Optimization-Based Shift Scheduling Improves Schedule Quality for Residents in a Pediatric Emergency Department

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ABSTRACT

We created an optimization-based scheduling tool that can automatically create shift schedules that meet the needs of both the residents and the emergency department. Monthly schedules are traditionally handmade by the chief resident, a process which is difficult, error-prone, time consuming, and fails to take into account many measures of shift quality and equity. The optimization-based scheduling tool that we have created allows the chief resident to quickly produce a monthly shift schedule that meets requirements and improves sleep patterns, shift equity, and other measures of quality.

CREATING A SCHEDULE BY HAND

- **Time consuming process:** it can take many hours or even days of a chief resident's time.
- **Difficult to satisfy all requirements:**

Rules
  o All shifts assigned a resident
  o Appropriate coverage (e.g. certain shifts require a senior resident or a pediatrics resident)
  o 10 hour rest rule
  o Continuity clinics / Conferences
  o Varying start dates and time-off requests
  ⋮

- Easy to overlook a rule and create a schedule with violations in it. When a violation IS recognized, it is often too complex for the scheduler to backtrack and undo it. Similar to a Sudoku puzzle, the chief resident must start all over again from scratch!
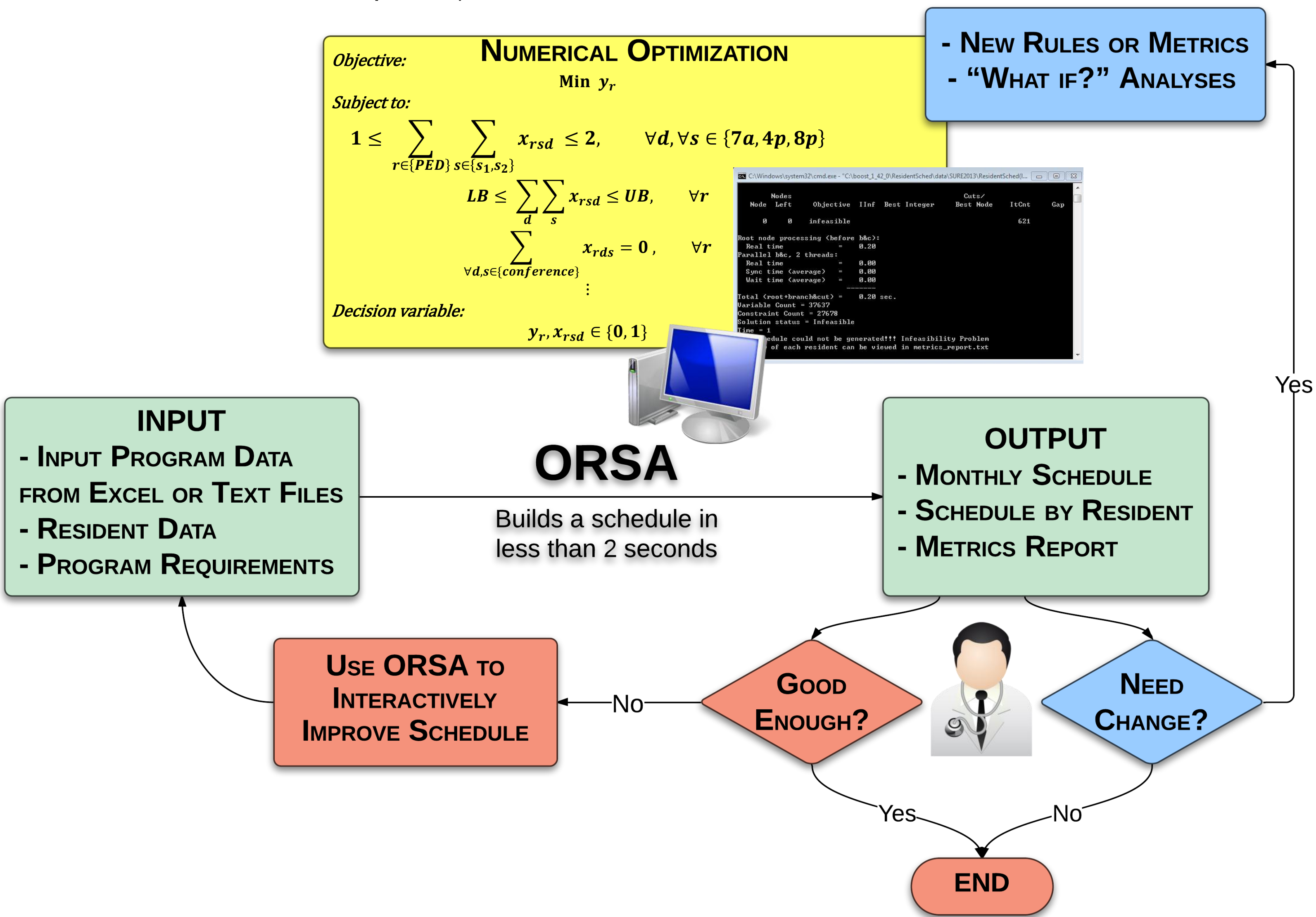

