CENTER FOR
HEALTHCARE ENGINEERING & PATIENT SAFETY
UNIVERSITY OF MICHIGAN

Block Scheduling for Medical Residents

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Disclosures

Cohn

None

Pozehl

None

Strohbehn

None

Presentation outline

1. Background
2. Model
3. Practical implementation
4. Conclusions

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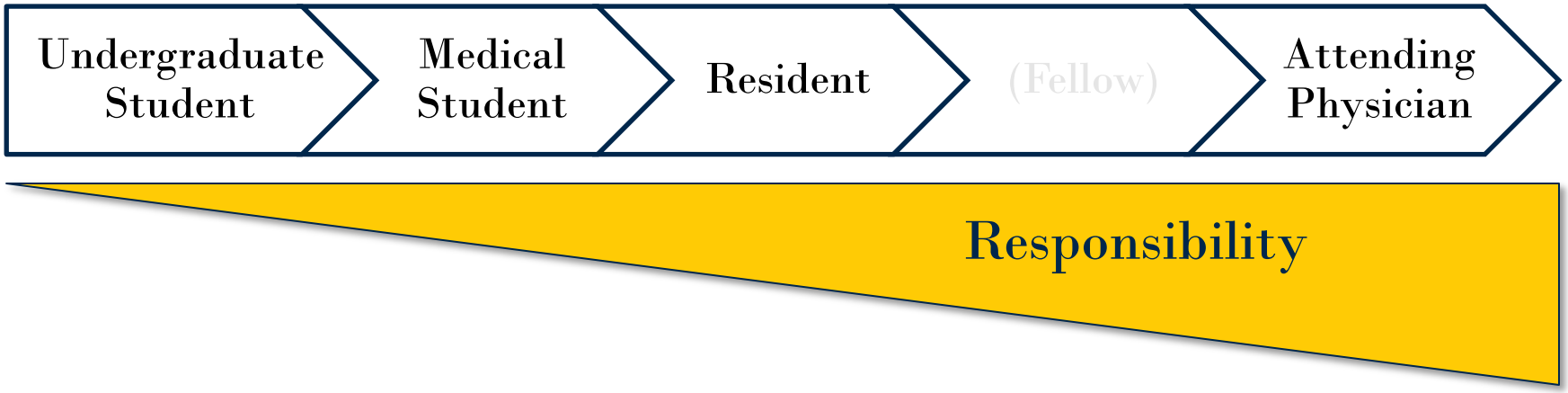
Medical training pathway



Resident

Post-medical school physician trainee

Patient care provider under attending physician supervision

Medical training oversight

American Board of Internal Medicine

Accreditation Council for Graduate Medical Education

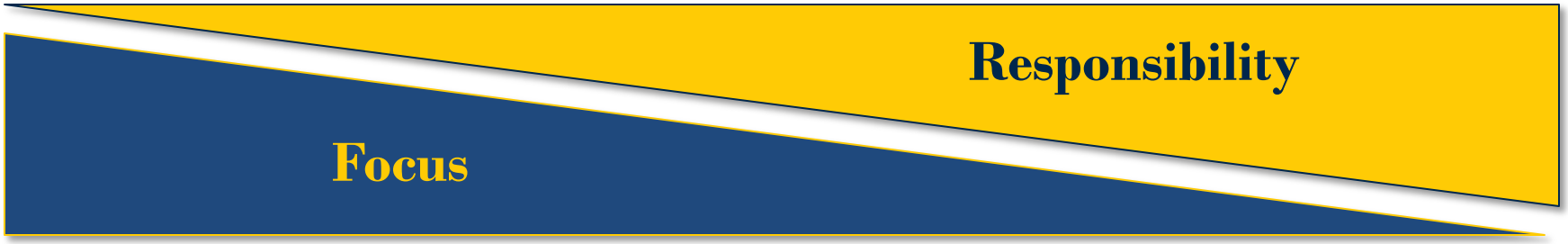
Core

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

Service

Disclaimer: ABIM and ACGME are in no way affiliated with this line of research or this presentation.

