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Simplification: ethical implications for modelling and simulation

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Abstract: Put simply a model is a representation of 'something else'. Models may take many forms ranging from scaled models used to represent real world physical objects, such as buildings and new consumer products, to sophisticated computer models used to represent quite complex and often abstract systems, such as financial and investment strategies. However since individuals perceive and interpret situations differently, the same can be said for their perceptions and interpretations of what a model might represent. In the case of a model this could include the model builder, users and even members of the public. Fundamental to the model building process, is the selection and use of various abstraction techniques used by model builders to simplify the 'something else' they are seeking to represent. One of the major issues concerned with simplifying 'something else', be it a relatively simple or complex situation, is determining which factors can be confidently removed from the situation without impacting on the reliability and validity of a model that is subsequently built to emulate or represent it. In essence, once a factor or series of factors are removed from a situation, the situation itself is changed. Further, models are often deliberately built and used specifically to form the basis for analysis and investigation over time using simulation techniques, the results of which are then used to support individual and organisational decision making the consequences of which may even impact on innocent third parties.

In this context, this paper will provide a brief examination of the concept of simplification and various approaches to simplification utilised by model builders and simulationists. It will then attempt to provide an ethical analysis of the implications associated with how much and what kind of information should model and simulation builders be reasonably required to disclose to potential users of their products so that any decisions these users make on the basis of information obtained from a model or simulation output can be undertaken in the utmost good faith.

Keywords: *disclosure, ethics, model, simplification, simulation*

1. INTRODUCTION

The use of models and simulations continues to be a significant resource for many human activities, spanning leisure and critical decision making. However, it is quite common for the terms 'model' and 'simulation' to be used synonymously. Many individuals use both terms to mean the same thing. A model may be described as a possible representation of 'something else', that is a system or event, and may take many forms ranging from scaled models used to represent real world physical objects, such as buildings and new consumer products, to sophisticated computer models used to represent quite complex and often abstract systems, such as financial and investment strategies, while a simulation may be described as an attempted implementation, reproduction or manipulation of a model over time. Cook & Skinner (2005) assert that modeling and simulation are typically used for one of three purposes: descriptive, predictive and normative models. In brief descriptive models are used to explain how real-world activities function, predictive models are used to predict future events in addition to describing objectives and events, while normative models are designed to not only describe and predict, but also provide direction about a proper course of action.

Shannon (1998) noted that while the development and use of model and simulations have undoubted advantages, such as testing new designs, the exploration of existing situations without disturbing current practice, hypothesis testing, the control of time in that a simulation can be run under manipulated time conditions, and of course experimentation, there are also some disadvantages. These include, the need for practitioners to receive specialized training, difficulties associated with obtaining quality input data, and the recognition that simulations do not offer optimal solutions but rather should be seen as tools for 'analysis of the behavior of a system under conditions specified by the experimenter.' Shannon (1998) makes two further important statements. Firstly, the 'utility of a (simulation) study depends on the quality of the model and the skill of the modeler' and secondly, the 'essence of the art of modeling is abstraction and simplification'. The first is a particularly important observation in that it recognizes a fundamental limitation of the modeling and simulation process. That is, the development of a model and a working simulation is no automatic guarantee of a valid or successful outcome. The second observation highlights the basic nature of modeling and simulation practice. That is, identifying the critical characteristics of the system or event which can then be usefully used to develop a valid and reliable model and simulation. Fundamental to the model building process then, is the selection and use of various abstraction techniques used by model builders to simplify the system or event they are seeking to represent. This paper will provide a brief examination of the concept of simplification and the various approaches to simplification utilised by model builders and simulationists. It will then attempt to provide an ethical analysis of the implications associated with how much and what kind of information should model and simulation builders be reasonably required to disclose to potential users of their products so that any decisions these users make on the basis of information obtained from a model or simulation output can be undertaken in the utmost good faith.

2. SIMPLIFICATION AND SIMPLIFICATION TECHNIQUES

The basic objective of building valid and useful model and simulation packages is to produce something that works! Sha (2001) observed, in the context of software development in general, that complexity breeds bugs, all bugs are not equal, and perhaps more importantly only a certain amount of effort can be allocated to any one project. It would seem reasonable to suggest that these issues can also be applied to the development of model and simulation packages.

