Concept Paper: An Analytical and Computational Perspective on the Role of Cultural Competency in Disaster Management

Prepared by Paolo Gaudiano
Icosystem Corporation

Purpose: To provide input to the National Project Advisory Committee (NPAC), for the design and definition of curriculum modules on culturally competent care for disaster preparedness and crisis response based on the corresponding subset of National Standards for Culturally and Linguistically Appropriate Services in Health Care (CLAS) standards.

This was a commissioned "concept paper" for the November 2007 Consensus Building Meeting for the Cultural Competence for Disaster Preparedness and Crisis Response (CCDPCR) project. Funding for the paper and the CCDPCR project was provided by the Office of Minority Health, Office of Public Health and Sciences, U.S. Department of Health and Human Services.

Introduction

Recent disasters in the U.S. have highlighted the disparities that still exist in the quality of care available to different segments of the population. There is evidence that minorities suffer disproportionately at every stage of a disaster or emergency event. The Office of Minority Health (OMH) is taking steps to reduce these disparities and improve the quality of care available to minorities before, during, and after emergencies and disasters.

As a first step, in the year 2000 OMH launched the National Standards for Culturally and Linguistically Appropriate Services (CLAS) in Healthcare. The CLAS Standards consist of 14 guidelines and recommendations "to inform, guide, and facilitate implementation of culturally and linguistically appropriate services in health care." In order to foster widespread adoption of CLAS principles, OMH has developed a portfolio of cultural competency training programs tailored for physicians and nurses. More recently, OMH has launched a new initiative to develop a cultural competency curriculum for disaster preparedness and emergency response. This curriculum complements OMH's current offerings for physicians and nurses, by targeting public health service personnel, mental health and social workers, disaster relief organization employees, and emergency medical personnel. According to OMH, the goal of this expanded cultural competency curriculum is "to assist disaster preparedness and crisis response personnel in developing the knowledge, attitudes, and skills related to cultural competency education and to help mitigate racial and ethnic disparities in disaster preparedness and crisis response."

As part of its new initiative, with the assistance of SRA International, OMH has solicited feedback and opinions from practicing first responders and disaster relief personnel about cultural competency training programs. In particular, SRA International has commissioned articles from domain experts to discuss these issues from three different perspectives: health care providers (Scott, 2007), mental health workers (Hunt, 2007), and emergency medical personnel (Jones, 2007).

This paper aims to complement these perspectives by taking a systems-level view. Central to the paper is the proposition that there exist computational and analytical methodologies that can leverage expertise from a variety of domains to provide decision makers with tools to test scenarios, design interventions, and generally support their decision-making processes. This computational methodology provides a framework for integration of data and information from multiple sources, and it can support the creation of training programs and curricula for first responders.

The paper begins with a discussion of *complex systems* and how disaster management can be viewed as a complex system. Next we describe a technology known as *agent-based simulation*, which is ideally suited for the analysis of complex systems. The paper includes a summary of prior work in the literature, including work in the social sciences, health care, military, and other relevant fields. The paper also provides a broad outline of how agent-based simulation can be used as a way of integrating information from the three domains of expertise. Finally, the paper concludes with recommendations for how a simulation platform could be used to enhance a training curriculum for first responders.

The Complexity of Disaster Management in Multi-Cultural Environments

The papers by Scott (2007), Hunt (2007) and Jones (2007) provide complementary and consistent views on some of the key problems that affect disaster management, and how cultural competency is important when dealing with individuals who may require special attention as a result of cultural or other differences.

Understanding the impact of different initiatives is difficult because of the complexity of the real-world situations surrounding disasters and emergencies. We suggest that one useful way to examine issues around cultural competency is to analyze disaster and emergency response situations in the context of complex systems. We define a complex system as a system composed of a large number of elements that interact with each other and with their environment, such that the behavior of the system as a whole emerges as a result of the actions of the system's elements and their interactions with one another.

The best way to clarify the concept of Complex Systems is to provide some examples. A sports team is one type of complex system: just knowing how well each player on the team does, is not sufficient to predict how the team as a whole will do. Put differently, if a team is not performing well, it is not usually possible simply to replace one "bad" player with a better one. A financial market is another example of a complex system: the price of a single stock depends in a very complex way on many factors, including the interplay between investors, the performance of the company, and economic factors. Traffic (automotive) is yet another example of a complex system: a traffic jam cannot be attributed to a specific individual; rather, it is the action of individual drivers coupled with the interactions between drivers that cause the traffic jam. By comparison, an aircraft is not a complex system: if something goes wrong it is usually

possible to isolate an individual component, and fix the airplane by replacing the faulty component. It may be complicated, but it does not follow our definition of complex.

