PhD Open Days

Room usage optimization in timetabling: A case study at IST

PhD in Information Systems and Computer Engineering

Alexandre Lemos (alexandre.lemos@tecnico.ulisboa.pt)

Motivation

Room usage optimization for university timetables [1] is an important and complex task.

- Importance: "space, like time, is money"
- Problem: at certain time slots, there are no rooms available
- Current situation: the allocation of events is still handmade and therefore susceptible to optimization
- Goal: reduce the number of rooms required
- Goal: possibility of adding new events without disrupting the existing distribution

Results

The two solutions solve the data sets from both campi of IST.

The **ILP** approach:

- Finds the **optimal** solution for all data instances

The **greedy** approach:

- Is **two orders of magnitude** faster than the ILP approach
- Does not find an optimal solution.
- On average is within **2% of the optimal** for the number of seated students and within **34% of the optimal** for the room usage

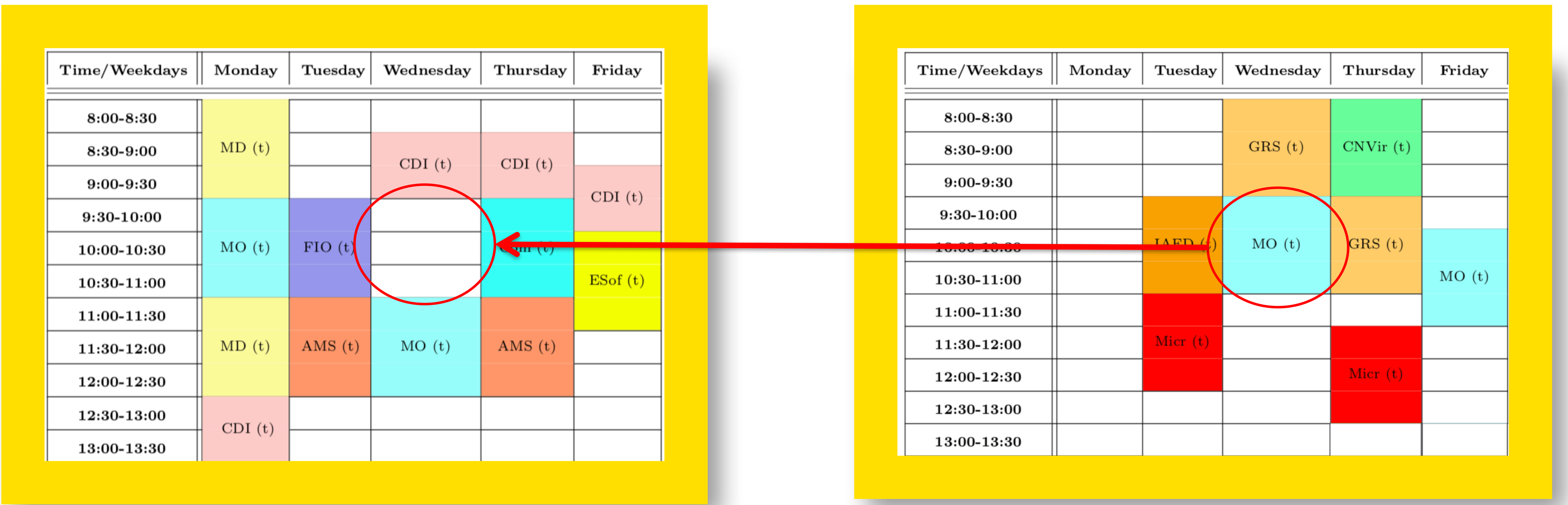

Fig 1: How to reorganize timetables for two rooms in order to obtain a more "compact" schedule.

What is a "compact" timetable ?

A timetable with the smallest:

- **Number of transitions**: the number of times a room changes status from vacant to occupied and vice-versa
- **Weighted transitions:** the weight is inversely proportional to the size of vacancies, as it is easier to schedule new events in longer vacancies

No **perfect metric**: quality of the definition depends on possible future disruptions.

