Evolutionary Dynamics of Knowledge

Carlos M. Parra
Tokyo Institute of Technology
cparra@soc.titech.ac.jp
Masakazu Yano
Tokyo University
myano@p.u-tokyo.ac.jp

1. Introduction

Knowledge is of extreme importance from an economic viewpoint because it leads to informational asymmetries, which can have perverse effects that move systems away from economic conditions (i.e. Paretian equilibrium) the invisible hand was supposed to guarantee. Informational economics is therefore concerned with the limitations of the perfect information assumption (Stigler, 1961; Arkelof, 1970; Spence, 1974; and Stiglitz, 1975) and has sought to overcome its deficiencies within an analytical framework that not only lacks the adequate tools, but more importantly keeps on applying assumptions that are as unacceptable as the one in question (i.e. individual rationality, competitive equilibriums, diminishing returns, etc.)

Some economists, however, have found a solution inside the problem by letting these informational asymmetries account for desirable competitive advantages, as in strategic theories of the firm (Teece, 1987; Burgelman, 1988 and 1991; Dodgson, 1991 and 1993; and Hitt *et al*, 2000), endogenous or "new" growth theories (Romer, 1990 and 1994) and evolutionary economics (with the post or neo-Schumpeterians: Nelson and Winter, 1982; Dosi *et* al, 1988; and Nelson, 1991), in turn dismantling other key neo-classic assumptions, namely: perfect competition and diminishing returns – or the convexity needed to reach equilibriums - but again these approaches insist on using some of the previously mentioned unacceptable assumptions (i.e. individual rationality.)

On the other hand, behavioral economists (Gintis, 2000; Kahneman, 2002 ; and Camerer, 2003a, 2003b) as well as experimental discoveries (Smith, 2000) have imposed serious limitations on the rationality assumption, by evidencing how economic agents repeatedly violate individual utility maximization canons. Eventhough recent neuroeconomic approaches (Glimcher, 2003) acknowledge that any and all mathematical systems consisting of axioms (i.e. self-evident truths like the individual rationality one) are incomplete because they are built on top of non-provable statements (Goedel, 1962), they fail to recognize that neo-classical assumptions are too axioms.

Complexity economics (Lane 1993a and 1993b; Arthur *et al*, 1997; Axelrod, 1997; and Tesfatsion, 1997) has approached the shortcomings of these assumptions computationally, but has nevertheless encompassed them to different extents, either: by using them to specify agents' motives of behavior; or by ascribing these agents global learning schemes "in which the strategies of the computational agents jointly evolve in an attempt to satisfy one or more globally specified goals (e.g., productive efficiency)" not just overlooking the fact that these goals are being toppled one by one, but failing "to incorporate the salient characteristics of actual human decision-making behavior" (Tesfatsion, 2003, pg 3.)

This paper proposes an inner-world reconstruction model (or learning model) that can overcome neo-classic obstacles, and increase the predictive power of computational economics, by letting agents' knowledge evolve by itself, irrespective of globally specified goals and even individual motives of behavior. In order to accomplish this, the next section will briefly describe traditionally used agent-based learning procedures focusing on their deficiencies, so as to justify and present our knowledge-based evolutionary model in its human form; and then in section 3 in its artificial approximation, speculating about the outcomes this type of implementation could provide; the fourth section discusses the importance of variety for managing variation within this framework. And finally, in section 5 we will provide some conclusions.

2. Agent-based learning models

A detailed description of Genetic Algorithms (GA) used in agent-based learning processes is beyond the scope of this paper.[1] In general, they begin with a population of competing trial solutions to a practical problem (i.e. maximizing utility or minimizing uncertainty), new solutions are created by *randomly altering* the existing solutions. However, an objective measure of performance is needed in order to assess the fitness or adequacy of each trial solution, and a selection mechanism (i.e. a globally specified goal like enhancing productivity or ensuring market efficiency) determines which solutions are to be kept as "parents" for the subsequent generation of trial solutions (Fogel, 1997.) It is important to note that various studies have pointed out the need for a clearer understanding of the *variety generating mechanisms* in charge of altering

[1] For a classic Genetic Algorithm (GA) tutorial see Goldberg (1989), and for a review of Holland's (1992) schemata and Arifovics's (1994) augmented GA see Birchenhall, *et al* (1997.)

solutions, how they function and how to manage them properly (Birchenhall, 1997 as well as Pallbo, 1997) bringing up the first limitation of using GAs for agent-based learning models.

