Proceedings of the 2015 Winter Simulation Conference
L. Yilmaz, W. K. V. Chan, I. Moon, T. M. K. Roeder, C. Macal, and M. D. Rossetti, eds.

A DISCUSSION ON SIMULATIONS' VISUALIZATION USAGE

Andrew J. Collins
D'An Knowles Ball

Virginia Modeling, Analysis and Simulation Center
Old Dominion University
Suffolk, VA 23435, USA

Julia Romberger

English Department
Old Dominion University
Norfolk, VA 23529, USA

ABSTRACT

The usage of a simulation's visualization varies enormously within our community: for some, it is the simulation; for others, it is a development annoyance used for a screen-shot in presentations before the "proper" statistical results can be shown. Real-world systems are, for the most of us, explored visually so a simulation's visualization allows us to reconnect the simulation to its underlying system through the same media we experience it. However, simulation models are not perfect representations of reality and some of these imperfections maybe left out of the simulation's visualization. At best, this might be due to parsimony concerns by the developer (e.g. the color of a simulated entities shirt usually does not matter); at worst, charlatanism to sell the simulation package. In this paper, a detailed discussion is given on the use (and potential misuse) of simulation visualization and possible solutions.

1 INTRODUCTION

The advancement of computer technology has allowed us to see the world through a different lens. Computers are capable of manipulating millions of data points in seconds which a human would take a lifetime to calculate. Humans are not only limited in their speed of calculation but also their ability to absorb and process data as such a computer output needs to be presented to the human user in a helpful way; this is especially true of modern computer simulations which can generate Giga-bytes of data per single run. The main approaches to summarizing the output data of a computer simulation are statistics and visualizations. Statistics not only summarizes the data succinctly – descriptive statistics - but it also provides a standard way of presentation to which the user can compare to previous experiences; these comparisons allow for hypotheses to be formed and tested - inferential statistics (Upton and Cook 2008). However, statistics are presented numerically or graphically which can be difficult for a non-expert to follow (Huff 1954); within a computer simulation, presenting the outputs numerically means a further abstraction of the system which has been modeled. Unlike numerical or graphical approaches, computer visualization provides a means to reconnect the simulation's output with the real-world system being modeled; hence, the propagation of the use of visualization in Modeling and Simulation (M&S).

The use of visualization in M&S to represent data can be linked to advances in computer technology. Its great value lies in its ability to show the audience statistics in visual form which is less abstract than numerical representations. It takes advantage of human capacity to conceptualize and fill-in patterns based upon visual input (Yau 2011). However, within the field of M&S there are several issues with human decision-making. In this article, one issue has been identified — the current trend toward a focus on graphics and presentation over clarity, organization, and understanding. It is argued that an interdisciplinary approach that incorporates principles of visual rhetoric can assist in addressing this problem and lead to better representations of data that more ably assist the audiences' understanding.

978-1-4673-9743-8/15/$31.00 ©2015 IEEE

In the next section , M&S Visualization is defined and its purpose is discussed. This includes a discussion on the problems relating to visualization rhetoric. This section is followed by a discussion on possible solutions to these problems and conclusions are given.

2 M&S VISUALIZATION

From casual discussions over the years, lay-people tend to believe that "computer simulations is just pixelated entities moving around on a monitor's screen. Those within the M&S community are well aware of this expectation, and their advertising material is usually littered with screen-shots from their simulation's visualization capabilities.

However, the focus of the M&S community, both developers and analysts, is not on a simulation's visualization but on the mechanics that make up the simulation, e.g., queuing theory, or the process of abstracting reality to enough detail for the problem at hand, i.e., modeling. Since visualization does not directly affect the simulation and/or its underlying model, it is seen as a secondary consideration. This secondary consideration is evident in teaching of M&S to university students; the two standard texts used for teaching M&S to Master's students have virtually no discussion on visualization and only briefly introduce animations in the context of existing simulation software packages, i.e., Banks (Banks 1998) and Law (Law 2006). Averill Law's book "Simulation, Modeling and Analysis" has over 160,000 copies in print and is on its 5th edition; the book says that animation is a desirable quality and discusses its importance in manufacturing. Jerry Bank edited the "Handbook of Simulation" which was a collection of articles from leading M&S experts; Banks (1998) mentions animation software in one section (25.3.5) and briefly mentions visualization as validation and verification technique another (10.4). Only recently have M&S textbooks begun to discuss visualization in some depth (Sokolowski and Banks 2010).

