Improving User Experience in Interactive Job Scheduling

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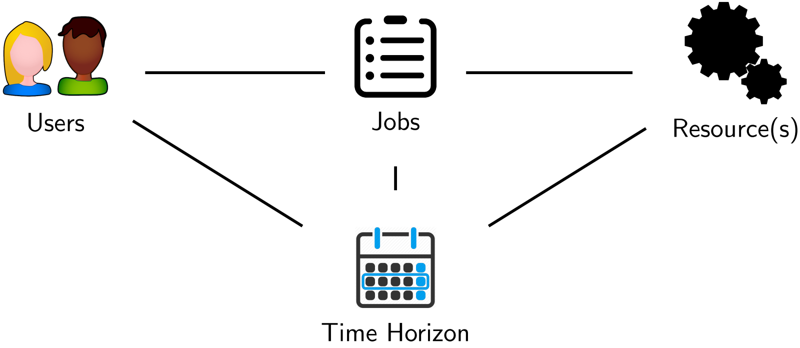
General Problem Setting

How to organize processes best that involve humans?

Formulate as scheduling problem

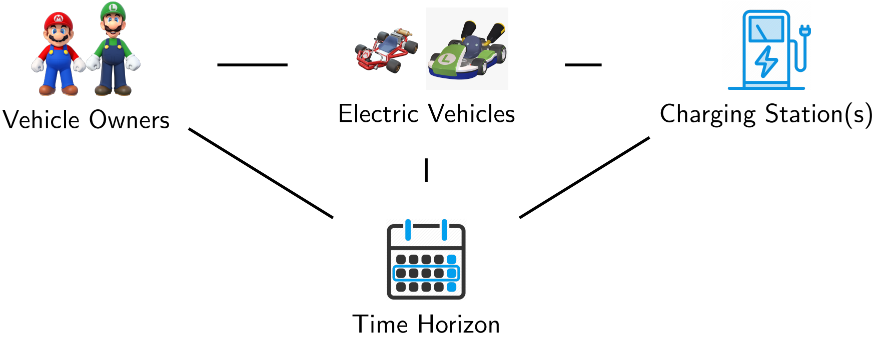


Scheduling the Charging of EVs[1]

Time-dependent electricity prices

Limited number of charging stations

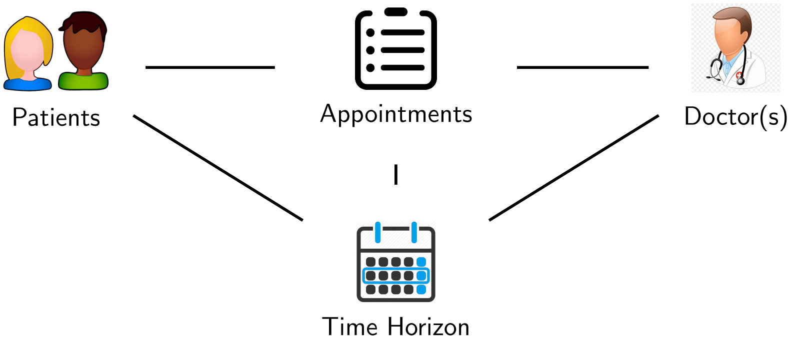
E.g. weekly schedule



[1] Johannes Varga, Günther R. Raidl, and Steffen Limmer (2022). "Computational Methods for Scheduling the Charging and Assignment of an On-Site Shared Electric Vehicle Fleet". In: *Access* 10, p. 105786.

Scheduling Doctors Appointments

Rolling time horizon



Timetabling Classes

Semester-wise schedule

Lecturers

Classes

Lecture Room(s)

Time Horizon

Classical Approaches

EV Charging Scheduling:

- Users specify preferences beforehand
- Optimization approach computes schedule

Doctors appointments: Secretary coordinates appointments with patients

Timetabling classes: Expert coordinates access to lecture rooms

Common disadvantages:

- Labour intensive
- Annoying for users
- Suboptimal results

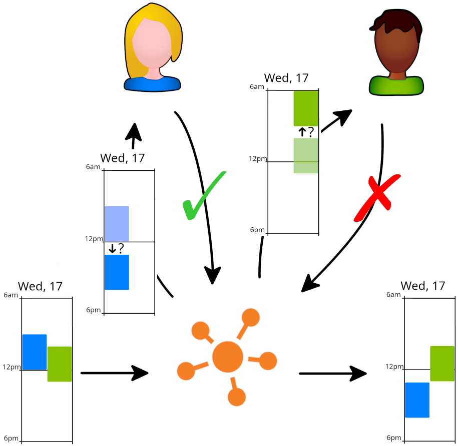
Cooperative Approach

Central unit: Scheduler

- Coordinates schedule among users
- Interacts with users to find out about their most relevant preferences