In this study we propose to understand and design *variety generating mechanisms* in variational terms through variation, vis-à-vis, *handle variation by providing additional variety*. In particular, we will illustrate a way of simulating human decision-making based on providing increasing variation, instead of restricting it. This should not be understood as the infinite inclusion of variables in a specific model, but as a significant increment in the degrees of freedom ascribed to each variable considered in it. Specifically, our study encompasses this by, once again, giving up the need for a single ever-present motive of behavior or a globally specified goal. This in turn leads to a more general discussion about the deficiencies of GAs.

2.1. Deficiencies of current approaches

Brenner (1998) presented some of the first objections to GAs by pointing out three problematic issues when using them for modelling social evolution, namely: they generally disregard the past history of individuals; the definition of fitness in social evolution is determined by the programmer[2]; and they fail to consider motivational effects during selection, because selection processes are “influenced by the distribution over strategies in a complicated way which cannot be reproduced by common evolutionary algorithms” (Brenner, 1998: 282.) In general, Varela (1999) regards these approaches as dualistic concessions, between eliminitivism (or neuro-reductionism) and the irreducible nature of human experience, giving rise to neural Darwinism (Edelman 1989 and 1992) and genetic and/or adaptive algorithms (Goldberg, 1989 and Holland, 1992), which imply the identification of modular items of cognitive capacities (Birchenhall, 1995) and then putting them together through a theoretical framework (ranging from Phylogenetic to Ontogenetic adaptation as described by Pallbo, 1999) so that their unity amounts to an account of experience. Moreover, Varela (1999) asserts “the strategy to bridge this emergent unity and experience itself varies, but typically it is left vague since the entire approach relies on a third-person or externalistic approach to obtain data and to validate a theory.” (pg. 186) and in so doing corroborates Tesfatsion’s (2003) concerns in terms of the “unconsidered adoption of off-the-shelf learning algorithms.” (pg. 4.)

However, Tesfatsion (2003) citing Dawid’s (1999) dynamic multi-agent models, in which GAs implement the evolution of individual agent strategies, re-justifies the use of Agent-based Computational Economics (ACE) for scrutinizing the sensitivity of economic outcomes to changing the parameters of the learning specifications, namely: adjusting the variety generating mechanism and/or constraining it, that is, controlling the types of alterations imposed on trial solutions to generate “offspring”; which is in turn defined by the methods employed for selecting new “parents”, thus determining the fitness function definition that assesses the adequacy of solutions; or correcting the frequency for applying this selective mechanism; and refining the ways of combining

[2] On alternative fitness definitions see Sen, 2002.

data structures in order to regenerate solutions. Our proposal falls squarely within this computational strategy, namely: the use of simultaneous (or parallel) GAs to evolve a single agent's learning strategy, each GA with different general specifications, in a multi-agent setting. But, in order to describe the overall specifications of these GAs, we need to discuss our "human" model first.

2.2. Experiences, distinctions, choices and knowledge[3]

In order to provide a human version of Arthur's *et al* (1997b) artificial "interpretative devices" (pg 7), we will follow Varela's (1999) neurophenomenological perspective coupled with a cybernetic understanding of Piercian semiotics to present a *human development-based* definition of interpretants.

Let us then begin by considering an interpretant as "a modification of consciousness" (Peirce Collected Papers 5.485) using the "analogous" sense initially ascribed by Peirce. And at the same time, let interpretants account for experiences, insofar as the smallest modification of consciousness is an experience itself (Lalor, 1997.) However, interpretants, besides being experiences, are here comprised of alternate bundles of embodied experiences (distinctions), presenting a definition reminiscent of Sen's capabilities (1993) that implies alternate modifications of consciousness continuously reconstructing themselves through experience. Therefore, we can define *interpretants as experiences, composed of embodied experiences (distinctions), which when experienced can be embodied as new distinctions, which will in turn potentially constitute, or influence the constitution of, a brand new interpretant.* Because once an interpretant is either used successfully[4] or considered adequate (in artificial terms by a globally specified criteria, a motive of behavior, or a fitness function; or even any influencing factor including that of chance) it will no longer represent a mere experience, it will be embodied as a newly available distinction.