Medical training pathway



Resident

Developing internal medicine clinical skills

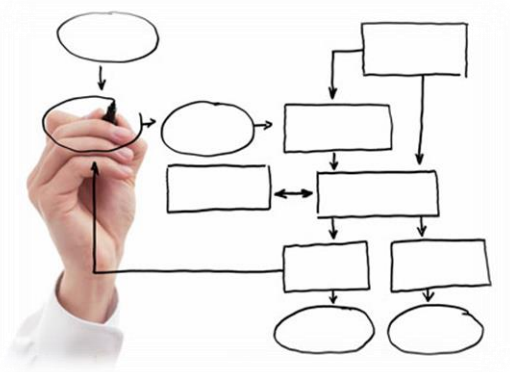
vs

Seeking early subspecialization

Roles/responsibilities of CMRs

Chief Medical Resident

Impact of residency schedules



…clinical and administrative workflow

…patient access, care quality, safety, and satisfaction

…training quality and burnout rates


A B C D E F G H
I J K L M N O P Q
R S T U V W X Y Z

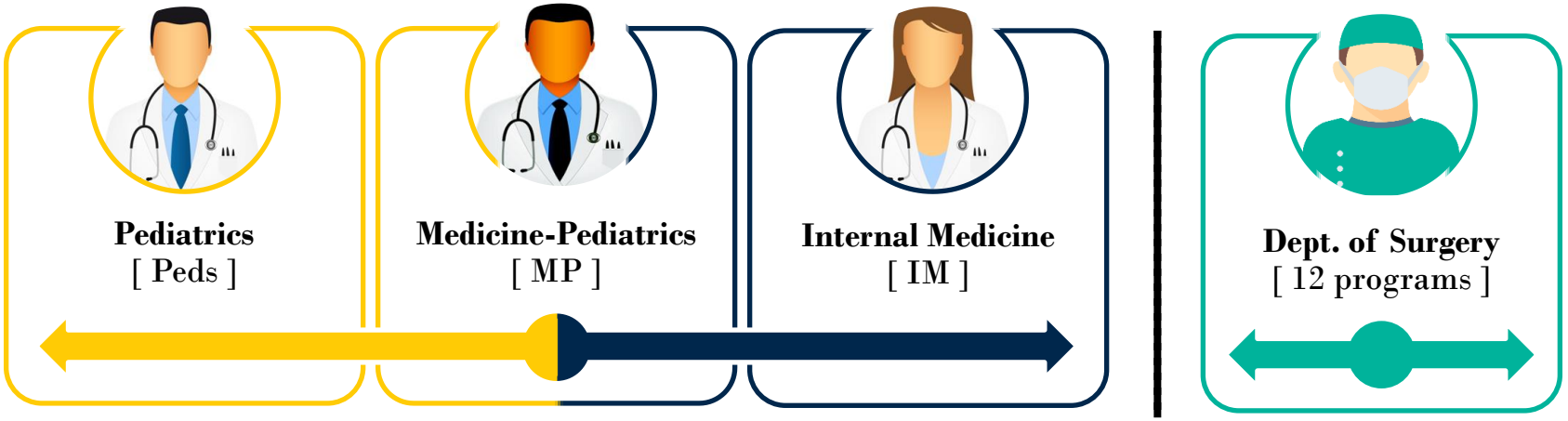
Two years ago, we knew three things:

1) We were likely unnecessarily impacting our residents' (and patients') lives in a negative way.

2) We needed to be better at meeting their needs.

3) We needed a way to advocate for residents and their needs.

