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Computational Environment Behavior Research: Case Studies of Sustainability and Population Collapse in a Northern Arizona Region

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While most would call Environment-Behavior Research a discipline and work to defend it's existence, I prefer to take an "Environment-Behavior" perspective into my research, teaching, and practice endeavors. This way I need waste little time in defending the field per se. While my interests originally focused upon seeking defensible justifications for "value added by design" relative to schools, residential developments, and commercial complexes with an eye toward greater levels of expected success in long term sustainability for the human communities and cultures that inhabited them with stable and flourishing natural ecosystems – over the years the focus has shifted more and more deeply toward capturing the essences of and working toward collective capacities to simulate "coupled human-natural systems."

Using Agent-Based Modeling Simulations we can capture from the "bottom-up," in the form of simple algorithms the essence of some system of interest, by capturing the essential behaviors of the key players and/or components within that system. These algorithms (computations) are then allowed to interact with one another, resulting in a new model system that can be explored. Agent based modeling is well suited for analysis of dynamic systems of heterogeneous, adaptive "agents." Complex, adaptive, systems such as these are difficult if not impossible to capture using more traditional modeling tools like axiomatic mathematics, statistical methods, or even qualitative/descriptive methodologies.

For nearly a decade our research group has been working toward integration of socio-spatial elements of culture, and/or cultural landscapes into an earlier model of the Anasazi in a Northern Arizona Region that was primarily environmentally deterministic. To date this research has indicated that earlier hypotheses, seemingly un-testable, about ideological and cultural factors not included in original models being responsible for the abrupt dissolution of the Anasazi culture are more than mere conjecture – they are highly plausible.

However, as models/simulations grow ever more complex and numerous, problems have emerged with regard to interchangeability of models among researchers, re-use of earlier existing models, and solid data tracking into the design of model components and construction of modeled causal networks. Beginning with a description of the Long House Valley (Arizona) and Mesa Verde (Colorado) Anasazi research teams, their models, their development, and a short discussion of experimental results from these research teams and present plans for future work the discussion here will turn to matters of methodology and rigor. Using the Anasazi model for a Northern Arizona region as a case study, we will explore the process of taking an existing model as a piece of earlier research, reverse engineering it, and designing an extension utilizing insights gained through the Perspective of Environment-Behavior Research. An extension that, like all environmental designs and public policy developments, is geared toward user needs – in that instance the Archaeologists, Dendroclimatologists, Computer Scientists, Anthropologists, Epidemiologists and Sociologists/Public Policy Analysts that comprised the original Artificial Anasazi Model.

In the process of achieving those goals it became clear that a new generation of models is needed, and indeed there is a great deal of work being done all around the globe by researchers, as the emergence of the new field "computational social science" indicates, in this area. However – looking at this new field of "computational social science" and the other sub-disciplines popping up – it seems undeniable that the same deficiencies will re-create themselves in this new social science perspective as with it's environmental science version. The need for the Perspective of Environment-Behavior Research is clear – not so much in the form of our pre-existing body of substantive works – but by way of the collective insights we in EBR have gained over these past 4 decades.

My present work centers on designing the methodologies and protocols that can pull together the many diverging skeins within Agent Based Modeling Simulation (especially those that pertain to development of deeper understandings of sustainable systems at all units of analysis). Pull them together so that the current team of researchers can begin to develop

a new class of model that combines Agent Based Modeling Simulation + 3d GIS through "Middleware" development (a third component, not yet in existence) – so that researchers in Architecture and Planning can begin to dialogue with and through the work of other researchers in the many fields that come together to a degree never before considered within the global community of researchers focused on this type of research. In particular – the problem that needs the most work is the one that EB has labored so long and hard itself to master. Development of valid and/or trustworthy research designs and subsequent results for problems in the real world that involve persons and the environment.

