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Heuristic-based management (I): variation

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Abstract

Purpose – The paper considers model-based management and, based on it, proposes a heuristic-based management. This paper aims to assert that heuristic-based management, for complex systems, a process of free variation, of pairs of models and actions – called organisational strategies, maximizes the chances of improving the system's performance in open environments.

Design/methodology/approach – A conception of complex systems are introduced and characterized as open and self-organising systems. Then, the proposal to heuristically use pairs of models and actions, called organisational strategies, to manage social systems based on evolutionary thought is supported. Subsequently, a computational experiment is proposed to show that, even in a simple framework, variation processes are required.

Findings – The paper shows that two processes may be required to preserve self-organising systems. This finding indicates that variation and selection processes, related to evolutionary thought, are necessary for managers to deal with complex systems interacting with complex environments. Finally, it is shown that, even in simple computational environments, variation may be required.

Research limitations/implications – The paper is the first part of an ongoing research agenda on the subject of heuristic-based management and only refers to variation processes.

Originality/value – The paper links complex systems theories to evolutionary thought. It also relates principles of cybernetics to those of game theory. The proposal has been formalized based on these relations, and has been called heuristic-based management. Principles first developed in information theory, organisational cybernetics, and evolutionary thought are used so that a complex system can be effective when interacting with a complex environment.

Keywords Problem solving, Corporate strategy, Modelling, Cybernetics

Paper type Conceptual paper

> Heuretikos – Gk.: "inventive"
>
> "All models are wrong. [...] All models, mental or formal, are limited, simplified representations of the real world" Sterman (2000, p. 846).

The authors wish to thank COLCIENCIAS for the "Programa de apoyo a los programas de doctorado nacionales a través de créditos condonables", CeiBA complejidad, and to FONDECYT regular projects 1070854. The authors are also very grateful to an anonymous reviewer for their thoughtful and precise suggestions, to B. Toledo, J. Rogan, and V. Muñoz for the fruitful discussions, and to Magdalena Holguín for her kind collaboration.

Kybernetes
Vol. 39 No. 9/10, 2010
pp. 1513-1528
© Emerald Group Publishing Limited
0368-492X
DOI 10.1108/03684921011081141

1. Modeling

Management models can be conceived as models for helping organisations effectively complete tasks (Schwaninger and Janovjak, 2008). However, according to Schwaninger (2009), the use of models for supporting managerial processes appears to be an under-researched issue; he proposes a research agenda for model-based management with an emphasis on the need for developing methodologies for exploring the role of models and modeling in management.

Following this suggestion, this paper considers model-based management. Our starting point is that the intuitive notion regarding the word "model" brings to our mind the idea of a purposeful representation, i.e. a simpler representation of something for a given purpose. Therefore, one of the fundamental questions about modeling is whether it is possible to assess if a model is a good representation of the represented object. Another fundamental question could be whether the model is useful or not; if it is, it allows the modeler to close the gap between what she observes and what she desires (her goals). We want to stress the fact that these questions apply to closed systems, that is, systems that can be isolated from surrounding variables and entities; the modeler knows what she desires and is able to identify the complete set of variables, entities and relations in order to isolate the object she observes and wants to model.

However, the systems that managers are usually interested in are complex systems, i.e. systems interacting and evolving with their environment. For this kind of systems, we suggest that the fundamental questions about "models", mentioned above, should be reformulated. For instance, what happens when it is impossible to establish the set of all variables and entities that might affect a system? Is it still possible to build a comprehensive relationship? Is this question still pertinent? And, in this sense, is it possible to have complete (or finished) models that are useful for complex systems? Notice that, regarding the above, the notion of "method" (in contrast to that of "heuristic") is also linked to these reflections, since it suggests a sequence of steps designed to achieve a given goal, i.e. the "model". Thus, if we consider the impossibility of having a complete or finished model, how should we then define the notion of "method" itself? What promises can we honestly make?

We believe that the issue here is not whether the model is good or useful, but how it can be useful; or, better yet, how a set of models can be useful. At this point, we are suggesting that, as far as complex systems are concerned, a perfect fit cannot be achieved. However, the process itself of seeking such fitness may result in learning for modelers – or managers. What we mean to say is that an honest answer to these questions should be "heuristic" rather than methodological.

