MAYO CLINIC

INTELLIGENT SURGICAL SCHEDULING

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Annual Patient Encounters

MAYO CLINIC 150 Years SERVING HUMANITY

Total clinic patients:
1,260,000

Hospital admissions:
131,000

Hospital days:
608,000

Employees:
> 60,000

MAYO CLINIC

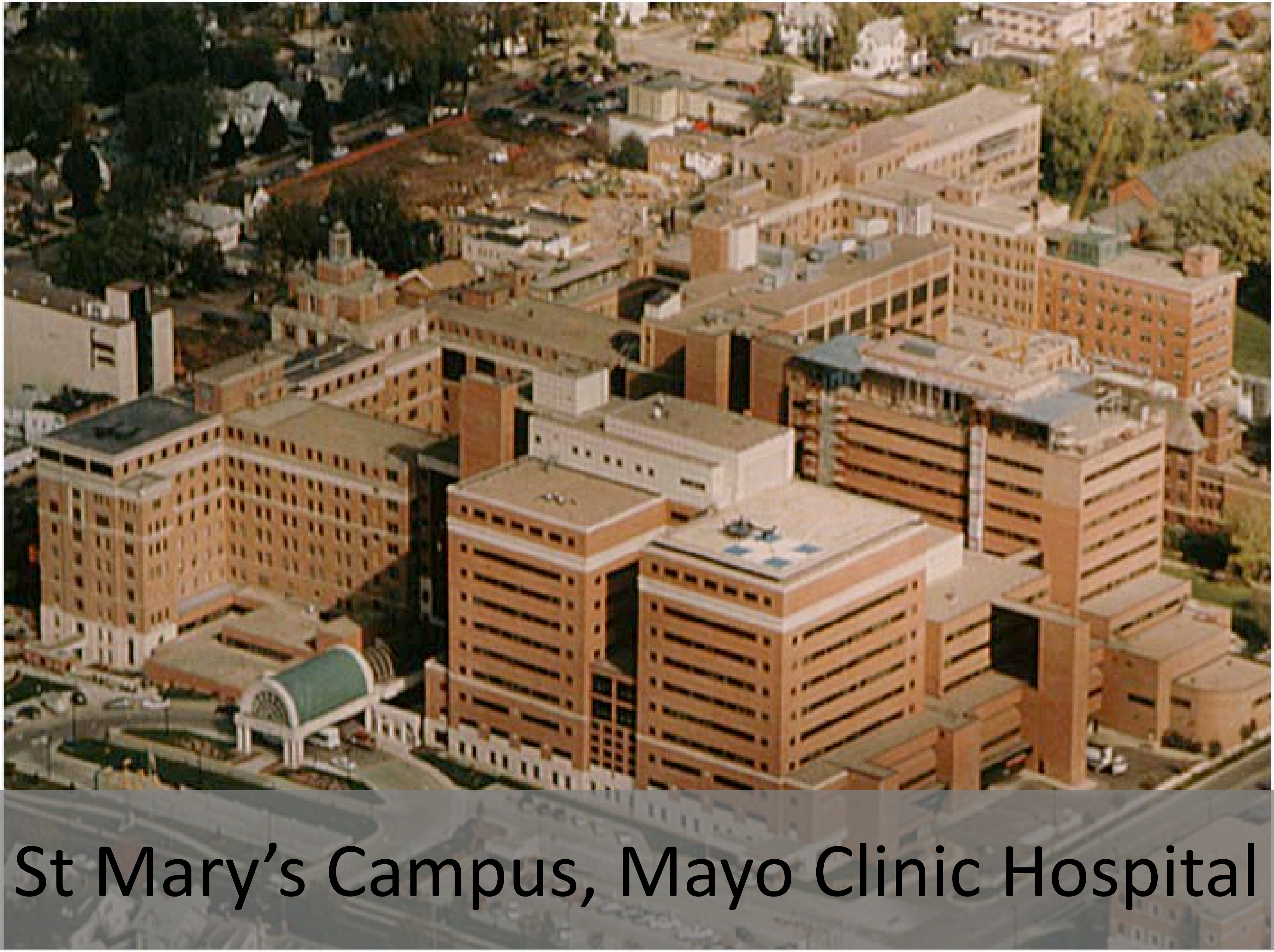
Revenue*

Total revenue: $9,421

Income : $612

Benefactors: $399

* In millions



St Mary’s Campus, Mayo Clinic Hospital

