Effective Methods For Solving a Large-scale Resident Block Scheduling Problem with Multi-criteria Objectives

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Rx

A prescription to address system complexity in healthcare

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...

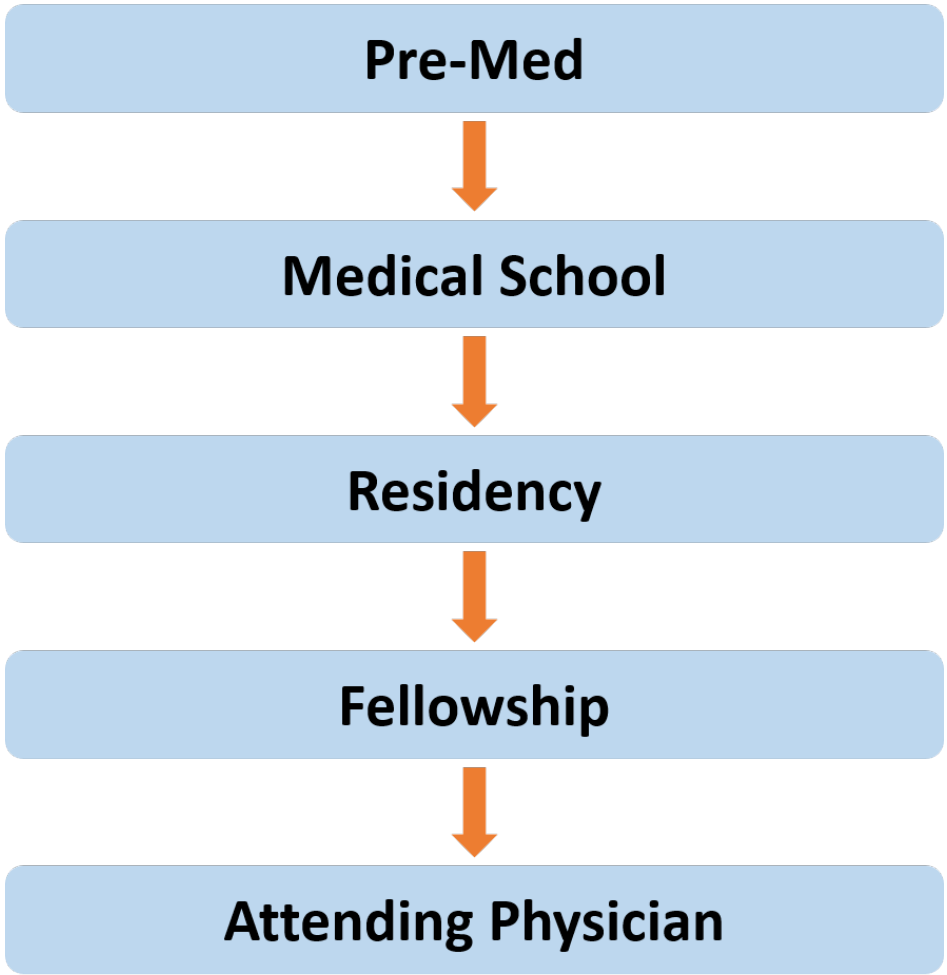
Research
Education
Implementation
Outreach
Dissemination

