Exploring the "Whys" of Simulation Visualization

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ABSTRACT

Simulation is not the only thing to have benefited from the rapid advancement of computers over the last few decades; animated graphics have been transformed from simple square blocks on the screen to near life-like renditions of system of interest. Simulation developers have taken advantage of this new technology to graphically display their simulation results to decision-maker and potential customers alike. However, the focus of simulation developers has been on implementing the latest visualization approaches (the "hows") as opposed to determining the best way to express their results (the "whys"). This paper discusses some of the issues of the simulation visualization and their potential impact on the simulation community; this includes charlatanism and the rise of "chart junk." The paper concludes with a discussion on some of potential solutions.

ABOUT THE AUTHORS

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She has presented at numerous conferences in the field of rhetoric and writing studies. Her publications include a book chapter on rhetorical memory and the use of multiple modes of evidence in digital composition and a chapter on ecofeminism and research methodology in the collection Digital Writing Research, winner of the Computers and Writing Best Book Award of 2007. Her research includes the application of ecofeminism to digital environments and visual rhetoric as well as the use of the rhetorical canon of memoria in online writing environments.

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INTRODUCTION

The changes in computer visualization since the computer game Pong was released in the early 1970s are staggering; it has gone from black and white boxes on a screen to near- indistinguishable replication of live video recordings in films like The Curious Case of Benjamin Button. This rapid change to the simulation visualization industry has been followed by an even more rapid increase in user visualization expectations. Thus, these rapid advances in the visualization technology have meant that visualization researchers have focused on the "hows" of visualization and not the "whys." This focus is not without its consequences. Fancy graphics can have a mesmerizing effect on simulation novices and as such have led to problems which Paul Roman labeled "Garbage In, Hollywood Out!" (Roman, 2005). This phrase highlights the demand for practical research into requirements and potential future usages of visualization for Modeling and Simulation (M&S). Our purposes here is to highlight the need on giving the visualization process some transparency and giving some suggestions to achieve this.

Rise of Simulation

M&S visualization is being applied in areas where, traditionally, statistical quantitative measures were used because of the limitation of these statistics. One such limitation is accessibility; statistics relies on mathematics which can be a "turn-off" to many decision-makers, whereas, as Macal (2001) puts it, "visualization offers one of the most promising means to convey information from a simulation model to decision makers in a meaningful way." Visualization gives a modeler the ability to convey a significant amount of information succinctly using images of what is actually modeled as opposed to confusing algebraic variables.

Mentioning the words "computer simulation" to a lay-person usually conjures up images of pixelated entities moving around on a monitor's screen. Thus, for the analysis of simulations to become a main-stream activity within our society, M&S researchers should pander to this expectation through the use of visualization. This paper explains the need for development of visualization methods and practices which will aid the M&S researcher to express his or her results in a meaningful and accessible manner.

VISUALIZATION

Sokolowski and Banks (2010) define Modeling and Simulation visualization as "a process that generates visual representation such as imagery, graphs, and animations, of information that is otherwise more difficult to understand through other forms of representation, such as text and audio." Simulations of complex systems are difficult to understand as text or statistics, and thus visualization could be the appropriate approach to present their results.
The benefits of a simulation's visualization are not limited to enabling non-specialists to understand the complex system. A simulation's visualization might highlight salient patterns that maybe otherwise unnoticeable through statistical means, especially if those patterns are non-linear in nature. Thus Kuljis, Paul and Chen (2001) define the goal of visualization as seeking insights from patterns that can be identified from visual representations. For example, a standard approach for determining if a simulation has converged is essentially to look at a graphic of simulation output. An example is shown in Figure 1.

