HDformer: A Higher Dimensional Transformer With a Novel Time Square Attention Mechanism Utilizing Long Range Vascular Signals for Diabetes Detection, and an AI-Based PPG Wearable

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Diabetes mellitus is a global concern, and early detection can prevent serious complications. 50% of people live with undiagnosed diabetes, disproportionately afflicting low-income groups. Non-invasive methods have emerged for timely detection; however, limited accuracy constrains their clinical usage. In this research, Phase-1 creates a novel Higher Dimensional Transformer (HDformer), the first Transformer-based architecture which utilizes long-range photoplethysmography (PPG) to detect diabetes. Long-range PPG maximizes signal contextual information when compared to the <30 second signals commonly used in existing research. To increase the computational efficiency of HDformer's long-range processing, a new attention module, Time Square Attention (TSA), is invented to reduce the volume of tokens by >10x, while retaining the local/global dependencies. TSA converts the 1D inputs into 2D representations, grouping the adjacent points into a single 2D token. It then generates dynamic patches and feeds them into a gated mixture-of-experts (MoE) network, optimizing the learning on different attention areas. HDformer achieves state-of-the-art results (sensitivity 98.4, accuracy 97.3, specificity 92.8, AUC 0.929) on the standard MIMIC-III dataset, surpassing existing research. Phase-2 develops an end-to-end solution where a low-cost wearable is prototyped to connect with the HDformer in the Cloud via a mobile app. This scalable, convenient, and affordable approach can provide instantaneous detection and continuous monitoring for individuals, help doctors easily screen diabetes, and safeguard underprivileged communities, minimizing treatment delays and saving lives. This work can also be generalized to analyze other long-range biomedical waveforms, further expanding its impact.

Awards Won:
Second Award of $2,000
Shanghai Science Association for Young Talents: Science Seed Award
Association for the Advancement of Artificial Intelligence: AAAI Student Memberships for each finalist that is part of the 1st, 2nd, and 3rd Prize Winning projects and 5 Honorable Mention winning projects (up to 3 students per project) (in-kind award / part of the 1st-3rd prize)
Association for the Advancement of Artificial Intelligence: First Award of $1,500