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CENTER FOR HEALTHCARE ENGINEERING & PATIENT SAFETY
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Recursive Method for Finding Pareto-Dominant Shift Schedules for a Pediatric ER Department

Jonathan Mogannam, Young-Chae Hong M.S.E., Amy Cohn Ph.D., Marina Epelman Ph.D., Stephen Gorga M.D.

Problem Statement

» Background:

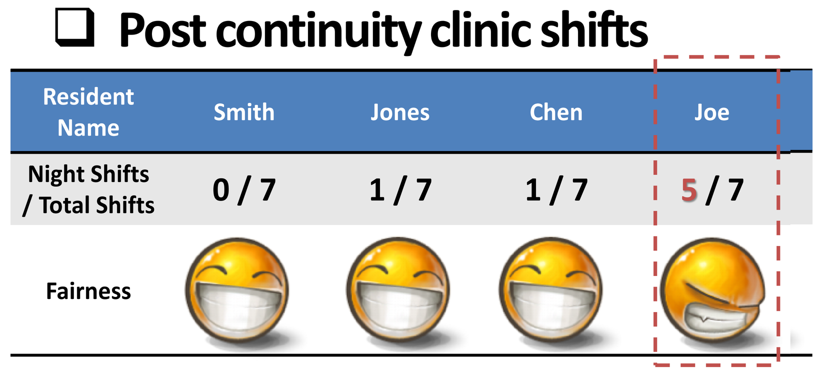
Building resident shift schedules for the U-M Pediatric Emergency Department is a multi-objective combinatorial problem. It is difficult to satisfy the 25+ governing rules and requirements in addition to individual preferences. Additionally, there is no single objective function or clear weights to trade off governing metrics.

» Schedule ≈ Combinatorial Problem:

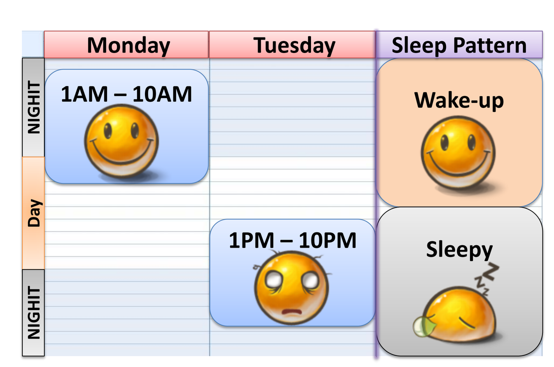
- ❑ Time consuming process
  - 20 – 25 hours/month
- ❑ Difficult to satisfy all requirements:
  - 25 Governing rules & Preferences
    - ✓ Educational Training Requirements
    - ✓ Patient Safety
    - ✓ Regulations
    - ✓ Resident Satisfaction

» Healthcare ≈ Multi-objective Problem:

- ❑ Shift equity / Vacation requests
- ❑ Bad sleep patterns
- ❑ Post continuity clinic shifts

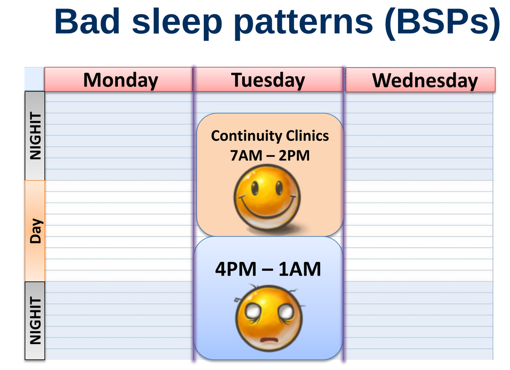


Total shift equity (TSE) / Night shift equity (NSE)



Bad sleep patterns (BSPs)