Analyzing or controlling a complex system cannot be done with traditional methods for several reasons that we now outline. First, when a system is complex, it is not possible simply to analyze each element's behavior in order to deduce the behavior of the system as a whole. For example, asking a baseball player how he is swinging his bat will not be useful in understanding how the team as a whole is performing. Second, the emergent behavior of a system typically cannot be deduced by knowing what each element is doing and how it interacts with other elements. For instance, if you ask drivers at rush hour what rules they are following, they may say things like how fast they drive, how closely they follow other drivers, or how often they switch lanes. But nobody will say "my rule is to cause a traffic jam on the highway." Third, by a similar token, in a complex system it is extremely difficult to determine how to change the rules of behaviors and interactions of individual elements to achieve a certain system-level behavior. If this were possible, teams would never lose, markets would never crash, and traffic would never slow down. Fourth, many complex systems exhibit tipping points, that is, situations in which even a small change in conditions can lead to a sudden, large change in the state of the system. Tipping points are the result of nonlinearities that arise from the interactions among the elements of the system, and between the elements of the system and its environment. A traffic jam is an example of a tipping point: as the number of cars on the highway starts to increase, the traffic at first may continue to flow at a normal speed, and then suddenly a jam will occur either because there are too many cars (interactions among elements), or because something may happen, such as a construction

site or an accident (interactions between the elements and the environment). A market crash and a stampede are other examples of spectacular tipping points. The fifth and final point we want to make about complex systems is that sometimes even a slight change in the way elements behave or interact can have dramatic, unpredictable effects on the behavior of the system as a whole.

A Simple Complex System: The Aggressor-Defender Game

To illustrate the points we just made about complex system, we have developed a simple game. This game can be played easily by any group of people in a room – there should be at least eight to ten people, and there can be as may as several hundred. With everyone standing around the room, the moderator asks everyone to choose two other people in the crowd (without telling them): one is the aggressor, the other is the defender. When the moderator says "go," each person has to move around the room in such a way as to keep the defender between himself and the aggressor. This rule set is illustrated in the top left side of Figure 1, with the arrow indicating the direction in which the player should move.