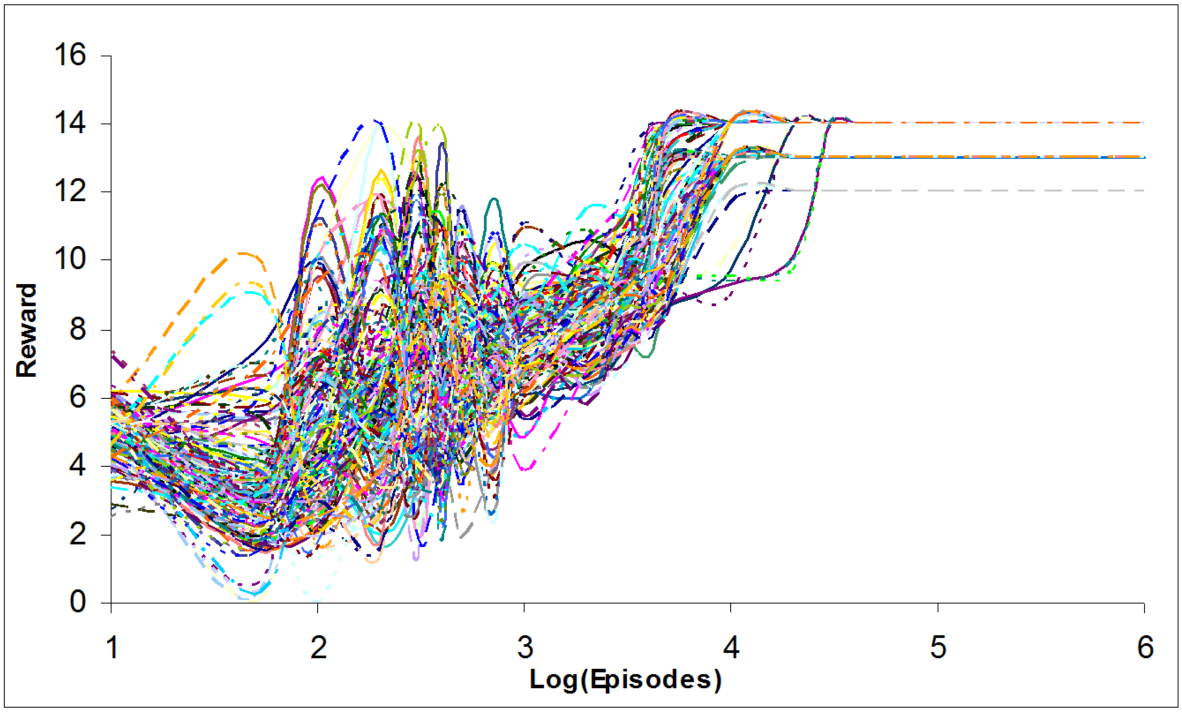

Figure 1. "Humming bird" example showing convergence of run (A. J. Collins, 2007)

Visualization is also utilized within the M&S community during the validation and verification process. Osman Balci stated that: "Visualization/animation of a simulation model greatly assists in model [verification and validation]" (Banks, 1998, p. 377); if the processes displayed from a simulation look "funny," this may be due to an error within the simulation or, even worse, the underlying model. However, these errors might be due to the way that the primitives of the visualization represent the simulation and not the simulation or model itself; thus the model and simulation might be technically correct but the chosen visualization displays the results in an awkward, ambiguous, or tedious way. This awkwardness may affect the user's willingness to understand and accept the simulations results, which is called the simulation's creditability (Sokolowski & Banks, 2010).

A simulation's visualization might also provide an unwanted negative effect on the verification and validation (V&V) of a simulation. A visualization designer might choose to hide some of the dubious parts of a simulation from the visualization and then over-emphasize limited parts of the simulation, or worse, imply that the simulation includes functionality which it does not; thus a simulation might look credible but is not valid. Robert Sargent (2010) warns that subjective validation approaches, like using visualization for validation, can mislead the observer in such a way.

Changes in Visualization

Collins and Knowles Ball (2013, p. 176) discuss this rapid change to the simulation visualization industry and the even more rapid increase in user visualization expectations that have come with it. This expectation has lead simulation visualization researchers to focus on mimicry of the real systems being modeled as opposed to the "whys" of simulation visualization. The focus of the M&S community, both developers and analysts, is not on a model's visualization either but on the mechanics that make up the model or simulation, e.g., the process of abstracting reality to enough detail for the problem at hand. Since visualization does not directly affect the simulation or its underlying model, it is also seen as a secondary consideration.

