Block Scheduling for a Surgical Residency Program

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University of Michigan
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My Collaborators

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Presentation Outline

• Background
• Motivation
• Model Formulation
• Model Implementation
• Conclusions and Future Work
Presentation Outline

• **Background**
  • Motivation
  • Model Formulation
  • Model Implementation
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University of Michigan Health System

- 105 training programs (25 residency, 80 fellowships)
- 1,199 residents in training
Residency in General Surgery

- **House Officer I**
  - **Broad introduction** to surgical operations and perioperative care

- **House Officer II**
  - **Graduated responsibility and autonomy** in patient care

- **House Officer III**
  - **Substantial increases in operative duties** and senior responsibilities

- **House Officer IV**
  - **Lead many aspects of clinical care** as senior resident on service

- **House Officer V**
  - **Direct all aspects** of clinical care, administrative duties, and education as chief resident
Block Scheduling Basics

- Assigning residents to a service each month
- Residents must demonstrate competency in various aspects of clinical care
- Services must provide appropriate clinical care
Resident Education Requirements

- Satisfying program-specific competency standards requires sufficient experience in certain service areas.
- Residents spend some number of monthly rotations on specific services to demonstrate competencies.
Resident Education Requirements

1ST YEAR GENERAL SURG

BLUE
MAIZE
WHITE
ACS
SICU
DSP
PLA
STX
SVA
VA CT
VA G&V
Service Coverage Requirements

• Each service requires a resident complement comprised of varying skillsets and disciplines

1ST YEAR GENERAL SURG

1ST YEAR PLASTIC SURG

1ST YEAR VASCULAR SURG

WHITE

SICU

STX
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- Background
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Traditional Scheduling Approach

1. Build rotation templates

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Traditional Scheduling Approach

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

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1. Build rotation templates
2. Adjust for coverage and educational needs
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Issues with Traditional Approach

• Education Director typically works on building the schedule from January to late April
  – Roughly 80 hours of work
  – Frequent and continuous negotiation with other departments and institutions

• Lingering educational deficiencies for some residents

• Unsatisfactory resident complement on some services
Design a binary integer programming formulation to create a block schedule satisfying the needs of the residents and services.
Presentation Outline

• Background
• Motivation
• **Model Formulation**
  • Model Implementation
  • Conclusions and Future Work
Model Overview

Sets

\( R \): residents
\( C \): resident categories
\( S \): services
\( M \): months

Parameters

\( a_{rc} \in \{0, 1\} \): whether resident \( r \) is in category \( c \)

\( \mathcal{L}_{csm}, \mathcal{U}_{csm} \): lower, upper bounds on staffing of residents fitting category \( c \) in service \( s \) during month \( m \)

\( \lambda_{rs}, \mu_{rs} \): lower, upper bounds on months resident \( r \) must spend on service \( s \)

Decision Variables

\( x_{rsym} \in \{0, 1\} \): whether resident \( r \) is assigned to service \( s \) in month \( m \)

\( \forall r \in R, s \in S, m \in M \)

Objective Function

\[
\min 0
\]

Constraints

\[
\sum_{s \in S} x_{rsym} = 1, \quad \forall r \in R, m \in M
\]

\[
\lambda_{rs} \leq \sum_{m \in M} x_{rsym} \leq \mu_{rs}, \quad \forall r \in R, s \in S
\]

\[
\mathcal{L}_{csm} \leq \sum_{r \in R} a_{rc} x_{rsym} \leq \mathcal{U}_{csm}, \quad \forall c \in C, s \in S, m \in M
\]
Sets

\[ R: \text{residents} \]
\[ C: \text{resident categories} \]
\[ S: \text{services} \]
\[ M: \text{months} \]
Parameters

\(a_{\downarrow rc} \in \{0, 1\}:\) whether resident \(r\) fits category \(c\)

\(\mathcal{L}_{\downarrow csm}:\) lower bound on staffing of residents fitting category \(c\) in service \(s\) during month \(m\)

\(\mathcal{U}_{\downarrow csm}:\) upper bound on staffing of residents fitting category \(c\) in service \(s\) during month \(m\)

