Fostering Creative Emergences in Artificial Cultures

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Abstract

Empirically, culture is that complex whole which results from the interaction of a multitude of ideas, individuals, behaviors, groups, artifacts, workplaces and architectures, each distributed uniquely and differentially in space and time. *Artificial culture* is the program of describing, understanding and explaining such human complex systems in computer simulations. Several recent conferences in *evolutionary computation* (i.e. *dynamical hierarchies*, *computational synthesis*, and *dynamic ontology*) have focused on the problem of automatically creating novel and compounded emergences in natural and artificial worlds. This paper reviews current progress toward that goal from the perspective of an anthropologist.

Cultural Complexity

Each culture is as different as are its members. Moreover, the minds of individual members of a culture are often filled with different and competing thoughts. To further complicate matters, cognition is unevenly distributed not only among people, but also among their behaviors and the products of their technology. Culture is the totality that emerges, through complex webs of mutual causation at increasing levels of complexity, through *dynamical hierarchical synthesis*, from such seemingly dissimilar things:

> 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).

More formally, we might define culture as a complex network of activity through multidimensional multiagent webs of mutual causation, a computational process that is both massively parallel and simultaneous. Culture is the emergent product of the variety of beliefs held by a single individual and the variety of individual behaviors that constitute a society. Complexities of this kind are everywhere and everywhere they defy casual description. Although *complex adaptive systems* are largely intractable to traditional discursive and mathematical representations, the "new sciences of complexity" offer some fresh alternatives. Beginning about 1950, we created computational languages for describing, explaining and understanding these dynamic technicalities. *Artificial culture*[1] is a program that extends the trajectory that began with distributed *artificial intelligence* and grew from *artificial life* to *artificial society*, towards a new social scientific practice. Creative, critical, experimental and empirically informed, a*rtificial culture* is the project of describing the technical complexities of culture in computational terms. Much existing discursive and mathematical cultural theory may be amenable to translation; much may need to be completely reformulated. In short, we need to encode a population of agents, along with their social and physical environments, inside simulations. This enables us to begin to describe, understand and explain the complex causal web of biological and cultural evolutionary processes that distinguished us as humans from our primate ancestors. Experiments of this kind allow us to evaluate the nature of alternative counterfactual "what if" scenarios by observing the entailments of different initial patterns of similarity and difference, different constellations of individual and group (local and global) interaction and different degrees of ideational and material agency. Inspired by the epistemological convergence between evolution and computation (e.g. Rozenberg, et al. 2010), such investigations offer rich new insights into cultural complexity: the individual and society (local versus global), distributed cultural cognition (including the intermediation between humans and their technologies) and the coevolution of the unlimited variety of cultural *things-that-think*[2] and things-that-work. Vital to understanding the evolution of culture is understanding networks of trust, secrecy and deception, the human practice of judging the reliability of other individuals in exchanging matter and information, the practice that builds

[1] A term originally suggested by Michael Dyer.
[2] A phrase originated by the MIT Media Lab.

reputation. *Artificial culture* enables us to describe and experiment with the coevolution of seemingly disparate processes in natural culture and it suggests to us some new critical perspectives from which to evaluate our methods of anthropological inquiry.

Metaphors and Media

Although cultural evolution clearly outpaces genetic evolution in the natural world, it does so only to the degree in which it is freed from the constraints of biological materiality. Cultural change, considered as the reproductive cycle, takes place in seconds, minutes, days, years or decades, whereas human biological change takes at least a decade and a half. In the natural biological and cultural worlds the media of evolutionary transmission behave quite differently: genes reproduce slowly; ideas reproduce quickly. In the artificial world of the computer, whether modeled on a cultural or genetic metaphor, the medium through which evolution unfolds is essentially the same for both. The generations over which evolution unfolds are constrained by the same system clock. Although cultural evolution proceeds more quickly than biological evolution in the natural world, there is no *a priori* reason to believe that cultural processes will be quicker than genetic ones when evolution runs in simulation. Computational algorithms metaphorically modeled on culture may well run faster than those metaphorically modeled on biology, but even if we find this to be true, the argument that what holds true for the natural world must also hold true for the artificial world is simply unsupported (Gessler, 1998). Consequently, when we create simulations using artificial agents, we must critically question the representational analogies and metaphors we use.