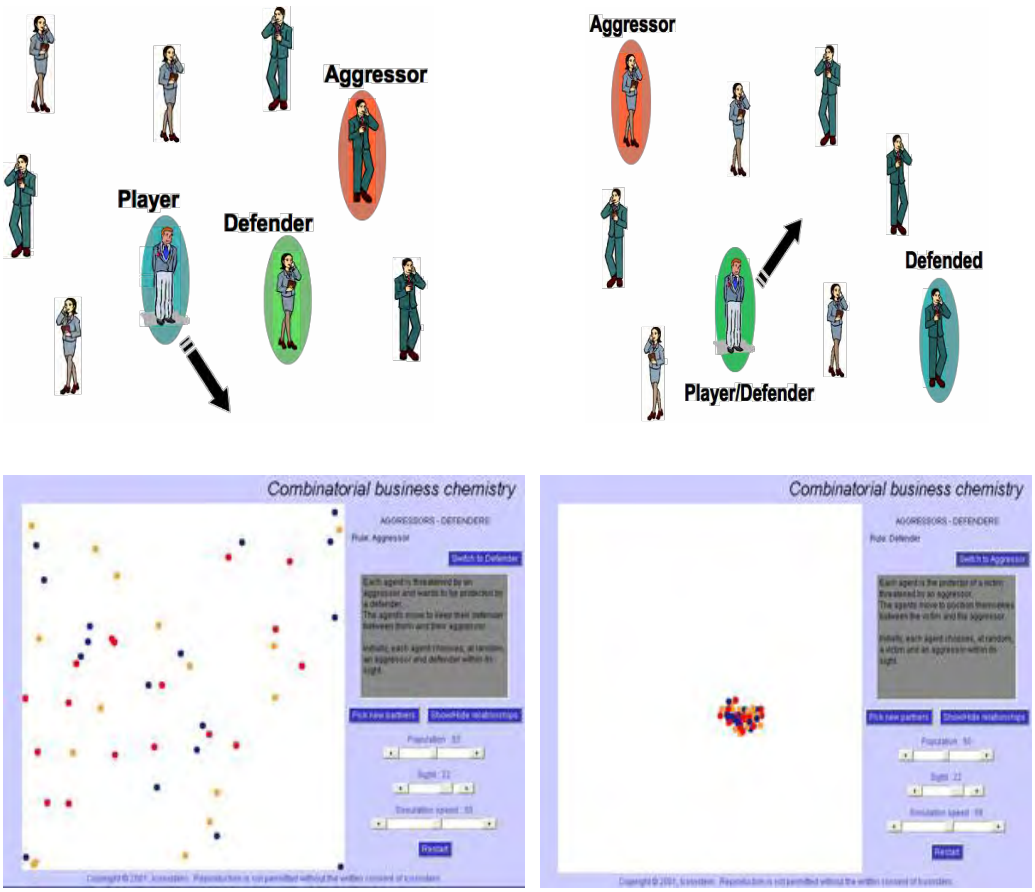

Figure 1: The Icosystem aggressor-defender game

The bottom left image of Figure 1 shows a computer simulation of this game[1], illustrating the outcome of playing with these rules: people move around the room somewhat randomly, sometimes moving around like galaxies, but with no clear pattern.

The moderator then stops the participants and asks them to play by a slightly different set of rules. Once again each player selects two other people in the room. However, this time the player has the role of the defender. One of the selected people is the aggressor;

[1] The computer simulation of the Icosystem game can be found on our web site, http://www.icosystem.com/game_launch.htm, and it should be playable through any standard web browser.

the other person has to be defended by the player. The top right part of Figure1 illustrates the new set of rules, and the direction in which they should move when the game starts.

When the moderator says “go,” the entire room will quickly collapse into a tight cluster of people, as illustrated by the screenshot in the lower right panel of Figure 1. We have played this game with players ranging from a Cub Scout troop to a room full of executives, and it always works.

There are several points to be made about this simple game. First of all, in spite of its simplicity, it exhibits the hallmarks of complex systems as outlined above: clearly, if you ask people in the room what they are doing, they will not tell you “we are trying to form a cluster;” second, even by knowing the rules of the game, predicting how the system as a whole (the crowd in this example) will behave is not obvious; third, a simple change in rules can lead to a dramatic change in the system’s emergent behavior.

The purpose of this game is to make people pause and think about the potential impact of decisions they may make in trying to manage their own complex, real-world systems. A company CEO may try to improve the bottom line by changing the behavior of its employees or its customers; a baseball manager may change the training routine of his players to win more games; a government organization may instate different rules to handle emergency response. Without an understanding of how low-level rules influence the system’s emergent behavior, the outcomes can be unpredictable at best, and sometimes altogether undesirable.

By now the relevance of complex systems to emergency and disaster response should be evident. In this case the “system” includes many types of elements: the people affected by the disaster, first responders of various types, social organizations, friends and

families, equipment, infrastructure, suppliers, and so on. The environment also includes many factors: the nature of the disaster (such as fire, flood, earthquake), the landscape, and the weather, among others.

Any initiative that manipulates the behavior of "elements" of the system needs may lead to unintended consequences. For instance, all three of the papers commissioned by SRA International for the OMH consensus building meeting (Hunt, 2007; Jones, 2007; Scott, 2007) suggest teaming up with local organizations to facilitate cultural competence. However, the nature of the organization being targeted (church, social club, neighborhood groups), the nature of the intervention they affect (dissemination of preparatory materials, training classes, on-site response, translation services) and the way in which each organization interacts with its community (meetings, email, surface mail, phone calls, door-to-door visits) all have different impacts on the outcome of any situation. Furthermore, the same set of activities implemented by the same organization in the same community will have different outcomes depending on environmental and other factors: door-to-door visits may not be possible during a fire or in inclement weather; e-mail and telephone may not be available after earthquakes or flooding.

The paper by Jones (2007) summarizes eloquently one aspect of the "unintended consequences" that can result even from well-intentioned activities: Jones (2007) summarizes data suggesting that cultural competency training does not always have a positive outcome, eloquently stating that sometimes "overly simplistic approaches to cultural competence can do more harm than good" (p. 19).

We hope that the material in this section has made clear the following point: while it is clear that most activities that improve cultural competency can have beneficial effects,

making a sound judgment about the impact of any cultural activity promoted by OMH is extremely difficult, and it requires an understanding of the complexity of the system within which disaster and emergency response are taking place.