In this context Henriksen (2008) has recently suggested an algebraic expression for measuring the efficiency and usefulness of simulation packages. Henriksen argues that the simulationists' goal is to maximise what he refers to as the 'objective function' measure of the success or usefulness of a simulation package. The objective function is defined as:

$$Objective\ function = \frac{Applicability \times Correctness \times Obedience \times Ease - of\ - use \times Performance}{Cost \times Complexity}$$

where *applicability* is described as a measure of whether the simulation package can be used to solve a particular problem, *correctness* as the probability that a result produced by the simulation package is 'correct', *obedience* with two exceptions, disallowing obvious errors and querying questionable uses, as the simulation package doing what it has been programmed to do, *ease – of – use* as recognising that a simulation package ease – of – use is not constant, and is influenced by the complexity of the project, time and the simulation package (software's) interface, and *performance* as the execution efficiency of a simulation package. *Cost* is described as the limitation placed on all terms in the numerator and as being directly proportional to *complexity* or the degree of difficulty, including both hardware and software issues, associated with a model or simulation's components. This approach in particular, highlights the significance of simplification, or complexity reduction, in model and simulation development. While recognising that complexity in itself is at times a difficult concept to deal with, it provides a very useful tool for analysing and describing the impact complexity might have on the development of a simulation package. That is, as complexity increases, so does cost and more importantly so does the 'value' of the denominator in the objective function, but as a consequence the output of the 'objective function' more than likely decreases, implying that the efficiency and usefulness of the simulation package it is measuring also decreases.

Robinson (2004) has asserted that simplification is concerned with reducing the complexity of a model with the aim of increasing the model's utility while not significantly affecting its validity or credibility. This involves reducing the scope and level of detail in a *conceptual model* either by removing components and interconnections that have little effect on model accuracy, or by representing more simply components and interconnections while maintaining a satisfactory level of model accuracy. Robinson (2004) defined the term conceptual model, as a non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model. Decisions made about the development of a conceptual model then fundamentally underpin the development of a working model and simulation which follow and therefore need to be made with the utmost care and judicious consideration of their implications. Perhaps the key phrase here is the 'model that is to be developed' in that the conceptual model might be described as the ideal the model builder is trying to emulate or represent. In reality however, the actual model and simulation that are ultimately developed might be described as what is possible or what is achievable. Hence moving from the ideal to what can be achieved requires simplification. In essence, conceptual model development is concerned with deciding how the virtual world of the simulation will work (Wang & Brooks, 2007). Robinson (2004) suggests a good simplification is one that brings the benefits of faster model development and run-speed (utility), while maintaining a sufficient level of accuracy (validity). This is in turn determined by the previous experience of the model builder, judgment and testing.

In a now well known paper, Innis and Rexstad (1983) suggested that simplification is the removal of inappropriate complexity, with the aim of producing model and simulation products which were less expensive, required fewer inputs, were easier to transfer and/or combine with other products, and easier to interpret. For this purpose, they identified 17 possible simplification techniques which were currently in use and which they noted were neither mutually exclusive nor collectively exhaustive. These are essentially functional in nature and include: system organization, filtering, stochastic features, graph theory, sensitivity based results, structure and logic analysis, dimensional analysis, repro-meta modelling, time constraints, analytical solutions, interdependence, perturbation methods, calculation of output moments, languages, coding improvements, variance reduction, and linear system techniques. Further, they noted that complexity can take on a number of forms. These are the inclusion of processes that contribute little or nothing to performance, inclusion of data based descriptions of functions that are easily represented with a few parameters, too many state variables, and coding that is difficult to read or takes excessive amounts of computing time. In addition, they also identified what they suggested were three overlapping or interdependent concepts of simplicity: simpler is shorter, more transparent is simpler and more efficient is simpler. Moreover they noted that the interdependence of the simplicity concepts depended on the problem, experience of the analyst, model objectives, and the user of the results. More recently Henriksen (2008) has offered what might be described as a more reflective and strategic approach, suggesting 12 essentially pre-emptive methods for complexity reduction. While this approach to simplification or complexity reduction, is but one, it recognises the need to proactively manage the process. The methods are listed in table 1 together with a brief description.

3. SIMPLIFICATION: ETHICAL IMPLICATIONS FOR MODELLING AND SIMULATION

Balci et al (2002) suggest the evaluation and credibility or acceptability assessment of modeling and simulation products demands rigorous collaborations among those individuals and groups associated with their development. More broadly however, Sterman (1991) earlier argued that whether members of society like it or not they are all becoming consumers of computer models and observed:

> "The ability to understand and evaluate computer models is fast becoming a prerequisite for the policymaker, legislator, lobbyist, and citizen alike."

