Energy and Business Digital Twins

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20 February 2024
Agenda

• What are Digital Twins?
• Energy Digital Twins
  • Ahuora Research
• Business Digital Twins
  • Integration Gap

Digitalisation word cloud, Chris Hamblin, Keynote, Advances 2021
Digital Twins
Digital Twins

Hype?

Focus on problem solving
Not just new shiny tech!
What is a Digital Twin?

A digital representation that looks-like, behaves-like, and connects-to a physical system.

With the goal to optimise decision-making across all time horizons.
Digital Twin Classification

- Digital Model
  - Non-automatic data flow

- Digital Shadow
  - One-way automatic data flow

- Digital Twin / Digital Manager
  - Two-way automatic data flow

\[ \dot{x} = f(x, u) \]

\[ \dot{x} = f(x, u, \theta) \\
y = g(x, \theta) \]

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y = g(x, \theta) \\
\theta \leftarrow h(\theta) \]

\[ x = f(x, u, \theta) \\
y = g(x, \theta) \\
\theta \leftarrow h(\theta) \\
u^* = C(x) \]
Energy digital twin technology for industrial energy management: Classification, challenges and future

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Digital Twin Classification

- **3-D**: Point Cloud LiDAR, 3D Building Information Model, 4, 5 or 6D Building Information Model, Steady-state CFD, Transient CFD
- **1-D**: Block Flow Diagram, Process Flow Diagram, Neural Networks, Steady-state Process Simulation, Dynamic Process Simulation, Process Control System (e.g., PID, MPC)

Indicative Computational Intensity: Low to High
Behaves-like Fidelity: Single-state, Multiple Steady-states, Dynamic

**ENGINEERING**
Energy DTs
Energy Digital Twins

Advanced Energy Technology Platform

Govt funded, industry support
$12.5 Million / 7 years
12 initial industry partners
rep >50% of NZ process industry
Started October 2020

11 Academics
3 Post Docs
12 PG students
15 UG students
Ahuora Research

• Energy Digital Twins for Process Heat Decarbonisation
• Re-engineer the way we use, convert, and provision energy for process heat using a smart systems approach
  - Plant efficiency
  - Boilers & Heat pumps
  - Renewable energy
• Produce open-access software tools for NZ industry
• Develop the next generation of Digital Twin technology called a Adaptive Digital Twin

Smart design and operation
How will Digital Twins help?

- Real time optimisation & control
- Evolve Energy Assets for efficiency
  - Retrofit, Replace, Retire (R3)
- Integration and optimisation of energy
- Energy storage
- Energy procurement
- Emissions management

Example
Industrial Heat Pumps
Design, Integration & Operation
DTs & Improvement Cycles

Operational Optimisation Cycle

Industrial Processes & Site

Site Edge

Big System Measurement & Data Reconciliation

Hybrid Models & Learning

Discrete Cases

Technology Options, Models & Costs

Automated R^2 Analysis

Asset Optimisation Cycle

Control & Scheduling Digital Shadow Optimisation

Digital Shadow Optimisation of Retrofitted System

Business Case, Risk Analysis & Implementation

University of Auckland Engineering

13
Tool Development

- Tool development necessary
- Existing ones are rebranding
  - e.g. process simulation
- New methods to exploit industry 4.0, IoT, big data, machine learning
- Integration between DTs
  - e.g., energy DT & business DT
Open Source Platform

Process Integration Tools
Process Electrification Tools
Process Simulation

Simulation Core

“IDEAS”
Institute for Design of Advanced Energy Systems

Surrogate Modeling
Likeness Modelling
Data Analytics
Fuel Switching
Community Integration
Open Source Platform

Process Integration Tools
- Pinch Analysis Tools
- Bridge Analysis Tools
- Spatial Analysis

Process Electrification Tools
- Heat Pump Design
- PI&E Tools

Process Simulation
- Steady State Modelling
- Dynamic Modelling
UOA Ahuora Research

Michael Kalpage
Operational Digital Twins

Bryan Li
Site Edge
Big System Measurement & Data Reconciliation

Isaac Severinsen
Hybrid Models & Learning

Tonn Aeowjaroenlap
Discrete Cases

Dr Wei Yu

Lily Peng
Business Case, Risk Analysis & Implementation

Jun Chang
Digital Shadow Optimisation of Retrofitted System

Automation R3 Analysis

Prof Brent Young
Engineering/Design Digital Twins

Technology Options, Models & Costs
Process Safety DTs

- **Objectives**
  - Energy Efficient
  - Safer

- **Approach**
  - Risk analysis

- **Problem Space**
  - Multi-criteria optimisation
Process Safety DTs

- Energy efficiency
- Inherent Assessment
- Safety indicators
- Risk Quantification
Digital Modelling

• **Efficient, dynamic, digital twin models** of unit operations using modern regression

• First Principles:

• Data Driven:
Digital Modelling

- Demand Response
  - Residential Hot water
- Price Response Hydrogen Production
Time Series Forecasting

Machine Learning for Time Series Forecasting

• Machine Learning Approach: Trends, Patterns, Fluctuation, Outliers

• Time Series Modelling: e.g., Naïve, ARIMA, ANN

• Applications: Process and Energy Optimization in the Dairy Industry
Refrigeration Control

Jun Chang
Refrigeration Control

Dynamic Model
• Identifying operational issues and potential improvements
• Developing advanced control methods

Advanced Control
• Stable operation closer to design
• Economic benefit
Energy flexible planning

- Optimise production throughput and scheduling
- Optimise energy mix
- Evaluate different scenarios using economic, productivity, and sustainability criteria

Michael Kalpage
Energy flexible planning

- **Simulation**
  - 30-minute time intervals

- **Current/Future work:**
  - Storage implementation
  - Scheduling demand
  - Classical optimisation
Multi Plant Clusters

Dynamic Large Scale Digital Twin for Optimization of Multi-plant Industrial Clusters

• To develop a novel digital twin to dynamically simulate and optimize the use of energy and product streams for large-scale multi-plant industrial clusters.

• To ultimately identify the types of new businesses which could join the cluster to bring about mutual benefits.
Energy and Business DTs

Physical twin

Information Connection

Digital twin
Energy and Business DTs

- In this talk and in our research we have so far focused on company level DTs
- For decarbonization & demand response, DTs **need** to include: The ‘**Big System**’, i.e., the company, the grid, and the community DTs
New research proposed

Energy Demand Response Dynamic Digital Twins

• A system and a framework of dynamic digital models and twins
• That will integrate energy digital twins and business digital twins
• To provide optimal demand response and flexibilization for industry, business and residential
Acknowledgments

• MBIE for funding of the Ahuora Advanced Energy Transformation Program
• Colleagues and collaborators at University of Auckland, University of Waikato, Massey University and our industrial partners
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