Leibniz Universität Hannover

Decision Support for Rehabilitation Hospital Scheduling – Ideas for Heuristic Algorithms

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Agenda

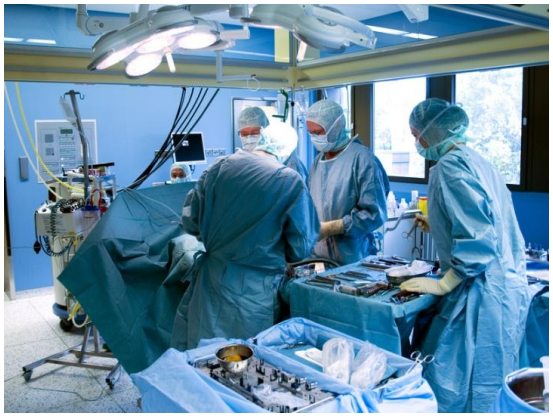
1. Motivation
2. The Monolithic Planning Approach
3. Outline of a Heuristic Algorithm
4. Next Steps

Rehabilitation vs. Acute Hospitals

Rehabilitation Hospital

- Restoring patients‘ health after surgery or injury
- Long length of stay (up to 6 weeks)
- Planning problem of high complexity due to long time horizon

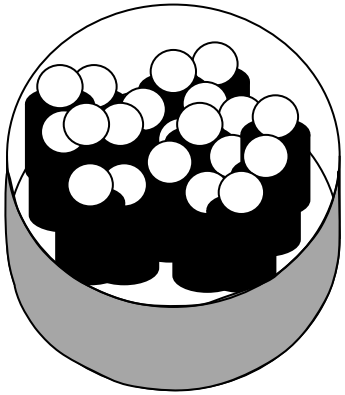
Acute Hospital



- Intensive diagnosis and therapy
- Short length of stay (<1 week or emergencies)
- Bottleneck resource (surgery) dictates planning process

Planning Problem of Existing Patients in Rehabhospitals

Existing Patients



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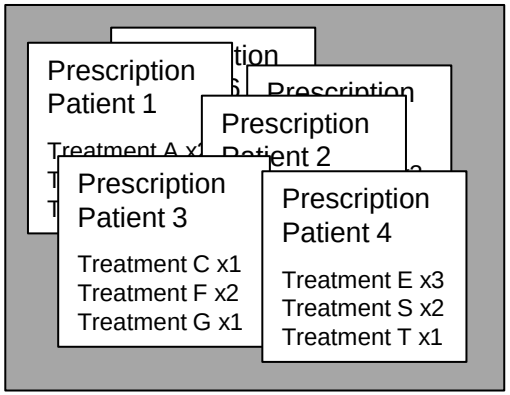
Submitted Prescriptions



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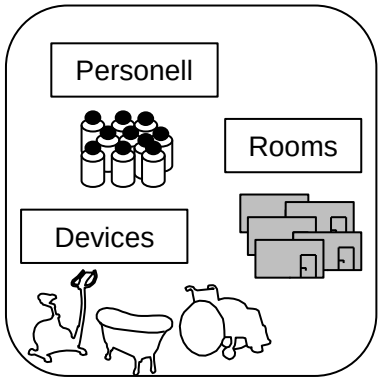
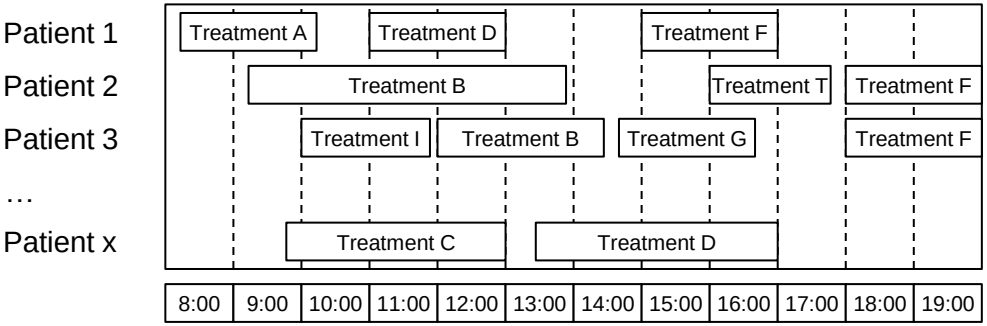
Fixed Resources