The field of complexity science is devoted to the study of complex systems, and we believe the knowledge accumulated in this field can be brought to bear in the context of emergency and disaster response and the role of cultural competency. In the next section we describe *agent-based modeling* (ABM), also sometimes known as *agent-based simulation* (ABS). ABM is a technology borne out of the study of complex systems, which we think could be applied beneficially to many of the problems being tackled by OMH.

Agent-Based Modeling: An Introduction

Agent-based modeling (ABM) is a technique that uses computer software to simulate the behavior of a complex system from the bottom up (Axelrod, 1997; Bonabeau, 2002; Epstein and Axtell, 1996). In a nutshell, an ABM captures in software all the relevant elements of a system or process from the bottom-up. Each software *agent* represents an entity in the system being simulated, including its main characteristics, its behaviors, and its responses to external factors. In most cases, an ABM includes multiple types of agents, representing all the relevant entities. Agents can include people (civilians, emergency personnel, health care professionals), companies and organizations (churches, social clubs, government agencies), and other types of entities whose behavior can change during the course of a simulation (the media, elements of the infrastructure, equipment). Note that the nature and level of detail of agents can be quite heterogeneous: while some agents represent individual people, other agents can represent an entire

organization, or a piece of equipment. Certain aspects of the environment can also be treated as agents, for instance the weather.

The ABM simulates how all these elements and factors vary over time. An internal "clock" cycles through the simulation. At each time step, various events can take place. For instance, during a simulated emergency, civilians may hide, flee, go to a local shelter, go to a store, or exhibit other relevant behaviors. Simulated emergency personnel with different skills and competencies can arrive at the scene and perform a variety of activities. Different agent types may interact; for instance an EMS may interact with an injured civilian, a government agency may send some information to local organizations, and a relief organization may send personnel and supplies to the scene. As the simulation unfolds, all the agents behave and interact. At the conclusion of the simulation period the ABM can show the final results, while keeping track of everything that happened during the simulation for deeper analysis.

ABMs include a certain degree of stochasticity, or randomness. For instance, given a disaster scenario, a given agent decides to go to a shelter during one simulation, or stay home during another simulation. Typically the ABM captures probability distributions to determine how likely a given behavior might be, but, just as in the real world, the specific behavior of a given agent may vary. Hence, even when all initial conditions and external factors are identical, it is possible to get different outcomes. For this reason, usually each simulation is run multiple times to gain an understanding of the robustness of any given outcome.

More importantly, the ABM makes it possible to see how the behavior of the system changes under different scenarios. A scenario may be defined in terms of the initial

conditions (e.g., simulate an urban rather than rural environment), the agent characteristics (e.g., make the seniors less likely to seek government assistance), or aspects of the overall policies and strategies (e.g., allocate more money to personnel training). By running multiple simulations under each scenario, it is possible to understand how each factor influences the outcome, and how sensitive the overall system behavior might be to each of these factors.

ABMs have been used successfully to simulate a wide variety of business, technology and social systems. Several publications in particular describe ABM applications in the social sciences (Epstein, 2007; Epstein and Axtell, 1996; Gilbert & Terna, 2000; Gilbert & Troitzsch, 2005).

We are not aware of any projects that focus specifically on cultural competency. However, several researchers have proposed to apply ABM to a variety of problems related to disaster response. Several examples are cited in the next section.

How ABM Can Help OMH

How can agent-based simulation be applied to the problem of cultural competency, and more specifically to the impact of cultural competency on the effectiveness of disaster and emergency response? We believe that ABM can be beneficial in three ways:

1. Play out different scenarios and test different strategies
2. Understand and evaluate tradeoffs, including long-term costs due to health issues
3. Train personnel for emergency and disaster response

In this section we provide brief overviews of each of these application areas, and discuss how OMH might benefit from the adoption of ABM.

A Scenario-Testing ABM Tool

Several researchers have used ABMs as a scenario-testing tool to aid decision making in a variety of settings. In the context of the OMH's cultural competency initiatives, an ABM could be used to simulate a variety of disaster scenarios. Scenarios could vary for example:

- The nature, duration and extent of the disaster or emergency;
- The presence and location of victims of different cultures;
- The quantity and characteristics of available personnel and resources;
- The training level and cultural competency of first responders.

