Development of a Surgery Duration Prediction Model for Operating Theatre Optimization

Shao Wei Sean Lam[1]; Nguyen, Ngoc Huang Long[1]; Boon Yew, Ang[1];
Qi Qi, Wang[2]; Claire Wong Yin[2]; Eng Hock Marcus, Ong[1,2,3]; Hiang Khoon, Tan[3,5]

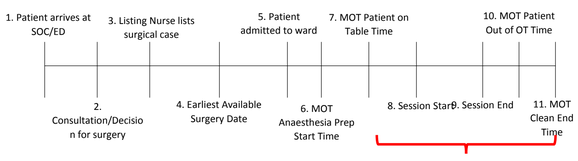
[1]SingHealth; [3]Singapore General Hospital;
[4]Duke-NUS Medical School; [5]National Cancer Centre Singapore

Singapore Healthcare Management 2019

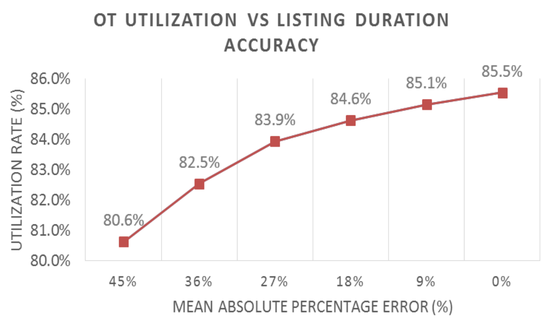
Background

Operating Theatres (OTs) are known to be the largest cost centre as well as the main revenue generator in most hospitals. Uncertainties in the prediction of surgical durations may lead to sub-optimal scheduling of surgical cases, resulting in under-utilization of OT resources and also to cancellations and delays of patients' surgeries. The ability to accurately predict the length of the surgical procedure is hence essential in creating OT schedules to mitigate such effects.

Definition of Surgical Duration



Impact on OT Utilization



The aim of this study is to improve the accuracy of surgery duration estimates using all available factors known at the time of scheduling as well as to determine important factors contributing to surgery duration.

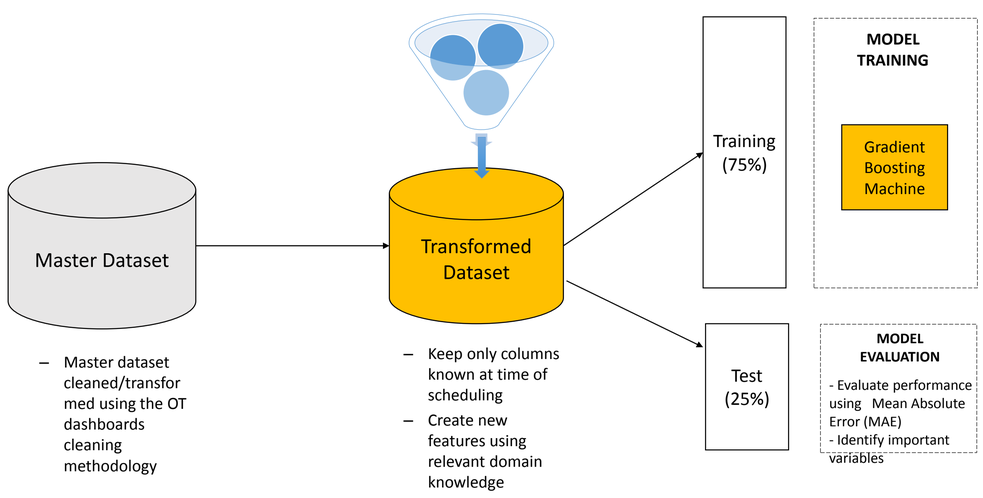
Methodology

Electronic records on 59,293 surgical cases performed in SGH involving only a single surgical procedure from January 2016 to December 2017 were retrieved. Patient demographics, clinical information and surgical team characteristics for each surgical case were also obtained. Feature engineering techniques and transformations were carried out on selected variables to enhance the use of the variables.

