Hospital Length of Stay Estimation using Interpolative Boolean Algebra

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Abstract. Introduction and the Problem: Healthcare organizations are increasingly analyzing patients' length of stay (LOS) to enhance productivity, service quality, and cost reduction efforts. Accurate estimations of LOS allow healthcare organizations to systematically plan the sequence of operations and patient flow within the hospital as well as a balanced ratio between patient demand and available resources. Additionally, predicting LOS provides healthcare organizations with a valuable tool to evaluate the effectiveness of surgical interventions and the overall quality of care delivered by surgeons. Through a comparison of estimated and actual LOS, hospitals can critically assess the performance of individual surgeons and pinpoint areas for improvement.

Due to the importance of predicting LOS, numerous authors have recently focused on its analysis. While many researchers have primarily concentrated on identifying factors that significantly influence LOS in various contexts, fewer have delved into research involving the direct estimation of LOS as an output attribute [1]. Recognizing the valuable insights that the precise number of days spent in the hospital can provide, this paper aims to propose a method for predicting it.

Methodology: Interpolative Boolean algebra, as introduced by Radojević [2], represents a [0,1]-valued realization of classical Boolean algebra. Founded on the principle of structural functionality, IBA emphasizes the importances of treating the structure of a logical function separately from its value representation, thereby preserving all Boolean axioms. Therefore, IBA finds utility in areas where conventional many-valued techniques fail to appropriately address the problem.

Logical aggregation (LA) is the most commonly used technique based on IBA. It is an aggregation procedure where multiple inputs are aggregated to a single result using logic and pseudo-logical functions based on IBA [3]. LA functions are usually defined by an expert in the respective field, although they can be derived from the data. Given its clearly defined and transparent nature, LA proves particularly useful in the medical field where understanding and justifying estimations are paramount.

In this paper, we aim to present two aggregation models that may be a basis for the LOS estimation. Both models are defined in cooperation with a medical field expert. The first, simpler model is based on a weighted sum, while the oth-

er aims to incorporate logical dependencies in the data using LA. Rankings obtained with these models are compared with real outcomes for evaluation. Finally, the results of the proposed models are compared with the performance of IBA-VNS machine learning approach [4], which derives the model from the data.

Dataset and Model: The dataset applied in this study comprises 1811 instances collected between January 2015 and December 2023 as part of the LapSerb program, the Serbian National Training Program for minimally invasive colorectal surgery. The experts in the field selected the 5 attributes (age, gender, ASA physical status classification system category, body mass index (BMI), and if a patient had some previous surgery) as the relevant factors to describe the patient's condition. The outcome variable in this study is the number of days spent in the hospital following laparoscopic colorectal resections.

Keywords: Interpolative Boolean algebra, Logical aggregation, Hospital length of stay.

References

1. Stone, K., Zwiggelaar, R., Jones, P., & Mac Parthaláin, N.: A systematic review of the prediction of hospital length of stay: Towards a unified framework. PLOS Digital Health, 1(4), e0000017 (2022).
2. Radojević, D.: [0, 1]-valued logic: a natural generalization of Boolean logic. Yugoslav Journal of Operations Research, 10(2), 185-216, (2000).
3. Radojević, D.: Logical aggregation based on interpolative Boolean algebra. Mathware & Soft Computing, 15(1),125-141, (2008).
4. Čolić, N., Milošević, P., Dragović, I, Ćeranić, M. S.: IBA-VNS: A Logic-Based Machine Learning Algorithm and Its Application in Surgery. Mathematics 12(7), 950 (2024).