- To make a change to a complete schedule, have to start again!
- Non-standardized method passed down from chief resident to chief resident
- Quality of schedule may be poor: Inequity across residents, post-continuity clinic calls, "bad sleep patterns"

ORSA: AN ENGINEERING-BASED SCHEDULING TOOL

Optimized Residency Scheduling Assistant (ORSA)
- Optimization-based tool that takes program data and automatically creates a schedule
- All rules are guaranteed to be satisfied
- Reporting enables chief resident to easily assess schedule quality
- Interactive capabilities allow the chief resident to quickly fine-tune for improved quality and to meet specific preferences
- Easily addresses last-minute changes (e.g. a resident request for a day off after the schedule has been completed)

NUMERICAL OPTIMIZATION

Objective: $\text{Min } y_r$

Subject to:

$$1 \le \sum_{r \in \{PED\}} \sum_{s \in \{s_1, s_2\}} x_{rsd} \le 2, \qquad \forall d, \forall s \in \{7a, 4p, 8p\}$$

$$LB \le \sum_d \sum_s x_{rsd} \le UB, \qquad \forall r$$

$$\sum_{\forall d, s \in \{conference\}} x_{rds} = 0, \qquad \forall r$$

⋮

Decision variable: $y_r, x_{rsd} \in \{0,1\}$

- NEW RULES OR METRICS
- "WHAT IF?" ANALYSES

INPUT
- INPUT PROGRAM DATA FROM EXCEL OR TEXT FILES
- RESIDENT DATA
- PROGRAM REQUIREMENTS

ORSA
Builds a schedule in less than 2 seconds

OUTPUT
- MONTHLY SCHEDULE
- SCHEDULE BY RESIDENT
- METRICS REPORT

USE ORSA TO INTERACTIVELY IMPROVE SCHEDULE — No ← GOOD ENOUGH? → Yes

NEED CHANGE? — No → END

Yes

- Can also be used for "What if?" analyses (e.g. What would the impact be of a change in the number of residents in the program?)
- Tool can be modified to incorporate new rules or program characteristics (e.g. change in number of shifts or coverage requirements)