The Practice Problem

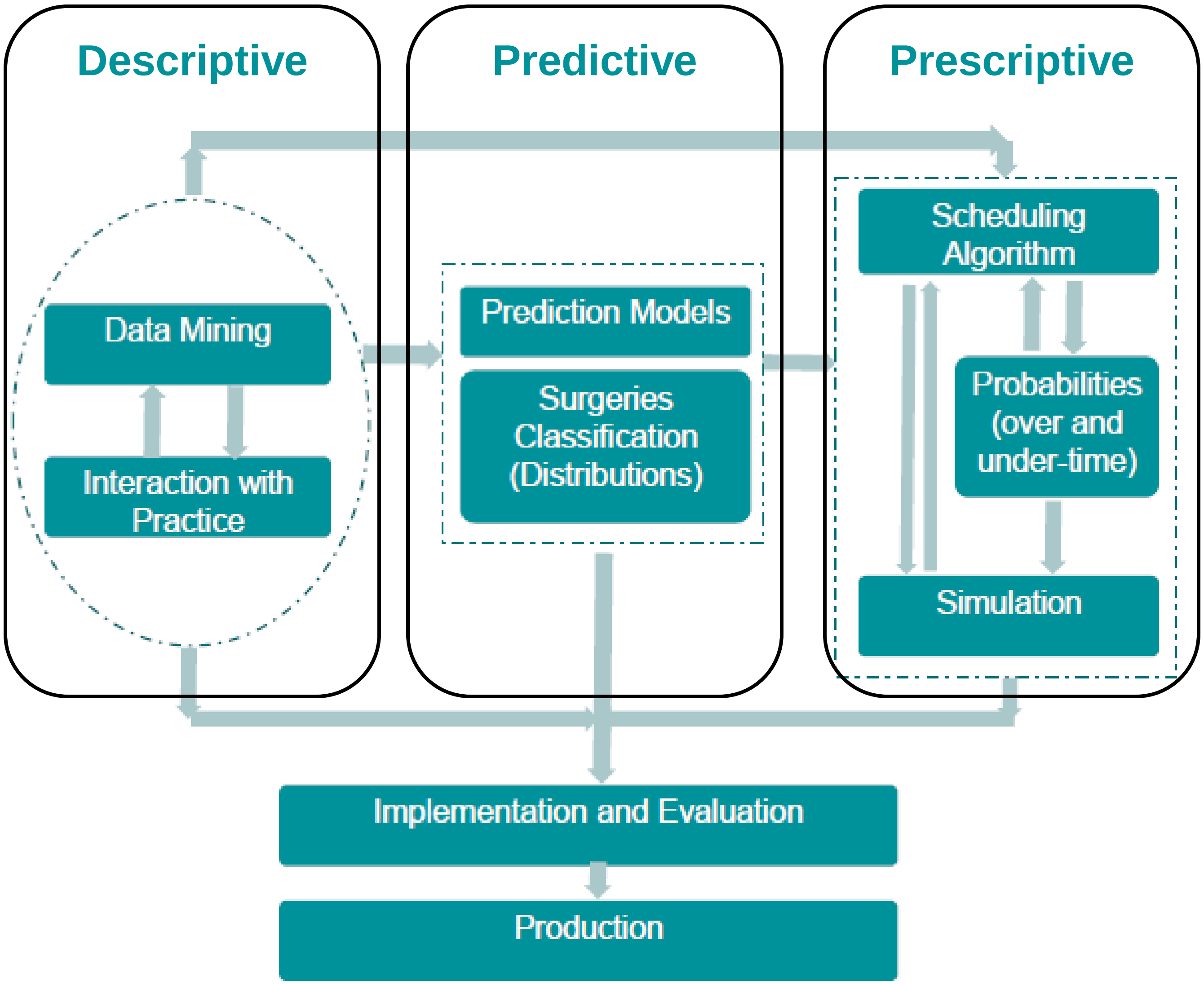
- Surgeon variation in utilization rates
- Empty days (last minute cancellations)
- Fluctuating days with low and over utilization
- Surgeries past 11 pm – unsafe days
  - Fatigue/burnout, higher likelihood of errors
- Unnecessary hospital weekend days
- Causes
  - Duration of surgery is not estimated correctly
  - Surgeries are not assigned to a optimal day

