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On the time and space complexity of genetic programming for evolving Boolean conjunctions. (English) Zbl 1494.68253

Summary: Genetic programming (GP) is a general purpose bio-inspired meta-heuristic for the evolution of computer programs. In contrast to the several successful applications, there is little understanding of the working principles behind GP. In this paper we present a performance analysis that sheds light on the behaviour of simple GP systems for evolving conjunctions of $n$ variables ($\text{AND}_n$). The analysis of a random local search GP system with minimal terminal and function sets reveals the relationship between the number of iterations and the progress the GP makes toward finding the target function. Afterwards we consider a more realistic GP system equipped with a global mutation operator and prove that it can efficiently solve $\text{AND}_n$ by producing programs of linear size that fit a training set to optimality and with high probability generalise well. Additionally, we consider more general problems which extend the terminal set with undesired variables or negated variables. In the presence of undesired variables, we prove that, if non-strict selection is used, then the algorithm fits the complete training set efficiently while the strict selection algorithm may fail with high probability unless the substitution operator is switched off. If negations are allowed, we show that while the algorithms fail to fit the complete training set, the constructed solutions generalise well. Finally, from a problem hardness perspective, we reveal the existence of small training sets that allow the evolution of the exact conjunctions even with access to negations or undesired variables.

MSC:

68T20 Problem solving in the context of artificial intelligence (heuristics, search strategies, etc.)
68N19 Other programming paradigms (object-oriented, sequential, concurrent, automatic, etc.)
68Q25 Analysis of algorithms and problem complexity
68T05 Learning and adaptive systems in artificial intelligence

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