AGENT-BASED MODELS AND ETHNOGRAPHY: COMBINING QUALITATIVE AND COMPUTATIONAL TECHNIQUES WITH COMPLEXITY THEORY

By Amanda Andrei and William Kennedy

Increased interaction, adaptability, diversity, and emergence are all hallmarks of complexity (Miller and Page 2007; see Simon 1996). While anthropologists may not use these specific complexity theory terms, they have long been interested in how diverse people interact and adapt in their negotiation of identity and society and what sorts of social phenomena emerge from these interactions. A complexity theory perspective can interpret culture or cultural practices as either the base rules from which identity emerges (consider Appadurai 1996) or the emergent system itself, the "webs of significance" in which humans are embedded (see Geertz 1973).

In understanding and analyzing the increasing complexity around us, the technique of agent-based modeling can be successfully used with other qualitative methods, specifically ethnography. In this way, computational, quantitative, and qualitative research can be meshed together in order to generate a holistic and experimental model of a system grounded in and validated by real world data. Integrating agent-based models and ethnography serves to not only create more useful and realistic models, but also to unify social science techniques and concepts within the new field of complexity theory.

In this article, we focus on two agent-based modelings within anthropology: the *subaks* (traditional irrigation systems of Bali) and water temples model (Lansing and Kremer 1993) and DrugTalk (Agar 2005). Lansing and Kremer take a fresh look on a classical topic using computational techniques to analyze social phenomena, while Agar's model is more centered on contemporary social issues and policymaking. In the second part of this article, we provide recommendations to anthropologists of when and how to use agent-based models.

Background on Agent-Based Models

Agent-based models have been used throughout the social sciences for a variety of reasons, including understanding, predicting, discovering, and formalizing both conceptual models and theories of social systems (Epstein 2008; National Research Council 2008). They also assist in guiding data collection, training practitioners, and policymaking (Gilbert and Troitzsch 2005). Furthermore, Macy and Willer's (2002) review of computational sociology offers specific sociocultural applications and nuances of agent-based models that are as applicable for sociologists as for anthropologists, as well as questions for a social scientist to ask regarding the purpose of the simulation and how it should fit into the current research.

Agent-based models consist of three basic components: agents, environments, and interaction rules (Cioffi-Revilla 2010; Epstein and Axtell 1996). In the social sciences, an agent can represent an individual person or a group of people such as a household or an organization. Environments may be geo-spatial or abstract depending on how space matters in the social phenomenon. For instance, models about agriculture or ecology would probably include specific geographic space, while models about transmission of rumors or goods may not depend on physical landmarks or features. Interaction rules determine how agents behave towards each other and the environment as well as how agents update their internal states. Diversity in the model can mean heterogeneity in the agents, environment, or rules. The increase in diversity increases the level of complexity within the system. As a simulation progresses, agents react and adapt to each other and the space around them. These micro-level interactions give rise to an aggregate dynamic which may differ significantly from an individual agent's choices and decisions (Axtell 2005).

Tubaro and Casilli (2010) address the issue of integrating ethnography and agent-based models. They classify agent-based models into two families: "pure" models that are more theoretical and abstract in nature and "empirical" models that are open to qualitative and quantitative validation. Ethnography can serve to "counter the 'black box' criticism" encountered with many simulations (Tubaro and Casilli 2010:67) and provide both computational and conceptual models that are more grounded in the real world to produce more relevant and understandable results.

Subaks and Water Temple Networks

Since the 1970s, Stephen Lansing has conducted ethnographic research in Bali, with some of his most notable work focusing on networks of water temples and irrigation systems. With additional computer scientists, Lansing created simulations of these water temple networks in order to explore and understand the relationship between the environment, natural resources, and systems of conflict and cooperation between Balinese farmers. While not explicitly branded as an agent-based model, Lansing's work on subaks can be considered a predecessor to the anthropological agent-based models of today, and at the very least, an early and successful example of anthropologists simulating cultural systems and using complexity theory.