Perspectives to be considered

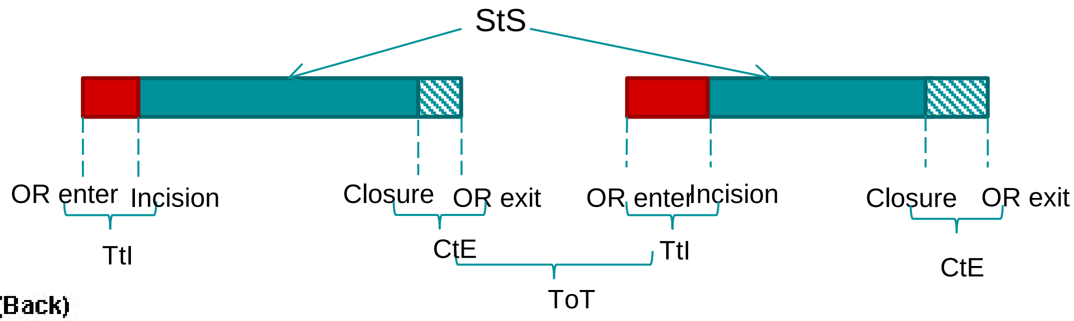
Practical Requirements

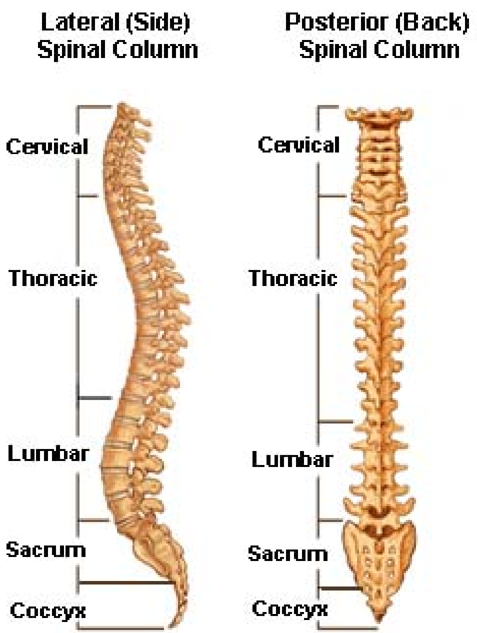
- Promote patient engagement in decision making
- Scheduling system that is clinically relevant and flexible
  - Respect surgeon autonomy
  - Informed decision making: Provide probability of overtime for the day and estimate end of the surgery day
  - Provide multiple options for scheduling spread over the 90 day horizon
- Optimize prime time OR utilization for all surgeons
- Eliminate surgical days with no surgeries
- Avoid weekend discharges of patients for initial nursing home placement
- Reserve enough capacity for long surgeries

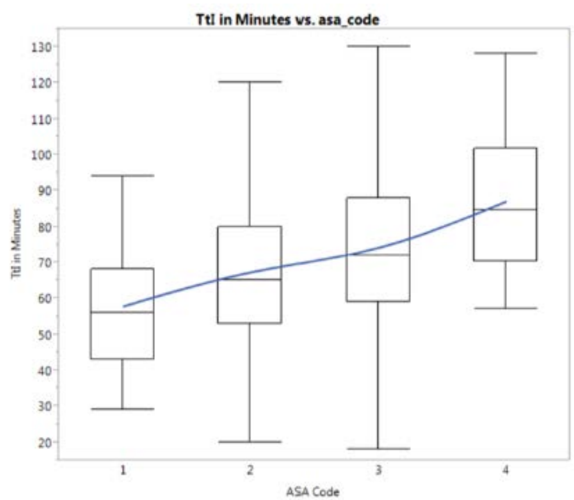
Surgery Scheduling Analytics Approach

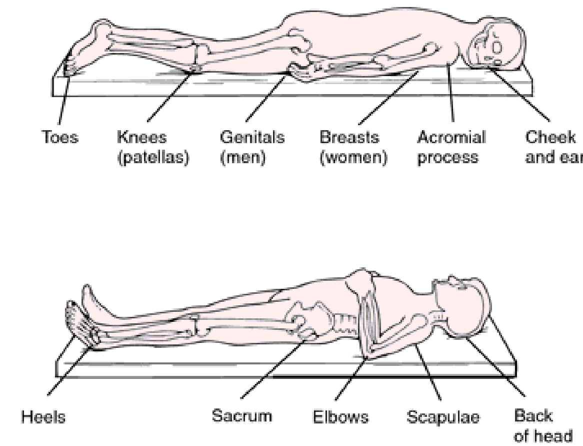


Descriptive Analytics









Prediction of Surgical Durations and Length of Hospital Stay

State of the Practice

- Moving average of OR times modified by scheduler

Literature

- Distribution as random generator
- Surgeon/staff prediction of times
- Prediction models based on general factors
- Prediction of surgical times is studied based on ICD9 codes
  - ICD9 codes are not usually known at the time of scheduling
  - ICD9 codes are design for financial purposes

Data Mining and Text Mining

- Spine surgeries highly variable
- General information such as age, gender, etc can not represent the duration of spine surgery
- Interaction with practice, survey, etc to identify initial set of variables
- Only general information such as age, gender, etc are stored as data fields
- Unstructured data, free text pre and post operative notes