A simulation tool could enable decision makers to test many different situations, and use that information to improve available resources, to provide superior training, or to support and promote the need for increased cultural competency. Several papers have been published on a variety of aspects of disaster response, including evacuation (Helbing, Farkas and Vicsek, 2000; Pan *et al.*, 2006), and emergency rescue (Bellamine-Ben Saoud *et al.*, 2006; Marecki, Schurr and Tambe, 2005).

Relative to the OMH curriculum an the papers commissioned by SRA, an ABM could simulate the impact of recruiting the help of various types of organizations before, during and after disaster. An ABM could also be used to understand the impact of specific training curricula and the impact that they will have on the efficiency and effectiveness of disaster response activities.

Evaluating Costs and Trade-Offs

Because the ABM can capture a variety of factors and scenarios, it is possible to use the ABM as a way of evaluating the relative merit or cost-effectiveness of different

approaches to cultural competency. For instance, the cost of training emergency personnel can be compared to the benefits that result from the increased cultural competency.

In some cases, a direct comparison or trade-off may be possible, *e.g.*, it may be possible to compare the cost of training with the reduce cost (short-term or long-term) of health care for victims. In other cases, the cost of training can be shown to have a direct impact on factors that do not have monetary value, but that are nonetheless extremely valuable. This might include saving lives, reducing the spread of disease, improving the quality of life of victims, or accelerating return to normalcy.

In some cases it is also possible to combine an ABM with an optimization module. The optimization module is provided with an objective function, such as minimizing cost, maximizing speed of responses, and so on. The optimization module can then be used to find the best possible trade-offs to achieve a certain set of goals.

For example, Narzisi *et al.* (2006) use an evolutionary computing algorithm to perform multi-criterion optimization to tune the parameters of an ABM for emergency response planning. In a nutshell, these authors show that emergency response is the type of problem that includes multiple constraints that may be counter posed to one another: minimize the number of casualties, fatalities, disease and discomfort, while maximizing survivability, resource utilization and economic factors. Narzisi *et al.* show, in a simplified situation, how the combination of ABM and evolutionary computing can help policymakers make effective trade-offs among a number of constraints.

The ability to quantify trade-offs of this type can be extremely useful for OMH. For one thing, OMH could use such a tool internally to assess the relative merit of various

proposed programs and interventions. Additionally, OMH could use an ABM externally to garner support for its activities, to justify budgets, and to facilitate the task of explaining the objectives of some of its programs and initiatives.

ABM for Personnel Training

ABMs can also be used specifically to assist with personnel training. ABMs have been used for training in many different settings. In the context of disaster response, an interesting example is the work of Schurr *et al.* (2006), which describes the use of an ABM to assist the Los Angeles Fire Department with personnel training.

The OMH could use an ABM to train emergency response personnel as part of its proposed cultural competency curriculum. An agent-based simulation could be coupled with an immersive, 3-D environment simulation to allow trainees literally to "walk through a disaster scenario." Some of the virtual people encountered during the simulation could actually be controlled by real people, including other trainees or instructors. However, the majority of the virtual people could be software agents whose characteristics and behaviors replicate those of civilians from a variety of economic and social levels.

An immersive, 3D simulator would offer several benefits. First, trainees could be exposed to a variety of scenarios, making it possible to acquire a significantly more rounded training than is possible with traditional didactic materials. Second, as discussed by Jones (2006), multi-sensory learning can be significantly more effective than simply reading materials or listening to a lecture. Third, the simulation tool could be adapted to meet the needs of different classes of responders. Fourth, a simulation tool can also reduce the cost of training by providing hours of self-guided training. Finally, the

electronic nature of this type of training affords a greater degree of flexibility in terms of scheduling than more traditional course-style training programs.

Implementing ABMs for Disaster Response

If OMH considers developing an ABM as an aid in its cultural competency initiatives, there are several available options. The three primary possibilities are:

1. Hire a company to implement an ABM
2. Work with an academic research group
3. Develop an ABM in-house

Each of these approaches has pros and cons. In the rest of these section we summarize each approach, and then provide some general advice. Because our own expertise is in the first of these approaches (work with a company), we are able to provide significantly more detail on working with a company than on the other two options. Nonetheless, we hope that the information in this section will be useful regardless of the specific approach selected.

