Applying Optimization Techniques to Surgical Call Scheduling

William Pozehl

Research Area Specialist
Presentation outline

1. Residency
2. Model
3. Implementation
4. Conclusions
Medical training pathway

- Undergrad Student
- Medical Student
- Resident
- (Fellow)
- Attending Physician

Resident

Post-medical school physician trainee
Patient care provider under supervision of attending physicians
Importance of residency schedules

...clinical and administrative workflow

...patient access, care quality, safety, and satisfaction

...training quality and burnout rates
St. Joseph Mercy Hospital

Ypsilanti, MI
545 beds
150 residents

32,300+ visits per year
11,200+ surgical cases per year
2,100+ general surgery cases per year
General Surgery Residency
@ St. Joseph Mercy Hospital

5-year program | 5 residents per graduating class

Extensive training with trauma, peripheral vascular, and cardiac patients

Monthly rotations offer exposure to subspecialty disciplines (e.g., anesthesia, emergency medicine, endoscopy, ICU, pediatrics, etc.)

Residents work daily call and rounding teams
Call and rounding teams

Chief resident tasked with building these teams

Teams built in accordance with:

- Monthly rotation assignments
- Call team needs
- Rounding team needs
- Resident well-being guidelines
- Schedule preferences
Monthly rotation assignments

**Core Rotations:**
- Purple
- Orange
- Red
- Green
- Blue
- Yellow

**Additional Rotations:**
- SICU
- SMMH
- SJLH
- Endoscopy
- Thoracic
- ED Nights
- Anesthesia
## Call team needs

<table>
<thead>
<tr>
<th>CALLS</th>
<th>SUN</th>
<th>MON</th>
<th>TUE</th>
<th>WED</th>
<th>THU</th>
<th>FRI</th>
<th>SAT</th>
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<tbody>
<tr>
<td>Chief</td>
<td>1 (PGY4/5)</td>
<td>1 (PGY4/5)</td>
<td>1 (PGY4/5)</td>
<td>1 (PGY4/5)</td>
<td>1 (PGY4/5)</td>
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<td>1 (PGY4/5)</td>
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<tr>
<td>Mid-level AM</td>
<td>1 (PGY2/3)</td>
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<td>1 (PGY2/3)</td>
<td>1 (PGY2/3)</td>
<td>1 (PGY2/3)</td>
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<td>1 (PGY1)</td>
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# Rounding team needs

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<th>MON</th>
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<tr>
<td>(PGY3/4/5)</td>
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<td>(PGY1/2/3)</td>
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Resident well-being guidelines

1. Residents may not be assigned tasks that conflict with pre-scheduled vacations

2. Chief residents (PGY4/5) may not be given call on more than one Friday or Saturday

3. Every resident must get 2 full weekends off

4. If assigning a resident to work on Saturday, they must also work on Sunday (and vice versa)
5. Residents need adequate rest between tasks

6. Residents may not be assigned more than 2 calls in any 6 consecutive days

7. Certain residents have pre-assigned duties but are otherwise unavailable
Schedule preferences

1. Try to distribute call and rounding assignments equitably

2. Try to assign a senior and junior from each of the Purple, Orange, Red, Green, and Blue/Yellow core rotations to each day’s rounding team

3. Try to avoid assigning PGY1s on the Purple team to calls Sunday-Tuesday

4. Try to avoid assigning PGY5s on the Orange team to calls Tuesday-Wednesday
Research objective

*Develop a decision support system to enable fast construction while simultaneously improving quality of call schedules*
Presentation outline

1. Residency
2. Model
3. Implementation
4. Conclusions
Inputs and decision variables

\[
\begin{align*}
R & \quad \text{Set of residents} \\
& \quad \text{(w/ level & monthly rotation assignment)} \\
T & \quad \text{Set of tasks} \\
D & \quad \text{Set of dates in horizon}
\end{align*}
\]

\[x_{rtd} = \begin{cases} 
1: & \text{if assigning resident } r \text{ to task } t \text{ on date } d \\
0: & \text{otherwise}
\end{cases}\]
Constraints

Task Coverage
\[ l_c \leq \sum_{r \in R_c} \sum_{t \in T_c} \sum_{d \in D_c} x_{rtd} \leq u_c \quad \forall (R_c, T_c, D_c) \in C \]

Resident Needs
\[ l_q \leq \sum_{t \in T_q} \sum_{d \in D_q} x_{rqt_0} \leq u_q \quad \forall (r_q, T_q, D_q) \in Q \]

Spacing
\[ x_{rsd} + x_{rtd'} \leq 1 \quad \forall r \in R, d \in D, d' \in D_s, (s, t_s, D_s) \in S \]

Paired Tasks
\[ x_{rfj}d_j - x_{rsje_j} = 0 \quad \forall r \in R, (f_j, d_j, s_j, e_j) \in J \]

Pre-assignments
\[ x_{rat_0}d_0 = 1 \quad \forall (R_a, T_a, D_a) \in A \]

Prohibitions
\[ x_{rpt_0}d_0 = 0 \quad \forall (R_p, T_p, D_p) \in P \]
Objective?

