The Alan Turing Institute

Models and Data Sciences in Digital Twins

05.05.2022

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Growing Underground

–Track the environment of the world’s first **underground farm** in London

–Long-term monitoring programme to predict models to support expansion, optimize crop performance and reduce energy use

–The Digital Twin allows simulation of a hypothetical farm to inform equipment needs for a stable environment and minimal energy use

"This project brings the capability of digital twinning to energy modelling of built environment in manners that are transformative and have lasting impact."

UK Research and Innovation

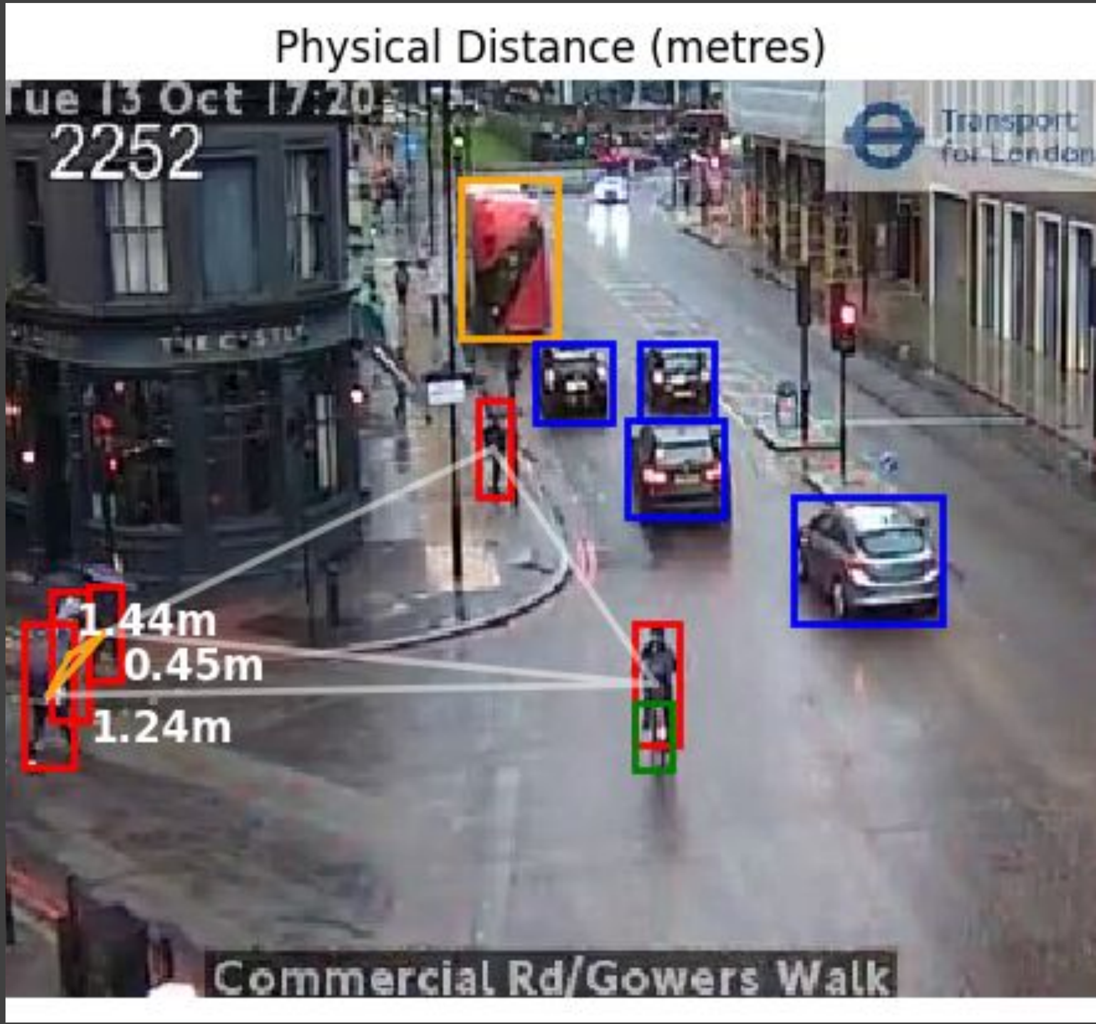
Lloyd's Register Foundation

The Alan Turing Institute

Data-Centric Engineering Programme

Project Odysseus

- Capturing activity over London to better understand ‘busyness’ and aid effective policy-making strategies for exiting the pandemic lockdown
- Aims to bring together multiple large scale and heterogeneous datasets capturing mobility
- 700 targeted TfL interventions & effective policy making



