Deep Learning for Time Series Data in Healthcare

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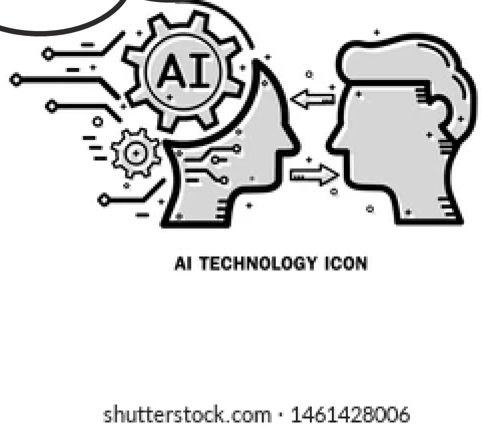
Motivation: Healthcare Jarvis

Based on your current status and **time series data**, I **predict** that you have 50% chance of getting COVID. I have scheduled an appointment for you with Dr. Recovery tomorrow…

I am feeling tired and having a fever and a cough…



Healthcare Jarvis

Iron man's Jarvis

https://www.shutterstock.com/zh/image-vector/artificial-intelligence-ai-communication-human-brain-1461428006
https://gifs.alphacoders.com/gifs/view/10851

Outline

- Background
- Neural Networks and Recurrent Neural Networks in Precision Healthcare
- Methods in Deep Learning Models
- Using Recurrent Neural Networks in Healthcare
- Conclusion and Future Directions

BACKGROUND

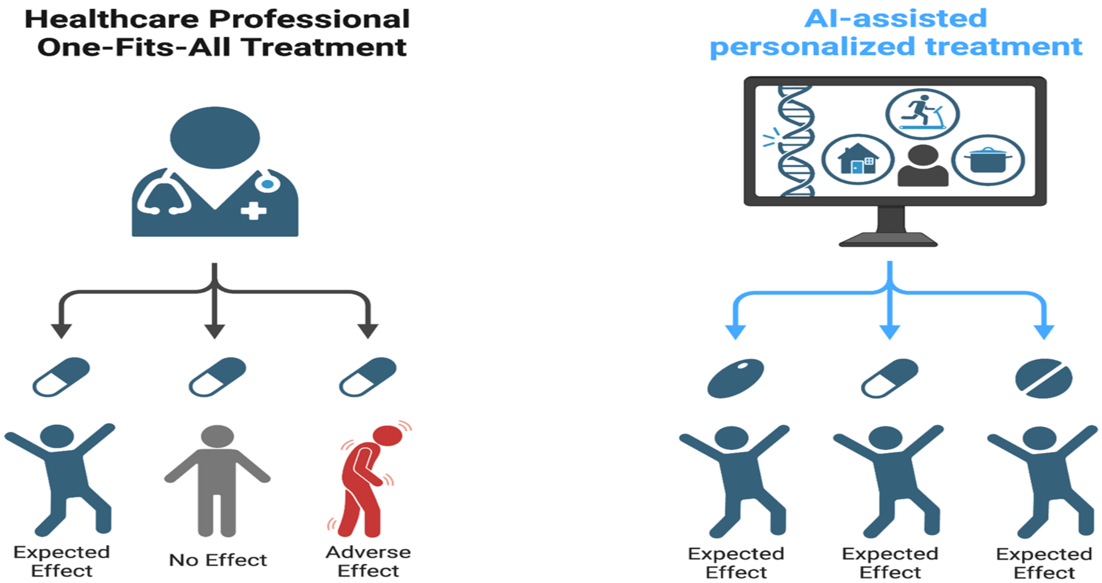
Introduction to AI in Precision Medicine

Transformative Effects of AI in Healthcare

- AI, Artificial Intelligence in general enhances diagnostic accuracy.
- Personalized treatment plans are optimized using patient-specific data.
- Real-time AI monitoring tracks vital signs, alerting providers to critical changes.
- Faster responses and improved patient safety result from AI-driven insights.

Image generated from chatgpt

Difference between Personalized treatment and traditional treatment.



Personalized treatment, unlike traditional treatment take your personal medical history into account making it much more effective.

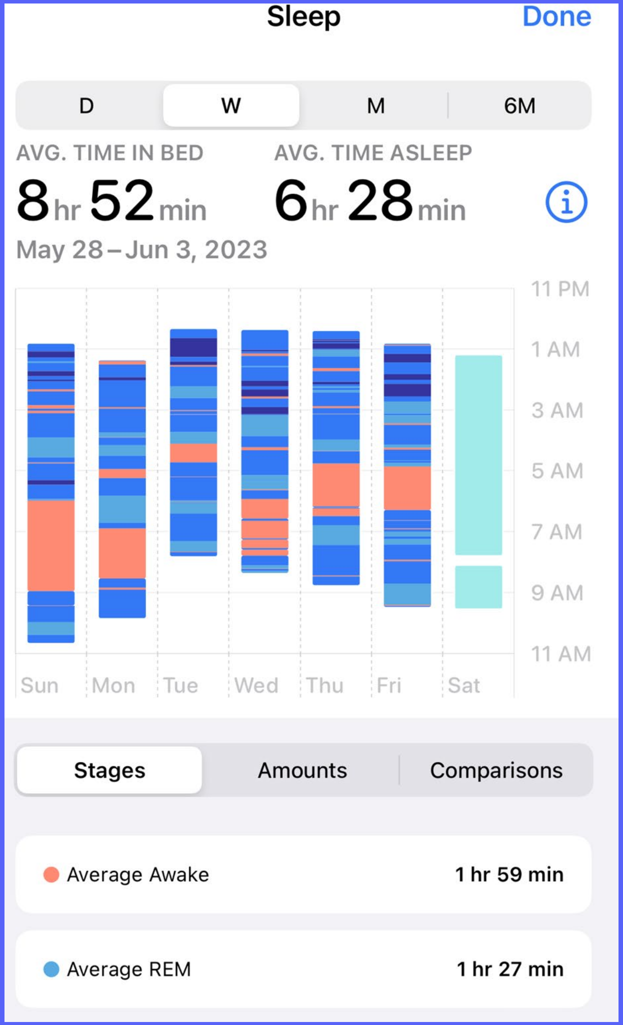
https://www.biorender.com/blog/revolutionizing-our-healthcare-infographic

What is Time Series data

- Time series data is a type of data collected over time at regular intervals.

- Crucial for identifying trends and patterns over time.