Hierarchically synthesized emergences are likely to be more ephemeral and complex in culture than they are in physics, chemistry or biology, and certainly of a completely different nature. In those non-cultural domains, spatial and temporal proximity may be adequate for creating many emergent syntheses. The hierarchical two-fold emergences of monomers to polymers and polymers to micelles, spanning three levels of hierarchical complexity, may be readily visualized as aggregates of dots in three dimensions (Rasmussen, 2002). However, in cultural domains, although space and time may adequately define some features of human interaction (such as households, settlements and trading patterns) other emergent objects are more amorphous and atemporal. Cultural emergences are more difficult to circumscribe. How would a program automatically recognize, capture and repurpose the emergence of a concept such as trade, reciprocity or kinship in an evolutionary simulation? How would a programmer design a graphical user interface to visualize an emergent instance of an institution? In creating *artificial cultures* for social scientific research, one must be careful not to collapse the spatial, temporal and physical constraints of the real natural world into unrealistic artificial world representations. To exacerbate the problem, if one used natural or *artificial culture*s as inspiration for creating populations of synthetic artificial software agents interacting on the Internet, would those same spatial, temporal and physical constraints, that were so important to a science of culture, take on completely different meanings for so-called cultures of software agents? Can they really be "cultural agents" if they are so disembodied? To what extent can software agents be expected to behave like natural human agents? Should they even be modeled on human agents? Or might they better serve our purposes if freed to shape themselves according to their own natures?

Emergence

Among the goals of the "new sciences of complexity," if not of all the sciences in general, is the explanation of emergence in the natural world. In artificial worlds this translates to how to foster emergence in simulations. We often choose to talk about emergence, metaphorically, as levels in a hierarchy. Much research focuses on defining the primitive elements of a simulation at a "lower (local) level" and fostering emergences at a "higher (global) level" of system behavior. Several workshops and labs have focused on creating increasingly higher levels of emergence (Bilotta et al. 2003, Anonymous 2010).

> Given a particular framework, there is a tight correspondence between the complexity of the simple objects used and the system's ability to generate dynamical hierarchies…. The complex systems dogma encourages those studying dynamical hierarchies always to seek models with the simplest possible element. Our *ansatz*, by contrast, encourages us to add complexity to system elements to explore more levels of the hierarchy… Of course, we want to preserve the complex systems dogma to the extent that is possible; we want the simplest possible models of dynamical hierarchies. But we want to stress that the complex systems dogma should not block us from building simulations with enough object complexity to model multilevel dynamical hierarchies successfully. (Rasmussen, 2002:350).

The term "emergence" conflates at least two entangled, yet distinct, meanings. We may talk about it historically (diachronically), as the emergence of everything from the beginning of time to the present, and we may talk about it instantaneously (synchronically), as the structural foundation of the moment. Although the hierarchy of emergence, which we experience as the reality of this instant, may resemble the hierarchy of emergence, which historically enabled us to reach this point, they are qualitatively different. The hierarchy of emergence that we experience as the reality of this instant is in an instantaneous state of self-creation and self-maintenance. From the smallest quark up to the largest quasar, everything in the "now" is held together by emergence. Historically, if agriculture had not first emerged in Mesopotamia, it likely would have emerged somewhere else. We don't need to maintain every level of historical emergence in the present; it has passed. However, if at this instant, sub-atomic particles should change their nature, all instants now and in the future would change dramatically. Scenarios of the destruction of an emergent hierarchy in the "now" make good reading, such as the fictional account of the emergence of a seed crystal of "Ice-Nine," a new solid form of water that melts at 114 degrees (Vonnegut, 1963). However, such collapses at a human scale are common.