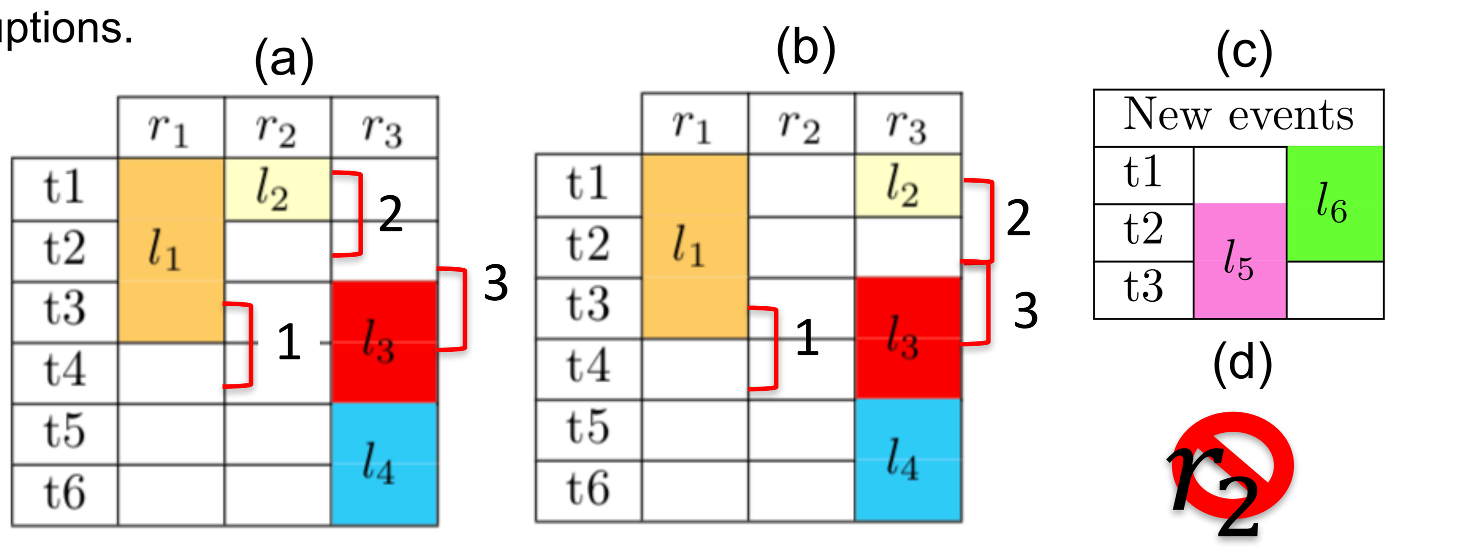

Fig2: Two optimal timetables in terms of compactness, and two possible disruptions. r1 to r3 are rooms, t1 to t6 are time slots and l1 to l6 are events. The timetable (a) is better for the disruption (c) and the timetable (b) is better for the disruption (d).

Improvement: students seated

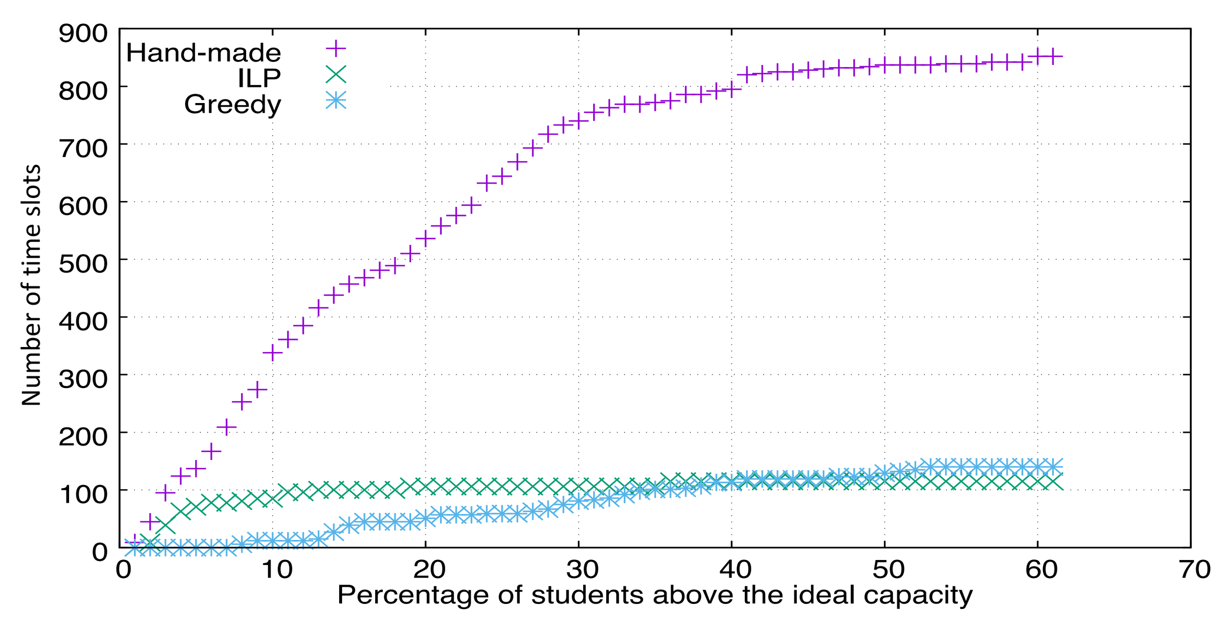

Fig 3: The cumulative distribution of slots (30 min) with the number of students enrolled above the ideal capacity as a function of the percentage of students above the ideal capacity for Alameda 1st semester.

Solution

We want to optimize the room occupation by determining the events allocated to each room, while ensuring that the rooms have enough capacity to "seat" all people. This approach will not change the schedule of the lectures, and therefore avoids all curriculum based constraints. For more details see [2].

We propose a lexicographic optimization with the following optimization criteria:

1. **The number of students seated**
2. **The number of transitions**

The result should improve the timetable in both criteria.

In order to obtain a solution we propose two different methods:

- **Integer Linear Programming** (ILP) using CPLEX [3]
- A **greedy algorithm** with a cost function that allows us to ensure that the solution is within **63%** of the optimal value [4]

Conclusions

We propose two different approaches to optimize the space usage. Both approaches were successfully tested with data sets from both campi of IST. The two proposed approaches improve the quality of the hand-made solution for both optimization criteria.

References

[1] Beyrouthy C, Burke EK, Landa-Silva D, McCollum B, McMullan P, Parkes AJ. Towards improving the utilization of university teaching space. J Oper Res Soc 2009;60(1):130–43.

[2] Lemos, A.; Melo, F. S.; Monteiro, P.T. ; Lynce, I. "Room Usage Optimization in Timetabling: A Case Study at Universidade de Lisboa". Op. Res. Persp. 2019 (in press)

[3] IBM ILOG. Optimization studio CPLEX user' s manual, version 12 release 7. 2016.

[4] Edmonds J. Submodular functions, matroids, and certain polyhedra. Comb Optim 1970;11:11–26.

Acknowledgements

This work was supported by Universidade de Lisboa, Instituto Superior Técnico and Departamento de Engenharia Informática (DEI) and by national funds through Fundação para a Ciência e a Tecnologia (FCT) with reference UID/CEC/50021/2019 (INESC-ID multi-annual funding).