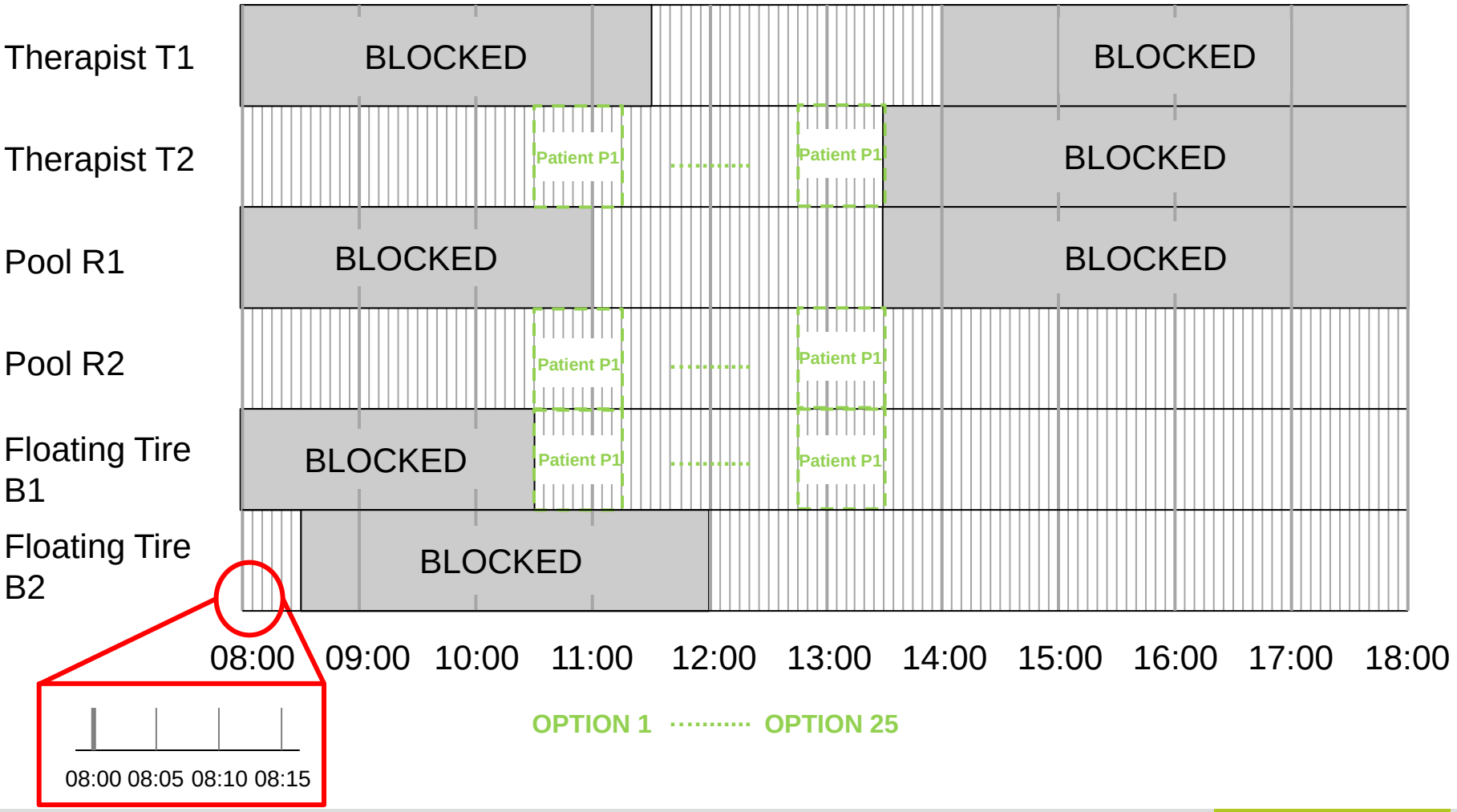


combined to

Schedule

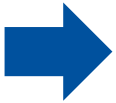


Example for Scheduling a Single Water Aerobics Treatment on a Tuesday



Example of a Large Sized Rehabilitation Hospital

- Planning horizon 4-6 weeks
- ~400 patients
- ~600 activities available (wateraerobics, physiotherapy etc.)
- 6.800 prescribed orders result in >38.000 single events
- 80 categories of resources contain >380 single resources
- 2-3 resources necessary per event
- Discrete time slots à 5 minutes
- Rolling planning with partly fixed events



