On the Evolution of Agency and Implications for Comprehensively Modeling it

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Abstract

The basic premise of this proposed article is that agency is an evolved trait. Agency in nature exists to the degree that organisms can act independently from their environment, and is here considered to be the result of an evolutionary process that takes places hierarchically and in multiple dimensions. The article proposes further discussion on the need to create appropriate simulation methodologies that capture the multiple levels of reality, particularly in the social and biological realms. Such methodologies should allow for the joint representation of micro, meso and macro ontological levels of agency. This work proposes the methodology of Distributed Agency as a means to capture the fractal nature of the agents that may more realistically capture the contextualized interaction present in social and biological phenomena. Agency is proposed as a 'currency' in which we can express structure and information to express and eventually understand the way in which evolutionary processes interact to create the complex world we inhabit.

1. INTRODUCTION

How does anything come into existence? From its origins in classic times, the question has been reframed, reconsidered and reformulated in increasingly sophisticated terms, and although humanity has achieved significant technological feats, the essence of the epistemological and ontological question remains, particularly in the social and biological sciences. How does an agent evolve? How does nature 'decide' how much agency to grant it? The field of Modeling and Simulation (M&S) has been growing at a rapid pace in the last few decades. The advent of complexity science and the computer simulation have opened research avenues that were impossible a few years ago, as well as forced researchers to reconsider the basic premises of the reductionist paradigm on which traditional linear sciences—such as neoclassical economics and individual selection theory in evolutionary biology—are built [Beinhocker 2006].

In the emergent, nonlinear, non-reducible world of complexity, nature exists in many non-orthogonal levels, with each level potentially being governed by different laws, granularities and structure. Given this fact, it follows that evolution must also be multilayered. This conception stems directly from the core concept of complexity, in which *wholes are more than the sum of their parts* [Abbot 2006, and Bar-Yam 2004]. Describing each level of reality brings about significantly different challenges, with entities of interest that have aspects of their nature reflected in related but distinct dimensions [Tolk 2012]. More generally, the field of M&S must develop generalized methodologies that can capture these levels of reality in overarching, simultaneous models [Seck and Honig 2012].

To tackle the novel challenges and opportunities that a nonlinear view of the world provides, the M&S field has relied heavily on Multi-Agent Systems (MAS)—a growing field that is able to capture many of the emergent social phenomena that researchers are interested in exploring. However, the problem with the current MAS approach is that it is ultimately also plagued by some of the constraining assumptions of science's linear past. In particular, this work is built on the idea that the definition of agents and agency is outdated, as it does not allow for the incorporation of a fractal, hierarchical and multidimensional view of the world that the complexity paradigm has revealed.

This essay is speculative in nature. Its intent is to promote a healthy discussion of how our computational models of an evolving reality need to adapt to be able to capture the intricacies of an agent that is not clearly defined [Goldspink 2000]. If we think of a consumer as an agent, then we can think of her as an individual in one dimension, but as a member of a family unit in another dimension, just as an ant can be thought of as a unit but also as a dependent part of an anthill. If we think of a more abstract agent, such as the Republican Party in the U.S., then it quickly becomes obvious that our conception of such a social agent must allow for its description in multiple levels and dimensions. In this work, we think of a level or dimension as an arena, a canvas in which information can be stored and processed. To the degree to which such a level selects outcomes based on ordinal preference, then the claim is that it may be usefully modeled as an agent.

The idea of multiple levels of reality also has immediate repercussions for the way we think about natural selection and the evolution of organisms, norms and institutions [Hodgson 2007]. Contrary to the implicit assumptions of the traditional paradigm, real-world agents do not exist in a vacuum; agency needs to be contextualized [Edmonds 2010]. In other words, if we take the reductionist paradigm to its ultimate consequences, then the phrase "survival of the fittest" becomes tautological. We must create a framework in which a multilevel selection theory is appropriately expressed [Damuth and Heisler 1988], where selfishness is defined in terms of the survival of an organism with many (potentially 'selfish') genes [Wilson 1997a]. Sexual organisms must find mates that increase the diversity of their offspring's gene pool, making other organisms of the same species competitors in one dimension and potential reproductive partners in another.

As a natural extension of the concept of Nash Equilibrium, an *Evolutionary Stable Strategy* (ESS) is one in which any given organism acts optimally given the actions of others, while at the same time every other actor involved is performing an action that is optimal given the actions of that individual. According to the reductionist paradigm championed among others by Richard Dawkins, the world should be full of organisms following ESSs [Dawkins 2006, and Taylor and Jonker 1978]. In contrast, we argue that such a view incorrectly de-contextualizes organisms that are partly independent agents, but also partly composed of relatively independent or modular organs, and also partly belonging to groups and co-evolutionary processes that influence their decisions. We expect the world—as seen in through the lens of the nascent complexity paradigm—to be full of organisms following evolutionary unstable strategies; precisely because their agency is not absolute and reducible, but rather contextualized. In simple terms, the world is full of 'cooperating prisoners' [Axelrod 1980]. It is important to stress that, for the purpose of understanding behavior, what is considered the self is not necessarily what the physical self is, but only that which is dearest.

