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Improving Hospital Bed Management: Machine Learning for Predicting Length of Hospital Stay

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Abstract: *This study proposes a novel approach to managing short-term inpatient stays by predicting the length of stay (LOS) upon patient admission using machine learning (ML). This study demonstrates that ML algorithms (i.e., Random Forest, XGBoost, and Convolutional Neural Network can predict LOS with almost twice the accuracy compared to conventional physicians' assessment. As a result of the higher LOS estimation accuracy, simulation results show a higher bed occupancy rate and lower patient waiting time. Overall, this study concludes that with better decision support system for short-term hospitalization management, a hospital can increase the number of short-term patient admissions or operate with fewer hospital beds.*

Keywords: *length of hospital stays, machine learning, hospital bed management, discrete event simulation*

I. INTRODUCTION

One of the most critical issues in healthcare management is the effective utilization of limited medical resources. This is especially true in Japan, where its society is aging rapidly, leading to increased demand in healthcare industry [1]. Through a better utilization of medical resources, the healthcare industry can improve its services and quality, thereby providing more satisfaction not only to patients but also their families.

Specifically, this study focuses on hospital bed management due to several reasons. First, the number of beds available in a hospital can be scarce when compared to the population around the hospital area [2]. Second, appropriate bed allocation should be based on the type and needs of the patient [2]. Third, the increasing frequency of large-scale disasters and pandemics necessitates a flexible and rapid response, highlighting the importance of an organized hospital bed management system [3].

Nevertheless, the current hospital bed management system often struggles to provide optimal care due to the complex procedure of patient admissions and the lack of data-driven decision-making. Therefore, this study aims to provide a machine learning (ML) model for focusing on the prediction of short-term length of stay (LOS) and evaluate the overall impact of LOS estimates using discrete event simulation.

II. DATA

The materials of this study are inpatient data admitted to Ebina General Hospital from 2019 to 2023, which cover around 30,000 admissions. For each admission case, in addition to patient's basic information and diagnosis, the dataset also contains patient's vital data, laboratory test data, and admission & discharge date. A patient may be admitted multiple times.

In contrast to prior studies on LOS prediction [4], this study focuses on short-term hospitalization. Specifically, this study focuses on LOS of no more than

5 days, which accounts for around 20% of total admissions in the sample.

III. METHODOLOGY

A. Prediction of Short-Term LOS

Traditionally, the hospital bed management systems center on physicians' assessment of the patient's condition upon admission to the hospital. A better assessment (i.e., LOS estimation) often leads to higher efficiency of bed management (i.e., higher bed occupancy rate or lower number of beds required). This study aims to improve the LOS prediction accuracy by employing ML approach. Figure 1 shows the steps of the modelling processes.

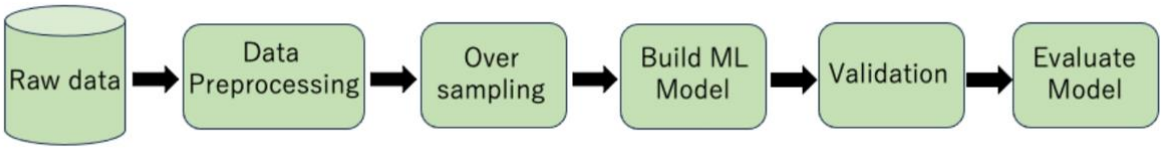

Figure 1. Machine learning modelling process for prediction of length of stay

To predict the LOS using ML, the following basic features are used, namely: age, gender, body temperature, heart rate, systolic, diastolic, initial laboratory parameters, major diagnostic category (MDC), physician ID, ward ID, department ID, admission route, homecare status prior to admission, ambulance transport to the hospital, scheduled/emergency medical admission category, outpatient status, and referral from other hospitals.

For data preprocessing, this study further adds three additional features derived from feature engineering, namely: past MDC, number of hospitalizations, and average past LOS (if any). All numerical features are standardized. Missing values are imputed with the average value. Outliers are removed if the value is outside the interquartile range. Moreover, to address the class imbalance, this study performs oversampling method, called Synthetic Minority Over-sampling Technique (SMOTE).

This study then builds LOS estimation models using ML algorithms, such as Random Forest (RF), XGBoost, and Convolutional Neural Network (CNN). All the models are validated using five-fold cross-validation. Lastly, this study evaluates the model accuracy using confusion matrix.

B. Discrete Event Simulation

Hospitals are resource-intensive, and using discrete event simulation can optimize patient flow and hospital bed utilization, and staff allocation, ultimately leading to better management decisions. This simulation focuses on updating the patient flow from admission to discharge in real-time based on the hospital's usage status. The simulation compares the actual admission date with the predicted admission date as well as the actual discharge date with the predicted discharge date. Through this process, daily tasks such as bed release, processing new admissions, and managing the waiting list are performed. Eventually, this study evaluates statistical data regarding bed occupancy rate and the total number of patients on the waiting list.

IV. RESULTS

Table 1 summarizes the performances of different methods used to predict short-term LOS and its implications on bed management.

Table 1.
LOS Estimation and Its Implications on Bed Management

Method	Accuracy	Avg. Bed Occupancy Rate in 90 Days	#People in Waiting List
Physicians' Assessment	27%	91%	14
RF	42%	92%	14
XGBoost	40%	93%	17
CNN	52%	93%	10

Specifically, it shows that CNN has the highest accuracy of 52% for predicting the number of admissions. This is followed by RF and XGBoost, which both models have an accuracy of about 40%. Nonetheless, all ML models outperform the LOS estimation accuracy based on physicians assessment. Additionally, the results of bed scheduling show that improving LOS prediction accuracy has a clear impact on bed occupancy rate, which translates into the number of people in the waiting list prior to their admission.

V. CONCLUSION

This study proposes ML models for focusing on the prediction of short-term LOS (i.e., ⩽ 5 days) evaluates the overall impact of LOS estimates using discrete event simulation. First, this study shows that all three ML algorithms outperform physicians' assessment in predicting short-term LOS. In particular, the accuracy of the ML algorithm is almost twice as good as the physicians' assessment. Second, this study finds that higher accuracy of LOS estimation is associated with higher bed occupancy rate. Third, this study demonstrates that through a discrete event simulation, a lower number of patients in the waiting list is expected with a better LOS estimation. Taken together, the results suggest that it is possible for a hospital to operate with fewer beds after adopting the proposed ML models. In future work, the ML models will be improved by increasing the accuracy of LOS prediction via feature engineering.

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