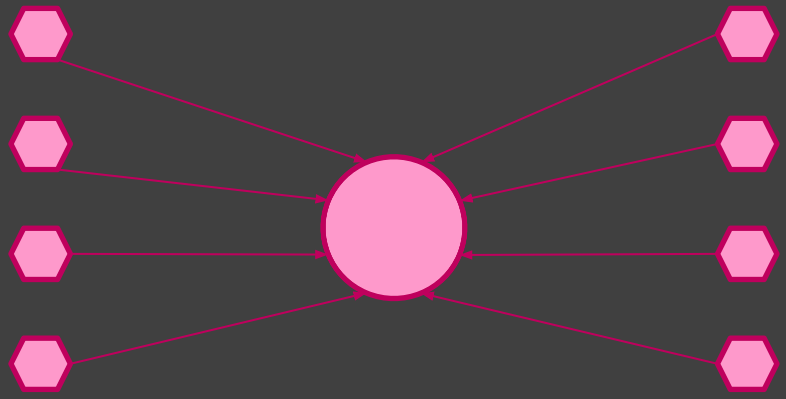
Definition

A set of virtual information constructs that mimic the structure, context and behavior of an <u>individual or unique physical asset</u>, that is <u>dynamically updated</u> with data from its physical twin through out its life cycle and that ultimately informs decisions that realize value[1]

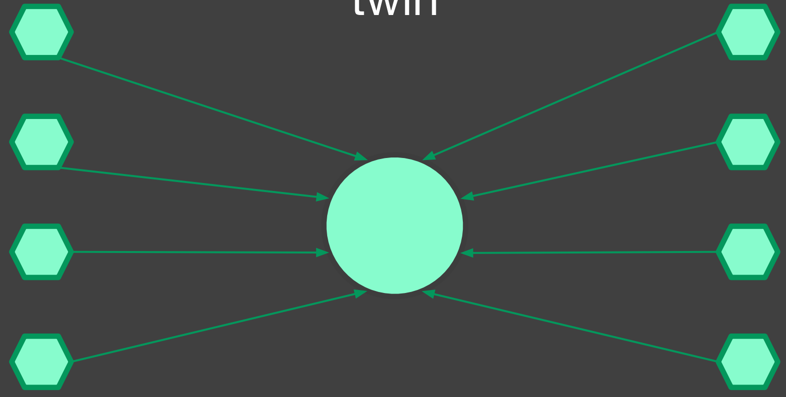
Digital Twin Definition and Value: AIAA Position paper

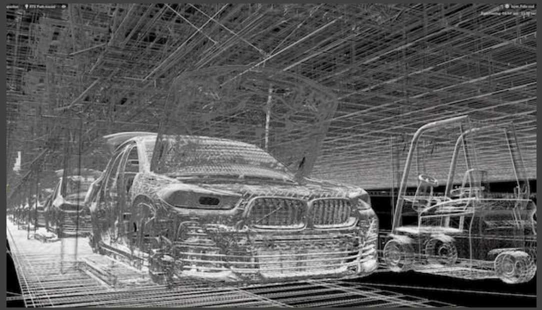
Components need to be delivered with digital twins that are combined in a digital factory

Suppliers deliver **Physical parts** that are combined in **Physical Factory**



Suppliers deliver **Digital Twins of parts** that are combined in a **Digital Factory** to create a digital twin



