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A GRASP Heuristic for the Minimum Binary Cost Tension Problem

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1 Introduction

The study of tension problems in graphs is motivated here by synchronization problems in hypermedia documents [2]. These documents are composed of various media objects such as text, audio, video, image, applet... that are connected by temporal relations. For instance, a video has to start just after a song has finished and a scrolling text is displayed during all that time. When designing an hypermedia document, authors need powerful tools to schedule automatically the temporal specifications of these objects in the document. Any media object u has an ideal duration o_u and an interval $[a_u; b_u]$ in which its scheduled duration can vary. The authors also specify temporal constraints in order to express the way the presentation of the document should happen. The problem is finally to schedule the duration of each media object so that it satisfies both the tolerance interval and the temporal constraints.

This problem can be interpreted as a Minimum Cost Tension Problem (MCTP) in a graph. Let $G = (N, A)$ be a digraph, where N is the set of nodes and A is the set of arcs, $n = |N|$ and $m = |A|$. The nodes represent events in the hypermedia presentation (starting time or ending time for the presentation of media objects) and the arcs express temporal constraints between two events (precedence and duration between two events). Let $\pi : N \mapsto \mathbb{R}$ be a function that assigns a potential to each node. It corresponds to the date scheduled for each event. Hence, given a media object $u = (i, j)$, the tension $\theta_u = \pi_j - \pi_i$ is the duration between its starting event i and its ending event j .

Many proposals have been made to measure the quality of an hypermedia document. The first works considered a piecewise linear cost function on the interval $[a_u; b_u]$ with a minimum at o_u [4, 6]. Thus, the resulting problem is linear and it can be solved efficiently by using polynomial time algorithms [1, 3]. However, optimal solutions are likely to force many objects to be slightly perturbed from their ideal duration. This could be time consuming in a real-time context where the scheduler would have to alter the ideal duration of those objects. Thus, maximizing the number of media objects scheduled at their ideal duration can also be considered. By using the number of objects scheduled at their ideal duration as the quality of an hypermedia document, the MCTP becomes NP-hard due to the discrete nature of the objective function. It is referred here as the

Minimum Binary Cost Tension Problem (MBCTP).

2 A GRASP heuristic

In this work, we propose a hybrid GRASP heuristic to solve the MBCTP. A GRASP [5] is a multi-start or iterative process, in which each GRASP iteration consists of two phases: a construction phase, in which a feasible solution is generated, and a local search phase, in which a local optimum in the neighborhood of the constructed solution is sought. The best overall solution is kept as the result.

In our construction phase, a feasible solution is first computed on the linear relaxation of the problem by using an efficient method developed in [3]. Thus the date of each event are compatible with the interval of each associated media object. Then, the date of each event is changed in order to stay feasible and to set some media objects to their ideal duration. At each iteration, a Restricted Candidate List (RCL) is constructed from the pairs (event, date) where each pair is evaluated by the number of media objects set to their ideal duration. The insertion of a pair into the RCL is controlled by a parameter α in order to get a balance between greediness and randomness. A candidate pair is randomly chosen in the RCL. The event is set to the corresponding date and the procedure iterates.

The local search phase is performed by a VND [7] using embedded neighbourhoods \mathcal{N}_k . Rather than working on the date of each event, those neighbourhoods work on the state of each media object, either at its ideal value or not. Thus each neighbourhood \mathcal{N}_k is defined as the set of all solutions obtained by changing the state of k media objects. Checking the feasibility of a state vector can be done in polynomial time (see [2]). Other local search strategies (namely restricted versions of simulated annealing and of tabu search) are also tested within the GRASP and compared with the VND.

A path relinking strategy is then added to the GRASP in order to further improve the efficiency of our approach. Computational results are presented on several sets of randomly generated instances. The approach is evaluated with respect to the quality of the solutions produced and also by its ability to be used in a real-time context.

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