Applying Physics-Informed Neural Networks and Eye-Tracking Data to Gain Cognitive Insights in Human-Centred Applications

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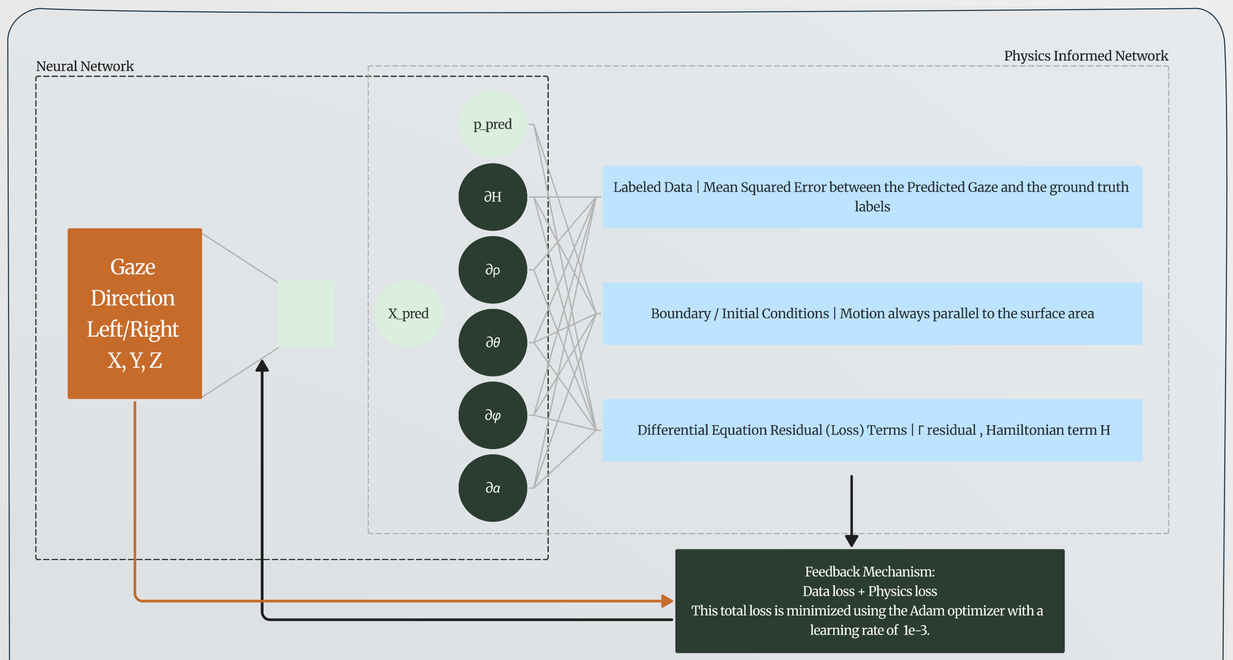
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A **Physics-Informed Neural Network (PINN)** is a network whose loss combines a standard data term with a physics term, derived from the equations governing the system. Combining the **equations governing the dynamics of an eye** with **eye-tracking data**, we created an algorithm that essentially replicates the function of an eye-tracking software.

Through this process, we examined different approaches and neural networks to this problem, and we even correlated the lower-accuracy instances with specific cognitive states.

Objectives

- Model gaze with physics, not just data.
- Turn gaze into cognitive insight.
- Keep it responsible and sustainable.



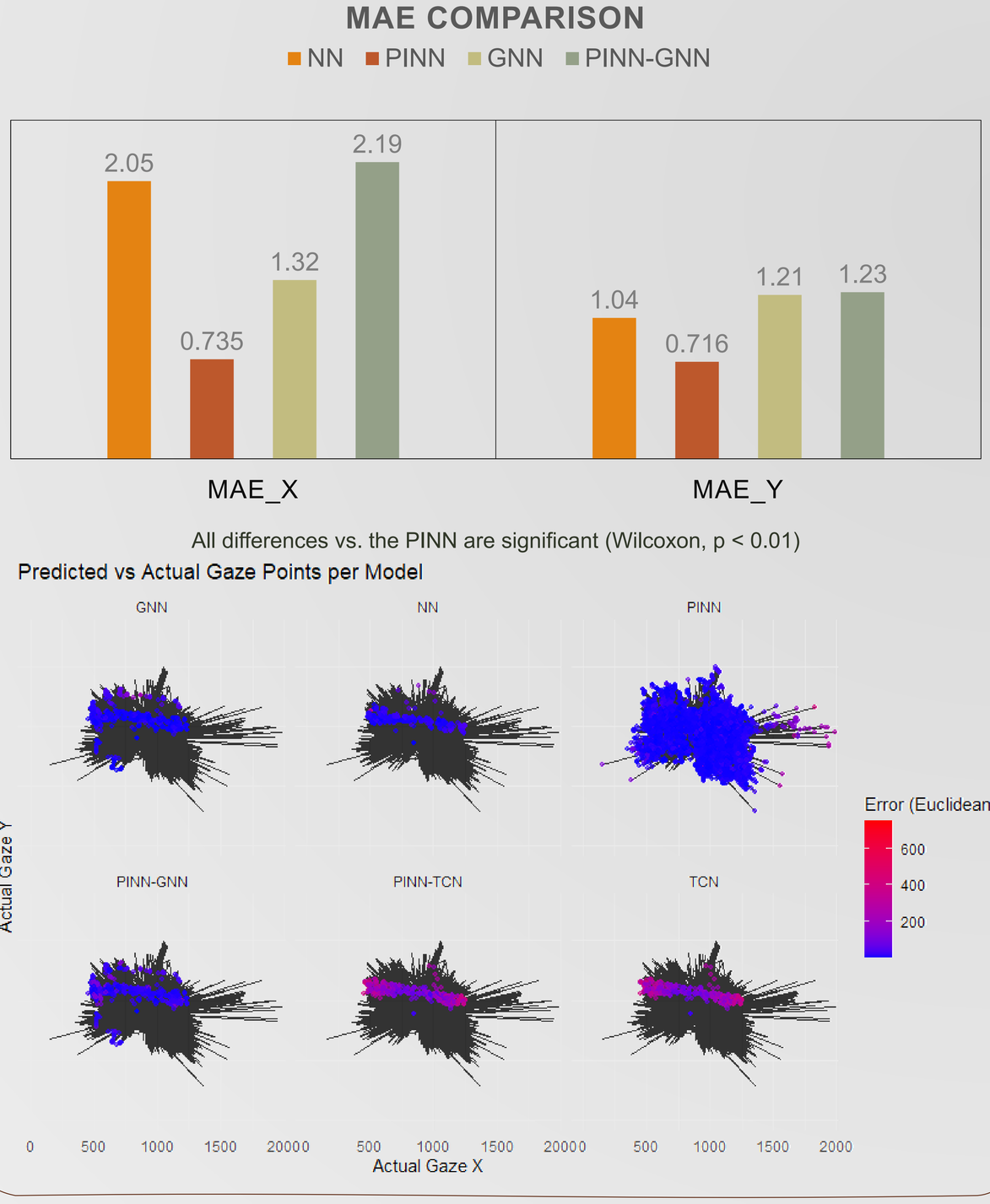
$L_{total} = L_{data} + \lambda L_{physics}$ *(physics weight $\lambda = 1.4$, tuned)*