Moreover, if we redefine collections of individuals as operational units—such as ants forming an indivisible anthill—then we must redefine what we mean by ubiquitous concepts such as altruism and selfishness [Gilboa and Samet 1989]. Distributed Agency (DA) proposes a benchmark position in which all actions are revealed as selfish once one understands what the benefited acting agent is. Traditionally, we began with a clearly defined agent and tried to understand its actions as a maximization of objectives given constraints [Suarez and Castanón-Puga 2010]. In DA, we assume maximization occurs and then work towards the delineation of the benefited entity involved. Such an understanding of an individual as an agglomeration of relatively independent aims can serve as a starting point for a broader theory that describes the formation of complex hierarchical objects [Allen and Starr 1982], stressing the in-group vs. out-group dichotomy as it applies to evolutionary biology, but also to economics, sociology, social psychology and political science [Wilson 1999].

2. HISTORICAL BACKGROUND

In many ways, Adam Smith [Smith 1776] and Charles Darwin [Darwin 1872] can be thought of as the fathers of the paradigms that define what we now know as economics and evolutionary science. At their core, both of these disciplines are based on a selfish and unitary agent. These disciplines implicitly claim that all aggregate complexity can be traced back to the micro level of the system, without regards to the context and structure in which these agents live. Even though both paradigms have been extremely successful at explaining much of the world we live in, they now find themselves at a theoretical crossroads, brought about by the oversimplification of a unitary, well-defined, and to some degree exogenous agent used as the cornerstone of their theories. Both research agendas de-emphasize the existence of any level other than that of the individual. The idea of emergence, however, reflects the fact that different and irreducible levels of interaction will naturally arise in complex systems such as the ones studied by these disciplines [Cilliers 1998].

In structuralism [Culler 2007], the individual is ascribed little agency when compared to the group or social structure; classical economics, on the other hand, grants zero agency to upper level creatures, as the selfish actions of individuals are carried by an invisible hand to a plateau of overall organization. As it applies to evolutionary biology, this distinction represents the core of the controversy between individual selection theory and group selection theory [Wilson 1997a]. Even in the absence of any agency, an abstract upper level may be subject to evolutionary pressures, and therefore potentially malleable by its subcomponents. Standard economic representations have focused on individuals as the smallest unit or the ultimate irreducible atom of the paradigm, but such units may actually be agglomerates, the products of internal networks that deserve attention [Kahneman and Thaler 2006]. Models in these disciplines normally take either a macro or a micro approach, but not both simultaneously.

Significant advancements have been made in evolutionary biology at considering the possibility of other relevant levels [Wilson 1997b], but there is a core of proponents of the promises of reductionism who dissolve away any aggregate level to its individualistic source, or even further to the genetic level. Along this line of thought, if we see an act of altruism in nature, it is assumed that it must be because the individual performing it is expecting something in return, as in reciprocal altruism [Trivers 1971]. This reductionist thinking can also be seen in kin selection theory, which in simple terms implicitly states that if a mother gives her food away to nurture her babies, it is because a possible copy of her genes is being benefited [see, for example, Griffin and West 2002]. Traditional economics offers some instances of inter-level analysis, such as in the study of agency problems: the conflict of interest that arises from the disjointed objectives of the ultimate owners of a corporation—the stockholders—and the administrators who actually make the decisions for a company [Fama 1980].

In this article, the definition of an individual is itself brought to the forefront of the discussion, re-conceptualizing such concepts as selfishness, altruism, and rationality in a representation that recognizes the inherent subsequent decomposition of all agents. Literature on the matter has focused on broadly defining altruism as actions that negatively affect the individual who performs them while at the same time benefiting someone else. It is commonly shown in the proposed models that altruistic cooperators can survive in the end, mainly because their resulting stronger groups can defeat other groups formed by non-cooperators (see, for example, Flack and De Waal 2000, or Fletcher and Zwick 2007). With that result in mind, we can think of less myopic agents, or some created by eons of evolution, which are forced to give up their lower-level objectives in return for upper-level ones. The true altruism of natural organisms is to act today to guarantee the existence of tomorrow.

The conception proposed in this article is also heavily influenced by the groundbreaking work of Herbert Simon [Simon 1981]. Simon's work in artificial intelligence brought about the involvement of modularity and levels of selection to the discussion, transforming the watchmaker analogy, made famous by the English philosopher William Paley, into an analogy that reflects the need for robust internal subcomponents of complex entities. For evolution to work most efficiently, it must continuously and simultaneously adapt different levels of an organism. In this sense, the proposition of this work can be considered a generalization of this idea to include the conceptualization of how agency evolves in a realistic, contextualized and complex environment; one in which many different levels of agency are tinkered with, enhancing and diminishing agency in order to create a multifaceted organ, organism or group that can best exploit a changing environment.

3. DISTRIBUTED AGENCY (DA)

Agents, as they are commonly defined, are often thought of as having a high degree of agency, or even unbounded, exogenous agency. Most often, the idea of an agent refers to a human, but as we argue, humans are not necessarily units and definitely not independent. Instead, in this work we accept the possibility that a person is an agglomerate and that groups may behave as a unit. A person's incentives now may be in contradiction with the same person's incentives a year later [Schelling 1984]; alternatively, a military coalition, racial subgroup, or social class may behave as a whole with properties that emerge in the aggregate.