Methods of Prediction

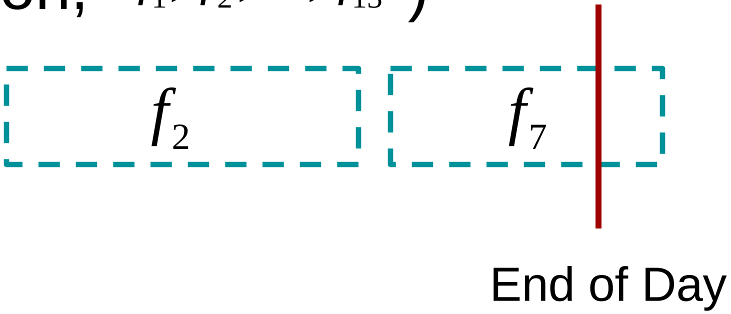
- Compared different prediction models
  - Stepwise Regression
  - Least Square Regression
  - Classification
  - Neural Network

Predictor		RSquare	RASE	AAE
Stepwise		0.6375	1.2934	0.9296
Stepwise 2L		0.8168	0.9215	0.6842
Stepwise 3L		0.9284	0.5762	0.4064
Classification		0.6032	1.3517	0.9565
Neural Network		0.6674	1.2416	0.8783
LSQ		0.6396	1.2924	0.9305

Predictor		RSquare	RASE	AAE
Stepwise		0.5895	1.4464	1.0459
Stepwise 2L		0.3019	1.8902	1.1929
Stepwise 3L		0.0021	3.5715	1.9479
Classification		0.5459	1.5171	1.0397
Neural Network		0.5736	1.4762	1.0351
LSQ		0.5899	1.4488	1.0478

Calculation of Probabilities

- The distribution of surgical times are wide
- Using classification we categorize surgeries based on previously defined factors (13 categories each with different distribution, $f_1, f_2, \ldots, f_{13}$)

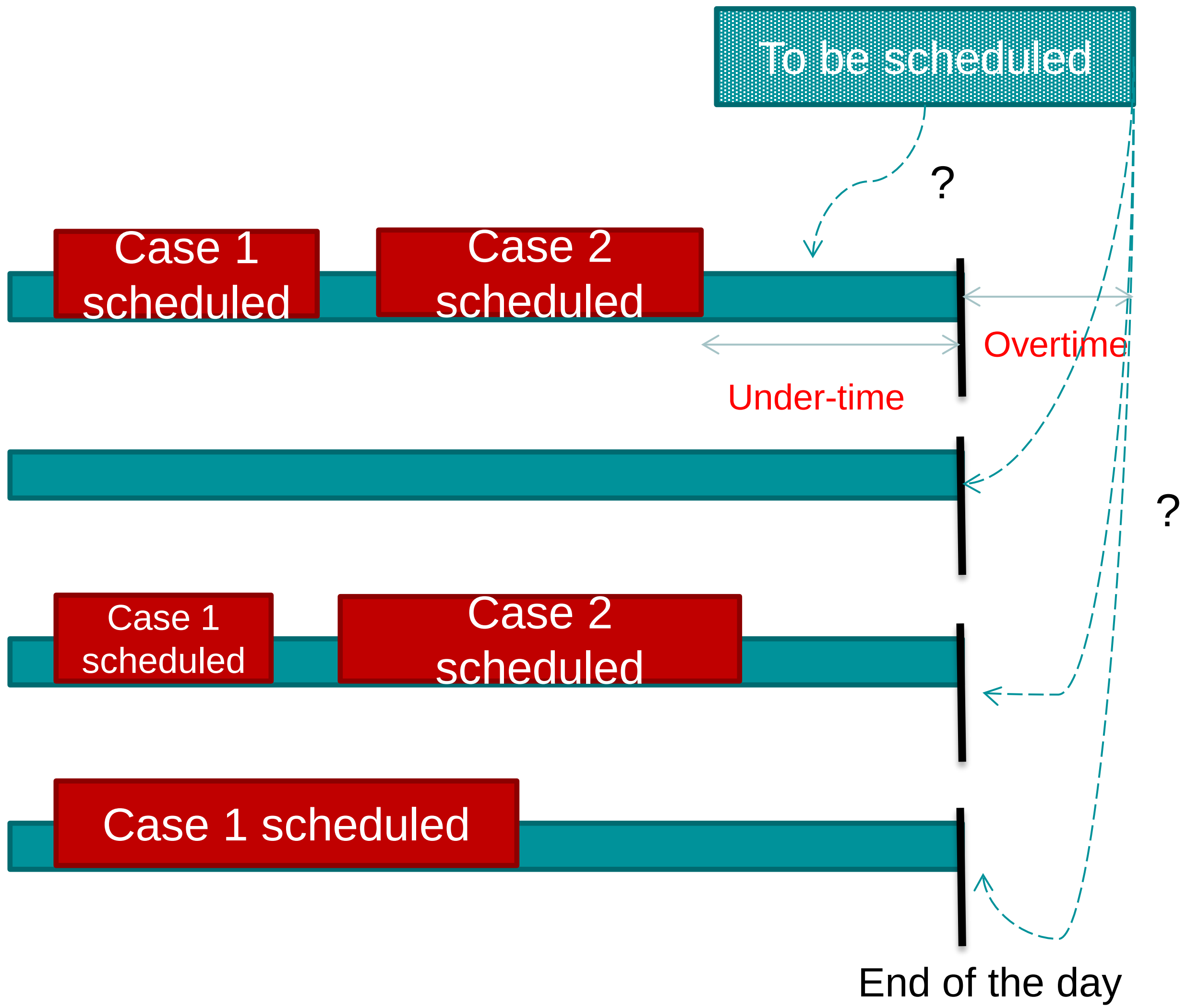


- The density function of sum of random variables is convolution of f_2, f_7
- The convolution does not have close form in this case

