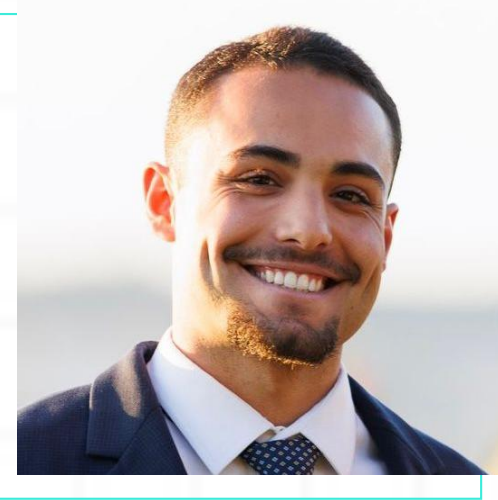


A Sociotechnical AI Digital Twin Framework for Modelling and Assessing Hybrid Human-Artificial Actor Networks

From Knowledge
to Competitiveness
Portugal-US Partnerships 2026 Summit

MIT Portugal
Program



Vítor Neves Pereira

vitor.n.pereira@inesctec.pt

Supervisor(s): António Lucas Soares^{1,2}, Fábio Couto^{1,2}

1. INESC TEC – Institute for Systems and Computer Engineering, Technology and Science, Porto, Portugal
2. Faculty of Engineering, University of Porto, Porto, Portugal

Under the 2025 MIT Portugal Program Seed Project, "AI Maturity Impact on Social-Environmental Sustainability of Cities"
Sustainable Cities

1 Research Motivation

AI is evolving from a decision-support tool into an **autonomous actor**, turning organisations into **hybrid human-AI networks** that share tasks, authority and responsibility [1].

This makes AI integration a **sociotechnical challenge**, shaped by human capabilities, AI performance, trust, delegation and collaboration.

Existing maturity tools can identify **gaps**, but offer limited insight into the **actors and interactions causing them** [2].

2 Research Objective

Research question How can the **Digital Twin** concept be extended to assess the sociotechnical integration of AI in hybrid human-AI networks?

Objective 1 Develop the **Sociotechnical AI Digital Twin (STAI-DT)**, a framework representing human, AI and hybrid actors and their interactions.

Objective 2 Derive an **indicator system** from the STAI-DT, mapped to the SC-STAI maturity dimensions, for actor-level assessment of AI integration maturity.

3 Methodology

Rigor Cycle

Literature review on Digital Twins, Human-AI collaboration and sociotechnical systems.

Design Cycle

Iterative human-LLM co-ideation of the components, properties and indicators.

Design Science Research (DSR), Three-Cycle View [3]

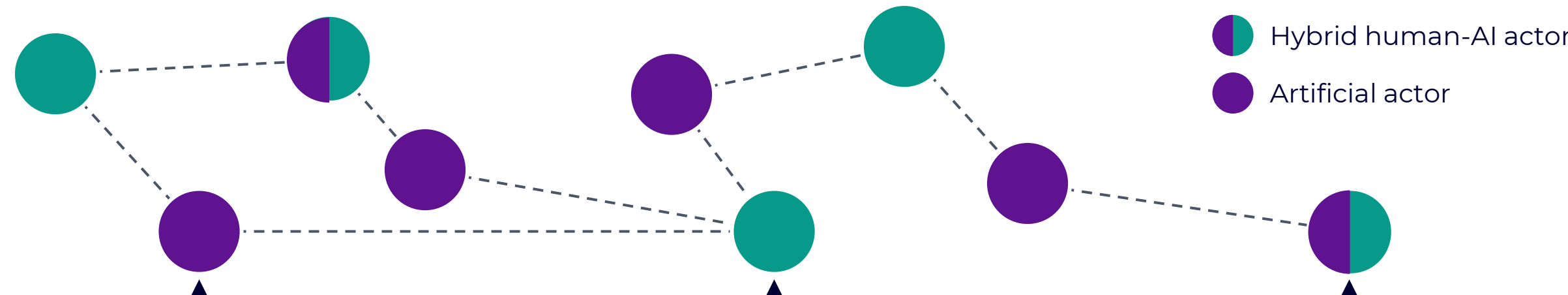
Relevance Cycle

Field validation in real organisations: future work.

