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Predicting Nursing Staff Care Capacities in Hospitals with Machine Learning

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Abstract

Background: Hospitals struggle to find adequate staff to secure an optimal quality of care. Continuing nursing staff shortages combined with absences for scheduled personnel, extended by high workloads, lead to complex shift planning problems in hospitals. The limited staff available must be used as efficiently as possible. We are developing methods to predict the available nursing staff care capacity and the absences of staff for a hospital ward, predictions that allow for better planning. This leads us to a prediction of the realized and missed care capacity for up to 14 days.

Methods: We propose predictions based on state-of-the-art machine learning approaches (Deep Neural Network and Extreme Gradient Boosting) and evaluate them based on actual datasets from a university hospital. We use data extracted from past schedules and calendar variables as inputs for our forecasts. A large part of this information remains an untapped potential for optimization. However, data is still scarce. Thus, we investigate whether incorporating information from a different ward can enhance prediction as well. We implemented this data enrichment process in two ways: once by including data from other wards as additional features, and once by adding the information as extra data points.

Results: Our study demonstrates that both missed and realized nursing care capacities can be reliably predicted using machine learning. Incorporating data from other wards might improve prediction accuracy for certain forecast horizons. Our Machine Learning approaches outperformed classical time series forecasts based on Holt-Winters, reducing the mean squared error (MSE) of missed and realized care capacity predictions by up to 33.9% and 43.6%, and reducing the mean absolute error (MAE) by up to 18.3% and 24.6%, respectively. Compared to conventional planning, which is typically based on a moving average approach, the models reduce MSE by up to 23.8% and 46.8% and MAE by up to 10.6% and 25.8%, respectively.

Conclusions: These predictions provide valuable decision support for shift scheduling by leveraging historical staffing and care data, allowing hospitals to define target staff levels and appropriate safety buffers. Overall, our study makes an important contribution to improving workforce planning in hospitals facing limited nursing capacities.