Now, this definition of interpretants is especially useful from a *human development* perspective (UNDP, 1990) when capabilities are comprised of alternate bundles of choices or functionings (an individual's beings and doings, see UNDP, 1990 and Sen, 1993) and these choices then, standing for embodied distinctions, stem from distinctions that in turn stand for embodied experiences. Moreover, this definition is key to our argument insofar as Sen's capabilities use liberty instead of utility for interpersonal comparisons, where choices or functionings become the main unit of economic decision-making[5], so that there is no longer an overaching need for a rational motive guiding individual behavior.

Brier (2003) considers interpretants as signs in our minds that make us recognize something as a thing, and relates them directly to Von Foerster's eigenvalues of

[3] This section and the next one, refer to a model developed in a phenomenological and semiotic context, presented in Parra and Yano (2004.)
[4] Successful could mean that the interpretant managed to establish a structural coupling (Maturana and Varela, 1998) between the individual and its environment.
[5] For a detailed discussion of how choices are related to welfare and learning, when represented by embodied distinctions see Parra and Yano (2002.)

cognition. Comparing it with our definition of interpretants, one could find them similar, but they differ in terms of the eminently evolutionary way in which interpretants are put together here, in order to handle knowledge that is illustrated in the next section.

Pallbo (1997) justifies the use of evolutionary processes in the context of knowledge acquisition by showing how it helps overcome Meno's dilemma, namely: the fact that we cannot learn (or notice, in the phenomenological case) what we do not already know (experience) because we are unable to search for it or to recognize it should we stumble upon it. When knowledge is understood in evolutionary terms it is allowed to grow and expand, it becomes "animated" and can therefore evolve by itself. That is why we regard evolutionary contributions as indispensable in our framework, and also why our definition of interpretants falls back on itself, rendering it paradoxical. Furthermore, according to Hodgson (2002) any and all social applications of Darwinian evolutionary models must include three main features: variation, selection and inheritance (the latter feature will be referred to as retention from now on), which is why, our learning model encompasses all three of these evolutionary aspects.

2.3. EDGE model for generating individual worlds

In this model, interpretants (as well as the evolutionary process providing variation, selection and retention for constituting these interpretants) are present all throughout the process out of which distinctions emerge to become possible choices.

1. Experiencing experiences – NOTICING EXPERIENCES

This is the first stage of the process by which experiences are embodied. When an individual experiences an experience, interpretants are constituted with the basic motivational aim of noticing, therefore, interpretants active during the *experiencing* stage are the product of a process providing variation, selection and retention of distinctions that help an individual notice. This process usually leads the individual to doubt and generates a break in the individual's ontological security. In other words, when an individual is trying to notice something, a break is generated by *experiencing interpretants* that have been retained out of a few selected ones that where in fact variations generated with the aim of noticing. For example, if an individual is hungry it is unlikely, though not impossible, that the interpretant constituted (as well as those prevalent during the constitution of the interpretant in question) for the act of noticing possible food sources, corresponds to the one for noticing shelter, and vice-versa, if the individual is cold.

2. Distinguishing experiences – GENERATING VARIATION

Now once the *experiencing interpretant* is constituted and active, it should eventually be resolved by providing the individual with various sources of experience. This should in turn activate the prevalent interpretants associated to processes providing variation, selection and retention of distinctions that help the individual generate as much variation as possible, for the effective constitution of *distinguishing interpretants*. This means that the generation of variation should be the main active motivation during the evolutionary process that eventually constitutes a *distinguishing interpretant*, but not just any variation, the generation of variation should be guided by the *experiencing interpretant* as well. For example, our hungry individual has an active *experiencing interpretant* for noticing food; this in turn yields to the activation of *distinguishing interpretants* that emerge out of an evolutionary process generating variation in terms of that prevalent *experiencing interpretant*.