Our previous research has paved the way to this research topic (Zarama *et al.*, 2004, 2007; Calderón and Zarama, 2006; Lammoglia *et al.*, 2008; Olaya, 2008). This paper is the starting point of a new research agenda. Here, we develop some intuitions to support our proposal that, for complex systems, a process of free variation of models and corresponding actions maximizes the chances of improving performance in open environments. We propose this option, instead of a process of adjustment between system and model (i.e. the process of "validating" a model). Here, the emphasis is placed on unrestricted processes of production of variety; that is *production and iteration of models* that, in an open world with an uncertain future, may offer more options in order to be prepared for unpredictable disturbances. It is the process of producing different models itself what benefits modelers and managers, for instance because it promotes critical discussion of "the system" that is being modeled, e.g. the borders ascribed by different observers, the selection of what is considered as relevant, the incomplete nature of models, the usefulness of models, etc.

We suggest a reflection regarding some issues related to our understanding of models. These considerations question the notion of "method", especially when applied to complex systems. We would like to suggest replacing "method" with "heuristic". We shall introduce "heuristic" as the process of generating conjectures in knowledge systems, namely, the continuous process of generating new models to support decision making by increasing knowledge of and about organisational complexity management. In this framework, models are not understood as representations, but as observational and communicational devices that enable us to collect and distinguish information from the environment (complexity attenuators, in cybernetic language). This information is subsequently transformed into knowledge that allows for effectiveness in our domain of action. In this sense, models become an organisational means that must be articulated with the actions carried out by the organisation to be effective. These pairs of models and actions are what we call organisational strategies.

Our proposal is based on the idea that the continuous and free generation of new conceptual entities should provide better ways to improve the chances to manage organisational complexity. The process proposed here favours modeling over model, i.e. process over result, with a special emphasis on "experimentation" and "trial-and-error" search of solutions to be selected by the system during its interaction with the environment. This selection guarantees that the best trials survive through consistent error-elimination processes. Here, then, management is understood as a process of producing inventions (in complex systems) instead of a process of closing gaps by artificial selection (made by managers or technicians) of finite options (in closed systems).

This paper, as the first part of our current research agenda on the subject of heuristic-based management, holds that our ideas about complex systems and evolutionary thought are organisationally effective. We shall first introduce our conception of complex systems and characterize them as open and self-organising systems. We then support our proposal to manage heuristically social systems based on evolutionary thought. We include a computational experiment to show that, even in a simple framework, variation can be required, especially as the environment becomes more diverse. And, finally, we conclude the paper with an invitation to think of heuristic-based management by increasing organisational variation to manage complex organisations interacting with complex environments.

2. Complex systems

This section offers a characterization of what is considered a complex system. Gallagher and Appenzeller (1999) understand them as "[those systems] whose properties are not fully explained by an understanding of its component parts". The *Compact Oxford Dictionary* defines "system" as "a set of things working together as a mechanism or interconnecting network," from the Greek *sustema*, and this from *sun-* "with" and *histanai* "set up" (Soanes and Hawker, 2005). And "complex" as "consisting of many different and connected parts" from the Latin *complexus*, from *complectere* "embrace, comprise" (Soanes and Hawker, 2005). In this context, the adjective "complex" adds, at least, two characteristics to the noun "system". The first one asserts that the things that make up a system are different things. The second one brings to mind an action, because “complex” is derived from the past participle of the Latin verb *complecti* (Corominas, 1998). This tells us that complex systems are observed as sets of different related things able to continuously organise themselves, whose properties are not fully explained by the understanding of their component parts. Particularly, social systems can be observed as complex systems, i.e. sets of different things (subjects) who are able to organise themselves, and whose properties are not fully explained by the understanding of their component parts (Zarama *et al.*, 2004).

On the other hand, the fact that we can consider something as a “complex system” suggests the idea of invariance, i.e. the idea of order; despite the fact that a complex system is constantly changing. Therefore, complex systems must be able to preserve their internal organisation despite, or better yet, because of their internal operational dynamics. The Austrian biologist Ludwig Von Bertalanffy first developed this characteristic of complex systems. He noticed that the duality between order and change challenges the second law of thermodynamics. According to this law, “every isolated or ‘closed’ system [proceeds] spontaneously in the direction of growing disorder” (Capra, 1998). To answer this objection, von Bertalanffy himself would have asserted that “[t]he organism is an open system in a (quasi) stable state [. . .] where matter is continuously going in from and going out to the environment” (von Bertalanffy, 1968, quoted in Capra, 1998).

