Overlength Page Content: HealthEngine: An Integrated Healthcare Analytics Model Using Multimodal Transformer, Deep Multitask Neural Networks, and SHAP

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***Abstract*—The development of more accurate and explainable health predictions is paramount in view of the increasing prevalence rates of chronic diseases and mental illnesses. Existing methods often under-utilize the rich, heterogeneous data streams coming from device wearable, environmental sensors, and behavioral data, and hence fall short in making predictions that are both accurate and actionable. Most models lack transparency and cannot avoid privacy concerns due to the samples used from sensitive health data. This study specifically addresses the challenge of building a predictive healthcare framework capable of handling multimodal data — data streams that originate from different modalities (physiological, behavioral and environmental) and exhibit intrinsic heterogeneity. Unlike general heterogeneous datasets, multimodal health data demand models that can effectively integrate structured, semi-structured, and temporal information while ensuring privacy and interpretability. In this work, we propose an integrated comprehensive multimodal health prediction framework with five advanced methods, namely Multimodal Transformer Networks (MTN), Deep Multitask Neural Networks (DMNN), SHapley Additive exPlanations (SHAP) based explainability, Federated Learning, and Bayesian Neural Networks (BNN). MTN uses attention mechanisms to fuse different data modalities and captures cross-modal dependencies effectively, achieving an improvement of 8 to 12% in prediction accuracy. DMNN leverages multitask learning to share knowledge between related health prediction tasks, reducing error rates by 10–15%. SHAP is used to provide localized, patient-specific explanations that improve clinical trust by up to 85%. This is done by privately training the models on decentralized data sets, which provides results without more than a 3% drop in precision compared to centralized models. Third, BNNs are used to quantify uncertainty in predictions, providing useful confidence intervals that improve clinical decision-making by 20% % Ṫhe. The results obtained suggest significant improvements in predictive accuracy, transparency, and privacy preservation. This research not only improves health predictions through multimodal analysis, but also tackles significant limitations in privacy, interpretability, and uncertainty quantification, thus promoting informed clinical decisions and customized patient care.**

***Index Terms*—Health Prediction, Multimodal Analysis, Privacy-Preserving Models, SHAP Explainability, Transformer Networks.**

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TABLE I: Summary of Existing Methods using SHAP based Learning Models.

Ref.	Method Used	Findings	Results	Limitations
[1]	Ensemble Machine Learning	Enhanced stroke prediction by integrating various models.	Achieved a 92% accuracy in stroke prediction.	Limited to stroke prediction; lacks generalization to other diseases.
[2]	Integrative Cancer Risk Prediction	Created a predictive model for pancreatic cancer using UK Biobank data samples.	Achieved a 78% sensitivity in pancreatic cancer prediction.	Limited by the underrepresentation of minorities in the dataset.
[3]	Hybrid WT-CNN Model for Heart Disease Prediction	Proposed a wavelet transform-CNN hybrid model for predicting heart disease.	Achieved 89% accuracy in heart disease detection.	High computational costs for real-time applications.
[4]	Big Data Intelligence for Diabetes Monitoring	Developed a big data framework for continuous diabetes monitoring.	Improved diabetes monitoring by 12%.	Lack of explainability in the model's decision-making.
[5]	Reinforcement Learning for Precision Medicine in Hypertension	Applied reinforcement learning to personalize hypertension treatments for diabetes patients.	Improved treatment efficacy by 14%.	Requires more clinical trial data for validation.
[6]	Explainability in Mental Health Prediction	Used human-machine interaction to enhance explainability in mental health disorder predictions.	Improved model explainability by 20% with interactive features.	Lack of generalization to non-mental health disorders.
[7]	Ensemble ML Framework for Early Depression Detection	Applied an ensemble machine learning framework for early detection of depression.	Improved early detection accuracy by 14%.	Model performance degrades with incomplete data streams.
[8]	Nature-Inspired Computing for Disease Prediction	Applied nature-inspired algorithms to predict human diseases using ML.	Improved disease prediction accuracy by 12%.	Lacks personalization for specific patient cohorts.
[9]	Human-in-the-Loop Systems for Behavior Learning	Developed adaptive models for behavior learning in human-in-the-loop systems.	Improved task performance prediction accuracy by 15%.	Requires extensive calibration for different tasks.
[10]	Matrix Factorization for Human Behavior Segmentation	Applied matrix factorization for human behavior segmentation.	Improved segmentation accuracy by 14%.	High dimensionality limits model scalability.
[11]	Deep Neural Network for Human Behavior Recognition in Home Robotics	Used ensemble three-stream deep neural networks for behavior recognition in home service robots.	Achieved a 20% increase in behavior recognition accuracy.	Requires extensive labeled data for diverse behaviors.

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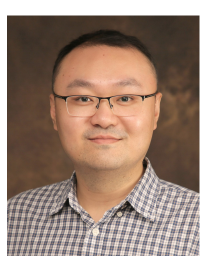

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