The considerations of the philosophical and psychological underpinnings of visualization have been left on the sidelines while researchers chase the latest technological applications of modeling and simulation (M&S). It is only through trail-blazers, like Tufte (2001), that any discussions on the "why" of visualization have occurred. Visual rhetoric can be profitably applied to M&S to improve understanding of its communicative abilities. Our focus in this paper is to develop the view, both now and in the future, of rhetoric's importance to simulation visualization. To this end, we hope to eventually develop guidelines and approaches which will give validity to using visualization to present phenomenon of complex systems.

Complexity of Systems

Complex systems are difficult to capture by statistics; to explain this point further, consider an example of two graphs given in Figure 2. The two graphs represent two distinctly different networks with the first graph containing a central connector. Let us consider some statistics of the two graphs, as given in Watts (2004): both have five nodes, both have six arcs, both have an average shortest path length of 1.4, etc. It is only when we consider something like the clustering coefficient that we notice any difference (6/8 for the first and 3/7 for the second) but what does that tell us? Does it highlight the importance of the central node in the first graph? A cynic might say that the wrong statistical measures were used but when, in complex adaptive systems, emergent behavior is of interest; it is difficult to know what to measure. Visualization gives us the best tools to detect unprecedented emergent phenomenon; a new phenomenon can usually only be captured in a single statistics if that statistics is for measuring that phenomenon. In other words, "a picture is worth a thousand words (statistics)."

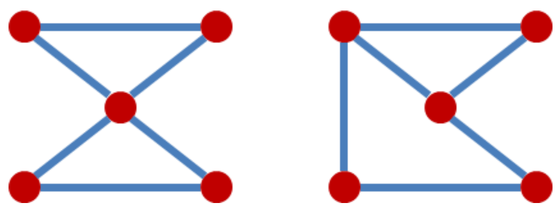

Figure 2. Diagram depicting two distinct graphs

The work of Darrell Huff, entitled "How to lie with Statistics," highlighted many misleading practices that are used with the numerical and graphical representations of statistics (Huff, 1954). Though the book is over sixty years old, the battle has not been won and many of the problems that Darrell Huff presented over fifty years ago are present in our everyday life and the rise of the internet has led to even more ways to misuse statistics, e.g., dynamically changing graphs (Kostelnick, 2008).

The misuse of statistics might not be from something as innocent as user misunderstanding. It was suggested within the book that the causes of these misrepresentations were deliberate rhetorical choices to skew the communication, e.g., the use of cut-off graphs to exacerbate gradient changes within the data. This issue can be summed up by the famous cliché from 19th-century British Prime Minister Benjamin Disraeli: "There are three kinds of lies: lies, damned lies, and statistics."

Statisticians recognize the need to counteract these problems with ethical uses of rhetoric because of the bad press their subject has received over the years. Most modern statistics books will discuss the proper use of statistics, e.g., descriptions of type I errors versus type II errors.

PROBLEMS WITH VISUALIZATION

We have just discussed the problems of statistics and benefits of visualization. This does not mean that visualization is without its problems, and we are not suggesting that all visualizations are useful and should replace quantitative measure. With modern technology, producing a graphic can be easy, as shown in Figure 3, but producing a good graphic can hard.

Misuse of Visualization

Given that a simulation novice might not know the difference between validation and credibility compounded by "animated graphics seem to have a mesmerizing effect on the simulation novices" (Banks & Chwif, 2011), there is a danger that new purchaser of M&S that they might end up with a "lemon."

