Scheduling Healthcare Providers Using Optimization

CENTER FOR HEALTHCARE ENGINEERING & PATIENT SAFETY
UNIVERSITY OF MICHIGAN

Paige Mollison[1], William Pozehl M.S.E.[2], Amy Cohn Ph.D.[1,2], Stephen Gorga M.D.[3], Janice Davis[4]

1: Industrial & Operations Engineering 2: Center for Healthcare Engineering & Patient Safety 3: Pediatric Resident Program 4: Department of Surgery

Problem Statement

The University of Michigan Medical School (UMMS) offers comprehensive training programs across many disciplines

Coordinating the long- and short-term schedules for all these trainees is a complex challenge

Traditional Approach:

Hand-made schedules built by the Chief Resident or some other administrator

Benefits	Drawbacks
1) Intimate knowledge of problem	1) Time-consuming construction
2) Administrative consolidation	2) High cognitive demand
3) Streamlined approval process	3) Limited tradeoff consideration

Importance of Schedule Quality:

Schedule quality impacts

- Patient access, care quality, safety, and satisfaction
- Training quality and burnout rates
- Clinical/administrative workflow

The Problem:

The construction process is resource-intensive yet often fails to satisfy the individual & collective needs of stakeholders for long- and short-term schedules

Objective:

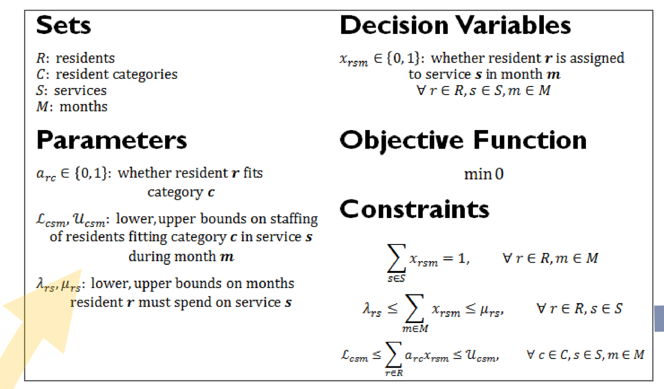
Develop decision support systems (DSS) to enable fast construction of high-quality rotation & monthly schedules while improving measures of quality.

Quality ↑ Time ↓

	PGY1	PGY2	PGY3
Jul	GEN / GEN	ADOLESC	ELECTIVE / V7
Aug	NICU	PER / ELECTIVE	GEN / GEN
Sep	PEDS SURG	ELECTIVE / V7	PER / NITES
Oct	BEHAVIOR	DAY SR / PHO	PICU
Nov	V14 / NITES	PER / ELECTIVE	ELECTIVE / ELECTIVE
Dec	NEWBORN / PHO	ELECTIVE / V7	ELECTIVE / V7
Jan	GEN / GEN	SILVER / SILVER	NICU
Feb	PER / PER	V14 / NITES	ELECTIVE / V7
Mar	NITES / NEWBORN	ELECTIVE / ELECTIVE	ELECTIVE / V7
Apr	PHO / V10	PCH	GEN / GEN
May	GEN / GEN	PICU	NITES / PER
Jun	GEN / GEN	NICU	PCH

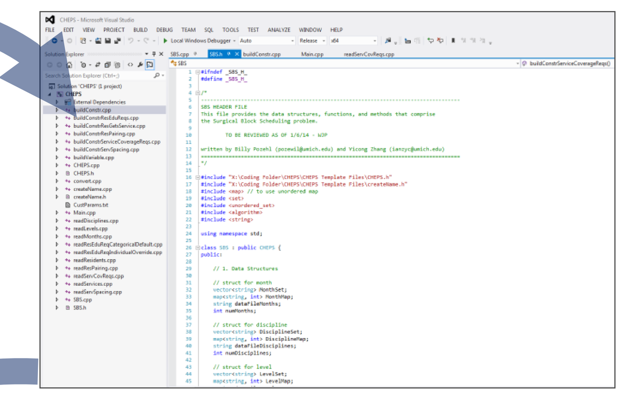
Sample rotation for Pediatrics
24 residents per level per year

Annual Blocks: Solution Approach



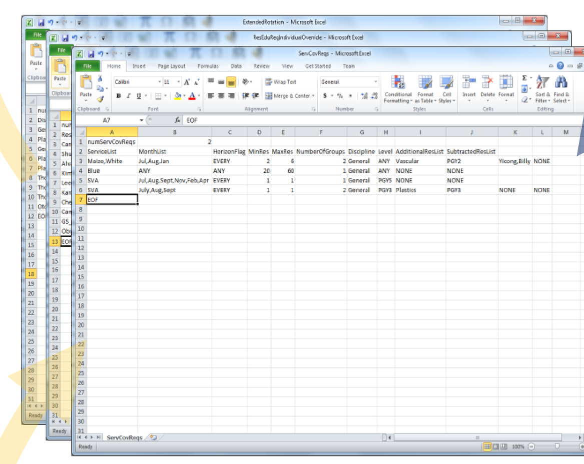
1. Formulate

Two models, each customized to specific needs of the program(s)