\(\lambda_{\downarrow rs}:\) lower bound on months resident \(r\) must spend on service \(s\)

\(\mu_{\downarrow rs}:\) upper bound on months resident \(r\) must spend on service \(s\)
Decision Variables

\[ x_{rsm} \in \{0, 1\} : \text{whether resident } r \text{ is assigned to service } s \text{ in month } m \]
\[ \forall \ r \in R, \ s \in S, \ m \in M \]

The base model does not have an objective function.
Constraints

1. Every resident gets assigned to one service every month
   \[ \sum_{s\in S} x_{rsm} = 1, \quad \forall \ r \in R, \ m \in M \]

2. Every resident satisfies their educational requirements
   \[ \lambda_{rs} \leq \sum_{m \in M} x_{rsm} \leq \mu_{rs}, \quad \forall \ r \in R, \ s \in S \]

3. Every service satisfies their service coverage needs
   \[ L_{csm} \leq \sum_{r \in R} a_{rc} x_{rsm} \leq U_{csm}, \quad \forall \ c \in C, \ s \in S, \ m \in M \]
Expanded Model

- Service-Distributed Educational Requirements
- Service-Distributed Coverage Needs
- Extended Rotations
- Service Sequencing
- Service Spacing
- Resident Pairing
Model Overview

Sets

$R$: residents
$C$: resident categories
$S$: services
$M$: months

Parameters

$\begin{array}{c}
a_{rc} \in \{0, 1\}: \text{whether resident } r \text{ fits category } c \\
\ell_{csm}, \mu_{csm}: \text{lower, upper bounds on staffing of residents fitting category } c \text{ in service } s \text{ during month } m \\
a_{irs}, \mu_{irs}: \text{lower, upper bounds on months resident } r \text{ must spend on service } s
\end{array}$

Decision Variables

$x_{rsm} \in \{0, 1\}: \text{whether resident } r \text{ is assigned to service } s \text{ in month } m$

$\forall r \in R, s \in S, m \in M$

Objective Function

$\min 0$

Constraints

$\begin{array}{c}
\sum_{s \in S} x_{rsm} = 1, \forall r \in R, m \in M \\
\ell_{irs} \leq \sum_{m \in M} x_{rsm} \leq \mu_{irs}, \forall r \in R, s \in S \\
\ell_{csm} \leq \sum_{r \in R} a_{rc} x_{rsm} \leq \mu_{csm}, \forall c \in C, s \in S, m \in M
\end{array}$
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Model Testing

- Encoded in C++ using the Cplex 12.6 Optimization Studio
- Tested on AY 2014-15 after schedule was finalized
  - 75 residents
  - 6 residency programs
  - 17 resident categories
  - 41 services
- Feasible solve time: 4 seconds
  - Windows 7 PC
  - i7 @ 2.8 GHz CPU
  - 8 GB RAM
Plans for Enactment

• Currently collecting input data for AY 2015-16
• Preliminary parameters
  – 103 residents
  – 7 residency programs
  – 24 resident categories
  – 45 services
• Aim to finalize schedule by February 1
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Conclusions

- Scheduling surgical residency programs at UMHS is highly interdependent but poorly executed.
- The block schedule must satisfy both resident educational and service coverage needs.
- A binary integer programming formulation describes the scheduling needs well and may be solved quickly.
Future Work

• Generalize constraints for expanded model
• Define metrics for schedule optimality
  – Minimize deviation from desired resident complement by service
  – Maximize satisfied requests for educational customization
• Create tools to facilitate interdepartmental communication and negotiation
Acknowledgements

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• The Doctors Company Foundation
CHEPS and the HEPS Master’s Program

- CHEPS: The Center for Healthcare Engineering and Patient Safety
- HEPS: Industrial and Operations Engineering (IOE) Master’s Concentration in Healthcare Engineering and Patient Safety offered by CHEPS
- CHEPS and HEPS offer unique multidisciplinary teams from engineering, medicine, public health, nursing, and more collaborating with healthcare professionals to better provide and care for patients
- For more information, contact Amy Cohn at amycohn@umich.edu or visit the CHEPS website at: https://www.cheps.engin.umich.edu
Feedback and Questions

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