Most humans may commonly believe to have a lot of free will. In reality, however, humans may not necessarily possess much agency, as we may actually exemplify machine-like structures that react to the incentives presented, based on a utility function that is endogenously determined. In other words, we can think of humans as agents because they have a utility function—that is, an input-output relationship in which the inputs are the choices presented by the situation and the outputs are the choices made—but this may actually be completely controlled by the environment [Stigler 1950]. One could only dread to wonder, for example, what a suicide bomber feels as he presses the deadly button, but it must be nonetheless something that he would not have felt in the absence of social pressures. This is not exactly a standard conception of an agent, since the utility function may itself be a product of the upper levels that gave rise to it, and in this sense it is only a portion of the whole. A society may consciously decide to close its ranks, follow rules, establish norms, or stand united so that the resulting, more efficient group can more effectively compete with peer groups.

In a contextualized view of agency, the superstructure presents a set of options for what the individual can be, making some placements of the utility function 'cheaper' than others. In this sense, individuals could become unfriendly, criminals, traitors, and generally undesirable, but the society will create mechanisms to discourage such outcomes, here modeled by an 'expensive' region in the realm of action of the agent's utility function. By the same token, honorability, courage, honesty, friendliness, and all sorts of likeable characteristics will be praised and encouraged, thus modeled as 'cheap' regions. To encapsulate the complexities of a fractal, potentially hierarchical and multidimensional agent, its conception must be generalized to allow for entities that can be thought of as more or less of an agent, depending on how much autonomy they have from upper-levels and how much autocracy they have in controlling their internal lower-levels [Mandelbrot 1982]. The upper level may force lower level members into behaviors that are only optimal for the former, and it is in this sense that we can understand the behavior of an unselfish soldier.

DA redefines agents in two ways. First, in this conception there are no obvious atomic agents, for all actors represent the emerging force resulting from the organization of—potentially competing—subsets. The subcomponents in turn form an internal system that is actively reorganized, and shall be referred to as the 'lower level' of a structure. On the other hand, agents are to be described within a group to which they belong, which will be defined as the 'upper level' of the hierarchical representation, and will constrain its subcomponents' behavior. Individuals or groups of individuals may wholly or partially belong to an agent, in many different coordinates and according to drastically different definitions. The agency of a group is defined by the network that composes it, representing a system interconnected with varying intensities. The main contribution of DA is that it allows for the description of macro-level realities that are captured with a top-down model, as well as the mirco-level strategic interactions of individuals, captured accordingly with a bottom-up model [Castañón-Puga et al. 2008].

If we are to consider internally-disconnected people as well as some groups as agents, then the question becomes: To what degree are the decisions made by such an agent? To what degree is an upper-level agent simply an epiphenomenon of the actions of its subcomponents, and to what degree is it established enough to make its subcomponents behave according to its objectives? In the process of creating a multilevel, multidimensional simulation, it is imperative that we have a clear understanding of what each one of the abstract agents described actually mean, for one can otherwise fall into a trap of ascribing qualities that do not actually belong to them. An agent must not be a simple reflection of the interaction between lower levels. In other words, an aggregate agent may seem to be ruled by an external and perhaps conscious force, while in reality the patterns it describes can be completely attributed to its participant components. We must distinguish between an upper-level agent and a simple environment in which the agent finds itself, and in this sense not ascribe unreal agency to a flock of birds. With this in mind, we can think of some societies as more of an agent than others, with a society full of working institutions such as the United States as much more 'in control' of the majority of its American agents and therefore considered an agent, and a developing and relatively dysfunctional society such as Mexico as much closer to a simple aggregation of individuals.

How do we know where the agent's boundaries will appear? In other words, in light of the discussed complexities, is a tractable model possible? Perhaps the real-world, complex and chaotic nature of the elements at play will prove too extreme for direct predictions to be made. Nonetheless, we can begin by observing where these boundaries appear in reality, and then use backwards induction to portray the forces at play that could have given rise to the observed behaviors and structures. In the methodology DA, we begin with a benchmark position in which all behavior is optimal, so long as we identify the actual agent that is enforcing its will, recognizing that such will or behavior may actually be the resulting force of the interactions of several abstractly-defined and multidimensional agents. Traditionally, we have begun with a clearly defined agent and tried to understand its actions as a maximization of objectives given constraints. Here, we assume maximization occurs, and then work towards the delineation of the benefited entity involved.

In the view proposed by DA, when we arbitrarily zoom in and analyze a relatively well-defined agent, we may classify its behavior as irrational or suboptimal in relationship to its own abstract objective function, but only because we would be artificially studying it in isolation, or without regard for the struggles of its internal nature [Chavas and Cox 1993]. At the same time, the upper level may force lower level members into behaviors that are only optimal for the former, and it is in this sense that we can understand the behavior of a soldier. The 'agglomerate individual' will have to organize its subcomponents in order to maximize its objectives, since suboptimal internal coalitions can materialize, in the way a drug addict cannot overcome the desires of a strong drug-craving self, or a tyrant may force a society to extinction. For this reason, we refer to these types of intermediate agents as fuzzy agents [Suarez et al. 2008] or, based on the seminal work of Arthur Koestler, as holonic agents that are at the simultaneously part and whole [Koestler 1967, and Marik et al. 2003].