In other words, the organisation of the system is not determined by the environment, but is rather the result of the interaction between the system and its environment. This shows another characteristic of complex systems: self-organisation. However, authors like Heinz von Foerster (1984) say that there is not such a thing as “self-organising systems”. Self-organising systems are better understood as mental constructs made by an observer who draws a border that separates the system from its environment, where the criterion used to decide what is a system and what its environment is that the former is able to organise by itself, while the latter increases its entropy. Even so, he tries to formalize them. His proposal takes the definition offered by Claude Shannon of information entropy and, as we understand it, adapts it by using a measure of complexity called variety, defined as the number of possible states of a system (Ashby, 1956; Beer, 1985).

The measurement of entropy proposed by von Foerster is understood as a relation between the number of possible states in a system and the probability that any of these can be observed. In this sense, entropy is nothing more than a statistical property of the states of the system. Having this in mind, it is possible to measure the present entropy of a system as well as its maximum entropy. Moreover, the system’s entropy and its maximum entropy are related to the total number of possible states in the system. Furthermore, by using two additional measures, called relative entropy and redundancy, a system’s entropy may be standardized.

Relative entropy is the proportion between a system’s present (H) and maximum (H_{max}) entropy; and redundancy (R) is equal to one minus relative entropy. Redundancy may thus be understood as a statistical measure of order in a system. Using the redundancy measure of a system and adapting the proposal made by von Foerster (1984), a system’s process of self-organisation may be formalized, as shown below. Redundancy is defined as:

$$R = 1 - \frac{H}{H_{\max}}. \tag{1}$$

Now, assuming that the redundancy of a self-organising system is a function of time (*t*), then the first derivative of the system's redundancy in relation to time must be positive, as shown below:

$$\frac{\delta R}{\delta t} > 0. \tag{2}$$

It may therefore be concluded that self-organisation is only possible if:

$$H \times \frac{\partial H_{max}}{\partial t} > H_{max} \times \frac{\partial H}{\partial t}. \tag{3}$$

Therefore, according to equation (3), at least two mechanisms are active when we observe a self-organising system. There is an internal mechanism modifying the probability that any possible state may be observed (that reduces entropy). And there is also an external mechanism increasing the possible states of the system during its interactions with the environment (that increases maximum entropy).

However, according to Capra (1998), quoting Prigogine, reinforcing loops, and not only balance loops, are a source of order. According to this, von Foerster's proposal must be reconsidered. It means that the internal mechanism that reduces entropy by selecting states through a balance loop, increases at the same time the chances that the selected states be selected again in the future. It implies that the likelihood of a state being observed today increases the probability of its being observed in the future. On the other hand, Prigogine also suggest that a system's entropy is not only reduced by means of the internal process, but also by reducing the possible states of the system (decreasing its maximum entropy) by sending residues – produced by these self-organising processes – to the environment. This last mechanism increases the entropy of the environment and the second law of thermodynamics holds (von Foerster, 1984).

In sum, organisations clasified as social and complex systems may be seen as sets of different related things capable of continuously organising themselves, whose properties are not fully explained by the understanding of their component parts. Furthermore, in order to be observed, a complex system must exhibit invariant properties despite its operational dynamics. And these can only be observed in open and self-organising systems. Two mechanisms are required for this:

1. an internal one that selects states and increases the probability that the selected ones be selected again in the future; and
2. an external one which increases and decreases the system's maximum entropy by interacting with its environment.

3. Towards heuristic-based management

Based on the above, the increment of a system's internal order may be observed as an evolutionary process that increases the chances to survive in a changing milieu that continuously attacks the system. Let us suppose that the logic of natural selection appears to be the most successful hypothesis in explaining the survival of organisms under changing conditions. Therefore, the goal of management may be defined as the continuous promotion of the self-organising capabilities of the system (the organisation). von Foerster's results indicate, therefore, that the tasks for the manager are:

- Incrementing H_{max} by increasing the total number of the system's possible states and, particularly, by admitting those that do not increase H (the internal entropy) faster than the increase of H_{max} (adapted from von Foerster, 1984).
- Reducing the system's entropy (H), i.e. by changing the probability distribution of the possible states to be observed (Von Foerster, 1984).

