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Validation Issues in Computational Social Simulation

A Working Paper

by

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Validation Issues in Computational Social Simulation A White Paper

This white paper discusses the notion of validation as applied to computational simulations of social phenomena. Its purpose is to identify areas needing attention if a rigorous framework and process are to be developed to validate these types of simulations. As such, it does not claim to be a comprehensive literature review, nor do we propose to take steps here toward development of frameworks and tools. Such development will require significant programs combining research and testing with active computer modelers and their products.

Validation and verification in computer-based modeling and simulation is a field with little standard terminology, tools, or theory (see (Kleijnen [1995] for general discussion and references). Of the two activities, 'verification' seems closer to a generally accepted definition. Most agree that verification refers to the performance of the code itself, that is, does the code perform as the modelers intended (is it 'bug-free') (Kleijnen 1995), (Williams 1998), (Gilbert et al. 1999). A suite of tools (primarily statistical in nature) has been developed to determine the 'goodness of fit' of the code to performance as access through output. It is in the validation realm that significant issues of definition and approach arise, particularly in the emerging field of computational social simulation.

Validation has been defined as a determination as to whether a particular computer program is "an accurate representation of the system under study," (Kleijnen 1995), whether the simulation is a "good model of the target" (Gilbert et al. 1999:), or a legitimate "representation of the actual...system under design or study" (Williams 1998). All these definitions suggest that validation measures the output of the code against some 'reality'—that validation compares the end product of the modeling process against some standard. This conception of the process is shown in Figure 1.

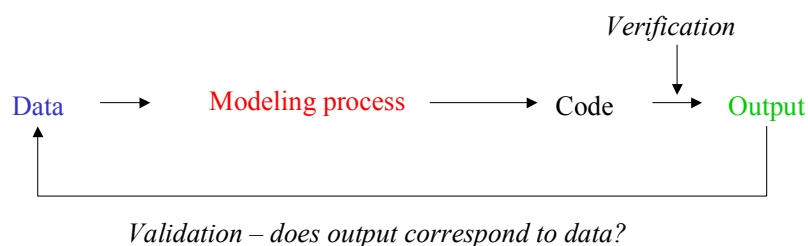


Figure 1: Traditional place for validation

We suggest that validation is a complicated project when dealing with social phenomena, and should address several different points in the modeling process. To that end, we begin with

a re-conceptualization of the modeling process. All the definitions of validation given above assume some object of study as they presuppose some circumscribed 'target' or 'system.' They also assume some specific way of conceptualizing these systems, and particular ways of embodying those systems in computer code. The code then produces some output that is accessed by the user. We parse this process into 'data', conceptual model, 'conceptual model as formalized into computational form,' and 'code.' This concept is shown in Figure 2.

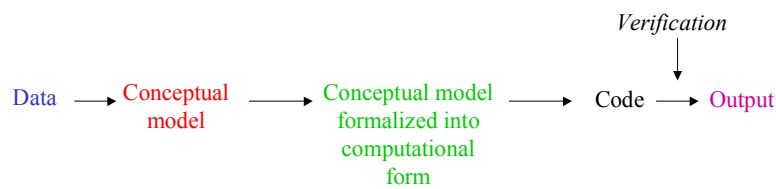


Figure 2: Elements of the modeling process

The remainder of this white paper is an exposition of the elements of Figure 2. In the course of this exposition, we will highlight problematic areas that are ripe for study and formalization in the development of validation techniques for computational social simulations.

Data

All models are grounded in data. As Kleindorfer et al (1998), Naylor and Finger (1967), and others note, most validation efforts in simulation come from a logical positivist viewpoint. There is an implicit assumption that there is a 'world out there,' and that the model is a representation of some part of that reality. This begs two questions in the case of simulations of social phenomena. The first relates to the nature of the posited reality, and the second to the process by which some portion of that reality is identified as relevant and selected for use in the model. We will address questions around the nature of the posited reality (i.e. that which is re-presented in the model) in this section. The process of selecting some portion of that as relevant is discussed in the following section, 'Conceptual Models.'

