Block Scheduling for a Pediatric Residency Program

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My Collaborators

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Presentation Outline

- Background
- Motivation
- Model Formulation
- Model Implementation
- Results
- Future Work

Pediatrics at Michigan

- Based in C.S. Mott Children's Hospital
- Around 100 residents at Mott every year
- The hospital is very diverse in the programs it offers

Services in Pediatrics

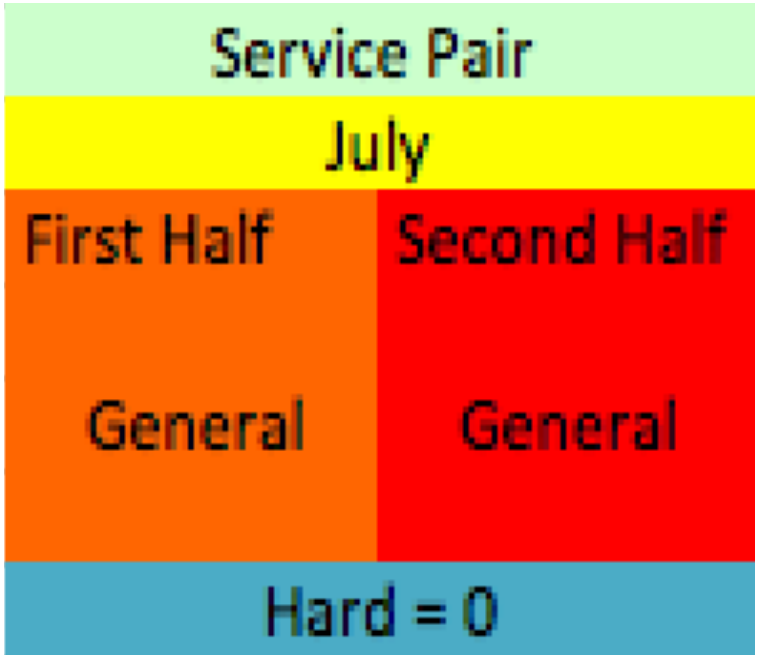
- There are many different areas in Mott that residents must gain experience in:
  - E.g. Neonatal Intensive Care Unit (NICU), General Care, Hematology & Oncology (HemOnc)
- Every month each of these services must be adequately staffed and there is a minimum and maximum number of residents allowed in each service

Residency at Michigan

- After four years in medical school the students are “matched” to a residency program
- These first year residents are called “interns”
- After the first year they become “senior residents”
- Every resident has a minimum and maximum amount of time (in half months) that they must spend in each service
- We were tasked with compiling a block schedule for just the interns

Service Pairs

- A cuplet of services that can be worked during the same month.
- The first service in the pair is worked for the first half of the month and the second service is worked for the second half of the month
- Different examples of service pairs could be:
  - General/general or NICU/general
- Different combinations can also be determined as hard or not



What is a Block Schedule?

Joe Smith	Service Pair 1		Service Pair 2		Service Pair 3	
	July		August		September	
	First Half	Second Half	First Half	Second Half	First Half	Second Half
	General	General	NICU	HemOnc	General	Vacation
	Hard = 0		Hard = 1		Hard = 0	
Jill O'Brien	Service Pair 4		Service Pair 1		Service Pair 2	
	July		August		September	
	First Half	Second Half	First Half	Second Half	First Half	Second Half
	HemOnc	NICU	General	General	NICU	HemOnc
	Hard = 1		Hard = 0		Hard = 0	

Assigning service pairs to residents over the course of a year

NOTE: vacation as a service

Motivation

- Before:
  - Block Schedule was compiled by hand by the chief resident
    - This took a lot of time
    - If changes needed to happen after a draft was completed they had to rewrite the entire schedule
- Now:
  - A computer program compiles the schedule in less than 5 minutes
  - Changes are effortless

Model Overview

Sets:

R : set of all residents that need to be scheduled

P : set of all service pairs

S : set of all services that need residents

M : set of months

D : set of desires. this is a list given to us by the chief resident that details the residents vacation requests

$p_{si} \subset P$ subset of service pairs P that have service S in half-month i where $i \in \{0, 1\}$

$h_p \subset P$: set of pre-defined hard service pairs

$C_d \subset D$: set of candidate assignments for desire D

Model Overview

Parameters:

q_{ps} the number of half-months of service s that are in service pair p $\forall s \in S, p \in P$

b_p if service pair p is difficult 1, if easy 0, $\forall p \in P$

u_{sm} : an upper bound for the number of residents service s needs in month m $\forall s \in S, m \in M$

l_{sm} : a lower bound for the number of residents service s needs in month m $\forall s \in S, m \in M$

u_{rs} : a upper bound for the number of months required on service s for the year $\forall s \in S, r \in R$

l_{rs} : a lower bound for the number of months required on service s for the year $\forall s \in S, m \in M$

l_d : a lower bound for the number of desires filled for month $\forall m \in M$

u_d : an upper bound for the number of desires filled for month $\forall m \in M$

Model Overview

Decision Variables:

X_{rpm} : Whether or not resident r is scheduled to service pair p on month m $\quad \forall r \in R, p \in P, m \in M$

Y_{rm} : Whether or not resident r works 3 or more hard services in a row beginning on month m $\quad \forall r \in R$

Z : Helper variable for maximum number of times a resident works 3 difficult shifts in a row.

