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The Emergence of Reputation in Natural and Artificial Cultures

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Abstract

Empirically, culture is the complex product of ideas, individuals, groups, artifacts, and architectures, as well as their interactions. These elements of culture are differentially distributed. Each culture is 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 among people, their behaviors and the products of their technology. Culture is the product that emerges, through *dynamical hierarchical synthesis*, from such unruly things (thoughts, people, groups, artifacts and architectures). 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. Largely intractable to traditional discursive and mathematical representations, the "new sciences of complexity" offer some promising alternatives. Beginning about 1950, we created computational languages for describing, explaining and understanding these dynamic intricacies. *Artificial culture*[1] is a program that extends the trajectory that began with distributed *artificial intelligence* and arose through *artificial life* to *artificial society*, towards a new social scientific practice. At once creative and critical, empirically informed and experimental, a*rtificial culture* is the project of creating new theory compatible with complex computational simulations. Much existing discursive and mathematical cultural theory may be amenable to translation; much may need to be completely recast. In short, we encode a multitude of agents, along with their social and physical environments, inside a simulation, a process enabling 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 nature allow us to evaluate spaces of alternative counterfactual "what if" scenarios by observing the entailments of different 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 phenomena of instantaneous and historical emergence and the epistemological convergence between evolution and computation, such investigations offer rich new insights into the complexities of distributed cultural cognition, the intermediation between humans and their technologies, and the evolution of the myriad variety of cultural-*things-that-think*[2] and work. Vital to the evolution of culture is the practice of learning about the reliability of other individuals and exchanging that information, the process that builds reputation. A*rtificial culture* enables us to experiment with the coevolution of reputation and other processes in natural culture, but presents us with a new critical perspective with which to evaluate the role of agent reputation in other artificial worlds.

METAPHORS AND MEDIA

Although cultural evolution clearly outpaces genetic evolution in the natural world, it does so only to the degree with 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 about 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 is limited 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 assume that cultural processes will be quicker than genetic ones when evolution runs in simulation. Computational algorithms modeled on culture may well run faster than those 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. 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 in physics, chemistry or biology, and certainly in many cases 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 one? In creating a*rtificial 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 inspirations 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 new and different meanings for so-called cultures of software agents? Can they really be "cultural agents" if they are 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 recent workshops have focused on creating increasingly higher levels of emergence[3, 4].

> 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 meaningfully distinct, senses. We may talk about it historically, as the emergence of everything from the beginning of time to the present, and we may talk about it instantaneously, as the 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. However, if at this instant, sub-atomic particles should change their nature, all instants 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). The consequences are quite devastating. However, such collapses at a human scale are not 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. 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 algorithms 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 becomes 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 critique. In creating so-called cultures of software agents, we must be constantly aware that there is nothing underneath the cloud. Perhaps our scientific and commercial agents might be sustained by historical and instantaneous emergence from the bottom-up, evolved solely from the primitives of the computational universe that they inhabit. How might they best grow to serve both themselves and us? 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 for insights into the origins of culture:

- Hominization & 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 you might aspire to, or not. Culture in this sense is the "culture" spoken of in circles of the arts, film, music, literature and fashion. It is the "culture" preserved in museums, galleries, lists of 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 only those things about an "other" people that we find interesting and worthy of preservation that we call "culture." Those things that we find morally or ethically repugnant we call something else. From the perspective of a science of the evolution of us humans from our primate forebears, "culture" must necessarily embrace a much broader meaning. Lightheartedly, "culture" is everything we've got that primates 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). Establishing 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 to a more universal taxonomy of meanings:

- Descriptive: enumeration of content.
- Historical: social heritage or tradition.
- Normative: rules and ways.
- Normative: ideals or values plus behaviors.
- Psychological: adjustment, a problem solving device.
- Psychological: Learning.
- Psychological: Habit.
- Psychological: Attitudinal relationships among men.
- Structural: Pattern and organization.
- Genetic: Product or artifact.
- Genetic: Ideas.
- Genetic: Symbols.
- Genetic: What distinguishes us from animals.