- **Healthcare Applications**: Used to monitor vital signs (e.g., heart rate, blood pressure) in real-time and predict health outcomes.

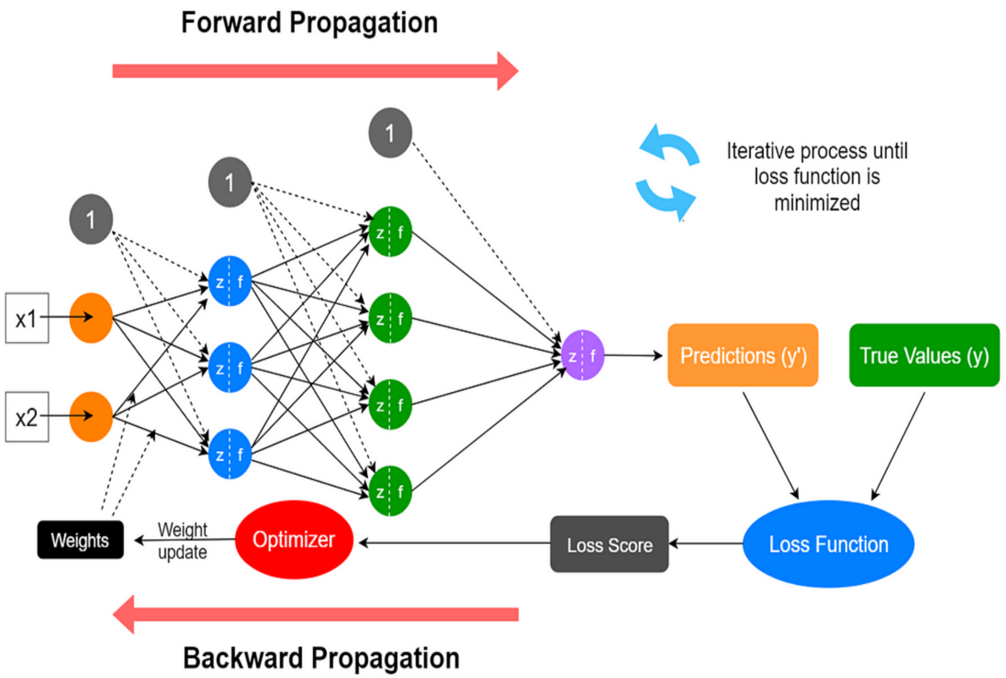


Understanding Neural Networks (NNs)

- Neural Networks (NNs) are layered structures of interconnected neurons: an input layer, hidden layers and output layer.

- NNs handle complex data like medical images and health records, aiding in diagnosis, risk prediction, and personalized treatment.

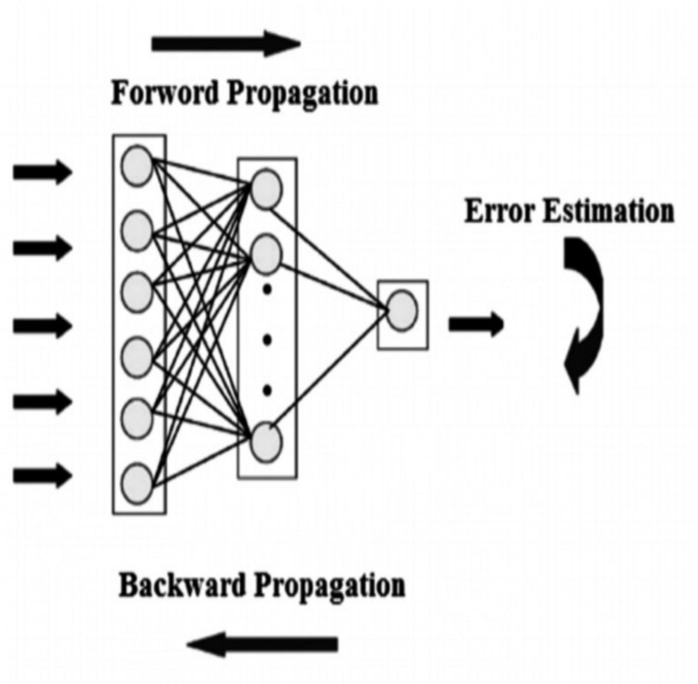
-Traditional neural networks lack memory, struggle with time-dependent patterns, and risk overfitting with sliding windows. Static structures can't adapt to dynamic changes.



https://encord.com/blog/intelligent-character-recognition-icr/

Recurrent Neural network in Time series data

- Input Layer
- Hidden Layer
- Output Layer



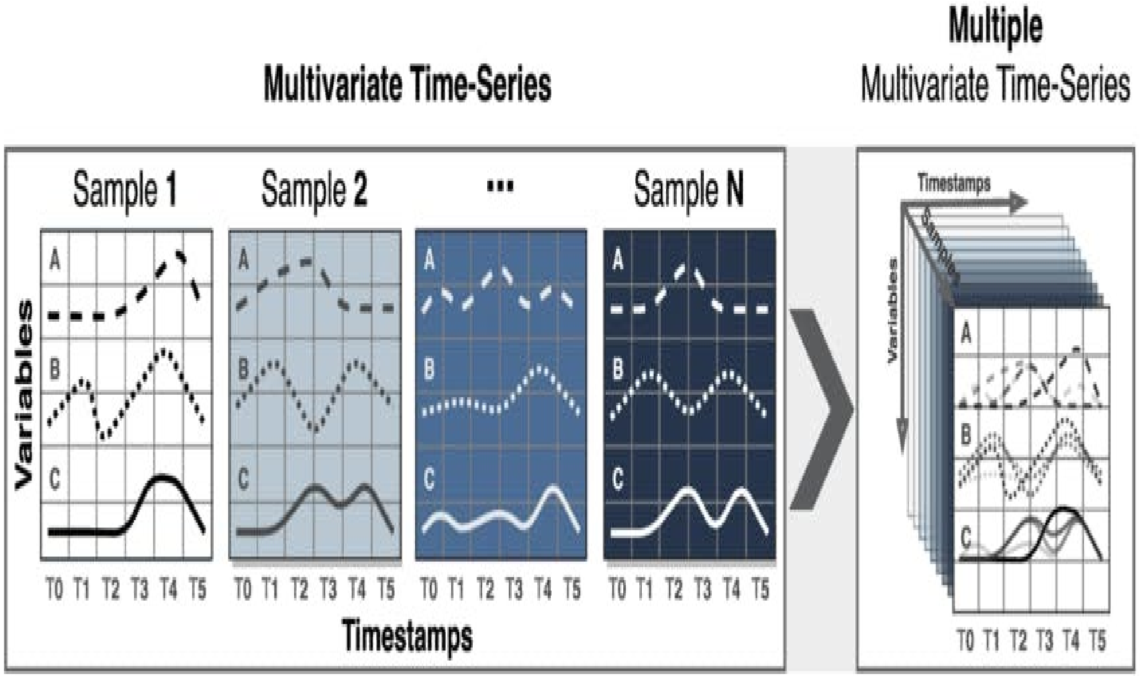
Variants of RNNs:

GRU (Gated Recurrent Unit): A simpler version of RNNs, GRUs help process sequences quickly by using fewer steps to "decide" what to remember, making them faster for real-time tasks.

