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Integrated Reference Architecture for AI-Enabled Healthcare Research: An Australian Harmonized Approach

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Integrated Reference Architecture for AI-Enabled Healthcare Research:
An Australian Harmonized Approach

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Introduction

This paper presents a co-design approach to developing a reference architecture for AI and advanced analytics infrastructure supporting healthcare research in Australia.
The Australian Research Data Commons (ARDC), as the national research data infrastructure provider, recognized various transformative opportunities and challenges in employing and providing a research infrastructure for AI and advanced analytics, and initiated a systematic co-design process to develop a framework. This systematic, inclusive co-design process yielded comprehensive insights into research community needs while identifying potential partners.

Approach

ARDC collaborated with the Australian Data Science Network and Australian Cancer Data Network through a comprehensive twin study involving a survey (n=110), multiple workshops (6), environmental scanning, and interviews (6). The ADSN-ARDC "Framework Project" provided broad coverage of key issues, while the ACDN-ARDC "Pathfinder Project" examined sensitive healthcare data challenges where movement is restricted by privacy regulations and organizational policies.

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Armstrong et.al. (2024) DOI:. 10.5281/zenodo.13831386 | Holloway et.al. (2024). DOI: 10.5281/zenodo.13831454
Diagram (Figure 1) summarises the systematic and inclusive process ARDC has gone through in arriving at the co-investment projects.

Findings from Co-Design

Researchers identified needs across the advanced analytics lifecycle including secure, scalable infrastructure, interoperable tools with no-code capabilities, and AI-ready data. Many prioritized upskilling resources and guidelines matching their technical proficiency.

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The Pathfinder project, relating to sensitive data and federated learning, revealed socio-technical barriers like computational requirements, manual inspection processes in Trusted Research Environments (TREs), standardization gaps, and complex cross-institutional governance.
These findings collectively demonstrated the necessity for an integrated approach addressing both technical infrastructure and socio-technical dimensions of advanced analytics.

Reference Architecture

Drawing on the outputs of the co-design, we developed a Reference Architecture for advanced analytics infrastructure.
This architecture is organized through the lens of the infrastructure, namely underpinning the cloud (Nectar), tools and platforms, data assets, socio-technical resources, and all being made available through virtual research environments (refer to Figure 3: AI & Advanced Analytics Reference Architecture).

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The Reference Architecture created by ARDC provides a comprehensive foundation for integrating clouds, tools, platforms, data assets, and socio-technical resources into Virtual Research Environments (VREs).
This architecture explicitly embeds AI capabilities, supporting researchers with GPU-based computing resources, intelligent delivery mechanisms, and contextual training. For example, not only does the architecture provide resources to carry out AI research (compute GPU), access to tools, models, and data through a single platform, but it also provides contextual training and socio-technical resources through intelligent delivery vehicles, such as co-pilots and intelligent LMSs, to support Virtual Labs and direct learning.
In the architecture, we also outline key principles guiding the architecture development, including prioritization of FAIR data practices, modularity, interoperability, and sustainability.

Leveraging architectural thinking, we identified common patterns across virtual research environments to conceptualize a unified Virtual Research Environment (xVRE) framework (Table 1). This framework positions VREs along a complexity-security continuum from Open to Federated systems, accommodating diverse research workflows and governance requirements through modular, incremental development. This would potentially reduce duplication and cost over-runs.

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Face Validation

The framework and reference architecture underwent validation through sector engagement via consultation drafts, workshops at national AI Month events, and presentations at forums including eResearch Australia and ADSN conference, demonstrating ARDC's alignment with national and sectoral needs.

Architecture to Program Design

Translating the reference architecture, we have four extensible and interconnected projects, the foundational cloud upgrade, the AI Resource Hub, Federated Machine Learning Network, and AI Virtual Research Environments. These provide a cohesive ecosystem that addresses both broad researcher needs and specialized requirements such as machine learning with sensitive healthcare data.

Discussion and Conclusions

The reference architecture addresses critical gaps identified during co-design by tackling both technical and socio-technical complexities. It integrates skill development through embedded tools and intelligent delivery mechanisms, while streamlining governance with standardized compliance frameworks for sensitive healthcare data.
The architecture resolves five key challenges: (1) reducing technical barriers through accessible interfaces, (2) democratizing specialized computing resources including GPUs, (3) enabling collaborative analysis of distributed datasets via federated learning, (4) simplifying regulatory compliance, and (5) supporting researcher upskilling through integrated training resources.
Our contributions encompass a co-design methodology for architecture development, a holistic reference architecture addressing socio-technical requirements, implementation strategies through interconnected projects, conceptualization and modularization of VREs on a continuum, and an evaluation framework for measuring impact.
The AI & Advanced Analytics Reference Architecture represents a strategic approach to healthcare research

infrastructure in Australia. By demonstrating the value of co-design methodologies and federated approaches for sensitive data, this work strengthens Australia's capabilities in AI-driven healthcare research while ensuring responsible implementation. As a cornerstone of ARDC's strategic framework, this architecture employs principles of accessibility, interoperability, and sustainability to accelerate responsible AI adoption in healthcare research, ultimately advancing data-driven health outcomes.

Images

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