Organizations, Modularity and Multi-dimensional Fitness

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(Theme D - C)

The very basic definition of an evolutionary system is a population of heterogeneous entities that innovate their state and are subject to a selection process (Nelson, 1995). The typical model for an evolutionary system considers the selection process as a procedure measuring the *fitness* of entities; such measure is then used to reward higher than average individuals and punishing lower than average ones. This method permits to ignore the representation of the actual competition mechanism among entities. You don't need to specify the actual mechanism by which a novelty affects the relative position of the innovator against the competitors', but you just provide the measure of its effectiveness.

This method has the great advantage of extremely simplifying the modelization, but it comes at a cost. It removes from the analysis one of the main characteristic of real world complex problems, that is the presence of trade-off's due to the uncertainty of the novelty introduction. In the real world, nobody can actually know the final outcome of any one decision. Generally, a decision maker has available a set of alternatives. All that he can know is that choosing one alternative has one direct effect, and some other indirect, and largely unknown, effects. For a decision maker in a complex environment does not exist anything such a single global *fitness* value, but only many partial indicators that (likely) influence the overall position. Making a decision means to affect many of the indicators, and the links between the decisions and the indicators are mostly unknown. The overall final outcome can be only observed with time, and the possibility to link directly the effects on the fitness to the cause of the decision is severely hindered by the likely raise of many events.

Consider a very simple example: a firm that is considering whether to cut the price. The certain effect of such decision is to lower the unit revenues, which may be compensated by a future increase in the number of units sold. The net effect of the decision is all but certain, since it depends on the aggregate market functioning, like the possibility that competitors' react to such decision cutting their prices. The final result for the firm of cutting or not the price is all but certain. Moreover, it is also debatable how to measure the outcome: should we consider the variation in total profits in a week, a month, or a year time? How many other events can take place in such a period, which affect profits besides the price cut?

The problem of multiple, partial and unreliable performance indicators is strongly linked to the analysis of organisations. In fact, different parts of an organization are likely to adopt one indicator as their unique (or at least principal) performance measure, while the management has to mediate the conflicts likely to arise between the components' proposals. The problem of carrying on such analysis is that, however intuitive and sensible this perspective, it is very hard to formalise in such a way to provide useful insights.

Many works on the subject of complexity have recently used the formalism of *fitness landscapes* (Kauffman, 1993). Such model represents a problem with a research space and a fitness measure. The research space is the set of all possible solutions to the problem, while the fitness, represented as a real value for each solution, is the outcome obtained if that solution is adopted. The power of such formalism relies in the possibility of using distance measure between solutions. They are represented as binary strings, therefore one solution is "close" to another if there are few bit differences between their associated binary strings (hamming distance). The modeller can freely determine the complexity of the problem by determining the "smoothness" of the landscape. A problem is simple if neighbouring solutions have similar fitness values. Conversely, a problem is complex if close solutions provide very different fitness values. Given the fitness landscape set up, the modeller can "select" a complexity level by deciding the fitness values, and then let an artificial agent “walk” on the landscape. The agent is placed randomly on one point (a binary string); then it uses a decisional algorithm to switch the bits in its current string to obtain a new one. If the new point provides higher fitness, then the agent makes one step moving onto the new point. Otherwise, it remains on the previous point. Repeating this procedure for a number of time steps a simulation generates a sequence of points associated with a sequence of fitness values. The modeller can then compare the eventual outcome of such a sequence with the complexity structure embedded in the fitness function.

Although the original metaphor for the fitness landscape model was the biological evolution of species, its capacity to formalize complexity has suggested the use NK models, as it is also known, to represent innovative firms facing technological complexity (Levinthal, 1998, Frenken et al., 1999, Valente, 2000, vol. I, ch. 3). For example, Frenken et al. underlines that the complexity is not a function of the fitness landscape only, but it depends on the research strategy adopted. The paper shows the properties that different modular strategies have in respect of different types of problems, so that that (apparently) complex problems become simple when using the correct modular approach.

Most works using the NK systems apply the analysis to the complexity of the research space, but provides the artificial agents with an unrealistic capacity to distinguish between the effectiveness of different alternatives with certainty and no delay. The problems represented in this way are the ones where you need to choose the right solution among a huge number of other ones, but it is immediate to acknowledge values of given alternatives. The modularity considered is limited to be the modularity of the search space, that is, it is an instrument to limit the number of solution one has to test before finding the best one. This paper proposes a NK model where the agents are not endowed with the capacity of measuring their overall performance to assess innovations. The modularity is extended to encompass not only the research space, but also the “sensors” of an organisation. A “module” is an autonomous centre to select a potential innovation *and* the evaluator of such innovation as compared with a (partial) performance measure. The management of the organisation has the task of mediating between potentially conflicting innovations proposed by the organisation modules.

The model is based on the same structure as in Frenken et al.: the research space is de-composed in different blocks, each of which act on a sub-set of all the dimensions. However, the mutation procedure is not applied for one single block per time: at each time step each block attempts a mutation in parallel and independently. The result of the mutation is tested against the partial fitness function obtained from all and only the dimensions in the block, instead of using the unique, global fitness function from all the dimensions of the research space. Such partial results from each block are used for “bidding” a mutation at level of the whole organisation. The management selects the highest bidding proposal and carries on the mutation proposed by the winning block. The global fitness function is then used indirectly to increase or decrease the “credibility” of the blocks, represented as a measure that is used by the management to discount the bidding process of future attempted mutations. The model is used to assess the capacity of different modular organisations facing different types of complexity. Moreover, the model permits to study the “internal competition” between components of the organisation, based on their relative capacity to propose successful innovations. This competition, is suggested, is likely to drive the long term development of a company as the technological and/or demand conditions force to choose between strongly different patterns.

References

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