Nurse Scheduling Problem for Maximum the Staff Satisfaction

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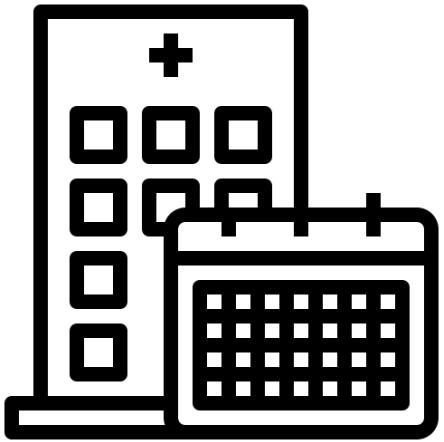
Introduction

Nurse Scheduling Problem

- The nurse scheduling problem involves organizing a nurse's work schedule in a healthcare facility

- Multi-target Optimization[1]
  - Nurses' skill level, contracts and requirements, rest period, preference …



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Nurse Scheduling Problem

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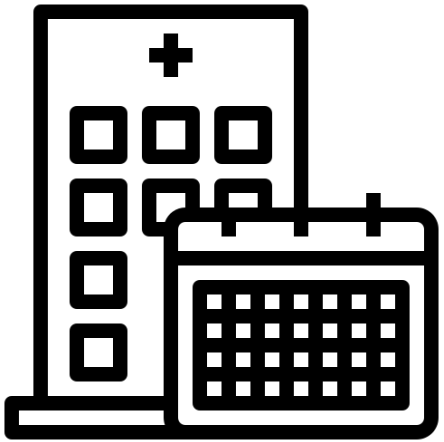
- Multi-target Optimization[1]
  - Nurses' skill level, contracts and requirements, rest period, preference …

- 24-hour labor cost shift system[2]
  - Employee shortages
  - Irregular working shifts
  - Job dissatisfaction and might influence patient[3]



Introduction

The real-world implications of NSP being NP-hard

- Healthcare systems need to create schedules that meet all requirements, but optimally for large sets is **infeasible with brute-force approaches**

- It tend to have **factorial time complexity** in polynomial time

3 people and 3 jobs , 6 possible solutions

	Person A	Person B	Person C
Solution 1	Job 1	Job 2	Job 3
Solution 2	Job 1	Job 3	Job 2
Solution 3	Job 2	Job 1	Job 3
Solution 4	Job 2	Job 3	Job 1
Solution 5	Job 3	Job 1	Job 2
Solution 6	Job 3	Job 2	Job 1

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3 people and 3 jobs , 6 possible solutions

4 people and 4 jobs, 24 possible solutions
more people… n! possibilities

	Person A	Person B	Person C
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The real-world implications of NSP being NP-hard

- Healthcare systems need to create schedules that meet all requirements, but optimally for large sets is **infeasible with brute-force approaches**
- It tend to have **factorial time complexity** in polynomial time
- Most solutions are used to find approximate solutions[5]
  - Mixed integer programming(MIP) or heuristics learning

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Constraints in the problem[4]

- Hard Constraints
  - All required shifts must be assigned
  - e.g. government policy

- **Soft Constraints**
  - Ideally satisfied but can be violated with penalties
  - Personal preferences and fairness
  - e.g.
    - Rest periods with maximum and minimum numbers of shifts
    - Maximum number of consecutive working weekends
    - Nurses' requests for day on/off or shift on/off

Proposal

Goal

Develop an optimized scheduling plan taking into account various soft constraints

Example

- Nurse A: Prefers day shifts and weekends off.
- Nurse B: Prefers night shifts and is okay with weekend work.
- Nurse C: Prefers evening shifts and works part-time
- Nurse D: No preference, flexible across all shifts.

Day	Morning Shift (7 AM – 3 PM)	Evening Shift (3 PM – 11 PM)	Night Shift (11 PM – 7 AM)
Mon	Nurse A, Nurse D	Nurse C, Nurse D	Nurse B, Nurse D
Tue	Nurse A, Nurse D	Nurse C, Nurse D	Nurse B, Nurse D
Wed	Nurse A, Nurse D	Nurse C, Nurse D	Nurse B, Nurse D
Thu	Nurse A, Nurse D	Nurse C, Nurse D	Nurse B, Nurse D
Fri	Nurse A, Nurse D	Nurse C, Nurse D	Nurse B, Nurse D
Sat	Nurse D (filling gap)	Nurse C, Nurse D	Nurse B, Nurse D
Sun	Day Off for Nurse A	Nurse D	Nurse B, Nurse D

Proposal

Considering **teamwork** to increase scheduling satisfaction

- Reduce communication costs
- Higher division of labor coordination
- Reduce the incidence of errors