Advantages:

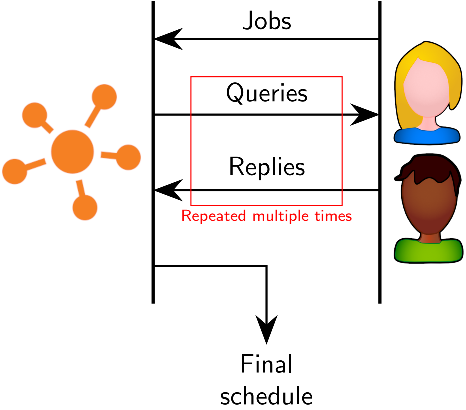
- Automated
- Low effort for users
- Optimized results



User Interaction

Key requirement: Do not annoy users
→ Limit user frustration

- Low number of queries
- Low effort
- Only queries, where positive feedback is likely
- Queries make sense to the user



Algorithmics Behind the Scenes

Integer Linear Programming (ILP)

- Technique to solve optimization problems
- Formulate with decision variables, linear constraints and linear objective
- State-of-the-art solvers: Gurobi, CPLEX
- Advanced techniques: Stochastic Programming, (Logic-based) Benders decomposition

Bayesian Learning and Probabilistic Programming

- Based on Bayes theorem: $\overbrace{p(\text{Parameters}|\text{Observed})}^{\textit{Posterior}} \sim \overbrace{p(\text{Observed}|\text{Parameters})}^{\textit{Likelihood}} \cdot \overbrace{p(\text{Parameters})}^{\textit{Prior}}$
- Sample from posterior with e.g. Markov Chain Monte Carlo methods
- Advantages: Sample efficient, flexible, uncertainty measure of prediction

User Model

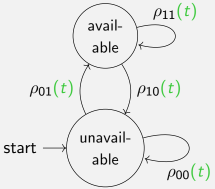
Task: Predict reply to query ($\rightarrow$ acceptance probability)

Assumptions:

- Availabilities change slowly
- Users behave similar

Markov-Model:

- Two states
- Time-independent vs. time-dependent



Interval model:

- User is available in 2-3 intervals throughout the day
- Normally distributed start- and endpoints

Learn parameters from user interaction of previous instances[2]

[2] Johannes Varga, Günther R. Raidl, and Tobias Rodemann (2025). "Learning to Predict User Replies in Interactive Job Scheduling". [submitted to AAAI].

Approaches

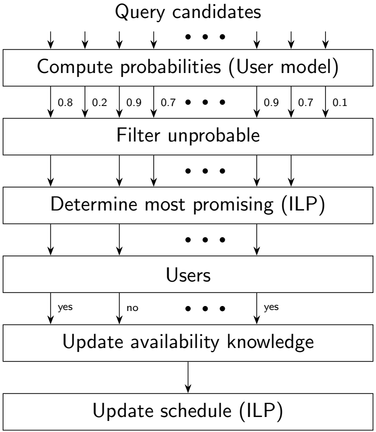
Query candidates: Move any job to any other time

Threshold approach[3][4]:

- Discard queries below probability threshold
- Select queries that minimize costs

Stochastic Programming approach[5]:

- Prefer queries more that are likely accepted
- Minimize expected costs



[3] Johannes Varga et al. (2023). "Interactive Job Scheduling with Partially Known Personnel Availabilities". In: *OLA 2023: Optimization and Learning*. Ed. by B. Dorronsoro et al. Vol. 1824. Communications in Computer and Information Science. Springer, pp. 236–247

[4] Johannes Varga et al. (2024). "Scheduling jobs using queries to interactively learn human availability times". In: *Computers & Operations Research* 167, p. 106648

[5] Johannes Varga, Günther R. Raidl, and Tobias Rodemann (2024). "Selecting User Queries in Interactive Job Scheduling". [to appear]

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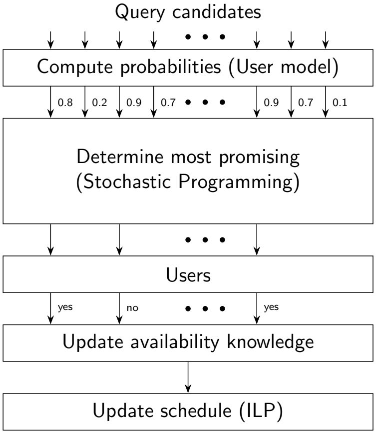

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Simulation Results[6]