While significant advances are being made in development of protocols for Agent Based Modeling with regard to standardization of basic model structure descriptions (OOD) and toward standardization/synchronization of modeling components (Mr. Potatohead), a significant gap still remains in to create an appropriate "ecological context" for next generation Agent Based Modeling research; that of providing satisfactory documentation/citation protocols. This paper suggests the addition of a third component to complement Standardized Model Descriptor protocols [1] and Standardization and/or Coordination of Object Oriented Model Designs so that components and/or algorithms might be interperable (e.g.: Mr. Potatohead development[2] pattern protocols). This third component would provide linkages into the respective literatures, or other verifiable sources, upon which model designs are based.

ABM researchers who wish to emulate scientific research designs must meet the requirement that experiments be repeatable, and that they be (in principle) open to challenge. Agent based modeling simulations in general fail to track backwards into the literatures on, or documented descriptions of the actual entities, that our models are purported to capture. This represents a dimension of scientifically legitimate inquiry[3] that ABM simulation research designs must begin to satisfy.

For several reasons the time has ended when models circulate only within circles where data sources are common knowledge. ABMS are becoming more complex, researchers are working toward components becoming interoperable and used in construction of and/or modification of other models and increasingly across disciplines, and ABMS couplings with GIS may likely become the standard. Without the development of protocols for properly "citing" sources (as is standard in scientific research and publication) the emergent ABMS boom will unquestionably bog down and become mired within legitimate protestations that its assertions are little more than pseudo-science that will be difficult, if not impossible to counter.

Our research team's utilization of NVivo, a software package for the analysis and synthesis of qualitative data, to provide data tracking from literatures, interviews, and/or observations for the successful modification of the original Artificial Anasazi Model[4] (Gumerman, Dean, Epstein, Axtell, Parker, Swedlund, and McCarrol) to incorporate "ideological and cultural factors not present in the existing model" is presented as an example of what is needed to bridge this gap.

Beginning with a description of the Long House Valley (Arizona) and Mesa Verde (Colorado) Anasazi models, their development, and a short discussion of experimental results from these research teams - followed by a description of why and how the original model was modified and presentation of new experimental results. Next the reverse engineering of the existing LHV Anasazi model, interviews of original team members, evaluation/choice of hypotheses to be tested in new version of model, and research into literatures of anthropology, archeology, ethnography, psychology, sociology, environment-behavior research, CAS, ABMS and philosophy were utilized and tracked (using NVivo) from their sources into the process of "program modification specification," development of UML code, Java code, and debugging will described in detail.

Concluding remarks discuss the pro's and con's of the protocols followed, outline a conceptual design for new tools to fill the gap that was found between data analysis and synthesis software such as NVivo and high level symbolic programming protocols such as UML, and suggest this as an opportunity for additional collaborative research and development. Collaborative research and development where not everyone need be a programmer or mathematician – but everyone must

1 e.g.: "Overview, Design Concepts, and Details" , or ODD (Polhill, Parker, Brown, Grimm; 2008)

2 The "Mr. Potatohead" framework is a "conceptual design pattern" (CDP) that represents key elements of Agent Based Models (ABM) for Land Use/Land Cover Change (LUCC) research – and demonstrates how multiple models can be represented and compared within a single meta-model.

3 Kuhn, T. S. (1996). The structure of scientific revolutions; Popper, K. R. (1968) The logic of scientific discovery; Voss, J. L. (2000) Transcending Geographies of Paradox: coextensive essences of phenomenological and scientific inquiry.

4 This model was jointly developed by the Brookings Institution and the Santa Fe Institute by George Gumerman, Jeff Dean, Miles Parker, Alan Swedlund, Joshua Epstein, Robert Axtell, and Stephen McCarrol. It it a model of the Anasazi of the Long House Valley in North Eastern Arizona – capturing land use patterns, changes in ecological context (weather, water table), demographics, settlement patterns, and maize production from 800 to 1350 AD. The model seeks to explain LUCC, demographic + settlement changes, and eventual abandonment of LHV in 1300.

be interested in solving complex problems beyond the capacities of any individual discipline to do alon