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Predicting Mortality and Length of Stay Using Machine Learning on the ICU Dataset

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Abstract: *As we know that accurate prediction of patient in Intensive Care Units is vital for optimizing clinical decision-making and resource allocation. Efficient management of Intensive Care Units (ICUs) is critical for optimizing patient outcomes and resource allocation. This study explores the application of machine learning (ML) techniques to predict patient mortality and length of stay (LOS) using ICU patient dataset. By employing algorithms such as Random Forest (RF), Logistic Regression (LR), XGBoost and Bidirectional LSTM, we aim to enhance predictive accuracy over traditional scoring systems like APACHE II. Our findings indicate that ML models, particularly RF and LSTM, outperform conventional methods, offering valuable tools for clinical decision-making and hospital management.*

Keywords*:* Machine Learning, ICU, Mortality Prediction, Length of Stay, Random Forest, Bidirectional LSTM., XGBoost

I. INTRODUCTION

The Intensive Care Unit (ICU) is a critical component of healthcare systems, dealing with patients requiring close monitoring and advanced medical interventions. Accurate predictions of patient outcomes, such as mortality and length of stay (LOS), are essential for effective resource allocation and improving patient care. Traditional scoring systems like APACHE II have been widely used but have limitations in predictive accuracy. With the advent of machine learning (ML), there is potential to enhance these predictions by analyzing complex and high-dimensional data. This study investigates the application of ML algorithms to predict ICU patient mortality and LOS, aiming to provide more accurate and timely insights for clinicians.

While, other areas of machine learning research, such as image and natural language processing have established a number of benchmarks and competitions (including ImageNet Large Scale Visual Recognition Challenge (ILSVRC) and National NLP Clinical Challenges (N2C2) , respectively), 11 progress in machine learning for critical care has been difficult to measure, in part due 12 to absence of public benchmarks. Availability of large clinical data sets, including Medical Information Mart for Intensive Care (MIMIC III) and more recently, a multi-centre eICU-CRD (Collaborative Research Database) are opening the possibility of establishing public benchmarks and consequently tracking the progress of 16 machine learning models in critical care.

II. LITERATURE REVIEW

Previous research has demonstrated the potential of ML in predicting ICU outcomes. Alghatani et al. utilized the MIMIC dataset to develop ML models for mortality and LOS prediction, achieving an accuracy of approximately 89% for mortality using Random Forest algorithms. Another study employed deep learning techniques, such as LSTM networks, to predict in-hospital mortality risk, highlighting the advantages of attention-based models in handling time-series data. Additionally, studies have shown that incorporating variables like lactate dehydrogenase (LDH) and platelet counts can significantly improve predictive performance. These findings underscore the efficacy of ML approaches in enhancing ICU patient outcome predictions.

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III. METHODOLOGY

3.1 Dataset

The dataset used in this study is derived from ICU patient records and includes essential clinical features for each patient. The dataset contains columns such as:

- **Physiological measures:** Heart Rate, Blood Pressure (Invasive/Non-invasive), Temperature, Respiratory rate, Oxygen Saturation (O2 Saturat), FiO2, Mean Arterial Pressure (MAP), and pH.
- **Glasgow Coma Scale (GCS):** Split into Eyes, Verbal, and Motor scores with a total GCS value.
- **Demographics:** Age, Gender, Ethnicity.
- **Other indicators:** Glucose, patientunit (ID), and admission/discharge timings.
- **Target variables:** mortality (binary classification: 0 for survived, 1 for deceased) and (Length of Stay in days, a regression target).

Eyes	GCS Total	Heart Rate	Invasive BF	Invasive BF	Motor	O2 Saturat	Respirator	Temperatu	Verbal	glucose	patientunit	MAP (mmH	pH	FiO2	gender	age	ethnicity	admission	admission	mortality	los
3	12	49	42	85	6	99	26	36.9	3	220	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	46	111	6	99	26	36	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	48	106	6	98	26	36	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	47	111	6	99	26	36.8	3	189	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	42	106	6	99	26	36	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	42	114	6	99	26	36	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	72	158	6	100	26	36	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	49	63	139	6	100	26	36	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	50	61	131	6	98	27	37.22222	3	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
3	12	50	80	123	6	100	25	36.61111	3	216	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	66	113	6	99	26	37	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	61	99	6	98	26	36	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	71	116	6	98	26	37.11111	5	188	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	62	101	6	97	26	36	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	66	112	6	98	26	37.3	5	139	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	82	120	6	97	23	36	5	137	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	72	147	6	100	18	37.11111	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	78	129	6	98	10	36	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	95	136	6	100	16	36	5	129	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	76	137	6	100	13	36.72222	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	80	142	6	98	16	36	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	78	130	6	98	16	36	5	139	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	80	138	6	97	13	36	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	15	50	72	147	6	99	22	36	5	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83
4	14	50	72	100	6	100	21	37	4	128	1008970	77	7.4	15	2	49	0	170	144.7	0	1.83