These mechanisms remind us of the evolutionary process, where information regarding the environment is incorporated into organisms through adaptation (Bartley, 1987). That is, through the continuous interplay of two steps: variation and selection. Variations are selected, maintained and propagated through evolutionary cycles. This means that the "raw material" upon which natural selection operates is the generation of variations. It was clear for Darwin that such variations should be generated in copious and dependable amounts (Gould, 2002) to expand the range of options for survival under changing external conditions. Campbell (1987, p. 92) coined the expression blind variation; "blind" denotes, essentially, that "variations are produced without prior knowledge of which ones, if any, will furnish a selectworthy encounter". Here, "blind" does not mean strict equiprobability of alternatives, it simply emphasizes that the probability distribution of variations is independent of previous experiences, potentially successful trials or targeted goals. Campbell emphasized three conditions:

(1) The variations generated are independent of the environmental conditions surrounding their occurrence.

(2) The individual occurrence of trials is not correlated to the solution – specific correct trials are no more likely to occur at any point in a series of trials than other, or than specific incorrect trials.

(3) The rejection of the notion of a "correcting" process among variations, that is, a variation occurring after an incorrect trial is not a "correction" of an earlier one.

The direction of evolutionary change pertains to the second step, selection as such, that acts upon generated variations. Natural selection occurs due to the elimination of unsuccessful forms. A Darwinian stance emphasizes blind variation and the fact that adaptation and selection are driven by the environment based on the fitness of possible solutions. What takes places is trial and error-elimination of unsuccessful responses. Exploration goes beyond the limits of foresight or prescience. In this sense, variation is blind, and adaptation is explained as the result of selection.

Linking these ideas, and as we already mentioned, management models may be conceived as models for helping organisations achieve tasks effectively (Schwaninger and Janovjak, 2008). In this work, we tie the function of managerial models with the tasks for managers identified at the beggining of this section. We would like to associate the generation of free variations with the increment of H_{max}, and the process of selection with the reduction of H. Furthermore, we think these variations may be generated with the help and continuous generation and improvement of management models. In particular, we emphasize the process of increasing H_{max}, that is, the expansion of options or, in our case, new possible states. This is a subject seldom examined in evolutionary theories, at least when compared to the traditional emphasis on processes of selection over variation (Ellerman, 2004).

In what follows, models and the actions they enable correspond to the possible states that may be observed in a system. Moreover, we shall call these pairs of models and actions organisational strategies. This means that, for us, a strategy is the articulation between a model, that allows us to observe the world in a particular way, and an action, that interacts with the world in order to achieve something, based on the image of the world provided by the model. In cybernetic terms, we are saying that the pairs of complexity attenuators and amplifiers are what we call strategies. These strategies are a system's possible observed states.

We are, therefore, interested in processes of continous production and improvement of what we call strategies. Different models allow for the exploration of different paths and, furthermore, these models may become:

- vehicles for the creation of new realities (Schwaninger, 2009); and
- variety amplifiers of the behavioural repertory of actors in organisations (Schwaninger *et al.*, 2007).

Pairing these issues increments the system's posible states. This allows us to observe a larger potential disorder (increment of H_{max}), but also a larger potential for successful interaction with the environment.

The emphasis on continuous improvement is central to our proposal, since it entails a dynamic view that assumes a constantly changing environment for the organisation. The significance of this framework may be appreciated if we consider the traditional criterion for a model's quality, its validity, which usually depends on how accurate the representation is, on the "fit" between model and what it purports to represent (Schwaninger, 2009). We would like to emphasize that a management model is not a frozen product whose results are used. The process of improving is the process of looking for fitness through permanent iterations of blind variation production. These selectionist systems do not operate based on partial truths; any prior knowledge of the environment or any information transfer from the world are not necessarily needed for proposing variations or for directing adaptation. Adaptation is related to the profuse generation of possibilities and the selection of successful ones. Within this constant generation of options, the possibilities of survival are maximized, since internal change is not restricted and the probability that managers may find sucessful responses increases.

4. Computational experiment

Summarizing the above, we suggest that managers should increase the number of the system's possible states, i.e. the pairs of models and actions to be effected, while keeping the internal entropy constant and strive towards its reduction. We have also stressed the importance of an evolutionary frame regarding these objectives.