Computational social simulations are designed to simulate or represent some part of the social reality. Does this mean that the output of the model should 'look like' some portion of the real world? Or does it mean that the 'rules' that the model uses to generate the simulation should be the same rules used by social actors (see Dreyfus [1999])? Is the model focused on behavior or on the meaning placed on the behavior¹? If the model evaluator is not

¹ If not on the meaning—what makes a *social* simulation different from a simulation of the movement of inanimate objects in space?

clear on the nature of the target system intended to be re-presented, s/he cannot assess the degree to which the model output reflects it.

The current state of computer sciences requires that the data used must be measurable. It can be quantifiable, or measured by qualifiers such as 'a lot.' However, even with such qualifiers, the modeler still must have a sense of how much (quantity) constitutes 'a lot,' although it can be expressed as 'greater than' rather than as a specific amount. This requirement for measurability is implicitly transformed into a requirement that the data be based on observables. This is the positivist orientation to which we referred earlier. It is important to note that this excludes structures of significance (or meaning) as candidate data, unless they are represented by surrogate observables. Church attendance, for example, becomes a surrogate for the belief in God. While there is merit in this type of substitution, the model evaluator must be clear as to the referents for the labels attached to data points.

There also is a school of thought that questions the legitimacy of the notion of interpretation-free social data. This school argues that data becomes social data only through its embeddedness in a social system (see, for example, Wittgenstein [1999]). A building with a cross on it, for example, is a 'church' and not 'a building with a cross on it' because of the cultural streams that define the significance of the cross. The model evaluator must have some means to ascertain that the data selected by the modeler do have the socio-cultural significance the modeler imputes to them.

The discussion so far is summarized in Figure 3.

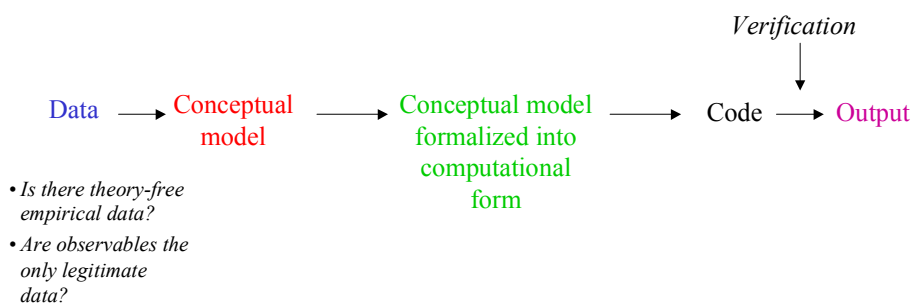


Figure 3: Elements of the modeling process: data

Conceptual Model

A model (by definition) portrays only a part of the target system, otherwise it would *be* the target system. How, then, does the modeler select the portion of the target system to portray? We suggest that this is constrained by three factors: the modeler's own notions of

the construction and functioning of the target system; the model's purpose; and the modeling approach or type of model chosen.

There is a school of thought that argues we can only see a system through the lens of the paradigmatic preconceptions we bring to it (Guldenmund 2000) and so we cannot ever see all of it. Even ethnomethodology, an anthropological approach generally interpreted to focus on and only on observable social behavior, actually is primarily interested in the conceptual structures that give that behavior coherence (Garfinkel 2002:). This position is taken to some logical extremes by postmodernism, which argues that reality is nothing more than perception. There is no 'there' there. This clearly is related to our early question about the (non)existence of theory-free empirical data. This is not the forum to continue that argument... but even if we could see 'all' of reality, the model must select only a part of that reality to portray.

The criteria for selection for inclusion in the model are part of an argument for salience. This salience, in turn, is based partially on the model's purpose. If the purpose is to understand conflicts over water, for example, legal and geo-political variables will be of importance for the model; if the purpose is to understand water allocation and management practices, end-use variables and information on water management institutions would be more important to incorporate.

This presupposes the explanatory power of certain theoretical constructs. If, for example, terrorism is best understood in *realpolitik* terms, access to various types of resources and power bases are important to include in a model; if it is understood as 'theater,' data on media, audiences, communication channels, text/word analysis, and the like are more important to include. In best practice, the modeler will make this theoretical construct explicit. In any case, the model evaluator must be aware of the modeler's theoretical bias, as it will determine the portion of the target system chosen for inclusion in the model—in fact, it will help determine the boundaries of that system. The selected theoretical construct thus will have a large part to play in defining that against which the model output is compared. Morrison and Morgan (1999) refer to this as the 'mediating' function of conceptual models. The evaluator must ensure that his/her conceptual model is congruent with that of the modeler for purposes of the evaluation.

