CAMBRIDGE CARES CAMBRIDGE CENTRE FOR ADVANCED RESEARCH AND EDUCATION IN SINGAPORE LTD.

Towards intelligent thermal energy management in eco-industrial park through ontology approach

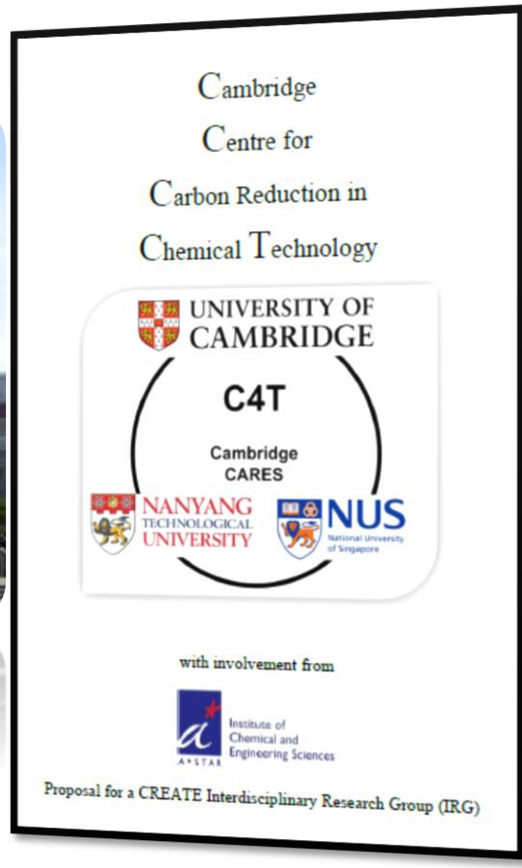
Chuan Zhang

czhang026@e.ntu.edu.sg

2016 October

CAM.CREATE C4T Cambridge Centre for Carbon Reduction in Chemical Technology

The 8th international conference on applied energy



Cambridge
Centre for
Carbon Reduction in
Chemical Technology

with involvement from

Proposal for a CREATE Interdisciplinary Research Group (IRG)

Chuan Zhang
czhang026@e.ntu.edu.sg

1. Background

- **Apply Industrial 4.0 to eco-industrial park**

2. Model based intelligent expert system - JParkSimulator

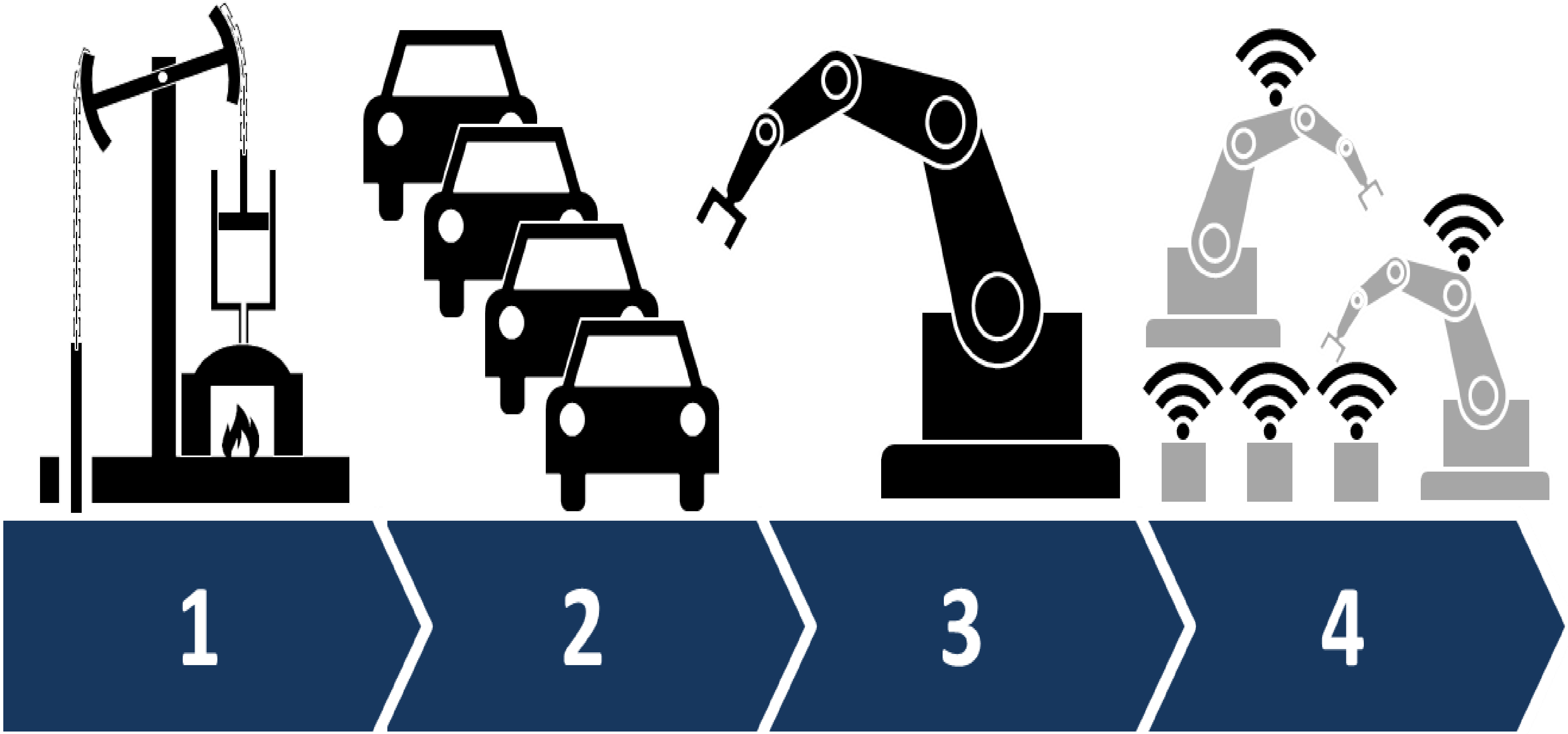
- Integrated platform for EIP energy management