To those engaged in *artificial life* or *artificial societies* the term *artificial culture* evokes a scientific confrontation with the challenge of simulating emergence at the top of the scale of dynamical hierarchical synthesis. To many anthropologists, 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," privileging "their people's'" epistemological and ontological views of the world over those of "Western science." Adherents to this practice of cultural relativism are unfortunately quite influential. Other anthropologists express amusement, derisively observing that culture is, by its very definition, artificial, and that the phrase is thus redundant and consequently sterile. Many involved in so-called "cultural studies of science" claim to occupy a higher intellectual ground. Their descriptions of culture are largely narrative and discursive and their epistemological stance often pre-evolutionary and pre-computational. Whereas they use traditional mindsets to study people who write and use simulations, our goal is to use evolutionary and computational mindsets to study people by writing and using simulations. Anthropological opponents of a science of culture frequently call themselves *postmodernists,* not realizing that postmodernism does not consistently discount scientific knowledge. The 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 or quipu, an abacus or computer and the larger spatial architecture of a home or workplace. Without trying to limit the generality of the above, cognizers would include beliefs, goals, plans, actions, images, algorithms, languages, observations, performances, desires, emotions, memories, dreams, fantasies, etc. Cognizers, and the instances that they refer to, have different "values" at different times and in different situations. Such evaluations of their referents' usefulness might appropriately be called reputations. The key questions are, of course, how are reputations formed and communicated, how are they manipulated and which are necessary and sufficient to investigate the origins and maintenance of cultural cooperation in a scientific simulation, or the mediated flow of goods and information in a commercial setting?

The fitness (origin and maintenance) 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 them. In the cultural domain these are likely to be widely varied and unevenly distributed in space and time. Cultural organization is conditional upon the individuals in a population being recognized by one another, and the acquisition by each individual of information about others. Such information, whether arising from personal experience or exchange, constructs a database of trustworthiness, credibility or "reputation" of other individuals. Reputation may be shaped from first-hand observations, gossip, material associations or more formal exchanges of information. The human options for creating, maintaining, manipulating and leveling reputations are complex and cannot be ignored. But the human individual is not the only level at which the reputation of agents may be essential. Agency, and thus agents, may be reasonably invoked at many levels in a cultural setting. Below the level of the individual they might include agents in a cognitive society-of-mind. Above the level of the individual they might include groups, their artifacts and behaviors. Reputation could profitably be considered as attributes of agents at all these levels; thoughts and institutions have their reputations too.

Keeping tabs on reputations does not come free. Misinformation and disinformation mingle coadaptively with uncorrupted information flow. Reputation circulates through overlapping 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 in multiple media 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 means and medium of representing reputation is mitigated by its performance (benefit) in confronting fitness. Cognitive compression of reputational information can be beneficial. But in as much as such reductions in load bring with them opportunities for managing yet more highly nested constellations of emergences, literally emergences of emergences, the down-side is that in encapsulating and simplifying these compressions, we loose the mechanisms of their creation and maintenance. Since cognitive algorithms are emergent processes they too are subject to the same caveats introduced in the previous discussion of historical versus instantive emergence. As pointed out earlier, each time an emergence is captured as a primitive for a higher level, it looses its infrastructure, and floats like a cloud with no underlying support.

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 lay just outside our ken, and without direct confirmation from the real world, complexity will simply be an esoteric speculation. The psychology of perception implies that in the absence of a formal way of representing and talking about complexity one is likely to not recognize it at all, and consequently settle for some gross simplification of events. In the empirical world those things that we do not understand often go unrecognized, or if recognized are readily dismissed as noise. We simply do not see what we are not looking for. Innovation in science thus 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.

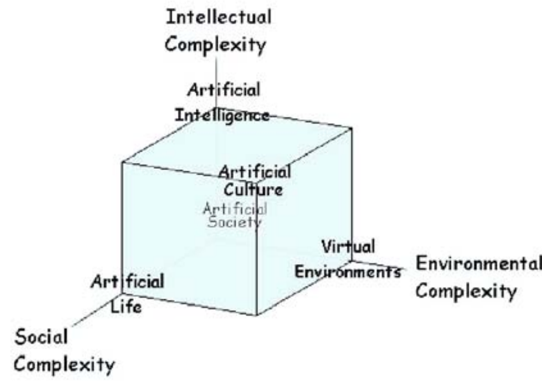
ARTIFICIAL CULTURE

Empirically, culture is the product of individuals, artifacts, and their interactions at increasingly emergent levels of complexity. Variation is its omnipresent hallmark: Cultures are different. Its members are different. Its members' heads are filled with thoughts that are different (Minsky 1985, Brooks 1999). Moreover, people not only think and work, they make things that think and work. Thus cognition and behavior are distributed among both people and their technologies. Culture emerges through complex multiagent webs of mutual causation, through 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.)
>
> Humans create their cognitive powers by creating the environments in which they exercise those powers. (Hutchins 1995: xvi)