As visualization becomes more realistic and easier to integrate within a simulation, its role within the modeling process is increased. Thus what started as a simple add-on to many simulations is now an integral part of them. This means that the influence of visualization on a simulation's design and output has grown over the years to a point where people are now starting to question its role. Paul Roman highlighted the impact of visualization's influence in his paper: "Garbage In, Hollywood Out" (Roman, 2005). The title of the paper is a metamorphosis of the George Fuechsel's adage "Garbage In, Garbage Out" (Butler, Lidwell, & Holden, 2010), implying that bad data and design going into a simulation will result in unusable, and invalid, results being produced. Roman's play on the phrase comes from the tendency of some commercial simulation vendors to mask the inadequate simulation designs behind advanced graphics.

This mesmerizing of simulation novices might initially seem innocent enough but it leads to a charlatan aspect of the M&S industry. Simulations, with fancy graphics, are being sold as tools for problems they are not equipped to solve. Analysis simulations with pretty front-ends but no substantial back-end are being peddled to unwary decision-maker. The results of such charlatanism might make a quick buck for some businesses, but what is the effect on the industry as a whole? That decision-maker will most likely obtain bad results from the simulation and thus look unfavorably at the simulation and M&S as a whole. Is that decision-maker likely to recommend simulation to others? Quite the contrary, for a new and fledgling industry like M&S, the bad press could be devastating to its growth and, ultimately, survival.

It should be noted that rhetoric is not limited to visualization (or politicians, and lawyers). Rhetoric is fundamentally a set of theories about communication. Rhetoric is in use all around us and its effects are affecting the way we model and how modeling is funded; for an example see Collins (2012) on the rise of the 80% solution.

Social Bias

A startling study by Jone Tiffany showed that social biases towards avatars were present within the social virtual environment of Second Life® (Tiffany, 2011). In the study, the participants took on the roles of various minority groups, including those with obesity and disabilities, and interacted with other users of the Second Life environment using an avatar that reflected their roles, e.g., one avatar was displayed using a wheel-chair, etc. The participants found that they were excluded from many conversations and group interactions within the virtual environment and these exclusions were attributed to the visual appearance of their avatars.