3. Demonstration of ontology-based approach capability

- Process integration of waste heat power cycle

4. Conclusion and future work

Chuan Zhang
czhang026@e.ntu.edu.sg



"Industry 4.0: Working together on a fascinating new problem set"

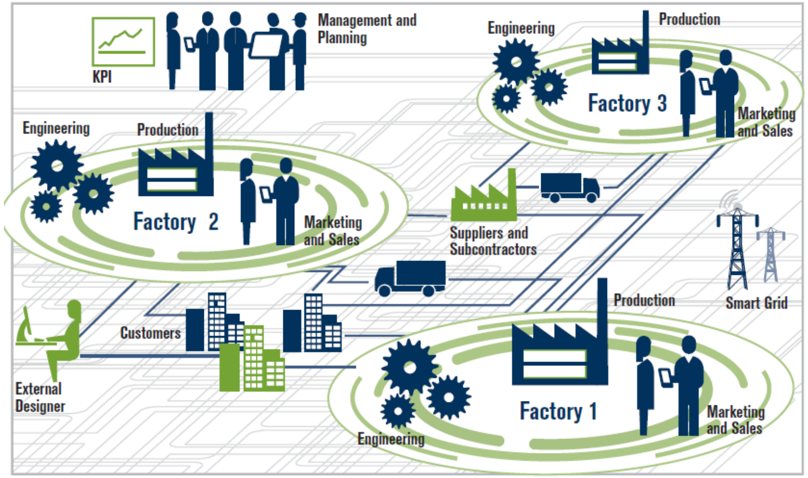
Chuan Zhang
czhang026@e.ntu.edu.sg

Smart factory in the future scenario of Industrial 4.0

Internet of things

Cyber-physical infrastructure

Cloud computing



Source: Hewlett-Packard 2013

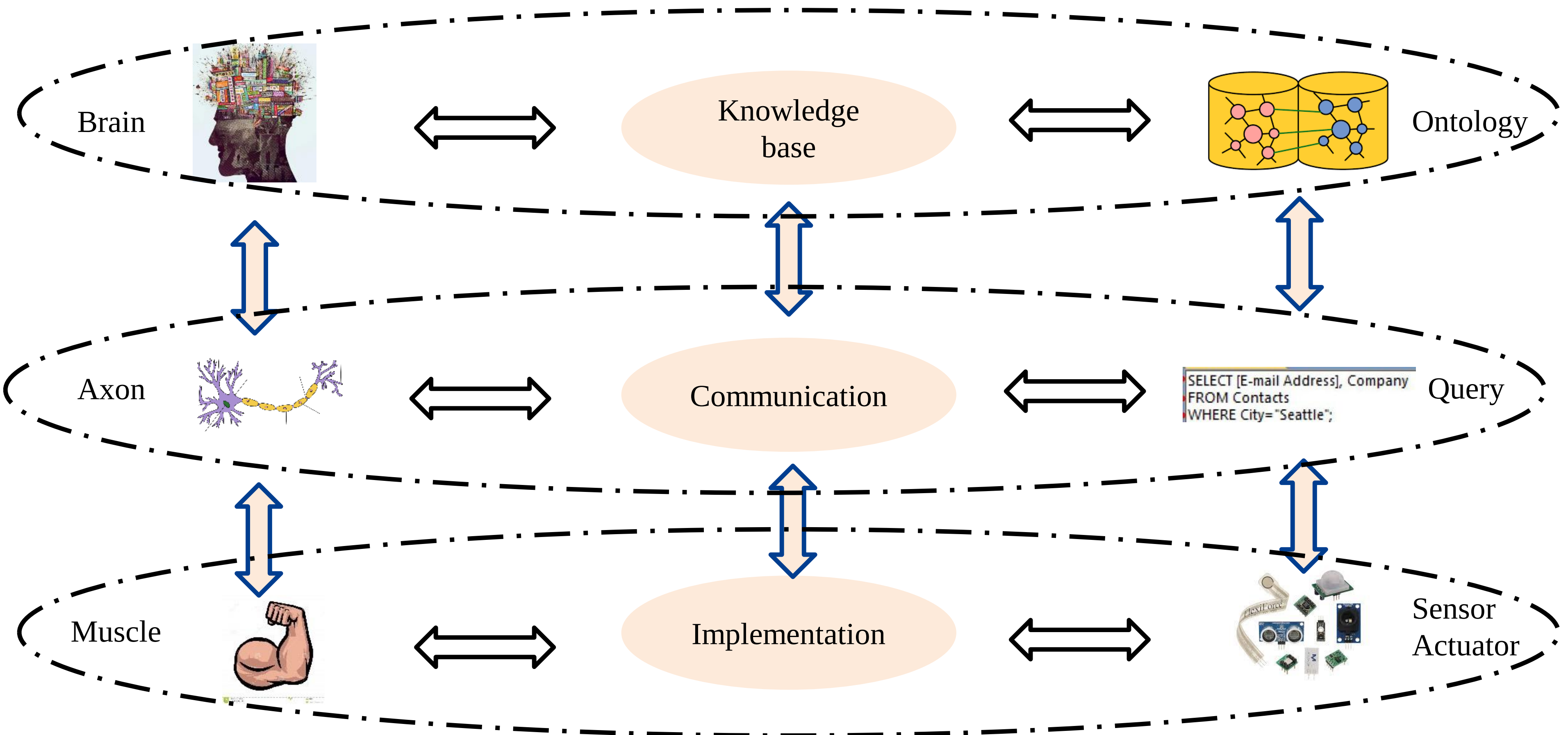
self-configure, self-optimize, self-protect, and self-heal

1. Monitor physical processes
2. Create virtual copy of the physical world
3. Make decentralised decisions
4. Machine to machine communication in real time

Chuan Zhang
czhang026@e.ntu.edu.sg

Analogy between human and machine decision making

Human being | *Role in the system* | *Machine*



Chuan Zhang
czhang026@e.ntu.edu.sg

Ontology: Backbone of Knowledge Base

What? A method for describing entities and relationships among them.

Why? To share knowledge among people and **software agents**; to enable reuse of domain knowledge.

