論文の内容の要旨

論文題目　Learning Potential Inheritance in Baldwinian Evolution
（Baldwin進化における学習能力の遺伝）

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Evolutionary algorithms imitate organism evolution in the natural world, and are proved effective and efficient to handle optimization problems, especially when the search space is huge and the landscape is irregular. To accelerate evolution, and to overcome even more difficult problems, researchers have been trying to combine evolution with learning techniques in the recent decades. Baldwinian evolution is a hybridization of evolution and learning. It claims that learning throughout the individuals' lifetime can guide evolution to better solutions, without transferring acquired characters back into genotypes. The theme of this thesis is to study Baldwinian evolution's mechanisms. This thesis is on Baldwinian evolution and the search efficiency issue.

Baldwinian and Lamarckian evolution are different in inheritance, and this makes their learning processes playing significantly different roles in the whole search. Considering computational resources, the cost-performance also varies. We investigate Baldwinian evolution's mechanism, in term of computational costs and fitness improvements, to find what is produced in Baldwinian learning, and what role Baldwinian learning plays. We found that, on the static landscapes involved, learning cost is paid to maintain a certain level of potential to reach good solutions, rather than to further explore on the landscape. Plasticity codes in genotypes can help in selecting appropriate parts to refine and improve search performance. However, this improvement remains limited because no learned traits are passed on, and does not enable exploration far beyond parents.

In Baldwinian evolution, refined fitness influences selection. However, unlike Lamarckian evolution, refined traits are not passed on to the offspring. This loss of refined trait information implies that the guiding effect of learning comes from the inheritance of learning potential. Offspring do not directly inherit beneficial traits, but instead inherit genes that lead to beneficial traits after their lifetime learning. We verified the existence of such potential, and then study how it works. The realization of learning potential, namely, how learning behavior compares to the previous generation's learning, are studied, in addition to how much learning improves the current generation's initial phenotypes. Since children are affected by learning schemes and genetic operators, they may prefer either to follow and repeat their parents' learning, or to explore a new direction. We investigate how learning schemes and genetic operators affect the realization of learning potential,

and, in turn, how this influences search performance. The results show that learning schemes and genetic operators have different impacts: uncertainties in learning schemes slow down speeds and lower fitness, whereas genetic operators balance exploitation and exploration. The guiding effect of Baldwinian learning is thus implied to originate from only what children can inherit or follow.

Furthermore, learning cost punishment is an essential factor in Baldwinian evolution. In Baldwinian algorithms, a selective penalty on individuals with high learning costs is usually implemented by the addition of a negative term to the fitness function. This penalty is necessary for genetic assimilation, and influences the search by limiting the increase of learning intensity. Although a cost penalty can accelerate search, it sometimes inhibits the discovery of better solutions. Appropriate design of a penalty is important for building effective algorithms; however, the exact effect of penalties and how best to design them is still not fully understood. This thesis also investigates the mechanisms of cost penalties in depth, focusing on their influence on learning intensity during the search phase. Our results show that genetic assimilation may start long before search convergence, and cost penalty effects may vary considerably dependent on the employed selection scheme. A selection scheme has to provide competitions of individuals learning the same traits, to guarantee the occurrence of genetic assimilation. High punishments transform the landscape significantly, and assign individuals learning the same traits different fitness. It is a substitution of converged individuals' structural competitions, but has the side-effect of inhibiting the "smoothing" effect.

In the thesis, we present three sets of experiments, and collect some conclusions about Baldwinian evolution's mechanisms. The findings provide new mechanism knowledge, as well as design rules that may be useful in application attempts. These three parts are connected to each other, under the new aspects of viewing the evolution-learning hybridization beyond conventional studies. We also discuss how these ideas can be extended further, to reveal more about Baldwinian evolution. We follow the spirit of analysis, study isolated algorithm components instead of entire algorithms, and study individual dynamics instead of group behaviors.

In this thesis, Baldwinian evolution's mechanisms are studied, in order to attain in-depth understanding of the theory, and ultimately to design effective and efficient algorithms for real world tasks. Differing from conventional researches, we divide algorithms to components, and groups to individuals. The change in the view point enabled us to reveal new knowledge about Baldwinian evolution. The findings provide directions to applications, as well as materials for biology and philosophy.