Models are a set of 'things' or variables connected to each other in certain ways (Kleijnen 1995). Both the variables and the nature of the relationships among them are specified by the modeling approach. For example, systems dynamics talks of stocks and sinks connected by inflows and outflows, agent-based models work with individual agents who interact according to 'rules' either exogenously developed or emergent from the interaction, and the like. The modeling approach chosen will impact the way in which the modeler sees the target social system, and the types of elements s/he identifies for inclusion.

The selection of salient variables and the description of the relationships among them is initially expressed textually by the modeler in the form of a conceptual model. In best practice, the modeler will be able to justify his/her selection through reference to the theoretical literature that supports the conceptual frame that identifies those variables as important for the target problem and system.

To conclude this section, we note that the development of the conceptual model underlying the computational model is an important step toward gaining agreement from participants (model builders, evaluators, users) of the problem or system under study. If the target system is identified at this stage as driven by economics, the resulting simulation will look very different than if the target system is described as driven by ideology (Barreteau et al. 2003:)). While the individual evaluating the validity of a computational model need not agree that the target system is appropriately characterized, s/he must be aware of that characterization in order to move forward with the validation exercise. Our discussion so far is expressed in Figure 4.

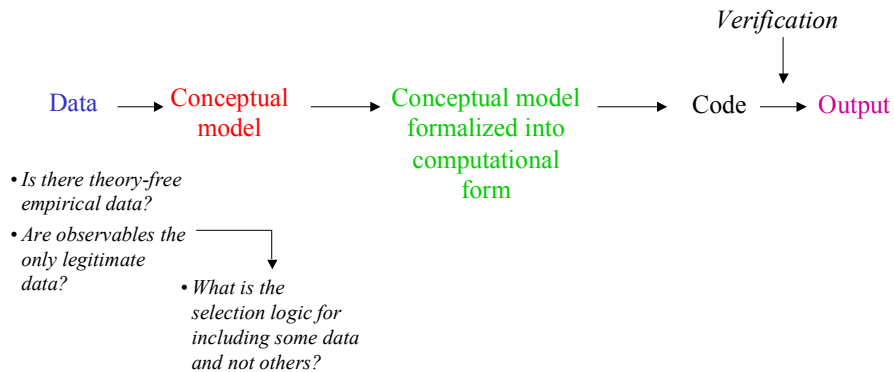


Figure 4: Elements of the modeling process: conceptual model

Formalization of the conceptual model

The next step in the modeling process is to transform a textual expression into one that can be handled computationally. Given the level of formalization and precision required, this step suggests that computational simulation “has a similar role in social sciences...[as] mathematics in the physical sciences” (Gilbert et al. 1999:5). It forces the theorist to demonstrate that his/her model is complete and coherent. This transformation is not a trivial task, not in the least because it is here that social and computer scientists must interface. The intellectual transformation problem is compounded by communication difficulties that often arise between those trained in the social sciences, where theory is generally

expressed in a narrative form with precedence given to interpretation and argument, and those trained in computational or information sciences with emphasis on precision and formalism (Snow 1998 [1959]).

The operational requirements of computers place a variety of constraints on the type of data that can be manipulated². At some point, given the current state of computer science, the data must be measured (see earlier discussion under 'Data'). This makes positivist approaches very attractive to computational manipulation, and more qualitative approaches less so. For example, it is much easier to manage 'church-going behavior' in a simulation than it is 'ideological system' so the former often becomes a surrogate for the latter. This defaults most models to behavior rather than to rules or conceptual frames that drive that behavior. This has implications for the way in which the model outputs are used, as well as how those outputs are assessed against the inputs (that is, the assessor must be sure that the inputs are those which the modeler used³). This requires close attention by the evaluator to elements such as data and output labels.

Our earlier discussion of the constraints that the modeling approach places on data (data here refers to both variables and the relationships among them) also comes into play here. Certain types of discussions cannot be had using certain types of modeling approaches. For example, if the selected approach is social network modeling, discussion of stocks and flows such as one might have in a systems dynamics environment are nonsensical. The validation exercise should explore whether transformation to the selected formalized form represents the critical elements of the textual form in a reasonably faithful fashion. Development metrics for this goodness of fit in this arena will be challenging. Figure 5 continues our graphic presentation of the process.

