The Development of AI-Based Software for Scheduling the IUE

Bruce McCollum (CSC)

Mark Graves (Baylor College of Medicine)

The NASA IUE schedule has generally been done with minimal software support. In an effort to simplify this task, we have developed more sophisticated software which takes advantage of relatively recent developments in artificial intelligence (AI) and programming languages. Our work has been described at greater length elsewhere (Graves and McCollum 1994; McCollum and Graves 1994), but we present here a brief non-technical description of our work for the IUE community, because our results can potentially be applied in other satellite missions.

Several considerations guided the development of the software. In general, we sought to retain the IUE's scheduling flexibility while reducing the amount of time needed to revise and generate schedules. The success of an IUE schedule is not measured only by the number of images obtained, but also by the qualitative value of the images in the context of the guest observers' science objectives. In the case of scheduling conflicts, the decisions made by guest observers as to the best trade-offs are more complex than can be represented by ranking targets numerically in order of relative priority. Consequently an important consideration was to retain the ability to take into account the scientific judgement of guest observers when conflicts arise and compromises are necessary. A further requirement was that the software be able to easily accept changes in the constraints themselves, e.g. beta limits, and to be able to handle the infamous targets of opportunity. No existing scheduling software was able to provide a solution within all of these constraints.

Our scheduling algorithm is designed to generate a limited set of possible schedules, taking into account both general instrument constraints and constraints specific to the science objectives of GO programs. Irreconcilable conflicts are flagged for the human scheduler to deal with. The schedule is built out of discrete shifts, as usual, rather than a fully integrated schedule. The input also includes exposure information and target lists supplied by the GO, which could be entered interactively by the GO's at the beginning of an episode.

The ability of the software to quickly list a set of possible alternative schedules would be especially helpful when a target of opportunity program is activated on short notice. At such times, the scheduling problem can be complicated by the fact that moving one shift can produce a "ripple effect" through several following weeks, as one program bumps another which bumps a third and so on. Since most programs have fairly limited windows of observability due to beta constraints and the FES streak, in addition to being sandwiched between other programs with more severe constraints, a few target of opportunity shifts inserted into the schedule can affect a disproportionate number of other programs. Our scheduling routine also would allow a rapid appraisal of the scheduling impact of not only ToO shifts, but also of a sudden change in observing constraints such as the appearance of the FES streak.

Our software constructs a schedule starting with the most highly constrained programs. For example, programs requiring a specific day of the year with no tolerance are scheduled first. This reduces the number of remaining GO programs to be considered, progressively simplifying the logic problem as the schedule is constructed. The final output consists of a set of possible schedules. The best schedule is selected by the human scheduler according to additional input from the guest observers, so that their scientific judgement can be taken into consideration where appropriate.

Our scheduling algorithm is implemented in the constraint logic programming language LIFE, which is a combination of functional, object-oriented, and logic programming being developed by Digital Electric Corporation (Ait-Kaci, 1991). We chose constraint logic as the programming approach because, as a practical matter, using constraint logic it is easier to develop and modify complex systems of constraints than it is within other approaches (e.g. SPIKE, which uses the more common approach of constraint-satisfaction programming (Johnston, 1990)). Also, constraint logic progamming provides a way for solving constraints using a high-level programming language. We used LIFE because it is especially well suited to handling constraints which are expressed in a declarative, nonmathematical way. Also, LIFE is available for free from DEC, and runs under Unix or VMS on a standard workstation.

Because much of the information must be entered into a database manually, which is time-consuming, and because our algorithm was not completed until part of the 18th Episode had passed, it has not been used to schedule the current episode. However, we have successfully tested our algorithm on a sample set of programs taken from the 18th Episode. If it had been the case that NASA IUE operations were to continue for another year, we would have been able to schedule a 19th Episode using this software.

Since one aspect of our algorithm is that it is relatively easy to modify to take into account changes in scheduling constraints, we believe that it would be practical to adapt it to aid in scheduling ground-based observatories or other satellite missions in which observing time is allotted in something analogous to traditional IUE shifts.

References

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