

Geometry-Based Multi-Modal Integration and Digital Twin Modeling for Alzheimer's Disease and Related Dementias

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Fully free BVIDAL SaMD organizes Imaging, pathology and multimodal biomarker evidence into a review-only geometry digital twin that can support Alzheimer's Disease and Related Dementias progression modeling, drug testing, drug monitoring, and drug-discovery hypothesis generation.

INTRODUCTION

Alzheimer's disease and related dementias involve interacting structural, molecular, biomarker, clinical, and temporal changes. A digital twin workflow can help organize these multimodal signals into an interpretable disease-state representation rather than treating MRI, PET, CSF, plasma, cognition, and metadata as isolated evidence layers. BVIDAL SaMD uses a Bansal pillar-guided, B-AI/PyTorch-style projection framework to convert observable evidence into review-only geometry-state representations for digital twin modeling, drug-testing simulation, drug-monitoring support, and drug-discovery hypothesis generation.

Objective : To demonstrate a review-only BVIDAL SaMD workflow for geometry-based multimodal digital twin modeling by integrating OASIS longitudinal MRI progression with CSV-based NACC/ADSP-PHC MRI, amyloid PET, CSF, plasma, cognition/diagnosis, and metadata evidence layers, and by showing how the resulting state representation can support conceptual drug testing, drug monitoring, and drug discovery workflows.

METHODS

Proposed Novel B-Bio Theory, Frameworks and Pillars on SaMD- BVIDAL Clinical Software Suite

OASIS-2 longitudinal MRI cases were used as the subject-specific progression backbone for serial structural-state tracking. Uploaded CSV evidence layers were used as multimodal context, including commercial MRI, ADSP-PHC amyloid PET, ADSP-PHC plasma, commercial CSF, ADSP-PHC CSF, and UDS4 RDD metadata. Source size, subject coverage, longitudinal readiness, modality coverage, PET QC/tracer readiness, CSF/plasma biomarker completeness, and metadata support were summarized as evidence-readiness indicators. BVIDAL SaMD then organized these layers into a conceptual digital twin engine using geometry-state extraction, Bansal projection logic, and B-AI/PyTorch framework feature projection. Outputs were represented as a unified B-state vector, geometry-state trajectory, progression stage map, and review-only report.

Conclusion

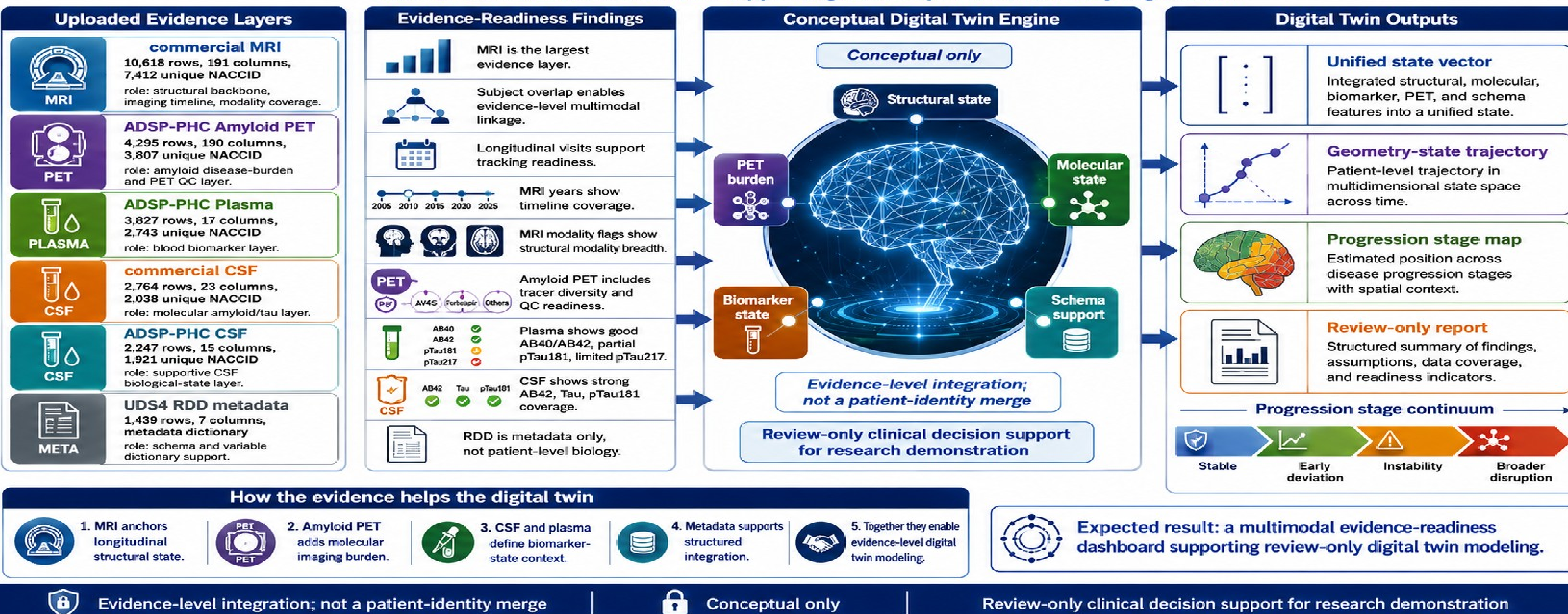
The BVIDAL SaMD demonstrates a review-only, geometry-based multimodal digital twin workflow for Alzheimer's Disease and Related Dementias. MRI provides the longitudinal structural backbone, while amyloid PET, CSF, plasma, cognition/diagnosis, and UDS4 RDD metadata add molecular, biomarker, clinical, and schema-level evidence layers. These layers support evidence-level digital twin modeling, where disease state is represented as a trajectory from stability to early deviation, instability, and broader disruption. The same state representation can be reused conceptually for drug testing, drug monitoring, and drug-discovery hypothesis mapping by evaluating how candidate interventions may shift the geometry-state trajectory.