² This is an area ripe for investigation and exploration in computer science. There is much social science data that cannot be quantified and hence is now inaccessible to computational processes. New computer languages or techniques that can deal with this type of data would greatly extend the informative capabilities of computational models.

³ As an example of the pitfalls, the author attended a presentation of a modeling project in which the modeler claimed to show 'friendship ties' among the agents when model inputs were 'number of contacts' over some period of time. Imputing 'friendship' from 'contacts' can lead to false conclusions.

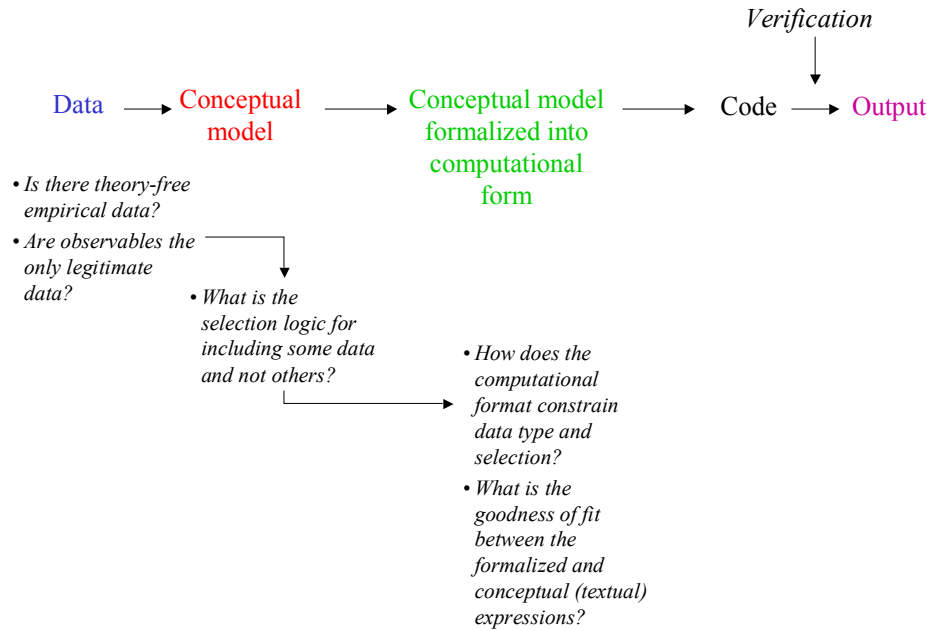


Figure 5: Elements of the modeling process: formalizing the conceptual model

Code and Output

The next step is to encode the conceptual model in some computer language. The encoding process is accessed through the output. The relevant evaluation process here is verification not validation. Does the code do what the programmer intended? Note that verification does not address the 'goodness of fit' of the code to the conceptual model. At best, it addresses the relationship to the formalized version of the conceptual model. The dashed arrow in Figure 6 represents the weakness of this relationship in the verification process. At worst, it is self-referential ensuring that similar inputs will give similar outputs each time. As we noted earlier, this is usually done through the application of a variety of different statistical techniques to the model output.