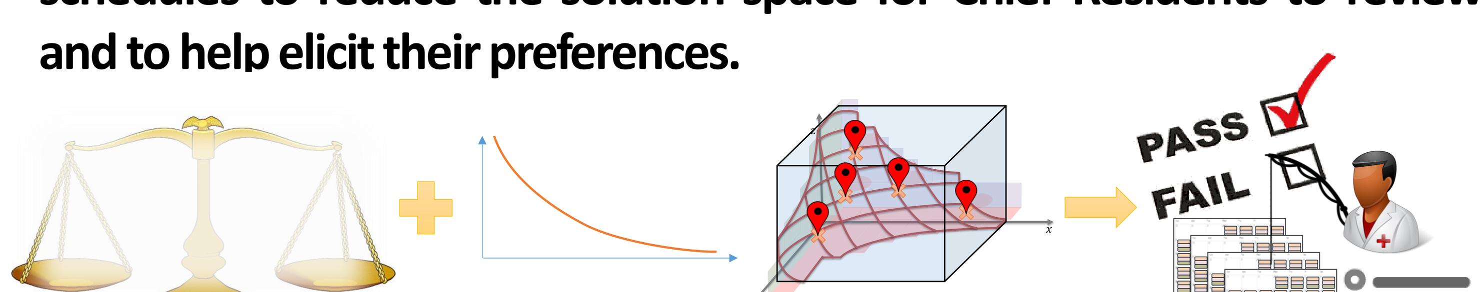
Denied vacation requests (DVRs)



Post continuity clinic shifts (PCCs)

» Goals

We are developing an algorithm for generating Pareto-dominant schedules to reduce the solution space for Chief Residents to review and to help elicit their preferences.



Preferences, tradeoff | Pareto Optimality

Solution Approach

» Notation

$\mathcal{H}$ (Solution Space) : the set of feasible solutions

$\mathcal{I}$ (Objective Space) : the set of objective values, $\mathcal{I} = \{f(x): x \in \mathcal{H}\}$

$\preccurlyeq$ (Dominance) : $x \preccurlyeq x'$ if and only if $f_i(x) \leq f_i(x')$ for all i with at least one strict inequality.

$\hat{z}$ (Pareto solutions) : there is no other feasible solution x' such that $x' \preccurlyeq x$

$\mathcal{E}$ (Efficient Set) : set of all Pareto solutions in the solution space $\mathcal{H}$

$\mathcal{F}$ (Pareto Front) : the set of solutions in objective space $\mathcal{I}$, $\mathcal{F} = \{f(x): x \in \mathcal{E}\}$

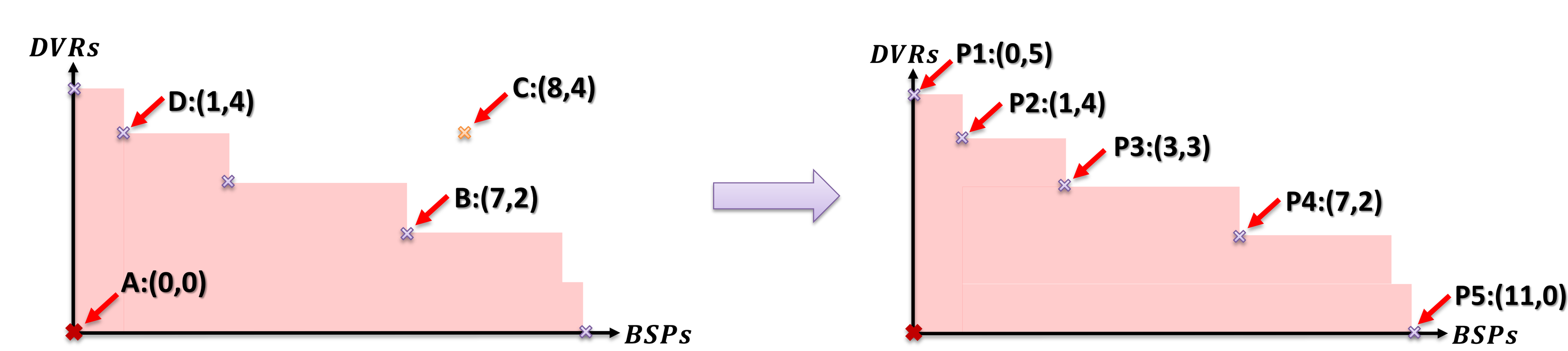
z_i^* (Ideal Value) : the best value of z_i over the efficient Set, $z_i^* = min\{f_i(x): x \in \mathcal{E}\}$