2.1 Why Do We Have Visualization?

Macal said that "Visualization offers one of the most promising means to convey information from M&S to decision makers in a meaningful way" (Macal 2001). Sokolowski and Banks (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 though other forms of representation, such as text and audio." For the purposes of this paper, this definition of M&S visualization is assumed to be correct.

The critical thing about this definition is the descriptor "otherwise more difficult to understand." The sciences, both classical and social, favor statistics over visualization because of the quantitative results it provides; however, a statistic is just a single measure of some attribute of a sample, which assumes that you know how to measure the attribute of interest. Visualization offers to a way to explore attributes that otherwise would be difficult to quantify, for example, the spread of a contagion. An example of useful visualization can be found in the foreclosure contagion effect simulation shown in Figure 1 above (Gangel, Seiler et al. 2013). The visualization shows the spread of foreclosures over a generic lattice neighborhood, which would be hard to show, and less effective, if a quantitative measure was used instead.

It is not suggested that all visualizations are useful and should replace quantitative measure. An example can found in a follow-on study to the foreclosure simulation. This study incorporated a social network in its "forenet" simulation, which is shown in Figure 2 (Seiler, Collins et al. 2013). Apart from showing the complexity of the social network, the visualization is of very little practical and/or analytic use. In this scenario, the user will probably gain more insights from using quantitative measures of the social network, i.e., average number of neighbors, average shortest path length, clustering, or maven prevalence.

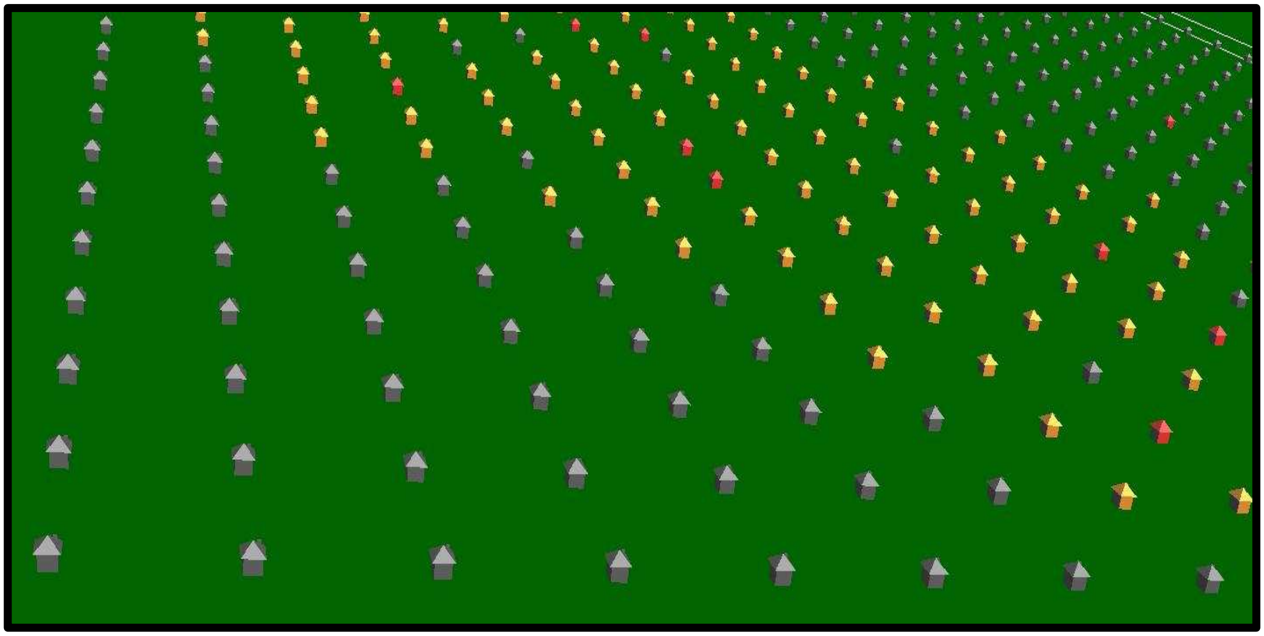

Figure 1: Screen-sheet from foreclosure simulation, showing the spread of foreclosures (red) across a lattice housing neighborhood (Gangel, Seiler et al. 2013).