LSTM (Long Short-Term Memory): A more advanced RNN that's better at remembering important details over long sequences, useful for tasks like understanding health trends or speech patterns over time.

https://builtin.com/data-science/recurrent-neural-networks-and-lstm

Recurrent Neural network in Time series data



- RNNs retain memory, ideal for detecting patterns in sequential data.

- They handle temporal dependencies, suited for prediction, anomaly detection, and sequence classification.

- RNNs work with variable-length sequences, enabling real-time, dynamic predictions.

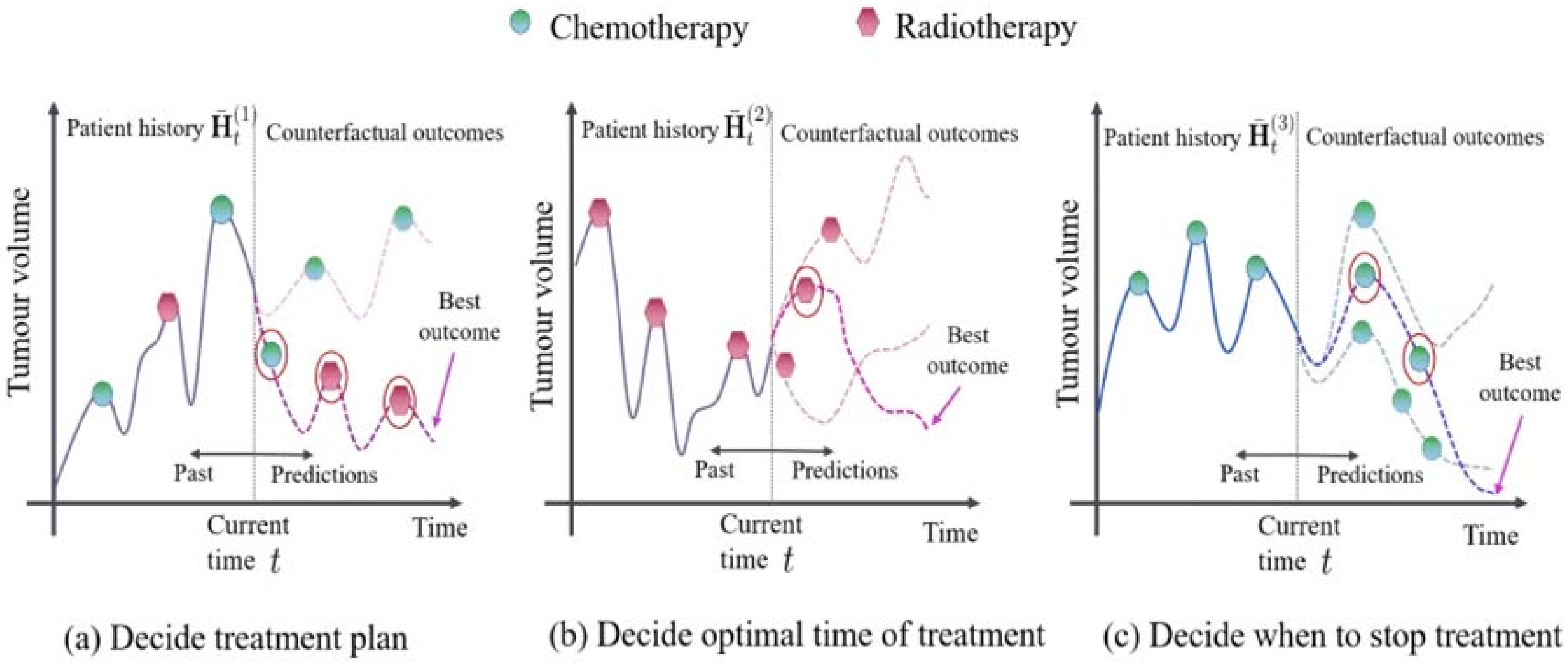
- Advanced variants like LSTMs and GRUs improve long-term dependency handling for extended sequences.

https://encord.com/blog/time-series-predictions-with-recurrent-neural-networks/

Practical application of RNNs in Time series data analysis

- Vital Sign Monitoring
- Sepsis Risk Prediction
- Chronic Disease Management
- Patient Deterioration Alerts
- Heart Disease Detection
- Diabetes Management

Applications



https://www.vanderschaar-lab.com/time-series-in-healthcare/

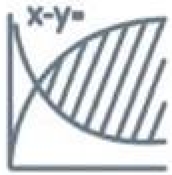
METHODS

AI Model Training and Validation

Data Prep

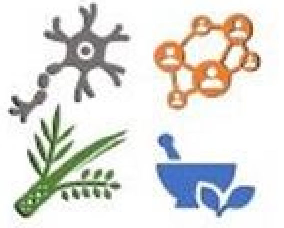
Cleaned Dataset
Normalized Values
Data Split (Train, Val, Test)

Model Training



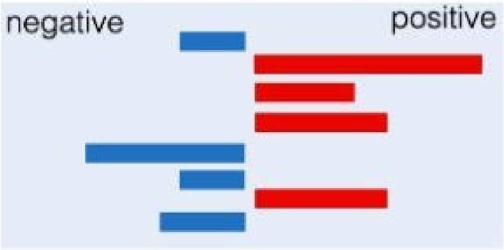
Trained Model
Performance Metrics
Validation Results

Model Evaluation



Evaluation Report
Performance Metrics
Generalization Assessment

Deployment & Monitoring



Deployed Model
Monitoring Dashboard
Retraining Plan

C.J. Wu, et al., “Sustainable AI: Environmental Implications, Challenges and Opportunities,” *MLSys*, 2022.