4. EVOLVED AGENTS

The idea behind a model of distributed agency stems from a view of the world in which emergence is pervasive, in which we find wholes that are irreducible to their parts, and therefore can be thought of as existing in different dimensions. In such a world, the independence that is assumed in classical statistics theory no longer applies, and a holistic approach is necessary. The methodology of holonic agents is proposed as a means for—if not explaining—at least classifying and describing the way in which "us vs. them" lines are established. In this view, the agent can represent a level of strategic decision-making, or the evolution of adaptability and responsiveness. The agent confines the subcomponents that belong to it, but at the same time it is constrained by the upper levels to which it belongs.

The agent, as is defined in this work, is both subject and object. It is a combination of levels of interaction. Organisms are thus a product both of the struggles of their ancestors, but also the reflection of an environment that begs to be exploited. They are part exogenous and part endogenous to Mother Nature. We can think of reality as a product of what exists and what wants to exist. In a similar fashion, economists think of a transaction as a product of the interplay between the abstractly defined concepts of supply and demand.

Organisms thus represent the current stage of long, recursive processes that have searched vast phase spaces to find the combination of complicit levels that sustain the information they entail. Random mutations are generally not the best tool for such processes; rather, controlled ways of adapting to an ever changing environment will naturally develop. In other words, exchanging a known successful situation for an alternative that will be drawn from an infinite space of unknown possibilities is unfeasible—too chaotic. For example, the emergence of sexuality provides a systematic way for the mixing of populations with information that has proven useful and constantly recreates the organism in order to stay ahead of predators and parasites. It also creates within-species heterogeneity which represents as many experiments as there are individuals, always looking for the best forms to exploit a given situation. We could think of an enhanced sexuality that provides other improvements to the population, such as superior genetic material that is phenotypic and recognizable.

If we optimize the nature of relationships within a group, searching an ever-changing space of possibilities in search of a kind of species that would be fittest for such an environment, what we would find is that a cooperative one would be at least as well equipped as its non-cooperative counterpart, by definition. This process, however, is not the one that actual organisms encounter, for the nonlinear world of increasing returns to scale and technological lock-in is one where history matters [Arthur 1989]. In this sense, the optimized phase space of the environment represents a series of demands for exploitation, while the existing species represent a series of supplies. When the two meet, a recursive and self-sustaining entity is produced. In this sense, we can think of evolutionary pressure as a situation in which one group of individuals is in position to mutate and fill up a niche that the environment presents. Social structures must then be analyzed in the same fashion we would think about the limb of an organism: the way in which evolution acts upon a social network must be studied just as an ethologist studies animal behavior.

Evolution is therefore not a process in which autarkic individuals compete to be the fittest, but rather a historical multiplex of intertwined levels. In this sense, the phrase "survival of the fittest" takes on a more specific meaning; it does not mean just that the genes of the best-suited individuals in a population will survive, but that the populations themselves will become more adaptable, deadlier, more complex, and all together 'more fit' at exploiting environments. Individuals are merely a part of this complex process. If we conceive of natural selection as a process which seeks to assemble a Super Bowl-conquering football team, what is important to recognize is that the rules of the game are themselves being selected, and it is in this sense that we can talk about more fit individuals, but also about more fit selection processes in which the process of adaptation is itself being fine-tuned, or, in other words, that we are witnessing the "evolution of evolvability" [Wagner 1996]. So long as these aggregates proactively 'choose' and 'coordinate' their subcomponents, the claim is that they can be usefully modeled as agents.

What is special about the organisms that inhabit today's earth? For one, they reproduce in one way or another. This is but one restriction of the countless that apply to any existing species, without which their populations would not survive long. Since these restrictions are external to the individual organism, they may be modeled as upper levels. Natural selection applies, then, not only to individuals, but just as well to groups, heuristics, species, and ecosystems. Because there is no visionary designer looking out for the correct implementation and discovery of these upper levels, it is plausible that a group as a whole will behave in ways that do not maximize its potential to keep its recursive process going;

however, those that do happen to follow strategies optimized with a longer term horizon are more likely to be observed.

In a world full of uncertainty, anything can potentially exist, but the further away from the global optimum, the less likely it will be to appear. A monopolist may have the capability of raising his price to maximize his current profits, and yet he will not be able to ignore the perils of huge profits that would entice potential competitors to break entrance barriers and storm the market. Even a tyrant may be interested in the wellbeing of his citizens [Olson and Kahkohnen 2000], since the further away he takes society from the optimum of social welfare, the more likely he is to incite a revolution. Similarly, the worse a species is at exploiting the environment, the more likely it is that it will become extinct.

Who are the agents in a hierarchically decomposed world? As we argue, organisms are not independent from the evolutionary progression of their species, both historically and looking into the future. The structures of long-term optimality appear to the organism as instincts, 'natural' drives, needs, feelings, etc. To a human, these upper levels may have even more abstract undertones, and come about as rules of thumb, superstitions, morals, conscience, ethics, implicit rules of social behavior, and the like. These 'tunnels of behavior' are reflections of the social structures that represent the optimal *scale of exploitation* of the agent. Sexual animals are incomplete. Not that they immediately die in isolation, but they will not form part of the recursive process of its species. Social animals are thus smaller pieces of a puzzle. It is interesting to note that an individual who acts in a resolute manner (that is, forced through the pre-commitment of a previous self to act in a way that is not optimal for her current self) is deemed by some as irrational; a statement which is in direct contrast with calling myopic someone who does not recognize the opportunities of intrapersonal rearrangements to achieve preferred outcomes, as when having a longer horizon on which to base a decision. In other words, what may be considered a sunk cost for an agent with a really short-term planning horizon may be part of what makes a longer-term agent optimal.