1. Data Cleaning

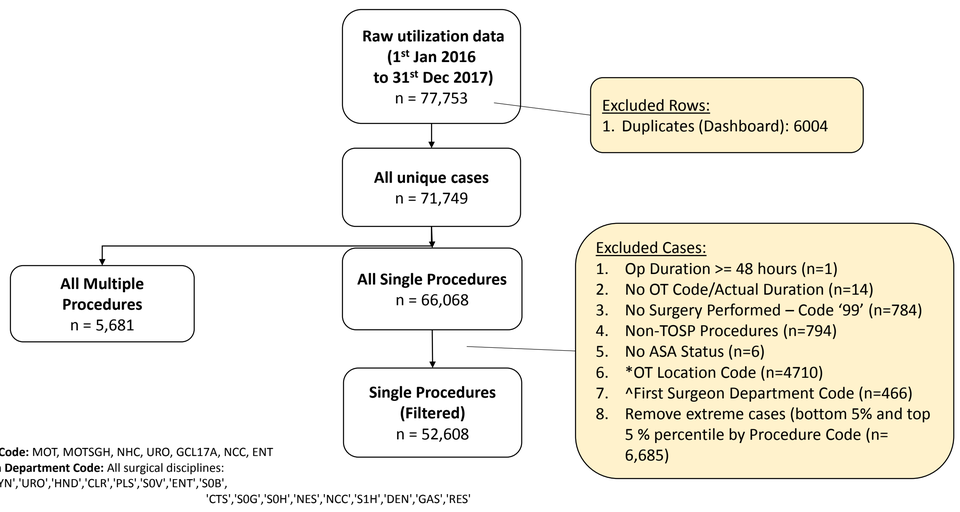
2. Feature Engineering

3. Developing Predictive Model



– Master dataset cleaned/transformed using the OT dashboards cleaning methodology

– Keep only columns known at time of scheduling
– Create new features using relevant domain knowledge



***OT Location Code:** MOT, MOTSGH, NHC, URO, GCL17A, NCC, ENT
^First Surgeon Department Code: All surgical disciplines:
'OTO','SUR','GYN','URO','HND','CLR','PLS','S0V','ENT','S0B',
'CTS','S0G','S0H','NES','NCC','S1H','DEN','GAS','RES'

A generalized predictive model for surgery durations using the **Gradient Boosted Machine (GBM) algorithm** was developed and was compared to the current practice of estimating surgery durations as well as the listed duration using 3 performance metrics:

1. Mean Absolute Error (MAE)
2. R-Squared (R2)
3. Cases within +/- 20% of Listing Duration

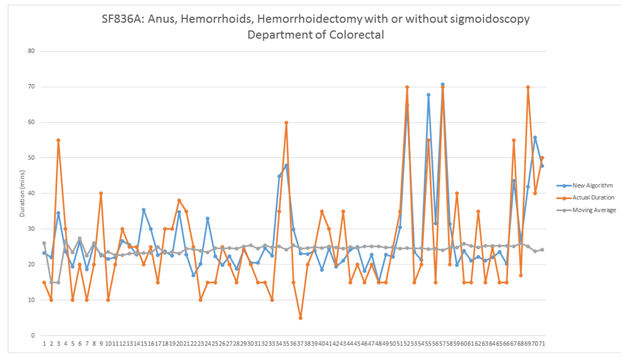
Results & Discussion

The new predictive model developed in this study provides an overall improvement in accuracy when estimating actual surgery durations across all three performance metrics compared to the current practice of using a moving average.

Overall Performance of GBM Model

	Mean Discrepancy	R-square	Percentage within 80-120%
Current Listing	32.5 mins	75.0	40.6%
OTM estimation	25.7 mins	83.6	50.0%
New algorithm	22.5 mins	87.0	53.4%

The new algorithm also better captures the variations in surgery durations as the current practice over-smooths the predictions of surgery durations.



The Gradient Boosting Machine (GBM) model achieved **22.5 minutes MAE**, an improvement of about 10 minutes compared to the current practice of estimation. Improvements in all 3 metrics were also observed across most departments.

Performance of GBM Model Across Surgical Disciplines

Behavioural Implications: However, accurate predictions may not be sufficient to improve the listing accuracy of surgical cases – staff behaviour and actions in response to different stimulus may introduce bias and affect OT utilization.

Behavioural science approaches, such as nudging may be necessary to reduce this bias

Listing Duration, (d)	Likelihood of completion within d, $Pr(T < d)$	Utilization of listed slot, $\frac{E(T)}{d}$
300min	70%	1.2
350min	80%	1
360min	90%	0.8
400min	95%	0.6

Conclusion

This study shows that the current practice has limited predictive power as it only considers the procedure code and surgeon, and does not capture the variations in surgery durations. The general predictive model developed for all surgical departments improves the accuracy of estimating surgery durations and also considers a wide range of factors in the model.