The Difference between Individual and Population Genetic Algorithms

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Abstract

We distinguish a population learning Genetic Algorithm (or pure GA), and an individual learning Genetic Algorithm (a GA combined with a Classifier System). We show that for a certain class of problems these two types lead to widely differing performances.

1 AN EXAMPLE

Consider a Cournot market with 40 firms producing the same commodity. The only decision variable for firm *i* is the quantity q_i to be produced. Given the total production, the market price *P* is determined through the confrontation of market demand and supply. The inverse demand function is $P(Q) = a+bQ^c$, where $Q=\Sigma q_i$. Making the appropriate assumptions on the parameters *a*, *b*, and *c* ensures that this is a downward-sloping curve. We assume that the production costs are such that there are negative fixed costs, whereas the marginal costs are 0. Details of the economic model can be found in Vriend [1999].

Assume that each firm needs to learn which output levels are good. There are two ways to implement a GA. First, as a model of *population learning* (or pure GA). Each firm in the population is characterized by an output rule, a binary string of fixed length, specifying the firm's production level. Each trading day, a firm produces a quantity as determined by its output rule, the market price is determined, and the firms' profits are computed. After every 100 trading days, the population of output rules is modified by applying some genetic operators (details of the GA can be found in Vriend [1999]). The more successful rules have been, the more likely they are to be selected for this process of imitation and re-combination. The second way to implement a GA is as a model of *individual learning* (a Classifier System with on top of it a GA). Each firm has a *set* of rules in mind, but each period only *one* of these rules is used to determine its output level actually supplied to the market. Attached to each rule is a measure of its success when it was activated. On top of this Classifier System, the GA is used every 100 periods to modify the set of rules a firm has in mind exactly as above. Figure 1 presents the time series of the output levels for 25 runs.

2 ANALYSIS

The output level for which it holds that if all firms choose it, no firm can increase its profits by deviating unilaterally, is called a symmetric Cournot-Nash equilibrium. However, if a firm increases its output above this level, it would hurt the other firms even more than itself. It can be shown (see Vriend [1999] and the references therein) that this *'spite effect'* implies that whenever aggregate output is *below* the competitive or Walrasian equilibrium level, the firm that produces at the *highest* output level realizes the highest profits. And whenever aggregate output is *above* Walras, the firm producing at the *lowest* output is best off. Figure 1 shows that the GA with individual learning moves close to the Cournot-Nash output level (998), whereas the GA with population learning converges to the competitive Walrasian output level (2006). How can we explain this?

In the *population learning GA*, each firm is characterized by its own production rule. The higher a firm's profits, the more likely is its production rule to be selected for reproduction. Due to the spite effect, firms that produce closer to their equal share of the Walrasian output are more likely to be selected for reproduction by the GA. As a result, the population of firms tends to converge to the Walrasian output.

In the *individual learning GA*, however, the production rules that compete with each other in the learning process do not interact with each other in the same Cournot market, because in any given period, a firm applies only one of its production rules. Hence, the spite effect does not affect the learning process. There is a spite effect on the payoffs realized by the other firms' production rules, but those do not compete with this firm's production rules in the learning process. As a result, the population of firms tends to converge to the Cournot-Nash output, where profits are definitely higher than at the Walrasian output.

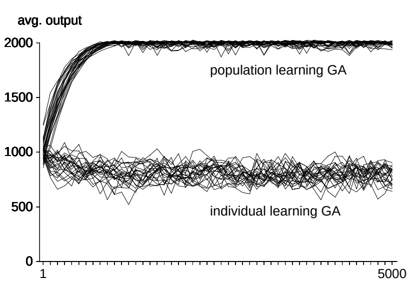

Figure 1: Output Levels

References

Vriend, N.J. (1999). An Illustration of the Essential Difference between Individual and Social Learning, and its Consequences for Computational Analyses. *Journal of Economic Dynamics and Control*.