Partner programs



Research objective

Develop a decision support system to enable **fast construction** *while simultaneously* **improving quality** *of annual rotation schedules*

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Model

Minimize:	Ranked resident requests denied
	Ranked administrative preferences denied
	Seasonal (interview, graduation) conflicts
	Burnout sequences
	Undesirable activity assignments
	Ambulatory credit variability
Subject to:	**Basic assignment rules**
	Rotation duration
	Service coverage demands
	Resident education requirements
	Service spacing and sequencing
	Resident pairings
	Prohibitions and pre-assignments

Model parameters

Sets

R: set of residents

S: set of services

T: set of time periods

A: set of activities

Activity a

Service s Duration d

Decision variables

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

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

Constraints

Basic assignment

$$\sum_{s \in S} x_{rst} = 1, \quad \forall\, r \in R, t \in T$$

Rotation duration

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

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

$$\lambda \leq \sum_{s \in S'} \sum_{t \in T'} x_{r^e st} \leq \mu, \quad \forall\, e \in E, (S', T') \in e$$

Service spacing

$$y_{rAt} + \sum_{i=t+d_A}^{\min(t+d_A+g-1,T-1)} y_{rBi} \leq 1, \quad \forall\, t \in \{0, \dots, |T| - 1 - d_A\}$$

Service sequencing

$$0 \leq \sum_{i=0}^{t-1} \sum_{s \in A^*} x_{rsi} - x_{r\beta t}, \quad \forall\, t \in \{1, \dots, |T| - 1\}$$

Resident pairings

$$\sum_{r \in R_1^g} \sum_{s \in S_1^g} \sum_{t \in T_1^g} x_{rst} + \sum_{u \in R_2^g} \sum_{v \in S_2^g} \sum_{w \in T_2^g} x_{uvw} = 0, \quad \forall\, g \in G$$

Pre-assignments

$$x_{r_n s_n t_n} = 1, \quad \forall\, n \in N$$

Prohibitions

$$x_{r_o s_o t_o} = 0, \quad \forall\, o \in O$$

Objective function

Important to consider **numerous metrics**, but no obvious objective function

- ❑ Ranked resident requests denied
- ❑ Ranked administrative preferences denied
- ❑ Seasonal (interview, graduation) conflicts
- ❑ Burnout sequences
- ❑ Undesirable activity assignments
- ❑ Ambulatory credit variability

Options:

1. Optimize **weighted sum** of metrics
2. Optimize metrics **hierarchically**
3. Something else?

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Implementation process

Sets

R: residents
C: resident 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

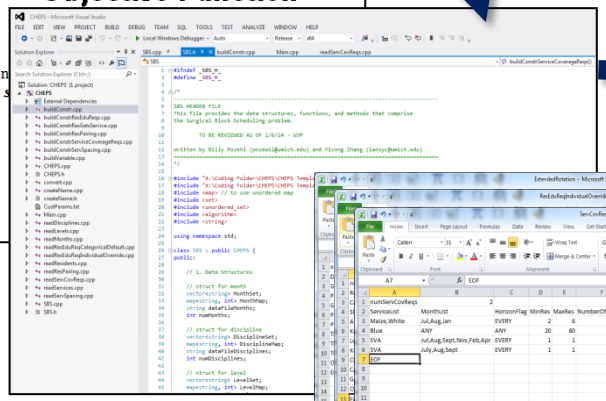
λ_{rs}, μ_{rs}: lower, upper bounds on months resident r must spend on service s

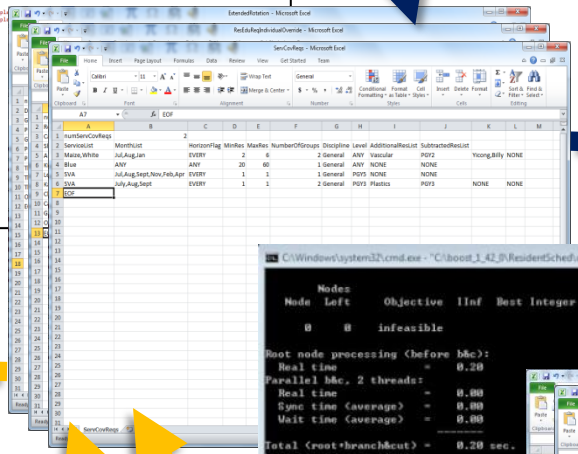
Decision Variables

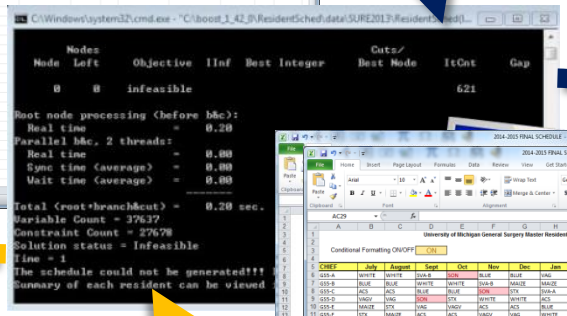
$x_{rsm} \in \{0,1\}$: whether resident r is assigned to service s in month m
$\forall r \in R, s \in S, m \in M$