In this section, as a testing ground for our ideas, we suggest a computational experiment that captures them in an intuitive and simple way. The purpose of this experiment is to provide evidence that indicates that variation is required in order to deal with complex environments. We intend to show this by providing experimental results that indicate a correlation between the environment's diversity and the variation required by the organisation to be effective. Our experiment compares the results of two simulations where the control variable is the environment's diversity. For the first simulation, the environment is composed of homogeneous agents, for the second, agents are heterogeneous. Our experiment is based on a game inspired in the iterated prisoner's dilemma (PD) and a search technique based on a genetic algorithm (GA). However, it should be emphasized that we are not trying to solve a problem using GAs; we are using the typical steps of a GA to simulate a simple environment.

We follow (Smith, 1989) in the description of our experiment; accordingly, we describe the three dimensions essential to the design of any market experiment: the environment (E) (the set of all the agents' characteristics); the institution (I) (that defines the communication languages and the rules of interchange between agents); and finally the agents' behaviour (A).

4.1 The experiment

We describe our experiment in terms of the three dimensions E, I, and A.

4.1.1 Environment (E). The environment in our experiment is given by an adaptation inspired in PD. PD was first developed by M. Dresher and M. Flood in 1950 (Poundstone, 1992). Later, it was widely studied by Axelrod (1997), among others. Instead of guilty criminals, however, we have a group of N interacting organisations. Interactions occur between couples of organisations, and they have only two choices on how to act regarding one particular interaction, either c (cooperate) or d (defect). A payment matrix shows the payoff for the resulting negotiation (between corporation i and another corporation):

$$P_i = \begin{pmatrix} cc & cd \propto_i \\ dc(1-\beta_i) & dd \end{pmatrix}. \tag{4}$$

According to equation (4), the payoff for any organisation i depends on its own decision and on the decision made by its counterpart. Thus, for example, if the organisation i chooses c and the other organisation chooses d, the payment it receives is $cd\alpha_i$, and so on. The meaning of α_i and β_i is explained in the agents' behaviour section. Two players are selected for negotiation in the experiment. They play g rounds in a row between them and the total payoff of one negotiation is the sum of these g rounds.

Each organisation has an initial endowment of zero, and a size m memory, i.e. it can remember the last m plays made by its counterparts. Hence, organisations may have strategies, i.e. a model about the world (its memory) and act according to it. The set of possible strategies, given a size m memory, has cardinality $2^{2\,\mathrm{m}}$ (Ashby, 1956). Here, we translated cybernetics language into game theory language. It is possible to show that the cardinality of the set of strategies in a given game corresponds to the number of possible states of a system in a black box description. In evolutionary terms, each organisation has a genome that specifies the strategy pool for the organisation. We give each organisation a random subset, of random size, of these $2^{2\,\mathrm{m}}$ strategies. During each negotiation, each organisation randomly chooses one strategy from its own set and plays it.

For example, let us say that we have two players with a memory $m = 1$ and we play negotiations of $g = 3$ rounds. The total available strategies (S) are shown in the following table:

Past	$S1$	$S2$	$S3$	$S4$
c	c	c	d	d
d	c	d	c	d

Let us also say that the set of possible strategies for player one is *S2* and *S3*, and it chooses *S2* for this round of interactions. If its memory is set to *d* from the previous encounter, i.e. on the last interaction its counterpart played *d*, then it will play *d* on the first round and update its memory according to whatever the other organisation plays, *c*, for instance. Its payoff for this round will then be $dc(1 - \beta_i)$.

4.1.2 Institution (I). The rules for the game in terms of exchanges, namely the ways agents interact, and the possible interactions that may occur follow a GA structure. GA is a search algorithm used to find solutions to optimisation and search problems (Holland, 1975). We shall use GA as a way to simulate a competitive environment. All GAs must have a fitness function. In this particular case, the function is the accumulated payoff for each organisation. The algorithm for this experiment is described below:

- Randomly select two organisations i and j ($i \neq j$).
- Play a negotiation of g rounds between them (each player uses only one of its possible strategies and uses it according to its memory). Payoffs are accumulated.
- Repeat the previous two steps M times. Note that $M > 2N$ so that all players have a chance to play at least once, on average. The player may use different strategies each time, randomly selected from its pool of strategies.
- A tournament selection mechanism is applied. Randomly select organisations and compare their accumulated payoffs.
- Eliminate the organisation with the smallest payoff.
- Replicate the organisation with the biggest payoff with a chance of mutation (as explained below).
- Repeat the previous three steps R times.
- Set all accumulated payoffs to zero.