Artificial culture has been outlined in several previous publications (Gessler 1994, 1995, 1996, 1998, 2003, 2004). It seems that a program of *artificial culture* could not only advance cultural theory in anthropology but also could provide useful analogies and metaphors for research in *evolutionary computation* (Bäck, Fogel and Michalewicz 1997). It should provide *evolutionary computation* with new cultural metaphors and analogies, which could broaden its historical reliance on biological analogs 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. We can distinguish at least three important levels of cultural complexity. Within each human head we should anticipate a multiagent modularity of thoughts as insightfully explored in *The Society of Mind* (Minsky 1985) and *The Adapted Mind* (Borkow 1992). Among human heads (among individuals) we should anticipate a *distributed cultural cognition* (Hutchins 1995) dispersed among individuals, groups and institutions, as well as their material artifacts, workplaces, architectures and settlements. Cognition, however, is not the entire picture, so the dynamics of work, matter and energy exchanges among individuals, groups and their technologies are equally important. *Artificial culture* seeks a minimal representation of objects and processes, a small core set of functionalities that are essential in explaining aspects of the origins and evolution of culture, our uniquely human adaptation to our natural, and artificially enhanced, social and physical environments. *Artificial culture* builds upon the paradigms of *artificial life* and *artificial societies* by imbuing its constituents with a balanced mix of intellectual, social and environmental primitives both necessary and sufficient to give rise to cultural complexity. It is useful to visualize it at the corner of a cube, situated in space equidistant from the major paradigms of *artificial intelligence*, *artificial life* and *virtual environments*. At this position, it seeks to distribute the computational load of the simulation equally among those three sources of complexity. It is expected that *artificial culture* can be an experimental vehicle for discovering what it minimally takes to build a culture as well as 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 have the 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 (Harris 1979, Binford 2001). A third expatriate anthropologist has extended the modules of cognition to entangle them with the complexities real-world artifacts. Material culture has too often been neglected. The following passage reminds us that 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)

The "holy grail" of *artificial life* research is often cited as 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. So too is it the "holy grail" 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 not the often-cited "body of shared ideas and behaviors." While shared meanings and materials are essential requisites of culture, they are necessary, but not sufficient, to explain the entirety of cultural dynamics. Among shared concepts there 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 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)

Fortunately, we are not fully slaves to the languages, words, beliefs or categories that we generate and use to compute our responses to the world. We recognize and distinguish many more differences in objects and behaviors than there are symbols to express them. In natural language metaphors and other modifiers push or pull ambiguous words in one direction or another to disambiguate their referents and meanings. Natural language is only one system of representation, reasoning and calculation, and although we accord it great respect, we must remember that each mode of representation has its distinctive costs and benefits. Each has its accuracies and ambiguities, channel width and material and energy requirements. Without pretending to understand how the mind speaks to itself, how it thinks behind the silent voice inside it, it should be clear that thoughts can also be invoked as images, diagrams and gestures, as emotions, a touch or a bop on the head. Science may be considered as the formalization of these more intuitive modes of description and evaluation by inventing new practices of representation and confirmation. Through mathematics and computation, science has become the art of building increasingly reliable, comprehensive and economical representations of the world. Just as some modes of representation may be more useful when housed in the single mind of a human individual (e.g. meditation), others may be more useful for exchanging information between individual minds (e.g. spoken discourse). Mathematics inhabits both our minds and our technologies. Computational simulation uniquely entrusts representations to the minds of our machines. The downside is that simulation is beyond the ken of those who do not reason with machines. *Artificial culture* often invites the quip: "If you can't wrap your mind around it as an individual, if you can't understand it without the 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 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. 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)