3. Grounding experiences – EVALUATING VARIATION

Now in order for us to be able to pinpoint the source of experience (through active *distinguishing interpretants*) and be able to describe it, we also need *grounding interpretants* that should be the outcome of a simultaneous process providing variation, selection and retention of selective distinctions that help the individual evaluate the provided variation, and in turn enable him or her to focus on a specific source of experience by describing it. Of course the evaluation of variation, just as the generation of variation, should be directed by the *experiencing interpretants*' noticing aim. Therefore, out of the multiple possibilities (provided by *distinguishing interpretants*) of thousands of phenomena taking place around our hungry individual (noticed or not by *experiencing interpretants*), the *experiencing interpretant's* need to notice food should be the ubiquitous funnel of *grounding interpretants*. However, noticing food should not strictly be the only active or prevalent motivational aim at all times in *experiencing, distinguishing* and *grounding interpretants,* it could be replaced by the need to stay alive for example, or in fact any other aim, should the surroundings require the individual to do so (more on this ahead.)

4. Embodying experiences **–** FIXING DISTINCTIONS IN INTERPRETANTS

Finally *embodying or fixed interpretants* are those that, after a process providing variation, selection and retention of distinctions helping individuals preserve suitable interpretants, allow individual's to fix these interpretants as prevalent during the constitution of interpretants. For example, the habit of recognizing regularities and making generalizations is a very strong *fixed interpretant* in humans, this means that our hungry individual can then, without being conscious: recognize what a possible source of food regularly does (i.e. time when fruits grow, or when fish come near shore, or deer go drink water), or where it could generally be found (i.e. on trees, in holes, etc.), or simply notice what other humans usually do (i.e. exchange commodities), or what the individual him or herself often undergoes (i.e. getting hungry approximately every four hours.) Particularly, this *fixed interpretant* – the habit of recognizing habits - is deeply rooted in us because it has been of great help throughout human history, especially for the development of science. However, these *fixed interpretants* also refer to pre, sub or unconscious interpretants that individuals are not aware of. *Fixed interpretants* are in general difficult to recognize or replace, and can actually hinder individuals from noticing and experiencing in the first place.

We still, however, need to account for the salient features of human behavior, that is, eventhough at each stage of the EDGE model there is a "motive of behavior" or a motivational aim through which simultaneous evolutionary processes constitute experiencing, distinguishing, grounding and embodying interpretants for noticing, generating, evaluating and fixing experiences, respectively, it does not mean that this motivations should be the only aims at work. In other words, *interpretants are* *constituted at each stage with a motivational aim in place, nevertheless there are also other aims configuring interpretants that can become prevalent at any stage regardless of the task at hand* (i.e. a globally specified goal; should there be one at all) as mentioned before, which can end up attributing a particular meaning to the experience in question “partly for the sake of survival, partly for the sake of human flourishing beyond mere survival, and partly by chance” (Lakoff and Johnson, 1999: 91.) Apart from all of the other strongly *fixed interpretants* influencing the evolutionary constitution of interpretants that we might still be unaware of. This is essentially why we propose that our learning model (or inner world reconstruction model) can work irrespective of rigorously specified motives of behavior.

Now all of the previously described interpretants should interact simultaneously with each other through a widespread synchrony (Varela, 1995) in order to attribute particular meanings to experiences and provide our hungry individual with perspective. Let us now speculate about the way in which this model could be implemented in artificial agents, through the use of parallel interpretative devices.

3. Parallel genetic algorithms for individual agents

In order to simulate the human process just outlined, artificial agents would need to be designed so as to: first ex*perience* something (generating a break in their inner world triggered by **interpretative devices aiming to notice**); then di*stinguish* the source of this experience (separate it from other simultaneous disturbances by means **interpretative devices that generate variation**); also *ground* what they are experiencing (describe it, define it, characterize it, exemplify it, associate it using ‘inner world’ terms and conditions in order to establish the experience’s properties and structure, with the aid of **interpretative devices aiming to evaluate variation**); and when this new experience is finally employed (i.e. it enters a bundle of distinctions constituting an interpretative device by means of **interpretative devices aiming to fix**) be able to *embodied* it as a distinction. Now, our artificial agents would also need an additional set of **interpretative devices providing random interpretations** accounting for the effects of chance, and leading to “misinterpretations” that could end up having a positive effect in the performance of an agent.