In Bali, a subak is an organization system of irrigation managed by the farmers of a village. Each village

controls its own subak and is dependent on other villages to manage their own subaks properly. As farmers follow varying cropping patterns, water flows into the rice terraces at proper intervals, thus, ensuring that each crop receives the appropriate amount of water. These processes also control the amount of pests that attack the rice. In addition to this water management system, there is also a hierarchical religious system of deities, priests, and water temples which guides farmers by structuring schedules and patterns for cropping and farming. Several subaks are associated with each water temple, making this an intricate system between physical geography, human activity, and divine cosmology.

In one particular study, Lansing and Kremer (1993) created a model of subaks and water temples along two Balinese rivers in order to explore the synchronization of the irrigation system under various environmental and agricultural conditions. A main goal of this model was to understand the importance of human agency and cooperative behavior in this particular ecosystem. The model included geographic data as well as real data on weather, irrigation flow, crop yields, pest damage, and water stress.[1]

Lansing and Kremer experimented with different levels of coordination of the subaks in order to see under what conditions an optimal harvest solution occurred. In one corner case, all the subaks followed identical cropping patterns; in the alternative corner case, subaks set their own cropping pattern. In this first scenario, the simulation showed that following identical cropping patterns minimized pests but increased water stress. In the other scenario, pest damage was maximized, while water stress was minimized. One of the important initial conclusions from these results is that social coordination matters when managing the irrigation system. Furthermore, when a subak changes its cropping pattern, it changes ecological conditions for all of its neighbors. The emergent system from these subaks and water temples is an entire ecosystem that is able to adapt and react to external shocks to the system. For instance, different levels of pest or

water damage in one subak have ripple effects on all the other subaks, but the overall system maintains its structural integrity and adapts to the perturbation. Furthermore, the existence of water temples and the religious guidance offered to the farmers results in higher harvest yields and more effective and efficient cooperation between villages.

By combining ethnographic research, historical data, and computational modeling, Lansing and Kremer were able to explore and predict the effects of different conditions within the subak and water temple networks. When the simulated agricultural system operated under traditional methods instead of modern methods, the system stabilized and still produced high yields of crops while being sustainable. As a result of Lansing and Kremer's conclusions, consultants working on the Bali rice systems reported to the Asian Development Bank that there would be no more opposition to the traditional management of the subaks and water temple networks. This is a powerful example of how qualitative research and computational modeling can make a huge impact on preserving a cultural and ecological system that is essential to the livelihood of many.

DrugTalk

Michael Agar is one of the pioneers of agent-based modeling in anthropology, using complexity theory and computational models to analyze culture in illicit drug markets. Agar (2005) believes in "the importance of knowing a world well before one models it," meaning that any assumptions that go into building a model and an artificial society should be grounded in real-world observations. For anthropologists, this usually means deriving the rules from ethnographic research.

One of Agar's (2005) NetLogo models, DrugTalk, simulates a drug epidemic based on qualitative research that Agar conducted of heroin use among suburban youth in the late 1990s. Youth who were interviewed would relate how drugs would originally be used by more "adventurous" users; depending on a positive or negative experience, others would be more or less

willing to try a drug. Based on this "flow of narratives," Agar and his colleagues modeled how communication of positive and negative drug stories ("buzz") could accelerate or stop a drug epidemic. Unlike other drug epidemiology models, Agar's agent-based model focuses on social interaction processes and rules.

Agents in the model are endowed with an "attitude" and a "risk" value. A user sets the initial attitude value for all agents (between 0 and 100, where 100 is completely anti-drug), which represents a "norm" for the society. Individuals' attitude values may change during the simulation depending on the local buzz. In contrast, the risk value follows a random-normal distribution for each agent but remains constant for that agent throughout the simulation. Agents also move at random and are embedded in social networks produced by an inverse power law distribution.[2] While drug users in the real world probably do not move at random, this simplifies DrugTalk and allows future modelers and researchers to refine the movement if they find it a significant feature.