Example Knowledge we want to share: “Water has boiling point of 100°C”

Ontology

```
<!-- http://www.semanticweb.org/administrator/ontologies/2016/2/WaterBoilingPoint#has -->
<owl:ObjectProperty rdf:about="&WaterBoilingPoint;has">
<rdfs:domain rdf:resource="&WaterBoilingPoint;Materials"/>
<rdfs:range rdf:resource="&WaterBoilingPoint;Property"/>
```

Object Properties

```
<!-- http://www.semanticweb.org/administrator/ontologies/2016/2/WaterBoilingPoint#Magnitude -->
<owl:DatatypeProperty rdf:about="&WaterBoilingPoint;Magnitude"/>
```

Data Properties

```
<!-- http://www.semanticweb.org/administrator/ontologies/2016/2/WaterBoilingPoint#Materials -->
<owl:Class rdf:about="&WaterBoilingPoint;Materials"/>
```

Classes

```
<!-- http://www.semanticweb.org/administrator/ontologies/2016/2/WaterBoilingPoint#BoilingPoint -->
<owl:NamedIndividual rdf:about="&WaterBoilingPoint;BoilingPoint">
<rdf:type rdf:resource="&WaterBoilingPoint;Property"/>
<Name rdf:datatype="&xsd;string">Boiling Point</Name>
</owl:NamedIndividual>

</rdf:RDF>
```