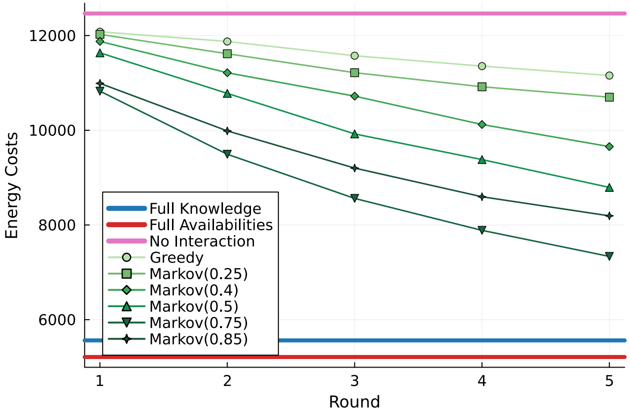
Setting: Employees of company want to use expensive machine

5 machines, 30 users

5 rounds of user interaction, 30 queries per round

Threshold approach with different thresholds

Cost reduction after five rounds: $12400 \rightarrow 7300$ (41%)



[6] Johannes Varga et al. (2024). "Scheduling jobs using queries to interactively learn human availability times". In: *Computers & Operations Research* 167, p. 106648.

Currently: Psychological Factors

Cooperation with Christiane Attig

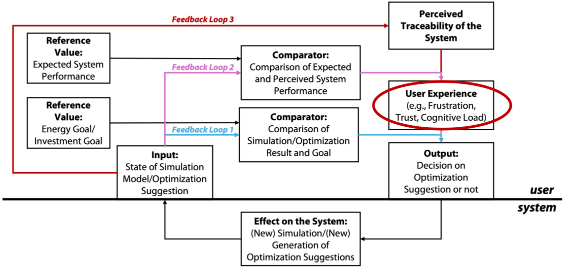
Plan: submit at Conference on Intelligent User Interfaces (IUI)

Idea: Model user frustration with system

Consider in the scheduler

Important aspects we plan to consider in the future:

- Cognitive Load[7]
- Explainability/Traceability[8]



[7] Paul Slovic et al. (2013). "Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk and rationality". In: *The feeling of risk*. Routledge, pp. 21–36

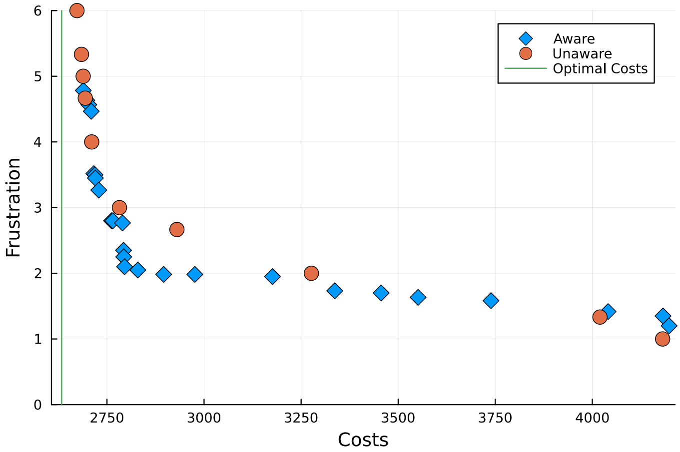
[8] Serge Thill et al. (2018). "Driver adherence to recommendations from support systems improves if the systems explain why they are given: A simulator study". In: *Transportation research part F: traffic psychology and behaviour* 56, pp. 420–435

Currently: Psychological Factors

Frustration: linear with number of queries

Approaches

- Unaware: Minimizing only costs
- Aware: Multi-objective optimization considering frustration and costs



First insight: Better tradeoff between frustration and costs when considering frustration

Outlook: Fairness[10]

Differences in frustration between users $\rightarrow$ unfair?

"Min–max fairness: The primary objective for distribution is to ensure an allocation of resources that maximizes the minimum benefit received by any user."[9]

Benefit (aka utility) depends on frustration and time of the scheduled jobs

Potential research questions:

- How much does fairness cost?
- How can incentives be used to increase fairness?

[9] João Soares et al. (2024). "Review on fairness in local energy systems". In: *Applied Energy* 374, p. 123933.

[10] Violet Xinying Chen and John N Hooker (2023). "A guide to formulating fairness in an optimization model". In: *Annals of Operations Research* 326.1, pp. 581–619.

Conclusion

Optimization important when scheduling human activities

Works better when coordinating cooperation

Also important:

- Optimization approach
- User frustration
- Fairness

We implemented and evaluated: efficient scheduling system
Cost reduction after five rounds: 41%

References I

- Slovic, Paul et al. (2013). "Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk and rationality". In: *The feeling of risk*. Routledge, pp. 21–36.
- Soares, João et al. (2024). "Review on fairness in local energy systems". In: *Applied Energy* 374, p. 123933.
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