Improving Patient Flow in an Outpatient Infusion Center

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Introduction

- Cancer treatment demand exceeds ambulatory infusion capacity
- Improving efficiency of ambulatory infusion can lead to increased capacity and decreased patient wait times
- Goal: Generate appointment schedules that reduce patient waiting times and total length of day of operations
- We are developing a mathematical optimization model and easy-to-implement heuristics to generate infusion patient appointment times which are evaluated through a discrete event simulation model

Methods

- 60+ hours of observations
- 37,000 patient visit records reviewed from 3 electronic health records

- Mapped patient and process flows through the infusion area, oncology clinics, and pharmacy

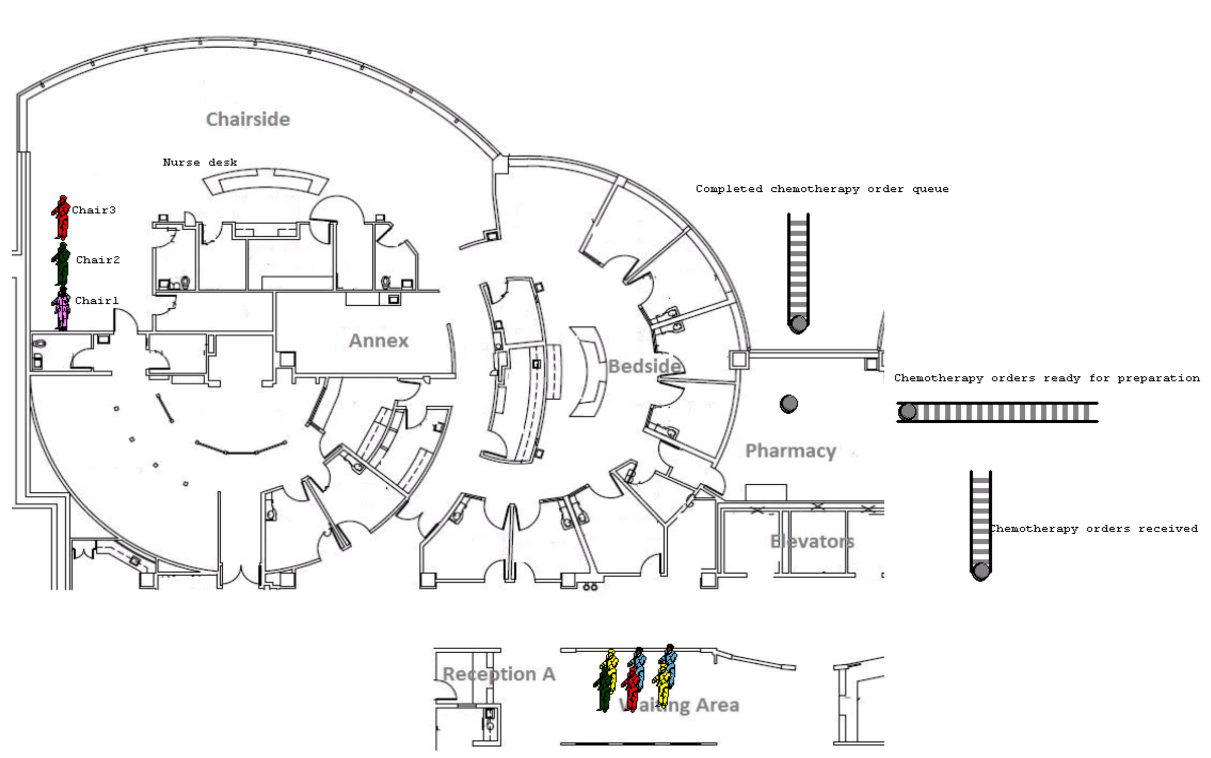
Observations & Data → Patient Flow Mapping → Simulation Model → Output → Analysis

Heuristics → Simulation Model ← Optimization Model

Scheduling Heuristics
- LPT: Longer infusions are scheduled earlier
- SPT: Shorter infusions are scheduled earlier

- Computer simulation allows for evaluation of new appointment schedules without disrupting operations

Computer Simulation



- Models a simplified version of the UMHS outpatient infusion center
- Features:
  - 12 patients
  - 1 Nurse
  - 1 pharmacy technician
  - 1 pod (3 chairs)
  - Random treatment times
- Inputs:
  - Distributions of treatment, preparation and pharmacy times
  - Appointment schedules (e.g Baseline, LPT, SPT, Optimization model)
- Output:
  - Expected patient waiting times
  - Expected length of day of operation