2.1.1 The Role of Audience in Visualization

Kuljis, Paul and Chen (Kuljis, Paul et al. 2001) claim that any visualization representation of a simulation should be iconic "so that non-computer specialists can understand what the simulation model is trying to do;" thus a simulation of a hospital should contain iconic images of doctors, wards, etc. The non-computer specialist who is likely to be looking at simulation's output is the simulation's customer (decision-maker); these customers come from a diverse set of backgrounds, they might be: an east-coast resident watching a simulated prediction of a hurricane's progress on a television to decide if they will evacuate, a factory manager deciding on a new efficient layout for their production floor or even illiterate Sri Lankan farmers (Collins, Vegesana et al. 2013); thus a simulation visualization should be "enabling the participants to observe and to understand the implications of their decisions" (Kuljis, Paul et al. 2001).

The benefits of a simulation's visualization are not limited to enabling non-specialists to understand the simulation. A simulation visualization might highlight salient patterns that where otherwise unnoticeable to users through statistical means especially if those patterns are non-linear in nature. Thus Kuljis, Paul and Chen (Kuljis, Paul et al. 2001) define the goal of visualization to seek insights from patterns that can be identified from visual representations; their article is one of the few in a major M&S journal looking at the purpose of simulation visualization, as opposed to technical advances, and has been rarely cited since; this lack of citation indicates the lack of interest by the M&S community in the purpose of visualization. Other examples of similar work include Chen (Chen 2000) and Kuljis (Kuljis 1994).

2.1.2 How Clarity, Organization and Understanding Have Become Secondary to the Way Data is Presented

Visualization's role in the simulation process has increased as these visualizations have beefed up on realism, integration, and accessibility. There is no debate that what was previously a luxury to simulation is now expected and the norm. With the modern expectation of visualization's inclusion, some have turned a critical eye towards visualization's influence on the design and output of a given simulation. What role does it play? While great efforts have been placed on researching visualization's role in application, very little emphasis has been placed on analyzing and developing guidelines for the design of simulation visualizations (Healey, Booth et al. 1995). The use of visualization as a medium allows users to evaluate the structures and practices at play as dictated by the medium rather than by the content. Do our current visualizations amplify certain aspects while downplaying others in any given simulation? (McLuhan 1994) Clarity and understanding permeate mainly from the organization of data within the visual framework – its form.