Generally, the incentives for cooperation and trade are obvious for individuals who could normally not survive in isolation [Traulsen and Nowak 2006]. The nature of atomic decision makers is one intrinsically possessing an appetite for abstract resources that social superstructures can provide. Individuals are born into predetermined arrangements. The behavior of complex organisms is not reducible to genetic coding—which only represents an adaptable basic model acquiescing to the realities presented by its species—but is also a product of its epigenetic processes, sexuality, relatedness, education, culture, and ecological immersion. Therefore, the contextualized individual will normally face a payoff structure that allows him to survive if he stays with the proposed boundaries of the upper level to which it belongs.

Aside from other incentives for joint effort (such as specialization and risk sharing), individuals mostly make decisions based on incomplete information, and often without a clear objective to maximize. Therefore, the current individual may often find herself in a position where she may evade searching for drastic, egoistic outcomes, and instead settle for strategies that have proven useful at maintaining the long-run individual alive and healthy. In the same fashion, groups that have found cooperative structures to abide by will tend to survive longer than groups that are penalizing themselves internally for lack of such coordination.

We can think of the prisoner's dilemma payoff matrix as an environment, one that cooperating humans participating in real-life experiments are better able to exploit than their unrealistic and yet 'rational' theoretical counterparts. Real humans exploit this environment better by extracting more money from the experimental researcher in charge than they would have if they did not cooperate with each other [Davis and Holt 1992, and Smith 1994]. By acting as they do, these cooperating 'prisoners' are able to exploit the hyper-productivity provided by an upper-level coalition agent. A staunch linear biologist may ask: "but how can the upper level, this cooperating group, protect itself from infection by the free-riders?" That remains an open question. But Mother Nature is savvy, and through the ages has figured out ways in which these upper levels can become more cohesive and binding to their subcomponents, thus restricting their individual agency.

Another incentive for individuals in a group to merge their incentives lies in the fact that discontented individuals have the tendency to be malicious. The payoffs of a more realistic version of the prisoner's dilemma are naturally determined by the history of the game—most importantly, whether the participants are anonymous or known participants, whether they can switch partners and by the previous experiences of the participants in the game [Joyce et al. 2006]. Non-cooperative actions can always set a precedent, with an angry participant that sets drastic reactionary payoffs, possibly to instill fear in possible rivals of future similarly afflicted selves, just as the grim reaper strategist would drastically react to engagement [Mason and Phillips 2002]. Any malicious action played against a peer can become institutionalized and potentially harmful for the meta-temporal self [Axelrod 1981].

Consider a species of ferocious animals in which the males fight for courting rights. An animal species for which deadly fights that determine rights to female access may be considered suboptimal, in the sense that both parties could benefit from avoiding the fight, if only enough information correctly assessing who would win it could be exchanged in advance [Frank 2012]. On the other hand, a brother could fight to death to avenge an attacked sister, in an act that may be considered suboptimal unless we look high enough up the ladder to find an abstract agent—such as the family's honor—for which the strategy is optimal. Such an upper-level strategy may have provided defense to the group in many occasions, but requires occasional individual action to remain a credible defensive threat [Schelling 1980].

As we relate identification and optimal (read: deadlier) scales of social groups, one of the aspects that define the formation of social groups is organized violence. This refers back to the concept of *optimal scale* for the agent, in the sense that the necessary group size is dependent on peer circumstances and auto-sufficiency constraints. Specifically, the social structure involved in conflict must procure the creation of 'altruistic' and risk-loving individuals, and be large enough to allow itself to lose some heroic sons. These expendable individuals would seem to forgo maximizing their utility functions, but only if we fail to recognize the 'cage' they are being put in by the superorganism to which they belong. In other words, meta-temporal structures in conflict will often need to be able to support subsets that take on strategies that are not sub-game perfect [Binmore and Samuelson 1994]. It is in this sense that we can think of the development of religion as an upper level that may become so strong that the subagents completely let go of their individuality, as is the case of the dreaded suicide bomber.

5. THE SIZE OF A MULTIDIMENSIONAL AGENT

The previous section explored conflict as one of the forces that may give rise to active levels of agency. Naturally, there are many other upper- as well as lower-level environmental pressures that determine the construction of all contextualized agents that we could conjure. When more than one dimension is at play, some forces will tug agents to be smaller while others will stimulate the creation of ever larger entities. It is this tradeoff that researchers such as Samuel Bowles and Jung-Kyoo Choi capture when they talk about "The Co-Evolution of Love and Hate" [Bowles and Choi 2003], as well as other related models where individuals have an incentive not to cooperate, while the group as a whole has an incentive to have cooperators that will allow it to prevail against other, less effective groups.