Key Techniques in AI Healthcare Models and how it differs from traditional machine learning methods:

Feature Engineering

Identifies and enhances critical data features to improve AI's ability to interpret complex healthcare information.

Attention Mechanisms

Directs the model's focus to important data points, boosting interpretability—especially useful in imaging to highlight potential problem areas.

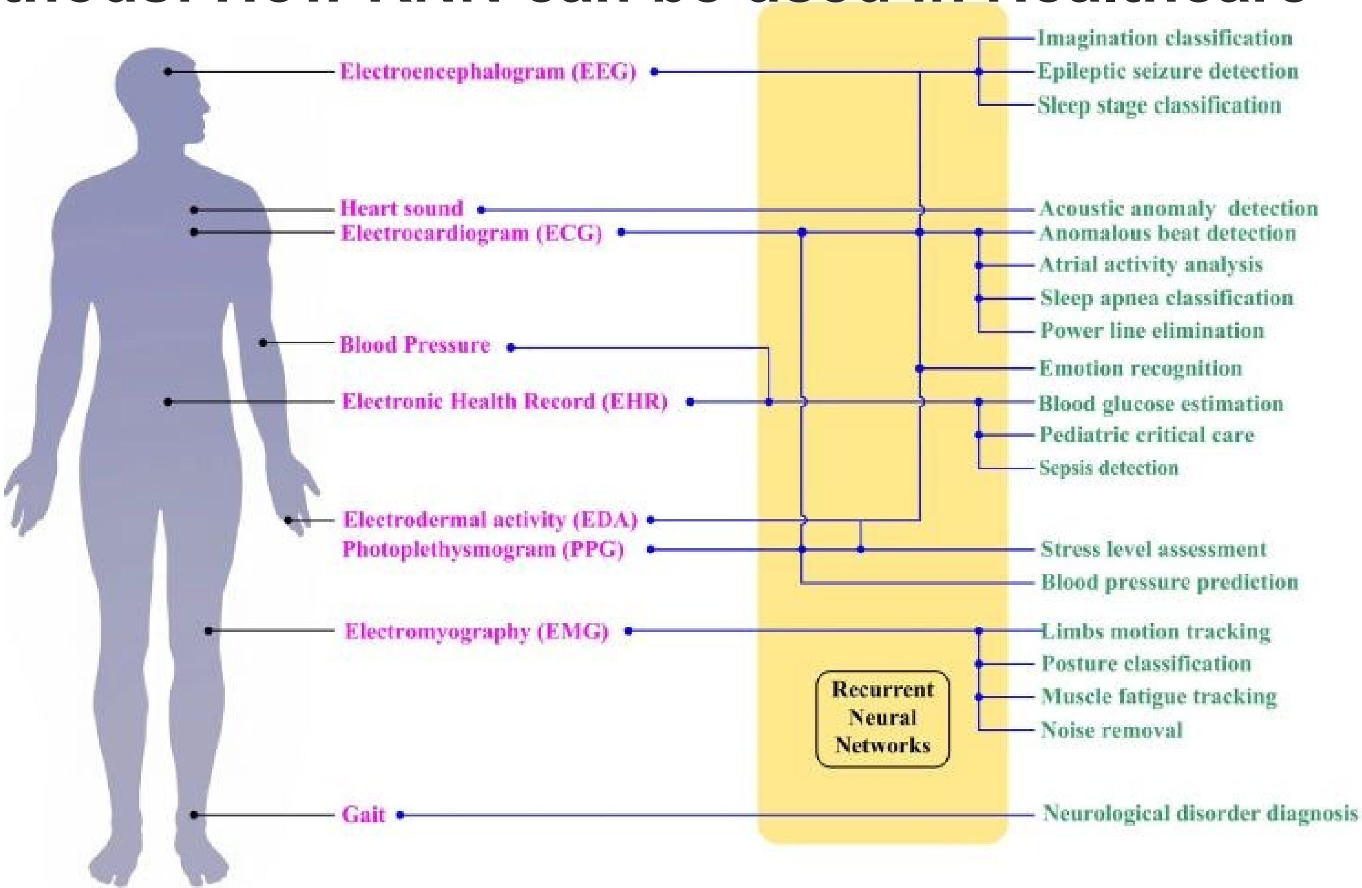
Regularization Techniques

Strategies like dropout help prevent overfitting, making models more adaptable and reliable on new patient data.

Data Augmentation

Expands training data through transformations (e.g., rotations, scaling), increasing model robustness in applications like imaging.

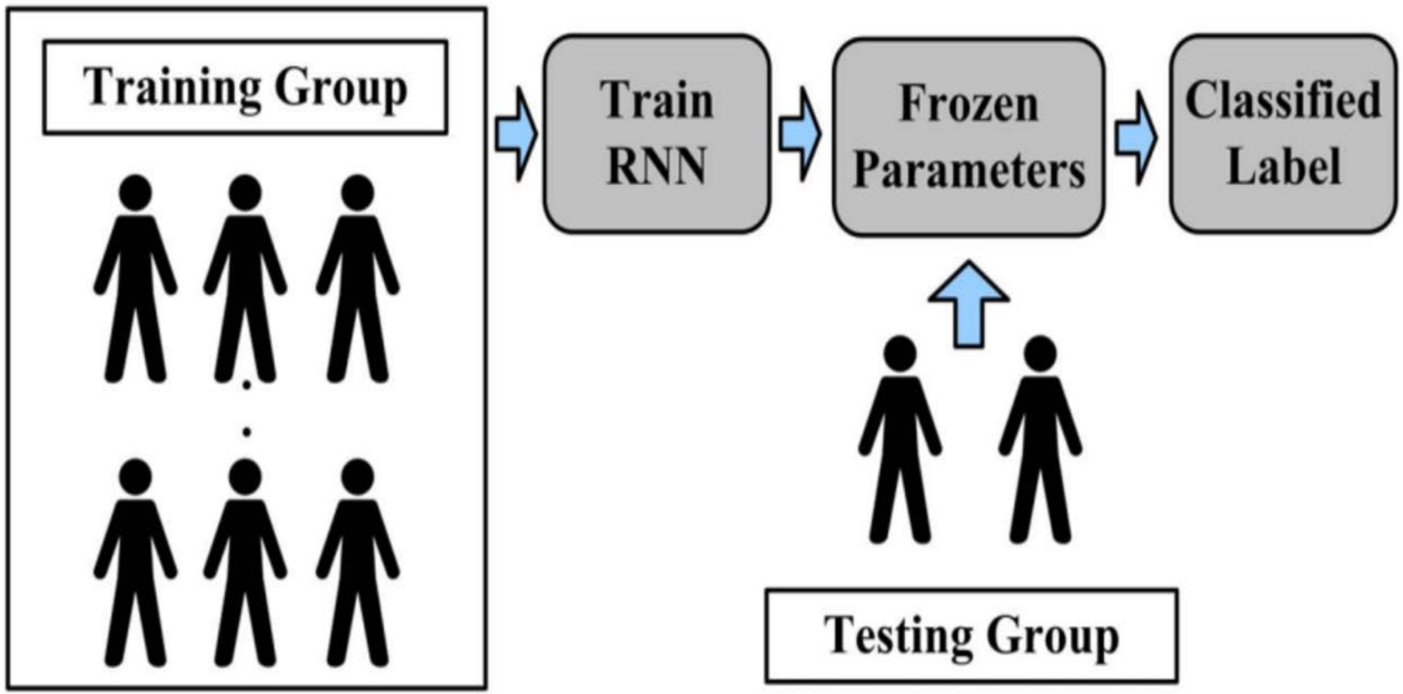
Methods: How RNN can be used in Healthcare