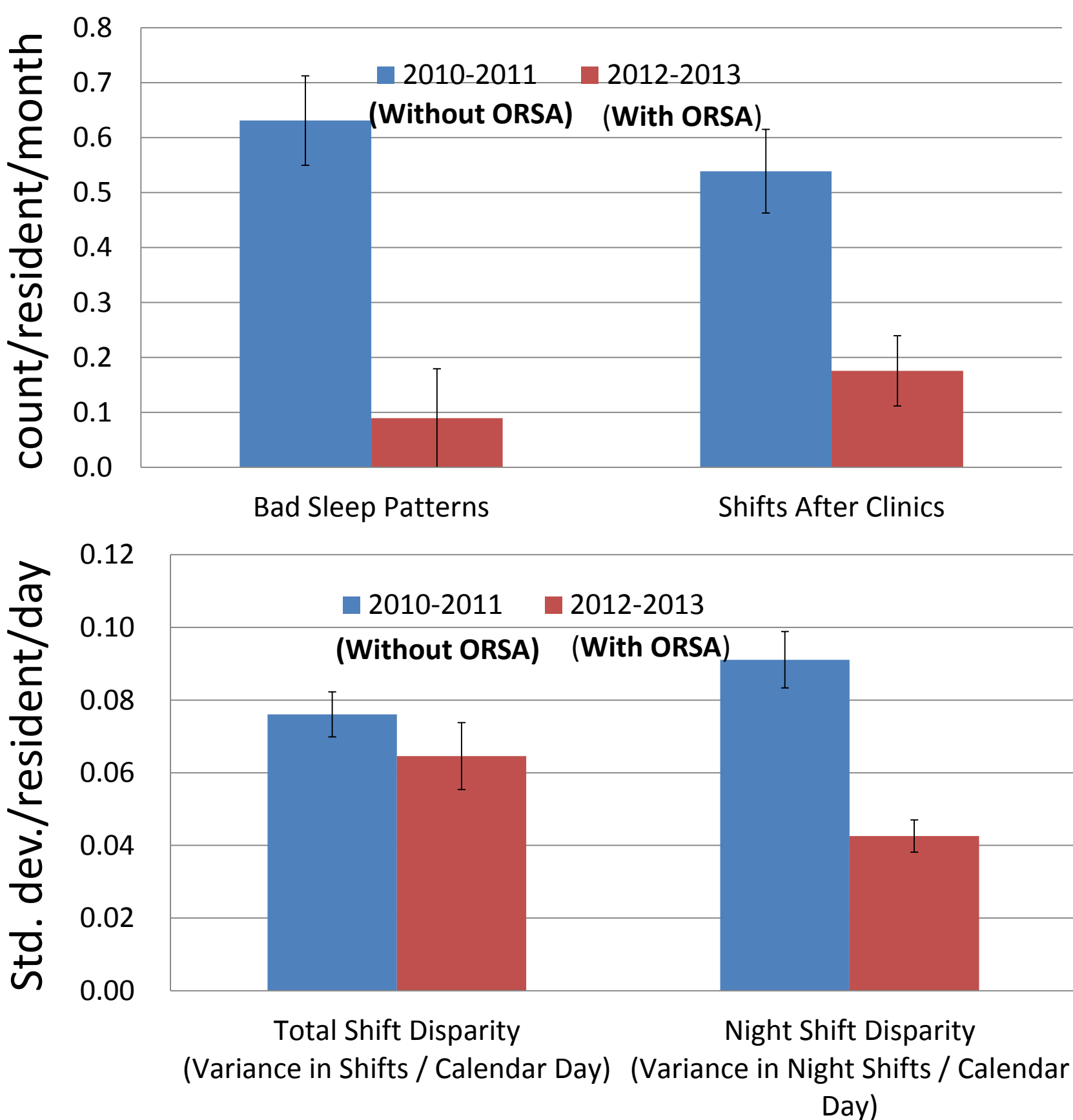## METRICS OF SCHEDULE QUALITY

Metrics for U of M PEDs
- **Total day / night shift equity**
  - The number of shifts is related to practice quality in education training
  - Unfair night shift division results in poor morale and decreased learning ability
- **Number of Bad Sleep Patterns**
  - Poor sleep habits cause cognitive decline, which have been associated with decreased quality of patient care
- **Number of shifts worked post-continuity clinic**
  - Fatigue common in post-continuity clinic shifts

Resident Name	Smith	Jones	Chen	Joe
Night Shifts / Total Shifts	0 / 7	1 / 7	1 / 7	5 / 7
Fairness				

	Monday	Tuesday	Sleep Pattern
NIGHT	1AM – 10AM		Wake-up
Day		1PM – 10PM	Sleepy
NIGHT			

RESULTS

- ORSA has been used since July 2012 to build the monthly resident shift schedule for the UMHS Pediatric Emergency Department
- Run time to generate a single schedule is under two seconds
- The time for the chief resident to interactively improve the solution until satisfied is typically between one and two hours
- ORSA guarantees the schedule will have no rule violations
- Several metrics have significantly improved over the manual process:

CONCLUSIONS

Our optimization-based scheduling tool:
- Allows chief resident to compare tradeoffs
- Reduces time to create schedule
- Improves measures of schedule quality

FUTURE WORK

- User-friendly GUI
- Increase automation
- Apply to other departments/scheduling problems

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