Interplay of Adaptive Selection and Synergistic Performance: As an example of natural selection and self-organization

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Abstract

The purpose of this study is to elucidate the effect of self-organizing processes, in particular the synergistic increase in performance of individuals in diverse collectives, on the adaptive selection process (the engine of variation generation, selection and amplification). The systems under consideration include the more traditional systems undergoing adaptive selection as in biology and ecology, as well as more novel information and economic systems, in the presence and absence of scarcity of resources. Because the two processes, adaptive selection and synergistic collective processes, utilize individual diversity by selective versus additive means, adaptive selection systems with and without these self-organizing processes may exhibit fundamentally different dynamics. The three major observations are 1) the performance increase from synergistic processes may reduce or eliminate selection pressure, 2) because diversity is required for synergistic performance, once synergistic performance starts and selection is reduced, the increase in diversity could increase the synergistic performance in a positive feedback cycle (coined the "synergistic performance-diversity bootstrapping"), 3) if the synergistic performance is present, even selection on the least fit may actually reduce individual performance due to the drop in diversity and could result in a positive feedback cycle of decreasing performance and selection, possibly leading to system-wide failure (coined "synergistic performance-diversity collapse"), and 4) in systems with little scarcity as in some Internet consumer markets with long-tail distributions, the generation of greater and greater diversity coupled with synergistic performance may result in a previously unrealized collective performance model, possibly greater than traditional systems with selective pressures. These conclusions are supportive of the summary by Batten, et al. in this volume that " Self-organization proposes what natural selection disposes".

1 Introduction

The context for the current study is defined in the adjoining paper, "Visions of Evolution" by Batten, Salthe and Boschetti (Batten, Salthe, & Boschetti, 2007); they, after a review of the competing premises (views) of evolutionary studies, assert that "Self-organization proposes what natural selection disposes". The current study examines the interplay of the two processes, natural selection in the form of the engine of adaptive selection (variation generation, selection and amplification/reproduction) and self-organization in the form of the synergistic improvement of performance observed in diverse collectives. Within the context of the Batten, et al., natural selection plays a focusing role (deposes), where self-organization plays an additive role (proposes). In the current study, the scope is made narrower by focusing on specific examples of both processes and providing insights into the interplay of two performance-generating processes that utilize diversity in different ways. The intent is to avoid much of the ambiguity of many generations of evolutionary theory of natural selection and recent investigations of self-organization — apparently without convergence to core concepts, but still address the richness of the interplay between the two processes.

The systems under consideration are assumed to be under constant environments or slowly changing conditions in order to limit the discussion (the effect of changing environmental rates is examined elsewhere (Johnson, 2002)). But we extend the systems under consideration beyond the more traditional ones undergoing adaptive selection, as in biology and ecology, to more novel systems, specifically information and economic systems. Because of the unique aspects of technology-based information systems — where replication and distribution can occur with minimal energy requirements, we also consider the systems of interest in the presence and absence of scarcity of resources. An example of a relatively scarcity-free system is the growing occurrence of long-tail consumer product markets, argued (Anderson, 2006) to occur because of the convergence of relatively cost-free production and distribution with the

ability of consumers to find uniquely matched products within the nearly infinite sea of options. The generation of nearly unbounded diversity in these systems is a clear example that our perceptions of the essential role of selection (in this case, restricting the number of products) in healthy, evolving systems may be flawed. The existence of these viable systems because of the lack of scarcity is quite different than the arguments in Batten, et al. where the effectiveness of selection is discussed to be limited by the complexity of the system or the presence of self-organizing processes. Therefore, to capture the breadth of modern evolving systems, the effect of scarcity on the evolution and dynamics of the systems are also considered. An essential observation that does connect the selection-limited (such as Kimura's neutral theory (Kimura, 1994)) and selection-absent viewpoints is that in both types of systems unbounded diversity generation is the outcome where selection is largely absent.