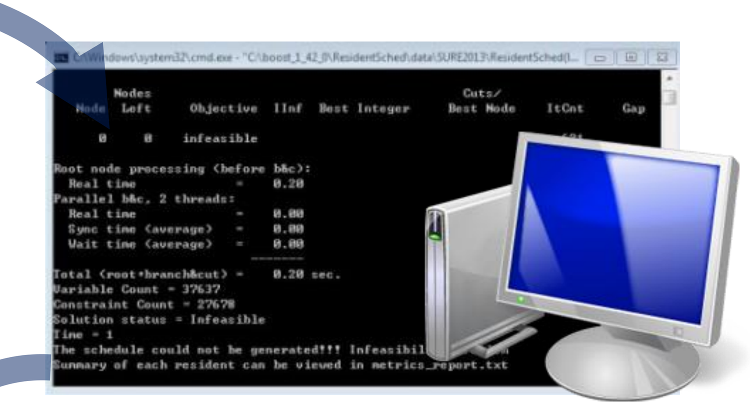
2. Encode

Written in C++ using CPLEX 12.4, implemented in Visual Studio 2012



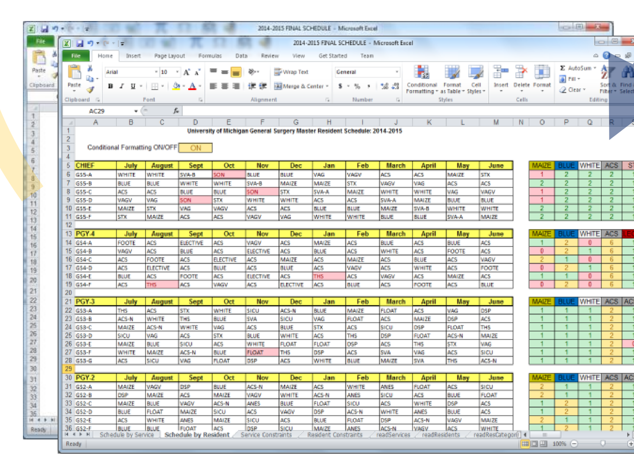
3. Load

Inputs provided in a collection of *.txt*, *.csv*, and *.xls* files



4. Solve

Software solves to optimality under input conditions



5. Review

Schedule and metric reports generated for presentation to administrators

Annual Block: Impact/Results

The **Surgical Block Scheduling** DSS aided schedule construction for:

- **118** residents
- **10** programs
- **62** services

Solve time per iteration: **< 5 min**

217/1199 of UMMS residents scheduled

The **Pediatrics Block Scheduling** DSS aided schedule construction for:

- **99** residents
- **2** programs
- **14** services

Solve time per iteration: **< 3 min**

98% of resident requests satisfied

Monthly Schedules: Solution Approach

Metrics:

- Total Shift Equity (TSE)
- Night Shift Equity (NSE)
- Bad-Sleep Patterns (BSP)
- Post-Continuity Clinic Shifts (PCC)

Preferences? Weights? Trade-off?

Feasibility ~~Optimization~~ Problem:

✗ Quantifying objective weights (w_i) is difficult due to
- Non-linearity
- Subjectivity

✓ Feasibility with metric bounds offers
- Flexibility
- Speed

$$\textbf{Min } \cancel{w_1(TSE) + w_2(NSE) + w_3(BSP) + w_4(PCC)}$$

s.t. "rules/requirements"

$$x_{rsd} \in \{0,1\}$$
$$lb_{TSE} \le (\boldsymbol{TSE}) \le ub_{TSE}$$
$$lb_{NSE} \le (\boldsymbol{NSE}) \le ub_{NSE}$$
$$lb_{BSP} \le (\boldsymbol{BSP}) \le ub_{BSP}$$
$$lb_{PCC} \le (\boldsymbol{PCC}) \le ub_{PCC}$$

Iterative Improvement:

Engage Chief Resident to review, revise and finalize the schedule

Resident Name	Number of Shifts	Number of Night Shifts	Number of Post-CC Shifts	Number of Bad Sleep Patterns
Stumpos	8 (7,9)	2 (2,3)	0 (0,1)	0 (0,0)
Schwein	8 (7,10)	2 (2,3)	0 (0,1)	0 (0,0)
Grum	8 (7,9)	2 (2,3)	1 (0,1)	0 (0,0)

Monthly Schedules: Impact/Results

Implementation Results:

- Statistically significant improvement in 3 of 4 metrics
- Reduced schedule creation time

20 hrs / month ⇒ 1 hr / month

Next Steps:

- Generalize models into universal formulation
- Extend models to address other residency programs' needs
- Apply algorithm to apply maximally feasible sets of requests

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