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MODES OF SIMULATION PRACTICE IN BUSINESS AND THE MILITARY

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ABSTRACT

Although simulation is performed in a wide range of disciplines there has been almost no debate about the practice of simulation across these domains of application. This paper concentrates on two domains of practice, business and military simulation, and identifies three modes of practice: simulation as software engineering, simulation as a process of social change and simulation as facilitation. The facets of each of these modes of practice are described, and the predominant usage of the modes in business and the military are identified. The implications for simulation software suppliers, practitioners, researchers, educators and users are discussed.

1 INTRODUCTION

Simulation is used in a broad range of fields ranging from pure mathematics and the physical sciences, though engineering and computer science, business and the military, to economics and social science. What is apparent is that the practice of simulation is quite different between, and even within, these fields. At one extreme, there are very large-scale parallel and distributed simulations, requiring many years of effort to develop. At the other, there are very small models, with a shelf-life that can be counted in hours. Some fields show a preference for continuous simulation, with others preferring to adopt the discrete-event approach. Even within these approaches there are several methods of simulation. Certainly, the community of simulation modellers cannot be seen as a homogeneous unit.

In discussions between simulation practitioners and researchers from differing domains these distinctions often become apparent, albeit that they are not necessarily directly expressed. As a result, there may be some misunderstandings during such discourse. The question arises: is it possible to identify and define the modes of practice that are prevalent within the simulation community? If it were, then this would provide a basis for a more meaningful discourse between the segments of that community. In particular, the implications of different modes of practice on simulation methodology, the modelling process, modeller skills and software requirements could be identified.

The purpose of this paper is to provide a beginning point for a debate about modes of practice in simulation modelling. In doing so, it identifies three specific modes of practice that can be identified in military and business simulation. There is no attempt here to look at broader uses of simulation. The paper starts by providing a brief description of the wider debate that has taken place on the practice of operational research (OR). Following this, three modes of simulation practice are described, and the facets of these modes of practice are identified. The nature of business and military simulation is then discussed with reference to these modes of practice. The paper concludes by discussing the implications of the debate and the need for further work.

2 MODES OF PRACTICE: THE OPERATIONAL RESEARCH (OR) DEBATE

There is some interest in simulation practice, see, for instance, Smith (1998), and Robinson and Pidd (1998). Most of this, however, centres on how simulation is used within a particular field. Smith, for example, discusses simulation in the military field, while Robinson and Pidd centre on business simulation. It is hard to find any higher level debate about the similarities and differences between simulation practice in different fields.

Within the OR community there is a wider debate. This is perhaps most pronounced within the "hard" OR, "soft" OR debate that exists within the UK. Rosenhead (1989) provides a useful review of this discussion, and lists six (bipolar) characteristics of the "hard" and "soft" OR paradigms. As such, these paradigms can be seen as modes of practice within OR, albeit that many sub-modes could be identified within the streams of literature that exist. Indeed, in their "system of systems methodologies",

Jackson and Keys (1984) identify six problem contexts (modes of practice) ranging from "simple-unitary" to "complex-coercive".

More recently, the debate within the OR community has turned to consider the mixing of methodologies. Mingers and Brocklesby (1997) discuss "multimethodology" as a means of using parts of different methodologies during an intervention. Jackson (1999) describes the combination of methodologies as "pluralism", while Lehaney (1996) uses the term "mixed-mode modelling". Both Flood and Jackson (1991) ("total systems intervention") and Ormerod (1997) ("transformation competence model") discuss how choices about methodologies, and possibly mixing them, can be made.

Much of the debate about "hard" and "soft" OR and the mixing of methodologies is at the paradigm and methodology level, that is, the philosophical assumptions behind interventions and the guidelines for performing interventions respectively. Very little consideration is given to different modes of practice at the level of technique, with specific techniques tending to be placed in the context of one methodological and paradigmatic set of assumptions. As such, simulation modelling is labelled a "hard" OR technique.

The exception to this, is the discussion that has arisen around system dynamics modelling. Many would consider system dynamics to belong in the "hard" OR paradigm, seeing it as simply another form of simulation modelling. Both Forrester (1994) and Lane (2000), however, argue that system dynamics is compatible with "soft" OR. Vennix (1996) discusses the use of system dynamics as a group support system, and as such, he also recognises a commonality with the "soft" OR paradigm. Lane and Oliva (1998) discuss the synthesis between system dynamics and soft systems methodology (Checkland, 1981). Lane (1999) sets out a detailed argument in which he places various modes of practice in system dynamics within a framework of social theory. In so doing, he recognises the ability of system dynamics to cut across paradigms.