This set of steps is understood as a generation and the experiment is run for G generations. Note that G must be a big number for the experiment to be meaningful. In this situation, the players all have the set of strategies that benefits them most, given their payment matrix.

We allow a mutation to happen in the offspring's genome with probability p. If the mutation takes place, the offspring will either loose or gain one strategy (same chance of both). This happens except when the number of available strategies, for the selected organisation, is 1 or $2^{2\mathrm{m}}$; in these cases the offspring either gets a new strategy or looses one, respectively.

4.1.3 Agents' behaviour (A). Agents will use one of their possible strategies (randomly selected) when interacting with another agent. Each agent will receive a different payoff depending on its particular α_i and β_i parameters. The payoff is given by equation (4) and we interpret the α_i and β_i parameters as a measure of envy and guilt, respectively, (Camerer and Fehr, 2003). Note that all organisations share the same payment matrix except for their particular set of $\{\alpha_i, \beta_i\}$ parameters. Therefore, we have as many different agents as sets of different $\{\alpha_i, \beta_i\}$ parameters we choose for a given experiment, i.e. if we have $\alpha i = \beta i = 0 \quad \forall i$, we will only have one kind of agent (organisation).

Synthesizing, we will run simulations using a set of organisations that interact in a given environment; the environment (E) is inspired in the PD and the institution (I) uses GAs techniques. By means of this simulation, we shall support our proposal, by observing the evolution of the mean number of strategies that the whole population of organisations has at the end of the experiment.

4.2 Treatments

Many different combinations of parameters $\{\alpha_i, \beta_i\}$ are possible (equivalent to having different agents) for this experiment. For the sake of brevity, we shall only have a control group and a treatment group using two different sets of parameters. These parameters are selected based on previous results reported by Rapoport (1965), Axelrod (1983) and Camerer and Fehr (2003).

In our control group, the payment matrix, in principle, favours self-interested organisations with high incentives to defect. That is, we keep $dc \gtrsim cc \gtrsim cd \gtrsim dd$ in equation (4). This is:

$$P_i = \begin{pmatrix} 3 & 0 \\ 5 & 1 \end{pmatrix}.$$

And all players (organisations) perceive the game (their payoffs) in the same way. That is $\{ \propto_i \beta_i\} = \{0,0\} \quad \forall i \ \in \{1, \ldots, N\}$. In other words, in this group, the entire set of agents is homogeneous in their social preferences, i.e. they have the same set of possible states (strategies), and their payment matrix is the same.

For our second simulation, the treatment group, we make the payment matrix more extreme by making $dc \gtrsim cc \gg cd \gtrsim dd$ in equation (4). This is:

$$P_i = \begin{pmatrix} 10 & -15\alpha_i \\ 15(1-\beta_i) & 2 \end{pmatrix}.$$

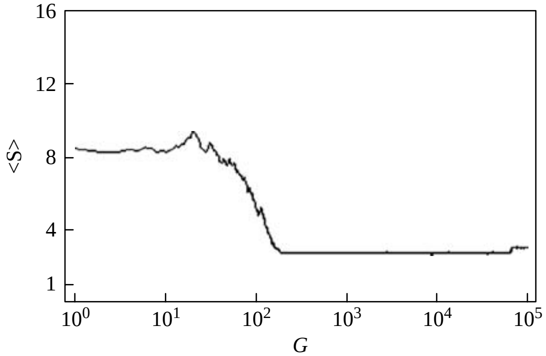
We also allow players to perceive the game in different ways; that is, each agent may have $\{ \propto_i \beta_i\} = \{\{0,1\},\{0,1\}\}$. This means that there are, initially, four different kinds of organisations competing in this experiment: egoists, envious, some that experiment guilt, and others adverse to inequality (Camerer and Fehr, 2003). In other words, in this group, the entire set of agents is heterogeneous in their social preferences, i.e. they have the same set of possible states (strategies), but the payment matrix is not the same for all of them.

For both groups, the remaining parameter values are $m = 2$ (which gives a pool of 16 possible strategies), $g = 5$, $R = 1$, $p = 10^{-4}$.

4.3 Discussion

4.3.1 Control group. Figure 1 shows the results of the simulation. On the vertical axis, we plot the average number of strategies at the start of a generation, and on the horizontal one we show the generation number (on a logarithmic scale). The dots are the average for ten simulations with the same parameters.

