Evolving Artificial Cultural[1] Things-That-Think[2] and Work by Dynamical Hierarchical Synthesis

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Growth in the new sciences of complexity relies on the intermediation of two lines of research. On the one hand, we must develop an effective means of representing both complexity and its entailments. On the other, we must examine the empirical world with freshly calibrated eyes. The two are intimately intertwined, for without an adequate language of description and synthesis complexity will always lay just outside our ken and understanding, and without direct confirmation from the real world complexity will always an esoteric speculation. The psychology of perception is such that without a formal way of representing and talking about complexity one is likely to not recognize it at all and so settle for some gross abstraction of events. In the empirical world disorder is casually dismissed as noise. We do not see what we are not looking for. Innovation in science thus requires new ways of looking at the world, new ways of looking at old theories and data. Recognizing complexity requires new ways of knowing. Discovery is seeing what has not previously been seen.

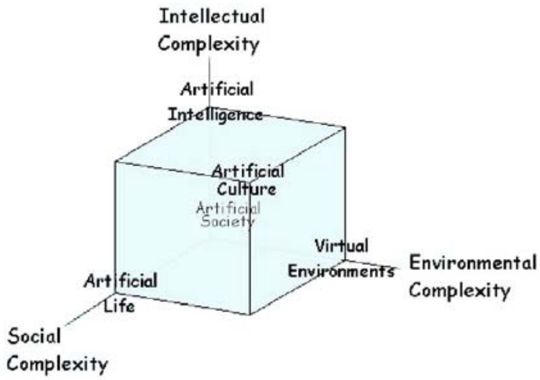
Empirically, culture is the product of individuals, artifacts, and their interactions at emergent levels of complexity. Variation is its omnipresent hallmark: Cultures are different. Its members are different. Its members' heads are filled with different thoughts (Minsky 1985, Brooks 1999). Moreover, both cognition and work are distributed throughout people and their technologies. Culture emerges from all these through complex multiagent webs of mutual causation, objects and processes that are both parallel and simultaneous.

> Ideas, and other atomic particles of human culture, often seem to have a life of their own – organization, mutation, reproduction, spreading, and dying. In spite of several bold attempts to construct theories of cultural evolution, an adequate theory remains elusive. The financial incentive to understand any patterns governing fads and fashion is enormous, and because cultural evolution has contributed so much to the uniqueness of human nature, the scientific motivation is equally great. (Taylor & Jefferson, quoted in Gessler 2003.)

> Culture shifts… with kaleidoscopic variety, and is characterized internally not by uniformity, but by diversity of both individuals and groups, many… in continuous and overt conflict in one sub-system and in active cooperation in another. (Wallace 1961: 28)

> Humans create their cognitive powers by creating the environments in which they exercise those powers. (Hutchins 1995: xvi)

I have previously outlined a program of research towards facilitating the convergence of *evolutionary computation* (Bäck, Fogel and Michalewicz 1997) and *cultural theory*. I call it *artificial culture* (Gessler 1994, 1995, 1996, 1998, 2003a, 2003b). It is positioned to draw from and inform both fields of research. First, it will provide *evolutionary computation* with new cultural metaphors and thus build upon the established successes of its founding biological analogs to evolution. Second, it will provide *cultural theory* with a realistic synthetic computational framework for describing and assessing the entailments of a distributed cultural cognition (Hutchins 1995) embodied in a society of modules of mind (Minsky 1985), individuals, groups and institutions, and their materiality in artifacts, workplaces, architectures and settlements. Paralleling cognition, of course, are the dynamics of work, matter and energy exchanges. *Artificial culture* seeks a minimal assemblage of objects and processes, a small core set of functionalities that appear to be foundational in explaining the evolution of culture, man's unique adaptation to the natural environment. *Artificial culture* builds upon the paradigms of *artificial life* and *artificial societies* by imbuing its models with balanced mix of intellectual, social and environmental complexity. It is situated midway in a hyperspace, somewhere between *artificial intelligence*, *artificial life* and *virtual environments*. *Artificial culture* is an experimental platform for evaluating theory against empirical observations by studying alternative "what if" scenarios, thereby separating what is possible from what is not.