The concept of an intermediary agent may come to be a kernel of a new social theory of complexity that attempts to get at the root of the interplay between individuality and collectivity, structure and agency, or exploitation and exploration [Byrne 1998]. This dichotomy is one of the most important issues in the process of building a new complexity paradigm for the social and biological sciences. In terms of evolution, one may wonder what kinds of species a world would produce? Will it produce macro-organisms whose subcomponents have very little leeway for adaptation, or a myriad of microorganisms that can easily adapt, but have very little group coordination?

As Bowles and Choi model it, groups encounter incentives for internal cooperation as they prepare for battle with other groups facing similar circumstances. The battle against these peer groups can be seen as a representative example of the implications of a Darwinian evolutionary environment. More generally, we do not need such structured competition to realize that internally cooperating groups will tend to survive longer and possibly grow, as their wealth, health, and general wellbeing will be higher than those afflicted by internal conflict. Just as the process of evolution perfects individuals, the effect applies just as well to groups and societies. The surviving members of a cooperating group, however, will not be 'fittest' or 'rational' at an individual level; their individual traits and natures will make sense only within the context of the cooperating group.

All organisms are incomplete, for they only represent a link in the long recursive process that gave them life, and that forces them to maintain it. To have a meaningful life in the evolutionary sense, sexual animals are required to find a partner and mate. Many species, including all mammals, are even further constrained by the fact that the young need constant care as they grow up. In a social species, where the optimal scale of environment exploitation requires the coordination of more than one individual, a peer may possess aspects of both a competitor and a potential partner. The optimality of the upper level correspondingly implies subdividing the agents until it finds cohesive subcomponents that are cooperating or competing in nature. This phenomenon appears in treaties such as the Geneva Convention, where countries that expected to have further bloody wars accepted common laws that would benefit the global upper level. In other words, a process of morphogenesis will insure the appearance of structures that better exploit an environment, even if these require constant energy to achieve relative homeostasis [Maturana and Varela 1980]. Once these structures appear, they are ontologically undeniable.

In the multidimensional world of nonlinearity, multiple levels of agency vie for existence, and in the process create increasingly complex and robust entities. The interaction among these multileveled agencies can take on many different shapes, including, as was discussed in the previous section, all-out war. Nonetheless, even conflict may be institutionalized over time, eliciting the best aspects of competition while inhibiting the worst side-effects. The resulting structures, institutions or coalition agents that come about from these interactions can be thought of as linked by markets in which behavior can be traded, for there will always be actions that are minimally costly to one agent while extremely beneficial to another, if only because of the benefits of coordination. Traffic on both sides of the road, for example, would prove catastrophic, and so the institution of driving on one side of the road naturally arises.

We can imagine that there will almost always be benefits of social reorganization. The fact that changing a behavior will always prove cheaper for some agents than others can be understood in direct analogy to the way economics traditionally promotes the benefits of trade among nations, as the relative price of one product in terms of another will most likely be different in both places, allowing for an intermediate price at which both trading parties benefit from the transaction [Krugman 1987]. The social reorganizations produced by these behavioral exchanges will affect multiple dimensions and planning horizons to determine the size of the resulting agent, just as micro-economists analyze the decisions of a firm based on short-term and long-term marginal costs, or industrial economists understand the optimal size of a firm based upon the tradeoff of producing internally or outsourcing [Coase 2007]. A similar process may give rise to the size of an evolving agent that is begotten to exploit a specific environment.

In the complex world of the socially possible, creating the appropriate agent or cohesive group is no simple task, for the optimized phase space of possibilities represents a multidimensional moving target which may be plagued by nonlinearities [Axelrod and Cohen 2001]. Any adaptive process that aims to exploit an environment by solving such a complex optimization problem must ably manage the tradeoff of *exploitation* and *exploration*, whereby the adapted agent 'learns' how to take advantage of the aspects in which it does get closer to the global optimum (exploitation), while at the same time not 'getting stuck' too quickly in a local optimum (exploration). The adapted entity must have a way of preserving useful information as well as the capability of gathering more.

Mastering the tradeoff between exploration and exploitation stands at the core of any evolutionary process in a nonlinear setting [Hazen and Eldredge 2010]. An adapted organism or group must have solved this dilemma in at least a rudimentary way [Tallbot 2005], with a resulting composition that matches the environment in which it is conceived. Such a tradeoff applies to the composition of all aspects of a human, including the way she thinks of herself in an intertemporal sense. For example, consider a general trend for wealthy countries and regions to be located in areas of the world that have a cold season, such as the northern hemisphere or the northern part of a country like Italy, which are relatively wealthier than a southern, more template, region. One way to think about this phenomenon is to consider the planning horizon of the agents that such a changing environment will produce: a cold winter forces the summer version of human or chipmunk to be hardworking, foreseeing the harsh conditions to be facing the winter-self. In this sense, the summer-self is not considered to be much of an agent, but rather a ‘slave’ of the longer-term-horizon self. The size of the acting agent is thus larger in an environment with changing seasons. In contrast, the temperate climate does not promote this longer planning horizon, creating instead much more myopic agents. Extrapolating the idea of the size of the intertemporal agent, we can envision advanced Western societies and financial systems to be the result of these larger agents. The dark side effect of this phenomenon may be revealed in the larger suicide rates in such societies, especially as compared to the stereotypically merry tropical cultures.