Planning process with high complexity

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The Monolithical Optimization Model[1]

- Modeling as an assignment problem
- Central binary decision variables:
  - Scheduling variable $x_{p,m,d,t}$: Patient *p* starts treatment *m* on day *d* in time slot *t*
  - Connection variable $y_{p,m,f,d,t}$: Patient *p* starts treatment *m* on day *d* in time slot *t* using resource *f*

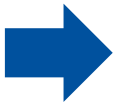
[1] Schimmelpfeng K, Helber S, Kasper S (2012) Decision support for rehabilitation hospital scheduling. OR Spectrum, Volume 34: 461-489

The Monolithical Optimization Model

- Objective Function: Maximization of number of scheduled treatments
- Restrictions:
  - … combining the two central binary variables
  - … reflecting the resource availability
  - … prohibiting the collision of treatments
  - … preventing overstressing patients capabilities
  - … ensuring correct sequences of treatments
  - … fixing the date of treatments
  - various more …

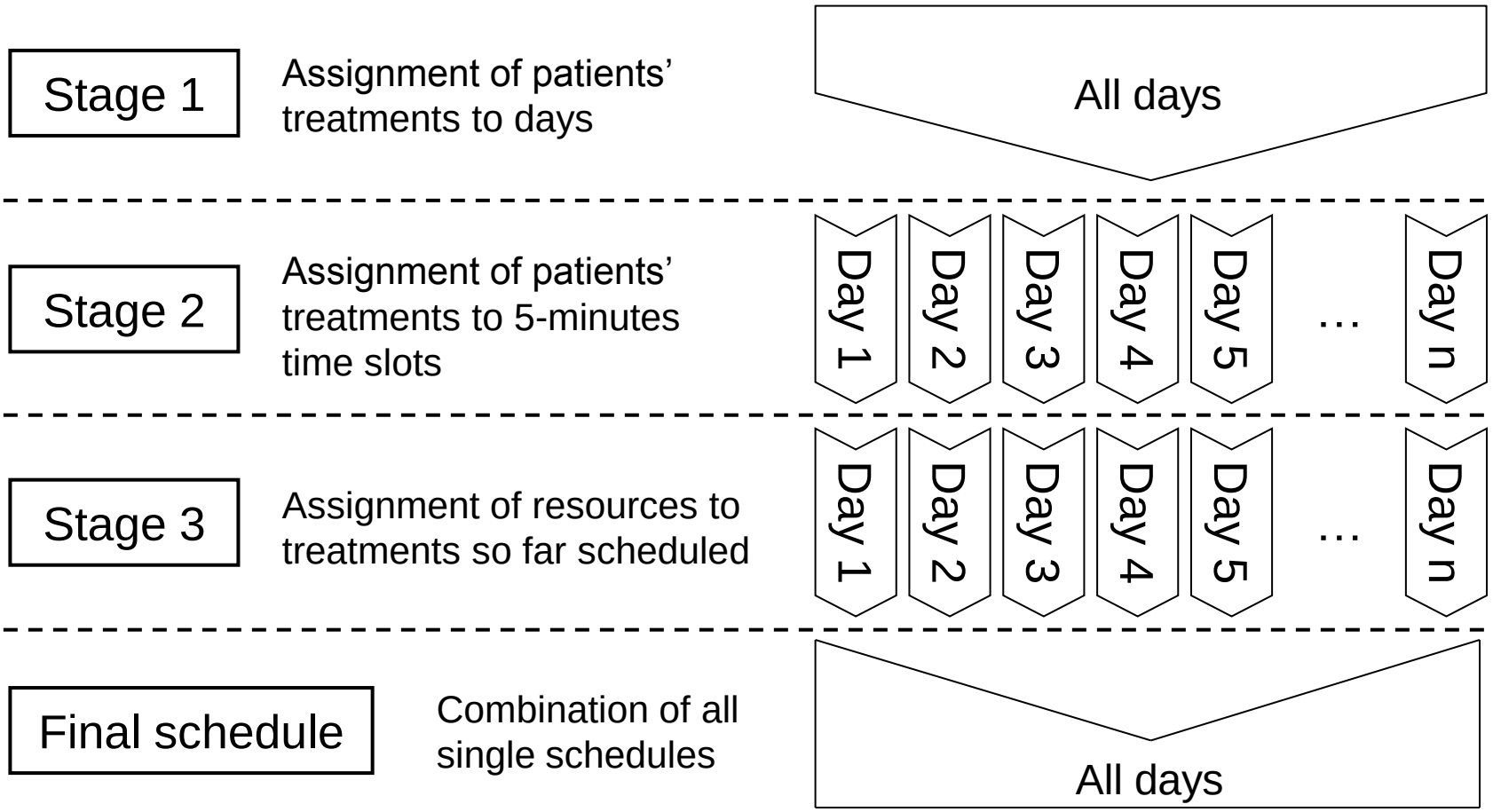
Solvability of the Monolithic Model

- Small problem instance:
  - 40 Patients, 18 resources, 30 days, 120 time slots
  - Nonzeros: ~30,000,000 (GAMS) / ~ 6,700,000 (CPLEX)
  - ~7% gap after 1hour, optimality after 24hours
- Large problem instance:
  - >400 Patients, ~100 resources, 30 days, 120 time slots
  - Nonzeros: ~800,000,000 (GAMS), -



Not solveable monolithically at the moment

Solving the Planning Problem Using a Decomposition Approach



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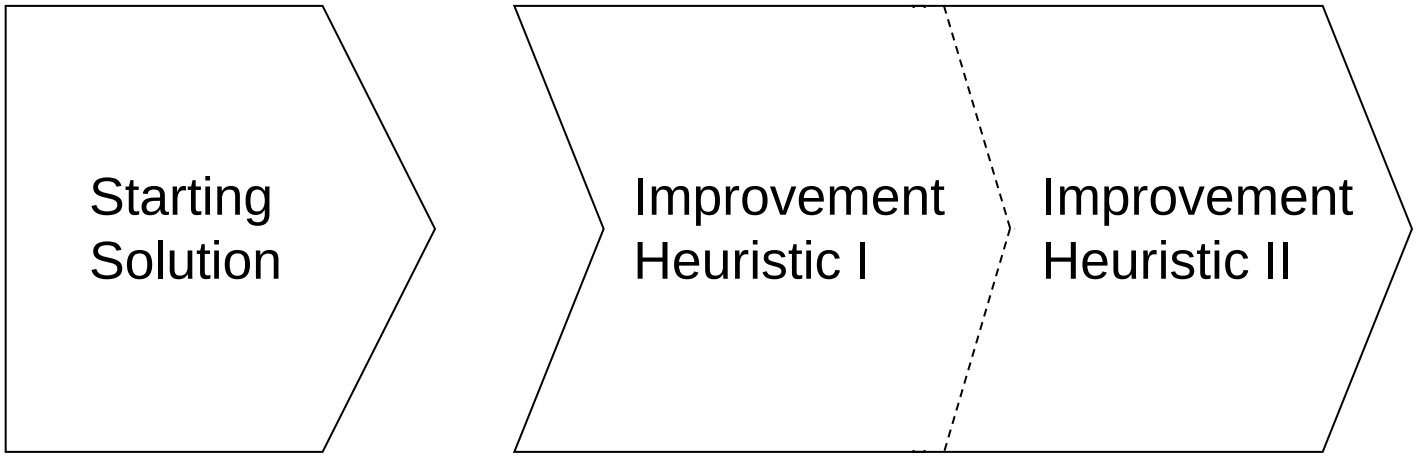
Overview: Iterative Heuristic Algorithm



- Greedy Heuristic with incentive scheme
- Local Search with incentive scheme
- Local Search without incentive scheme

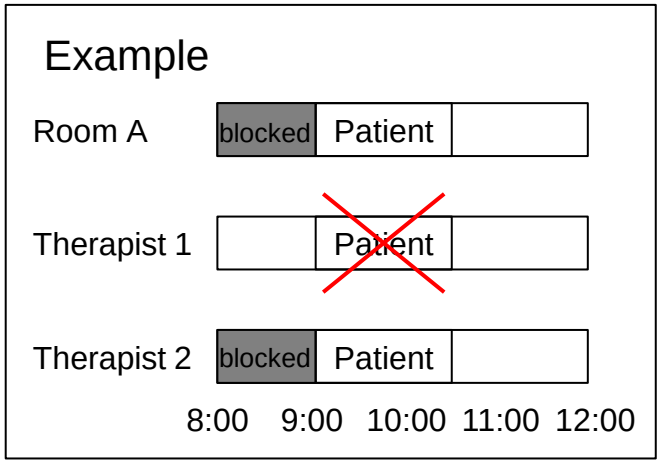
Iterative Algorithm:
Step 1 – The Greedy Heuristic