Agents keep track of their positive and negative experiences with the drug. To check the buzz on the drug, an agent checks its neighbors' experiences with the drug, sums up the positive and negative experiences, and adjusts its attitude accordingly. If an agent encounters a drug and the agent's risk value is higher than its attitude value, it uses the drug, evaluates its experience, and tells its neighbors.

Another feature of Agar's model is that agents are not simply classified as users or non-users. Some agents are addicts, meaning that they must obtain a drug above all else. In the model, this means that after a certain number of uses of a drug (arbitrarily set to five), addicts no longer check the buzz; since they don't care what anyone has to say about the drug, they will use it regardless of any negative or positive stories. Furthermore, when a non-addict encounters an addict, the non-addict's attitude increases; it becomes more anti-drug because it sees the damage of drugs inflicted upon the addict. This is in accordance with interviews and ethnographic research conducted by Agar.

Even though Agar does not make any hard and fast claims about the end results of the DrugTalk model, he leaves the model and findings open for other subject matter experts to examine and test. This marks a crucial difference in anthropological agent-based models compared to other social science agent-based models. Often, the goal of these anthropological models is not to predict or forecast but rather to explore and explain. It is not necessarily up to the anthropologist to make a conclusion but rather for a policy-maker or government official to take the information and apply it.

Agar gives ethnography a dual purpose and assigns it the role of a guide: it sets boundaries on the realm of possibilities to model as well as reminds subject matter experts of the obvious. In the case of Agar's own research on drugs, this means that people who have little knowledge of drug culture could use Agar's ethnography as guidelines for the model's assumptions. People who may be experts can use the ethnographic research to "go back to basics," as it stands.

Furthermore, DrugTalk served as an example in Agar's study to demonstrate the benefits of using ethnographic research in building a model and to discuss the theories of "emic" and "etic." As for the issue of emic/etic, Agar (2005:17) defines emic as "*a difference that makes a difference* in those agents' world, even if they are not aware of it. "Emic" is not as clear-cut as a direct quote from an interviewee. Rather, it takes an "outsider" to explore the insiders' world, analyze it, and identify that difference. The outside may be aware of a difference but not know its significance until he conducts ethnographic research. Ultimately, ethnographers should "be able to tell outsiders what matters to insiders" (Agar 2005:2).

One critique of DrugTalk (which Agar also recognizes) is the need for precision and clarity in assumptions, values, and variables. Agar admits that in his earlier version of the model, he was not careful enough with his model assumptions. For instance, in earlier work, by not clearly defining how addicts influenced or were affected by influence, he found a high variation of model outcomes in terms of final numbers of addicts (Agar 2005). His results suggest that this high variation was not consistent with his own ethnographic research, but after refining the models, the simulated results were validated by the real world data.

Agar's work is crucial for researchers interested in integrating ethnographic and agent-based modeling techniques with each other. In addition to providing an example of his own model grounded in qualitative research, Agar raises relevant theoretical issues about the purpose of agent-based models, the formation of model assumptions, and the interpretation of model results. Additionally, his work served as a springboard for another anthropologist's study of drug culture, complexity theory, and the intersection of ethnography and computational modeling.

Recommendations for Constructing Agent-Based Models

The above studies have demonstrated that the combination of ethnography and agent-based modeling is a fruitful area for social science exploration and policymaking. Furthermore, agent-based models can be used in different stages of the research process whether in deciding where to conduct fieldwork or in developing a new theory.

As agent-based modeling is still growing within anthropology, there are endless possibilities as to applying it to a variety of topics. In theory, any topic can be approached using an agent-based model, and anthropologists looking to use this technique should ask various questions about the social phenomena they are studying to see if it would be suitable for an agent-based model. One helpful question is determining if the social phenomenon or group follows properties of complex adaptive systems. For instance, do actors have multiple, interconnected interactions? Does the system have emergent elements? Are the actors and their interactions between themselves and their environments of a diverse nature? Does the system self-organize? Does the system adapt to various changes? Computational models are especially useful if the anthropologist is dealing with a "hidden population," as in Agar's example, which are shadow economies that do not have readily available data.