It is clear that in the natural world complexity evolves. The *big bang* was arguably simpler than the universe today, the planets more complex than dust from which the condensed and contemporary organisms more complex than cyanobacteria. Historical emergence builds the foundation for the instantaneous emergence of the "now." However, it is unclear to what extent both forms of emergence need to be represented in a simulation to produce persuasive results. My use of the adjective "creative" in the title refers to those emergences which serve as primitives for yet higher levels of emergence. They may perform this function autonomously as long as the causal infrastructure of their creation, from primitive to emergence, is maintained. Alternatively, they may perform it by proxy if their form and functionality can be captured in some other medium and the causal infrastructure of their creation is abandoned[3]. This is particularly likely if the maintenance of their proxy is less costly than the maintenance of the infrastructure of their creation, but other factors may come into play due to the different physical properties of that new medium. The evolution of an efficient route between A and B is replaced by its proxy: a well travelled path, a cleared path, a road. Mutually tolerated theft may lead to trade, a market, a designated market place. The relative advantages of autonomous emergences requiring high maintenance versus proxy emergences requiring low maintenance (as well as intermediate states) depend upon the circumstances in which they are embedded. Again it is interesting to look at science fiction to illustrate the point: Computist Paul Durham has created an artificial world called Elysium. Within it he has programmed two *artificial cultures*, Permutation City and the Autoverse. The inhabitants of Permutation City are modeled on their creators and called Copies. They resemble humans but are constructed of *ad hoc* rules and equations patched in at a high level, without the historical or instantaneous emergent structures that support their "originals" in the natural world. By contrast, inhabitants of the Autoverse, called Lambertians, evolved from a mutated artificial bacterium *in situ* and thus share their computational space with all the historical and instantaneous emergences that created them. Clocks for these two *artificial cultures* tick at different rates. Seven thousand years in Permutation City allow three billion years to pass in the Autoverse. The Autoverse, because of the thick richness of its emergences, evolves, while Permutation City, due to its thin superficiality, does not (Egan, 1994).

At the level of simulating living and human systems, maintaining representations of all the preceding and underlying levels of historical and instantaneous emergence is untenable. In this sense all our social science simulation models float, like Copies, upon a cloud of compromised reality. In creating increasingly immersive and compelling models, in suspending disbelief, we run the risk of ignoring this. In creating so-called "cultures" of software agents, we must be constantly aware that there is nothing underneath that cloud. Perhaps our scientific and commercial agents should be sustained by historical and instantaneous emergence from the bottom-up, evolved solely from the primitives in the computational universe that they inhabit. How might we best create an environment for their constructive coevolution with humans?

In The *Emergence of Everything*, 28 steps of historical emergence are identified (Morowitz, 2002). Little, if any, discussion is devoted to the emergence of the instant. However, it is useful to look at his last six steps to see the scope of the challenge for understanding culture:

- Hominization and Competitive Exclusion.
- Toolmaking.
- Language.
- Agriculture.
- Technology and Urbanization.
- Philosophy.

Culture

"Culture" is a term that has enjoyed a profound freedom in its use and meaning, dancing here and there to the tempo of political correctness and situational ethics. As a mark of status and distinction, it's a thing to which you might aspire to, or oppose. Culture in this sense is what is spoken of in circles of the arts, film, music, literature and fashion. It is the "culture" preserved in museums, galleries, heritage sites, and tourist brochures. In a world where political correctness demands that we respect cultural traditions and differences (c.f. Star Trek's *prime directive*), it is ironically only those things about an "other" people that we find interesting and worthy of preservation from our own perspective that we call "culture." Lightheartedly, "culture" is everything we've got that our primate ancestors and relatives don't. What is it then?

Heralded as "a monumental work of historical and critical analysis," two prominent anthropologists, Alfred Kroeber and Clyde Kluckhohn published *Culture – A Critical Review of Concepts and Definitions* (Kroeber, 1963). Finding the origin of the word in its anthropological and technical sense in 1871, they trace its slow disassociation from the concepts of cultivation and civilization and from this research extract taxonomy of meanings: the margins will therefore be as follows:

- Descriptive: enumeration of content.
- Historical: social heritage or tradition.
- Normative: rules, ways, ideas & values plus behaviors.
- Psychological: a problem solving device, learning, habit, attitudinal relationships among men.
- Structural: pattern and organization.
- Genetic: product or artifact, ideas, symbols, what distinguishes us from animals.

To those engaged in *artificial life* or *artificial societies* the term *artificial culture* evokes a scientific confrontation, the challenge of simulating emergence at the top of the scale of dynamical hierarchical synthesis. To many anthropologists, humanists and social scientists alike, largely unaware of the advances and potentials of *complex adaptive systems* and *evolutionary computation*, the term *artificial culture* stirs up apprehension. Some resent the intrusion of Western technology into the lives of "their people," promoting "cultural relativism," the privileging of "their peoples'"

[3] See Koza et al. 2005 on automatically defined functions, etc.

epistemological and ontological views of the world over that of "Western science." Others express amusement, derisively observing that culture is, by its very definition, artificial, and that the phrase is thus redundant and consequently sterile. Others in the "cultural studies of science" focus on narrative and discursive strategies of explanation. Some use traditional mindsets to study people who write and use simulations, but our goal is to use evolutionary and computational mindsets to study people by writing and using simulations. Opponents of a science of culture frequently call themselves *postmodernists*, not realizing that postmodernism originally did not discount scientific knowledge. A program of *artificial culture* is more closely allied to a *posthumanist* view (Hayles, 1999:2-3).