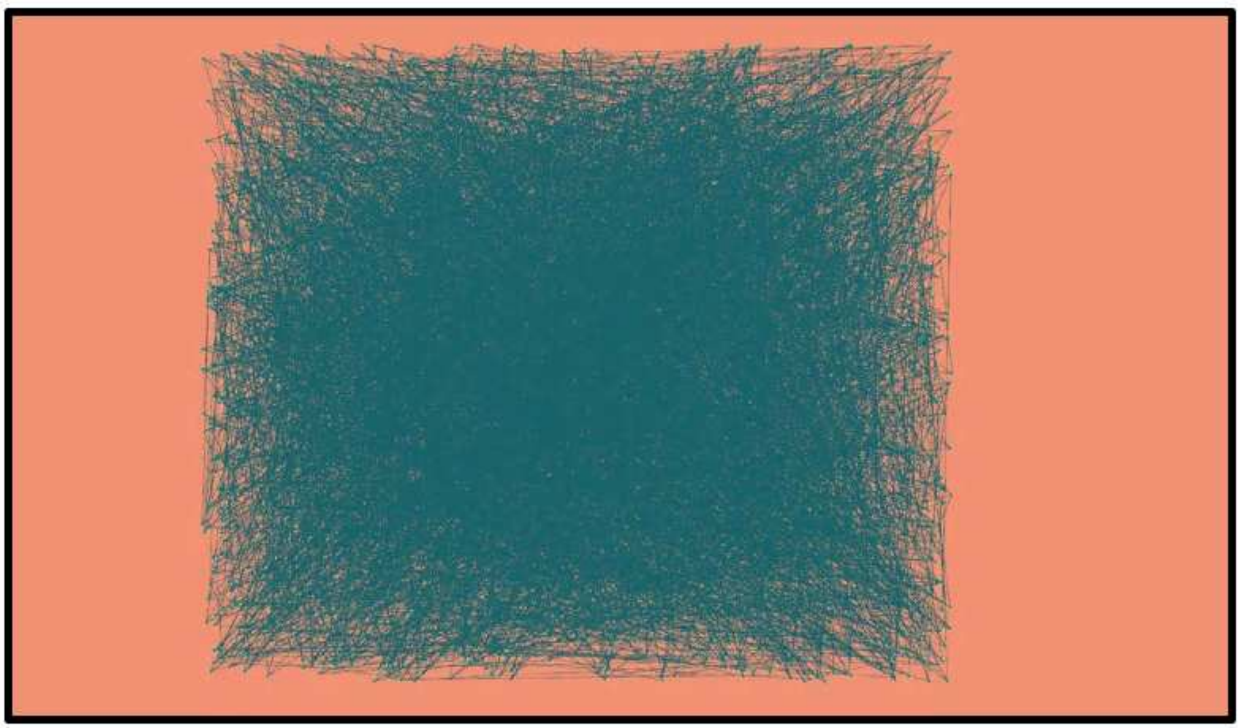

Figure 2: Visualization of the social network used in the “Forenet” simulation show an example of unhelpful visualization (Seiler, Collins et al. 2013).

The perceived usefulness of a simulation’s visualization – its function – can be deemed successful based upon the visualization’s resolution alone. Form is of utmost importance to any design. Humans are visual creatures by nature, and our incessant visual encoding and decoding is impacted by cultural narrative devices present in our visual world. The viewer/user of visual media is adept at filling in narrative story lines when viewing a graphic representation. Narrative production plays on our very basic social and cognitive desires for meaning formation. In simulation visualizations, it is found that connotative or denotative effects caused by aesthetic decisions similar to those used in ad campaigns that lead a viewer/user to associate a mass-produced product with valued emotions and authenticity. It is within these narrative appeals that designers of visualizations manipulate expectations for the user. Biases come about when these narratives are created for an end-user with certain expectations. The creator and the customer must be conscious of them.

2.1.3 Roman – “Garbage In, Hollywood Out”

When starting an M&S project, M&S developers are well-aware that an end product must be produced; thus, they consider the visualization limitation early on in the M&S development cycle. This consideration might be due to an honest desire to only display results that can be accurately presented; however, there is a potentially darker side to this intent. Ultimately, a simulation has to be sold to a decision-maker, the customer; this decision-maker will usually make that decision based on what they literally see: the visualization. Therefore, focus on "selling" the simulation to the decision-maker can be the driving force behind the visualization as opposed to accurately displaying the simulation's results. In an extreme case, the sole focus of the M&S development could be on selling the simulation, or making up for its short-comings, through its visualization with little or no thought in creating an accurate, or even useful, underlying model. This problem led Paul Roman to coin the phase "Garbage In, Hollywood Out " (Roman 2005). The derogatory usage of the word "Hollywood" is not accepted by all in the M&S community; Swartout and Lindheim (Swartout and Lindheim 2000) argue that M&S developers should embrace the methods used by the Hollywood film industry by trying to suspend the audience's disbelief when creating apparent reality as opposed to trying to replicate reality.

2.2 How Audience Expectations Contribute to the Issue.

Laypersons see the impressive graphics in cheap computer games and thus have an expectation that a computer simulation will have the same level of graphics. This expectation has led some simulation developers to focus on the producing fancy graphics for their simulations. The ease of producing these fancy graphics and the instinct to make visualization aesthetically pleasing has led to the rise of "chart junk." Chart Junk are visualizations that are pretty but are difficult to understand, at best, or misleading, at worst (Tufte 2001). Examples can be found in David McCandless' popular non-fiction book "The Visual Miscellaneum" (McCandless 2009). Some, like the perceptual cognitive-based school of thought, believe that graphs and graphics should be as simple as possible but their work looks dated and passé (Kostelnick 2008) and risks being rejected by the expectations of laypersons. The issue of rejection by audience, when determining the best ways to visualize, demonstrates how making decisions regarding the "whys" of visualization is a non-trivial task.