Introduction

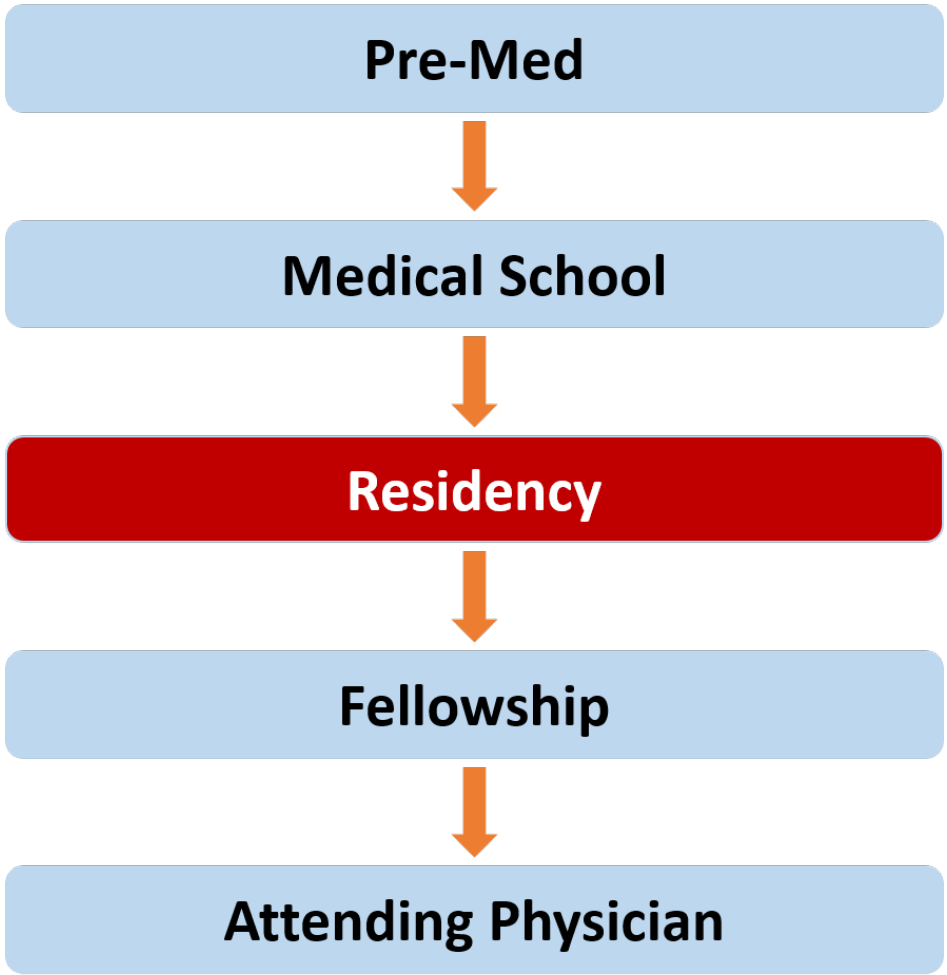
Overview

- Consider a personnel scheduling problem that assigns residents in a medical school to different service-specified rotations during the academic year
- Most research in the literature focuses on the modeling of the problem to generate valid schedules to achieve a well-defined objective
- Our work concentrates on handling the multi-criteria objectives of the problem to effectively produce high-quality solutions

Training Model for Physicians



Training Model for Physicians



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Rotation

A *rotation* is specified by a service and a duration in terms of blocks.

That is, assigned residents should do the specific service for the given number of blocks consecutively.

Resident Block Scheduling

Assign each resident to a sequence of rotations during a given planning horizon, where specific requirements are satisfied.

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Example

CCU	AMB	AMB	ELEC	ER	CCMU
July	August	September	October	November	December

VACA	ELEC	NICU	NICU	CCU	ER
January	February	March	April	May	June

Introduction

Instance Information

- Approximately 100 residents
  - Two programs: Pediatrics, Med-Pediatrics
  - Four Levels: PGY1, PGY2, PGY3, and PGY4
- There are 32 different rotations specified based on 24 different services
- The planning horizon is the academic year (July - June) with time periods in a length of two weeks (i.e. in total 26 blocks)

Block Scheduling – Feasibility

Requirements

- Basic Assignment Requirements
- **Resident Education Requirements**
- **Service Coverage Requirements**
- Service Duration Requirements
- Resident Pairing Rules
- Spacing Rules
- Sequencing Rules
- Prohibitions
- Pre-Assignments

Block Scheduling – Feasibility

Model

- The problem is formulated as an integer programming

Decision Variables

X_{rat} Whether resident r starts to do a rotation a at time period t

Y_{rst} Whether resident r is assigned to service s during time period t

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#Rows	#Columns	Solution Time
$\sim 200K$	$\sim 150K$	3 - 4 min

Block Scheduling – Multi-criteria Objectives

Motivation, Goal, and Challenges

- The flexibility of the feasibility problem allows preferences to be considered

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- Improve the satisfaction of residents on their annual schedules
  - Meet further educational goals for the career plan
  - Reduce conflicts against the plans in personal life
- Implicitly improve the quality of the care patients will receive