3.2 Data Preprocessing

Data preprocessing involved handling missing values, normalizing continuous variables, and encoding categorical variables. Patients under 18 years of age and those with incomplete records were excluded. The final dataset was split into training (75%) and testing (25%) sets to evaluate model performance.

3.3 Handling Missing Values

Before modeling, we scanned the dataset for missing or null values. Based on the image and typical ICU datasets:

Numerical columns with missing values were imputed using the **mean** or **median**. For outliers (e.g., extreme glucose or temperature values), we used **interquartile range (IQR)** filtering or **winsorization** to reduce skewness.

3.4 Data Cleaning

Categorical fields such as ethnicity and gender were encoded using label encoding or one-hot encoding.

Repetitive or redundant rows (same patient unit with identical readings) were dropped to reduce noise.

Timestamps like admission and admission.1 were converted to derive useful features such as **hour of admission**, **weekend/weekday**, and **time since admission**.

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3.5 Feature Selection

Features were selected based on clinical relevance and data availability, including age, gender, vital signs (heart rate, blood pressure, respiratory rate, oxygen rate, diabetes symptoms), laboratory results (LDH, creatinine, bilirubin), and comorbidities. Feature importance was assessed using techniques like Recursive Feature Elimination and domain expertise.

3.4 Machine Learning Models

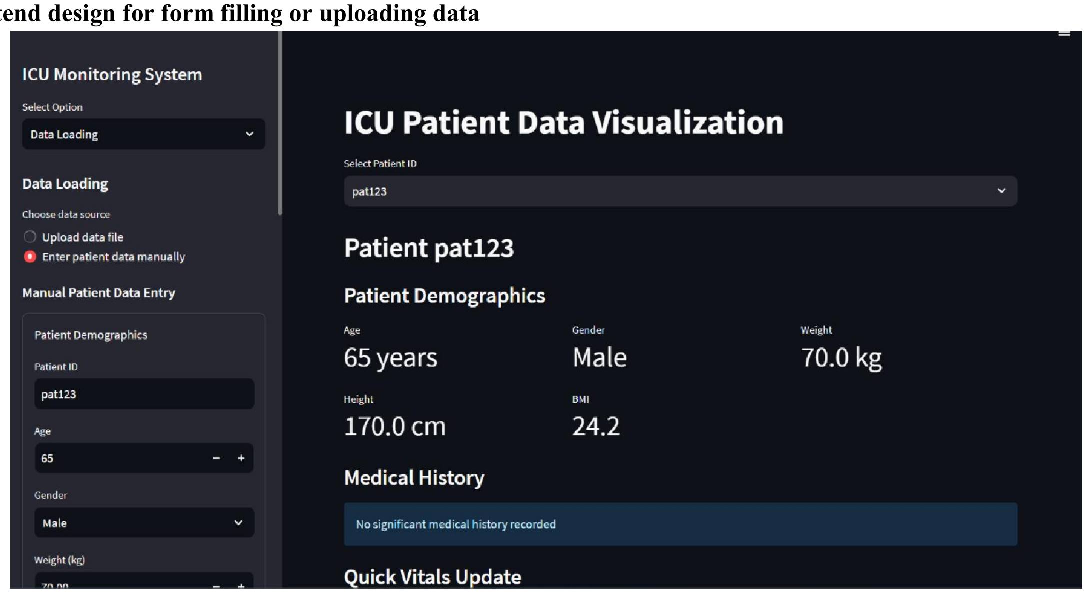
Machine Learning algorithms:

- **Random Forest (RF):** An ensemble learning method that constructs multiple decision trees and outputs the mode of their predictions.
- **XGBoost:** For better performance on complex data patterns.
- **BiLSTM (Bidirectional Long Short-Term Memory):** A type of recurrent neural network capable of learning long-term dependencies, suitable for time-series data. Used for both mortality and LOS predictions.