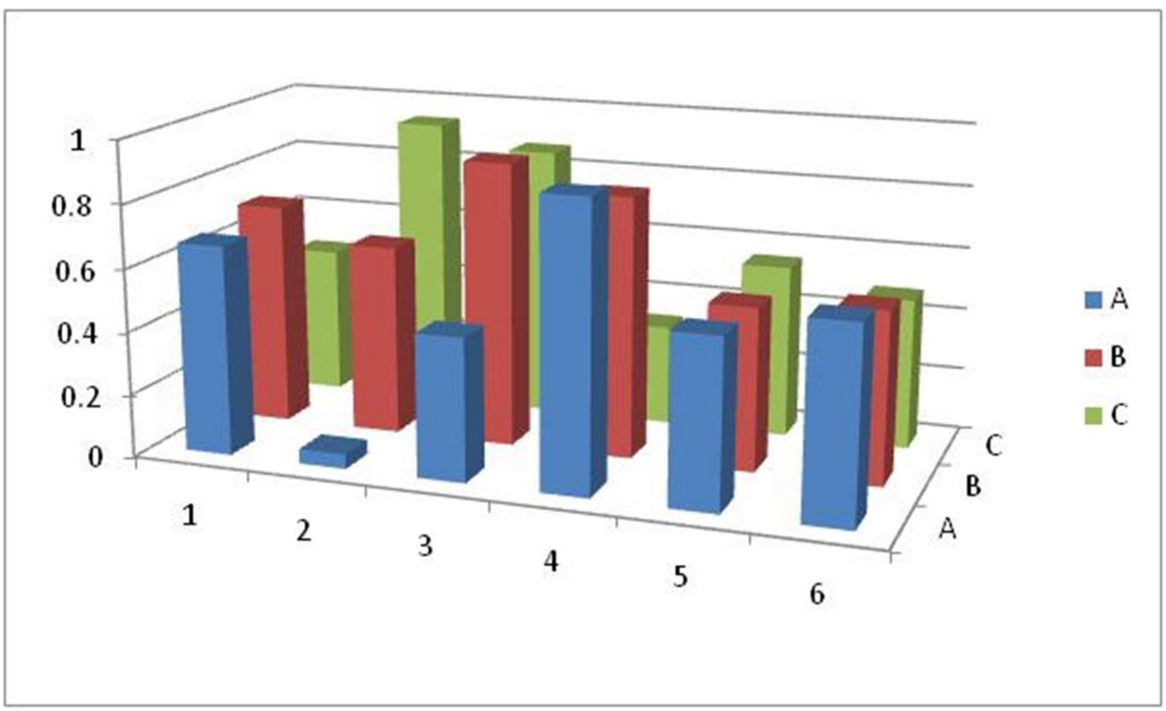

Figure 3. This graph and its data were produced in under two minutes in Microsoft Excel.

Human Perception

Visualizations allow us to organize ourselves in unpredicted new ways through software like TheBrain® (Figure 4). They allow us to communicate to others ideas that would be difficult to grasp otherwise; for example, consider the use of simulation (Figure 4) to help illiterate Sri Lankan farmers make better crop selection choices (A. J. Collins et al., 2013). Knowledge of human perception and the capabilities of the human eye-brain system can play an important role in the construction of effective visualizations. The most direct example of this is understanding that particular color choices may reduce the effectiveness of the visualization for the 8% of the population that has red-green color blindness (McIntyre, 2002). Other, less obvious examples have been demonstrated by the development work done at The Florida Institute for Human and Machine Cognition (IHMC) on the OZ-inspired systems for interactive human-centered visualization (Bradshaw et al., 2012; Still & Temme, 2001).