What is meant by the self-organizing process of synergistic performance? Here, synergism refers to the superior performance achieved by a diverse collective through the combination of individual differences, rather than through amplification of selection-favored individuals. The synergistic model of performance by the current authors grew out of research on self-organizing collectives of individuals that solve problems better than experts using knowledge systems such as the Internet (Johnson et al., 1998). The process by which the self-organizing, diverse collectives can exceed the performance of expert individuals is "synergistic" — which is taken to represent the *non-selective*, *emergent* and *collective* aspects of the process. An example of synergistic enhancement is the early stage of food source discovery in social insects (Bonabeau, Dorigo, & Theraulaz, 1999). Early in the exploration process, an ant colony, as a whole, is observed to perform better than any individual ant. In other words, no individual ant finds a path to food that is shorter in length than the *collective* path, the *emergent* solution that comprises the most treaded portions from diverse individual contributions within the foraging environment. An emergent property is defined as a global or system-level property that cannot be predicted from knowledge of the subsystems. The collective path is emergent because no individual ant takes the shortest path, e.g., the collective solution cannot be identified in the individuals. The emergent shortest path is a global property of the system because the shortest path can only be determined within a global perspective, a perspective that is not part of any ant in the system. The process is *non-selective* because it does not eliminate the path contribution of any ant in order to create the shortest path. Relevant to the above observation that diversity is essential for the synergistic process to function, one can easily see that if all ants took an identical, non-optimal path (no diversity), the synergistic process would fail. Once the emergent solution is established, individuals do "select" the optimal path to optimize collective performance, so ultimately the emergent solution can be observed in individual choices. In the condensed or converged state of the collective behavior, most of the ants do take the shortest path and the solution is no longer emergent.

2 The Roles of Diversity

An observation that introduces a starting point in the current study is that both processes — adaptive selection and synergistic performance — require diversity to function. In the absence of diversity, both processes fail as mechanisms to adapt to changes or to increase performance of the population. Because of the common understanding of the process of adaptive selection, it is sufficient to note that the process of selection consumes diversity on the presumption that surviving individuals will provide heritable qualities in later generations. In the above example of the synergistic performance in early food location by ants, diversity was used to describe the different segments of paths of the ants. Because diversity is a key concept, a precise definition and context is necessary. Similar descriptive terms for diversity might be heterogeneity and variety, but for synergistic performance, diversity can be defined specifically (Johnson, 2000):

> In the current context, diversity of a group is defined to be the degree of unique differences within a group in which its constituents have a common "world view" (see (Johnson, 1998) for a mathematical description). Applying this definition, if all the individuals within a group have identical qualities, then the group has zero diversity, even though the qualities of the individuals may encompass all possible variations of the system. If each individual contributes a unique quality not shared by others, then the diversity of a group is a maximum. The restriction to a common construct of the world is necessary, because differences between individuals in a group can arise from different assumptions (world-views) about the

system. While this source of differences may appear to be a source of diversity, we argue that comparisons between different world constructs are not advantageous within a self-organizing system. For example, the approaches to problem solving of a New Yorker and Australian bushman are likely mutually exclusive and therefore "unique", but because these approaches operate in very different environments, it is of questionable meaning to measure their diversity (as defined above) and ask how it correlates to system performance. This is equivalent to saying that meaningful expressions of diversity to the system dynamics require the unique contributions to be *potentially* coupled by the system dynamics. Implicit in the above definition is that diversity is a property of a *group* of individuals, not of a single individual. Hence, the common phrase, "she has diverse interests" is meaningful only in comparison to a group. Diversity can be a measure of any characteristic of the system *at a given time*, either in function, capability or information.

The above description and definition of diversity is for synergistic performance. The requirements and definition for adaptive selection — while related (population must express differences) — focus on differences in fitness (performance) that determines survivability, with no emphasis on the synergistic combination of differences. Because of the predominance of the adaptive selection studies, a detailed review of diversity for the selective performance model is not required, but a comparison of the two forms of uses of diversity are helpful for later discussions.

One essential difference between the two uses of diversity is the point in an individualÕs activities that the diversity is active. In synergistic performance, diversity is important in the process of achieving performance, as in the different decision points in the ant example above. In adaptive selection, the outcome of the decisions (or multiple task performance) determines the final fitness of the individual and may depend on a variety of prior factors: heritable features, learned behavior, environmental (structural) alignment, etc.. Hence, the two uses of diversity are expressed at different times in the individualÕs process. We do note that the synergist performance may contribute to the fitness of the individual, and therefore coupling the two types of diversity; the intersection of the two performance processes is discussed later.