From the figure, we can see that after a brief transient (a little over 100 generations) the mean number of strategies stabilizes between three and four for more than 10,000 generations. Basically, this behaviour is telling us that, in order to "survive", the



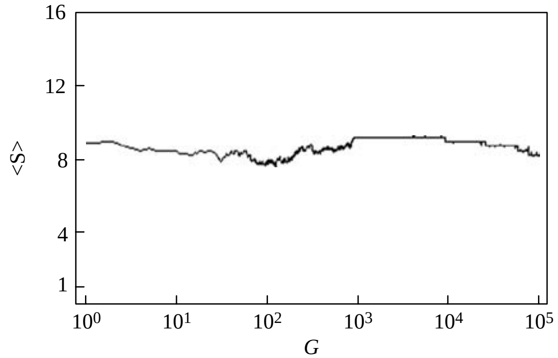
Notes: $dc \gtrsim cc \gtrsim cd \gtrsim dd$ and $\{\propto_i, \beta_i,\} = \{0,0\}$ (only one kind of agent); the horizontal axis, shown on a logarithmic scale, is the number of generations and the vertical axis shows the mean number of strategies

Figure 1.
Mean number of strategies for ten different simulations with $N = 50$ players

players must keep a pool of several (in this case three or four) different strategies. In this case, specialization is not favoured as the ideal way to remain "alive".

4.3.2 Treatment group. From Figure 2 we see that, for the treatment group, it takes longer for the number of strategies to stabilize (something over 1,000 generations) but afterward they stabilize at a value slightly above eight. Basically, this behaviour is telling us that, in order to "survive", players must keep a pool of several (in this case eight or nine) different strategies. Once again, specialization is not favoured by evolution as the ideal way to remain competitive. Note also that the environment is more diverse (different kinds of players and very different payoffs) than in the previous case.

Summarizing, we have provided evidence that indicates that for a very simple competitive game there is not a single "optimal" strategy. Results from both simulations show that, in order to "survive", without a selection mechanism, organisations must keep a



Notes: $dc \gtrsim cc \gg cd \gtrsim dd$ and $\{\propto_i, \beta_i,\} = \{\{0,1\},\{0,1\}\}$ (only four different kinds of agents); the horizontal axis, shown on a logarithmic scale, is the number of generations and the vertical axis shows the mean number of strategies

Figure 2.
Mean number of strategies for ten different simulations with $N = 50$ players

pool of available strategies from which to choose. We also note that the more diverse an environment is the more strategies (possible states of the system) are required by each player to stay "alive" in the game. For homogeneous environments (all players are alike and the matrix does not lead towards a particular set of strategies), the number of strategies is less than for more diverse ones. This supports our idea that real world organisations with complex environments must keep a variety of possible states, i.e. pairs of models and actions, in order to "survive", instead of looking for one perfect strategy. In other words, this experiment shows that, from the point of view of the organisation, minimizing its maximum entropy (H_{max}), despite the fact that there are no internal process that organise its possible states in an "optimal" way, does not seem to be the best choice. In fact, based on the experimental results, even egotistic agents choose variation over especialization.

5. Heuristic-based management – a final remark

Our discussion began by presenting our ideas on "models" and "methods". We argued that these ideas are linked to objects that can be isolated from their environments. But this is not the case with managers. Managers have to deal with organisations, i.e. complex systems interacting with complex environment. This means that they are not able to identify the variables, entities and relations that affect their systems in order to isolate and model them. In other words, managers are not able to build accurate models that satisfy their needs. We argue that this impossibility is not due to the managers' capabilities, the system's or the environment's stochastic behaviour, or a lack of information. This impossibility is rooted in the very nature of complex systems.

When we say that complex systems may be characterized as those whose properties are not fully explained by the understanding of their component parts, we suggest that we have to look for the explanation of their properties in the relationship among their constituent parts and their interaction with the environment. To explain this, let us take for example an airplane. It is possible to say that one of the main properties of an airplane is to fly. However, none of the parts of the airplane can fly by itself; flying is possible because of the particular relationship among the parts of the airplane, but also because of the interaction between the airplane and its environment, i.e. the resistance of air. Flying is a property of open systems. Closed systems affected by gravitational fields cannot fly.

