# 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 Motts 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

| Service Pair | |
|---|---|
| July | |
| First Half | Second Half |
| General | General |
| Hard = 0 | |

# 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 $m$ $\forall r \in R, p \in P, m \in M$

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

$Z$ : 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

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

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

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

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

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

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

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 model to make it more user friendly and easier to understand

# Questions?

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