S. Mao et. al., “A review of Recurrent Neural Network-based Methods in Computational Physiology,” *IEEE Trans. on Neural Networks and Learning Systems*, 2023.

Methods: Training RNN in Healthcare

(a)



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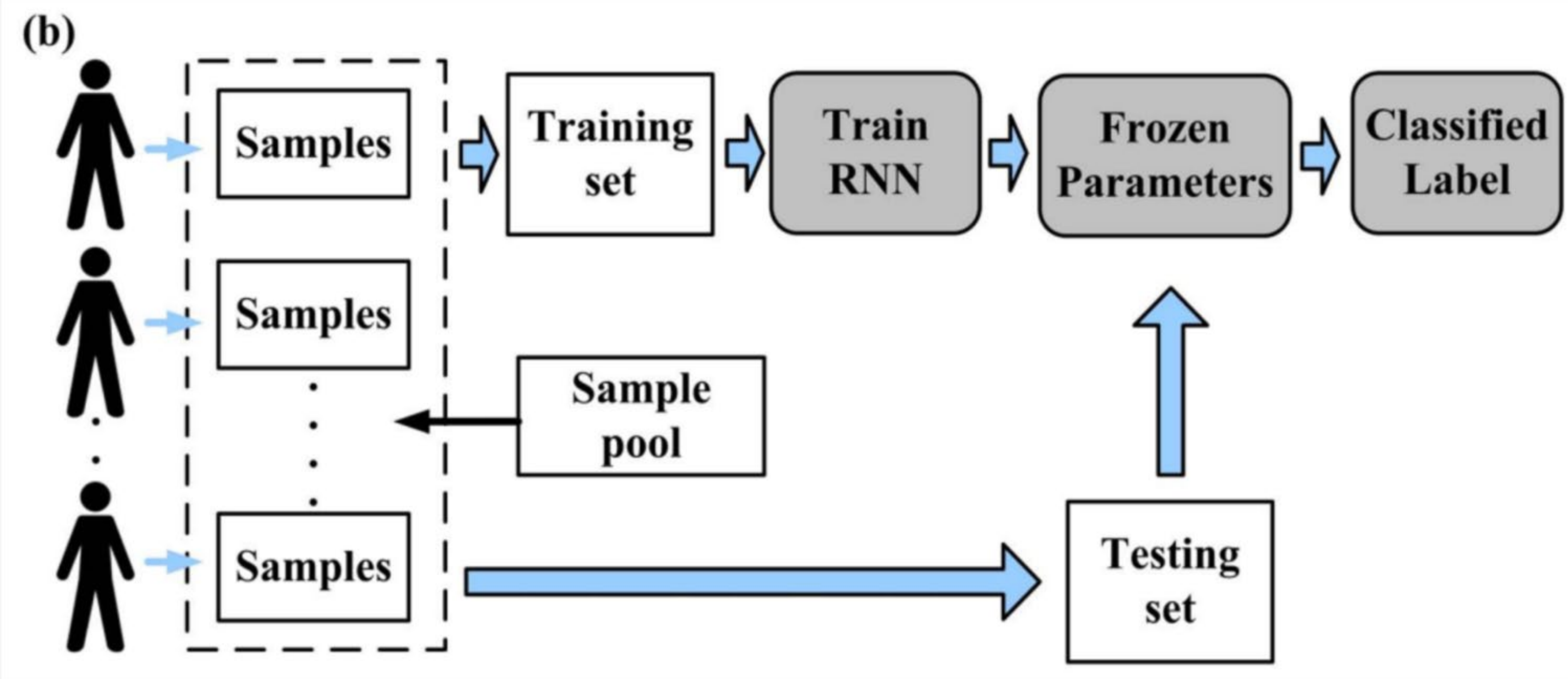

