An Individual-Based Approach to Multi-level Selection

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When trying to solve a complex problem, it is a natural reflex to divide this problem in a number of subproblems and solve them separately. Afterwards, the solutions to these subproblems can be combined in order to solve the entire problem. This approach is called divide-and-conquer and is applied in many circumstances.

Evolutionary Algorithms (EAs) are in this case counter-intuitive since they try to evolve a solution for the entire problem as a whole. EAs may show improvement when they can create more complex evolutionary units through some form of cooperative combination of sub-solutions similar to divide-and-conquer. In other words, instead of trying to evolve a single solution for the problem, solutions may try to cooperate to solve the problem. This cooperation results in groups of individuals which have more functionality than an isolated individuals. Hence, complexity, in terms of the structure of the solution, becomes an emergent property of the evolutionary system.

Inspiration on how to produce these cooperating groups can be found in natural systems investigated in the biological theories on Evolutionary Transitions (Maynard Smith and Szathmáry, 1997; Michod, 1997) and multi-level selection (Sober and Wilson, 1998; Keller, 1999). These theories capture the abstract principles of how higher-level structures can evolve from cooperative interactions between lower-level entities.

Similar characteristics can be observed in these transitions; In a collection of competing elements cooperative groups can emerge through spatial structuring or localisation of these individuals and their offspring. As a result higher level units, which consist of cooperating lower-level entities can emerge and hence complexity can increase. This cooperative behaviour could not have emerged in a single population due to the maladaptiveness of this behaviour. As a result of this localisation in groups and the fact that the fitness of each constituent of the group depends on the group composition, cooperative individuals were able to survive and spread in the population.

We developed a model based on a set of necessary and sufficient conditions for the emergence of cooperation proposed by Sober and Wilson (Sober and Wilson, 1998). The model consists of four iteratively repeated steps; *dispersal* of the individuals in the population into groups, *reproduction* in these isolated groups, *merging* of these different groups in some fitness proportional manner and *shrinking* of the new population to maintain the predefined population capacity.

This model results in a system where selection takes place at two different levels, i.e. at the level of the individual and the level of the group. The obtained results depend strongly on the iteratively executed disperse step. Under the right conditions, the experiments show that individual cooperative behaviour can only emerge when the selective force at the higher level can counter the selective force at the lower level. The statistical effects of these forces can be observed through the use of the Price covariance equation.

References

L. Keller, editor (1999). *Levels of Selection in Evolution.* Monographs in Behaviour and Ecology, Princeton University Press. Princeton, New Jersey.

R.E. Michod (1997). *Darwinian Dynamics; Evolutionary Transitions in Fitness and Individuality*, Princeton Paperbacks, New Jersey.

J.M. Smith and E. Szathmáry (1997). *The Major Transitions in Evolution*, Oxford University Press

E. Sober and D.S. Wilson (1998). *Unto Others, The Evolution and Psychology of Unselfish Behaviour.* Harvard University Press. Cambridge. MA