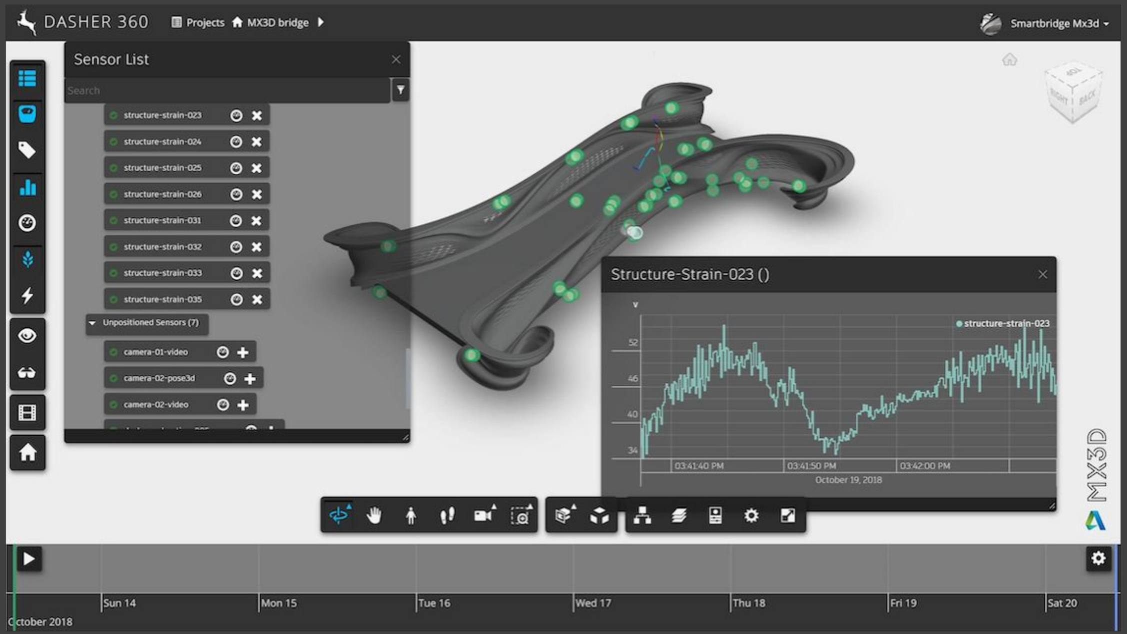


How you standardize Twin formats?
What software do you need to combine multiple Twins?
How do you numerically run an integrated Twin simulation?

Constraining a digital twin from operational data

Extreme planned experiments can be performed in labs to describe material properties

Operational data is noisy, over limited operational space, with no experimental design



Digital Twins need to work under **standard** and **edge case** conditions.

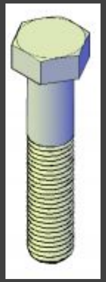
How do we infer Twin properties outside of standard conditions only using operational measurements

Improve Multi-Scale Computational Materials Modeling

Design Based Modelling

Idealized, representative, homogenous, well characterized material properties

Shape

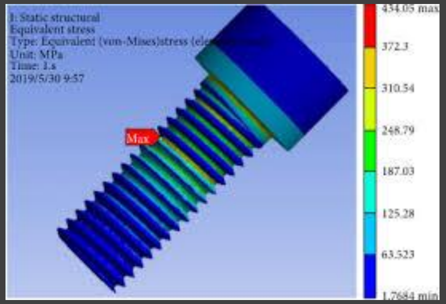


Properties

	Carbon steel	Aluminium alloy	Stainless steel
Grade	S275	EN AW 6061 T4	EN 1.4401(316)
Material yield strength σ_y or $\sigma_{0.2}$ (N/mm^2)	275	110	220
Young's modulus E (N/mm^2)	210000	70000	200000
Strain at fracture A_o (%)	24	12	45
Density ρ (kg/m^3)	7850	2700	8000
Thermal expansion coefficient α (K^{-1})	12×10^{-6}	23.2×10^{-6}	16×10^{-6}
Thermal conductivity k (W/mK)	54	250	16
Total amount of material recycled (%)	60[a]	70[a]	70[a]

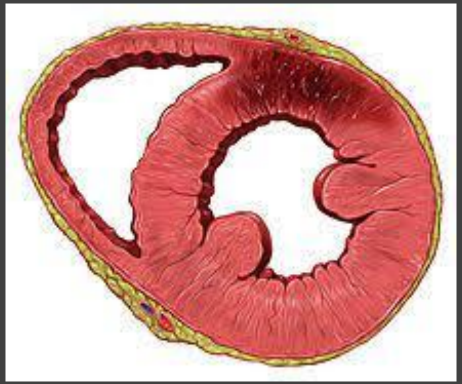
[a] Department of trade and industry, 2005