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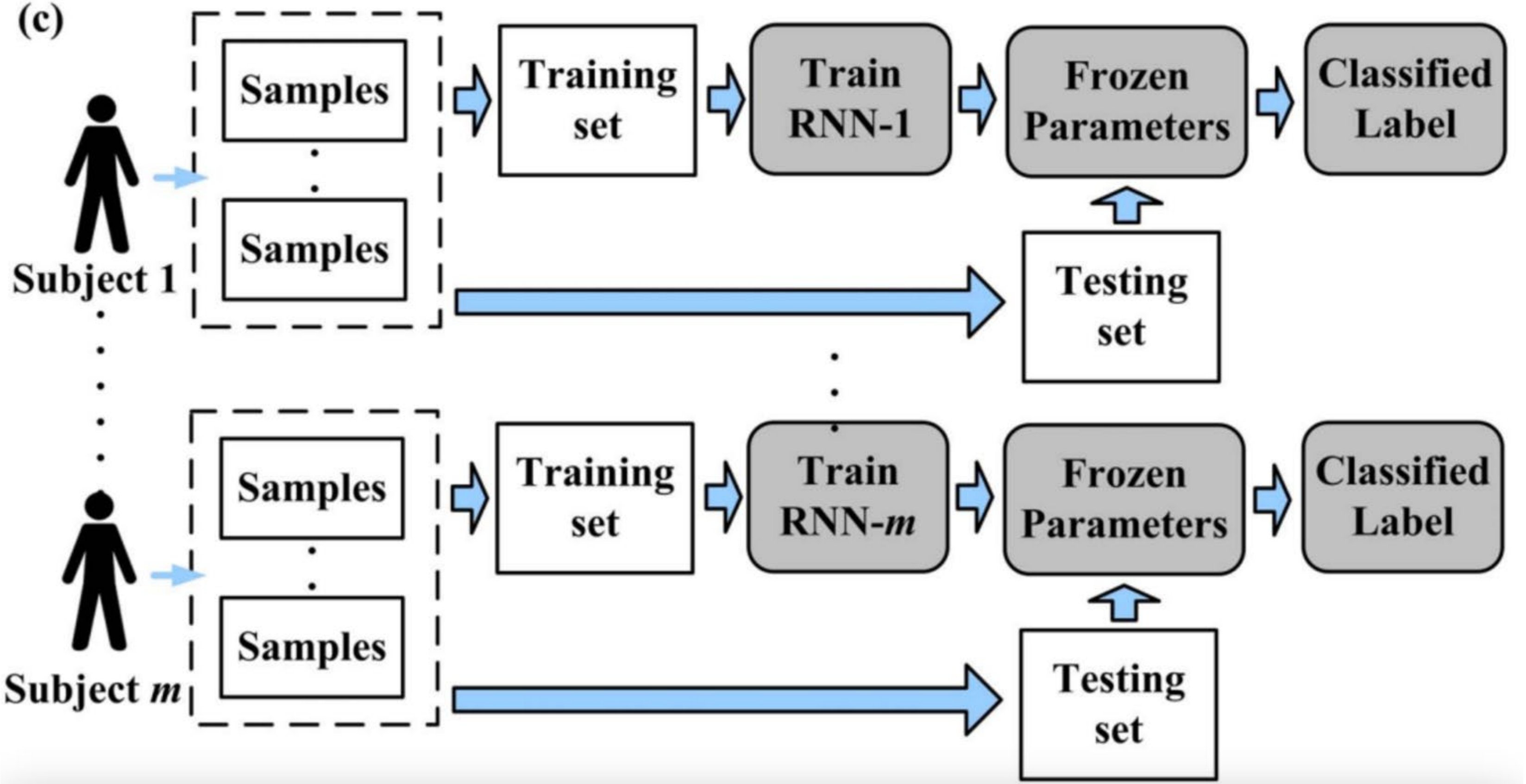

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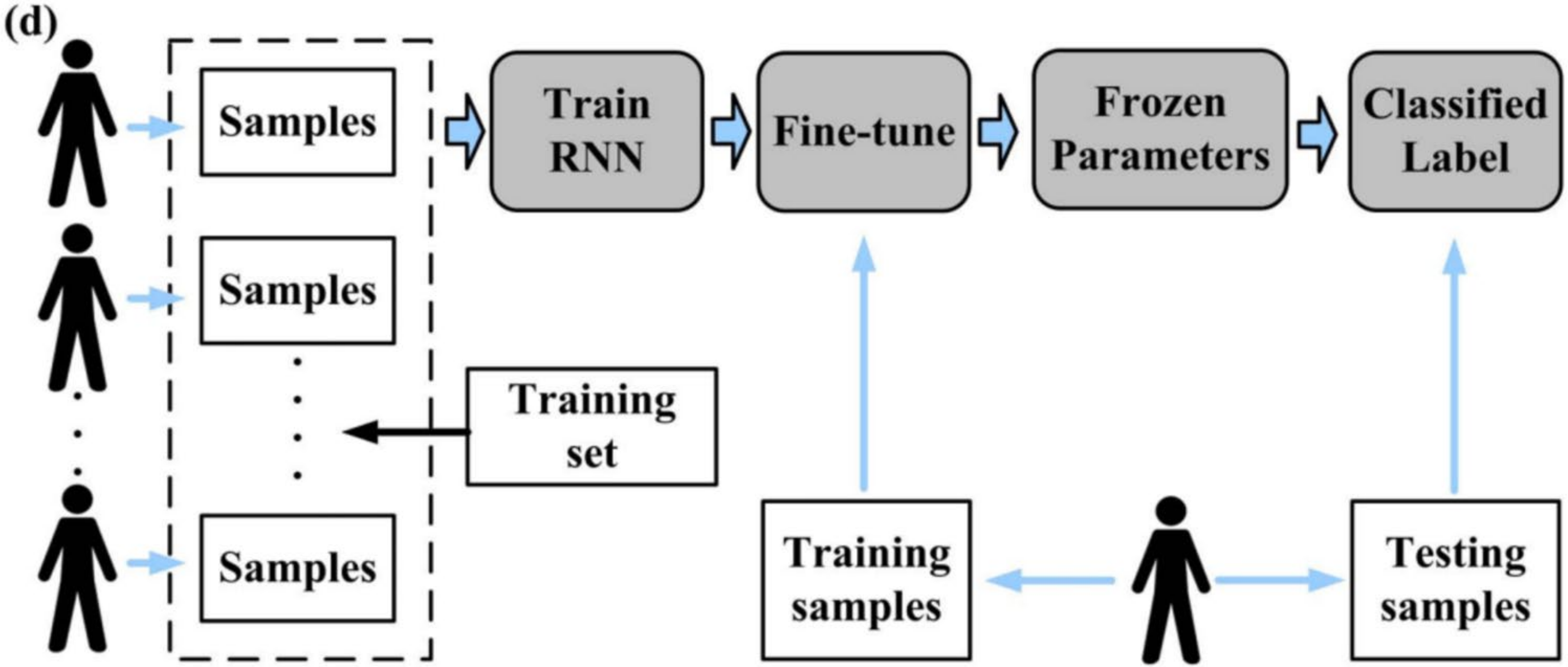