Calculation of Probabilities

- Fourier Transform (FT) is a transform that express a mathematical function of time as a function of frequency
- Theorem: Convolution in the time domain corresponds to multiplication in the frequency domain
- Use Discrete Fast Fourier Transform and its inverse as a numerical method to find density function
- Calculation of probabilities, over time and under time from that is straight forward

Scheduling Problem



Optimization based Template from Literature

- Patients are grouped (categorized) based on some common criteria
- The optimization model is solved for several times for historical based data (simulation)

Rule1: if case has conditions a, b, and c (is of category 1), then schedule it in a slot with conditions I, and II …

Rule 2: if case has conditions ….

Rule n: if case has ….

- Changes in demand makes template invalid
- Re configuring template is expensive
- Surgeons do not always follow suggested times

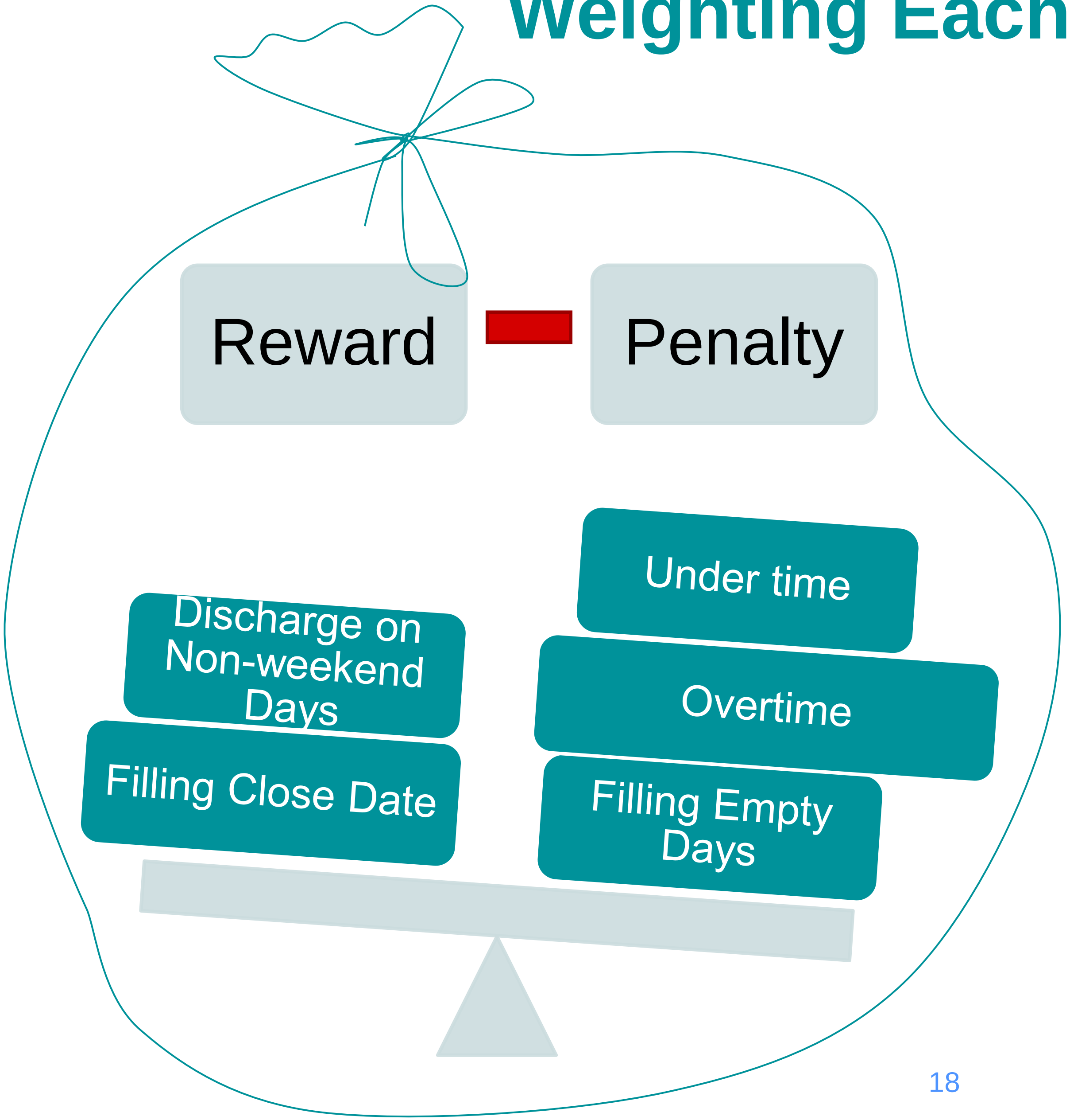
Proposed Scheduling Algorithm

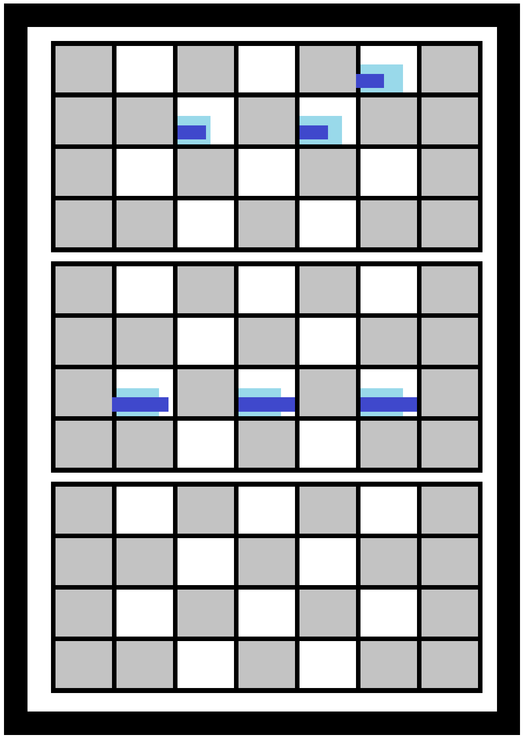
- Sub-horizons guarantee possible solutions within different time windows

Horizon 1	Horizon 2	Horizon 3	Horizon 4

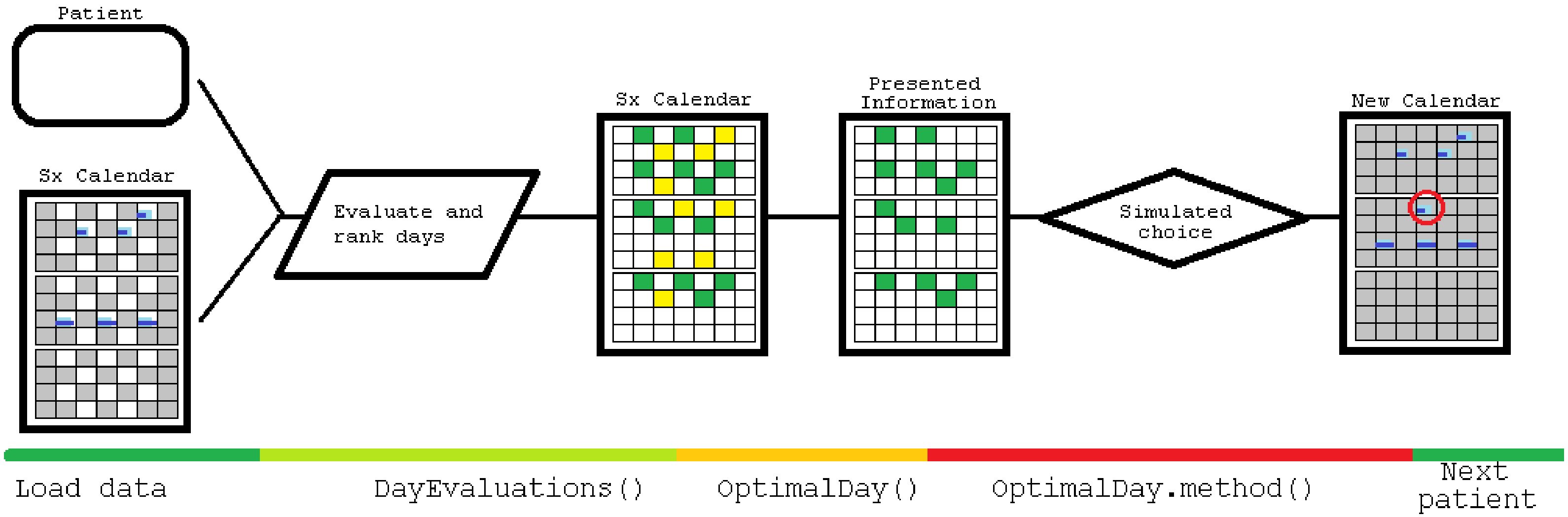
- Set a minimum number of ideal days per sub-horizon
- Reward and penalty functions to evaluate different days
- Rank days based on: (reward - penalty)

