Scheduling Complex Training Programs: Plan and Execution

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ABSTRACT

INTRODUCTION

In a classic Navy training setting, training takes place at specialized Training Sites following the specifications described in the corresponding Master Course Schedule (MCS) document. In this context, the planning problem arises when multiple instances (convenings) of one or more Courses must be taught throughout the year, necessarily overlapping, and sharing some limited resources. The problem is whether it is possible to schedule the desired number of instances of the Courses, and how; or find a schedule that minimizes the number of conflicts, otherwise.

Once an annual plan is determined, its implementation requires solving unforeseeable day-to-day situations.

ISERA Group LLC has developed a software System (TOURS) that solves these problems, based on heuristics that have proved to be very effective. This software has been in use by the Navy for several years and the users are familiar with the interface provided.

Recently, the Navy has undertaken the Revolution in Training: Course topics are replaced by Reusable Learning Objects (RLO); each one with possibly more than one Instruction Delivery Method (IDM). In addition to a more general definition of a Course, trainees can now be on a ship or in an intensive program at a training location; and --as RLOs can be shared among different Courses-- students might have a Course content partially satisfied from the start. A more personalized approach to training, while at the same time keeping the global goals of fleet readiness and economic efficiency, are the new challenges of the Navy's Revolution in Training.

In this context, potential individual flexibility clashes to a certain extent with global concerns. Therefore, a first question is what decisions should be taken by the Training System to guarantee its global cost efficiency, and what options should be left to the individual trainees to customize their training.

The approach we suggest here is based on the problem we face as a software development team: how to reuse and adapt the existing software to satisfy the needs of this much more complex training environment.

PROBLEMS

There are some new information: Each Course is defined as a set of RLOs related by precedence relationships, and with a known preferred order. Some IDMs, like self-paced activities, have duration and other related parameters expressed as estimate intervals. Also, some general constraints limit the IDM options for a Course.

There are two problem areas: Planning –i.e. determination of annual schedules at the training locations-- and Execution – dynamic adjustment of the annual plan for daily operations.

Planning

Our approach is to subdivide this problem into two. The first one would be to find an optimal assignment of IDMs to RLOs while satisfying the global constraints. The second problem would be, based on these assignments, to find the best annual layout for all the instances of the Courses. This problem can be solved by adapting our current software to handle data changes derived from durations expressed as intervals.

For the solution of the IDM assignment we construct a digraph $G= (V, R)$ representing the available alternatives. Given K RLOs, numbered according to the preferred sequence, then

$$V=\{ v_{kj} \mid k=1,\ldots,K;\ j=1,\ldots, J_k \}$$

where v_{kj} represents the *j-th* optional IDM for the *k-th* RLO; and R consists of all arcs $(v_{kj,} v_{k+1,h})$ between any two nodes in consecutive levels k and $k+1$. Additional origin and destination nodes v_{01} and $v_{K+1,1}$ are added to V, and the corresponding arcs. A 0-(K+1) dipath represents an assignment of IDMs to RLOs. The objective is to find an optimal 0-(K+1) dipath that satisfies the global constraints.

Global constraints are assumed to be bounds to additive and non-negative properties of the nodes. Notice that the existence of global constraints over the entire path makes impossible to use classic shortest-path algorithms where feasibility is not an issue. We propose a two-phase algorithm which calculates bounds for the constrained properties at each level $k=1,\ldots,K$ on the first phase, to accelerate the search of feasible and optimal paths on the second phase. This algorithm can be adapted to the structure of the constraints to make it more efficient, to combine shortest-path techniques when possible.

Execution

There are two different sources of variations to the annual plan:

- *Unavoidable changes* regarding resource availability, student arrivals; and training activities to add or cancel. The goal is to maintain the feasibility of the schedule under the new circumstances, finding the best alternative when possible. These changes can be handled by our existing software, with slights modifications.

- *Optional changes* derived from individual needs and preferences of the students. The goal is to improve the current schedule if possible by taking into account individual characteristics of the trainees not known a priori.

To respond to requests of optional changes we assume that the Training System offers some flexibility to start with, either as some extra capacity in group activities already scheduled; or as resource capacity not yet utilized, allowing alternatives to an individual schedule that don't affect other students' schedules.

We analyze two main situations: A student having one or more RLOs waived looking for a more accelerate path (*custom path*); and a student needing to retake an RLO, or take it at another date, to be able to continue his/her training (*local alternatives*). We assume that the System will respond to each request in a first-come first-served basis, and will propose to the student several alternatives.

In both cases the idea is to build a graph representing all available alternatives between the current moment and the end of the training, including self-paced alternatives not considered in the original schedule, and opportunities belonging to other convenings of this or other Courses, that fall in the time frame of interest. In this case the nodes are assumed to be connected by precedence requirements instead of the preferred order of the RLOs. All options have a *cost* or penalty associated to each one to promote the use of the most convenient options for the Training System.

The problem of customizing the student's training can then be roughly formulated as to find the minimum cost path. This is not a classic minimum cost path problem, since each group of nodes corresponding to a same RLO should be *visited exactly once*. Also, the total cost of a path is not linear, as it should reflect the savings corresponding to a shorter or longer stay. An algorithm is proposed to solve this problem, which is also applicable to the problem of finding local alternatives, with the appropriate definition of the graph representing the alternatives to consider.