

A Personalised Digital Twin Framework For Alzheimer's Disease Prediction And Intervention Simulation

P2-14

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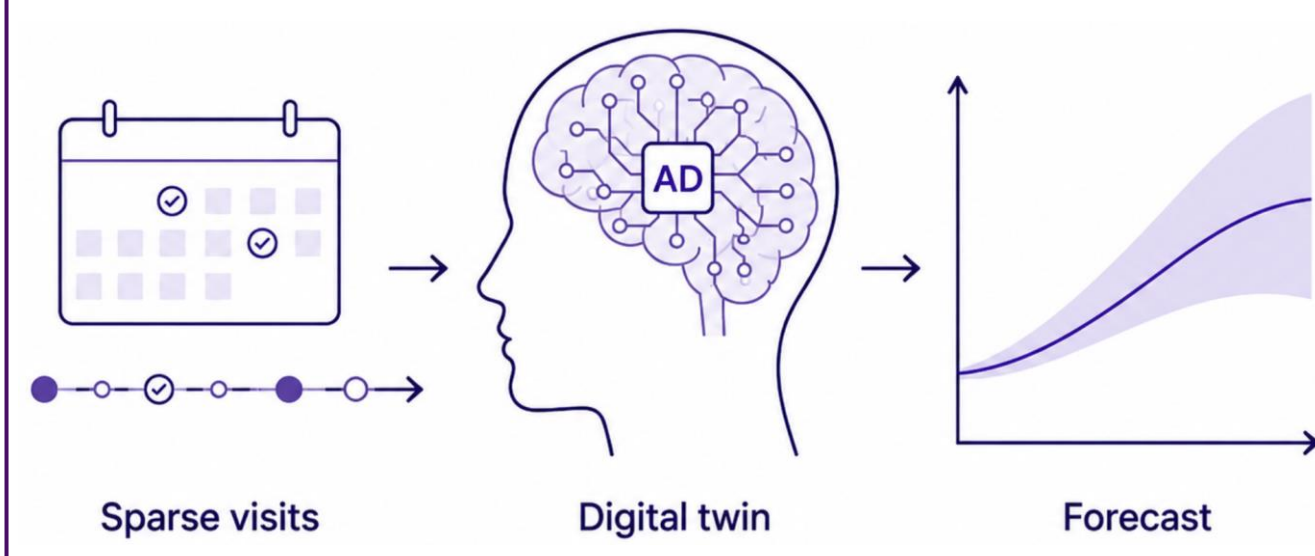
In sparse and irregular Alzheimer's Disease (AD) longitudinal data, local transition modelling provides a more data-efficient and robust digital-twin strategy than purely sequence-based modelling. The proposed framework enables personalised MMSE forecasting, diagnosis prediction, uncertainty estimation, and patient-level what-if trajectory analysis for interpretable longitudinal disease monitoring and risk assessment.

INTRODUCTION

Alzheimer's disease progression is highly heterogeneous and is commonly observed through sparse and irregular longitudinal follow-up visits.

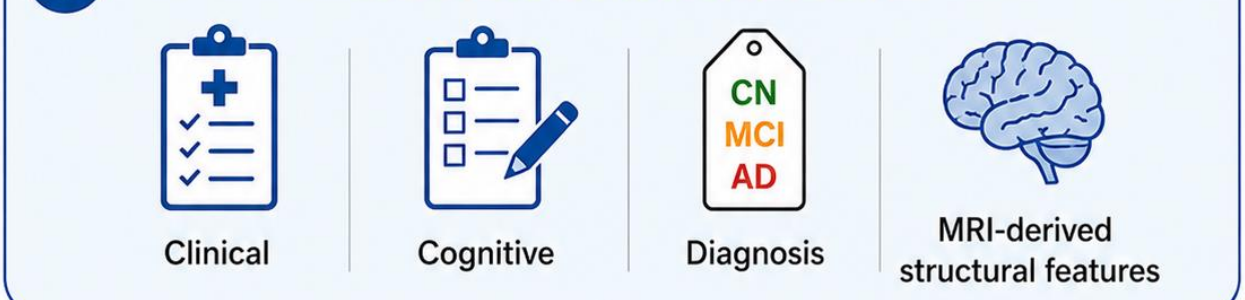
Most existing models focus on static classification or cohort-level risk prediction, which limits their ability to model personalised disease trajectories over time.