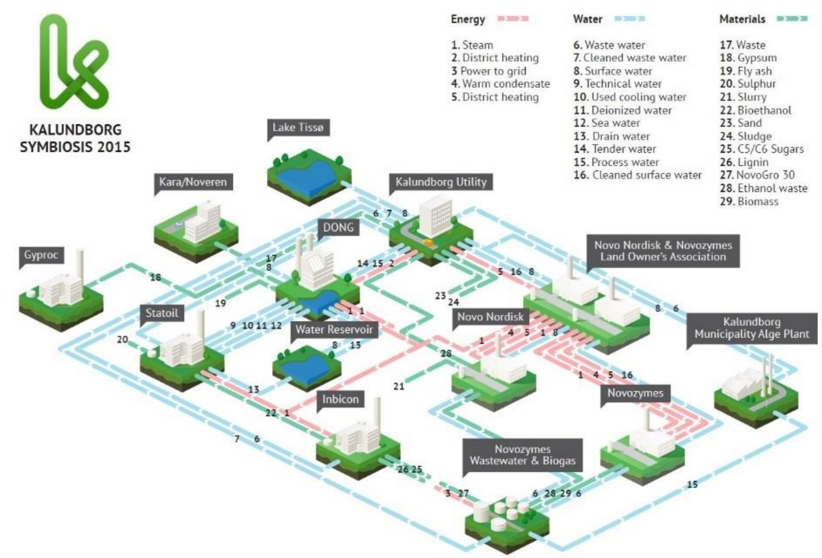
Individuals

Chuan Zhang

czhang026@e.ntu.edu.sg

The research objective: eco-industrial park

Jurong Island in Singapore



Kalundborg eco-industrial park located in Demark

Chuan Zhang
czhang026@e.ntu.edu.sg

1. Background

- **Apply Industrial 4.0 to eco-industrial park**

2. **Model based intelligent expert system - JParkSimulator**

- **Integrated platform for EIP energy management**

3. Demonstration of ontology-based approach capability

- Process integration of waste heat power cycle

4. Conclusion and future work

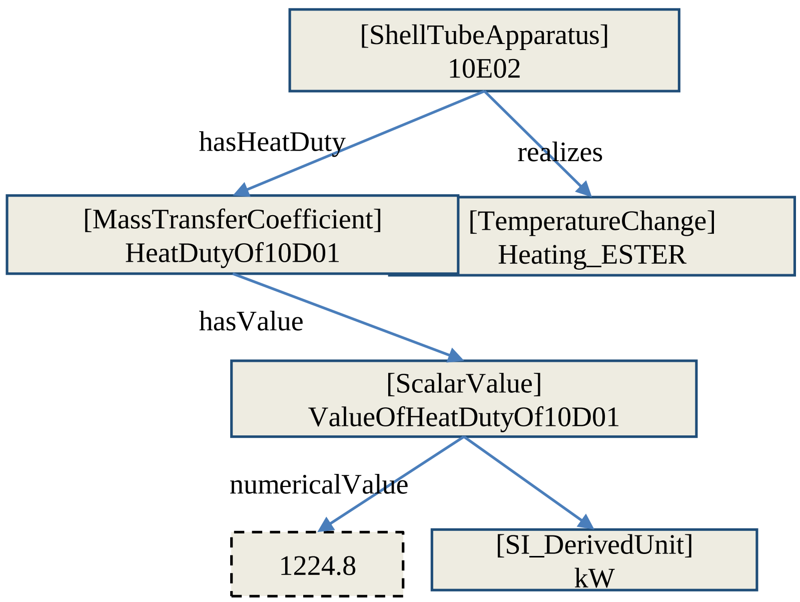
Chuan Zhang
czhang026@e.ntu.edu.sg

Challenge for developing EIP energy management expert system

Challenge 1: Knowledge representation in machine readable language

Solution

Use OntoCAPE as a framework.



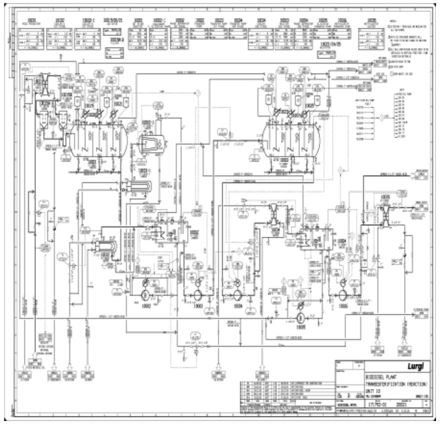
A shell tube heat exchanger has heat duty of 1224.8kW.