Hire a Company to Implement an ABM

One possibility is to identify a company, such as Icosystem, who can develop a customized ABM that matches OMH's needs and objectives. The amount of time, the cost of deployment, the quality and the success of the project can vary significantly from company to company. The most important factor is the clarity of the objectives. Another critical factor is to have at least one knowledgeable, responsible individual who can participate actively in the development project. The reason for this requirement is that creating an ABM requires a combination of two skills: deep domain expertise of the system being modeled and deep expertise in the design and analysis of computer

simulations. It is extremely rare for a single group, company, or an individual to possess both of these skills. A successful ABM development project is one in which the domain expert and the modeler work hand-in-hand toward the implementation.

Definition

- Refine Problem – Define all details to ensure project success
- Gather Data – Get available, relevant data; scrub data

Simulation

- Abstract/Simplify – Key elements, core tenets
- ID Agent Types – what do agents do, behave and interact
- Parameterize – Parameter ranges, default values, interactions
- Develop Code - Implement model (java, etc.)
- Calibrate & Validate – Compare to real world, sanity check

Analysis

- Analyze Base – Address original question(s)
- Scenarios What-Ifs – Test new situations, new ideas
- Optimize – Identify robust strategies

Figure 2: Typical development process for ABM implementation

While we cannot speak for other companies, we outline here the process that Icosystem would follow to implement and ABM tool. Our development process, which is depicted in Figure 2, has been honed over dozens of ABM development projects with large corporations and government agencies. We suspect that any company developing an ABM would follow a similar process.

Our projects typically begin with a two-day *kickoff meeting* attended by Icosystem team members and client members. The goals of the kickoff are: (1) for Icosystem to gain sufficient understanding of the problem, the available data, and the client objectives; (2) for the client to understand what can be achieved with ABMs, and what the expectations would be; (3) to come up with a *paper model*, that is, a description of the agents, agent behaviors, agent interconnections, the environment, and any other factors that should be considered for the simulation; and (4) to agree on a timeline, milestones, requirements and expectations.

Following the kickoff meeting, Icosystem's team begins development of the initial ABM. This includes gathering and cleaning up data from the client, designing the characteristics and behaviors of the agents, designing the user interface and the analytics engine that will enable the client to run desired scenarios and perform analysis. Typically within about six weeks a first, rough version of the ABM tool is ready for the client to begin testing.

The rest of the project is highly iterative and interactive, with the client trying the model, giving feedback to Icosystem, and providing additional data as needed. Meanwhile Icosystem continues to improve the model and the interface. This phase also includes some testing to ensure that the model is generating outputs that are at least directionally correct, meaning that the model is behaving in fairly reasonable ways. Usually within three to four months from the start of the project, the first fully functional version of the ABM is complete. The ABM typically includes a graphical user interface (GUI) that enables the user to set up different scenarios. The ABM should also include

some type of analytical or visualization GUI that enables the user to visualize the results of individual runs, or compare the results of different scenarios.

The first version of the ABM is usually meant for use by a single user or small set of experience users who have been involved with the development. Also, in situations where there exist significant historical data, a separate effort should be made to calibrate the ABM against historical data. This is a process whereby the model is run multiple times, adjusting parameters to obtain a sufficiently accurate reproduction of past events. The calibration process can be qualitative or quantitative, and it can sometimes be automated through the use of error-minimization or optimization techniques.

In some situations, the ABM developed to this point is sufficient for client use. In other cases further extensions are required. For instance, the client may wish to expand and simplify the tool for use by a broader class of users, including some who may not have had exposure to the ABM development process. This would be the case for example if OMH wanted to develop an ABM to be used for training, or to be distributed to other individuals and organizations for use.

Alternatively (or additionally), in some cases the client may wish to add an optimization module to the ABM. An optimization module makes it possible to use the ABM itself to suggest optimal or robust solutions. For example, if the OMH wanted to design an optimal strategy for allocation of resources to different types of organizations, an optimization module would essentially run thousands of simulations with different configurations until it found a solution that satisfied the client's criteria: minimize cost, maximize effectiveness, and so on.