A second essential difference is the relationship between diversity and flexibility of the individual. In the text that follows, the flexibility that results from diversity that enables synergy between individuals to occur is expressed as options in the systems. Because adaptive selection operates on fitness of the individuals — the final product of many decision points, options do not play a required role in the final fitness of the individual. For example, individuals with different levels of fitness may have no or few options that determined their performance. As a consequence of this distinction, options play an essential role in synergistic performance, but may or may not play a role in adaptive selection. The next section directly addresses the subject of options versus diversity and their relationship to structure.

3   The Roles of Diversity, Options and Structure

An additional distinction is essential concerning diversity and constraints in a system, a point not made in the discussion by Batten, et al., but relevant to the present discussion and is best illustrated by an example. A highly optimized but complex assembly line may have a high degree of diversity as defined as unique differences that are coupled, but almost no options (flexible alternatives in the process) because the system is so constrained by structure. Another example is a highly mature, possibly senescent, ecosystem in which all interactions are highly constrained, such as one moth species pollinating only one species of flower. Diversity in this ecosystem may appear to be extreme, but there are few options. From these examples, fitness or performance differences (a form of diversity) may be expressed in systems with no options.

The interplay between structure and options in a developing system is more complex than suggested in the above examples and is pictured in Fig. 1. The structure-options viewpoint is a gross simplification of "infodynamics" theory that attempts to combine thermodynamics and information theory (Salthe, 2001). *Structures* are the features/rules/constraints required to reproduce the non-stochastic dynamics of the system. Structures can constrain individual options that arise in the system evolution and can be static (e.g., material barriers) or dynamic (e.g., metabolic processes). A hierarchy of structures might

include "deep-system" constraints that are so strong that if the "tape" is played again, they always arise (e.g., in biology, we might guess bilateral symmetry and a separate nucleus in a cell). They also include "shallow-surface" constraints, which, when the tape is replayed, likely change, but which also determine later evolution once expressed (these are the so-called frozen accidents, e.g., universal DNA encoding and the supposed homeotherm predominance). Structures, as used here, do not include the two extremes that bracket the above constraints: the deep physical constraints that reflect how the physical laws are expressed (they always occur if the tape is replayed, e.g., hydrogen bonding) and "shallow-surface" features that are randomly expressed if the tape is replayed but do not directly affect evolution once expressed. Hence, structures, as used here, are environmental or system constraints that can evolve and can directly influence the evolutionary path of a system. The qualification of "directly" is to include the possibility of indirect or emergent effects.
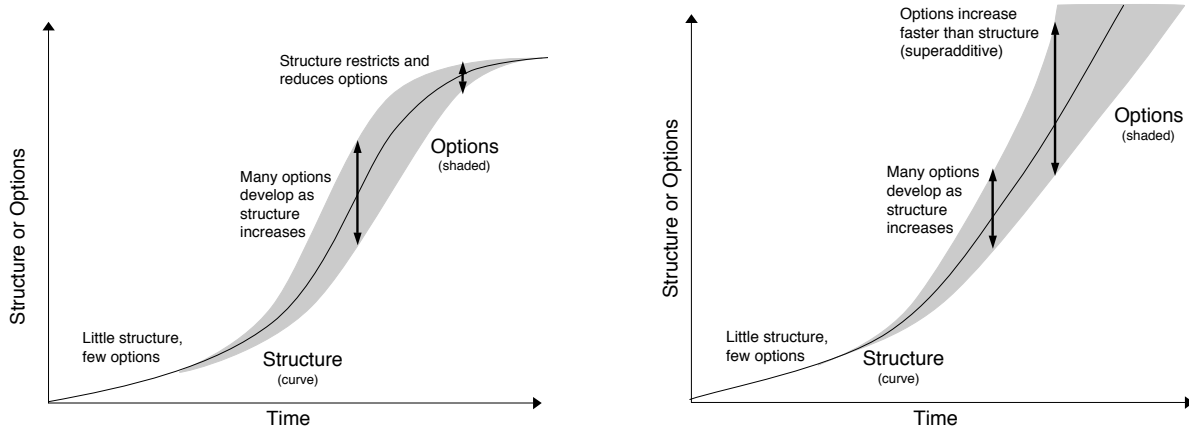

Figure 1: The interplay of structure and options in a decentralized, self-organizing system. Structures are the constraints that determine the next state of the system. Options are the alternative paths by which the system can reach the next state that are both created and limited by the structure. Scarce environments (on the left) eventually limit options through the constraints of structure, while non-scarce environments (on the right) continue to allow options to flourish.