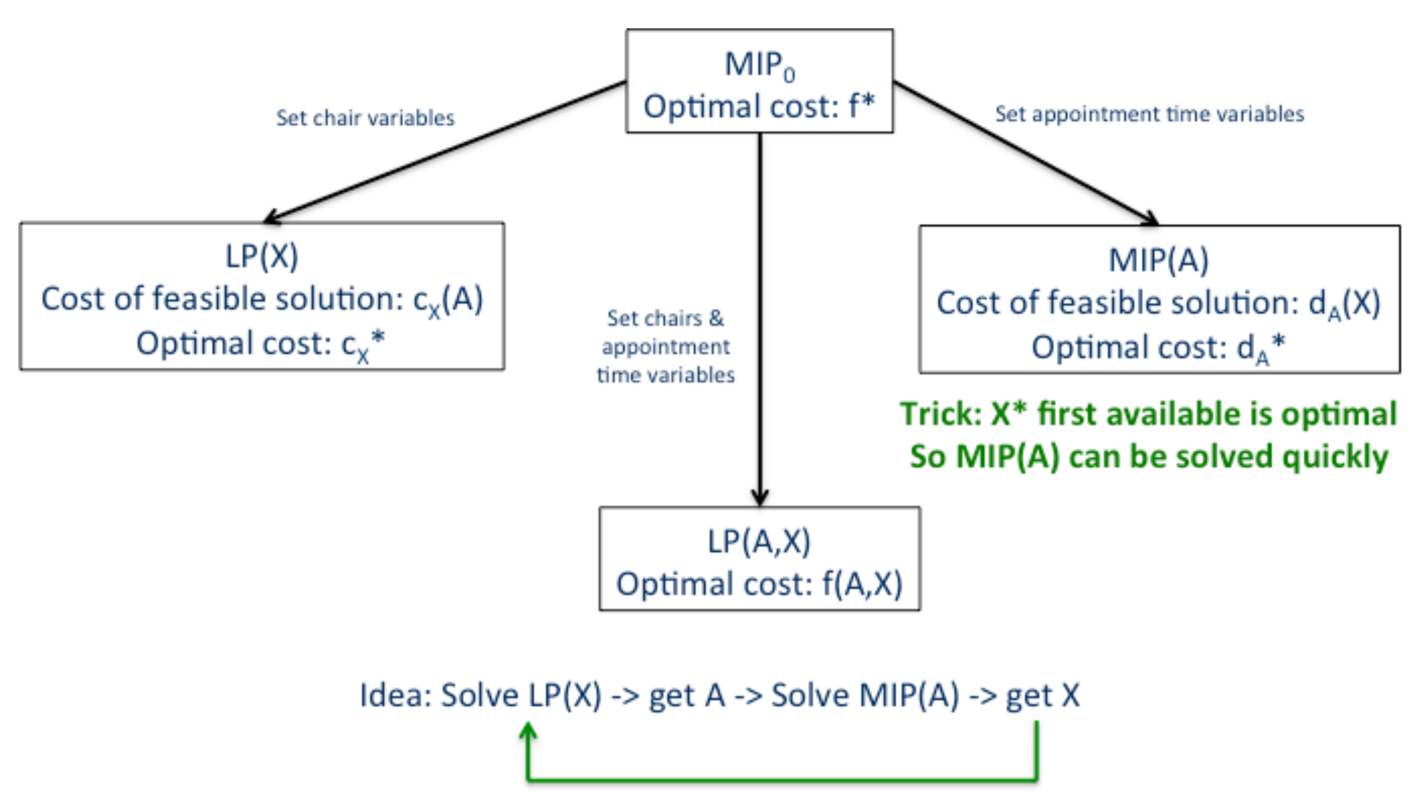
General Optimization Model

$$\min_{a,z,x^\omega,d^\omega,w^\omega,E^\omega} \lambda \sum_{p\in P}\sum_{\omega\in\Omega} p^\omega w_p^\omega + (1-\lambda)\sum_{\omega\in\Omega} p^\omega E^\omega$$

