Solving the Post Enrolment Course Timetabling Problem by Ant Colony Optimization

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In this abstract we present our work to tackle the problem of *Post Enrolment Course Timetabling* as specified for the International Timetabling Competition 2007 (ITC2007), competition track 2. The heuristic procedure is based on Ant Colony Optimization (ACO) where artificial ants successively construct solutions based on *pheromones* (stigmergy) and local information; see [1] for a more general introduction to ACO.

Representation. In our algorithm, which can be more specifically classified as Ant System (AS), ants are basically assigning events to rooms and timeslots based on two kinds of pheromone denoted by τ^{s}_{ij} and τ^{r}_{ik} which represent the probabilities of assigning an event i to slot j and room k, respectively. The decision to store pheromone information in this way is a key-feature of the algorithm, as it avoids the usage of a much larger data structure implied by a more traditional encoding using individual pheromone values for all slot/room/event combinations (see e.g. [3]), but contains more information than the exclusive use of room/event pheromones (e.g. [2]). Our pheromone concept is further supported by the observation that the assignment of a room is less critical in comparison to the assignment to a timeslot.

Solution Construction. The solution construction considers the events in a uniform random order and assigns each event to a feasible room and a feasible time slot in a greedy randomized way (if possible) considering the pheromone information. In more detail, for each event randomized permutations of the available slots and rooms (π^{s} and π^{r}, respectively) are derived in such a way that slots (rooms) with higher pheromone values for the current event are more likely to appear earlier than slots (rooms) with low pheromone values. The ant then tries to assign the current event to a slot/room combination based on their order in π^{s} and π^{r}, respectively. The first possible assignment not violating any hard constraints w.r.t. the current partial solution is accepted. To ensure that both kinds of pheromone are accounted for equivalently, the slot/room combinations are considered in the following order: $(\pi^{\mathrm{s}}_1, \pi^{\mathrm{r}}_1), (\pi^{\mathrm{s}}_1, \pi^{\mathrm{r}}_2), (\pi^{\mathrm{s}}_2, \pi^{\mathrm{r}}_1), (\pi^{\mathrm{s}}_1, \pi^{\mathrm{r}}_3), (\pi^{\mathrm{s}}_2, \pi^{\mathrm{r}}_2), (\pi^{\mathrm{s}}_3, \pi^{\mathrm{r}}_1), \dots$. To speed up this process the permutations are not entirely created in advance, but rather the requested elements are calculated on demand.

Pheromone Update. After each iteration ants with a better than average score add an amount of pheromone proportionally to the solution quality for the performed event/slot and event/room assignments. In the case of conflicts, the involved assignments are punished accordingly. Pheromone evaporation follows the standard AS method.

Improvement Method. Often, ACO approaches benefit significantly by including a local search procedure for improving candidate solutions derived by the ants. In our algorithm we employ an improvement heuristic, which which tries to move costly events to a different timeslot if this can be achieved without violating any hard constraints while removing at most one other event from the solution. If an event needed to be removed, the procedure is then applied recursively until either a suitable place is found or the maximum search depth is reached. The move is accepted if the chain of moves in sum reduces the soft constraint penalty. Our experiments indicate that this method is beneficial in our case, but definitely not a key-factor for finding high-quality solutions.

Instance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DTF_{best}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCP_{best}	0	0	110	53	13	0	0	0	0	0	143	0	5	0	0	0
DTF_{avg}	237	274	0	0	0	2	0	0	109	0	0	20	2	0	0	0
SCP_{svg}	613	556	680	580	92	212	4	61	202	4	774	538	360	41	29	101
σ_{DTF}	290	369	0	0	0	9	0	0	294	0	6	56	9	0	0	0
σ_{SCP}	612	671	255	268	55	165	24	47	492	18	247	605	167	56	104	72
$P(DTF = 0)$	.54	.59	1.0	1.0	1.0	.95	1.0	1.0	.85	1.0	.99	.86	.94	1.0	1.0	1.0

Fig. 1. Results for the ITC2007 early and late instances. The first two rows show the best results achieved within the given timelimit. Distance to feasibility is denoted by DTF, soft constraint penalty by SCP. The subsequent rows show the average values of 100 runs followed by the respective standard deviations and the probability to reach DTF=0.

Results. The large majority of the competition instances can with high probability be solved to optimality within the given time-limit (See figure 1 for details). Hence it seems that the Ant Colony Optimization metaheuristic is very well suited to the problem of timetabling, allowing slightly longer running times even better results could be produced.

References

1. M. Dorigo and T. Stützle. *Ant Colony Optimization.* MIT Press, Cambridge, MA, USA, 2004.
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3. K. Socha, J. Knowles, and M. Sampels. A Max-Min ant system for the university timetabling problem. In M. Dorigo, G. Di Caro, and M. Sampels, editors, *Proceedings of ANTS 2002 – Third International Workshop on Ant Algorithms*, volume 2463 of *LNCS*, pages 1–13. Springer-Verlag, Berlin, Germany, September 2002.