However, planes are not the same kind of system as organisations, because they are not able to organise themselves. This characteristic relates open systems and organisations to complex systems. We showed that this characteristic of complex systems requires two mechanisms. There is an internal mechanism that selects the most probable (successful) states of the system and increases the probability that they may be observed (used), and an external mechanism which increases and decreases the system's maximum entropy by increasing or decreasing the system's possible states. These two mechanisms relate organisations and complex systems operation to evolutionary theories. We suggest that these mechanisms correspond to selection and variation processes observed in evolutionary dynamics, respectively. In this sense, the task of the manager is not to close the gap between the present state of the organisation and its desired goals, but to continuosly increase the possible states of the system by selecting those states (strategies – models and actions) that best fit organisational requirements. It is not only about selection, but also about variation.

In other words, we assume that, for complex systems, a process of free variation maximizes the chances of better performance in open environments. We suggest that managerial efforts should be directed at unrestricted processes of production of variety, that is, production and iteration of pairs of models and actions which, in an open world with uncertain future, might increase options in order to be prepared for unpredictable disturbances to come. Moreover, it is this very process of producing pairs models and actions what benefits modelers and managers. This process calls for developing a modeling culture that emphasizes model building as a constant observational and communicational process among stakeholders instead of a mapping exercise concerned with the efficacy of the model itself.

How could this process be implemented by managers so as to warrant the introduction of sufficient variations? A natural option is to explore what is called "parallel experimentation", proposed by Ellerman (2004), based on the shifting balance theory of evolution. The central tenet of this position asserts that variation and exploration are improved by dividing populations into subgroups with different probes under semi-isolated selectional pressure; this partial isolation prevents premature commitments to initially promising but ultimately unfit solutions. The results of these subgroups should be cross-communicated and compared in order to enhance the performance of the whole group. The equivalent can be called "parallel modeling". In this case, there can be competing models developed through semi-isolated stages whose results are compared with concurrent models; this strategy differs from the traditional managerial principle of allocating resources only to the "best" or "optimal" model. This is a direct result of the premise of "blind" variaton, since there is no a priori criteria for allocating resources. In an unpredictable and constantly changing environment, exploration is preferred.

Hence, we use the term "heuristic" to designate the process of generating conjectures in knowledge systems. In this case, it denotes the continuous process of generating new pairs of models and actions that support decision making in order to enhance the growth of knowledge. Thus, heuristic-based management denotes a trial-and-error and model-supported process for producing inventions in which the continuous and free generation of new conceptual entities should maximize the probability of having more adequate knowledge, i.e. effective variations. This is a process that favours modeling over model, i.e. process over result, with a special emphasis on "experimentation" and on open search for the fittest trials to be selected. Management therefore, actually becomes:

- the process of producing inventions under undirected and unrestricted production of variations – instead of a process of closing gaps by artificial selection (made by managers) of finite options (in allegedly closed systems) based on correction channels concerned with future disturbances; and
- the process of boosting selectional pressure on generated inventions.

Summarizing, there are four processes required to characterize a system as self-organising. The system must:

(1) produce variety;

(2) randomly select states (strategies) and test their fit to the organisation's requirements;

(3) assign more opportunities to be selected to the succesful ones; and
(4) discard the unsuccessful ones.

In this paper, we only explored the process of variation. Our intuition indicates that, when the diversity of the environment increases, the need for variation also increases. To test this intuition, we provided a computational experiment based on a game inspired on the iterated PD and GAs. We wanted to examine which kind of strategies survived in a complex competitive environment. Our control group was composed of self-interested agents with high incentives to defect (Rapoport, 1965; Axelrod, 1983). Against our prior intuition, the stable number of strategies did not drop to 1 (always defect); it stabilized in three or four strategies. This indicates that even among egoists variation may be a good choice. Our treatment group was composed of four kinds of agents: egotists, envious, agents that experiment guilt, and agents adverse to inequality (Camerer and Fehr, 2003). Besides, their payoff matrix was built to incentive cooperation (Rapoport, 1965; Axelrod, 1983). As we had anticipated, the stable number of strategies during the experiment was higher than that observed in the control group. These results point in our direction. The more diverse the environment, the more variation the organisation needs to survive.

This completes the first part of our heuristic-based management proposal. However, our task has not concluded yet. Presently, we have started working on the next paper, where we hope to show that we can get more benefits from variation processes when we combine them with selection processes.

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