Tabu Search for the Constraint Satisfaction Problem as a General Problem Solver

Koji Nonobe and Toshihide Ibaraki

A weighted constraint satisfaction problem (WCSP) is defined by a set of variables X_i with domains D_i and a set of constraints with their weights. For each pair of variable X_i and value $j \in D_i$, 0-1 variable x_{ij} is introduced to denote whether X_i takes value j or not. Linear and quadratic inequalities on variables x_{ij}, and All-Different constraints for given sets of variables X_i are equipped as common tools to formulate constraints, while arbitrary problem-specific constraints can also be used. It is then asked to find an assignment of values to variables such that the weighted sum of penalties given to violated constraints is minimized.

Since many problems in the real world can be formulated as WCSPs, a powerful WCSP solver can play a role of general purpose solver. A tabu search algorithm in this direction has been developed in [1] and improved in [2]. It employs a simple shift neighborhood defined by the set of solutions obtained by changing the value of one variable X_i, but various enhancements are added to make the search more efficient. Furthermore, it introduces adaptive mechanisms for dynamically controlling tabu tenure, and for adjusting individual weights of constraints, reflecting the constraint violations in the best solution found after the last change of the weights. In this way, strategic oscillation between feasibility and infeasibility is naturally realized.

As a result of using a general purpose solver, users can spend all of their time to build good models of their problems in the forms of WCSP. This approach has been quite successful as evidenced by a wide range of real world applications, such as work shift scheduling in a number of companies, generalized assignment, set-covering and nurse scheduling [1, 2]. Two international competitions in which our tabu search WCSP solver participated reinforce the findings concerning its promise. These competitions pitted our general purpose solver against methods that were specialized to handle the problems addressed. In the Second International Timetabling Competition (ITC2007) [3], the WCSP solver succeeded in capturing the third, second and third places, respectively, for the three tracks of benchmarks. In the First Nurse Rostering Competition (INRC2010), addressing a somewhat different class of problems, it currently remains as one of the five finalists for all the three tracks (the final decisions are not released yet). These findings appear to indicate that the general purpose solver is competitive with the state-of-the-art algorithms specially tailored

to the respective problem domains.

References

[1] K. Nonobe and T. Ibaraki, A tabu search approach for the constraint satisfaction problem as a general problem solver, *European Journal of Operational Research*, Vol. 106, pp. 599–623 (1998).

[2] K. Nonobe and T. Ibaraki, An improved tabu search method for the weighted constraint satisfaction problem, *INFOR*, Vol. 39, pp. 131–151 (2001).

[3] B. McCollum, A. Schaerf, B. Paechter, P. McMullan, R. Lewis, A.J. Parkes, L. Di Gaspero, R. Qu and E.K. Burke, Setting the Research Agenda in Automated Timetabling: The Second International Timetabling Competition, *INFORMS Journal on Computing*, Vol. 22, pp. 120–130 (2010).

[4] INRC2010 website: `http://www.kuleuven-kortrijk.be/nrpcompetition/`