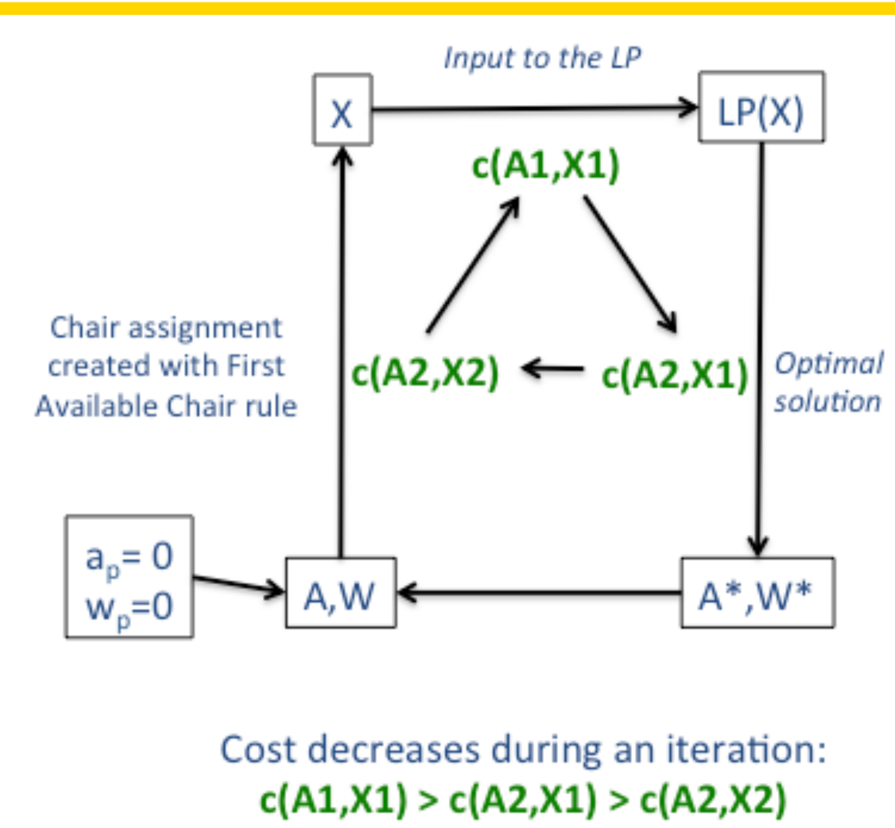
subject to

$$\sum_{c\in C} x_{pc}^\omega = 1 \quad \forall p\in P,\ \forall\omega\in\Omega$$
$$a_p + w_p^\omega + s_p^\omega + t_p^\omega = d_p^\omega \quad \forall p\in P,\ \forall\omega\in\Omega$$
$$a_j + w_j^\omega + M(3 - x_{ic}^\omega - x_{jc}^\omega - z_{ij}) \ge d_i^\omega \quad \forall c\in C,\ \forall i,j\in P,\ \forall\omega\in\Omega$$
$$a_j + w_j^\omega + M(1 - z_{ij}) \ge a_i + w_i^\omega + s_i^\omega \quad \forall i,j\in P,\ \forall\omega\in\Omega$$
$$E^\omega \ge d_p^\omega \quad \forall p\in P,\ \forall\omega\in\Omega$$
$$[a_{p_2} - a_{p_1}] + M[1 - z_{p_1,p_2}] \ge 0 \quad \forall p_1,p_2\in P,\ p_1<p_2$$
$$[a_{p_1} - a_{p_2}] + M[z_{p_1,p_2}] \ge 0 \quad \forall p_1,p_2\in P,\ p_1<p_2$$
$$z_{p_2,p_1} = 1 - z_{p_1,p_2} \quad \forall p_1,p_2\in P,\ p_1<p_2$$
$$x_{pc}^\omega \in \{0,1\} \quad \forall c\in C,\ \forall p\in P,\ \forall\omega\in\Omega$$
$$z_{p_1,p_2} \in \{0,1\} \quad \forall p_1,p_2\in P$$
$$a_p \ge 0 \quad \forall p\in P$$
$$w_p^\omega, d_p^\omega \ge 0 \quad \forall p\in P,\ \forall\omega\in\Omega$$