4 STAI-DT: Sociotechnical AI Digital Twin

Three interconnected Digital Twins (Human, AI and Hybrid) mirror the actors of a hybrid human-AI network and, fed with empirical data, enable **actor-level diagnosis** of AI integration maturity [4].

Organisation / hybrid network (e.g. supply chain)



AI DT

Human DT

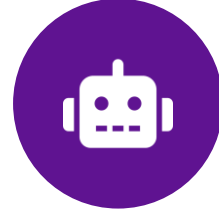
Hybrid DT

Each DT is a bidirectional feedback loop: indicator data in, diagnostics out



Human DT models each human actor

Experience / digital literacy, Performance Cognitive and physical state, Critical supervision and decision authority



AI DT new construct: the agentic AI system as an actor

Performance, Transparency and explainability, Autonomy and decision scope, Availability



Hybrid DT derived layer: the human-AI relationship

Co-evolution and mutual learning, Delegation pattern, Mutual trust, Interaction interface quality

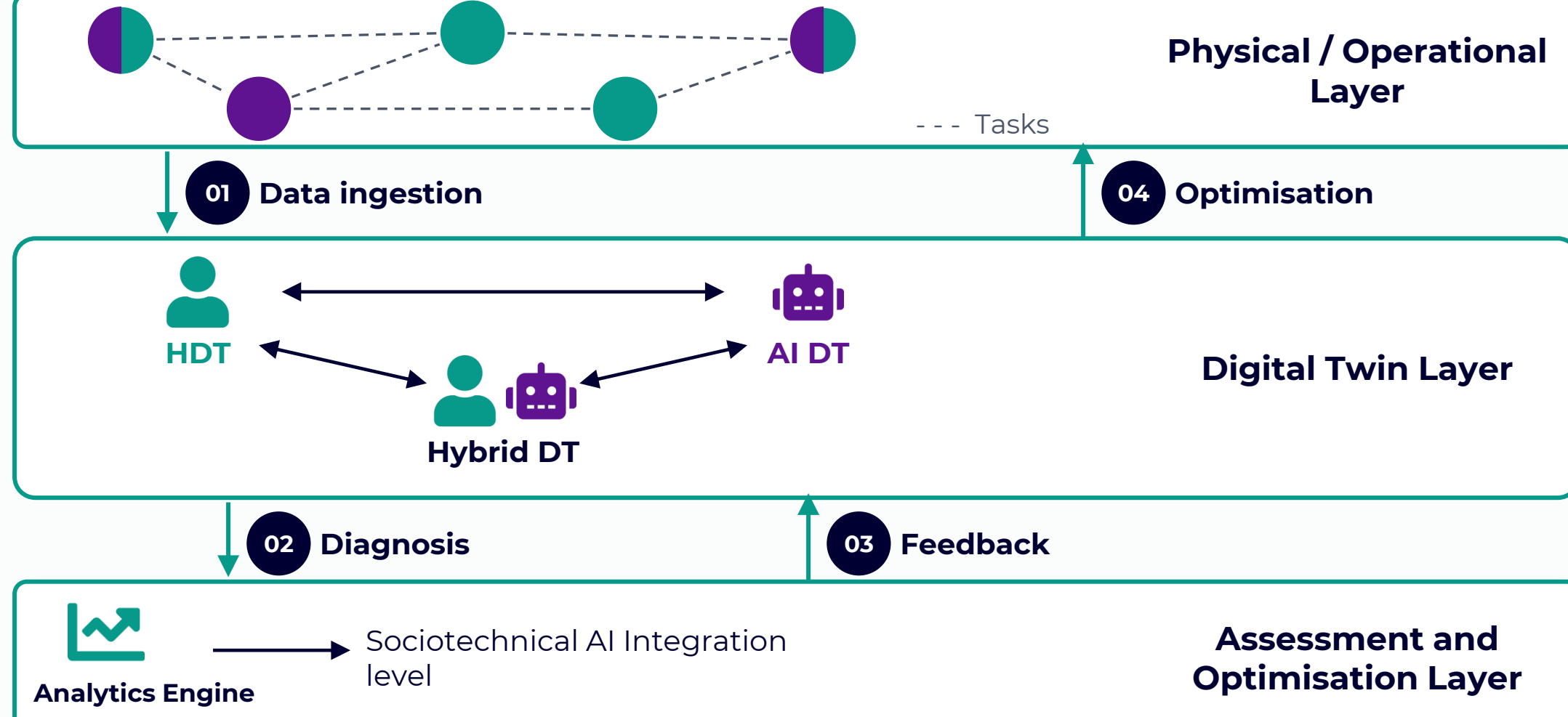
5 Indicator System

12 indicators, one per DT property, mapped to the SC-STAI (Supply Chain Sociotechnical AI) maturity dimensions

Actor	KPI	How to measure	SC-STAI (sub)dimension
HDT	Technological Skills Score	AISES questionnaire	Capability (Human)
	Productivity	System logs	Performance (Organisational)
	Cognitive Load	NASA-TLX questionnaire	Capability (Human)
	Override Ratio	System logs	Decision-making (Human)
AI DT	Decision Accuracy	AI system logs	Performance (Organisational)
	Explanation Satisfaction Score	Explanation Satisfaction Scale	Decision-making (Human)
	Escalation Frequency	AI system logs	Decision-making (Human)
	System Uptime	System logs	Resilience (Organisational)
Hybrid DT	Model Improvement Rate	Metrics compared across periods	Collaboration (Social)
	Delegation Rate	System logs	Collaboration (Social)
	Trust in AI	S-TIAS questionnaire	Trust (Social)
	User Satisfaction Rate	SUS questionnaire	Collaboration (Social)

6 STAI-DT Workflow

[00] Initial Trigger