This in practice means that each agent should have at least five (5) GAs at its disposal, in order to effectively learn or construct its world and let knowledge evolve by itself, namely: a *GA in charge of noticing*, replacing the combining data structures routine that regenerates trial solutions; a second *GA in charge of generating variation*, in place of the simple routine randomly generating initial and subsequent trial solutions; a third *GA evaluating variation*, replacing the variety constraining routine where the fitness assessing function acts and reconstructing it at all times; another *GA for fixing*, substituting the selection routine, aiding the reconstruction of the fitness function, and determining the frequency for applying it; and a final *GA for misinterpreting*, which should aim at disrupting the adequate widespread interactions between all the other GAs, playing the role of chance.

These 5 parallel GAs should interact with each other to reconstruct an artificial agent's inner world through synchronic mechanisms (i.e. resonant assemblies, matrix or reverberating networks, etc), which could also be made to vary among interacting agents, *adding yet another variable to our model and many respective degrees of freedom*. Meaning that each agent would essentially become a mini-artificial market with unique specifications, because eventhough there is a competitive dynamics *within* each GA that determines which is the best strategy for noticing, generating, evaluating, fixing and disrupting experiences (or disturbances), the interactions *between* GAs need not necessarily be competitive, again they should represent a widespread synchrony, so that it can together amount to an artificial agent's viewpoint.

And all of this should take place in a multi-agent scenario where globally specified goals are not indispensable, insofar as the exercise in itself could serve to scrutinize various interaction mechanisms among agents, defined not just by the initial conditions or the learning specifications of each GA, but more so by the interaction mechanism among GAs in a single agent. That is, we could establish what combination of attributes in an agent, instead of among groups of agents[6], would lead to the emergence of cooperation (Axelrod, 1997) or economic self-organization (Foster, 1996; 1999 and 2000.) In particular, it could help establish what is it that catalyzes the transition from freewill-guided agents to rule-based interactions or institutional behaviors (North, 1990) where even an individual utility maximizing attitude, for example, could spontaneously become one of the prevalent interpretative devices among agents.

It was never our intention to provide *detailed* specifications for how the model presented here could be adopted as an artificial agent's learning algorithm, we leave that task to future research in evolutionary programming, however, our redefinition of knowledge as an evolving entity that develops through continuously dynamic equilibriums still needs some exemplifying so that it can eventually be put into practice. In other words, precisely because the model we propose is most useful for exploring the adequacy of various interaction mechanisms: among GAs in a single agent, and among agents; *a priori* we cannot responsibly speculate about what the outcomes of such a computational exercise would be.

So in order to give programmers and computational economists some insights about the "upper scale" workings of this application, we will use an *institutional global goal* to

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[6] This strategy reduces variety by grouping agents with similar tastes and preferences together, however these similar preferences result from various forms of imitation (i.e. cultural transmission as in Gintis, 2000) implying the use of a single externally-imposed pattern-recognizing habit, instead of being the result of complex evolutionary neurophenomenological processes, as we propose here, given the fact that there are many other possible fixed interpretants. Including the possibility of grouping agents after they have each "cognitively" developed similar attributes and/or preferences in order to verify the emergence of rule-based behavior would, however, entail an interesting exercise that increases variety by adding another variable with its respective degrees of freedom, which we will not discuss here.

guide the interactions among agents, and because of this, to a certain extent the interaction among GAs within every single agent, and in turn the initial conditions and learning specifications of each GA. We realize that adopting this strategy for exemplifying the evolutionary dynamics of knowledge is self-defeating insofar as globally specified goals were, and still are, deemed unnecessary, however there are at least two reasons for doing this: first, since the number of alternative combinations of interaction mechanisms among agents, and among GAs in an agent, as well as the learning specifications of each of these interacting algorithms increases exponentially every time an agent embodies a new experience and/or a new agent enters the multi-agent scenario, it may well be that these detailed specifications, allowing for the transition from freewill to institutional behavior, are impossible to find; second, even if one manages to establish any detailed specifications, one would only have limited access to them. This is the case because every agent should be endowed with unique traits (not just in terms of alternative learning specifications and/or interaction mechanisms, but more so in terms of the GA in charge of disrupting and misinterpreting experiences) that could and should trigger unexpected behaviors, which could *for the sake of chance* end up, leading to cooperation or self-organization. This is the large-scale expression of the self-referential instability introduced in the definition of interpretants (or interpretative devices) that constitutes the advantage and the weakness of our proposal, vis-à-vis, accounting for the salient, paradoxical and contradictory features of human decision-making.