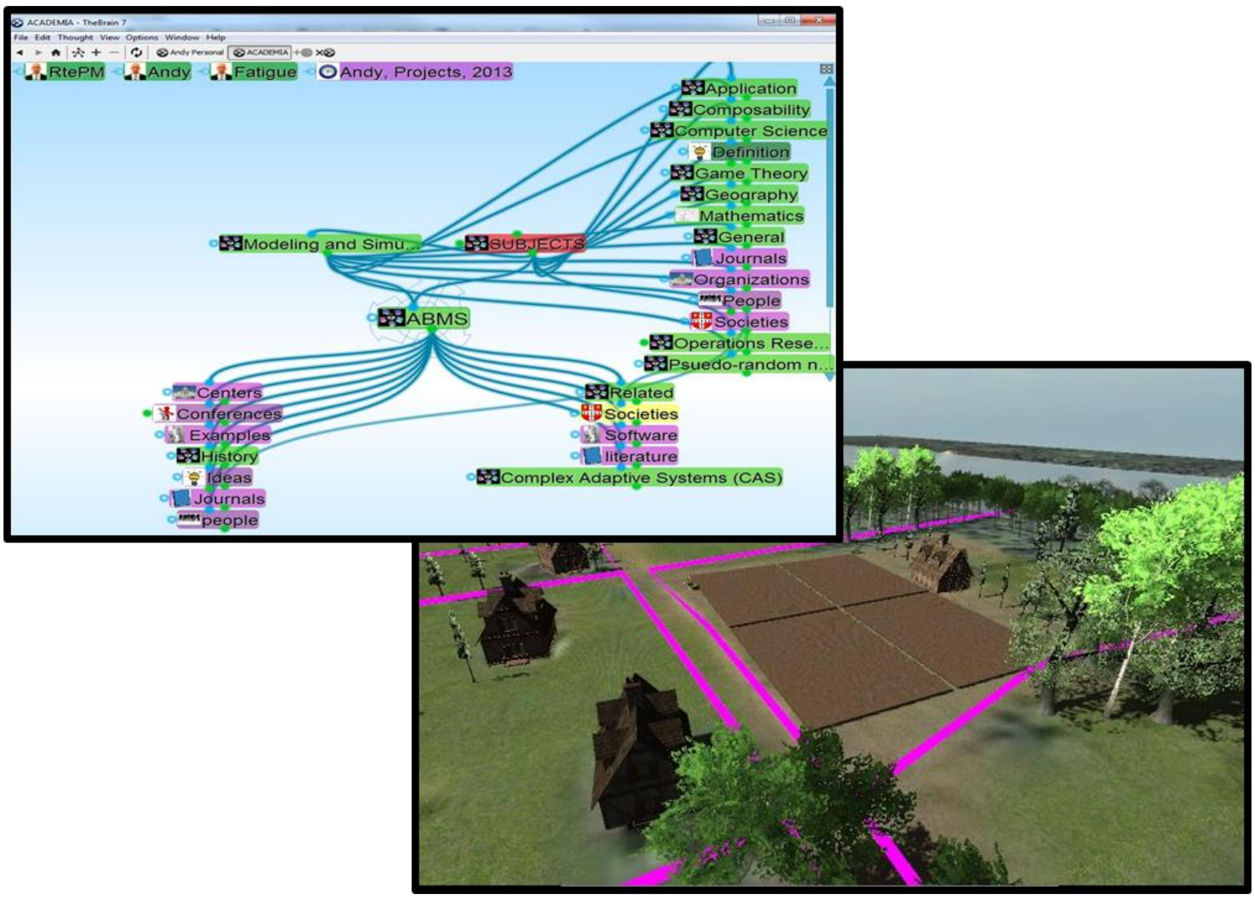

Figure 4. TheBrain® technologies organization software and 3D Virtual Reality Model of a Sri Lankan farm utilizing Geographical Information System (GIS) Data

POTENTIAL SOLUTIONS

There have been several suggested solutions to the problems of simulation visualization, and we will discuss each in turn. Kulljis et al. (2001) suggested that visualization standards were required to ensure consistency of presentation within the M&S community. There are two issues with that approach highlighted here. First of all, the standards development process is unlikely to keep up with the fast changing approaches to conducting visualization (A. J. Collins et al., 2010). Secondly, visualization should be fit for purpose.

Paul Roman says that the rhetorical issues with visualizations can be overcome with good Verification and Validation (V&V) in his statement that "[t]he primary defen[s]e against undue influence by impressive looking outputs is validation and verification" (Roman, 2005). However, V&V is a very subjective process and there is no agreed upon standard. The process of V&V is not an instant one, and it might not be possible to apply it to the simulation; this is especially true for simulation platform purchases. A simulation firm might release a limited version of the modeling platform for evaluation purposes, but inadequate, or misleading, documentation of the platform's capabilities make it difficult for the complexity modeling expert to evaluate the propriety components. And those that hold the purse strings for purchasing complexity modeling research are not necessarily, themselves, complexity experts. A focus on V&V would be just another example of the M&S community looking inwards upon itself; the issues of visualization are related to how the outside world sees us.

Our purposed approach would focus on giving the visualization process some transparency as advocated by Kostelnick (2008). The end results of the research would be tools, through papers or pamphlets, which would highlight some of the issues that modeling visualization novices should be aware off. Thus we propose that a "cheat sheet" is in order to provide M&S purchasers and users with tools to combat the poor rhetorical practices in visualization. The "cheat sheet" may include a list of questions to ask about the visualization or even simple explanation of the visualization process. If nothing else, a disseminated cheat sheet would make these "outsiders" aware of some of the visualization's rhetorical issues.

CONCLUSIONS

Modeling visualization has moved far beyond simple data representation into the world of visual communication over the past 15 years; ultimately, the acceptance of complexity models within main stream science and society will depend on the results that are produced visually. The rise of simulation visualization brings with it the rise of related problems. The increase of "snake-oil" visualization has the potential to damage the fledgling industry of Modeling and Simulation via the bad press their wares produce within our customer base.

The issues with visualization include those that are rhetorically based and those that are human perception based. Suggested solutions to these problems include the use of standards and more rigorous verification and validation. We propose that a simple cheat sheet for simulation novices will help them be aware of the issues relating to simulation visualization and that, being aware, might help them see-through some of the tricks of the trade. The cheat sheet will also give those working in the simulation development industry something to work with when designing their visualizations.

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