Important to consider numerous metrics, but no obvious objective function

- Equitable assignment distribution
- Senior/junior core team representation on rounding teams

Options:
1. Optimize weighted sum of metrics
2. Optimize metrics hierarchically
3. Something else?

- Purple interns off-duty Sun-Tue
- Orange PGY5s off-duty Tue-Wed
Presentation outline

1. Residency
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Deployment

- 4/24/17: Exploratory meeting
- 7/13/17: Project kickoff
- 9/17/17: Rules fully implemented
- 10/20/17: 1st schedule created

Implementation Team
- (2) Industrial Engineering undergraduates
- (1) Computer Science undergraduate

...under supervision of Prof. Cohn
Implementation process

1. Formulate

2. Encode (C++ w/ CPLEX 12.4)

3. Load (monthly inputs)

4. Solve (≤60 s)

5. Review
## Summary report

<table>
<thead>
<tr>
<th>RESIDENT</th>
<th>TEAM</th>
<th>LEVEL</th>
<th>CHIEF</th>
<th>MID AM</th>
<th>MID PM</th>
<th>INTERN</th>
<th>ROUNDS</th>
<th>VACAY</th>
<th>WKND DAYS OFF</th>
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## Task report

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<th>2/20/18</th>
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<th>2/22/18</th>
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<td>TUE</td>
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<td>Lorenz</td>
<td>Roose</td>
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<td>Mid-level AM</td>
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<tr>
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<td>Tang</td>
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<td>Schurr</td>
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<td>Suggs</td>
<td>Patel</td>
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## Resident report

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<th>Day</th>
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<th>Activity</th>
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<td>SAT</td>
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<td>2/18/18</td>
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<td>MON</td>
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<td>WED</td>
<td>2/21/18</td>
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<td>THU</td>
<td>2/22/18</td>
<td>Intern</td>
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<td>SAT</td>
<td>2/24/18</td>
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<tr>
<td>SUN</td>
<td>2/25/18</td>
<td>Wknd Day Off</td>
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Presentation outline

1. Residency
2. Model
3. Implementation
4. Conclusions
Impact
To date, scheduled December ‘17 through March ‘18

- **Time**
  - Solve time: ≤ 60 s
  - Review meeting: ≤ 1 hr

- **Quality**
  - Equitable assignment distribution
    Residents ± 1 assignment relative to cohort
  - Senior/junior core team reps on rounds
    100% days w/ 1+ resident from each core team
  - Purple interns off-duty Sun-Tue
    Granted every month since introduction
  - Orange PGY5s off-duty Tue-Wed
    Granted every month since introduction

Experiential learning for student team
Lessons learned

Robust constraint design + flexible input formats → rapid rule integration

Match reports to existing tools

“Accept the unexpected” – Aaron Kanne
Future work

Streamline process for revisions

“Predictively” identify problems

Implement additional rules/metrics based on collaborator feedback
Acknowledgements

Thanks to the chief residents for their collaboration and to the students who have helped build this tool.

Special thanks for the generous support from:

- Saint Joseph Mercy Health System
- Seth Bonder Foundation
Questions and comments

Thank you!

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Amy Cohn | amycohn@med.umich.edu
Task Coverage

Coverage

\[ l_c \leq \sum \sum \sum x_{rtd} \leq u_c \quad \forall (R_c, T_c, D_c) \in C \]

Coverage Constraints:

- Ensures the correct number of residents from a set of residents are assigned to cover a set of tasks over a set of dates
- Focused on staffing perspective to ensure tasks are covered
Resident Requirements

Resident Requirement Constraints:

• Ensures the correct number tasks from a set of tasks assigned to a resident over a set of dates
• Focused on resident learning perspective to ensure a correct number of shifts are assigned to each resident

\[
l_q \leq \sum_{t \in T_q} \sum_{d \in D_q} x_{r_q t d} \leq u_q \quad \forall (r_q, T_q, D_q) \in Q
\]
Task Spacing

Spacing \( x_{rsd} + x_{rstd'} \leq 1 \quad \forall r \in R, d \in D, d' \in D_s, \)

\[(s_s, t_s, D_s) \in S\]

Task Spacing Constraints:
• Ensures two specified tasks cannot be assigned to a resident within the specified time frame
• Used to ensure residents are provided the required amount of rest between shifts
Paired Tasks

\[ x_{rfjd_j} - x_{rsje_j} = 0 \quad \forall r \in R, (f_j, d_j, s_j, e_j) \in J \]

Paired Tasks Constraints:
• Ensures two specified tasks must be completed together on the specified dates
• Primarily used to ensure full weekends off are allotted
Pre-assignments & Prohibitions

Pre-assignments
\[ x_{\text{r}_{\text{a}}\text{t}_{\text{a}}\text{d}_{\text{a}}} = 1 \quad \forall \ (R_{\text{a}}, T_{\text{a}}, D_{\text{a}}) \in A \]

Prohibitions
\[ x_{\text{r}_{\text{a}}\text{t}_{\text{a}}\text{d}_{\text{a}}} = 0 \quad \forall \ (R_{\text{p}}, T_{\text{p}}, D_{\text{p}}) \in P \]

Pre-assignment and Prohibition Constraints:
- Used to enforce a mandatory or prohibited task for a resident on a specified date