A formalism (Johnson, 1998) that allows a precise description of the above concepts is to decompose the system in which an individual functions into a decision network, where nodes represent decision points (potential or utilized ones) and edges (links) represent how the decision points are connected. Each individual would have a different decision network, with some nodes being the same across individuals (places where synergy occurs). Any activity can be expressed within this construct: a solution of a maze, a chemical network, a financial market, the research/purchase of a product, a genetic algorithm, etc.. The evolution of the system is represented by changes in the edges (all nodes are presumed to pre-exist). We use the decision network construct to define key words used in the current presentation. For example, the previous used "common worldview" can now be stated as the degree of commonality of decision nodes as options (but not necessarily preferred decision nodes). Individuals with greater overlap of potential or actual decision nodes have a more common worldview.

Using the above formalism, structure is represented by the edges that connect the decision points. Note that one could include the creation of the decision nodes as new structure, but for simplicity of description we use the above presentation. This assumption is equivalent to saying that all decision nodes pre-exist but some will not have any connecting edges. An example of structure creating options is the addition of a new edge between two previously unconnected decisions points, enabling a new decision point. An example of structure limiting options is the removal of an edge such that there are fewer options in the decision network. In an extreme limit, a series of "decision" nodes can be linked together with no options capturing an assembly line-like process. Given the above formalism, the difference between the two utilizations of diversity becomes apparent: synergistic performance requires diversity (actually options) at nodes; adaptive selection requires diversity in the fitness of the individuals, captured in the entire decision matrix.

Two essential features of Fig. 1 are that diversity and options are initially created by structure. But in many systems, particularly ones that are physically bounded, the creation of additional structure (now as constraints) begins to limit the options in the systems, although diversity may continue to remain or increase. One way to view this transition is examining the options in the games of chess and checkers, both played on the same board layout. Initially rules (edges in the prior formalism) create many options as in a comparison of the game of checkers (few rules, few options) with the game of chess (moderate rules, many options). Suppose additional rules were added to the game of chess (e.g., the queenÕs knight can only turn left); at some point the options would be eliminated (edges removed) and the over-constrained result would no longer be a game with alternatives and may not even have a solution (no moves are possible).

For completeness, the effect of the lack of scarcity is also presented in the second graph in Fig. 1. This situation corresponds to the earlier observation about unbounded growth of diversity, as in some Internet economies. Note that in these systems, because of the combinatorial possibilities in the growing diversity, options can increase faster than the structure creating the diversity. One view of the figure on the right is that it sustains the earlier growth stage of the figure on the right. This explosion of options is observed in online content generation as new products are created from the combination of old products from the expression of the diverse interest of individuals. What is particularly relevant in this consumer example is that while one would think that this diversity generation would not have utility (i.e., be purchased) as argued in Kimura's neutral theory (Kimura, 1994), just the opposite is true: almost any product generated is purchased in this unique long tail market (Anderson, 2006). Instead of 80% of consumers purchasing 20% of the products with many never purchased at all (a survival-of-the-fittest market), 95% of the products are purchased regularly.