The majority of individuals outside the M&S community will only see the simulation's visualizations that are created. It is these visualizations that are presented to customers, subject matter experts, and stakeholders when a simulation results and outputs are evaluated and validated. Now try and imagine some standard simulation, let's pick on a classic: a simulation of a fast-food restaurant . In the nineties, this fast food simulation visualization would consist of blobs to represent the customers and squares to represent the cashiers and counters. A modern 3-D simulation visualization will show a human customer walk up to the cashier, even though they have no legs represented within the actual mathematical simulation model; talk to a female cashier, even though gender and conversation are not explicitly modeled in the actual simulation; hand over cash and receive their food, even though these objects are not modeled either. Some might argue that this extra visual "fluff" helps the viewer understand the purposes and intent of the simulation but there are consequences to it.

3 POSSIBLE SOLUTIONS

Individuals, who have direct involvement with M&S, can be categorized as either a 'user / customers / decision-makers' or a 'developer'. This is not a disjoint split of individuals as some will be both categories. Categorizing into these groupings is a useful tool for thinking about who is concerned with or affected by the various issues relating to M&S. For example, the users' focus will be the fields that use M&S, while the developers' focus will be on M&S itself. Not all users will be developers and even though they might be subject domain experts, they might not know the limitations of M&S and, more importantly, they will likely only see the visual outputs of the simulation. Thus the novice user might believe that the answers they are given are correct. It is important to bear in mind the different types of individuals that are involved with M&S when considering solutions to overcome the problems relating to M&S visualization rhetoric.

3.1 Through Verification and Validation

Paul Roman says "the primary defense against undue influence by impressive looking outputs is validation and verification" (Roman 2005). The problem with using Validation and Verification (V&V) to counter the effects of poorly designed visual rhetoric is that it requires that you understand the mechanics of the underlying simulation which can take time, usually a lot more time than is available at a M&S trade show when a decision-maker is wandering the isle looking for a new product. V&V can also be a very subjective process, especially when dealing with human factor modeling, and as such can be subjected to poor rhetorical choice in its own right.

3.2 Standard Visualizations

Kuljis et al. (Kuljis, Paul et al. 2001) believe that the future will hold further integration of visualization within simulation. They believe that there should be standard simulation visualizations for the most common problem domains, e.g., superstore layouts, transportation networks, etc. This standardization would include the use of color through our cultural conditions to, say, red, etc. We do not hold with this view because visualization should be fit for purpose. As an example of fitness for purpose, consider Figure 3, which shows two images of Mount Everest; if the purpose of the image user was to draw the mountain, then the bottom picture would be appropriate; if the purpose of the image user was to plan a route to climb to the summit, then the top image is likely to be appropriate one.

