Algorithmic Cooperation

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The landscape of boolean reasoning is dominated by two types of search algorithms: *systematic search*, and *stochastic local search*. Systematic search algorithms are empowered by their ability to learn new lemmas from mistakes made with their heuristically guided action selection steps. The lemmas help the search to avoid the same mistakes from happening in the future, and thus help pruning the search space. This makes lemma learning the most crucial feature of the systematic algorithms. Stochastic Local Search based methods solve a boolean formula by navigating local neighborhoods of the search space with heuristics guided search methods. While systematic solvers are well suited for solving problems from application domains, stochastic local search based solvers shine in the combinatorial domains.

In my current postdoctoral work, I am focusing on stochastic local search based algorithms for boolean reasoning. So far, I have revisited an obscure, but powerful algorithm named *Divide and Distribute Fixed Weights*. We have improved the algorithm by devising multiple extensions to it [1]. Some important spinoffs of this project are the following observations: local search based algorithms exhibit *complementary performance behavior* at different levels of granularity: (i) Given a diverse set of benchmark problems, different algorithms often exhibit different performance behavior on problems from different domains (level 1), (ii) For a given problem, any two algorithms could perform very differently at different stages of the search (level 2), (iii) Often, an algorithm exhibits unrobust behavior for a given problem with slight changes in its parameter values (level 3). Another interesting characteristic feature of these algorithms is the *commonality of structures*, such as heuristics and parameters in between them.

The first level of performance complementarity is exploited in portfolio based solvers, where a given problem is solved by the seemingly best algorithm, selected from a pool of algorithms. However, exploitation of the other levels of performance complementarity and commonality in structures has remained unexplored. In the future, I intend to develop a boolean reasoning framework `CoopReason` that exploits these two features. `CoopReason` will be a sequential reasoning framework that employs multiple local search algorithms, which cooperate with each other while solving a given problem. This framework will exploit performance complementarity and commonality in parameters of the employed algorithms by switching between algorithms and exchanging structures. I also plan to lift `CoopReason` into a parallel framework, where multiple `CoopReason` solvers will run in parallel and cooperate with each other. This parallel framework will facilitate gathering and aggregation of search statistics from sequential cooperating solvers, which will be used to further guide these sequential solvers. Furthermore, I intend to generalize cooperation between systematic solvers and `CoopReason` solvers in a parallel framework that will deploy both `CoopReason` and systematic solvers as sequential solvers, which will cooperate with each other by exchanging structural information [1].

I believe that algorithmic cooperation is a largely unexplored topic in boolean reasoning, and has strong potential to improve the performance of boolean solvers significantly.

References

[1] Md Solimul Chowdhury, Cayden Codel, and Marijn J. H. Heule. Revisiting the divide and distribute fixed weights algorithm. In *AAAI-2023* (Under Review).

[1] Currently, myself and my postdoc supervisor Dr. Marijn Heule are working on a NSF Computing and Communication Foundations (CCF) grant application on algorithmic cooperation.