Weighting Each Component

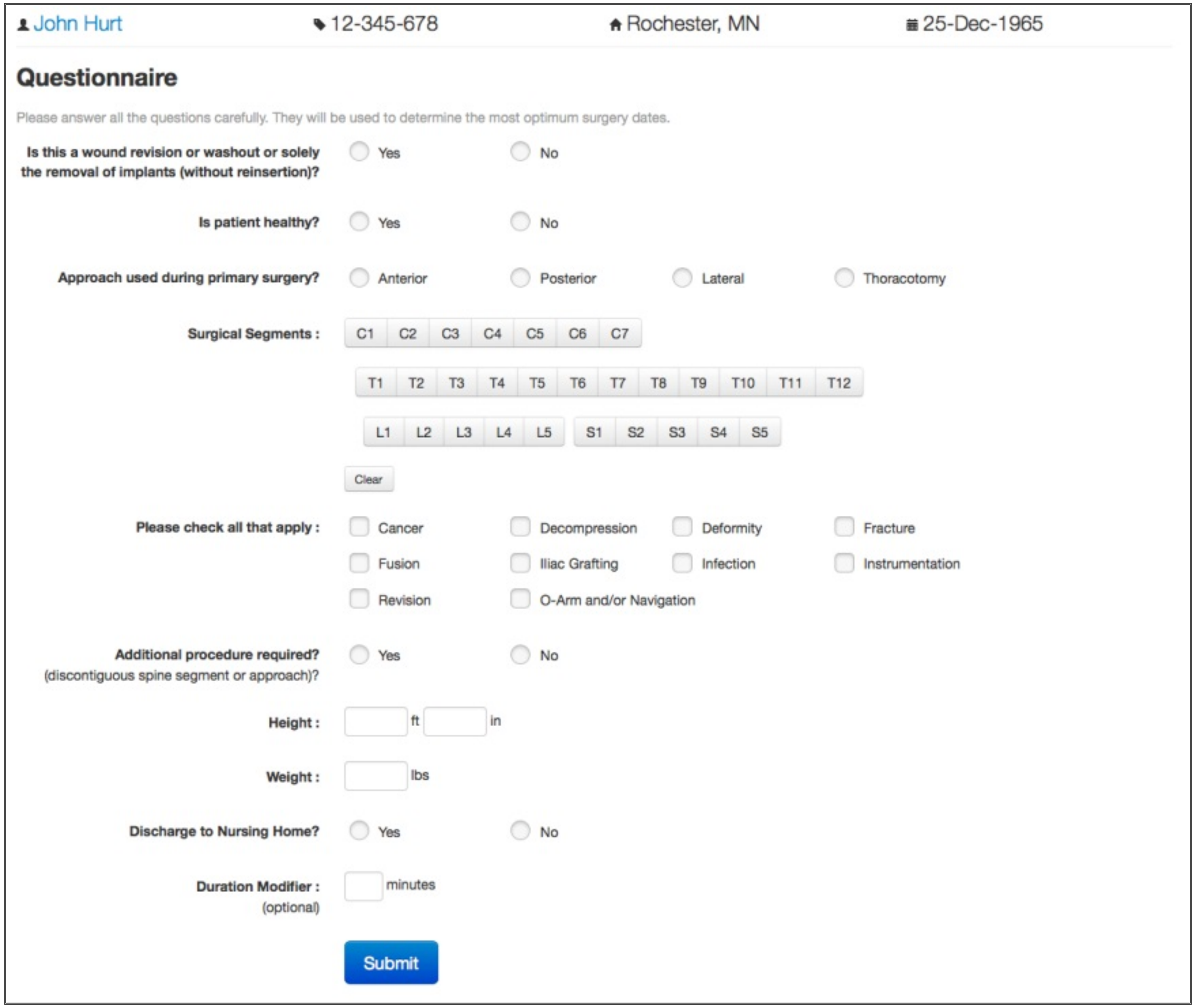




Simulation


Patient
Sx Calendar
Evaluate and rank days
Sx Calendar
Presented Information
Simulated choice
New Calendar
Load data
DayEvaluations()
OptimalDay()
OptimalDay.method()
Next patient

Screenshot: Personalized Scheduling



John Hurt
12-345-678
Rochester, MN
25-Dec-1965

Questionnaire

Please answer all the questions carefully. They will be used to determine the most optimum surgery dates.