1. Heed the Law of Least Astonishment (software should work the way it is expected to work) and The Principle of Minimum Regret (actions with large negative consequences should be hard to do!)
2. Know when to go back to the drawing board (redesign and simplify known system complexities in order to improve software performance)
3. Do the little things (evaluate the detail of both large and small issues)
4. Teach, teach, teach! (recognise the need for the effective education and training of users to assist them in dealing with complexity)
5. Provide easy access to true primitives (recognise that hiding access to true primitives can inhibit user activity)
6. Build orthogonal features that are easily combined (that is, build independent features)
7. Use formal methodologies, but only where appropriate (recognise that the use of formal methodologies, such as the use of simulation language grammars to define language syntax, can improve the structure of a simulation product)
8. Provide open architectures (recognise users may require access to code in order to evaluate its applicability)
9. What's useful to the developer may be useful to the user (recognise that a users may also benefit from information initially known only to the developer)
10. Provide extensibility mechanisms (that permit the combining of primitives in creative ways)
11. Build interface at the proper level (recognise that when interfaces are built at too low a level, users are forced to deal with unnecessary detail)
12. Build swimming pools, not wells, vast ponds or tarpits (build simulation products of appropriate size and complexity that users can confidently manipulate).

Table1: 12 approaches to complexity reduction (Henriksen, 2008)

Two points need to be considered here. Balci and his colleagues' statement appears to be limited in that it does not include consideration of the wider public. On the other hand Sterman's statement probably implied the inclusion of simulations, and while those individuals and groups primarily involved in the development of models and simulations might be interested in and appreciate the methods and techniques used to build these products, unfortunately not all members of society are necessarily focused by such concerns. Given these considerations, it is important that model and simulation builders appreciate the need to recognize the limitations of the products they produce because essentially they are all in the business of simplification or reducing complexity. While the aim of simplification is no doubt seen as a significant component of the model and simulation building process, an important question that needs to be asked is why it is necessary in the first place? Is the aim of simplification really concerned with producing efficient algorithms, improving interpretability of the simulation output, or is it just part of the accepted and expected intellectual activity normally associated with building models and simulations, or is it all of these?

Bunge (1963) suggested that while simplification (simplicity) might guarantee solvability, it should not be seen as a guarantee of truth. Simplification implies approximation, and therefore a model is at best an approximation of whatever it purports to emulate or represent. In essence, once a factor or series of factors are removed from a situation, during a simplification process, the situation itself is changed. Further, Bunge (1963) noted that simplification in one respect is often achieved through complication in another. A statement of a problem can be simplified in either of the following senses: without loss, with gain, or with loss. As a consequence, it would seem reasonable to assert that simplification methods should be seen as a means to an end, that is hopefully a functional model and simulation, and not necessarily as an end in themselves.

A basic issue that needs to be acknowledged in the model and simulation building process is that individuals perceive and interpret situations differently. In the case of model and simulation development and use this could include, the builder, users and even members of the public, and includes their perceptual interpretation of the system or event that is being modelled and simulated, as well as the output obtained from the model or simulation. One of the major issues concerned with simplifying a system or event, be it a relatively simple or complex situation, is determining which factors can be confidently removed from the situation without impacting on the reliability and validity of a model or simulation that is subsequently built to emulate or represent it. The problem here of course is the correct identification of the critical components of the system to be modeled. In essence, once a factor or series of factors are removed from a situation, the situation itself is changed. Brooks and Tobias (1996) suggest that the relationship between the level of detail or complexity of a model and model performance is complicated in that it does not generally follow that a simplified model performs more reliably and validly than a more complicated version of the same system. Moreover they suggest the selection of the best model requires two judgments. Firstly, an appreciation of the likely performance of a model compared with, secondly, a knowledge of the performance of possible alternative models.

In a broader ethical context, Jones (1991) has argued decision-making must be ‘issue-contingent’. That is, it must consider the characteristics of the issue itself. He uses the term ‘moral intensity’ which he suggests has six components: magnitude and consequence, social consensus, probability of effect, temporal immediacy, proximity, and concentration effect. Magnitude and consequence is defined as total harm/benefit resulting from the moral action in question, social consensus as the degree of agreement that an alternative is evil or good, probability of effect as the probability that the action will take place and will cause the harm/benefit expected, temporal immediacy as the time between the present and the consequences of the moral action, proximity as the feeling of closeness that the moral agent has for the victims/beneficiaries of the action in question, and concentration effect as the ‘inverse function’ of the number of individuals affected by a given act. Many ’remote’ users and consumers of simulation product outputs, such as members of the ‘public’, are very much dependent upon and vulnerable to the competence and professional expertise of simulation builders and users (Barlow, 2006). In essence decision-makers are increasingly vulnerable to the quality and appropriateness of the assumptions the model and simulation builders have made when developing a product, as well as its perceived credibility or believability. Taken further, they increasingly rely on the output of simulation products to provide the ‘facts’ on which they base their decisions.

Given this, it would seem the need for the disclosure of information associated with model and simulation development is also clearly important. Girill (1999) makes an important point here when he asserts:

> “Disclosing hidden software assumptions, and spelling out their implications for the output of simulation runs, will have a major impact on how astutely engineers and physicians can make good judgments based on simulated, rather than physical analysis.”

