Towards a More Intuitive Industrial Safety Environment

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Background: Automating Process Safety Management

Industry 4.0 (I4.0) technologies are increasingly applied in NZ manufacturing facilities. However, applications in process safety management (PSM) are still limited. This research proposes a novel framework for organising safety data and information under I4.0.

Process Industry

- Circular economy
- Data-driven control
- Electrification
- Industrial Symbiosis
- Process Intensification
- Sustainable development

I4.0 Principles

- Decentralisation
- Interoperability
- Modularity
- Real-time capability
- Service orientation
- Visualisation

Large Language Models in Process Safety

Application of Artificial Intelligence (AI) in PSM

✓ Using ChatGTP to augment HAZOP meetings
✓ Identifying hazards / making predictions of hazardous scenarios
✓ Retrieving safety related information by querying the language model

Limitations in state-of-the-art AI applications in PSM

× Inherent stochasticity of Large Language Models (LLMs)
× Hallucination in Natural Language Processing (NLP) & generation
× Engineering safety-tailored LLMs are not yet validated for PSM tasks

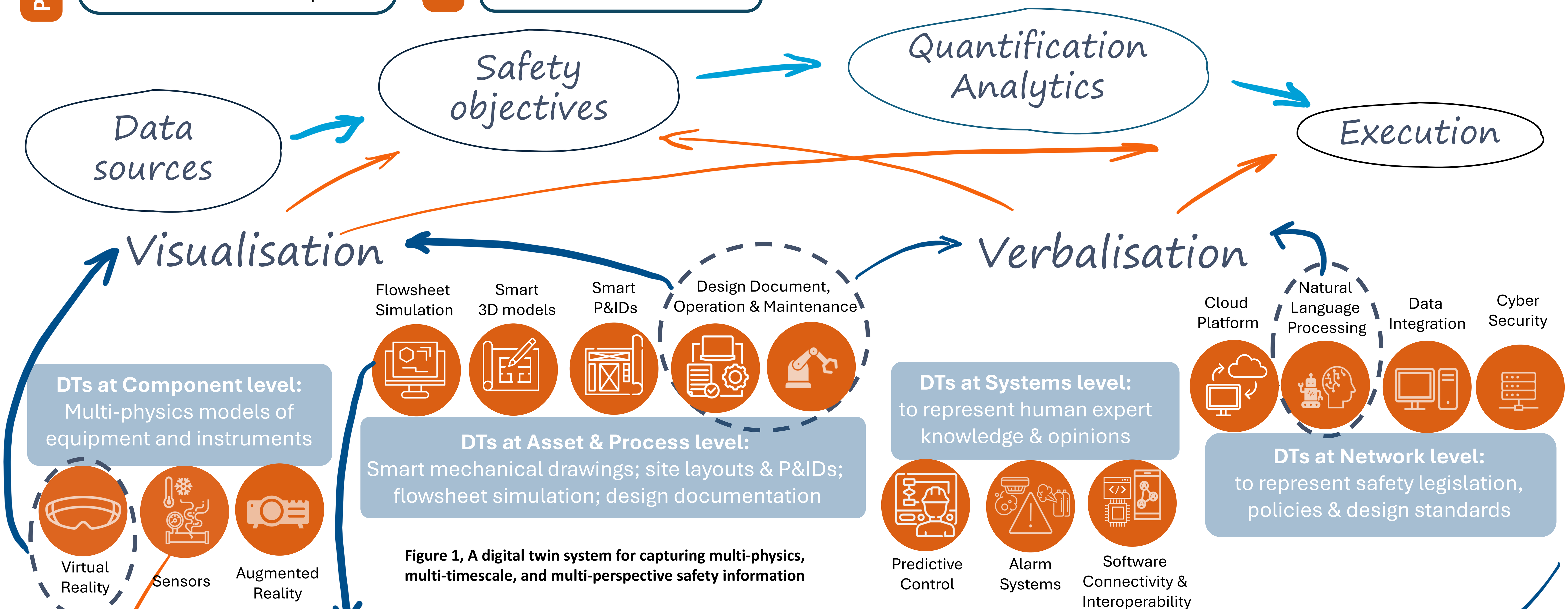

Figure 1, A digital twin system for capturing multi-physics, multi-timescale, and multi-perspective safety information