Most importantly, the point to make here is that the size of the agent will be a reflection of the environment in which it exists. The tradeoff between exploitation and exploration can be captured in what could be coined as the forces of *individuality* and *collectivity*. Both of these forces are necessary for adaptation. In this view, *left* and *right* political leanings can be thought of as manifestations of this tradeoff, with the right meaning exploitation (what you *are*) and the left meaning exploration (what you *can become*). In other words, the left always has a larger conception of *us*, while the right has a smaller, less inclusive one. The size of the agent will also be determined by the nonlinear characteristics of an environment that will always discretely allow for the existence of only certain agency sizes, thus describing an optimal scale of environment exploitation. The Law of Requisite Variety, sometimes known as *Ashby's Law*, implies that the variety in the control system must be equal to or larger than the variety of the perturbations in order to achieve control. To achieve homeostasis, the agent must therefore be at least as complex as its environment [Ashby 1958].

In the process of delineating multidimensional or hierarchical agents, the forces of individuality and collectivity may be captured in terms of how they create cohesive agents of an appropriate size, and we propose the concepts of *cohesion* and *bordered maximization* to capture its essential properties. Bordered maximization refers to the process by which the size of an agent is determined, while cohesion refers to the optimal internal design of the hierarchical agent. At the aggregate level, cohesion does not imply that all lower-level actors are acting in coordination with respect to each other, but rather that an upper-level agent exists for whom the actions of the lower-level agents are considered optimal.

A corollary of this proposition implies is that an upper level may ‘want’ some of its lower-level agents to compete, and in this sense perfect competition could be ideal for the upper level that an economy represents. Complete cohesion thus exists when—given a set of constrains—there are no reorganization possibilities that will better serve an upper level, and it is therefore a relative concept. As for bordered maximization, the proposed insight is that a subset of the components of an agglomerate will attempt to maximize what we can define as their objective, or utility function, in a process that can be considered irrational, selfish or myopic from the point of view of the whole, but optimal for the acting subset.

The electoral process in a simple majority-based democracy is a prime example of a bordered maximization of objectives, in which the winning party does its best to find an objective that satisfies the desires of a social contraption attempting to win the election, and in order to do so, they must bring the majority of the population to their side. The process is naturally a very complex one, and an experienced politician may declare that no situation is ever the same, but we nonetheless may explore common strategies that the optimization should include. In choosing wedge issues and sides, a political party may stand on principle, express opinions based on an ideology, or take on the issues that affect a previously defined group of people [Chhibber and Kollman 2004]. In the process of expanding its base, the party may also decide to propose wedge issues that will allow others to join the coalition without alienating its base [Axelrod et al. 1995].

Bordered maximization has two main implications for implementation: on the one hand, the political party searches for positions that are most agreeable for its core identity, while on the other, it must be careful to choose the issues that bring to its side the necessary amount of people to win the election. Naturally, these two sides are interwoven, as finding an acceptable political position for the base must include a directive not to alienate the general population by doing so. For example, many voters in the primaries of America’s two parties would love for their representatives to be much more out of the mainstream, but that would imply becoming extremists in the generalized political scale and losing the general election. In a heterogeneous population full of potentially controversial issues, we would expect a two party political arena of intense competition to produce very tight elections, and multi-party ones to provide platforms that will serve the needs of all large definable groups. Cohesive groups that are concentrated on single issues—and that will correspondingly join the party that best addresses those issues without asking for much on other issues—will be highly coveted and powerful.

How will the process of bordered maximization find successful coalitions in a two-party system? To provide an idea of the answer, suppose we were to enumerate all possible combinations of all conceivable wedge issues. Without any regard for which issues tend to clump together for ideological or cultural reasons, random division of the issues must by definition create winning majorities, albeit very odd ones. With the passage of time, however, political issues should fall into more understandable combinations in which the winning platform has some sort of internal consistency and is potentially more cohesive. Inside the winning coalition platform, we should find a group that is cohesive enough to accept the full implications of a proposed issue agglomeration, and that is formed by people who find themselves better off there than with the competition, or who belong to a subgroup that is benefited inside the platform.

The winning party must take into account that new elections will return, and that its actions must not disturb the losing party too much, for the disenfranchised could become a liability to the ruling coalition, as the opposition could let go of most of its issues in order to concentrate on just winning, and in extreme cases could start a revolution. This effect brings to light the fact that the entity created by a bordered maximization always operates within a context, having its position drawn in the canvas of a longer-term upper level of existence, with a corresponding objective function that should not get trapped in immediacy. This example represents a simplification of the larger description of the determinants of group formation, or the interplay of forces that gives rise to the delineation of the ‘us-them’ boundaries. In the election, the short-term goal is well established: to win. The more general concept of bordered maximization can be applied to a wider set of issues where the objectives are not as clear. Such would be the case if the political party not only wants to win, but wants to create an enduring majority platform.

The tradeoff between the forces of individuality and collectivism reflects the essence of a bordered maximization. As the history of the world's game unfolds, evolutionary pressures will solicit more complex and adaptive organisms or networks of coordinated organisms that find themselves better at exploiting the ever changing environments they encounter. These adapted organisms or cobbled groups will have a nature, a design that has been optimized for the exploitation of *that level*. The 'agglomerate individual' will have to become cohesive, and organize its subcomponents in order to maximize its emergent utility function, since suboptimal internal coalitions can materialize, in the way a drug addict cannot overcome the desires of a strong drug-craving self, or a tyrant may force a society to extinction.