Reputation

Cognizers are those *things-that-think*, known or unknown, real or imagined, that occupy a person's head. They may also extended beyond a person's head to include observed behavior, material artifacts such as a tally stick, a knotted cord (quipu), an abacus or computer and the larger spatial architecture of a home or workplace. Without limiting the generality of the above, cognizers include beliefs, goals, plans, actions, images, algorithms, languages, observations, performances, desires, emotions, memories, dreams, fantasies, etc. Cognizers, such as those for reputation, and their referents change at different times and in different situations. How are reputations formed, mediated and communicated? How are they manipulated? Which are necessary and sufficient to explain the origins and maintenance of cooperation and competition in a scientific simulation?

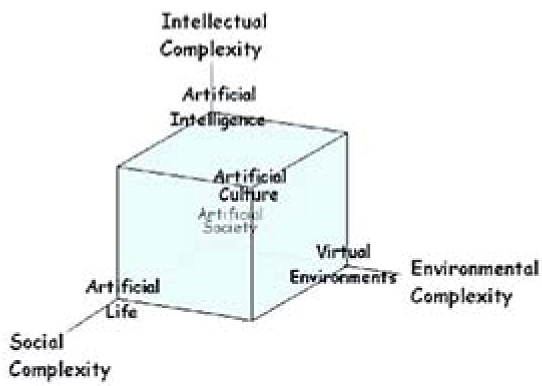
The fitness (maintenance and origin) of any naturally or artificially synthesized dynamical hierarchy rests upon the fitness of the structure of its emergences and the fitness of the primitives that give rise to it. In the cultural domain these factors are likely to be widely variable and unevenly distributed in space and time. Cultural organization is conditional upon its individuals being recognized as "same" by one another, and the acquisition by each of information about others. Such information, arising from personal or exchanged experience, constitutes a database of trustworthiness, credibility or "reputation." The human operations of creating, maintaining, manipulating and leveling reputations are complex. But the human individual is not the only level at which reputation resides. Agency may be invoked at many levels in a cultural setting. Below the individual they might include agents in a cognitive society-of-mind. Above the individual they might include groups, their artifacts and behaviors. Reputation is an attribute of agents at all these levels. Thoughts and institutions have their reputations too. Reputation does not come free. Misinformation and disinformation mingle coadaptively with uncorrupted information flow. Reputation percolates through mazes of cognizers, individuals, groups, artifacts and behaviors. Consequently, we should not be surprised to find reputation represented in more than one cultural medium, each adapted to a different niche or competing for the same niche.

Cognitive reputational schemes, natural or artificial, embodied in the mind or in the material artifactual world, each have concomitant costs and benefits. The cognitive load (cost) of any particular medium of representing reputation is offset by its performance (benefit) in calculating fitness. The cognitive compression of reputation can be beneficial. But as much as cognitive compressions bring with them opportunities for creating yet more highly nested constellations of emergences, literally emergences of emergences, they have a down-side. In compressing, encapsulating and simplifying representations of reputation, they leave behind the mechanisms of their origin and maintenance, and may lose relevance in their new instantiations. Cognitive algorithms are emergent processes and are subject to the same caveats introduced in the previous discussion of historical versus instantaneous emergence. Each time an emergence is captured as a primitive for a higher level of emergence, it looses its infrastructure, and floats like a cloud in a thin atmosphere.

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 complexity, describing it and calculating its entailments. On the other, we must examine the empirical world with freshly recalibrated eyes. The two are intimately intertwined, for without an adequate language of description and synthesis, complexity will always lie just outside our ken, and without direct confirmation from the real world, complexity will simply be an empty speculation. The psychology of perception implies that in the absence of a formal way of describing and talking about complexity one is likely not to recognize it in the world, and to settle for a simpler misperception. Empirically, things that we do not understand, we often do not see. Innovation in science requires new ways of looking at the world and new ways of looking at old theories and old data. Discovery is seeing what has not previously been seen.