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- Improve the satisfaction of residents on their annual schedules
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  - Reduce conflicts against the plans in personal life
- Implicitly improve the quality of the care patients will receive
- Residents will submit a survey to indicate their requests on:
  - Electives
  - Vacation times
  - Free weekends
  - Etc.
- Residents will **uniquely prioritize** their requests into (up to) **18 levels** to specify their relative importance

Block Scheduling – Multi-criteria Objectives

Motivation, Goal, and Challenges

Goal: construct valid block schedules that

- Satisfy resident requests as much as possible
- Maintain the fairness in terms of schedule satisfaction across all residents

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Challenges

Prioritized requests introduce multi-criteria objectives to our problem

- The definition of **"as much as possible"**
  Deny 2 (level-1) + 9 (level-2) requests **V.S.** 4 (level-1) + 3 (level-2) requests
- Take the **"balance"** into consideration
  Deny 8 requests of one resident **V.S.** deny 1 request for each of ten residents

Methods for Handling Multi-criteria Objectives

Approaches - General Information

- The total number of requests across all residents in each level

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	···	Sum
100	98	99	94	52	52	47	47	44	···	783

Methods for Handling Multi-criteria Objectives

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- Minimize the number of requests denied in each level **separately**

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	···
0	**2**	**1**	**0**	**0**	**0**	**1**	**2**	**0**	

Methods for Handling Multi-criteria Objectives

Approaches - Collectively

	Evenly Obj. Val.
Evenly Wt.	**118**

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	$\cdots$
Evenly Wt.	7	13	16	14	18	15	10	11	6	$\cdots$

Methods for Handling Multi-criteria Objectives

Approaches - Collectively

	Evenly Obj. Val.	Linearly Obj. Val.
Evenly Wt.	**118**	1,615
Linearly Wt.	120	**1,503**

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Evenly Wt.	7	13	16	14	18	15	10	11	6	$\cdots$
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Methods for Handling Multi-criteria Objectives

Approaches - Collectively

	Evenly Obj. Val.	Linearly Obj. Val.	Doubling Obj. Val.
Evenly Wt.	**118**	1,615	2,767,690
Linearly Wt.	120	**1,503**	1,546,894
Doubling Wt.	124	1,542	**1,367,085**

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Doubling Wt.	0	6	14	16	16	17	16	13	10	$\cdots$

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Hierarchical	124	1,542	1,367,085
RHier. (20%)	121	1,536	1,523,156

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	⋯
Evenly Wt.	7	13	16	14	18	15	10	11	6	⋯
Linearly Wt.	1	7	15	14	15	15	16	13	9	⋯
Doubling Wt.	0	6	14	16	16	17	16	13	10	⋯
Hierarchical	0	6	14	16	16	17	16	13	10	⋯
RHier. (20%)	0	8	15	16	16	16	15	12	9	⋯

Methods for Handling Multi-criteria Objectives

Approaches - At Individual Level

	Evenly UB
Evenly Wt.	**5**

Methods for Handling Multi-criteria Objectives

Approaches - At Individual Level

	Evenly UB	Linearly UB
Evenly Wt.	**5**	80
Linearly Wt.	7	**68**

Methods for Handling Multi-criteria Objectives

Approaches - At Individual Level

	Evenly UB	Linearly UB	Doubling UB
Evenly Wt.	**5**	80	253,952
Linearly Wt.	7	**68**	245,760
Doubling Wt.	8	92	**110,592**

Methods for Handling Multi-criteria Objectives

Approaches - At Individual Level

	Evenly UB	Linearly UB	Doubling UB
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Linearly w/ #Ctrl	5	68	245,760
Doubling w/ #Ctrl	5	71	110,592

Methods for Handling Multi-criteria Objectives

Approaches - Integrated

1. Add constraints to ensure no one receives a much worse schedule
   - No more than **5** requests can be denied for each resident
   - No resident can receive a more than **110,592** penalty-score, in doubling weighted summation
2. Apply the hierarchically process with a 20% relaxation for previous levels
3. Minimize the doubling weighted summation of the denied requests

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1st	2nd	3rd	4th	5th	6th	7th ···	Tot.	L.W.	D.W.
0	8	15	16	16	16	15 ···	119	1,526	1,523,116

Future Work

- Irreducible Inconsistent System (IIS)
- Ensure an efficient schedule for each resident
- Apply column generation techniques (e.g. branch-and-price) to speed up the solving process

Thank You for Your Attention

Q & A