For the sake of the argument let us then consider Martens' (1999) association between economic growth and the recognition of individual rights, and the gradual introduction of the concept of equality, as: not only defining the turning point that triggered a relentless race for differentiation and achievement-based meritocracy in most western countries; but more importantly as implying that our real-life example could indeed be based on a globally specified goal disposing that variety ought to be increased following a human rights arrangement. This, in artificial agent terms, enables us to approach the practical meaning of *enhancing agent-based modelling through the use of learning processes that manage variation by providing additional variety*, and setting the multi-agent scenario to follow the canons of externally promoted variational, selective and retentive institutions, namely: *evolutionary institutions*, because, we believe that if globally specified goals are to be used at all, they ought to be of an evolutionary nature as well. Meanwhile, in the human context, helps explain why a country with advanced intellectual property rights legislation, and an unimpeachable determination to protect both: civil and political; as well as economic and social rights, is more innovative, productive, and economically more efficient than those countries where these institutions are intermittently regarded as worth promoting or defending.[7] In the next section, we will illustrate the individual consequences of such an institutional set up.

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[7] Both of these propositions have been documented in detail: the relation between human rights and development has been undertaken by Sen (2000) and UNDP (2000), while the relation between intellectual property rights and economic growth has been approached by Gradstein (2002 and 2004.)

3.1. Evolutionary knowledge and institutions

Thanks to a community's (or country's) *variational institutions* promoting basic human rights (i.e. compulsory basic education) individuals could have access to essential choices and capabilities, and in turn be more likely to engage effectively in economic, social and political arenas of that community (Parra and Yano, 2002.) If additionally the community provides eager individuals with *selective institutions* promoting social rights (i.e. the possibility to have adequate access to credit or financial resources); and at the same time with *retentive institutions* guaranteeing property rights (i.e. equal access to judicial systems, or securing the returns of these individuals' current and future investments through good governance), then these members of the community will probably end up contributing productively and innovatively to the economy. Characterizing the adequate workings of *evolutionary institutions* that implicitly advance the evolutionary dynamics of knowledge, insofar as the innovativeness and productiveness of the individuals in question will expand the community's overall set of experiences, distinctions and choices. The evolutionary institutions of a community can empower individuals to improve the system's knowledge equilibrium, turning it into a dynamic and ever changing entity, because now, these newly conceived experiences, distinctions and choices should be offered out to the public (i.e. the bulk of all individuals) as additional and available variation, in the form of: news, through the right to free press; commodities, through the right to free enterprise; or new knowledge, that ought to be taught in public schools, which justifies the importance of promoting human rights in general, and basic education in particular. The next section offers a review of additional justifications for increasing variety as a way of handling variation.

4. Importance of Variation[8]

This section further documents the need to *manage variation, by augmenting the variety, in our models*. Specifically, increasing the experiences, distinctions and choices individuals, or artificial agents, have access or are exposed to.

When addressing the issue of ethics, Heinz von Foerster (1992) proposes a metaphysical postulate to describe the moment when one becomes a metaphysician "Only those questions that are in principle undecidable, we can decide." (Von Foerster, 1992, p. 6). That is, we become metaphysicians whenever we decide upon in principle undecidable questions, and due to the nature of in principle undecidable questions; they occur under no constraints (i.e. no logic, no right or wrong, no need for truth or even responsibility) yielding to overwhelming freedom of choice. In such scenario, Von Foerster proposes that the ethical thing to do is to increase the number of choices. Eventhough this proposal is metaphysical in nature, is corroborated by a systemic entropy analysis performed by Ashby (1956) who proposes the Law of Requisite Variety, by which only "variety can destroy variety" (pg 207.)

[8] Part of this section is a modified version of the introduction in Parra and Yano (2002.)

Accordingly but using a different outlook, the UNDP and the *human development* perspective, define poverty as the denial of choices and opportunities for a tolerable life, therefore, widening people's choices and the level of well-being they achieve relative to these choices, are at the core of the notion of *human development*. Such choices are neither finite nor static, but regardless of the level of development the three essential choices for people are: to lead a long and healthy life, to acquire knowledge, and to have access to the resources needed for a decent standard of living (UNDP, 1990; UNDP, 1997; UNDP, 2001). In particular, the acquisition of knowledge, for inner world reconstruction, has been the conducting thread throughout this study.