- Target: Construction of a starting solution

- Procedure:
  - Scheduling the first patient using all available resources
  - Blocking of used resource capacity
  - Scheduling the next patient using all remaining resources

Iteration

- Incentive scheme:
  - Problem: “Cluttered” schedules with many useless gaps
  - Reward seamless scheduling of treatments



Iterative Algorithm: Step 2 –Local Search

- Target: Optimization of the schedule from step 1

- Approach:
  - Optimization of treatments and resources for a limited number of patients
  - Selection of patients in each iteration: randomly or considering the amount of so far scheduled treatments
  - Deactivation of the incentive scheme as soon as the improvements are getting small

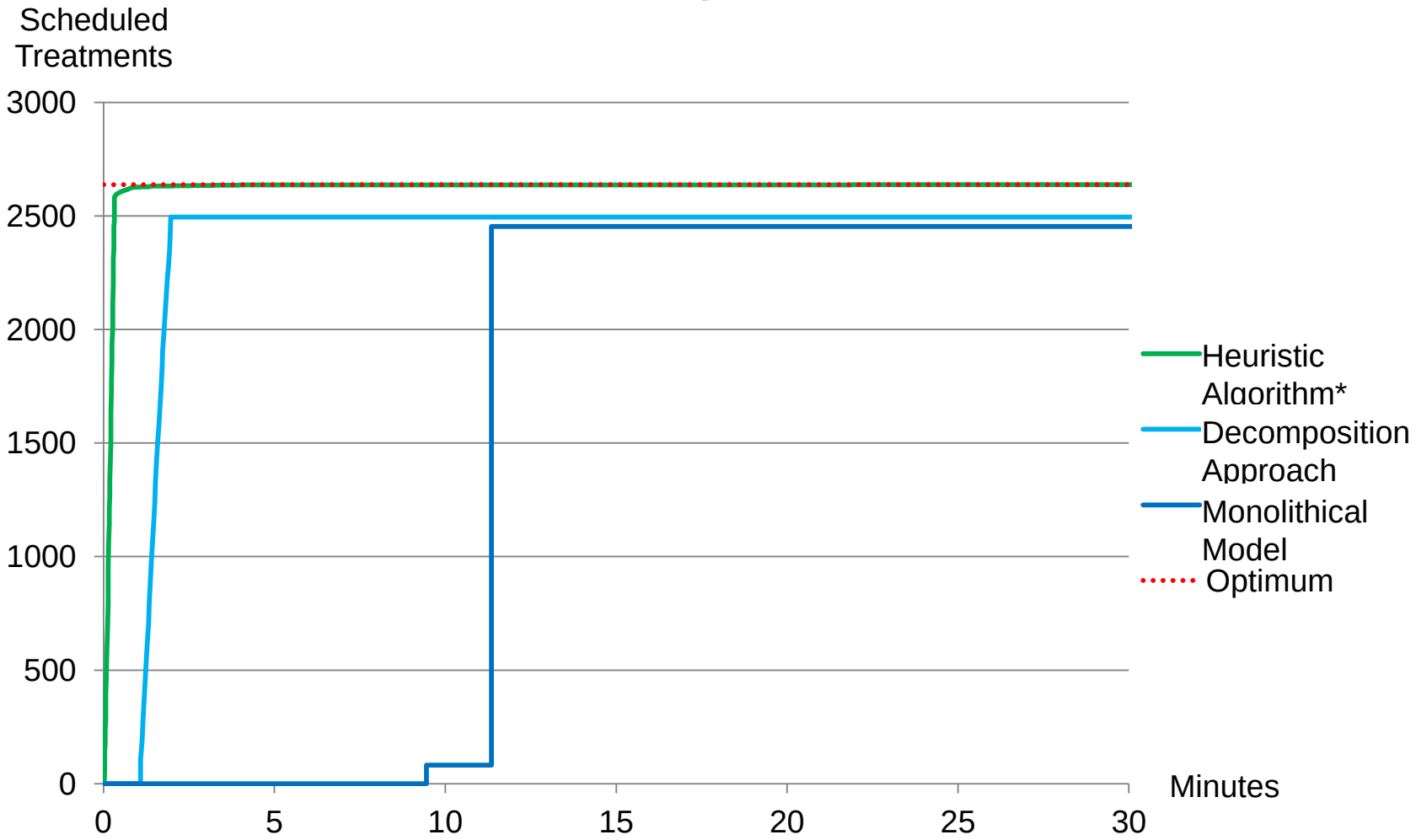
➡ Acceleration of the exchange operations