4 Options and the Synergistic Performance Process

The above discussion on structure, diversity and options plays out in the process of adaptive selection and synergistic performance. The adaptive selection engine is the process that "disposes" by the creation of new structure (by variation generation — the creation of new edges in the decision network formalism) that better matches the selection pressure, while removing old structure (selection — removal of entire decision paths that represent individuals) that no longer matches the selection pressure. In an isolated system, as captured in genetic algorithms for simple systems (Fogel, 1999), the dynamics of the process are to reduce diversity of individual solutions, as the algorithm matches and then optimizes the match to the selection pressure (this assumes the diversity is not excessively generated by a high mutation rate, thereby preventing the system from optimizing). From this discussion, one viewpoint that clarifies the two uses of diversity is by focusing on options (flexibility in the system): synergistic performance requires options in the process of achieving performance (or fitness) where adaptive selection requires options (variance) in the performance of the individuals. And from prior discussion, while the two forms of options may be related, neither process requires the other form of options to be expressed (Adaptive selection doesnÕt require the options required by synergistic performance and vice-versa).

In more complex co-evolving systems, such as plants and herbivores, the interdependency creates more structure and options, as for example, giraffes utilize tall plants and plants grow tall because of giraffes. We posit without additional discussion that the adaptive selection engine is the likely generator for the structure, diversity and options initially observed in Fig. 1 — largely captured by the discussion by Batten, et al. as the natural selection process "disposes". Because of the nature of adaptive selection, the selective process could operate on differences of structure (as defined above), diversity or options; the same is not true for the synergistic performance process.

A detailed study (Johnson, 1998) was done of the synergistic process within a context similar to the ant foraging example: the solution of a maze (a network or graph) by a collection of non-interacting, myopic individuals, essentially the decision network describe earlier. In this problem domain, diversity of experience results in solving the maze from initially random choices (the myopic individuals have no reason to initially choose one path over another). The study concluded that the unfiltered combination of individually-derived information resulted in finding the shortest path through the maze, even though no individual could perceive the shortest path or may have taken the shortest path. The ability of a composite of myopic individuals to find an emergent property (the shortest path) illustrates the com-

parable mechanism for collective performance presented earlier for ant foraging and by other authors (Surowiecki, 2004; Hong & Page, 2001). Furthermore in the maze study, the *current* performance of the composite collectives was found to strongly correlate with the diversity of the collective (and not with a superior performer in the collective) and that any reduction in the diversity as a result of selection of any kind caused a reduction in the collective performance; we stress "current", because the performance of the collective is enhanced without selection, unlike adaptive selection where selection is required to remove the more unfit performers before the collective performance is improved. An extensive study was done of the required network/graph structure necessary to support synergistic enhancements on a network (White & Henry, 2001) using graph theory. White and Henry found that the sequential problem domain (the maze) required redundant dominant paths with interconnectivity joining these paths, where the interconnectivity represents options in the present discussion. This requirement specifies the type of decision network in which the synergistic performance is possible.

The connection with the prior presentation of the structure-options concept can be made. The synergistic performance process requires both diversity and options: diversity to provide differences for the opportunity of synergy and options to enable the possibility for synergistic interactions. An example best illustrates this point. In the prior examples of diverse systems that are overly constrained (an assembly line) such that there are few options, the synergistic process is not operational because synergy requires individual options to interact, even though high system diversity may be present. This is in contrast to the process of adaptive selection where only the presence of diversity of fitness for selection is required. This distinction clarifies the confusion that can arise when self-organizing processes are differentiated from natural selection. Certainly, the adaptive selection engine is a self-organizing process because it spontaneously "organizes" population level adaptation to a change in selection pressure without being controlled by the environment or by some centralized process. But in terms of the requisite flexibility in the system, the self-organizing synergistic process requires a more dynamic environment in comparison to the adaptive selection process (adaptive selection doesnÕt require options in individual decision processes, only competing diversity of fitness). We posit without discussion that this is generally true for natural selection and self-organizing processes discussed in Batten et al. The synergistic enhancement of performance requires the presence of diversity expressed as options where the outcome of the collective is an individual or collective option.