What is it that a newly formed agent maximizes? Its utility function. But why not forgo a myopic definition of the self, and create a coalition? Why not break apart from the current coalition and form a group whose identity lies closer to the core identity of the main actors of the resulting subgroups? The world may begin with autonomous atomic agents, forming structures that are originally fragile but become increasingly larger and more complicated through a constant process of reorganization. *Bordered Maximization* is thus the term we would like to coin for describing the process through which an agent defines the line that separates itself from the environment it inhabits. It is a dual process, defining its identity and size simultaneously.

6. MODELING THE EVOLUTION OF AGENCY IN A MULTIDIMENSIONAL WORLD

This essay discussed salient questions relevant to the comprehensive modeling of complex adaptive systems. To appropriately describe the evolution of our planet's ecological diversity, a voter's decision or the building blocks of a modern society, the S&M field should further explore generalized methodologies for describing the multiple levels of reality in all-encompassing models expressed in a common language. Here, in contrast to other conceptions of complexity, nonlinearity is taken to more commonly mean multidimensionality, rather than the non-proportionality connotation of the concept.

One of the most important propositions of this essay is that optimality or rationality in a multidimensional reality can only be measured in relative terms. Distributed Agency has been proposed as a language that can host all interacting dimensions and levels in the common currencies of agency and influence. To understand agency in the holistic light of this work, it is imperative that we express it in contextualized terms. When we think of rationality, we are necessarily referring to a particular level of agency, one which will interact directly or indirectly with other levels that are relevant when our focus is placed elsewhere. The general framework in which to address these issues raised must harmonize advancements in economics, sociology, evolutionary biology, political science, psychology and social psychology within the greater paradigm of complex adaptive systems.

Understanding how agency evolves over time also implies the resolution of the ubiquitous tradeoff between exploitation and exploration. Perhaps because of an underlying idealistic view of human progress and democratic ideals, the process of evolving agency is often conflated with a continuous expansion in agency, implicitly equating more agency (or freedom) to increased personal and social welfare [Schwartz 2000]. As we have argued, however, adapted organisms and social structures do not maximize agency but rather distribute it to most efficiently exploit to a given environment. Ultimately, what we observe in reality is the result of the interplay between the current, suboptimal self and the outline of the optimized environment, interacting to elicit adapted entities and behaviors. Moreover, environments over time become adapted to the extent that they can develop capabilities to elicit particular outcomes from their lower-level inhabitants [Myerson 1979].

How do the upper levels enforce their will? How can an upper level inform you about the benefits that can provide you? In other words, how does the flower develop the capability to attract the bee? We must consider the extent to which an agent is adapted, for its degree of adaptation will reflect the contour of the optimized environment in which it exists. The exogenous environment is what ultimately delineates the size and objectives of the adapted agent, providing the influential 'sugar' or influence that elicits the creation of the particular intermediate agents and social structures we observe in reality, in a recursive process that may be path dependent and irreducible. The interaction of multiple agency dimensions creates a kind of key that matches the keyhole that the optimally exploited environment characterizes. To open this door, the adapted agent mimics the outline of its context, but may also proactively or evolutionarily manipulate it to leave traces of information in it. When you eat a simple meal like rice and beans, you may not be aware that this perfect protein combination has been developed over thousands of years. The environment is thus also adapted and because of the information it retains we can speak of its "exointelligence" [Cohen and Stewart 1999].

How does this co-evolutionary process take place? How should we model it? Can agents only be adapted in a traditionally Darwinian progression where the past chooses those who are fittest to survive? The focus of this essay is humans, but the general idea of this discussion should be applicable to any species. The center of the argument is that humans are alive because they are fit to be so in innumerable ways. In line with the theme of this work, a human's utility function is not created in a vacuum, but is instead the product of a culture and millions of years of natural evolution. One of the many reasons why humans have been so successful is the fact that we learned how to cooperate with each other. In this perception, the space of possibilities before the advent of Humans included many different possibilities for an emerging species to exploit. In particular, the human brain is an amazing feat of nature, one which can model the future and adapt its behavior to something that has not yet come to pass.

Humans can thus react to environments that have not existed. Is this unique in nature? Certainly, at some basic level the answer is a resounding 'no,' since many animals can at least implicitly model and predict the trajectory of an approaching object and react accordingly. Plants, on the other hand, may be prepared for a season that they haven't lived through, but their degree of adaptation to the environment may not be as adaptable to a possible unprecedented change like global warming [Diamond 2006]. We humans are a most amazing product of nature, the ultimate omnivores, manipulating the earth to produce our own genetically-engineered food. We create, to some extent, our own environment. Can humans rise to the challenges of our time? We are beholden to the way we were created, and our individuality can still represent our peril. Let us hope that we will have the capability to create the social structures that will elicit joint action to conquest the biggest threats of our time: nuclear war and environmental destruction.

The new capabilities of the computer bring about opportunities to benefit from a relatively unexplored field. The questions raised by this essay should be discussed using the muscle of the computer simulation and combine it with the depth of understanding present in the highest levels of social theory, systems theory and multilevel selection theory. The computational capabilities of our times provide us with an amazing new power to understand our biological and social natures, let us use it to its fullest extent.

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