3 THREE MODES OF SIMULATION PRACTICE

Three modes of simulation practice are now identified. The first two have been identified as a result of personal observation and descriptions of simulation modelling in the literature. The third is derived from some discussion with practitioners and proposals found in the literature. At present there is little evidence of significant practice of the third mode, and as such, it represents a potential future for simulation modelling. As already stated, these modes are derived from, and relate to, simulation modelling as it is practised in business and the military. That is not to say that they are exclusive to these domains, or that other practices do not exist.

3.1 Mode 1: Simulation as Software Engineering

Simulation as *software engineering* is typified by lengthy projects, possibly taking years to complete, that are performed by teams of modellers. The users of the models are often far removed from the development process, and may get involved only when a specific problem is to be tackled with the completed model. The prime motivation of such projects is the accurate representation of the real world. In some cases this is to such an extreme that a model is developed without having a specific problem to be tackled, leading to models looking for a problem. Ginzberg (1978), writing about OR, argues that this approach places the modeller in the role of a purveyor of a product (the model).

Balci (1985) describes in detail the methodology required for the development and use of such models, as well as the requirements for model validation. A number of authors detail the requirements for independent verification and validation of these models, for instance, Gass (1977, 1993), Gass and Joel (1981), Sargent (1981), Fossett et al. (1991) and Davis (1992).

Although these projects are described as "software engineering" here, it must be remembered that there are some differences between "simulation software engineering" and "software engineering" *per se*. Balci (1994) identifies the following differences:

- simulation studies require the application of the "art of modelling",
- simulation projects are based on the notion of experimentation and this may involve considerable repetition and replication of runs of a model,
- the results of simulation experiments require careful analysis and interpretation,
- simulation models are usually validated by some form of comparison with the real world rather than against a requirements specification.

3.2 Mode 2: Simulation as a Process of Social Change

In simulation studies that are a *process of social change* the role of the modeller is as an agent of change, whose task it is to help the user (who may better be described as a customer) perform his/her job better (Ginzberg, 1978). The modeller works with the customer to help him/her better understand the nature of the organisation's problems and to identify actions that may lead to an improvement. The prime motivation for such projects is problem understanding and problem solving. These projects tend to be short, typically a few weeks, are performed by a lone modeller, and require high levels of customer involvement. Ginzberg (1978)

argues that if the social change view is adopted then the modeller's role is one of providing a service.

Various authors describe the methodology required for the development, validation and use of such models, for instance, Robinson (1994), Pidd (1998), and Law and Kelton (2000). There is no sense of such simulation models requiring independent verification and validation in the literature, or indeed in practice.

3.3 Mode 3: Simulation as Facilitation

Mode 3, simulation as facilitation, can be seen as a special, but extreme, case of simulation as a process of social change. Here a model is developed and used (in an interactive manner) in a group meeting as a means for understanding the real world and for promoting discussion on potential improvements. The prime motivation is understanding and provoking a debate about the problem situation. Model accuracy is potentially of little significance as long as it is useful for promoting the group discussion. There is much similarity between this mode of practice and that described by Vennix (1996) for group decision making with system dynamics.

Robinson (2001) describes a case study performed in this fashion. He also argues that when simulation is used in this manner it has much in common with "soft" OR; the other modes described above have more in common with "hard" OR. Beyond this, it is hard to find examples of simulation used in this way, although anecdotal evidence suggests a growing interest and use of this approach. Indeed, the increasing power of computer hardware and availability of visual interactive modelling systems have made this approach more feasible.

4 FACETS OF THE MODES OF SIMULATION PRACTICE

The descriptions above provide brief outlines of the three modes of practice. A more detailed description, outlining various facets of these modes of practice, is given in Table 1. The facets are split into three groupings relating to the simulation model, the modelling process and the modellers. Many of the descriptions of the facets are self-explanatory. Those requiring more explanation are discussed below. Note that these descriptions are generalisations that identify the predominant approach; there will, of course, be exceptions.

In the software engineering approach the model is developed with a view to being used by a number of different users, possibly for quite different problems. At a lower level, component reuse is an important issue in enabling time to be saved when developing new models. The validity of the model is primarily judged by its representativeness during development, although once a specific use for the model has been found, its fitness for purpose becomes paramount. In terms of the modelling process, many questions could be asked of the model, which may not all be defined prior to model development. There is a certain amount of iteration through the stages of the project, but efforts are made to limit this by, for instance, having a detailed specification for the model prior to model coding. The beneficiaries are typically described as "users", who tend to only get involved at the experimentation stage (although some may aid with the specification of the model). Because the users are only involved during experimentation with the model, their learning is largely restricted to the information obtained from the results of the experiments. The model is validated by the modeller and sometimes by an independent third party before use. The users have little involvement with validation. Because of the nature of these projects, the predominant skill of the modellers is in software development.