Objective Function:

Constant

Variable Restrictions:

$X_{rtm} \in \{0,1\}$
$Y_{rm} \in \{0,1\}$
$Z \in (R)$

Model Overview

$$\sum_{p \in P} X_{rpm} = 1 \qquad \forall r \in R, m \in M :$$

Each Resident is assigned one service pair per month

Model Overview

$$\sum_{p \in P} X_{rpm} = 1 \qquad \forall r \in R, m \in M :$$

$$l_{sm} \leq \sum_{p \in P_{si}} X_{rpm} \leq u_{sm} \qquad \forall m \in M, s \in S, i \in 0, 1$$

Each service has at least the minimum number of residents but no more than the Maximum, for all half months

Model Overview

$$\sum_{p \in P} X_{rpm} = 1 \qquad \forall r \in R, m \in M :$$

$$l_{sm} \leq \sum_{p \in P_{si}} X_{rpm} \leq u_{sm} \qquad \forall m \in M, s \in S, i \in 0, 1$$

$$l_{rs} \leq \sum_{p \in P} \sum_{m \in M} q_{ps} * X_{rpm} \leq u_{rs} \qquad \forall r \in R, s \in S$$

Each resident has at least the minimum number of months in each service but no more than the maximum, for all months

Model Overview

$$\sum_{p \in P} X_{rpm} = 1 \qquad \forall r \in R, m \in M :$$

$$l_{sm} \leq \sum_{p \in P_{si}} X_{rpm} \leq u_{sm} \qquad \forall m \in M, s \in S, i \in 0, 1$$

$$l_{rs} \leq \sum_{p \in P} \sum_{m \in M} q_{ps} * X_{rpm} \leq u_{rs} \qquad \forall r \in R, s \in S$$

$$b_t X_{rpm} + b_t X_{rp(m+1)} + b_t X_{rp(m+2)} \leq Y_{rm} + 2$$

Y is equal to 1 if resident r works more than 3 ‘hard’ service pairs in a row

Model Overview

$$\sum_{p \in P} X_{rpm} = 1 \qquad \forall r \in R, m \in M :$$

$$l_{sm} \leq \sum_{p \in P_{si}} X_{rpm} \leq u_{sm} \qquad \forall m \in M, s \in S, i \in 0, 1$$

$$l_{rs} \leq \sum_{p \in P} \sum_{m \in M} q_{ps} * X_{rpm} \leq u_{rs} \qquad \forall r \in R, s \in S$$

$$b_t X_{rpm} + b_t X_{rp(m+1)} + b_t X_{rp(m+2)} \leq Y_{rm} + 2$$

$$Z \geq \sum_{m \in M} Y_{rm} \qquad \forall r \in R$$

Z is equal to the maximum number of times a resident works 3 difficult services in a row

Model Overview

$$\sum_{p \in P} X_{rpm} = 1 \qquad \forall r \in R, m \in M :$$

$$l_{sm} \leq \sum_{p \in P_{si}} X_{rpm} \leq u_{sm} \qquad \forall m \in M, s \in S, i \in 0, 1$$

$$l_{rs} \leq \sum_{p \in P} \sum_{m \in M} q_{ps} * X_{rpm} \leq u_{rs} \qquad \forall r \in R, s \in S$$

$$b_t X_{rpm} + b_t X_{rp(m+1)} + b_t X_{rp(m+2)} \leq Y_{rm} + 2$$

$$Z \geq \sum_{m \in M} Y_{rm} \qquad \forall r \in R$$

$$l_d \leq \sum_{c \in C_d} X_{r(c)p(c)m(c)} \leq u_d \qquad \forall d \in D$$

The amount of desired vacation requests filled in a schedule must be in between the upper and lower bounds

Model Implementation

- We coded the model into a c++ program with the help of the cplex library
- The Chief resident submitted input files specifying the interns, services, service pairs and their upper and lower bounds
- Our program read in the input files and then using their data produced a block schedule for the pediatric department interns

Results

- We created a block schedule for 27 interns for this current year in under 5 minutes per run
- We saved the chief resident countless hours in schedule making
- We found a more optimal schedule than the chief resident could have on her own

Future Work

- We want to integrate all types of resident regardless of their year in the program so that we can optimize the total schedule
- We are restructuring our code to make it more user friendly and flexible to future changes

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

Questions?

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