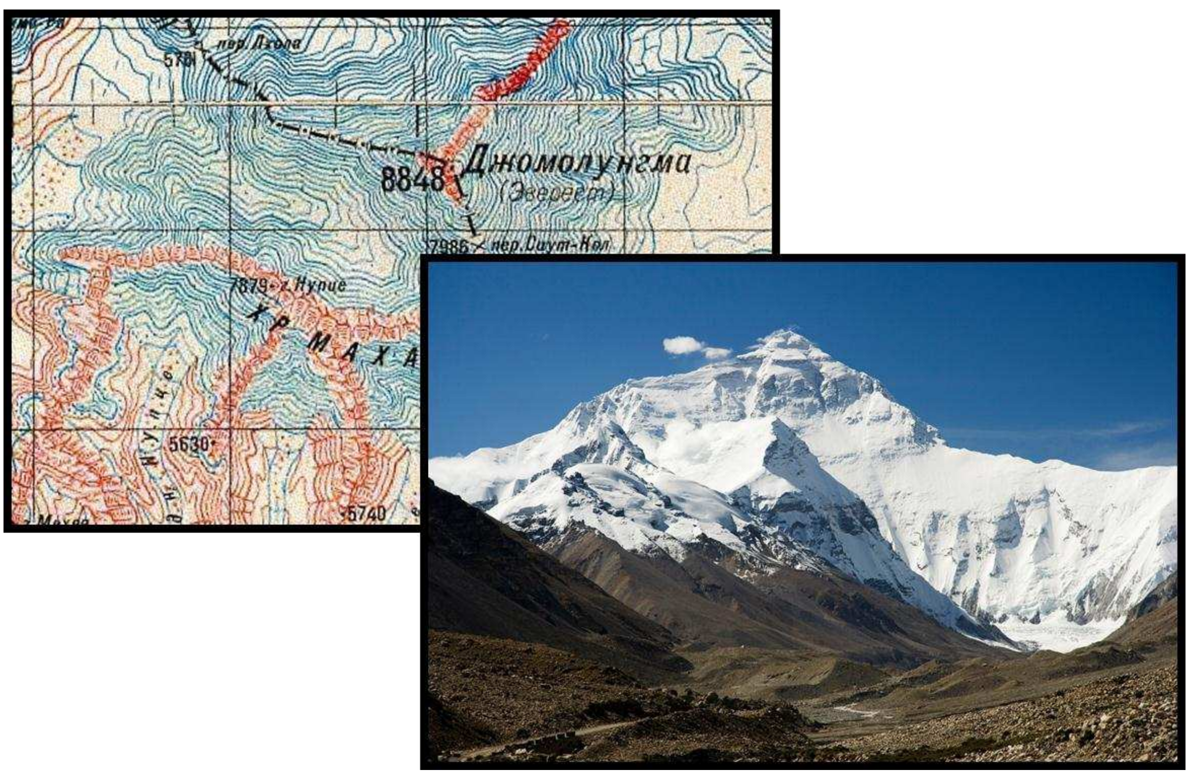

Figure 3: Two visual depictions of Mount Everest.

3.3 Education

So how do you visually formulate models, keeping real-world human perception in mind, to bring attention to and improve the role of rhetorical considerations in visualizations? One approach to develop a cheat-sheet of simulation visualization, which has been discussed in Collins et al. (2015). By providing developers and users with an education tool about visualization rhetoric and its considerations may help them overcome some of the issues that have been discussed here.

One result from Fishwick's case studies was a common response stating "sometimes you may get too off-track and lose the main meaning of a model in the visual complexity [of the] representation" highlighting the disparity between the data set and the visual representation of it (Fishwick, Davis et al. 2005). As Healey and his team point out, visualization is a multidisciplinary study and practice, but most research into visualization has focused on the application side with "relatively few efforts" to formulate "general guidelines for the design of visualization tools" (Healey, Booth et al. 1995). Such guidelines will help decision makers and end-users understand and evaluate how the designer's agenda has made its way into the visualization. Work on this "cheat sheet" has begun with the development of a prototype sheet (Collins, Knowles Ball et al. 2015); the next stage is to conduct survey analysis on the effectiveness of this cheat sheet.

4 CONCLUSION

This paper provides a brief discussion on visual rhetoric issue that relate to Modeling and Simulation visualizations. The advances that have been made within computer visualization over the last thirty years are staggering – from blocks moving on a screen to graphics that are almost indistinguishable from the real world. These advances have brought with them higher expectation by users of simulations. Users equate more advanced graphics with more advanced underlying simulation engines and, as such, some simulation developers have pandered to the requirement by focusing on the simulation's visualization over its mechanics. The "whys" of visualization as opposes to "hows" have been discussed. In doing so, several possible solutions were discussed, for a user, to dealing with misleading visualizations. It has been advocated that for the production of a communication lexicon for M&S developers and an increase in research in visual rhetoric in M&S visualizations, but, most importantly, the deception value of visualizations currently occurring in the M&S community must be brought to light.

REFERENCES

Banks, J. 1998. *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. New York: Wiley.

Chen, C. 2000. *Visualising information: A mosaic of perspectives. Advances in Visual Information Systems*. R. Laurini. Lyon, France: Springer.

Collins, A. J., D. Knowles Ball and J. Romberger. 2015. *Simulation Visualization Issues for Users and Customers.* 2015 Spring Simulation Multi-Conference, Alexandria, VA.

Collins, A. J., K. B. Vegesana, M. J. Seiler, P. O'Shea, P. Hettiarachchi and F. McKenzie. 2013. "Simulation and mathematical programming decision-making support for smallholder farming." *Environment Systems and Decisions* 33(3): 427-439.

Fishwick, P., T. Davis and J. Douglas. 2005. "Model representation with aesthetic computing: Method and empirical study." *ACM Trans. Model. Comput. Simul.* 15(3): 254-279.

Gangel, M., M. J. Seiler and A. J. Collins. 2013. "Exploring the foreclosure contagion effect using agent-based modeling." *Journal of Real Estate Finance and Economics* 46(2): 339-354.

Healey, C. G., K. S. Booth and J. T. Enns. 1995. "Visualizing real-time multivariate data using preattentive processing." *ACM Trans. Model. Comput. Simul.* 5(3): 190-221.