When simulation is performed as a process of social change, because the model is developed to answer specific questions about a specific problem situation, it has no wider applicability. Therefore, it is essentially thrown-away after the simulation study is complete. It is unlikely that the model could be used for a different problem situation because the questions are likely to be different, and each problem situation is likely to be unique. There may be some notion of component reuse, albeit at a very low level, for instance, a workstation. Validation is considered in terms of whether the model is sufficiently accurate for its purpose (Robinson, 1999) and is performed by the modeller in conjunction with the customers. There is a high level of iteration in the modelling process, with limited efforts at formalising the process. The beneficiaries are typically described as "customers", because they are direct beneficiaries from the whole modelling process. Indeed, the customers are highly involved at many stages of the modelling process, gaining benefits from all stages in terms of an improved understanding as well as the solutions that may be derived from experimentation with the model. The predominant skill of the modeller needs to be in modelling rather than software development.

The facets for simulation as facilitation are more extreme versions of those for simulation as a process of social change. The model's validity is judged primarily on whether it was useful, with quite possibly little cognisance for its accuracy. The questions to be answered may be very vague, particularly because there may be a poor understanding of the problem situation; the motivation for the model being to improve this understanding. The beneficiaries may be thought of as "actors" because of their very high involvement in the modelling process. Their learning is derived not so much from the results obtained from the model (which may be very inaccurate!), but from the debate that takes place during the modelling process. By nature, simulation performed in this manner will require a great deal of iteration between the stages in the process, and as a result, the modeller needs to be skilled in process management.

Table 1: Facets of the Modes of Practice

	Simulation as		
Facet	**Software engineering**	**A process of social change**	**Facilitation**
1. Simulation Model			
Prime motivation	Representation	Intervention in a problem situation	Understanding and provoking debate about a problem situation
Size of the model	Large scale	Small scale	Quick-and-dirty
Longevity of model	Long-term (years)	Short term (months/weeks)	Short term (weeks/days)
Model reuse	Reusable	Throw-away, possibly after customer use for experimentation	Throw-away
Validity of the model	Representativeness (during development) Fitness for use (during use)	Sufficient accuracy for its purpose	Usefulness
Software for the model	Programming language/simulation language	Simulation language/visual interactive modelling system	Visual interactive modelling system
2. Modelling Process			
Purpose	Many questions could be asked of the model	Specific questions to be answered	Vague questions to be answered
Length of the project	Years	Months/weeks	Weeks/days
Iteration through stages in the project	Limited iteration	Frequent iteration	Highly iterative
Beneficiaries	"Users"	"Customers"	"Actors"
Beneficiaries' involvement	Experimentation only	High at times e.g. conceptualisation, validation and experimentation	Very high throughout
Learning	From experimentation with the model	From the modelling process	From the debate surrounding the modelling process
Validating the model	Modeller and independent V&V	Modeller and customer	Modeller and actors
Cost	High	Medium	Low
3. The Modellers			
Number of modellers	Many	One	One
Predominant skill	Software development	Modelling	Process management

5 MODES OF PRACTICE IN BUSINESS AND THE MILITARY

Figure 1 places business and military simulations on a continuum from the software engineering mode of practice, through the process of social change mode, to simulation as facilitation. The height of the shape indicates the frequency of practice within a certain mode.

It is apparent in reviewing the literature on military simulation that the mode that predominates is that of simulation as software engineering. Most models are large-scale, require many man-years of development and are expected to be used and reused over a long period of time. This is not to say that simulation is never performed as a process of social change, but that this, and facilitation, are much less frequent in the military.

There are a number of reasons why mode 1 predominates in the military, among them are probably:

- the investments being considered, and so the risks and potential savings, are generally large (counted

in $millions and $billions), making large modelling efforts more cost beneficial,
- decision-making tends to take place over a long period of time, giving time for large-scale model development,
- models are seen to be useful for many decision situations, requiring model longevity,
- the nature of the real world being modelled involves many complex interactions, leading to large-scale models,
- plentiful finance tends to be available as most models are financed from the public purse, making larger scale developments more possible.

In contrast, business simulation is primarily seen as a process of social change. The models are generally small-scale and require a few weeks or months to develop (Cochran et al., 1995). The models are often used in only one intervention and are rarely reused. As already stated, at present there is little evidence of simulation being used for facilitation in business, although it is anticipated that the improvements in computing power will make this mode more and more possible in the future. Business simulations are sometimes performed in the software engineering mode, for instance, some detailed enterprise models (Love and Barton, 1996) and some real-time simulations (Drake and Smith, 1996).

