A Modular Multiphase Heuristic Solver for Post Enrolment Course Timetabling

Marco Chiarandini, Chris Fawcett, Holger H. Hoos

A Competition Retrospective.

Chris Fawcett

March 12, 2008

Outline

- The ITC format.
- The problem model for track 2.
- Our development strategy.
- What actually ended up happening.
- The Algorithm.
- Parameter tuning.
- Performance.

The ITC

- Second time the competition has been run.
- First was in 2003, with a different format.
- Three independent tracks, each with different problem models.
- Finalists chosen in each track based on publicly available instances.

The ITC

- Five finalists chosen based on algorithm performance on fourteen public instances.
- The problem? The performance is self-reported, along with the random seed used.
- Verification of that seed is performed by the track organisers.
- Our solution? Thousands of runs, of course!

Track 2

- Meant to describe the university timetabling problem where students pick courses before they are scheduled.
- Timetable constructed based on the course choices for all students.
- Each course (event) must be given a time slot and a room.

Track 2 Specifics

- *n* events to be scheduled into 45 slots (9 slots x 5 days).
- *r* rooms, each with a capacity.
- *f* “room features”
  - Satisfied by rooms.
  - Required by events.

Track 2 Specifics

- s students, each attending a set of events.
- Each event has a set of available timeslots.
- Possible precedence constraints between pairs of events
  - “A must be in an earlier slot than B”.

Hard Constraints

- No student can attend two events at the same time.
- The room chosen for a particular event must be big enough and have the right features.
- One event per room in each time slot.
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Hard Constraints

- Each event cannot be assigned to a time slot that is not in its “available” set.
- Events cannot violate the given precedence constraints.
- Can leave events unscheduled to prevent hard constraint violations.

Soft Constraints

- Try not to schedule events in the last time slot of each day.
- Students shouldn’t attend three or more events in successive time slots in one day.
- Students shouldn’t have only a single event on a given day.

Valid vs. Feasible solutions

- A valid timetable is one with no hard constraint violations, but where some events have been left unscheduled.
- A feasible timetable is a valid timetable with no events unscheduled.
- All solutions returned must be valid.

Development Strategy

- Try and integrate the automated parameter tuning process earlier in development.
- Expose as many parameters as possible, let ParamILS sort it out.
- Iterate based on the tuning results.

What Actually Happened?

- ~1 month of development and tuning.
- Some success using this model.
- Pressed for time, so in the end things were quite rushed.
- Not quite enough time for all of the tuning.
- Some parameters dropped in order to have faster tuning runs.

Our Algorithm

- Builds on work by Marco Chiarandini in the 2003 competition.
- Three phases:
  - Construction.
  - Hard constraint satisfaction.
  - Soft constraint satisfaction.

Construction

- Generates valid solutions, with possibly many events left unscheduled.
- Unscheduled events are iteratively placed into with feasible time slot that is available to the fewest unscheduled events.
- A topological order is used to make sure precedence constraints are satisfied.

Hard Constraint Solver

- Tabu search
- At each iteration, an unscheduled event is inserted into the best non-tabu time slot.
  - Selected by looking at the number of students involved.
- All events now causing violations are removed from the timetable.

Soft Constraint Solver

- Simulated annealing over several neighbourhoods.
  - 1-exchange
  - 2-exchange
  - Swap of time slots
  - Kempe chains.

Soft Constraint Solver

- The soft constraint neighbourhoods can introduce hard constraint violations.
- If a quick run of the hard constraint solver can’t repair them, revert.

Parameter Tuning

- During development, many tuning runs used to see how heuristics performed, as well as combinations of heuristics.
- Final tuning used 8 parameters with reasonably discretised domains, for time reasons.
- Each instance run took five minutes, with 16 instances in the training set.

Parameter Tuning

- 80 ParamILS runs performed on Arrow, with each run lasting approximately 24 hours.
- Several parameters ended up being set to the same value in all 80 final configurations.
- Others were set to several close values in their domains.