- [00] A change or action occurs in the physical hybrid human-AI network (e.g. AI takes over Task X).
[01] Empirical data updates the DTs.
[02] The STAI-DT triggers a sociotechnical assessment simulation.
[03] The engine flags a misalignment (e.g. human trust insufficient for the AI's authority level).
[04] Management recommendations flow back to the Physical / Operational layer.

7 Contributions

- AI DT**: a novel digital representation of agentic AI as an actor
- Unified STAI-DT framework** combining Human, AI and Hybrid DTs
- 12 actor-level indicators** linked to SC-STAI maturity dimensions
- Finer diagnostic granularity**, separating human, AI and interaction causes

8 References

- Couto, F., Malta, M.C., Soares, A.L.: Collaborating with Algorithms: AI for Collaborative Supply Chain Management. In: Camarinha-Matos, L.M., Ortiz, A., Boucher, X., and Lucas Soares, A. (eds.) Hybrid Human-AI Collaborative Networks. pp.185–200. Springer Nature Switzerland, Cham (2026). https://doi.org/10.1007/978-3-032-05673-3_12
- Soares, A.L., Gomes, J., Zimmermann, R., Rhodes, D., Dorner, V.: Integrating AI in Supply Chain Management: Using a Socio-Technical Chart to Navigate Unknown Transformations. In: Camarinha-Matos, L.M., Ortiz, A., Boucher, X., and Barthe-Delanoë, A.-M. (eds.) Navigating Unpredictability: Collaborative Networks in Non-linear Worlds. pp.22–35. Springer Nature Switzerland, Cham (2024). https://doi.org/10.1007/978-3-031-71739-0_2
- Hevner, A.R.: A Three Cycle View of Design Science Research. Scand. J. Inf. Syst. 19, (2007).
- Pereira, V., Couto, F., Soares, A.L. (2027). A Sociotechnical AI Digital Twin Framework for Modelling and Assessing Hybrid Human-Artificial Actor Networks. In: Camarinha-Matos, L.M., Ortiz, A., Boucher, X., Fornasiero, R. (eds) Dynamics of Hybrid Collaborative Networks. PRO-VE 2026. IFIP Advances in Information and Communication Technology, vol 804. Springer, Cham. https://doi.org/10.1007/978-3-032-41234-8_33

Funded by:

