency room. When the consultants needed access to the physical facilities and the employees, cooperation was difficult because management had not convinced the staff of the need for problem analysis. Moreover, the employees were skeptical of the reasons for bringing in the consultants. The team had to meet with the medical director and explain to him the benefits to be derived from the work as well as to assure him that the work posed no risk to him or his employees. Moreover, the consultants requested that a team consisting of the consultants and some key emergency room personnel be formed to develop the model and do the analysis.

Once access and cooperation were gained, the team was given access to all patient records, provided that they sign a confidentiality agreement. The consequences of releasing patient data, even information they might have considered unimportant, included the possibility of a lawsuit. The team found that while the patient charts contained some information about patient arrival times and the times that nurses and physicians first interacted with the patient, they did not include critical data about the lengths of time for examination and treatment. Data stored on the hospital's information system provided information about the number of arrivals per hour, but other data about x-ray and lab times could not be accessed because it was on incompatible computer systems which were actually operated by other physician groups who worked in the hospital under contract.

Some data regarding how to classify the patients into groups by severity of condition were available on the patients' charts, but medical expertise was required to interpret the data. This and other data were available on the hospital's information system, but could not be retrieved in a timely manner because the information system was old and the job of matching diagnosis codes to categories was too involved to be done in the time available.

Some data had to be collected manually by observing the activities in the emergency room. Over a period of approximately a week, data was collected on less than 50 patients to estimate lengths of times for examination and treatment by nurses, doctors and other technical personnel, times to complete registration information, the number of visits to the patient by the doctor and other operational measures for the system. Considerable effort went into collecting this very small set of observations.

The model that was constructed was much simpler than it could have been for two reasons: First, the model was built just to answer the questions and concerns posed by management. Second, while a more elaborate and more accurate model could have been built, data were not available to provide parameter estimates for a more detailed model. Data was the limiting factor in the model design. Once a model had been proposed and a graphical representation had been created and presented to the emergency room management, agreement was almost immediate. With current simulation software, model development was quick and painless.

The preliminary model was presented to hospital management, including the medical director of the emergency room. A lengthy discussion followed regarding what measures should be used to judge the performance of the system. For example, the administration stated that they wanted to minimize patient waiting time, but different patients have different waiting times. So, should the mean patient waiting time be used? Or, should some percentile, say the 90th percentile, be used? The consultants spent considerable time explaining the alternatives to the management and working to arrive at a consensus. Additional discussions concerned whether to present measurements of physician utilization (the percentage of time the doctors were busy) and whether these measurements were even meaningful since certain physician activities, such as charting, were ignored in the model. The decision was made to include physician utilization estimates but plot them on a graph with the maximum being 70 percent and assuming that 30 percent of the time they were charting or doing other required duties such as phoning to follow up on patients, calling in prescriptions, etc.

Before the model could be used, it had to be validated. Data on patient waiting times and the number of patients waiting were used for validation. However, current estimates of these performance measures were not available, although data were available on the hospital's information system. The consultants obtained the data from the database and computed estimates of these parameters. The data used to compute parameter estimates and fit distributions for the model were now several months old, and the hospital had made a point of noting that the workload on the emergency room was seasonal and appeared to be increasing. Moreover, the data that was used was collected in January, but the validation month was May. There was concern about the seasonal effects. The mix of illnesses and trauma is different in May because more people are active in warm weather. It was suspected that this difference could cause the model to be invalid. Nevertheless, the simulation was run and estimates computed from the output. Mean waiting time from the model was 20 percent greater than the actual mean for the validation period. Similar results were found for the mean number of patients waiting in both the emergency room and the urgent care facility. Although the consultants would have been happier with estimates that were closer, it was concluded that 20 percent was sufficiently close to conclude that the model was valid.

A final presentation was made to the hospital administration. In this presentation, a graphical version of the model was shown along with an animation, but most of the time was spent discussing the assumptions behind the model, the results obtained from the simulation runs and the recommendations to the hospital administration. The consultants concluded that the 90th percentile of patient waiting time could be cut almost in half if patients were more carefully screened in the urgent care facility and the average time to return labs and x-rays were reduced by 30 percent. Since these systems were not under the hospital's administration, specific recommendations regarding how to do this were not made, but this recommendation would become part of an upcoming contract renewal for the groups that do operate these systems. Among the recommendations was a strong endorsement of the idea that the hospital's information systems be upgraded to automatically collect data such as the length of time the physician sees a patient and the number of times the physician visits each patient, data that is needed for the simulation model. Specific recommendations regarding how this data could be easily and most cost effectively collected and merged with the current database were also made. Finally, the consultants suggested that systems could be put into place to allow the hospital to access the simulation models over the Internet. This would allow the hospital and the consultants to improve their efficiency and reduce cost.

The point of this example is to show that developing the model and running the simulation is just a small part of the overall simulation modeling activity. Problems with all of the following issues had to be addressed:

- Communicating with management and employees
- Collecting and analyzing data
- Lack of data for important processes
- Information systems
- Interpreting available data
- Performance measures
- Validation issues
- Implementation issues
- Presentation of results

The resolution of all of these required judgment, experience and creativity.

5 A CURRICULUM PROPOSAL

Based on the emergency room scenario, an effective simulation curriculum must continue to provide the basics of simulation modeling, but it also should encourage creative problem-solving and develop effective team participation skills. The following outline of a curriculum, which consists of two years of coursework and a year of supervised problem solving (the internship) will accomplish these goals:

1. Basic oursework consisting of mathematics, statistics, probability, stochastic models, optimization and simulation modeling. These are the foundations of decision modeling. These courses should focus on applied problem solving using the models rather than derivations.
2. Additional coursework presenting the fundamentals of accounting and business management (finance, marketing, logistics, business strategy), information systems management, computing, communication and technical writing. Some of these courses can be electives, but all students should have enough coverage to feel comfortable dealing

with nontechnical management in businesses and other organizations.

3. A year's program in supervised problem-solving should supplement the coursework. This problem-solving should be in real systems and also under the supervision of actual business managers. A year is required to allow a sufficient quantity of sufficiently large and realistic problems to be undertaken. The work experience should emphasize working in teams to analyze and solve problems.

At present, simulation analysts and other systems analysts are not normally given this level of responsibility or authority that physicians have. However, a curriculum such as this that prepares them for this level of responsibility can also be as useful to prepare them for staff positions with less authority, and it will serve to stimulate the market for such professional analysts. Many consulting companies have groups that do simulation modeling. The market also includes many medium to large corporations and government, and some people in this category would also choose to be independent consultants.

Another requirement for a recognized professional systems analyst is some form of competency examination. Virtually every other profession, with the exception of statistics, has professional licensing exams. This includes accounting, engineering, law, actuarial science and all medical specialties. Licensing exams serve to inform the public that the profession considers the work it does to be important enough that it needs to implement a quality control procedure on the people who do the work. For employers, certification exams give them some assurance that the person they hire to do the work is actually competent to do it. For educational institutions, certification exams allow some standardization in the curriculum. Most schools will choose to include instruction on all important topics in the exam, assuring that no major area is omitted For the student, certification exams provide a professional goal and for those who complete the exams, they will provide higher salaries.

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