Decoding Diabetes: Harnessing AI to Accurately Predict Real-Time and Future Blood Glucose Levels for Diabetes Management Using Diet, Exercise, Insulin Intake, and Heart Rate Variability

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Continuous glucose monitoring (CGM) systems are crucial in diabetes care, but focus only on monitoring blood glucose levels (BGL), neglecting diet, exercise, and medication and lacking predictive capabilities. This study introduces Dual Temporal Recurrent Ensemble (DTRE), a novel AI model enabling real-time BGL monitoring without traditional CGM systems and forecasting BGL for 30-120 minutes when integrated with CGM data. This research hypothesized that DTRE would achieve superior prediction accuracy in forecasting over multiple time horizons compared to existing models, provide clinically acceptable real-time glucose predictions using non-invasive biomarkers, and demonstrate better accuracy with high-frequency datasets. The model combines advanced machine learning architectures through two parallel branches, integrating key biomarkers including diet, exercise, insulin intake, heart rate, and heart rate variability. This research is the first comprehensive study on developing and testing AI models on two diverse datasets with different sampling frequencies, namely OHIOT1DM and D1NAMO. DTRE achieved forecasting accuracy with a Mean Absolute Relative Difference (MARD) of 7.6% at 30 minutes and 19.2% at 120 minutes, outperforming existing models by 13-41%. For real-time BGL predictions, DTRE surpassed commercial CGM systems with a MARD of 7.17% on the D1NAMO dataset compared to FreeStyle Libre 3 (7.9%) and Dexcom G7 (8.2%). The results confirmed the hypotheses by exceeding clinically acceptable benchmarks in multi-horizon and real-time BGL predictions. Future research should integrate additional data elements, modern wearable devices, Type 2 Diabetes, and datasets with more diverse populations to create an accessible and effective diabetes management tool.

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