Description of Test Instances

Test instance	Small Rehab Hospital	Large Rehab Hospital
Patients	40	429
Types of activities	25	182
Prescribed treatments	~3.400	~36.300
Days	30	
Time slots (à 5-min)	120	
Resource categories	18	26
Single resources	18	92

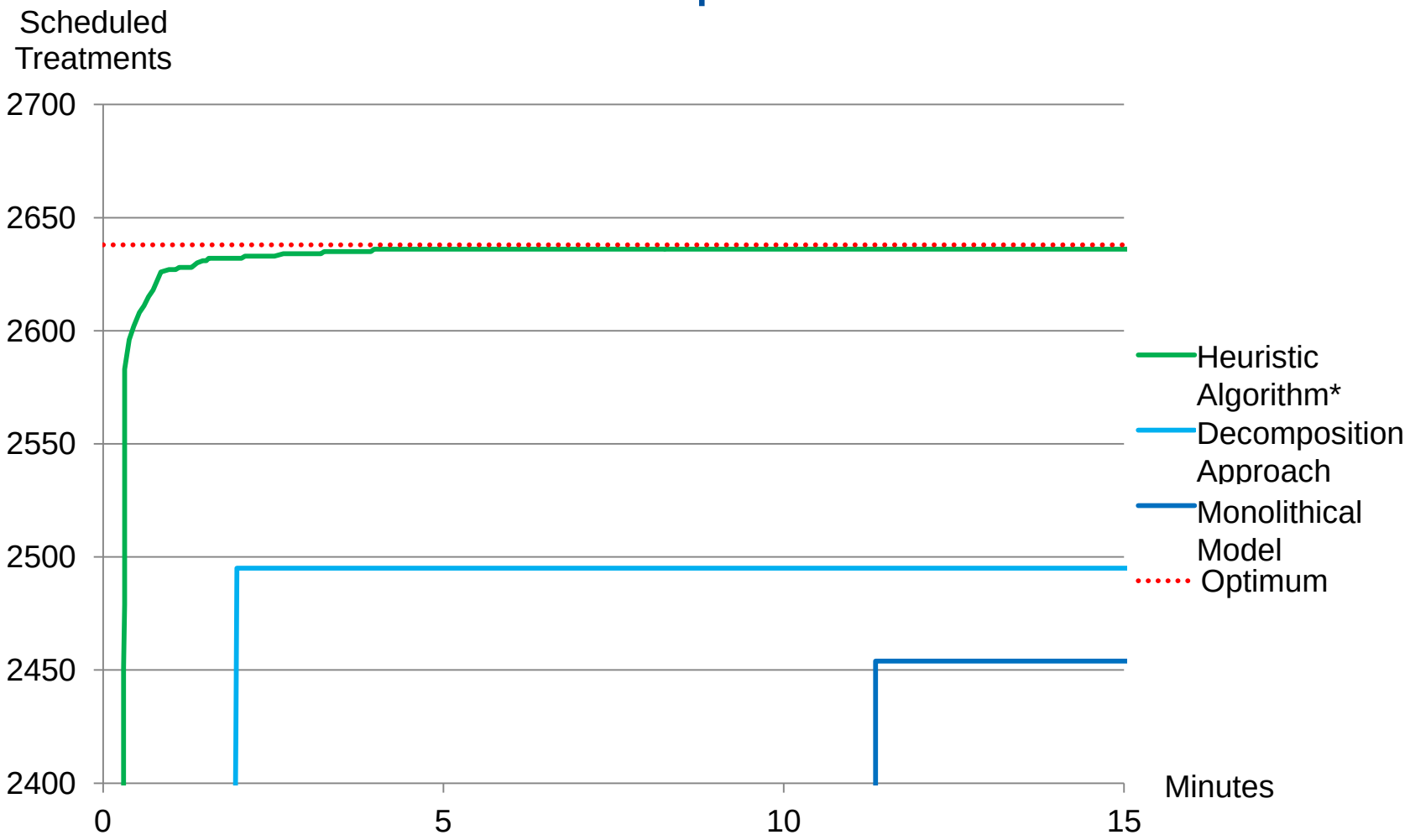
- Used computing capacity: 4 cores, 3GHz, 8GB RAM