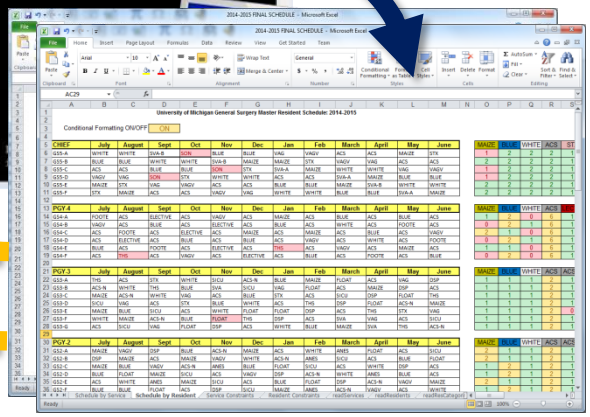
Objective Function

1. Formulate
2. Encode
3. Load
4. Solve
5. Review









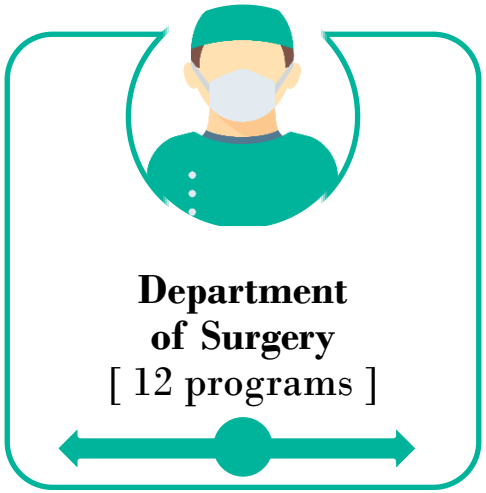
Setup

Encode the model in C++, using CPLEX 12.4

Design robust input file formats to match potential needs

Gather rules and requests for the respective partner programs

Dept. of Surgery model



175 residents

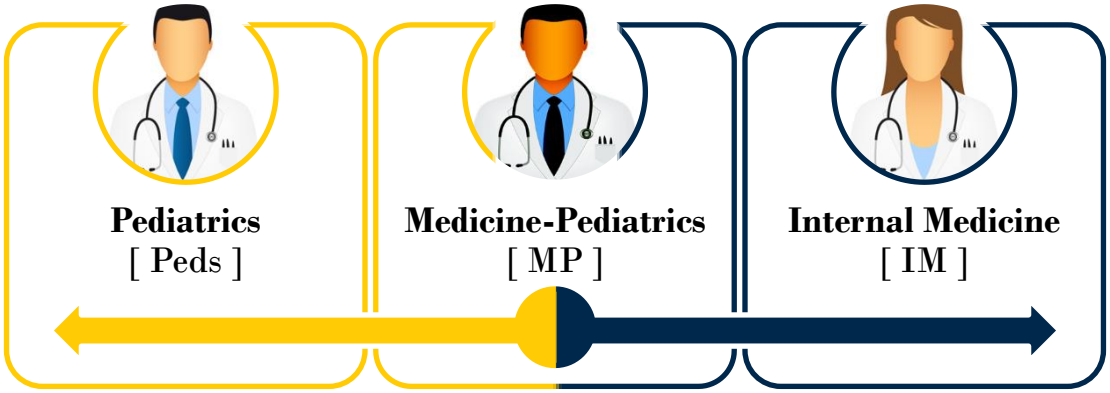
12 time periods

73 services

74 activities

Total Variables	208,543
Total Constraints	59,385
Integrated Solve Time	< 1 min

Peds – MP – IM model



245 residents

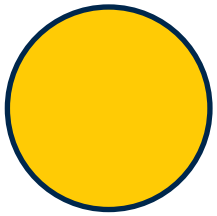
24 time periods

107 services

122 activities

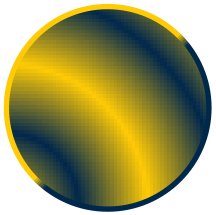
Total Variables	1,346,520
Total Constraints	1,992,897
Integrated Solve Time	1 – 24 hrs

