Block Scheduling for a Surgical Residency Program

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November 10, 2014

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Presentation Outline

- Background
- Motivation
- Model Formulation
- Model Implementation
- Conclusions and Future Work

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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

BLUE

MAIZE

WHITE

ACS

SICU

DSP

PLA

STX

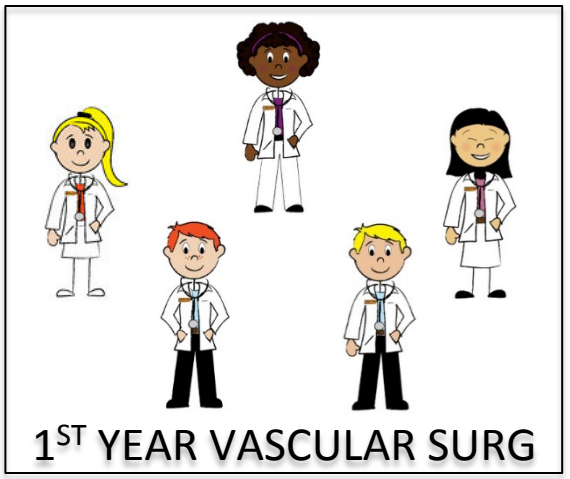
SVA

VA CT

VA G&V

Service Coverage Requirements

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



WHITE

SICU

STX

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Traditional Scheduling Approach

1. Build rotation templates

JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE
BLUE	MAIZE	WHITE	ACS	SICU	BLUE	DSP	PLA	STX	SVA	VA CT	VA G&V
VA G&V	BLUE	MAIZE	WHITE	ACS	SICU	BLUE	DSP	PLA	STX	SVA	VA CT
VA CT	VA G&V	BLUE	MAIZE	WHITE	ACS	SICU	BLUE	DSP	PLA	STX	SVA
SVA	VA CT	VA G&V	BLUE	MAIZE	WHITE	ACS	SICU	BLUE	DSP	PLA	STX

Traditional Scheduling Approach

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

JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE
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VA G&V	PLA	MAIZE	WHITE	ACS	SICU	BLUE	BLUE	PLA	STX	SVA	VA CT
VA CT	PLA	BLUE	DSP	VA G&V	ACS	SICU	BLUE	MAIZE	WHITE	STX	SVA
SVA	VA CT	VA G&V	BLUE	MAIZE	WHITE	ACS	SICU	BLUE	DSP	PLA	STX

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

Project Goal

Design a binary integer programming formulation to create a block schedule satisfying the needs of the residents and services.

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Model Overview

Sets

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

Parameters

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

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

λ_{rs}, μ_{rs}: lower, upper bounds on months resident r must spend on service s

Decision Variables

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

Objective Function

$\forall\ r \in R, s \in S, m \in M$
min0

Constraints

$$\sum_{s \in S} x_{rsm} = 1, \quad \forall\ r \in R, m \in M$$

$$\lambda_{rs} \leq \sum_{m \in M} x_{rsm} \leq \mu_{rs}, \quad \forall\ r \in R, s \in S$$

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

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R: residents

C: resident categories

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M: months

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$\mathcal{U}_{csm}$: upper bound on staffing of residents fitting
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λ_{rs} : lower bound on months resident r must spend on service s

μ_{rs} : upper bound on months resident r must spend on service s

Decision Variables

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

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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

- Center for Healthcare Engineering and Patient Safety
- University of Michigan Department of Surgery
- The Seth Bonder Foundation
- 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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