A General Model for Medical Resident Rotation Scheduling

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Medical training pathway

Undergraduate Student ➔ Medical Student ➔ Resident ➔ Fellow ➔ Attending Physician

Physicians who have completed medical school

Residents

Providers of patient care under the supervision of attending physicians
Annual rotation scheduling

Process of assigning residents to services to provide patient care and receive advanced training

Many residents (varying disciplines, seniority, educational requirements, personal needs)

Many services (varying difficulty, coverage requirements, preferred composition)
Ensuring adequate resident education and proper service coverage requires many training programs to integrate schedules.

Coordinating long-term rotation schedules is a complex challenge.

Traditionally, program leadership (chief residents and program directors) constructs the block schedule by hand.
Practical challenges

Challenges of general scheduling problems

Plus challenges of personnel scheduling (preferences, retention, quality of life)

Plus challenges of educational requirements

Plus challenges of patient care
Develop a decision support system to enable fast construction of high-quality rotation schedules while improving measures of quality.
Medical training at U-M

- 1,199 trainees
- 105 training programs
- 80 fellowships
- 25 residencies
Case study

Three interdependent residency programs

- Pediatrics
- Medicine-Pediatrics
- Internal Medicine
Formulation

Sets
Parameters
Design variable definition
Formulation

Constraints (all one page, refer to previous presentations for more detail)
Scheduling strategy

Strategy A
- Partially lock MP schedule
- Schedule Peds + MP
- Schedule IM + MP

Strategy B
- Partially lock MP schedule
- Schedule IM + MP
- Schedule Peds + MP
Facilitated concurrent scheduling of all 3 programs for first time

Enabled program leadership to more precisely specify scheduling needs compared to manual construction

Provided improved satisfaction (relative to prior years) regarding:

- vacation requests
- elective/research offerings
- fellowship interview and graduation conflicts
- schedule fairness
- pacing and challenging rotation sequences
Computational observations

Strategy A solves faster than Strategy B

Strategy B produces better quality than Strategy A
Lessons learned

Collaboration is key to getting the details right, buy-in, success of implementation

Variable definition key to tractability

Significant real-world impact on quality of schedules, resident satisfaction, and patient care
Next steps

Design new **modeling** approaches to better accommodate all three programs

Refine processes for **data acquisition**, interacting with the chiefs and program directors

Build tools to facilitate **schedule modifications** throughout the year
Ongoing work

- **Speed**: Evaluating alternative formulations for impact on solve time
- **Quality**: Implementing additional metrics based on leadership feedback
- **Efficiency**: Streamlining administrative and schedule revision processes
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Traditional strategy

1. Build rotation templates
2. Adjust for coverage and educational needs
3. Renegotiate after reaching a dead-end
Pediatric block scheduling

Collaboration with the **Pediatric Residency Program**
at the University of Michigan Health System

**Program Size**
- 3-year residency
- 22 residents per class
- 18 required services + electives + vacation
- 12 months, July – June

**Scheduling Considerations**
- One service / resident / period
- Service coverage needs
- Resident education needs
- Vacation periods
- Consecutive hard rotation limits
Metrics and objective

No obvious objective but numerous metrics important to consider

Treat as feasibility problem with bounded metrics

\[
\min \ 0 \\
Ax \leq b
\]
PBS model: phase 1

\[ x_{rsm} = \begin{cases} 1, & \text{if assigning resident } r \text{ to service } s \text{ during month } m \\ 0, & \text{otherwise} \end{cases} \]

2014-15

Constructed schedule for Pediatrics interns only

Total Variables: 4,752
Total Constraints: 6,576
Solve Time: < 20 sec
PBS model: phase 1.5

2015-16
Constructed schedule for all Pediatrics residents

Total Variables: 14,256
Total Constraints: 19,722
Solve Time: infeasible

Problem: unequal senior coverage needs in 1st and 2nd halves of months
PBS model: phase 2

2015-16

Constructed schedule for all Pediatrics residents

\[ x_{rpm} = \begin{cases} 
1, & \text{if assigning resident } r \text{ to service pair } p \text{ during month } m \\
0, & \text{otherwise} 
\end{cases} \]

where \( p \in P \), \( P := \) the set of valid "service pairs", and \( |P| = 64 \)

Total Variables: 50,688
Total Constraints: 64,722
Solve Time: < 1 min
Expanding our scope

**Internal Medicine (IM) Residency Program**
- 3-year program
- 44 residents per year

**Medicine-Pediatrics (MP) Residency Program**
- 4-year program
- 8 residents per year
- 3 months at a time on Pediatrics and Medicine

**2016-17 Goal**
build schedules for all in an integrated model
New features for IM and MP

Constraints
Service sequencing
Service spacing
Ad-hoc pre-assignments/prohibitions

Metrics
Graduation conflicts
Prioritized desires
Integrated model: phase 3

2016-17
Constructed schedules for Pediatrics, MP and IM

236 residents
3,896 service pairs (95 services)
12 months

Total Variables: 15,332,306
Total Constraints: 1,992,897
Solve Time: 8 – 48 hrs
Integrated model: phase 4?

\[ x_{rsh} = \begin{cases} 1, & \text{if assigning resident } r \text{ to service } s \text{ during half month } h \\ 0, & \text{otherwise} \end{cases} \]

\[ x_{rsh} = x_{rs}(h+1), \quad \forall r \in R, s \in F, h \in \{1,3,...,23\} \]
\[ x_{rsh} + x_{r\delta(h+1)} \leq 1, \quad \forall r \in R, s \in H, \delta \in D_s, h \in \{1,3,...,23\} \]

Must ensure valid month-long rotations