Artificial Culture

Artificial culture has been outlined in several previous publications (Gessler, 1994, 1995, 1996, 2003). It would not only advance cultural theory in anthropology but also provide useful analogies and metaphors for research in *evolutionary computation* (Bäck, et al. 1997). It should provide *evolutionary computation* with new cultural metaphors and analogies which will broaden historical reliance on biological analogies to evolution. For anthropology, it should provide *cultural theory* with a realistic computational framework for describing, synthesizing, experimenting and assessing the entailments of a variety of human complex systems. It would answer the skeptic's taunt, "If you really know how culture works, then build me one!" Culture is technically complex. Should our explanations of it be less so? We can distinguish three major levels of cultural complexity. Within each human head we find a multiagent multimodularity of thoughts insightfully explored in *The Society of Mind* (Minsky, 1985) and *The Adapted Mind* (Borkow, 1992). Among human heads (among individuals) we find a *distributed cultural cognition* (Hutchins, 1995) dispersed among individuals, groups and institutions, as well as in their physical artifacts, workplaces, architectures and settlements. Cognition is rarely the entire picture, so the dynamics of work, matter and energy exchanges among individuals, groups and their technologies may be equally important. *Artificial culture* seeks a minimal representation of objects and processes, a small core set of functionalities that are essential in explaining the desired aspects of the origins and evolution of culture. It builds upon the practices of *artificial life* and *artificial societies* by imbuing its primitives with a richer mix of intellectual, social and environmental primitives, necessary and sufficient to give rise to cultural complexity. It is useful to visualize *artificial culture* as the corner of a cube, situated in space equidistant from the major axes of *artificial intelligence*, *artificial life* and *virtual environments*. In this position, it distributes the computational load of simulation equally among those three schools of complexity.



Artificial culture can be an experimental vehicle for discovering what it minimally takes to build a culture, a desktop laboratory for evaluating theory against empirical observations by exploring alternative "what if" scenarios. I do not expect it to be predictive in fine detail, but I do expect that it will be insightful in helping us to separate those explanations that are viable from those that are not. If we can develop new approaches to social science theory by building leveraged computational models, models containing the minimal key features that produce maximal results, we can expect to advance both *evolutionary computation* and *cultural theory*.

Evolutionary computation is the convergence of a diverse collection of *evolutionary algorithms*. It embraces the historically separate trajectories of *genetic algorithms*, *evolutionary strategies*, *evolutionary programming*, *cultural algorithms* and *genetic programming* (Fogel, 1998) in a cooperative enterprise to automatically construct *dynamical hierarchies*. Under the rubric of a *computational synthesis*, it seeks, "formal algorithmic procedures that combine low-level building blocks or features to achieve given arbitrary high-level functionality" (Lipson, 2002). *Cultural theory* is an explicitly scientific enterprise in anthropology, a field that has traditionally had roots in both the sciences and the humanities. *Cultural theory* has made measured progress towards a *Science of Culture* (Harris, 1979). Anthropology has also been traditionally divided over the relative importance of cognition versus materiality in cultural causation. Two anthropologists have been particularly influential in articulating these relationships as "cultural materialism" (Harris, 1979 & 1998) and "culture processs" (Binford, 2001)[4]. A third expatriate anthropologist has extended cognition to the physicality of real-world artifacts. Material culture has too often been neglected.

> 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).

The "holy grail" of *artificial life* research is arguably understanding the bottom-up and top-down exchanges between local and global levels of complex adaptive systems, as each provokes emergences and constraints upon the other. This is also the goal of simulation in sociology, economics, political science, and anthropology.

> (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).

Despite our tendency to speak about "the culture" of a people, culture is more than the often-cited "body of shared ideas and behaviors." That "sharedness" is not a sufficient explanation of cultural dynamics. Cross-cutting shared concepts are abundant divergences and disagreements that are often the animating factors in exchanges, negotiations and the flow and quality of goods and information. Culture has eloquently been described as the 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).