The above discussion results in the observation that in Fig. 1 the optimal conditions for synergist performance in systems with scarcity are at the middle of the structure-options figure and continue to grow in systems without scarcity, providing that the prior restrictions on the window of individual performance and problem complexity are met. The interaction of the two windows of adaptive selection and synergistic performance are illustrated in Fig. 2, which shows how the utility of individual and collective processes varies with system complexity Note that in general there are three curves: individual (shown), collectively-enhanced individual (not shown) and collective (shown), but for simplicity only two curves are shown; one could argue that the expert is a collectively-enhanced individual or benefits from them. The utility of the individual is initially low because all individuals in a simple system will have equal performance; the utility of the collective is initially low because the individual performance on the same problem reduces the collective utility. Both the individual and collective utility decline as the complexity of the problem exceeds a threshold, expressed in the figure as complexity barriers respectively for individuals and collectives. As described earlier, but worth emphasis, the collective performance and hence utility is observed to be sustained at higher complexity because of the synergistic options provided by either a broader diversity of resources (a collection of plumber, carpenter, roofer, etc. builds a better complex house than any specialist singly or a jack-of-all-trades) or by a broader diversity of information as in the maze example above.

5   Discussion

Based on Fig. 2, two important conclusions can now be made regarding the interplay of the two processes for performance: synergy of diversity and selection from diversity. Suppose a comparison is made in a system experiencing adaptive selection with and without synergistic performance. Because of the superior performance of the individuals benefiting from the synergistic performance of the collective over individual performance without synergism in more complex systems, particularly beyond the individual complexity barrier, the synergistic performance can reduce or negate the need for selection in the
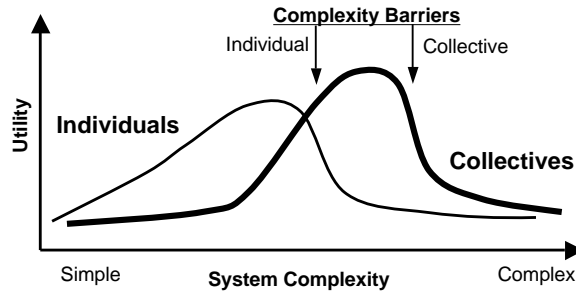
Figure 2: A summary plot of the utility of performance processes (individual and collective) as complexity increases. Individual and collective utility peaks as their respective performance processes matches system complexity. Performances decline due to their respective complexity barriers (Johnson, 1998). This figure was inspired by a similar figure in a study of the limitations of experts (Mauboussin, 2005, 2006).

adaptive selection process. In fact, the reduction of selection can lead to increased diversity, along the lines argued by Kimura's neutral theory, resulting in additional options for synergistic performance, and a possible further reduction in selection. A simple phrase to describe this process of reduced need for selection is Òsynergistic performance-diversity bootstrappingÓ. We also note that the supplanting of selection by synergistic performance also results in less chaotic dynamics at a system level because of the robustness of the synergistic performance (Johnson, 1998) and at an individual level from the absence of the disruptive effects of selection.

A related conclusion is that once the synergistic performance is utilized by the population, the addition of a selection process could result in reducing the diversity essential for the synergistic performance — the removal of individuals with unique performance likely will remove options in the decision network, making their contribution unavailable for synergy, and cause a reduction in individual performance due to the decline of synergistic performance. In some situations, a positive feedback loop might occur where diversity is further decreased from the selection, causing a lowering of individual fitness, resulting in more selection, and so on, until the synergistic performance is eliminated and the system returns to performance exclusively from the adaptive selection process. A simple phrase to describe this process of collapse in performance is Òsynergistic performance-diversity collapseÓ. We speculate that the cascade of failures observed in ecosystems when the population of a critical species declines is analogous to this process. This decline of a system as a consequence of selection is in contrast to the dominant viewpoint originally proposed by Fisher (Fisher, 1930) that the result of selection is always to increase the fitness of a population.

The origin behind the two major system dynamics above — synergistic performance-diversity enhancement and collapse — is that the two processes of adaptive selection and synergistic performance utilize diversity in different ways — one being subtractive and the other additive — leading to a potential conflict in the two processes at the expense or benefit of the system viability.