Is this a wound revision or washout or solely the removal of implants (without reinsertion)? Yes No

Is patient healthy? Yes No

Approach used during primary surgery? Anterior Posterior Lateral Thoracotomy

Surgical Segments : C1 C2 C3 C4 C5 C6 C7
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12
L1 L2 L3 L4 L5 S1 S2 S3 S4 S5
Clear

Please check all that apply : Cancer Decompression Deformity Fracture Fusion Iliac Grafting Infection Instrumentation Revision O-Arm and/or Navigation

Additional procedure required? (discontiguous spine segment or approach)? Yes No

Height : ft in

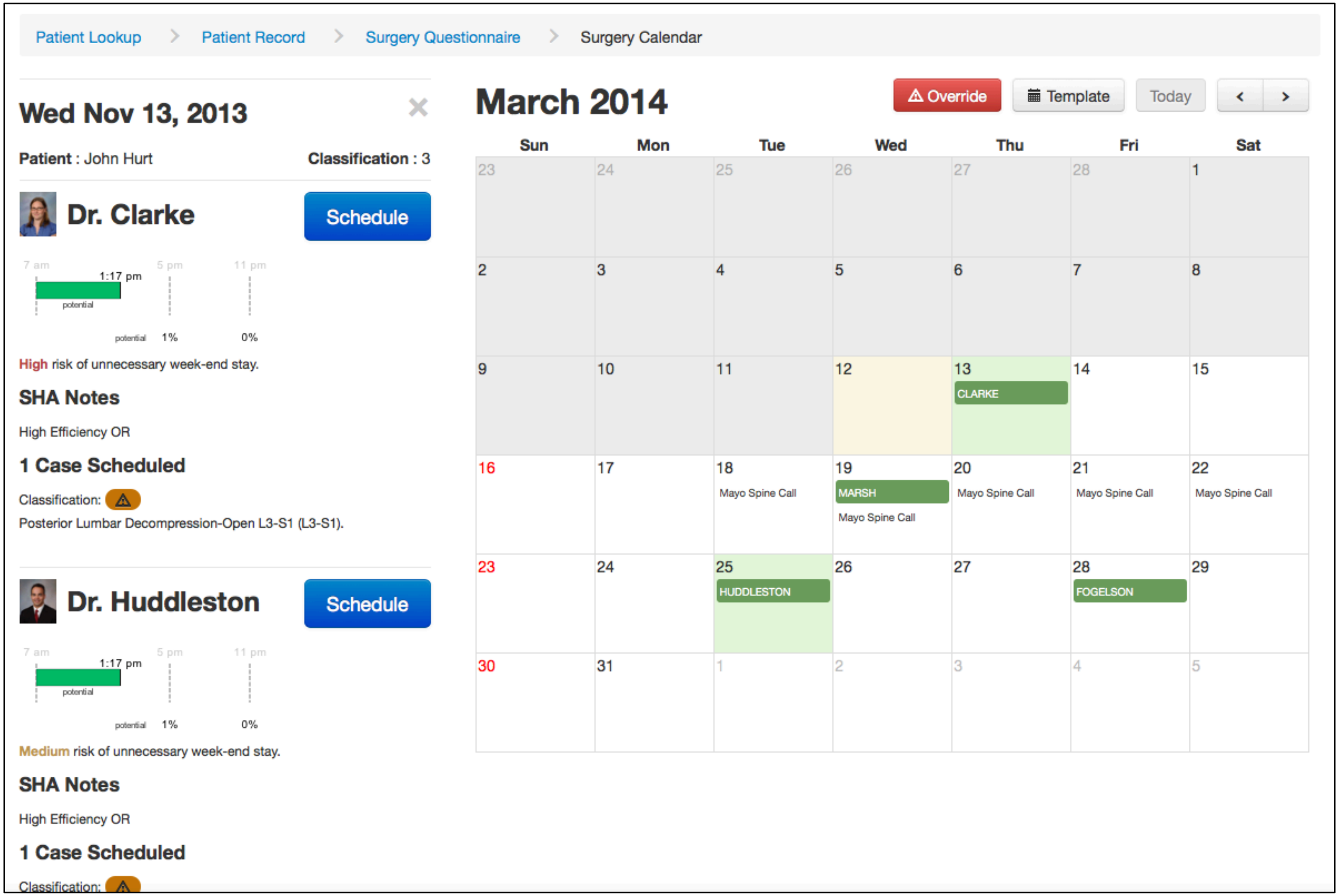
Weight : lbs

Discharge to Nursing Home? Yes No

Duration Modifier : (optional) minutes

Submit

Screenshot: “Green days” with probabilities



Implementation Process

- Data Extraction and Data Load
- Dual entry
- Cases not included (e.g. brain surgery)
- Workflow
- Acceptance and Trust

Before and After Implementation

Before

Measure	Before Project starts
Primetime OR utilization	47%
Days with No Surgery	33%
Days with Overtime	38%

After

Measure	After First Pilot
Primetime OR utilization	66%
Days with No Surgery	16%
Days with Overtime	28%

Impact and Summary

- Increased flexibility
- Increased OR utilization
- Reduced “no hitters”
- Reduced overtime
- Informed decision-making

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