Huff, D. 1954. *How to Lie with Statistics*. New York: W. W. Norton & Company.

Kostelnick, C. 2008. "The Visual Rhetoric of Data Displays: The Conundrum of Clarity." *Professional Communication, IEEE Transactions on* 51(1): 116-130.

Kuljis, J. 1994. "User interfaces and discrete event simulation models." *Simulation Practice and Theory* 1(5): 207-221.

Kuljis, J., R. J. Paul and C. Chaomei. 2001. "Visualization and Simulation: Two Sides of the Same Coin?" *SIMULATION* 77(3-4): 141-152.

Law, A. 2006. *Simulation Modeling and Analysis*, McGraw-Hill Science/Engineering/Math.
Macal, C. M. 2001. "Simulation and Visualization." *SIMULATION* 77(3-4): 90-92.
McCandless, D. 2009. *The Visual Miscellaneum: A Colorful Guide to the World's Most Consequential Trivia*, Harper Design.
McLuhan, M. 1994. *Understanding media: The extensions of man*, Boston, MA: MIT press.
Roman, P. A. 2005. "Garbage in, Hollywood out!" *SimTecT 2005.* Sydney, Australia.
Seiler, M., A. J. Collins and N. H. Fefferman. 2013. "Strategic Mortgage Default in the Context of a Social Network: An Epidemiological Approach." *Journal of Real Estate Research* 35(4): 445-475.
Sokolowski, J. A. and C. M. Banks. 2010. *Modeling and Simulation Fundamentals: Theoretical Underpinnings and Practical Domains*. Hoboken, NJ: Wiley.
Swartout, W. R. and R. Lindheim. 2000. "Does simulation need a reality check?" *Summer Computer Simulation Conference*, Society for Computer Simulation International.
Tufte, E. R. 2001. *The Visual Display of Quantitative Information.* Cheshire, CT: Graphics Press.
Upton, G. and I. Cook. 2008. *A Dictionary of Statistics.* Oxford: Oxford University Press.
Yau, N. 2011. *Visualize This: The FlowingData Guide to Design, Visualization, and Statistics.* Indianapolis: Wiley.

AUTHOR BIOGRAPHIES

ANDREW J. COLLINS is a research assistant professor at the Virginia Modeling, Analysis and Simulation Center (VMASC) at Old Dominion University. He holds a Ph.D. (2009) and an MSc (2001) from the University of Southampton in Operations Research, and a bachelor's degree in Mathematics from the University of Oxford. Dr. Collins current research focus is Agent-based Modeling and Simulation and he is the principle analyst on an award winning investigation which applies agent-based modeling to the foreclosure crisis. Dr. Collins research interest include investigating the practical problem of applying simulation to the real-world. He has spent the last 10 years, while conducting his Ph.D. and as an analyst for the UK's Ministry of Defen[s]e, applying game theory to variety of practical operations research problems. His email and web address is ajcollin@odu.edu and http://www.vmasc.odu.edu/collins.html.

D'AN KNOWLES BALL is a faculty member of Old Dominion University's Art Department, instructing students in art criticism, art theory and digital design. She is also the Marketing and Communications Manager at the Virginia Modeling, Analysis and Simulation Center (Suffolk, VA). With a B.F.A. in Graphic Design from Appalachian State University (Boone, NC) as well as an M.A. in Humanities from Old Dominion University (Norfolk, VA), she has worked professionally in the design and commu-nications industry for well over a decade. Ms. Ball is a Humanities scholar with a focus on visual rhetoric and new media communications. After completing a thesis entitled *Duchampian Authenticity and The Readymade Consumer*, her current research interests include visual rhetoric and visualization, mass communication recomposition and deconstruction, as well as the analysis of visual representations of wit. Her e-mail addresses is tknowles@odu.edu.

JULIA ROMBERGER graduated from Purdue University with a PhD in English with a focus on Rhetoric and Composition. She is currently an Associate Professor at Old Dominion University where she runs the English Department Instructional Computer Lab and serves as coordinator of the Professional Writing Program. She has presented at numerous conferences in the field of rhetoric and writing studies. Her publications include a book chapter on rhetorical memory (*memoria)* and the use of multiple modes of evidence in digital composition, a chapter on ethics and interface design, 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 and interface design. Her email and web addresses are jromberg@odu.edu and http://www.odu.edu/directory/people/j/jromberg.