Mode 2 probably predominates in the business context because:

- the investments being considered, and so the risks and potential savings, are generally smaller than in the military (counted in the $thousands and $millions), making large modelling efforts less cost beneficial,
- decision-making tends to take place over a short period of time, giving no time for large-scale model development,
- models are seen to be useful for single decision situations, therefore, model longevity is not required,
- the nature of the real world being modelled involves fewer complex interactions than in the military, leading to smaller-scale models,
- most models are privately financed, restricting the availability of funds and so making larger scale developments less possible.

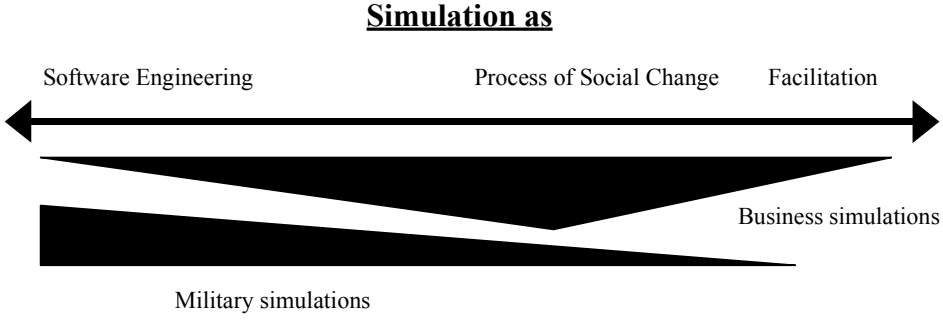

Figure 1: Modes of Simulation Practice in Business and the Military

One area of simulation modelling that does not fit directly with these archetypes is simulation for gaming, either for war-games or business-games. The models themselves are probably developed in the software engineering mode, the experimentation (gaming), however, is more akin to simulation as facilitation. As such a model moves from one mode to another during its life, in this case, in a very deliberate way.

A less deliberate way of moving from one mode to another sometimes occurs with simulation in business. A model that was developed for a specific purpose is then developed into a generic model that can be used by the same business, or others, to look at a similar class of problems. An example might be a model of a specific retail outlet that is later transformed into a data driven simulator. The original model was developed in the process of social change mode, but later, and with only limited effort, takes on some of the characteristics of the software engineering mode.

6 IMPLICATIONS

Having identified three modes of practice in simulation modelling, their implications for simulation modelling are discussed. These implications can be considered in terms of their effects on each of the parties with an interest in simulation, that is, simulation software suppliers, practitioners, researchers, educators and users. Firstly, for simulation software suppliers, there is a need to recognise the quite distinct software requirements for each of the

different modes of practice. At one end there is the need for specialist tools that will enable large-scale, complex simulations to be developed. At the other there is a need for ease of use and speed of development. It is perhaps the latter where, despite many strides in the last decade, there is still room for improvement, particularly if the use of simulation as facilitation is to grow. Simulation software suppliers need to recognise (and already seem to do so) that the different modes of practice represent quite different user bases, and therefore markets for their products.

Simulation practitioners also need to recognise that there are quite distinct markets for simulation modelling, and probably need to specialise accordingly. Again, this is already implicit in the practice of many consultancies who tend to specialise in business or military modelling, with few claiming to do both. Practitioners also need to identify and adopt quite different methodologies depending on the mode of practice being employed.

Researchers need to look in more depth at the nature of the modes of practice in business and military simulation, as well as in other domains of practice. A debate needs to take place so that simulation practice is better understood. They also need to consider in detail the implications of these modes of practice, particularly on the methodologies and methods that should be employed in simulation modelling.

Those involved in simulation education must identify the different skill sets required for the different modes of practice. Their education and training should be adjusted accordingly. Meanwhile, the users need to be able to select, or at least have help in selecting the appropriate mode of practice for the problem situation that is to be tackled using simulation.

7 CONCLUSION

There has been little discussion about the practice of simulation modelling, although such a debate is taking place about the nature of OR and of system dynamics modelling. This paper attempts to provide such a discussion with a view to generating a wider debate for simulation. In doing so, three modes of practice are identified: simulation as software engineering (mode 1), simulation as a process of social change (mode 2), and simulation as facilitation (mode 3). The various facets of these modes are described, and the manner in which simulation is performed in business and the military is outlined with reference to these modes. Finally, the implications of the three modes of practice are discussed.

This paper presents a starting position in terms of identifying modes of practice in simulation, it is certainly not meant as the completion of a debate. Further debate and discussion is required so that a better understanding of the practice of simulation modelling is obtained. In particular, this paper only considers simulation as it is practised in business and the military. The discussion needs to be broadened to include the use of simulation in other domains of application.

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