Even from the strict biological definition of evolution, Mayr (2001) asserts that "Darwin's theory of evolution through natural selection is best referred to as the theory of *variational evolution*" (pg. 85) because it requires enormous amounts of genetic variation for every generation so that only a few, of the vast number of offspring, produce the next one, namely: those that are best adapted in terms of a particular combination of attributes. It is our contention that this combination of attributes relates directly to our definition of interpretants, made of experiences that become distinctions, and then choices.

Recently, variation has claimed importance from an organizational viewpoint, Miner *et al* (2003) showed through field research that increasing experience generates more, not less, variability as traditionally implied by convergence and/or convexity theories. Moreover, it seems that this variation can be an important source of diversity for innovative activity, that is, greater diversity leads to faster technological changes (Cohen and Malerba, 2001) corroborating our intuition in the *evolutionary institutions* example. From a complexity economics perspective, when Martens (2000) incorporates the so-called Coase theorem to explain the emergence of rule-based behavior and institutions, he comes very close to the approach presented here in that he considers evolutionary mechanisms that "favor survival of agents who are best at giving appropriate responses to the widest possible range of events in their universe." (pg. 9) By doing so, Martens recognizes the need for variety as a way of managing variation, but fails to point to it directly, and instead decides to impute Information Gathering and Utilizing Systems (IGUS; Gell-Mann, 1995) a *'motive for behavior'* based on norms, namely: an institutional rule-based behavior that minimizes uncertainty and overcomes transaction costs through the division of labor, which limits an agent's perspective (i.e. interpretative devices) to the workings of a single motivational aim active at all times.

In any case, all of these assertions are proposing that the best way to handle variation is by providing additional variety; therefore, an additional consideration justifying the need for variety are the methods for handling its generation.

5. Conclusions

We cannot overemphasize the fact that we decided to base our model on Sen's capabilities approach not just because of the human development paradigm it advances, but more so because *its focus on liberty instead of utility helped us overcome the individual rationality assumption*, enabling choices, distinctions and experiences as possible substitutes for it during economic decision-making. Moreover, this in turn made us scrutinize human experience and develop a new definition of interpretants that can become the basis for designing an artificial agent's interpretative devices.

Informational economics, new growth economics, evolutionary economics have made contributions that Agent-based Computational Economics, and complexity economics in particular, have taken into account. However, this study proposes a way for computational economists to account for recent advances in behavioral and experimental economics, insofar as the overall specifications of *Parallel Genetic Algorithms for evolving Agent Strategies* not only avoid unacceptable neo-classic assumptions, but also deem *unnecessary any globally specified goals*. The outcomes of such a multi-agent exercise (i.e. in a setting with no globally specified goal) could illustrate the emergence of cooperation and of economic self-organization, and help establish under which learning specifications (i.e. active and/or prevalent interpretative devices) rule-based institutional behaviors can spontaneously appear; however, the more we incorporate the salient features of actual human behavior in our models, the harder will be to have access to the detailed specifications of the computational decision-making processes. In other words, the more artificial agents resemble our behavior, the less likely will they be to know exactly why or how they decided something. This is also why the evolutionary-neurophenomenological-cybersemiotic complex perspective inherent in the EDGE model, as well as in the artificial interpretative devices discussed, significantly departs from game theoretical approaches, which try to account for every possible future situation by adding constraints or restrictions, which is the opposite to the way variation is handled here.

The wide range of justifications for increasing variety yields to a Keynesian-type postulate (e.g. generating expenditure and internal demand by increasing public expenditure) for: scrutinizing and designing variety generating mechanisms in learning algorithms; managing the variety of possible methods of interaction between parallel GAs in a single agent; as well as among agents (i.e. increasing the number of choices available to all interacting agents), namely: *variation ought to be handled, by providing additional variety*. The discussion about how to determine what type of variety to provide is something being resolved on a day-to-day basis that has taken place since the beginning of recorded history, however, it could refer to human rights and related institutions as exemplified here.

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