I must confess to taking a similarly entangled, though less accomplished, approach to the subjects of *artificial culture* and reputation in this paper. Rodney Brooks cogently argues that intelligence and representation are not necessary for purposeful action. He eats away at our conventional wisdom of what constitutes 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 science and computation. 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 lays academic 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 and future. It also advocates a holistic view of culture. Consequently, anthropologists have repeatedly tried to transcend short-term historical particulars and contemplate 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, Gessler 1996), that we should 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"[3]. 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."[4] Based upon discussions at these workshops, the challenge of *artificial culture* will be to explore models of dynamical hierarchical emergence where selection is free to operate concurrently at different levels of complexity (cognitive agents, individuals and groups). This also implies a connectedness between different informational media (ideational, behavioral and material) as well as a somewhat fluid scheme for discerning the membership of agents in a variety of groups. Interactions need to be further mediated by space and time. Within this milieu of connections reputations will be free to form and be communicated among individuals as well as captured (frozen with a loss of information about their formation) for subsequent reuse. In other words, the simulation must include dynamic measures of the competitive fitness of each cognitive, individual and group agent as well as the potential for information being collected on the strengths of each agent's associations with other causative agents. Individuals make their own choices of partners or groups to cooperate with or not, based upon their individual beliefs and perceptions of categories of group membership. Individuals are free to display informative or disinformative cues as to those affiliations and reputations. 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 such a project. The first was a deconstruction of the concept of "carrying capacity" showing that foraging efficiency depends upon a myriad of factors that lay beyond the simple normative calculation of population size, per capita daily food consumption and the total food in a region. These include, but are by no means limited to, the pattern of the food resource distribution, search strategies utilized by the individuals and their daily food acquisition quota. Each of these local factors has a significant effect on the group's ability to access all the food that is globally available[5]. The second simulation 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 originally framed as "kinship," the simulation is easily expandable to account for any configuration of networked or other relationship based upon membership[6]. Although neither of the cited simulations are evolutionary, it should be feasible to instantiate many of the functionalities that I have outlined. What is important is exploring the coevolution of cultural things-that-think and 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, 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, 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.)

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, 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, structural changes and small events leading to grand consequences. Historical particularities continually induce emergences, reminiscent to the canon of chaos-theory: sensitivity to initial conditions.

A minimal *artificial culture* should be seeded with a population of individuals, each with the properties of age, sex and parentage, and situated in both space and time. Each should initially have four potentially competing goals: food, shelter, protection and reproduction. Cooperative associations will be free to form among agents at the cognitive, individual and group levels. At each level a dynamically derived fitness value will be computed. As individuals and groups interact, hierarchical selection is expected to emerge, although it may be difficult to identify because of the potentially shifting nature of the units of selection. Fitness advantages will accrue to different groups through successful negotiation with crosscutting sets of individuals. Cognitive structures will likely include basic friendship and kinship derived privileges and obligations, *theories of mind*, observed behaviors, as well as the accrued prestige, credit ratings and reputations of other individuals and groups. Information may be acquired either first-hand or from other individuals through exchange. Allowances should be made to facilitate reflexive second order exchanges of information, specifically information about information, in expectation that the reputation of information will also be an important commodity. The perception of boundaries among associated cognitions, individuals, groups and artifacts are expected to be different for each individual. Intermediations are anticipated, and boundaries among domains may not remain distinct. One goal of such a simulation is to allow emergences to crosscut boundaries.

Traditionally, complex problems have been confronted by breaking them down into simpler modules, solving each modular problem independently and then reuniting those solutions into one grand solution to the larger complex problem. Such a strategy has had many practical successes, but this is not the strategy that evolution takes. A striking case-in-point is the theory of endosymbiosis explaining the evolution from prokaryotes to eukaryotes as the symbiotic inclusion of one species inside the body of another. The problem with modular optimization or evolution is in the creation of boundaries between processes that might otherwise interact to produce serendipitous results. While one can posit many natural boundaries in biology, boundaries in culture are leaky if they are present at all. Creativity and innovation in evolution often rests on finding and taking advantage of unlikely coevolutionary interactions. Researchers in *evolutionary computation* will often tell you that breaking a problem down into simpler modules eliminates much of the potential for obtaining optimal solutions for the larger problem. The advantages of evolution are lost when modules are kept isolated from one another. Since boundaries are rarely clear in natural cultures and since it is precisely this kind of serendipitous creativity and innovation one wishes to understand in the evolution of culture, the grand challenge is to synthesize a system in its relative entirety letting boundaries dynamically evolve with minimal human intervention.

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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