Work with an academic research group

In the last decade there has been significant growth in the number of academic groups with expertise in agent-based modeling. An exhaustive list is beyond the scope of this publication. Some of the better-known academic centers, in alphabetical order include:

- Carnegie-Mellon University, Intelligent Software Agents Lab (www.cs.cmu.edu/~softagents).
- George Mason University, which includes several centers such as the Center for Social Complexity (socialcomplexity.gmu.edu), the Evolutionary Computation Laboratory within the Computer Science Department (cs.gmu.edu/~eclab), and the Krasnow Institute for Advanced Study (www.gmu.edu/departments/krasnow).
- Indiana University, Complex Systems Group within the Department of Informatics (cx.informatics.indiana.edu).
- Massachusetts Institute of Technology, several groups within the Computer Science and Artificial Intelligence Lab (www.csail.mit.edu), and within the Media Lab (media.mit.edu).
- University of Michigan, Center for the Study of Complex Systems (www.cscs.umich.edu).
- The NYU Bioinformatics Group at the Courant Institute of Mathematical Sciences (bioinformatics.nyu.edu/index.shtml).
- The Santa Fe Institute (www.sfi.edu), which is not a degree-granting institution, but is the cradle of Complexity Science and includes a large number of affiliated faculty members with positions at a variety of other academic institutions.

- University of Southern California, TEAMCORE Research Group (teamcore.usc.edu).
- University of Surrey (UK), Centre for Research in Social Simulation (cress.soc.surrey.ac.uk).

There are many more centers and academic departments that have performed excellent research in a variety of ABM-related areas, including areas directly relevant to the mission of OMH.

Working with an academic group is going to differ dramatically from working with a corporate partner in several ways. On one hand, the cost will generally be lower with an academic institution. On the other hand, an academic research project will tend to last much longer, and it will likely focus more on theoretical and analytical aspects of the simulation. Academic groups also tend to generate tools that are less consumer-oriented, and more oriented toward experienced, technical users. Hence if a client is seeking to develop a professional software tool, especially one to be deployed to a large user base, and if there is time pressure to get results, a private company may be a better choice. Please note that there are exceptions to these guidelines, as there are labs that are more industry-focused and more expensive, and there are companies that are more research-focused and less expensive. In general, we would advise the prospective client to explore as many options as possible before making a decision.

Develop an ABM in-house

A third and final option is to develop an ABM in-house. We usually discourage organizations from pursuing this avenue because of one simple fact: building an ABM can seem deceptively simple. How difficult is it to create a software agent with some

simple behaviors and characteristics? In our presentations on ABM we often use the analogy with computer games like the Sims™ and SimCity™, so one gets the impression that building an ABM might be easy. However, just as with any modeling and simulation technique, building an ABM requires a combination of art and science that can only be acquired through extensive experience.

One of the major problems we have seen is that it is difficult to determine the "right level" of detail. How many behaviors should be simulated? How many agents? How do the interactions take place? There is a tendency in people with minimal experience to include too much detail in their ABM. However, the resulting ABM will have so many parameters as to become practically useless. Another problem is that the dynamics of ABMs can be quite subtle and unexpected, and without a lot of experience, it can be difficult to tell what a feature is and what a bug is. Finally, there is some value in leveraging existing software, for instance any graphical user interface elements, or analytical modules.

Nonetheless, should someone wish to implement an ABM, there are several resources available. One good initial resource, especially for anyone interested in implementations related to social sciences, is an article by Axelrod and Tesfatsion (2006), which is also available online.

Another consideration is whether to develop an ABM from scratch, or whether to use an existing software library. In general, writing an ABM from scratch is not a good idea because it requires a significant effort, much of which is spent on software engineering, rather than on developing a sound model. The only drawback of using existing software packages is that ultimately every package is developed with a specific set of objectives in

mind, and this may impose some constraints as to the details of the ABM being developed. However, there is a sufficiently large set of available tools that it should be possible, with some initial research, to find a package that is well suited to the problem at hand. We list below some of the main public domain / open source packages:

- MASON: a multi-agent simulation library in Java, developed at George Mason University (cs.gmu.edu/~eclab/projects/mason).
- RePast: a Java-based social complexity simulation toolkit especially useful for social simulations (repast.sourceforge.net)
- Ascape: another popular Java-based social complexity simulation toolkit (ascape.sourceforge.net).
- Breve: software package to build 3D simulations of multi-agent systems. Includes graphic libraries and the ability to write agent behaviors in Python (www.spiderland.org/breve).
- StarLogo (education.mit.edu/starlogo) and NetLogo (ccl.northwestern.edu/netlogo): are two related simulation toolkits, originally developed for educational purposes. These are less useful for large commercial or government projects, but are excellent for rapid prototyping and for certain types of ABM applications.

Conclusions

In this paper we have discussed a technology known as Agent-Based Modeling, or ABM, and its potential applications to some problems related to cultural competency for emergency and disaster response.