Guiding equation. The physics term encodes the eye's rotational dynamics on Donder's surface:

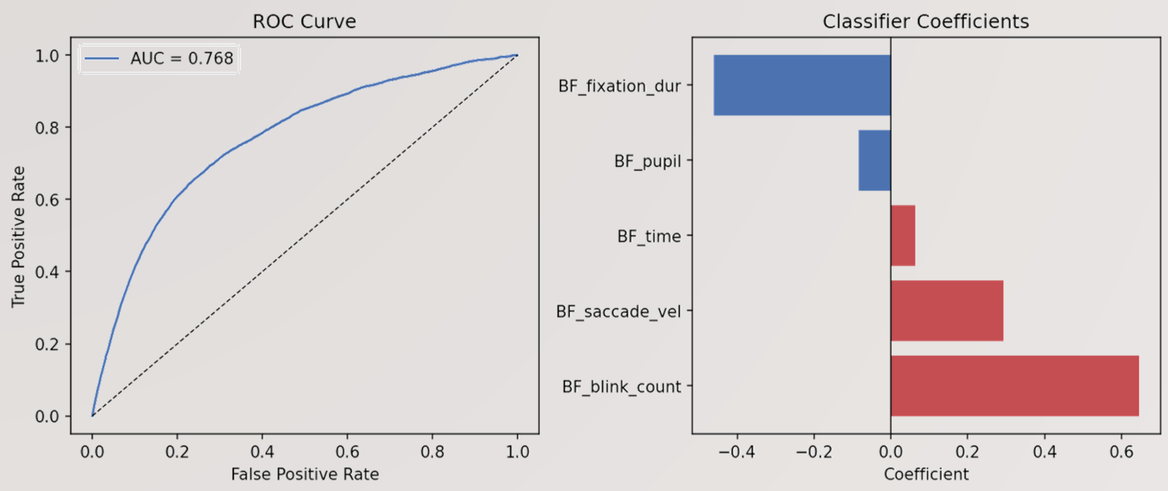
$$H = \frac{\delta}{2}\Gamma_1^T\Gamma_1 + p^T F$$

where $\Gamma = \frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{X}} - \frac{\partial \mathcal{L}}{\partial X}$ is the Euler–Lagrange operator on the Lagrangian $\mathcal{L}$, $\Gamma_1 = G^{-1}\Gamma$, and G is the metric of the gaze coordinates $(r_\theta, r_\phi, r_\alpha)$ with $\boldsymbol{r}_\gamma = \frac{\partial \rho}{\partial \gamma}$ for the mapping $\rho : [0,2\pi] \times [-\pi/2, \pi/2] \rightarrow S^3$; p is the Lagrange multiplier and δ a constant.

The pure PINN achieves the lowest error on both axes, beating the feed-forward, GNN, and TCN baselines and every PINN-hybrid.



An **AUC** of **0.768** is well above chance, which establishes that the ocular features carry real joint information about when the physics model fails. It is also far from perfect, and it should be. The value of the residual is precisely that it captures something the standard features do not fully explain.



Conclusions

- Physics-informed constraints give the most accurate gaze model tested.
- Adding graph/temporal layers to the PINN increased error variance, indicating the physics prior alone captures gaze dynamics most cleanly.
- The approach is interpretable and data-efficient.
- The same signals are a promising substrate for cognitive insight (attention, fatigue, comprehension).

References

Roumpas, K., Michanetzi, E.-L., Minas, D., Fotopoulos, A., & Xenos, M. (2025). A comparative study of physics-informed and conventional neural networks for predicting on-screen gaze points from eye-tracking data. Expert Systems with Applications, 281, 127655.

Roumpas, K., & Xenos, M. (2026). Modelling Eye Mechanics Using Eye-tracking Glasses and Deep Learning. 2026 4th Cognitive Models and Artificial Intelligence Conference (AICCONF), 1–6.

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