This project will develop new approaches to social science theory by building minimal computational models based on current advances in *evolutionary computation* and *cultural theory*. *Evolutionary computation* (also known as *evolutionary algorithms*), embracing the historically separate projects of *genetic algorithms*, *evolutionary strategies*, *evolutionary programming*, *cultural algorithms* and *genetic programming* (Fogel 1998), has coalesced as a cooperative effort aimed at a *computational synthesis* seeking "formal algorithmic procedures that combine low-level building blocks or features to achieve given arbitrary high-level functionality" (Lipson 2002). *Cultural theory*, embracing individuals in their interrelationships with others as well as their technologies, all in coadaptation with their social and physical environments, has struggled towards a "science of culture" (Harris 1979) through the efforts of a number of anthropologists. Among them, two have been particularly influential in articulating relationships between cognition and materiality (Harris 1979, Binford 2001). A third extends the modules of cognition, entangling them with the complexities real-world materiality. For him, the materiality of artifactual, architectural and physical environments are key players in a distributed cultural cognition:

> I hope to evoke… an ecology of thinking in which human cognition interacts with an environment rich in organizing resources… It is in real practice that culture is produced and reproduced… I hope to show that human cognition is not just influenced by culture and society, but that it is in a very fundamental sense a cultural and social process. To do this I will move the boundaries of the cognitive unit of analysis out beyond the skin of the individual person and treat (it) as a cognitive and computational system. (Hutchins 1995: xiv) Humans create their cognitive powers by creating the environments in which they exercise those powers. (Hutchins 1995: xvi)

Understanding the bottom-up and top-down exchanges between local and global levels of a complex system, as each provokes emergences and constraints upon the other, is the "holy grail" of *artificial life* research. So too is it in sociology, anthropology and *artificial culture*.

> (Multiagent systems) have attained a level of maturity where they can be useful tools for sociologists… (They) provide new perspectives on contemporary discussions of the micro-macro link in sociological theory, by focusing on three aspects of the micro-macro link: micro-to-macro emergence, macro-to-micro social causation, and the dialectic between emergence and social causation. (Sawyer 2003)

The situation is even more complex. While shared meanings are an essential element of culture, they are necessary but not sufficient to explain the totality of cultural behavior. Among shared concepts there is ample room for individual divergence and this disagreement in meaning oftentimes is the animating factor in negotiations and the unequal flow and quality of information (and disinformation). Culture has been described as an organization-of-diversity:

> Culture shifts in policy from generation to generation with kaleidoscopic variety, and is characterized internally not by uniformity, but by diversity of both individuals and groups, many of whom are in continuous and overt conflict in one sub-system and in active cooperation in another. (Wallace 1961: 28)

We are not fully slaves to the languages or non-articulated symbol systems that they generate and use. We recognize and distinguish many more differences in objects and behaviors than there are words or symbols to describe them. In natural language this is evidenced by the use of metaphor and modifiers that push or pull meanings in one direction or another. A language system is one representational system among many others. Science itself may be seen as the formal practice of building increasingly reliable, comprehensive and economical representations of the world.

Human cognition, whether biologically or culturally determined, is a myriad composite of representations, metaphorically a hall of mirrors, a set of nested Chinese boxes or Russian dolls. The connections among these representations are in a continual state of flux and intermediation. Computer scientists have proposed models of such complex cognitions. Minsky invokes a cultural (though he calls it a "societal") metaphor of mental process. Mind, he says, is a microcosm of society itself, with mental agents vying for control over the individual. Consciousness, he and others assert, sits as an epiphenomenal observer arrogantly taking all the credit.

> We'll show that you can build a mind from many little parts, each mindless by itself. I'll call "Society of Mind" this scheme in which each mind is made of many smaller processes. These we'll call *agents*. Each mental agent by itself can only do some simple thing that needs no mind or thought at all. Yet when we join these agents in societies --- in certain very special ways --- this leads to true intelligence… One trouble is that these ideas have lots of cross-connections. My explanations rarely go in neat, straight lines from start to end. I wish I could have lined them up so that you could climb straight to the top, by mental stair-steps, one by one. Instead they're tied in tangled webs. (Minsky 1985: 17)

Rodney Brooks takes a similarly entangled view. He has argued that intelligence and representation are not necessary for purposeful action. He erodes our conventional wisdom of what might comprise intelligence:

> The so-called central systems of intelligence… (are) perhaps an unnecessary illusion… (Perhaps) all the power of intelligence (arises) from the coupling of perception and actuation systems. (Brooks 1999: viii) The basic idea (of the first model) is that perception goes on by itself, autonomously producing world descriptions that are fed to a cognition box that does all the real *thinking* and instantiates the real *intelligence* of the system. The thinking box then tells the action box what to do, in some sort of high-level action description language. (The second model) completely turns the old approach to intelligence upside down. It denies that there is even a box that is devoted to cognitive tasks. Instead it posits both that the perception and action subsystems do all the work and that it is only an external observer that has anything to do with cognition, by way of attributing cognitive abilities to a system that works well in the world but has no explicit place where cognition is done. (Brooks 1999: x)

Computational views of culture present new challenges to both social science and computation. The anthropologist may wish to frame cultural explanations using advanced computational modeling. The evolutionary computationist may wish to invoke the complexities of culture in designing new algorithms for creativity and optimization.

Anthropology, in principle, lays academic claim to the entire domain of human cultural evolution, from our primate ancestors, through small-group hunter-gatherers to civilized society and global institutions. Consequently, anthropologists have periodically tried to transcend historical particulars and focus on the major factors that brought us to our present reflexive state (Boyd & Richerson 1988, Johnson & Earle 1988). A no less ambitious book was attempted a decade earlier earning praise from Margaret Mead:

> Scientists, from anthropologists to political scientists, and all students of living systems will find here a way of looking at changing scales, but comparable problems, which will enormously illuminate and simplify their attempts to relate one level of living system to another. (Miller 1978: dustcover).

It seems appropriate that half-a-century after the popular acknowledgement of the "thinking machine" (Anon 1950) and a milestone book on an *artificial society* known as Sugarscape (Epstein & Axtell 1996, Gessler 1996), that we should translate this discursive theorizing into computational models in an effort to create a fledgling *artificial culture*.

Two conferences were recently held on the convergences of evolutionary and computational ontologies and epistemologies. The first of these was in connection with the Eighth International Conference on Artificial Life in Sydney. The second was in connection with the American Association for Artificial Intelligence Spring 2003 Symposium in Stanford. The workshop titles were "Computational Synthesis: From Basic Building Blocks to High Level Functionality"[3] and "Modeling Dynamical Hierarchies in Artificial Life"[4] (respectively). Based on discussions at these workshops, I will integrate models of hierarchical selection (dynamical hierarchies) in a synthesis that will explain cooperation as the emergent properties of competitive individual and group fitness. In other words, the simulation will include dynamic measures of the competitive fitness of the individual and the competitive fitness of each of the institutions (groups) he participates in. Individuals will make their own choices cooperating partners or memberships based upon their own local perceptions of individual and group fitness. Individuals will be free to choose competitive and cooperating partners and memberships as well as to display informative or disinformative cues to those attributes. I have already authored two simulations, with appropriate visual user interfaces, space/time physics and scheduling in Borland C++ for Windows, to prove the feasibility of this project. The first was a deconstruction of the concept of "carrying capacity" showing that it depends upon a myriad of factors beyond the population size, per capita daily food consumption and the total food in a region. The pattern of the food resource distribution, search strategies of the individuals and daily food ration had significant effects on their ability to access all the food that was presumable available[5]. The second was an instantiation of kinship terminology, marriage and residence rules in a dynamic "living" population. Each of the 400 members of the simulation collected local information on their relationship to any of the others. Although framed as "kinship," the simulation is easily expandable to account for any notion of relationship[6]. Thus it should not be an intractable task to instantiate the functionalities that I outlined earlier, specifically the evolution of cultural things-that-think and work, cognitive, material and energetic exchanges, in a minimal *artificial culture*.

A theoretical model is no better than the empirical observations that it attempts to explain. While precise predictive detail is too much to expect from a minimal model, prediction in the sense of building an envelope of possibilities will be the goal. The resulting simulation might best be called insightful rather than predictive.