$\bar{z}_i$ (Nadir Value) : the worst value of z_i over the efficient Set, $\bar{z}_i = max\{f_i(x): x \in \mathcal{E}\}$

» Bi-objective Problem

$$\min f_1(x), f_2(x)$$
$$s.t.\, x \in \mathcal{H}$$

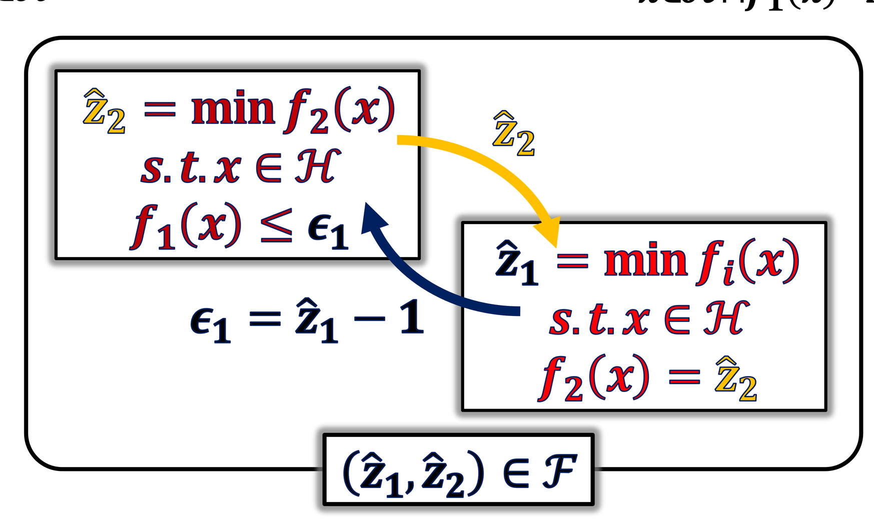
» Pareto Range: Ideal Point (z_1^*, z_2^*) & Nadir Point $(\bar{z}_1, \bar{z}_2)$