The quality and usefulness of a model or simulation is very much dependent upon the attributes of the assumptions, data and techniques used in their development. However, how much information about the limitations and assumptions underpinning the development of their product, should a model or simulation builder be compelled to provide to others, and perhaps more importantly how should such information be provided? Not only how much and what type of information should be disclosed is important, but also to whom should it be reasonably disclosed (colleagues, independent referees, members of the public), and for that matter how should it be disclosed? A further issue related to disclosure is the substance of the detail contained in the information to be released. Even partial disclosure of the rationale underlying a model and simulation development might result in an increase in the authority and mystique associated with the use of and results generated by the simulation which are totally unwarranted and which may lead to unintended consequences. Disclosure may provide a simulation with a ‘credibility aura’ well beyond its actual merits, particularly in the public domain where knowledge of the mathematical assumptions and other theories underpinning the simulation design and implementation is either non-existent or perhaps little understood (Barlow, 2006).

Recently, Blattnig at al (2008) have proposed a method for presenting information which could assist decision makers in their assessment of the credibility of model and simulation products. A model and simulation’s credibility is essentially presented in two parts: a comprehensive results statement and a rigor assessment. The comprehensive results statement has two sections: a best estimate together with an uncertainty statement. The uncertainty statement is also divided into two sections consisting of an estimate of the uncertainty and a description of how well the uncertainty is known. By implication then, the smaller the uncertainty and the more that it is understood, the more credible the model and simulation outputs are. The rigor assessment is based on a four level measure of rigor scale that reflects the rigor of each of the components used to produce the results. These include: code verification, solution verification, validation, prediction uncertainty, level of technical review, process control, and operator and analyst qualifications. Importantly, the levels vary from being a subjective and minimal ‘1’ to an objective and extensive ‘4’ measure of the conditions that affect critical decisions. Significantly each rigor component is (1) assessed separately and (2) reported by means of a simple graphic summary which also indicates both the required level of rigor for each component together with that which has been achieved. An example rigor graphic report is provided in figure 1.

While Blattnig and his colleagues’ proposal was developed within NASA, the method may have wider application, particularly in the context of how the rigor scales are reported. Clearly such a method for disclosing information about the credibility of a model and software product by no means guarantees it will be disseminated to or even read and understood by all potential users. Essentially however, the use of a simple graphic image as a reporting tool provides a means of clear and concise communication, and as a consequence may have the potential to convey significant information about the rigor and credibility of a model and simulation product, well beyond a technical audience to a range of users, including expert remote users, and even members of the public in appropriate circumstances. In addition, although the interpretation of this reporting tool should in some respects be almost self-explanatory, its simplicity requires minimal additional training in its use. As a consequence it might result in a wider use of such a tool as a model and simulation assessment tool in the wider community. While this approach does not guarantee a model and simulation product will always be used and interpreted appropriately, it has the potential to support and enhance informed decision making about these products.

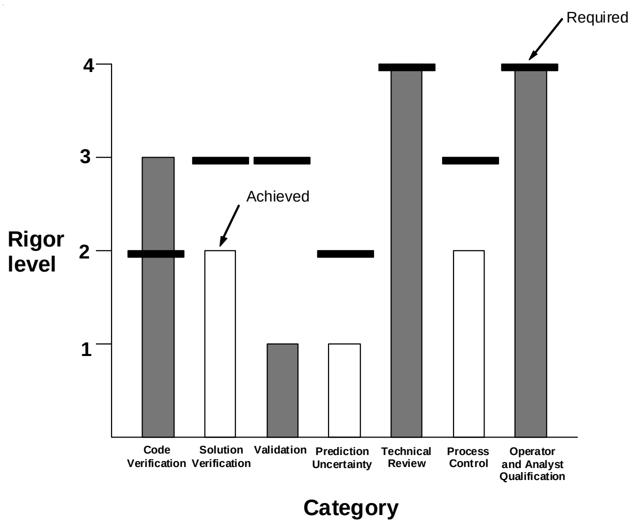

Figure 1: Example rigor graphic report (Blattnig et al, 2008)

4. CONCLUSION

This paper has provided a brief examination of the concept of simplification associated with the development and use of model and simulation products followed by a brief discussion of ethical issues that might need to be considered when the output of these products are used as in decision making. Disclosure of relevant information was identified as a key issue. The recent work of Blattnig et al was noted as a possible means for providing relevant information to a range of potential users.

It should be noted of course that the disclosure of appropriate information does not guarantee the proper use of model and simulation products. Sterman (1991) makes a very important point when he observes that most people are not able to make judgments about the veracity of computer models in an intelligent and informed manner, and makes the further point that computer models can be misused, accidentally or intentionally.

> "Thus there have been many cases in which computer models have been used to justify decisions already taken, to provide a scapegoat when a forecast turned out wrong, or to lend specious authority to an argument."

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