For my own part, I have spent nearly two decades in archaeological, ethnohistorical and ethnographic research on the Haida hunter-fisher-gatherers of the Pacific Northwest Coast. Although the empirical evidence is not commensurate, there is abundant direct and indirect evidence for complexly shifting causes of cultural change from pre-European contact days (circa 1750) to the present, 250 years of cultural evolution. Although early records were limited in scope, and many observers "spun" biases into their observations, there are many clear indications of small seeds growing far-reaching dynamical consequences. In such ways "historical" effects can initiate chaotic consequences in a manner similar to the chaos-theory canon "sensitivity to initial conditions." The absence of direct detailed evidence in these instances is not necessarily the evidence for their absence. The ethnographer Polly Wiessner (who is collaborating on this project) has documented similar dynamism in New Guinea.

> (Current) approaches often fail to take the recursive interaction between agents and egalitarian structure seriously… (I view) egalitarian structures as complex institutions which, together with their accompanying ideologies, have arisen to reduce the transaction costs of exchange in small-scale societies. (Wiessner 2002)

In contrast to this unevenly recorded evidence of change Polly Wiessner is compiling detailed records on the demographic changes of the Nyae Nyae !Kung hunter-gatherers of Namibia over the last 60 years. John and Lorna Marshall were the first non-Africans to meet these people. The Marshalls and Wiessner have been jointly collecting and collating data since that time. The !Kung have probably undergone the most violently rapid change of any of the three groups mentioned. She outlines the problem and focuses on the changes that have occurred in provisioning and trading patterns and the competing explanations offered in the ethnographic literature.

> For the better part of our evolutionary history as foragers, the well-being of any individual rested heavily in the hands of others… Relationships bearing mutual obligations were well distributed over the population, so that in times of hardship losses could be absorbed by others… Though ties of mutual obligation can be used effectively to reduce risks, they generate risks of their own – those of defection, debt, or dominance. (Wiessner 2001: 21.)

> The question of why hunters target large game knowing that most of the meat will end up far beyond their own hearths is an intriguing one. It raises the issue of whether foragers pursue nonnutritional goals in food procurement and which goals they pursue. (Wiessner 2000: 407.)

In accord with her observations, alternative modeling scenarios will include reciprocity, costly signaling, nepotism and the pursuit of long-term political goals. The interplay among these factors will be tested against this 60 years of data and extensive field notes.

Insofar as it is feasible, the foundational framework and functionality of the model will be scaled and generalized and applied to the ethnohistoric data on Haida and Enga cultural change as well.

The *artificial culture* will be seeded with a population of individuals. Each will have the property of age, sex and parentage, and will be situated in both space and time. Each will initially have four potentially competing goals: food, shelter, protection and reproduction that will contribute to its implicit fitness. Negotiated cooperative associations with others in groups or institutions will also constitute a fitness factor, since some goals can only be met only by negotiating with different sets of individuals. Goals may be reached through different strategies, mediated by evolved beliefs and local perceptions before becoming actions, with observable behavioral and material consequences. Cognitive structures may include basic relational privileges and obligations, *theories of mind*, observed behaviors, and prestige and credit ratings of other individuals. Beliefs may be acquired either first-hand or from other individuals through exchange. Each goal domain is allowed to evolve separately, and associated beliefs, strategies, plans and actions for each domain may remain distinct. While domains remain distinct, the model will allow emergences to crosscut boundaries thereby building modular structures by analogy. Opportunities for misinformation and disinformation will be available.

It is hoped that this project, in its attempt to integrate *evolutionary computation* with *cultural theory*, will assist both computationists and anthropologists by extending research in biological evolution through higher levels of complexity to culture.

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Notes

1. "Artificial Culture" was a term suggested by the computer scientist Michael Dyer.

2. "Things-That-Think" is a phrase used by the MIT Media Lab for several of their projects.

3. Artificial Life 8. *Call for Papers on Dynamic Hierarchies.* Electronic document: http://wdh.vub.ac.be/wepa_files/home.htm accessed 3/30/03.

4. American Association for Artificial Intelligence, Spring Symposium, 2003. Workshop on Computational Synthesis. Electronic document: http://www.mae.cornell.edu/ccsl/conf/ accessed 3/30/03.

5. "Forager" is available as executable code, source code and project files from: http://www.sscnet.ucla.edu/geog/gessler/borland/simulations.htm

6. "Kinship" is available as executable code, source code and project files from: http://www.sscnet.ucla.edu/geog/gessler/borland/simulations.htm