The above discussion focused on systems that include some scarcity of resources that triggers the presence, even if ineffectual, of selection and can also cause limitations in the development of structure (or diversity) in the system. How does the above discussion change when applied to systems without scarcity, such as the new Internet economy presented in the Introduction. The earlier discussion for the plot in Fig. 1 for a non-scarcity dominated systems suggested that structure continues to grow and that options, or minimally the potential for options, grows faster than the structure, a "superlinear" (Page, 2007) increase of options. Superficially, an increase in options leads to the possibility of greater synergistic performance. But the possibility must be qualified because the unbounded increase in structure and options must also lead to greater complexity and the likelihood of the collective complexity barrier being exceeded. Certainly on a personal level, many would state that the explosion of information on the Internet resulted in obvious opportunity for new synergy, but the complexity of finding what was needed or possibility of stumbling on opportunities was overwhelming. What has largely changed the complexity landscape for the Internet is the increased performance of search and recommendation engines by pro-

viding the right information at the right time and right place (Anderson, 2006; Vise & Malseed, 2005). What is not generally appreciated is that this explosion of options, made effective by modern resources, results in a new performance mechanism at the intersection of unbounded options and the synergist performance. This was coined "symbiotic intelligence" (Johnson et al., 1998) or more appropriate here, synergistic intelligence. In the context of the current discussion, all prior understandings of performance based on selective and self-organizing processes conclude that there are bounds, expressed here as the individual complexity barrier, in the ability of a system to increase performance(Batten et al., 2007). By contrast, the above discussion suggests that in some systems there may be realized relatively unbounded options and performance, surprisingly in the absence of selective processes.

6 Summary and Future Work

Within the context provided by (Batten et al., 2007) of the interplay of natural selection and self-organizing processes, this study focuses on the interplay of examples of the two related processes: adaptive selection and synergistic performance. The systems examined are ones with little or moderate environmental change, but include systems with and without the encumbrance of scarcity.

The first major conclusion is observed by examining the effect of system complexity on the two processes. Because synergistic performance can sustain higher performance as complexity increases, the introduction of synergistic performance may reduce the necessity of selection in the adaptive selection process for increasing population performance. The role of diversity (unique differences between interacting components or individuals) is the pivotal viewpoint, because while both require diversity to function for increased population performance, the two processes utilize diversity differently: the adaptive selection process consumes diversity in order to increase the population's fitness, whereas the synergistic performance combines diversity to achieve higher performance. This observation leads to a corollary on the conclusion above: if selection is reduced by synergistic performance and synergistic performance improves as diversity increases, then a positive feedback loop is established where reduced selection results in increased performance in the system, coined the *synergistic performance-diversity enhancement*. Similarly, the potential of a positive feedback loop of declining system performance also can occur, coined the *synergistic performance-diversity collapse*: because the synergistic process requires diversity to provide performance increases to individuals, the introduction of increased selection into a system with synergistic performance can cause a decline of this performance process, which in turn results in the decline of individual performance, which in turn results in greater individual failure, etc., possibly leading to a collapse of the system. These positive feedback loops suggest further support for the general conclusion in Batten, et al. that "self-organization proposes what natural selection disposes", and for Kauffman's assertion that selection must be strong enough, and fast enough, to offset the rate of exploration of emergent novelty arising in the "adjacent possible" by way of self-organization (Kauffman, 2000), reminiscent to the above discussion on options required for the synergistic performance.

Finally, an examination of systems without the encumbrance of scarcity, an unbounded growth of options can occur, as in the long-tailed economies of the Internet (Anderson, 2006). Under these conditions, the synergistic performance process also may be unbounded provided the individuals can accommodate the increased complexity. We are currently seeing these observations being realized in real time, leading to the possibility of an alternative model for boundless performance, without the predominance of selection, along the lines originally argued in (Johnson et al., 1998).

There are many aspects not addressed in the above simplistic presentation of the two processes of increased population performance. Certainly all increases in diversity do not result in increases in collective performance, even under the assumed conditions of a common worldview. There are aspects of social organisms that complicate the observation and assembly of information that can lead to synergistic improvement. Along these lines the authors are examining the role that group identity ("I'm part of your identity group if I feel attacked if someone attacks you") determines how synergistic groups form, interact and merge.

As introduced in Batten et al., a developmental perspective (evolving systems have different dominant processes as they develop over time) clarifies many aspects of the interplay between selective and non-selective processes. What is needed to fully address the different processes is a model problem that

exhibits all the processes discussed in this paper, where one can examine the thresholds and transitions between the different processes.

7   Acknowledgements

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