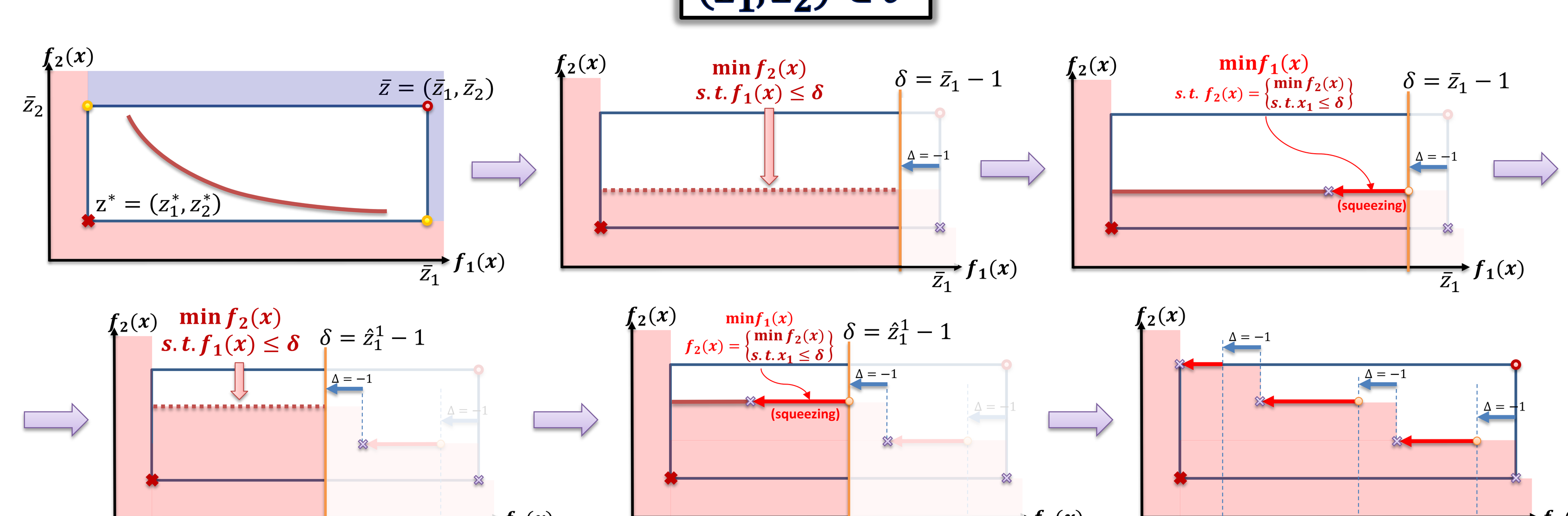


» Alternative ϵ-constraint Method

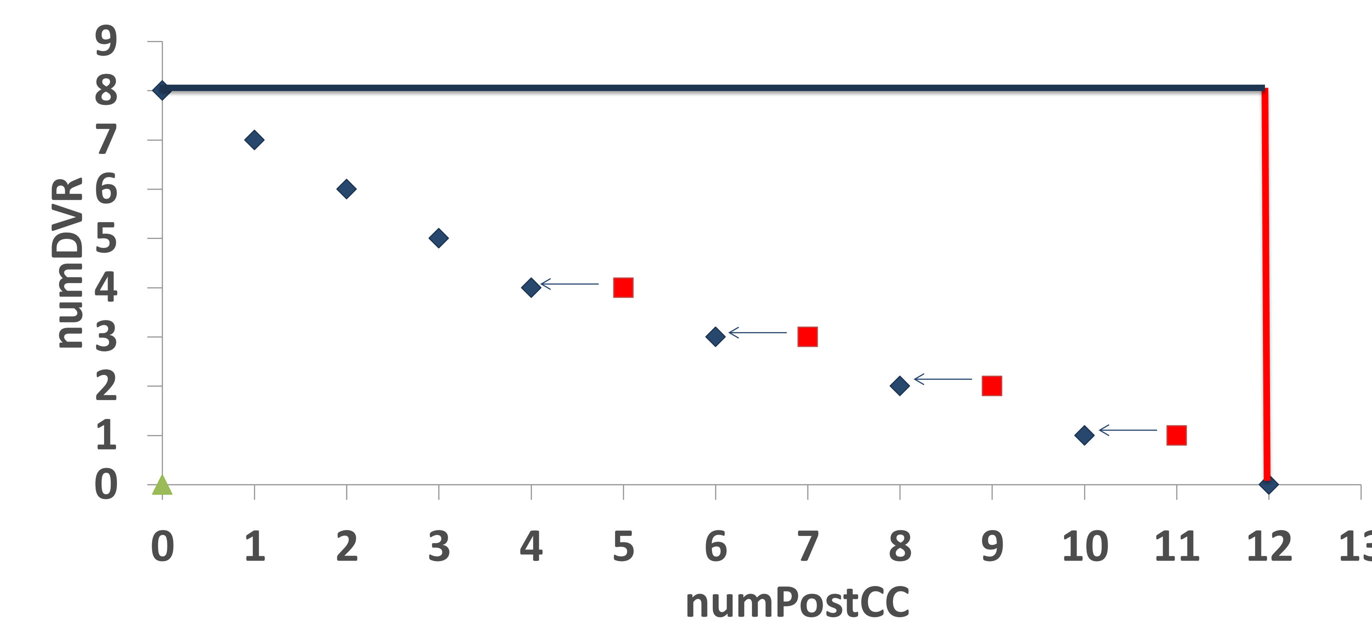
Solving a sequence of two constrained single-objective problems:

- ❑ $z_1^* = \min_{x \in \mathcal{H}} f_1(x)$
- ❑ $z_2^* = \min_{x \in \mathcal{H}} f_2(x)$
- ❑ $\bar{z}_1 = \min_{x \in \mathcal{H} \cap f_2(x) = z_2^*} f_1(x)$
- ❑ $\bar{z}_2 = \min_{x \in \mathcal{H} \cap f_1(x) = z_1^*} f_2(x)$





Results



- ❑ Candidate shift schedules created for a data set containing 18 residents with pre-determined continuity clinic shifts and vacation requests.
  - ✓ Bi-objective problem minimizing PostCC, DVR
  - ✓ Pareto-dominance shown between ◆ and ■

Ongoing & Future Research

» Tri-objective Problem

$$\min f_1(x), f_2(x), f_3(x)$$
$$s.t.\, x \in \mathcal{H}$$

» Recursive Method

Solving a sequence of constrained bi-objective problems:

INPUT : $\epsilon_3 = \infty, \mathcal{F} = \emptyset$

WHILE $\epsilon_3 \geq z_3^*$

STEP 1 : Solve $\bar{z}_3 = \max_{(\hat{z}_1, \hat{z}_2) \in \mathcal{F}_{2D}(\epsilon_3)} P_3^*(\hat{z}_1, \hat{z}_2)$

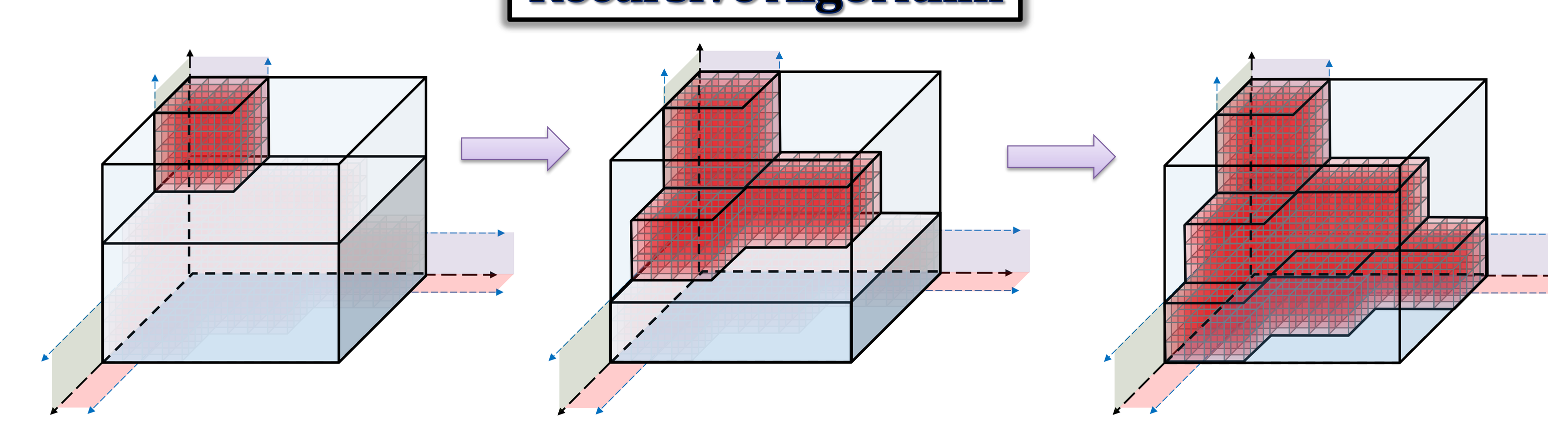
STEP 2 : Get $\mathcal{F} = \mathcal{F} \cup \{(\hat{z}_1, \hat{z}_2, \hat{z}_3): (\hat{z}_1, \hat{z}_2) \in \mathcal{F}_{2D}(\epsilon_3), \hat{z}_3 = P_3^*(\hat{z}_1, \hat{z}_2)\}$

STEP 3 : Set $\epsilon_3 = \bar{z}_3 - 1$

END WHILE

OUTPUT : $\mathcal{F}$

Recursive Algorithm



Acknowledgements

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