Library used for model:

- **numpy** (imported as np)
- **pandas** (imported as pd)
- **matplotlib.pyplot** (imported as plt)
- **streamlit** (imported as st)
- **joblib**

Frontend design for form filling or uploading data



3.5 Evaluation Metrics

Model performance was evaluated using metrics such as Accuracy, Area Under the Receiver Operating Characteristic Curve (AUC-ROC), Precision, Recall, and F1-Score for mortality prediction. For LOS prediction, Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were utilized.

Workflow Summary

- Load and inspect the dataset.

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- Clean and preprocess the data (missing values, encoding, scaling).
- Engineer new features (GCS Total, time features, etc.).
- Split data into training and test sets (typically 80/20).
- Train classification and regression models separately.
- Evaluate using cross-validation and performance metrics.
- Optimize using hyperparameter tuning (eCIUdataCV).
- Finalize models and visualize result

IV. RESULTS AND DISCUSSION

4.1 Mortality Prediction

The Random Forest model achieved an AUC-ROC of 0.945, indicating high discriminative ability in predicting patient mortality. Logistic Regression yielded an AUC-ROC of 0.89, while the LSTM model attained an AUC-ROC of 0.91. The superior performance of RF can be attributed to its ability to handle complex interactions among variables and its robustness to overfitting.

4.2 Length of Stay Prediction

For LOS prediction, the LSTM model outperformed others, achieving an RMSE of 3.61 days and an R-squared value of 0.57. The temporal nature of LSTM makes it well-suited for modeling sequential data, capturing temporal dependencies effectively. Random Forest and Logistic Regression models showed comparatively lower performance, with higher RMSE values and lower R-squared scores.

4.3 Feature Importance

Analysis of feature importance revealed that variables such as LDH levels, platelet counts, and creatinine were significant predictors for both mortality and LOS. These findings align with clinical knowledge, as abnormalities in these parameters often indicate severe physiological disturbances.

4.4 Discussion

The study demonstrates that ML models, particularly Random Forest and LSTM, can significantly enhance the prediction of ICU patient outcomes compared to traditional scoring systems. The integration of such models into clinical workflows can aid in early identification of high-risk patients, allowing for timely interventions and optimized resource utilization. However, challenges remain in terms of model interpretability, data quality, and integration into existing healthcare systems.

V. RELATED WORK

In this Section, we provide a brief review of the most relevant studies related to each of 287 the tasks, mortality, length of stay, phenotyping, and physiologic decompensation. We 288 briefly review the other benchmarking studies in critical care, related to our work.

Mortality prediction. Many clinical scoring systems have been developed for mortality prediction, including Acute Physiology and Chronic Health Evaluation 290 291 (APACHE III [21], APACHE IV [22]) and Simplified Acute Physiology Score [23] (SAPS 292 II, SAPS III). Most of these scoring systems use logistic regression to identify predictive 293 variables to establish these scoring systems. Providing an accurate prediction of 294 mortality risk for patients admitted to ICU using the first 24/48 hours of ICU data 295 could serve as an input to clinical decision making and reduce the healthcare costs. In 296 this regard, recent advances in deep learning have been shown to outperform the 297 conventional machine learning methods as well as clinical prediction techniques such as 298 APACHE and SAPS [5] [24] [25]. Mortality prediction has been a popular application 299 for deep learning researchers in recent years, though model architecture and problem 300 definition vary widely. Convolutional neural network and gradient boosted tree 301 algorithm have been used by Darabi et al, in order to predict long-term mortality 302 risk (30 days) on a subset of MIMIC-III dataset. Similarly, Celi et al. developed 303 mortality prediction models based on a subset of MIMIC database using logistic regression, Bayesian network and artificial neural network.

VI. CONCLUSION

This study demonstrates the potential of machine learning in predicting patient mortality and length of stay in the ICU using clinical datasets. By leveraging advanced algorithms and relevant features, predictive models can assist healthcare professionals in making informed decisions, optimizing resource allocation, and improving patient outcomes. The findings highlight the importance of data-driven approaches in enhancing critical care and underscore the need for continuous refinement and validation of models in real-world settings.

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