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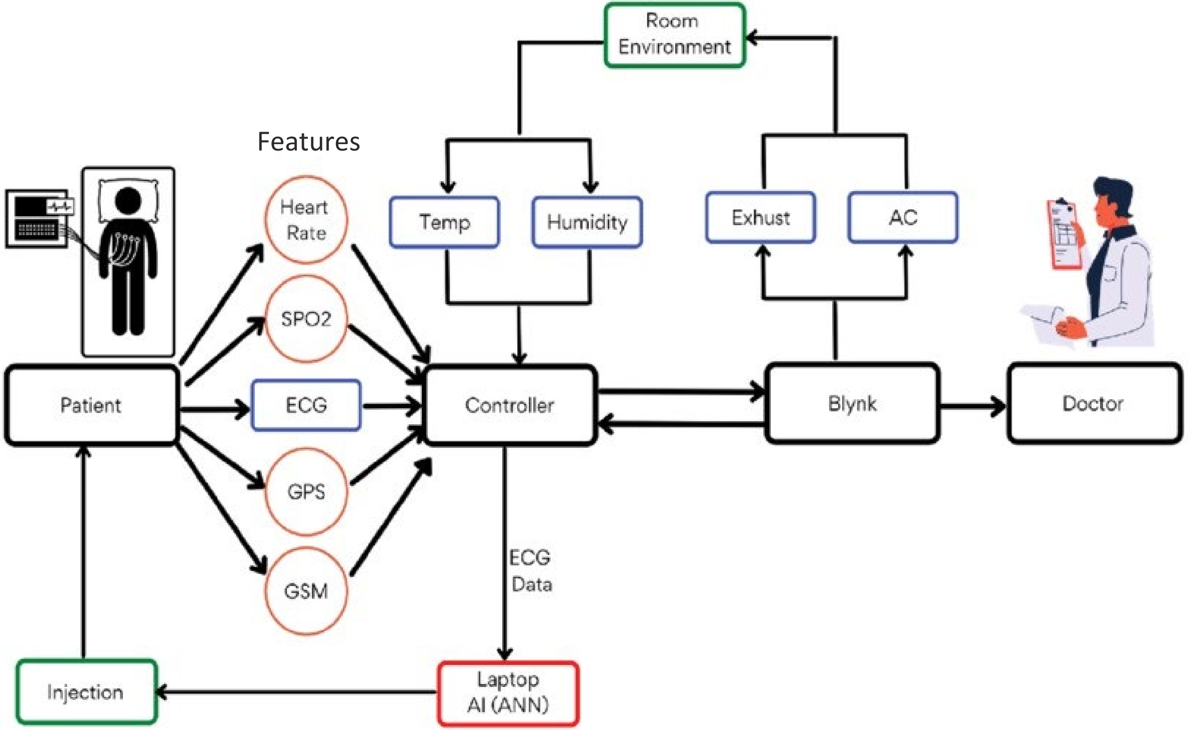
Methods: Using RNN in Healthcare



- Patient Monitoring: Tracks vitals (heart rate, SpO2, ECG) and room conditions (temperature, humidity).
- Data Processing: Controller processes data; RNN on laptop analyzes it.
- Alerts & Communication: Sends real-time updates to doctor via Blynk for timely intervention.

Using time series data to train RNN can design personalized treatment plans

S. Mao et. al., "A review of Recurrent Neural Network-based Methods in Computational Physiology," *IEEE Trans. on Neural Networks and Learning Systems*, 2023.

FINDINGS & RESULTS

Results: Using RNN in Healthcare

These results are based the cited papers below. My original paper is an overview paper.

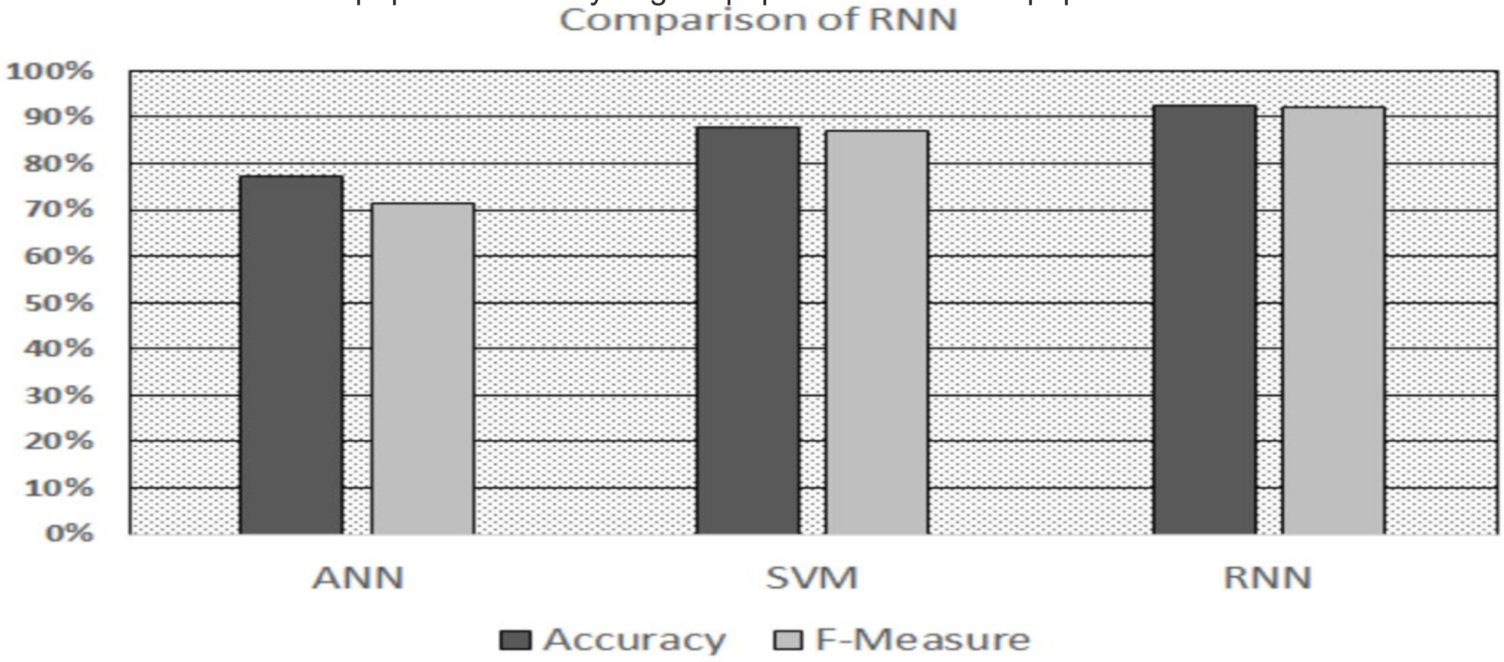


Fig. 3.2 Comparison of RNN with ANN and SVM.

