On the Value of Aspiration Criteria in Tabu Search

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ABSTRACT

Tabu search is a greatly successful metaheuristics, as illustrated through numerous publications showing its use for a range of difficult optimization problems. The tabu search literature is to a certain degree characterized by papers introducing new variations of the search, either presenting new components or proposing changes to existing components. Most often, these new variations are shown to perform well on a particular optimization problem, but are rarely thoroughly analyzed in terms of how they change the search characteristics. This work focuses on the aspiration criterion: A large number of possible variations of aspiration criteria exist, many different variations have been used successfully, and almost no results exist that directly compare the different variations in terms of their performance or behavior. Eight different aspiration criteria are considered, and computational experiments are performed to assess their merit within tabu search implementations for two different combinatorial optimization problems.

KEYWORDS
Aspiration Criterion, Knapsack, Local Search, Metaheuristic, Tabu Search, Vehicle Routing

1. INTRODUCTION

Tabu search (TS) has become one of the most successful metaheuristics, with numerous publications demonstrating its efficacy at solving combinatorial optimization problems. Its extensive use by an increasing body of researchers and practitioners does, however, result in a wide variety of implementations that include many different search components and variations thereof. Although TS shows good performance on many optimization problems, it is not always clear how each component of the algorithm contributes to this performance.

The literature on TS is to some extent characterized by papers introducing new variations of the search, either presenting new components or proposing changes to existing components. These new variations are often shown to perform well on a particular optimization problem, but the new components are seldomly analyzed in terms of how they contribute to create a well performing TS, in particular if several components are added or varied simultaneously. In general, although there exist good introductions to the conceptual ideas of TS, such as (Gendreau, 2003), it can be difficult to find guidelines for how to select and combine the various TS components in an efficient way. In some cases, this leads to unnecessary experimentation being required by the programmer in order to determine a suitable implementation for a given optimization problem.

Although different optimization problems may pose different challenges for the TS to overcome, and although it is impossible to give a standard implementation that can handle all problems equally well, it would be welcome to have more empirical analysis of how different search components affect the search behavior. In this work, such an analysis is attempted for the aspiration criterion used in TS,
that is, the criterion that allows the search to visit a solution even though it is currently considered to be tabu. Since an exact tabu criterion is usually deemed computationally too expensive, a rough approximation is often used; in the following we assume that a standard tabu list is employed, where attributes involved in moves made will be tagged as tabu for a predetermined (possibly random) number of iterations. It is often argued that employing an aspiration criterion, to allow the search to visit promising solutions even though they are otherwise considered tabu, can be beneficial. A large number of different aspiration criteria exist, of which many have been used successfully, but almost no results exist (Løkketangen, 2007) that directly compare the different variations in terms of their performance.

A number of aspiration criteria are outlined in Section 2. To compare the aspiration criteria, two important combinatorial optimization problems are given in Section 3 along with TS implementations that are used to produce heuristic solutions. Two tests are conducted: one test where short-term search statistics are recorded in order to describe the behavior of the search depending on the choice of aspiration criterion, and one test where long-term search performances are noted. These tests and their results are described in Section 4, followed by concluding remarks in Section 5.

2. ASPIRATION CRITERIA

Many aspiration criteria have been proposed for TS, and the following describes those being tested in this work. The most naïve option is simply to exclude aspiration; if a move is tabu it will not be allowed, even if there could be ways of detecting that it would lead to a previously unvisited solution. This option will be labeled as NO (no aspiration). This appears to be perhaps the second most commonly used aspiration criterion, although as already noted in (Glover, 1986) other alternatives have produced solutions of better quality.

The aspiration criterion that seems to be most commonly used will be labeled as NB (new best aspiration). It was described in (Glover, 1986) and appears both simple and reasonable: the tabu status of a move can be revoked whenever the move leads to a solution that is better than any solution recorded during the search so far.

A third alternative, alluded to in (Glover, 1989) and used in the unified TS algorithm (UTSA) (Cordeau et al., 1997, 2001), focuses on the attributes involved in a move. For each attribute one records the objective function value of the best solution visited with the attribute being present. If each move involves adding (and/or removing) an attribute from the current solution, the tabu status of the move can be revoked if the resulting solution has an objective function value that is better than the best solution seen so far with the added attribute being present. Thus, a new global best solution can always be accepted, but so can any solution that leads to a new best solution conditional on a given attribute being present. This aspiration criterion will be labeled SA (single attribute new best aspiration). A generalization follows immediately, that will be labeled AA (any attribute new best aspiration): instead of looking only at the attribute being added, one can look at all the attributes being present in the new solution: if any of these attributes have a worse best objective function value recorded, the move will lead to a solution not visited before. This observation is also the basis for attribute based hill climbing (Derigs and Kaiser, 2007; Whittley and Smith, 2004).

Another alternative described in (Glover, 1986) is based on avoiding visits to the same solution but on avoiding repeating the same moves (see also (Glover, 1989; Hertz and de Werra, 1990)). Two variations are tested here, the first labeled O1: let \( z \) be the objective function value of the current solution, and let \( A(z) \) be the value of the best solution ever reached after making a move from a solution whose objective function value was \( z \). If a move is considered that leads to a solution with a better objective function value than \( A(z) \), its tabu status can be revoked: it will represent a move that has not been performed before. In O1 one risks allowing the immediate reversal of a move, but in a second variation, labeled O2, this is prevented: Let \( A(z) \) be the better of 1) the best objective
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