An agent-based model can be applied before or after ethnographic research has been conducted. If an anthropologist has not yet conducted ethnographic fieldwork, she can use an agent-based model to find an optimal space for fieldwork. The anthropologist can also use pre-existing data and an agent-based model to hypothesize what she will observe in the field. In this way, agent-based models help with preliminary data collection and preparation for fieldwork, which can minimize costs and save time.

If the anthropologist has already conducted ethnographic fieldwork, then a model has to be chosen. If the anthropologist wants to build a new model, she can use her ethnographic research to abstract system rules (such as what Agar did with his interviews and participant-observation records.) The challenge in this case is being able to take subjective narrative and render it as computational heuristics and rules. Additionally, the anthropologist should consider how to represent links between data and agent development. What decisions lead to what consequences and why? These heuristics, rules, and links should be derived from and grounded in the anthropologist's ethnographic research. Another challenge to the anthropologist is in keeping the model simple. It is easier to start with a few simple rules for interaction, test the different versions, and add complexity.

After determining these rules, variables, and values, the anthropologist should begin coding the model—a process that often happens in a collaborative team with other computer scientists and modelers. This is an iterative process that involves frequent checking and reevaluation of model assumptions and outputs for consistency. The anthropologist (and team) should continually check if there are other agents, behaviors, or environmental features that need to be added and implement such changes to the code.

When the model is considered complete, the anthropologist should conduct verification and validation on the model. This means making sure that the model is internally consistent and that the rules within the model make sense given its
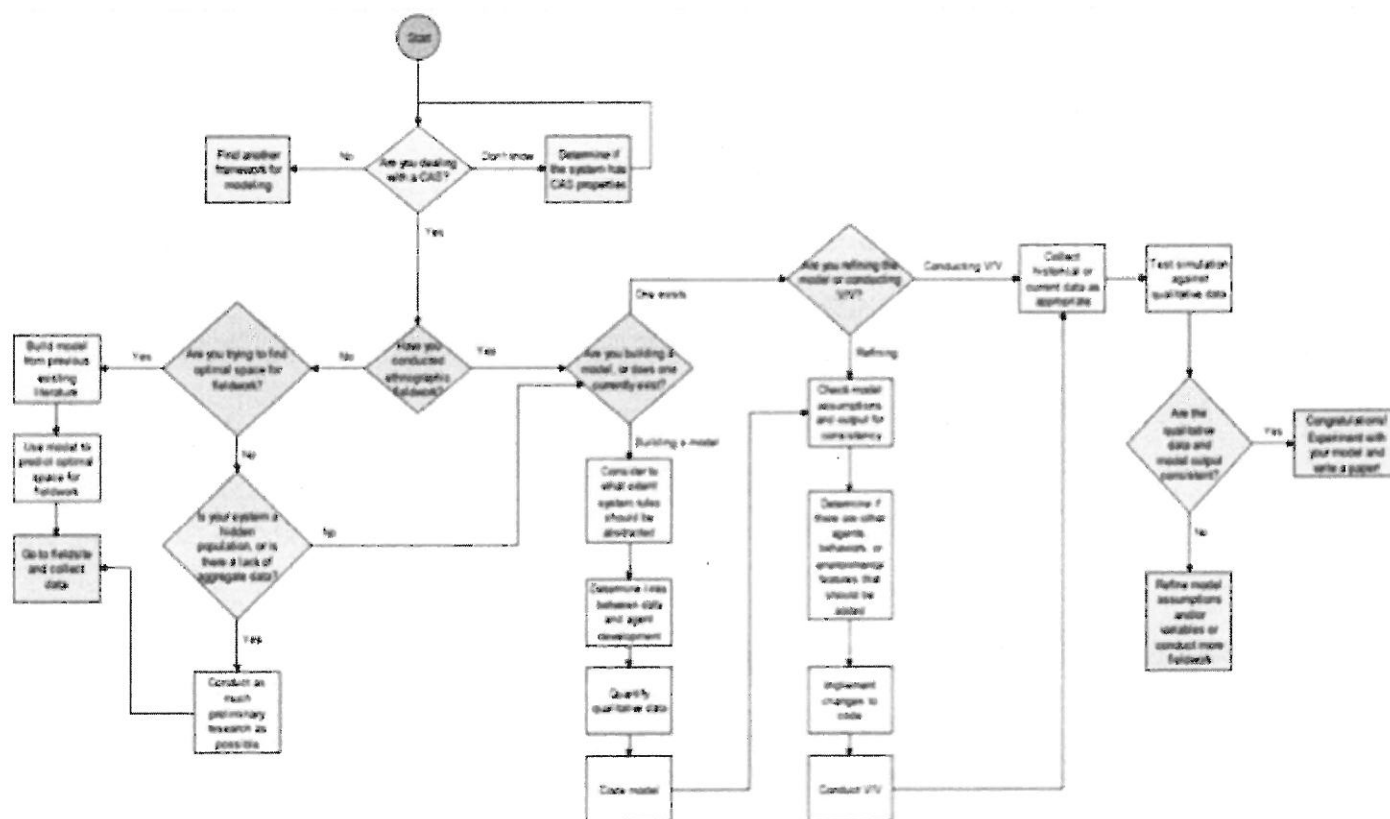
Figure 1. Decision Tree for Modeling a CAS (Complex Adaptive System) When Combining Ethnographic Research and Agent-Based Modeling. V/V stands for Verification/Validation.