We believe that ABM can be an extremely useful technology because it is the only technology that makes it possible to simulate and analyze real-world systems that are highly complex. By *complex*, we refer to systems in which the riche interactions among system elements and with the environment make the overall system behavior *emerge* in ways that can be surprising and unpredictable. ABM is a convenient way of analyzing different scenarios, or identifying optimal policies and strategies. ABMs have also proven themselves highly useful as training tools in a variety of settings.

Our paper includes a summary of several different ways that an ABM can be implemented. We hope that this information will be useful to OMH as it continues to enhance its efforts to improve cultural competency in disaster response and many other relevant problem areas.

Bibliography

Axelrod, R. (1997). *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration*. Princeton, NJ: Princeton University Press.

Axelrod, R. and Tesfatsion, L. (2006). A Guide for Newcomers to Agent-Based Modeling in the Social Sciences. Appendix A in Tesfatsion, L. and Judd, K.L. (Eds.), *Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics*. Amsterdam, the Netherlands: Elsevier/North-Holland. Available online at www.econ.iastate.edu/tesfatsi/abmread.htm.

Bellamine-Ben Saoud, N., Ben Mena, T., Dugdale, J., Pavard, B. and Ben Ahmed, M. (2006). Assessing large scale emergency rescue plans: an agent based Approach. *International Journal of Intelligent Control and Systems*, **11 (4)**.

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*. **99 (3)**, 7280-7287.

Dugdale, J., Pavard, B., Pallamin, N. and El Jed, M. (2004). Emergency Fire Incident Training in a Virtual World. *Proceedings of the International workshop on Information Systems for Crisis Response and Management*.

Epstein, J.M. (2007). Generative Social Science: Studies in Agent-Based Computational Modeling. Princeton, NJ: Princeton University Press.

Epstein, J.M. and Axtell, R.L. (1996). *Growing Artificial Societies: Social Science from the Bottom Up.* Cambridge, MA: MIT Press.

Gilbert, N. and Terna, P. (2000). How to build and use agent-based models in social science. *Mind & Society*, **1**, 57-72.

Gilbert, N. and Troitzsch, K.G. (2005). *Simulation for the Social Scientist*. Buckingham, UK: Open University Press.

Helbing, D., Farkas, I. and Vicsek, T. (2000) *Nature (London),* **407**, 487– 490.

Hunt, R.A. (2007). Cultural Competence in Disaster Mental Health. *CCDPCR Consensus Building Meeting Concept Paper.* Bethesda, MD.

Jain, S. and McLean, C.R. (2003). Modeling and Simulation for Emergency Response: Workshop Report, Standards and Tools. *NIST Modeling and Simulation for Emergency Response Workshop*, available online at www.nist.gov/simresponse.

Jones, A.-M. (2007). Cultural Competence: Solutions and Strategies for Emergency Medical Services. *CCDPCR Consensus Building Meeting Concept Paper*. Bethesda, MD.

Marecki, J., Schurr, N. and Tambe, M. (2005). Agent-based Simulations for Disaster Rescue Using the DEFACTO Coordination System. In: *Emergent Information Technologies and Enabling Policies for Counter Terrorism*, Wiley-IEEE Press.

Narzisi, G., Mincer, J.S., Smith, S. and Mishra, B. (2007). Resilience in the Face of Disaster: Accounting for Varying Disaster Magnitudes, Resource Topologies, and (Sub) Population Distributions in PLAN C Emergency Planning Tool. *3rd International Conference on Industrial Applications of Holonic and Multi-Agent Systems*.

Narzisi, G., Mysore, V. and Mishra, B. (2006). Multi-Objective Evolutionary Optimization of Agent Based Models: An Application to Emergency Response Planning. *The IASTED International Conference on Computational Intelligence,* **CI 2006**, 224-230.

Pan, X., Han, C.S., Dauber K. and Law K.H. (2006). Human and Social Behavior in Computational Modeling and Analysis of Egress. *Automation in Construction*, 15**(4)**, 448-461.

Schurr, N., Patil, P., Pighin, F. and Tambe, M. (2006). Using Multiagent Teams to Improve the Training of Incident Commanders. *Proceedings of the Fifth International Joint Conference on Autonomous Agents and Multiagent Systems*.

Scott, J.C. (2007). Importance of Cultural Competency in Disaster Management. *CCDPCR Consensus Building Meeting Concept Paper*. Bethesda, MD.