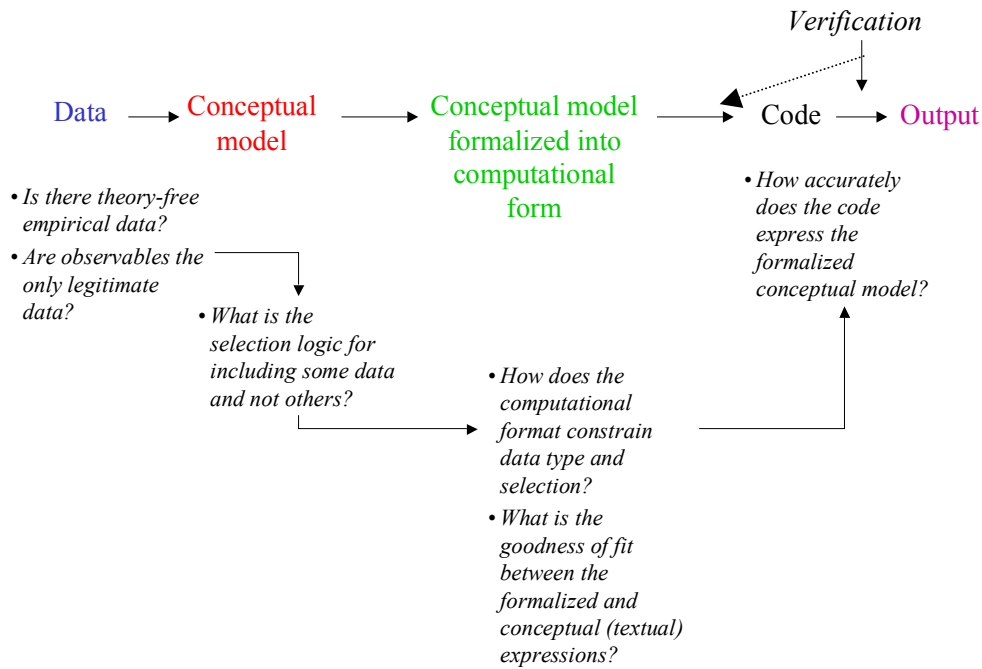


Figure 6: Elements of the modeling process: code

Validation

We now address how one might assess the validity of a computational social simulation. As we noted in our introductory section, traditional validation exercises match model output against a state of the 'real world.' As we have shown, at best validation exercises often compare model output to the implicit conceptual model or, in worst cases, to the formalized version of the conceptual model. This begs the question of whether (or to what extent) model output is compared to the target system itself. Furthermore, computational social simulations often deal with future states in which the intent of actors and other unknowns can significantly affect outcomes. Furthermore, complex system approaches are making it evident that many different initial conditions can lead to the same end state (Richardson 2002), and vice versa...a single initial condition can lead to many possible futures. Therefore, even validating social simulations against historical data is questionable.

Questions about the 'validity' of computational social models or simulations need to consider all steps in the modeling process. If the evaluator is asking 'how well does the model represent social reality?' s/he is asking a nested set of questions.

What 'social reality' is the model representing? This question from an empiricist point of view forces questions about the nature of the data and the bounds of the system. There also are the standard social science questions of observers' bias in the data and other issues related to the user's confidence in the data.

What is the selection logic for including some data and not others? This will force the modeler to be explicit about the social theory that gives salience to certain variables and specific relationships.

How does the computational format constrain data type and selection? The social data needs to be expressed in ways that can be handled computationally. This may impoverish some types of data, causing them to lose richness of nuance and dimension that contributes to the fullness of their reflection of the target system.

Underlying all these questions are the bigger humanist questions. How are 'meaning,' 'intent,' and 'affect'—very important dimensions of the human experience—captured computationally?

Additional areas for exploration

There are domains that have developed frameworks and some reasonably rigorous approaches for model validation. Computational physics, particularly that portion of it which is concerned with validating codes related to the functioning of nuclear weapons, is one (see, for example, Oberkampf, Trukano and Hirsch 2003). In this arena, validation often means comparison of the model output to experimental results, where the experiment serves as a surrogate for the 'real world.' If we transfer this validation approach to a social environment, we suggest a new set of questions.

Experimentation on 'real' social systems is ethically questionable and methodologically very difficult. As social actors are self-aware in ways in which (e.g.) atoms are not, knowledge of the fact of participation in the experiment can impact participants' behavior in significant ways. Experimental behavioral and social scientists often deal with this issue by creating laboratory situations, in which the environment is controlled so that only the variables under study can vary (and those variations will be within constrained conditions) and the experiment design controls for the subjects' awareness of their participation. However, since social systems are highly complex, dynamic systems, understanding subsystems in isolation may give the experimenter a false understanding of how that subsystem will respond in its full system context.

Models are often used *instead of* experiments in environments such as these. (This also was a large part of the genesis of computational physics. As nuclear weapons testing was precluded under various treaties and geopolitical regimes, the physicists needed new ways to

understand the weapons' performance.) This moves attention from the model as artifact or product, to the modeling process as a research method (Morgan and Morrison 1999; Ilgen and Hulin 2000). This supports our argument, implicit in this entire discussion, that validation is not only about model output, but also about how that output is generated. This also begs the question of how the knowledge we gain from models is the same as/different from the knowledge gained from experimentation.

We have highlighted some key areas for exploration as more and more computational social simulations are subjected to 'validation.' As noted in the introduction, development of rigorous methodologies in this arena, including a theoretical framework and tools, will take serious attention and investment by interdisciplinary teams.

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