Medical Residency Annual Block Scheduling

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Presentation outline

1. Motivation
2. Model
3. Solution approach
4. Conclusions
Annual block scheduling

Assignment of residents to services for advanced training and patient care delivery

**Resident educational requirements**
specialty, seniority, professional goals, etc.

**Service coverage demands**
patient mix, competencies, oversight, etc.

Construction process requires **coordination** across many stakeholders but typically **built by hand**
Interdependent programs

- **Pediatrics** [Peds]
  - 3-year program
  - 72 residents
  - 15 services

- **Medicine-Pediatrics** [MP]
  - 4-year program
  - 33 residents
  - 8 services [8 Peds + 37 IM]

- **Internal Medicine** [IM]
  - 3-year program
  - 140 residents
  - 84 services
Research objective

Develop a decision support system to enable fast construction of block schedules while improving schedule quality
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Model parameters

Sets

\( R \): set of residents
\( S \): set of services
\( T \): set of time periods
\( A \): set of activities

Decision variables

\( x_{rst} = \begin{cases} 1, & \text{if assigning resident } r \text{ to service } s \text{ during time period } t \\ 0, & \text{otherwise} \end{cases} \)

\( y_{rat} = \begin{cases} 1, & \text{if assigning resident } r \text{ to start activity } a \text{ during time period } t \\ 0, & \text{otherwise} \end{cases} \)
Constraints

Basic assignment
\[ \sum_{s \in S} x_{rst} = 1, \quad \forall r \in R, t \in T \]

Rotation duration
\[ x_{rst} - \sum_{a \in A: s(a)=s} \sum_{p \in \{\text{max}(0, t-d_a+1), t\}} y_{rap} = 0, \quad \forall r \in R, s \in S, t \in T \]

Service coverage
\[ L \leq \sum_{r \in R'} \sum_{s \in S'} \sum_{t \in T'} x_{rst} \leq U, \quad \forall (R', S', T') \in C \]

Resident education
\[ \lambda \leq \sum_{s \in S'} \sum_{t \in T'} x_{rest} \leq \mu, \quad \forall e \in E, (S', T') \in e \]

Service sequencing
\[ 0 \leq \sum_{i=0}^{t-1} \sum_{s \in A^*} x_{rsi} - x_{r\beta t}, \quad \forall t \in \{1, \ldots, |T| - 1\} \]

Service spacing
\[ y_{rAt} + \sum_{i=t+d_A}^{\min(t+d_A+g-1, T-1)} y_{rBi} \leq 1, \quad \forall t \in \{0, \ldots, |T| - 1 - d_A\} \]

Pre-assignments
\[ x_{rnsntn} = 1, \quad \forall n \in N \]

Prohibitions
\[ x_{rosoto} = 0, \quad \forall o \in O \]
Metrics

1. Undesirable assignments
2. Burnout-risk sequences
3. Ambulatory credit targets
4. Graduation conflicts
5. Fellowship interview conflicts
6. Nth priority requests denied (1st – 12th)
7. And more…
Objective

No obvious objective function but **numerous metrics** important to consider

Work through optimizing metrics **hierarchically** as determined by program leadership
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Problem size

Integrated model
  245 residents
  107 services
  24 time periods
  122 valid activities

Total Variables 1,346,520
Total Constraints 1,992,897
Solve Time > 8 hrs
Improvement strategies

1. Decompose senior and intern scheduling
2. Sequential scheduling
3. Two-stage IM scheduling
4. Warm-starting solver
Sequential scheduling

Option A

Schedule Peds + MP

Unlock part of MP schedule

Schedule IM + MP

Option B

Schedule IM + MP

Unlock part of MP schedule

Schedule Peds + MP
Observations

Option A generates schedules faster than Option B

Option B produces better schedules than Option A
Two-stage IM scheduling

Stage 1
Aggregate like services with composite educational requirements and service demands

Stage 2
Decompose aggregated services and apply individualized requirements and demands
Observations

Stage 1 reduces to **manageable** size

Stage 2 solves **rapidly** – typically in less than 1 minute
Warm-starting solver

1. Add subset of constraints to model
2. Solve model
3. Generate MIP warm start file
4. Repeat steps 1-3 until all constraints added
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Impact

Introduced **coordinated** scheduling of all 3 programs

Enabled greater **specificity** of scheduling needs compared to manual construction

Improved **satisfaction** (relative to prior years) regarding:
- resident requests
- schedule fairness
- elective/research matching
- pacing and challenging rotation sequences
- fellowship interview and graduation conflicts
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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Questions and comments

Thank you!

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