Discrete Optimization – Project 2025

The Integrated Healthcare Timetabling Competition

This project focuses on the challenge of integrated healthcare scheduling, an issue in hospital management where multiple scheduling decisions must be coordinated to ensure efficient patient care. It is based on the problem description and rules from the *Integrated Healthcare Timetabling Competition 2024* [1], with adaptations to suit the specific needs of this project. The official GitHub repository of the competition can be found at IHTC2024.

The project combines two scheduling challenges:

1. Patient Admission Scheduling – Determining when patients are admitted and assigning them to hospital rooms.

2. Nurse-to-Room Assignment – Scheduling nurses to cover patient care in different hospital rooms.

1 Problem Definition

1.1 Basic concept

Scheduling period: The scheduling period is defined as a number D of consecutive days. D is always a multiple of seven, and can vary from 14 (two weeks) to 28 (four weeks). Days are numbered from 0 to $D-1$.

Rooms: Rooms host the patients during their recovery. These rooms are characterized by their capacity, expressed in terms of the number of beds. Room equipment is not explicitly taken into account. However, as will be outlined in what follows, some rooms might be declared unsuitable for some patients.

Nurses: Each nurse has a skill level. Levels are strictly ordered (hierarchical) and represented by an integer that ranges from 0 (lowest) to $L-1$ (highest), where L is the number of skill levels. Furthermore, each nurse has a predetermined roster, which is defined as a set of days that the nurse has been assigned to, and the maximum workload the nurse can accommodate each day. This roster is fixed and cannot be changed.

The following information is provided for each patient:

- mandatory/optional: mandatory patients must be admitted during the scheduling period, while the admission of optional patients can be postponed until a future scheduling period.
- release date: earliest possible admission date for the patient.
- due date: latest possible admission date, provided only for mandatory patients.
- age group: the age group of the patient (e.g., infant, youth, adult, elder). The list of age groups is fully ordered.
- gender: the gender of the patient.
- length of stay: duration of the hospitalization in days.
- incompatible rooms: set of rooms that must not be allocated to the patient because, for example, they do not have the specific equipment or the necessary isolation.
- workload: the workload profile generated by the patient, which is described by a vector, starts at the admission day and ends at the discharge day. The length of the vector equals the patient's length of stay.
- minimum skill level: the minimum nurse skill level required by the patient for each day they are staying in the hospital; described by a vector similar to the patient workload vector.

1.2 Solution

The solution of an IHTP instance consists of the following decisions:

1. the admission date for patients, or, in the case of optional patients, potentially their postponement to the next scheduling period;
2. the allocation of a room for each admitted patient;
3. the assignment of a single nurse to each occupied room, for each day within the scheduling period.

We assume that a patient stays in only one room during the entire length of their stay, meaning a patient cannot be transferred from one room to another. A nurse can be assigned to more than one room in each day (but only one nurse is assigned to a room in a day)

1.3 Constraints

Constraints are categorized as either hard (starting with **H**) or soft (starting with **S**). The former must always be satisfied, while the latter contributes to the objective function. Violations of soft constraint $\mathbf{S_i}$ are multiplied by weight W_i. The soft constraint weights are instance-specific and thus given in each input file.

Constraints on Patient Admission Scheduling

H1 No gender mix: Patients of different genders may not share a room on any day.

H2 Compatible rooms: Patients can only be assigned to one of their compatible rooms.

H3 Room capacity: The number of patients in each room in each day cannot exceed the capacity of the room.

S1 Age groups: For each day of the scheduling period and for each room, the maximum difference between age groups of patients sharing the room should be minimized.

Constraints on Nurse-to-Room Assignment

S2 Minimum skill level: The minimum skill level a nurse must have to provide the required care for a patient during each day of their stay should be met. If the skill level of the nurse assigned to a patient's room in a day does not reach the minimum level required by that patient, a penalty is incurred equal to the difference between the two skill levels. Note that a nurse with a skill level greater than the minimum required can be assigned to the room at no additional cost.

S3 Continuity of care: To ensure continuity of care, the total number of distinct nurses providing care to a patient during their entire stay should be minimized.

S4 Maximum workload: For each day, the total workload induced by patients staying in rooms assigned to a nurse should not exceed the maximum workload of that nurse in that day. The penalty is the amount by which the total workload exceeds the limit, or 0 if it does not exceed it.

Global constraints

H4 Mandatory versus optional patients: All mandatory patients must be admitted within the scheduling period, whereas optional patients may be postponed to future scheduling periods.

H5 Admission day: A patient can be admitted on any day from their release date to their due date. Given that optional patients do not have a due date, they can be admitted on any day after their release date.

S5 Admission delay: The number of days between a patient's release date and their actual date of admission should be minimized.

S6 Unscheduled patients: The number of optional patients who are not admitted in the current scheduling period should be minimized.

1.4 Boundary data

We assume that some patients are already present in the hospital on the first day of the scheduling period. We use the term occupants to refer to these special patients. While these occupants contribute to the occupancy of the rooms and to all related constraints, their admission date and room assignment are fixed. For patients admitted during the current scheduling period and who stay after the end of it, no penalties are incurred after the end of the horizon.

1.5 Datasets and validator

Problem instances are supplied as JSON files. Each instance is contained within a single file. We provide a public dataset composed of 20 instances, named `i01, ..., i20`, with a scheduling period ranging from two to four weeks and a number of patients ranging from approximately 50 to 500. In addition, we provide ten instances, `test01, ..., test05`, for testing and debugging purposes. We also provide a solution for each test instance. We will employ a different *hidden* dataset to evaluate the groups. Generated solutions must be saved as JSON files adhering to the format given in the solution of each test instance. The validator, which certifies the feasibility and quality of a given solution, is provided as a Julia code in the file `validator.jl`

Deliverables

Students will work in groups of two for this project. For organizational purposes, each group must send an email to Laurie Boveroux (laurie.boveroux@uliege.be) by March 14, including the names of all group members. Each group must implement both a **Mixed-Integer Linear Program** (MILP) and at least one **heuristic** to solve the problem. The heuristic method must be stopped after a maximum runtime of ten minutes for each instance. Each group must submit a short report (maximum 4 pages, in PDF format) detailing the problem formulations used and the heuristic(s) developed. The submission should also include:

- The Julia code (cleaned and commented) supporting the report,
- A txt file explaining how to run the code,
- JSON solution files for each of the 20 instances.
  The name of the files should be `sol_i01.json, ..., sol_i20.json`.

All files (report, Julia code, txt file and JSON files) must be submitted to Gradescope by 8:00 PM on May 5.

Presentations of methods and results will take place on 7 May. However, groups will only present if the evaluators consider the content submitted sufficient. The exact format of the presentation will be communicated in due time.

If the instructions are not followed, the group will be penalised. **No second session will be organised for the project**, the grade will be final.

References

[1] Sara Ceschia, Roberto Maria Rosati, Andrea Schaerf, Pieter Smet, Greet Vanden Berghe, and Eugenia Zanazzo. The integrated healthcare timetabling competition 2024 – problem description and rules. Technical report, University of Udine & KU Leuven, January 2025.