output. Validation means that the model is tested against real world data—these data can be historical or current, as appropriate to the study. The simulation should then be tested against qualitative and quantitative data.

Depending on if the data and model output are consistent or not, the anthropologist should either refine the model assumptions and variables or conduct more fieldwork or formulate a new theory based on the model results. Additionally, a model does not have to be "finished" in order to use it to analyze data. During this time, the anthropologist should use the model to accomplish her overarching research goals, whether that might be to understand and explore a social system, predict or forecast outcomes, or experiment with different scenarios. For instance, in DrugTalk, Agar continued to adjust his variables to align with his ethnographic data when the outcome of the model did not make sense with real-world observations.

If the anthropologist has conducted ethnographic research and already has an existing computational model that she wants to check, she can follow the same steps mentioned: checking and reevaluating the model assumptions and variables and eventually verifying and validating the model. This process is a continual feedback of matching the data against the model and making sure that qualitative data are translated accurately into quantitative and computational expressions.

The anthropologist should also consider how she presents her findings. While ethnographies tend to be more literary in nature, the presentation of computational results is often more scientific. Keeping this in mind, the anthropologist should take care to craft a study that is comprehensive across disciplines. This might mean including graphs, charts, tables, equations, and decision trees in addition to descriptive narrative. For instance, Agar's work is written to an audience of anthropologists, and at times

his work includes descriptions when mathematical equations or tables might render the information more clearly. Additionally, the anthropologist should consider if and how she might want to make the model's code available so that it is easier for other social scientists to test and experiment with the model. To summarize, anthropologists and other social scientists should consider the decision tree in Figure 1.

Conclusion

The combination of ethnography and agent-based modeling is a rich area for exploration and experimentation for social scientists but especially applied anthropologists. Many current agent-based models in the social sciences focus on topics such as financial markets, group dynamics, or geographic issues. If anthropologists want to see their areas of study represented in this emerging transdisciplinary paradigm,

it is up to them to frame topics in a computational way and introduce their strengths to other social scientists. In this manner, anthropologists can have a huge impact on how computer scientists and modelers construct rules for their models. Furthermore, as anthropologists encounter more issues that involve globalization, networks, and larger scales, they can use their skills in theory, ethnographic research, and writing to create agent-based models that will address the increasing complexity in the world.

Acknowledgments

Notes

[1]Water stress in the model is calculated as "the percentage of subaks that experience a reduced rice harvest owing to water shortages" (Lansing 1991:42).

[2]This means that there are a few agents who are highly connected to many other agents, while the majority of agents only have a few connections to other agents.

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