Case study: Safety ontology for distillation columns

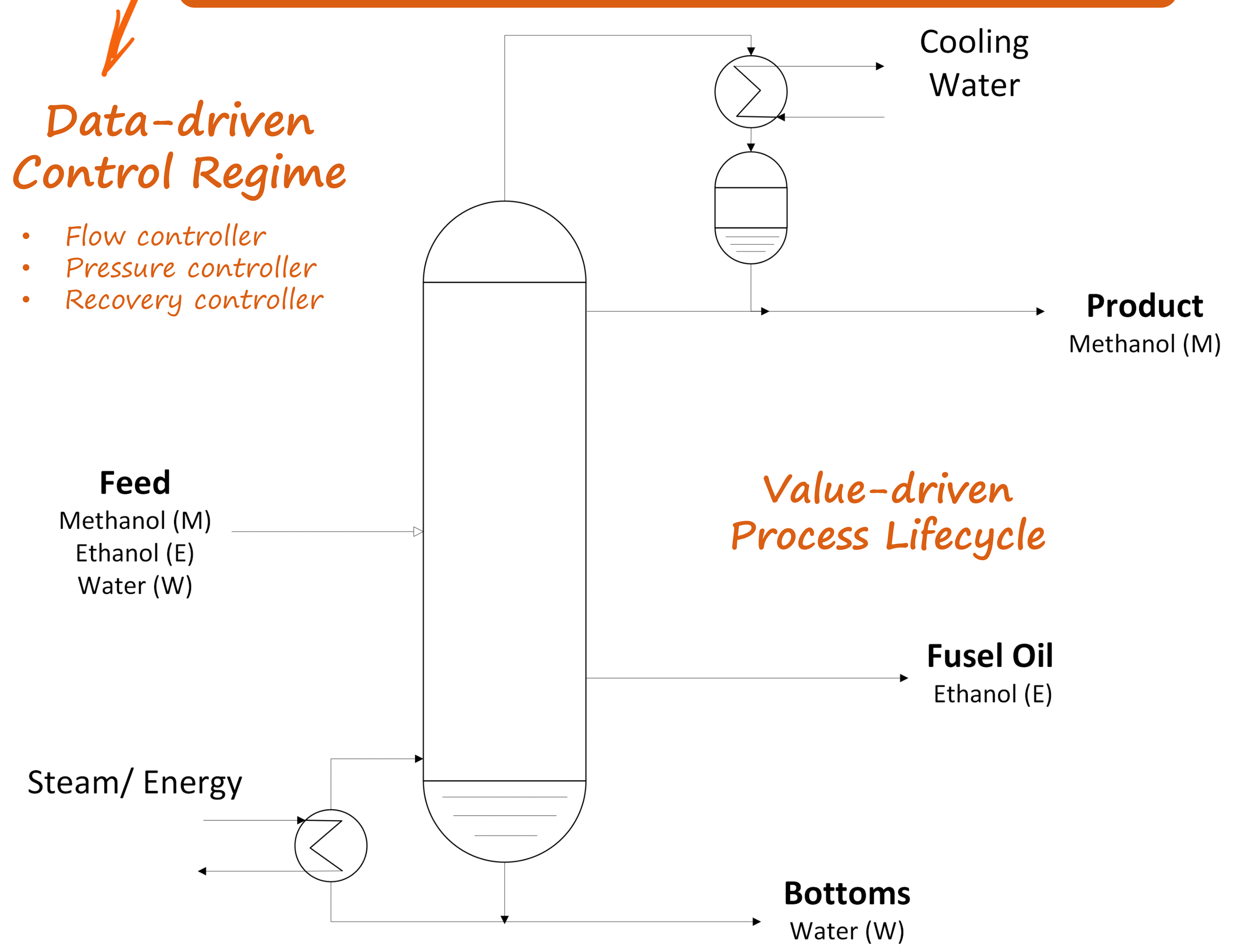

Figure 2, A Simple Schematic of a High-Purity Methanol Distillation Operation

Safety objectives for intensified distillation columns under I4.0.
Using DTs to obtain a 'compliance-based approach'

- Components: Physics-based models in the cyberspace
- Assets: High fidelity, analytical model of the pressure vessels
- Process: New data-driven/ machine learning (AI) controls
- Systems: Data integration between different software.
- Networks: Legislation and design code natural language processing

Safety Legislation Environment- Ontology Modelling

Laws

Resource Management Act
Hazardous Substances and New Organisms (HSNO) Act 1996
Pressure Equipment, Cranes and Passenger Ropeways Regulations 1999 (PECPR) under the Health and Safety in Employment (HSE) Act 1992
Health & Safety at Work Act (HSWA) 2015

Mandatory

NZ Building Code, WorkSafe requirement

MBIE/WorkSafe Approved Code of Practice for Pressure Equipment (Excluding Boilers)

Non- Mandatory

American Society of Mechanical Engineers (ASME) B31 Pressure Piping
NZS 4343 Hazard Level & AS/NZS 1200:2015 Pressure Equipment
Approved Code of Practice for Pressure Equipment (Excluding Boilers)
ENZ PN19, Seismic Resistance of Pressure Equipment and its Supports

Design decisions, Operational advice

Conclusions

1. Proposal of a novel framework of a digital twin system for multi-physics, multi-timescale, and multi-perspective process safety management
2. Using safety ontology and Knowledge Graphs (KGs) is identified for efficient computer-aided safety practices and query-based interactions
3. Conceptual development of knowledge graph for process safety management that is applicable for natural language processing.
4. Future work in process safety knowledge informed automated PSM

References

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