Sequential scheduling



Schedule Peds
(w/ MP pre-assignments)

Peds Solve Time < 1 min



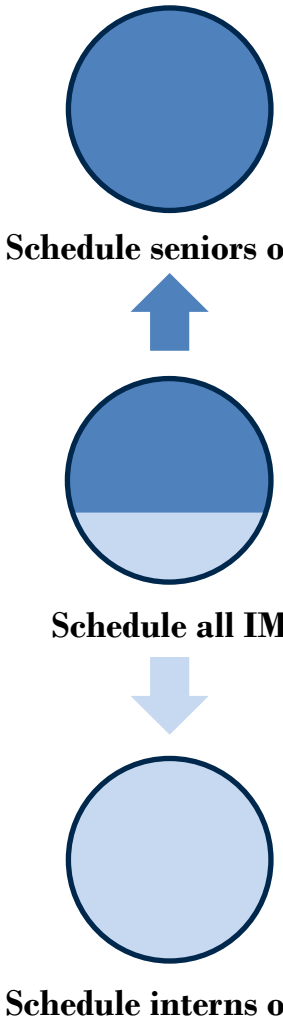
Schedule MP only

MP Solve Time < 1 min

Schedule IM
(w/ MP pre-assignments)

IM Solve Time > 30 min

Decoupled senior/intern schedules



Senior Solve Time 10 – 20 min

IM Solve Time > 30 min

Intern Solve Time < 5 min

Two-stage scheduling

Stage 1

Aggregate similar services with composite educational requirements and service demands

Stage 1

Stage 1 Solve Time 5 – 20 min

Stage 2

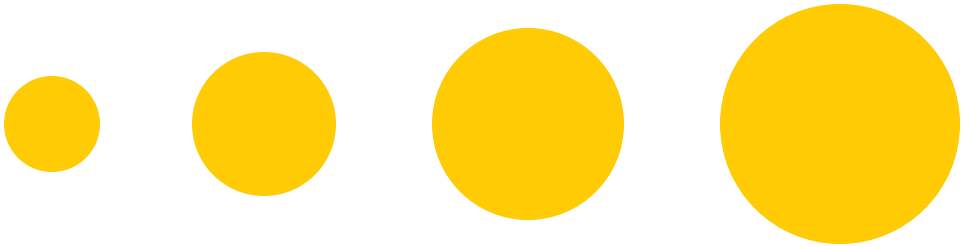
Decompose aggregated services and apply individualized requirements and service demands

Stage 2

Stage 2 Solve Time < 5 min

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 have been incorporated



Minimize iterative changes

After hierarchically optimizing metrics, minimize changes from previous draft

Reduces number of individual resident schedules that must be reviewed each iteration

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Summary

Facilitating **coordinated** scheduling for two separate groups of interdependent programs

Afforded leadership greater **specificity** of scheduling needs compared to manual construction

Improved stakeholder **satisfaction** regarding measures of schedule quality

Enabled **rapid** construction via algorithmic strategies

Ongoing work

Constraints Investigating impact of specific rules (and rule categories)

Engines Exploring whether modifications to CPLEX default settings, use of Gurobi, etc. improve solve time

Processes Streamlining administrative, input, iteration, and revision mechanisms

Challenges and opportunities

Challenges

- Each program is unique
- Mathematical complexity
- Ill-defined objective function and shifting / competing preferences

Opportunities

- Many benefits to close collaboration
- Blending of practical / theoretical research
- Standardization and developing deep knowledge of problem domain
- Key focus: Impact in practice

Acknowledgements

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MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

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Questions and comments

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Thank you!

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