Fortunately, we are not fully enslaved by the languages, words, beliefs or categories that we generate and use to formulate our responses to the world. We recognize and distinguish many more differences in objects and behaviors than we have symbols to express them. In natural language metaphors and modifiers push and pull words in one direction or another to disambiguate their referents and meanings. Natural language is only one system of representation and reasoning, and although we accord it great respect, we must remember that each medium of representation has its distinctive costs and benefits. Each has its specificities and

[4] For opponents of these views see Geertz 1977 and Hodder 2001.

ambiguities, its own channel width and physical and energy requirements. Without pretending to understand how the mind speaks to itself, I think it is clear that thoughts also flow through images and diagrams, gestures and emotions, a gentle touch and a bop on the head. Science is a formalization of these more intuitive media of description and evaluation which grows by inventing new practices of representation and confirmation. Science has become the art of building increasingly reliable, comprehensive and economical representations of the world. Just as some modes of representation are more useful when confined to the mind of a human individual (e.g. meditation), others are more useful for exchanging information between individual minds (e.g. spoken discourse). Mathematics inhabits both our minds and our technologies. Computational simulation alone entrusts representations to the minds of our machines. The downside of the mind of the machine is that it is beyond the ken of those who do not reason with machines. "If you can't wrap your mind around it intuitively, if you can't understand it without a machine, how can you call it an explanation?" It is unlikely that this epistemological myopia will change. I won't attempt a rebuttal here, but will simply echo Jay Forrester's audacious claim:

> It is my basic theme that the human mind is not adapted to interpreting how social systems behave. Our social systems belong to the class called multi-loop nonlinear feedback systems. In the long history of evolution it has not been necessary for man to understand these systems until very recent historical times. Evolutionary processes have not given us the mental skill needed to properly interpret the dynamic behavior of the systems of which we have now become a part.
>
> In addition, the social sciences have fallen into some mistaken "scientific" practices which compound man's natural shortcomings. Computers are often being used for what the computer does poorly and the human mind does well. At the same time the human mind is being used for what the human mind does poorly and the computer does well. Even worse, impossible tasks are attempted while achievable and important goals are ignored. (Forrester, 1971:61).

Human cognition, whether biologically or culturally determined, is a composite of representations, 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. Marvin Minsky invokes a cultural (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 cogently argues that intelligence and representation are not necessary for purposeful action. He eats away at our conventional wisdom of what comprises 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 mind and culture offer new challenges to both social and computer science. The anthropologist may frame cultural explanations using advanced computational modeling. The evolutionary computist may invoke the complexities of culture in designing new algorithms for creativity and optimization.

Anthropology ambitiously makes claim to the entire domain of human cultural evolution, from our primate ancestors through small-group hunter-gatherers to civilized society and the global institutions of our present. It also often advocates a holistic view of culture. Consequently, anthropologists have repeatedly tried to transcend short-term historical particulars by contemplating the major factors that advanced our cultures to their present reflexive state of complexity (Boyd & Richerson, 1988, Johnson & Earle, 1988). A no less ambitious book attempting to find commonalities among all "Living Systems" was published a decade earlier. It won this 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 "computist" and the "thinking machine" (Anon, 1950) and the recent publication of a milestone book on an *artificial society* known as Sugarscape (Epstein & Axtell, 1996 and Gessler, 1996), we should finally begin to translate this limited discursive theorizing into robust computational models in an effort to create a fledgling *artificial culture*.

A Grand Challenge

Two conferences were recently held on the ontological and epistemological convergences between evolutionary and computational thought. The first was in connection with the Eighth International Conference on Artificial Life in Sydney, a workshop on "Computational Synthesis: From Basic Building Blocks to High Level Functionality". The second was in connection with the American Association for Artificial Intelligence Spring 2003 Symposium in Stanford, a workshop on "Modeling Dynamical Hierarchies in Artificial Life." Based upon discussions at these workshops, the challenge of *artificial culture* should be to explore models of dynamical hierarchical emergence in which selection is free to operate concurrently at different levels of complexity (cognitive agents, individuals and groups). This implies a connectedness between different informational media (ideational, behavioral and physical) as well as a fluid scheme for allocating the membership of agents to a variety of levels. Interactions need to be further mediated by space and time. Within this milieu of connections, reputations will be free to form and flow among individuals, and they will be captured (frozen with some loss of information about their formation) for subsequent reuse. In other words, the simulation must include functionality for the formulation of the reputation of each cognitive, individual and group agent by those same agents, as well as the reliability of that information. Individuals make their own choices of partners or groups with whom to cooperate, based upon their individual beliefs and perceptions of categories of group membership. Individuals are free to display informative, misinformative or disinformative cues about those affiliations and reputations, or not. It is important to explore the coevolution of cultural *things-that-think* and things-that-work: the cognitive, material and energetic exchanges that are the minimal elements of an *artificial culture*. How complex do simulation primitives need to be, how rich do embedded emergences need to be, in order to foster further hierarchical emergences? No one really knows.