Prediction



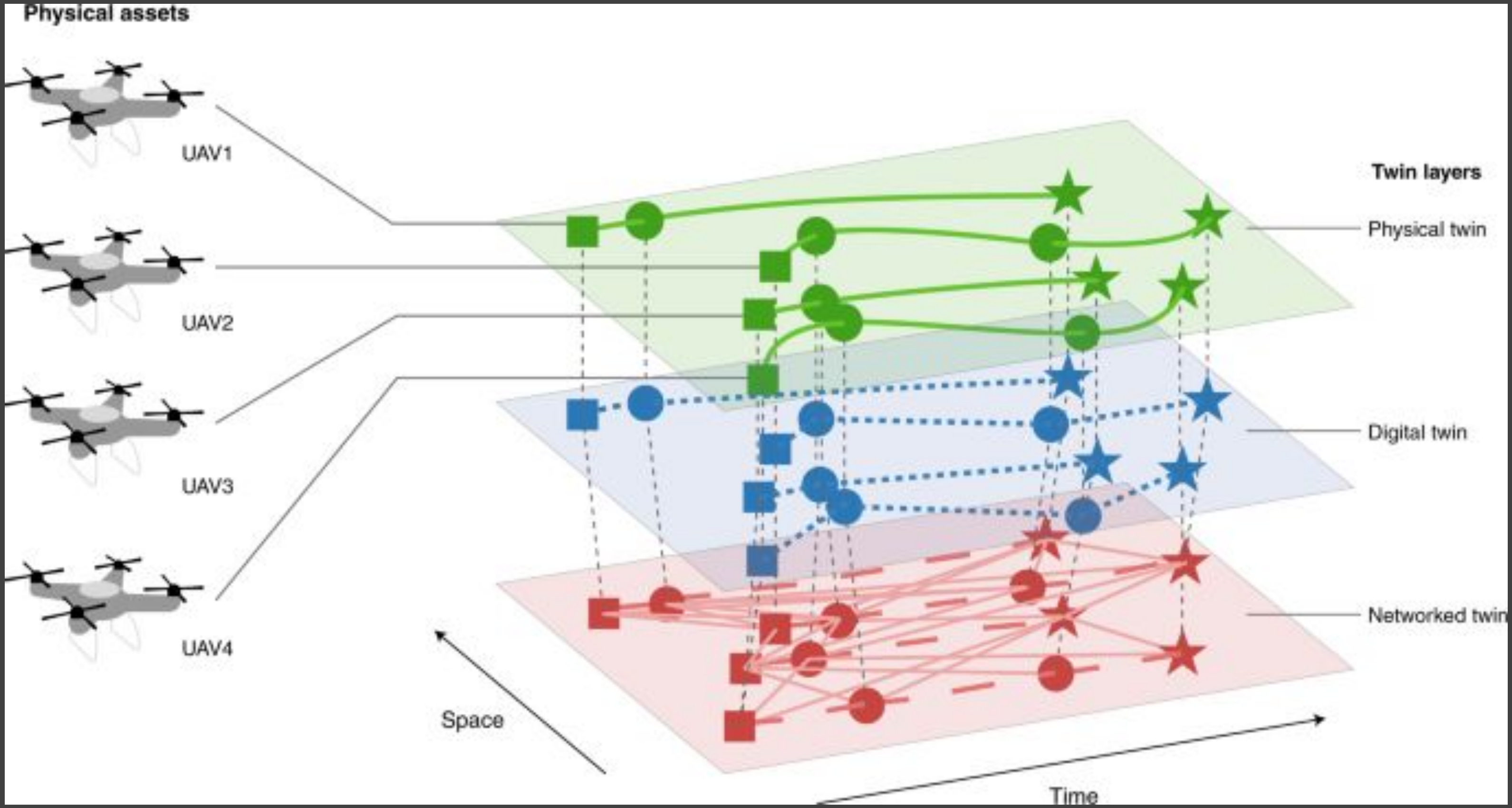
Digital Twin (operational) Modelling

Heterogenous, time evolving materials governed by changes across multiple scales



We need developments in multi-scale computational materials, time evolution of material properties and software to accelerate complex multi-scale simulations

Networking Digital Twins



How de we connect twins to improve twin creation, calibration and predictions?

Achieving digital twins at scale requires a drastic reduction in technical barriers.

To realize digital twins at scale needs investment in the mathematics, numerical, computational science and computer science methods that underpin digital twins to enable robust, rapid, and accessible deployment methods