The framework is not a standalone diagnostic or treatment system. Its value is an evidence-gated representation for progression modeling, drug-testing simulation, drug-monitoring support, and drug-discovery hypothesis mapping, without claiming clinical validation, regulatory approval, treatment recommendation, or autonomous decision-making.

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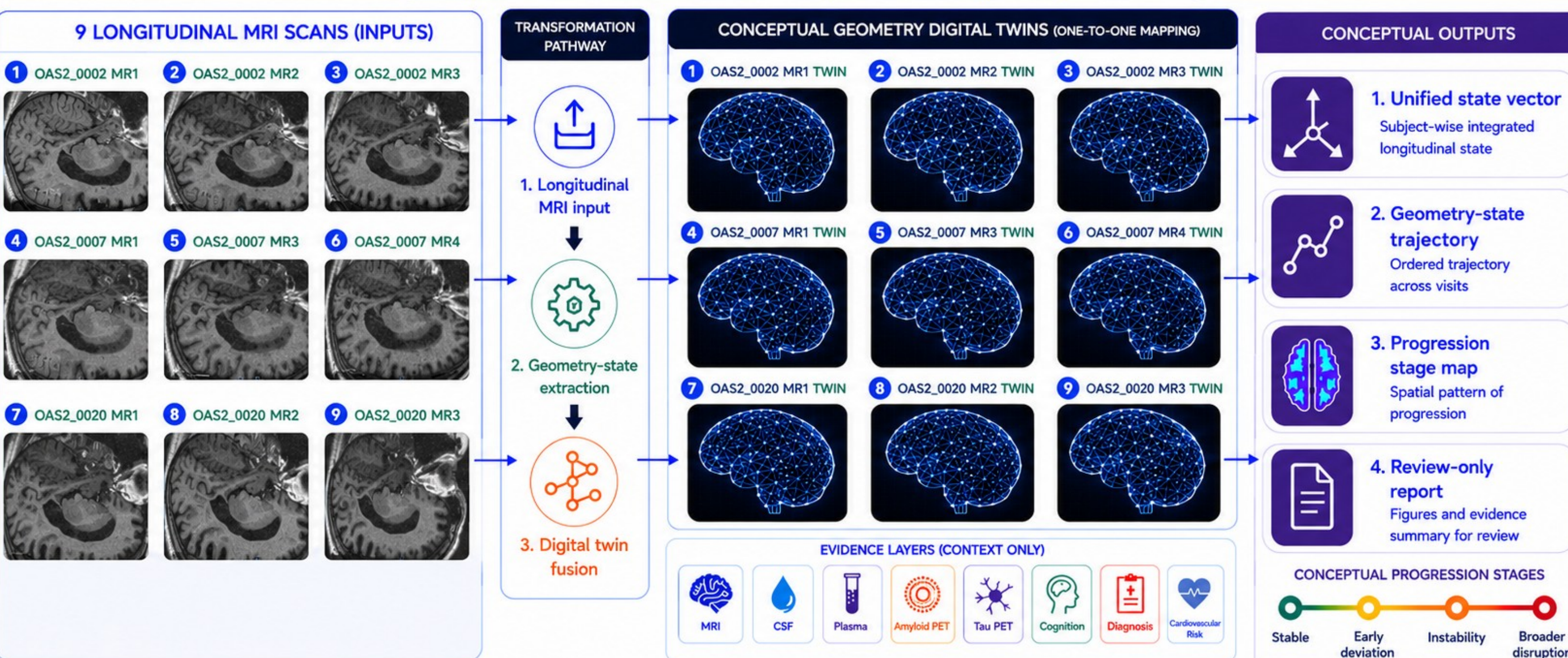
Multimodal evidence-readiness supporting a conceptual review-only digital twin



Conceptual Digital Twin Transformation

From 9 longitudinal MRI scans to a conceptual geometry digital twin

CONCEPTUAL ONLY — SaMD implementation partially successful



Bansal Digital Twin Framework

Drug Discovery • Drug Testing • Monitoring



REFERENCES

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- Original Data provided by OASIS : OASIS-2 Longitudinal MRI Data in Nondemented and Demented Older Adults. Marcus DS, Fotenos AF, Csernansky JG, Morris JC, Buckner RL. J Cogn Neurosci. 2010;22(12):2677-2684. doi:10.1162/jocn.2009.21407. Selected OASIS-2 : Selected OASIS-2 longitudinal cases included OAS2_0002_MR1-MR3, OAS2_0007_MR1/MR3 /MR4, and OAS2_0020_MR1-MR3,
- Selected NAAC : commercial_fcsf_nacc73.csv, NACC_CS_ADSP_PHC_Amyloid_Detailed_2026.02.18.csv, NACC_CS_ADSP_PHC_Plasma_2026.02.18.csv, commercial_mri_nacc73.csv, NACC_CS_ADSP_PHC_CSF_2026.02.18.csv, uds4-rdd.csv

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