A theoretical model is no better than the empirical observations that it attempts to explain. While detailed accurate, precise and repeatable prediction is too much to expect from a minimal *artificial culture*, prediction in the sense of building an insightful envelope of possibilities is a sufficient goal. Anticipating the criticism that such models are only "toy" explanations, I would ask how many of our discursive or mathematical models of social processes are any more than "toy?" The world is always much richer than simulations, and we must strike a balance between what is small and insightful and what is large and cumbersome. In short, our models must be guides to, not substitutes for, the empirical world:

> "That's another thing we've learned from your Nation," said Mein Herr, "map-making. But we've carried it much further than you. What do you consider the largest map that would be really useful?"
>
> *"About six inches to the mile."*
>
> "Only six inches!" exclaimed Mein Herr. "We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!"
>
> *"Have you used it much?" I enquired.*
>
> "It has never been spread out, yet," said Mein Herr: "the farmers objected: they said it would cover the whole country, and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well. (Carroll, 1982:727).

After nearly two decades of archaeological, ethnohistorical and ethnographic research among the Haida hunter-fisher-gatherers of the Pacific Northwest Coast, I could find no adequate single-cause explanation of culture change. Various lines of empirical investigation show abundant evidence for complexly shifting factors coming into play from pre-European contact days (circa 1750) to the present, a period of 250 years of cultural evolution. Early records were limited in scope, and observers "spun" assorted biases into their observations, but there are many clear indications of tipping-points and small events leading to major structural changes. Historical specificities continually spawn irreversible emergences, echoing the properties of chaotic systems: sensitivity to initial (and subsequent) conditions.

Clearly, developing a program of *artificial culture* will not be an easy undertaking. No single implementation of a simulation is likely to address more than a few of the unique processes extant in cultural evolution. Nevertheless it is important to develop examples of how these processes build creative emergences culminating in the variety of complex cultural systems we see today. Although the origins of culture may be traced back to our hominid ancestors 4.4 million years ago and are beyond the scope of this paper, Lovejoy's articulation of an "emergent adaptive suite" of causally interrelated processes is prescient (Lovejoy, 2009) precisely because these processes break the boundaries among biology, behavior and technology, all arguably elements of proto-culture. In much the same way, the processes of culture and emergence that I have discussed form a culturally emergent adaptive suite. What we initially need are simulations which explore information processing and storage across media (intermediation), matter and energy processing and storage across industries (technology) and patterns and modalities of emergence across levels (creative emergence). Researchers in *evolutionary computation* will often tell you that breaking a problem into simpler modules precludes much of the potential for finding optimal solutions for the larger problem. Creativity and innovation in evolution often result from finding and exploiting unlikely coevolutionary interactions. A striking example is endosymbiosis, the evolution from prokaryotes to eukaryotes as the symbiotic inclusion of one species inside the body of another. When boundaries become permeable, causation may become complicated. Evolutionary computists Karl Sims, John Koza and David Fogel have casually characterized the code underlying successfully evolved complex entities as unintelligible, incoherent and diffuse[5]. Perhaps culture is no less messy underneath.

The grand challenge is to synthesize a system rich in the physicality of its components, letting boundaries dynamically evolve with minimal human intervention. In order to accomplish this, a minimal *artificial culture* should be seeded with a population of individuals, each with the properties of age, sex and parentage, and situated in a physical environment with both space and time. Each should initially have four potentially competing goals: food, shelter, security and reproduction. Cooperative associations should be free to form among causal agents at the cognitive, individual and group levels. At each level a dynamically derived fitness value should be computed. As individuals and groups interact, hierarchical selection is likely to emerge, although it may be difficult to identify because of the shifting boundaries of the units of selection. Fitness advantages and disadvantages should accrue to each level of selection. Social structures would likely form around basic friendship and kinship-derived privileges and obligations, *theories of mind*, observed behaviors, as well as the accrued prestige, credit ratings and reputations of individuals and groups. Information acquired first-hand or second-hand from individuals should be tagged as such. Information about information, in expectation that the reputation of information will also be an important commodity, should also be kept. The perception of boundaries among associated cognitions, individuals, groups and artifacts are expected to be different for each individual.

I hope that incorporating many of these processes into simulations which exhibit limited historical and instantaneous emergence will help to foster proxied (intermediated) creative emergences, offering new rungs on which cultural theory may climb to look back upon the evolution and origins of culture.

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