# Research Summary

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I recently finished my doctoral work on local search for $\mathcal{NP}$-Hard problems. Since completing this work I have been reflecting on the state of the art in the SAT/CSP Search community. I see a great deal of good work on tightly focused sub-classes of SAT and CSP problem domains, and a little work on trying to generalize notions of "constrainedness" (read: unlikely to have solutions) and "hardness" (read: high computation time requirement). While there is good work to be done in finding results for limited regimes, I am becoming more and more interested in the problems surrounding reformulation.

My interest was recently piqued by the stories surrounding Kautz and Selman's SATPLAN and by Weld's follow-on experiences with automatic translations of planning problems to SAT representations, and also by Holger Hoos' experience in attempting to reformulate the Hamiltonian Cycle (HC) problem as a SAT problem. I have experimented with reformulating HC as a Constraint Satisfaction Problem (CSP) in an attempt to better understand some recent work on constrainedness as defined by Gent, Walsh, McIntyre, Prosser et. al. Briefly, this theory attempts to unify notions of constrainedness and hardness in the domain of randomly generated discrete $\mathcal{NP}$-Hard problems by using annealed theories of the reduction in the number of solutions by constraints. One aspect of this theory that has gone unexamined is how these constrainedness measures change under reformulation. My limited examination showed that, for the example of HC to CSP reformulation, the constrainedness measures changed in interesting ways. What impact this might have on the theory is certainly an interesting open question.

I have also worked on local search algorithms, in particular, analysis of local search landscapes and how to improve local search by changing the landscape during search. In the SAT domain, this is done by associating a positive, real-valued weight for each clause, changing the objective function to include these weights, and continually modifyng the value of the clause weight depending on whether a move in local search leaves the clause satisfied or unsatisfied in the resulting assignment. An excellent paper in IJCAI-97 by Benjamin Wah related this approach to the Lagrange Multiplier method. This approach combined both approximation and reformulation; approximation in that an incomplete methodology is used for solving an $\mathcal{NP}$-Hard problem, and reformulation in that the modification of weights is a continuous process of reformulating a search problem depending on past performance. I am interested in analyzing the tradeoffs between reformulation as an ongoing process and much more goal-directed reformulation strategies as "pre-processing" steps, similar to the approaches in Dechter's directed resolution and limited resolution approaches.

To further study issues in reformulation, I will be hosting the Constraint Problem Reformulation (CPR) workshop in conjunction with the 4th International Conference on Principles and Practices of Constraint Programming in October 1998. This workshop will focus on reformulating Constraints Problems to take advantage of efficient techniques in particular constraints problem domains. In particular, the workshop will focus on reformulating $\mathcal{NP}$-Complete problems and related optimization problems to translate them to domains which have good problem solver performance. Issues in this area include speed of translation procedures, exposing and hiding of information by reformulation techniques, translation of problem classes vs. problem instances, the uses of reformulation, and analyzing reformulation techniques.


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