Digital twins provide a patient-specific framework for forecasting disease progression, estimating uncertainty, and exploring scenario-based what-if analysis.



METHODS

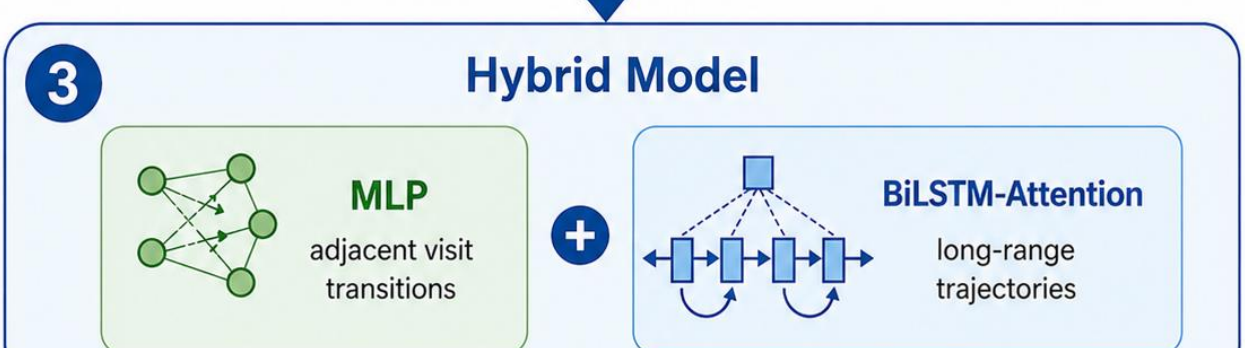
1 **ADNI Multimodal Data**



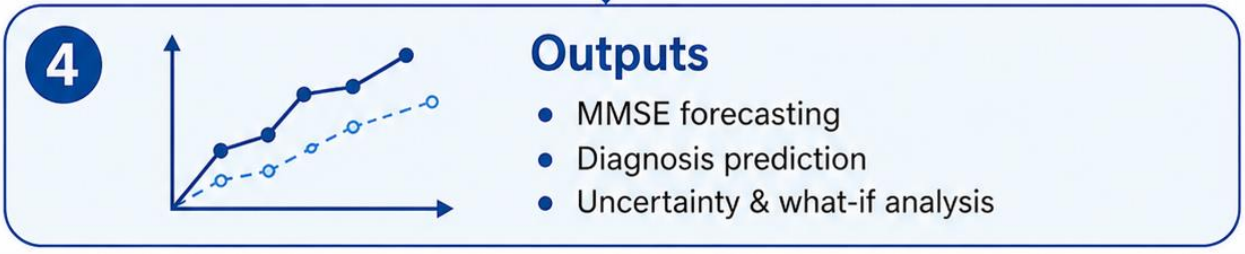
2 **Preprocessing**



3 **Hybrid Model**



4 **Outputs**



- MMSE forecasting
- Diagnosis prediction
- Uncertainty & what-if analysis

ADNI longitudinal data were aligned to six-month visits before hybrid digital-twin modelling. The framework predicts future MMSE and diagnosis while supporting uncertainty estimation and patient-level what-if trajectory analysis.

RESULTS

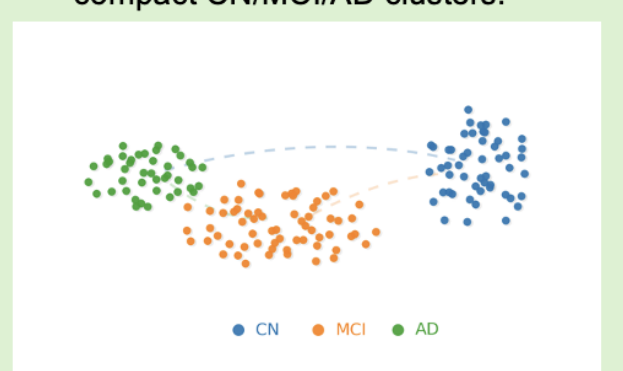
Held-out Test Performance

Model	RMSE	MAE	ACC	AUC	Macro-F1
MLP + mRMR	2.149	1.529	0.906	0.976	0.908
BiLSTM-Attention	2.687	1.926	0.806	0.928	0.798

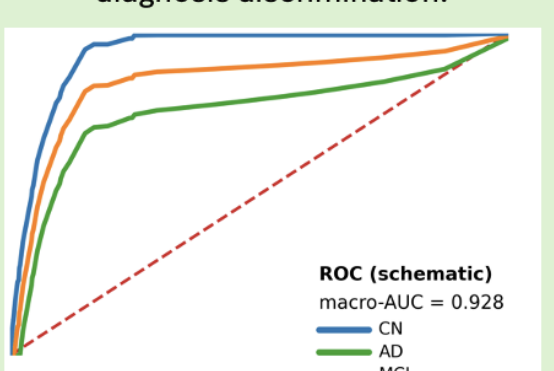
Lower RMSE/MAE and higher ACC/AUC/Macro-F1 indicate better performance.

Hybrid twin components

MLP+mRMR (F1 0.908): compact CN/MCI/AD clusters.

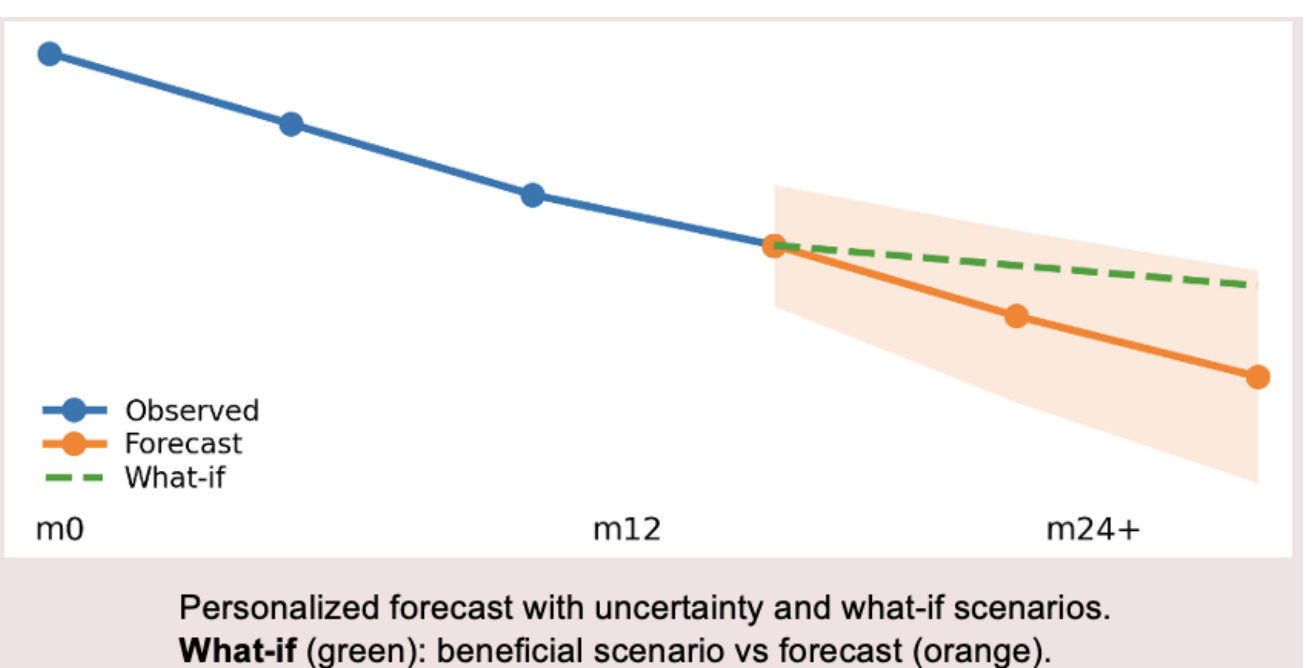


BiLSTM-Attn (F1 0.798): diagnosis discrimination.



- MLP + mRMR outperformed BiLSTM-Attention across all held-out test metrics.
- Local transition modelling was more data-efficient and robust under sparse, irregular AD follow-up.
- BiLSTM-Attention remained useful for uncertainty-aware forecasting and patient-level what-if analysis.

CONCLUSIONS



Personalized forecast with uncertainty and what-if scenarios. What-if (green): beneficial scenario vs forecast (orange).

- Transition-based modelling provides a practical and data-efficient strategy for AD progression prediction.
- The MLP branch achieved the strongest MMSE and diagnosis prediction performance.
- The BiLSTM-Attention branch enabled uncertainty-aware and patient-specific what-if trajectory analysis.

REFERENCES

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CONTACT



GitHub: Digital-Twin-for-AD

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