Public Instances

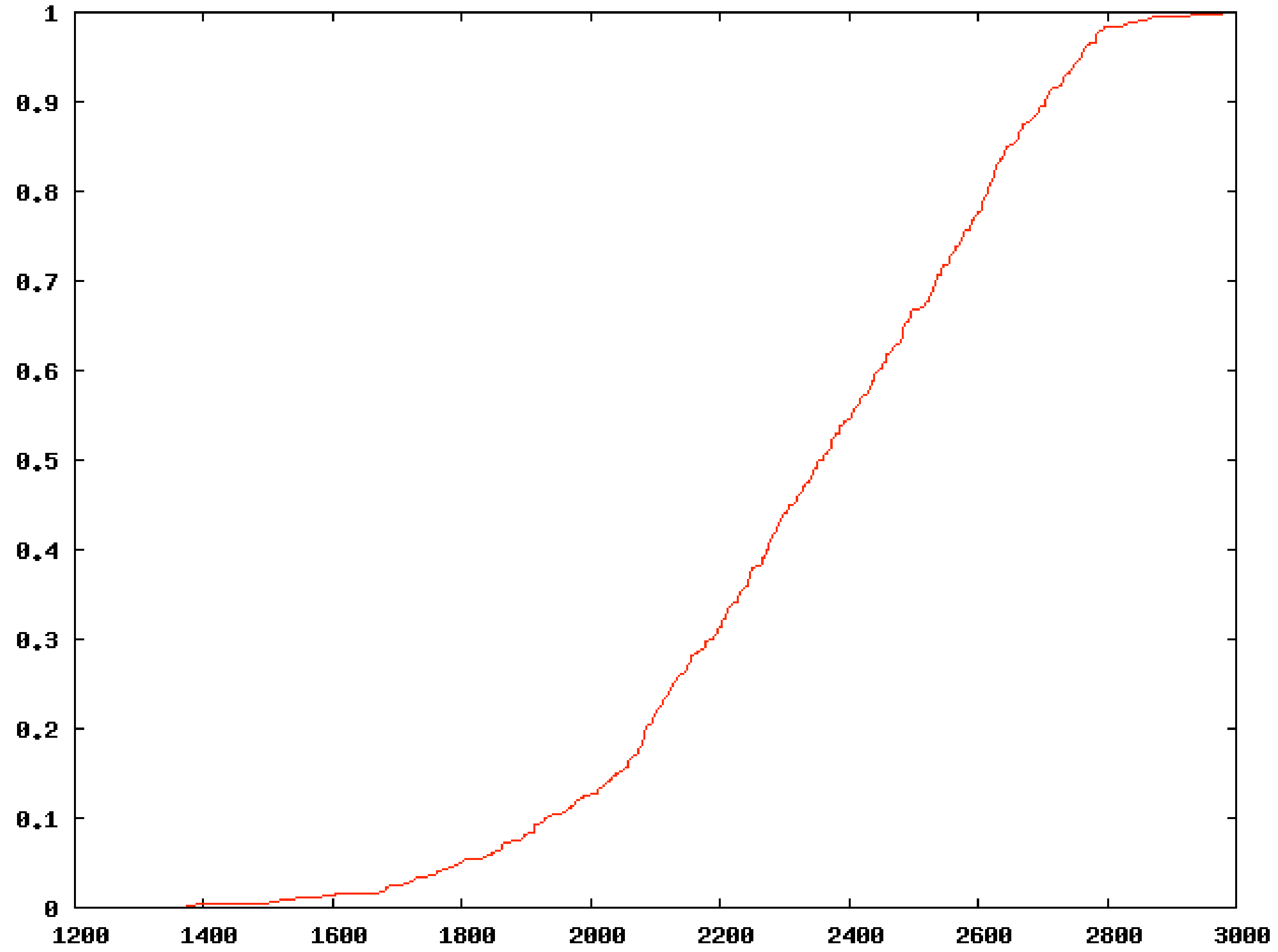
- Sixteen instances in total, with seven released two weeks before the competition deadline.
- 8 had only 200 events and were generally trivial to solve the hard constraints for.
- 8 had 400 events and were quite a bit harder.

Public Instance Performance

- 541 runs on each of the 16 instances, using the final parameter configuration.
- Best solutions found for each instance were feasible.
- For several 200-event instances, the soft constraint violations were brought to zero or very close to zero.

SQD

- This is the empirical SQD for instance 2-10 with the final parameter configuration.
- This is arguably the hardest public instance we had, our submission had quality 1364.



Conclusions

- We were selected as finalists, so hopefully that means the approach was at least decent.
- ParamILS was extremely helpful.
  - There is no way we could have manually tuned without taking a lot of time away from development.

Questions?