Decomposition

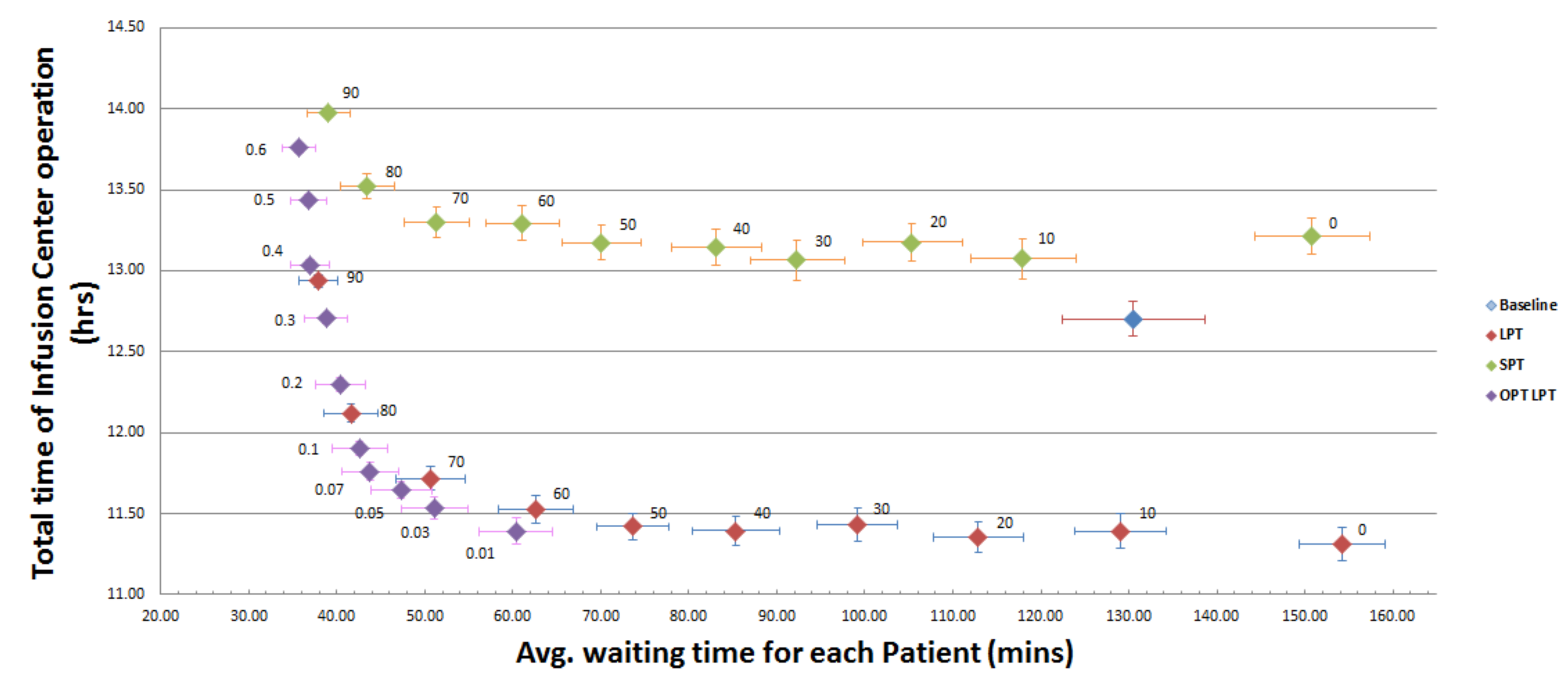


Algorithm for known sequence



	Number of scenarios			
	5	20	100	1000
MIP Solver	5 sec	2 min	≈3000 years	≈10^100 years
Algorithm	0.2 sec	0.3 sec	0.8 sec	8.7 sec

Results



- Appointment times generated by the decomposition algorithm (with LPT sequence) result in reduced patient wait times and total hours of operation compared to the ones generated by the Baseline schedule, and the LPT and SPT-based heuristics
- Initial results demonstrate a 70% reduction in patient wait times using the appointment schedules generated by the optimization model

Conclusions

- The effect of implementing different patient appointment schedules at an infusion center can be approximated by a mathematical optimization model
- Results of computer simulation suggest that scheduling patients with longer infusion times earlier in the day results in reduced patient wait times and total length of day

Future Research

- Run the algorithm to solve optimization model on different sequences to find characteristics of good sequences
- Develop a heuristic that can be easily implemented by schedulers
- Enhance simulation model
  - Addition of oncology clinic, increased complexity with additional nurses, chairs and patients

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