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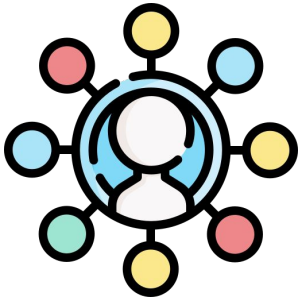
Factors affecting collaboration

- Past collaboration experience
- Performance



Proposal

	Alice	Bob	Charlie	Diana	Eva
Alice	–	0.8	0.9	0.7	0.5
Bob	0.8	–	0.6	0.9	0.7
Charlie	0.9	0.6	–	0.8	0.6
Diana	0.7	0.9	0.8	–	0.4
Eva	0.5	0.7	0.6	0.4	–

Proposal

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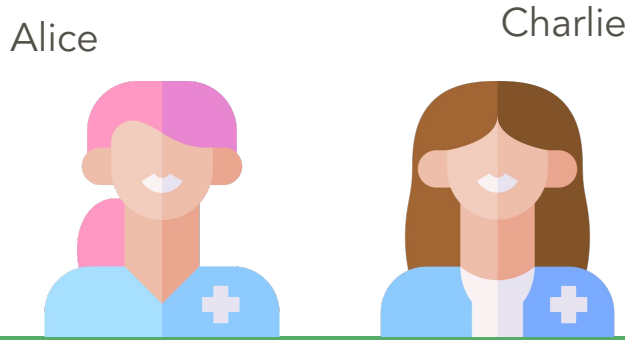

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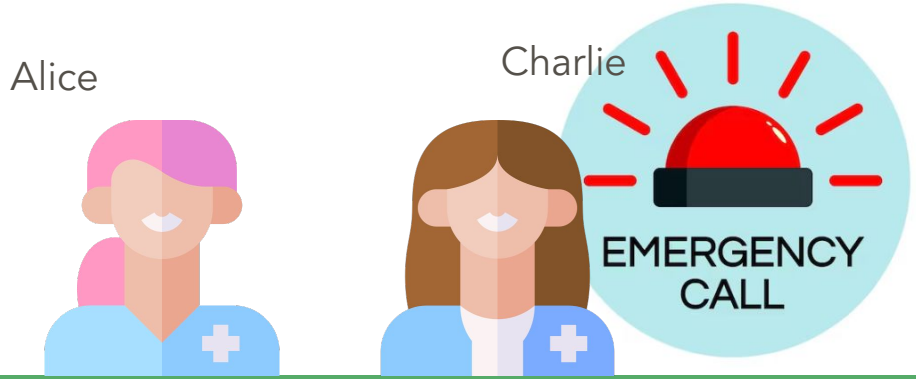

Proposal

Challenge

1. Dynamically adjust nurse scheduling to deal with uncertainty
2. Intelligently assign nurses based on their skills and professional backgrounds
3. Integrating nurses' quality of work and feedback on patient health outcomes

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Optimal Nurse Satisfaction

- [6] Nurse Scheduling Problem via PyQUBO to maximum the number of rest day off
- [7] A mathematical formula was proposed to quantify nurses' satisfaction
  - Weighted Constraint Satisfaction Problem(WCSP)

Dynamic nurse scheduling

- [8] Dealing with various sudden absences of a nurse

[6] Lin, Matthew M. et al. "Nurse Scheduling Problem via PyQUBO." (2023).
[7] Said, A.B., & Mouhoub, M. (2022). A Constraint Satisfaction Problem (CSP) Approach for the Nurse Scheduling Problem. _2022 IEEE Symposium Series on Computational Intelligence (SSCI)_, 790-795.
[8] Nagayoshi, Masato and Hisashi Tamaki. "A dynamic nurse scheduling using reinforcement learning: Dealing with various sudden absences of a nurse." _Proceedings of International Conference on Artificial Life and Robotics_ (2023): n. pag.

Reference

[1] Hamid, M., Tavakkoli-Moghaddam, R., Golpaygani, F., & Vahedi-Nouri, B. (2020). A multi-objective model for a nurse scheduling problem by emphasizing human factors. _Proceedings of the institution of mechanical engineers, Part H: journal of engineering in medicine_, _234_(2), 179-199.
[2] Thomas, J. (2024). Optimizing Nurse Scheduling: A Supply Chain Approach for Healthcare Institutions. _arXiv preprint arXiv:2407.11195_.
[3] Abdalkareem, Z. A., Amir, A., Al-Betar, M. A., Ekhan, P., & Hammouri, A. I. (2021). Healthcare scheduling in optimization context: a review. _Health and Technology_, _11_, 445-469.
[4] Ceschia, Sara, et al. "Second International Nurse Rostering Competition (INRC-II)---Problem Description and Rules---." _arXiv preprint arXiv:1501.04177_ (2015).
[5] Ceschia, Sara, et al. "Solving a real-world nurse rostering problem by simulated annealing." _Operations Research for Health Care_ 36 (2023): 100379.