RNN model outperforms the other two models Artificial Neural Network & Support Vector Machine, achieving a higher precision of 98.03% compared to 96.04% and 95.77% for ANN and SVM, respectively.

https://researchonline.gcu.ac.uk/en/studentTheses/an-integrated-remote-health-monitoring-system-for-ai-based-detect

Results: Using RNN in Healthcare

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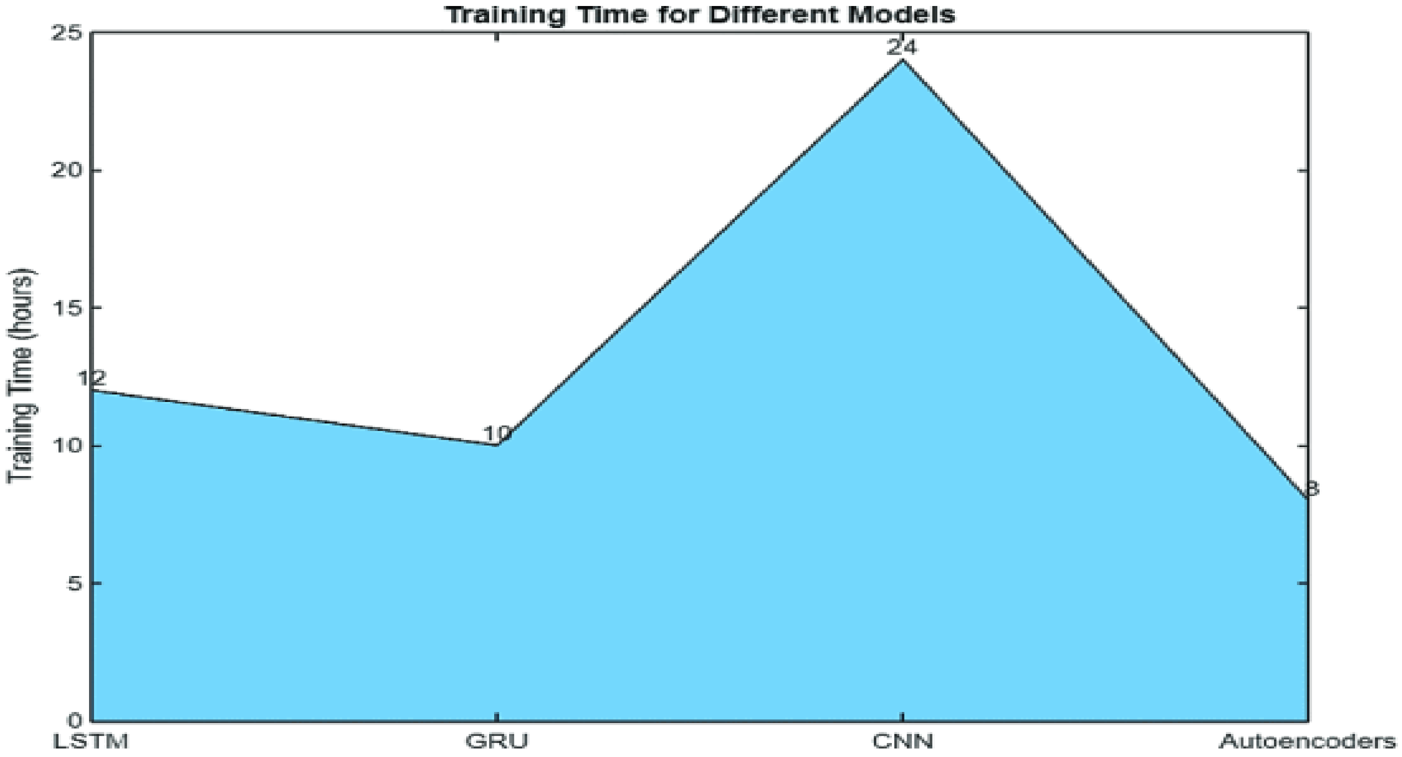

RNNs take less time to be trained as well making them more efficient.

D. Bhat, et. al., "Personalized Health Monitoring Platform with Privacy Preservation in IoT Cloud Networks using Deep Learning," *IEEE International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, 2024.

Research Insights

Key Findings

- RNNs, including LSTMs and GRUs, are used in 84% of healthcare studies for time series predictions, analyzing sequential data like patient vitals.
- GRUs outperform LSTMs by 1% AUC—a metric measuring model accuracy in distinguishing between risk categories, where 1.0 is perfect and 0.5 is random guessing.
- Bidirectional RNNs further enhance performance in predicting outcomes like hospital readmissions, mortality rates, and length-of-stay, aiding better healthcare decisions.
- GRUs' feature-specific decay patterns reduced Mean Squared Error (MSE) by 5%, enhancing accuracy in predicting long-term disease progression such as Alzheimer's.
- Incorporating time intervals into models for heart failure predictions increased the Area Under the Curve (AUC) by 3%, highlighting the importance of time-sensitive data analysis.

Key Findings

- RNNs have demonstrated a performance improvement of up to 15% over traditional methods in predicting patient mortality rates.

- GRUs in diabetes management have reduced false positive rates by 20%, allowing for better monitoring and intervention strategies.

- Early warning systems using RNNs have significantly improved survival rates for sepsis patients by facilitating timely interventions.

ETHICAL CONSIDERATIONS

Ethical Considerations in AI Healthcare

Data Bias in AI Models

- AI models trained on non-representative data can perpetuate existing biases.
- Bias in training datasets can lead to unequal healthcare outcomes across demographics.
- Examples of bias have been observed in diagnostic tools that perform poorly on underrepresented populations.

Model Transparency and Interpretability

- Many AI systems operate as 'black boxes', obscuring decision-making processes.
- Lack of transparency can erode trust among healthcare providers and patients.
- Explainable AI (XAI) aims to clarify AI decisions, enhancing clinician confidence in AI recommendations.

CONCLUSION

Conclusion

AI in Healthcare:

- Impact
- Challenges

Future Direction:

- Hybrid Models
- Explainable AI
- Data Diversity

Questions?

Acknowledgments

I would like to express my gratitude to everyone in Computer Science faculty for being very supportive and kind throughout the process, especially Dr. Elena, Dr. Nic and Dr. Wenkai for their invaluable insights and guidance throughout the research process.

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- Mohammad Amin Morid et al. 2023. Time Series Prediction Using Deep Learning Methods in Healthcare. ACM Transactions on Management Information Systems 14, 1, Article 2 (2023), 29 pages. https://doi.org/10.1145/3531326.
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Thank you