Numerical Results: Small Rehabilitation Hospital



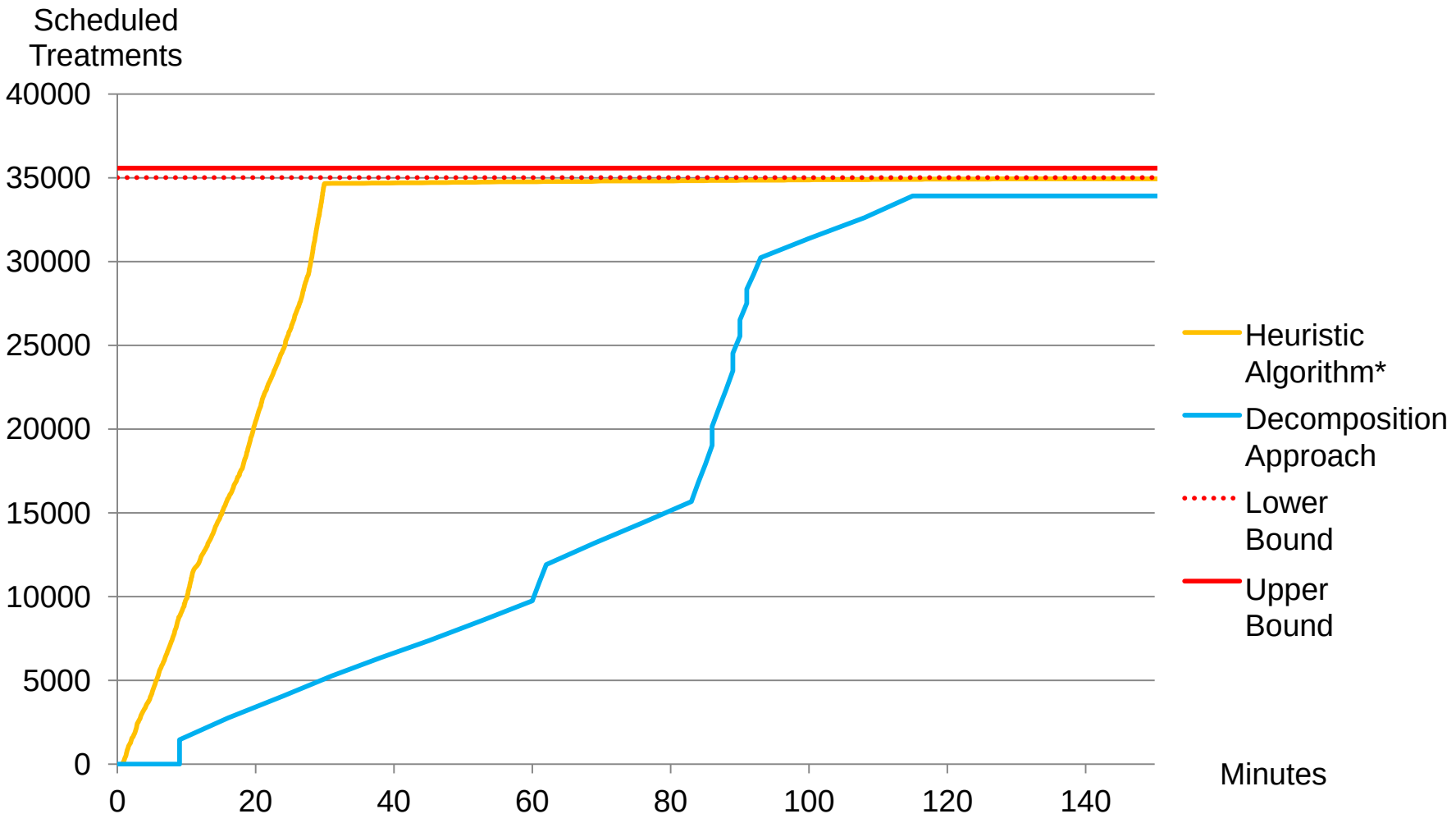
* exchange operation with 12 patients

Numerical Results – in Detail: Small Rehabilitation Hospital



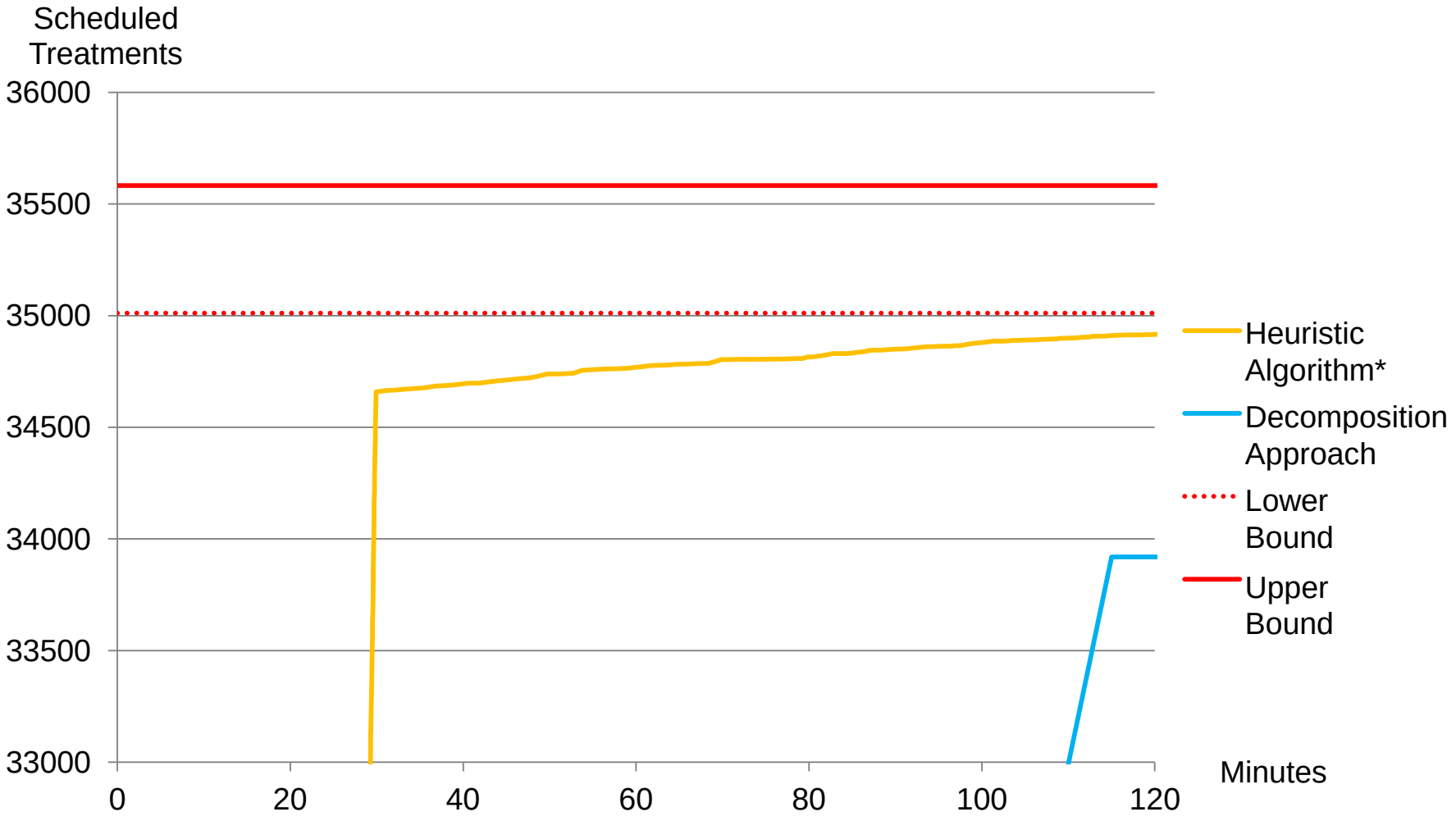
* exchange operation with 12 patients

Numerical Results: Large Rehabilitation Hospital



* exchange operation with 16 patients

Numerical Results – in Detail: Large Rehabilitation Hospital



* exchange operation with 16 patients

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Next Steps

- Testing the approach with further data
- Looking for a possibility of practical application
- Modeling of standardized, cyclic schedules representing typical clinical pathways in rehabilitation hospitals (e.g., rehabilitation after a hip replacement, heart attack etc.)