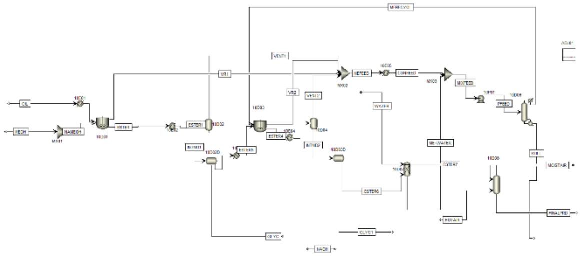
Chuan Zhang
czhang026@e.ntu.edu.sg

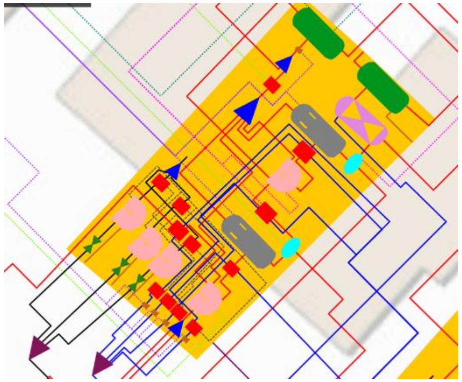
Challenge for developing EIP energy management expert system

Challenge 2: Reliable information sources

Solution Use simulation results as "place holder".







P&I diagram

Aspen plus model

JParksimulator model

Chuan Zhang
czhang026@e.ntu.edu.sg

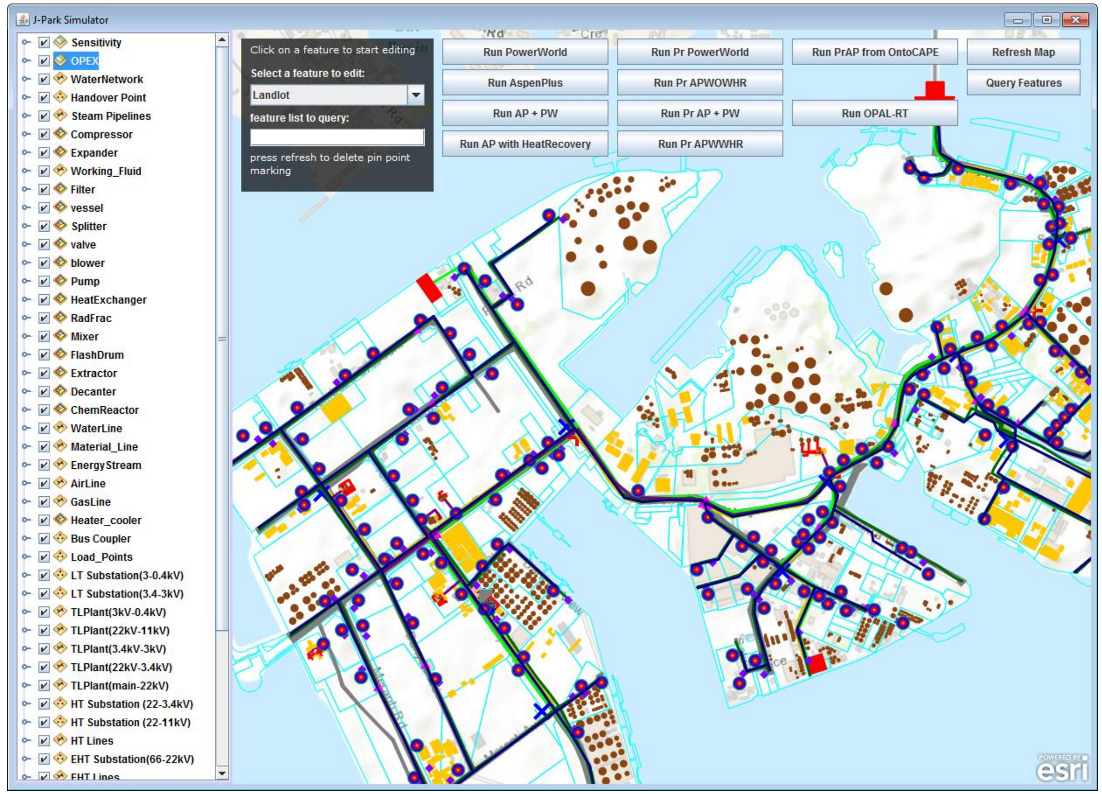
JParkSimulator – the representation of EIP in Industrial 4.0

Accurate

Interactive

Real-time

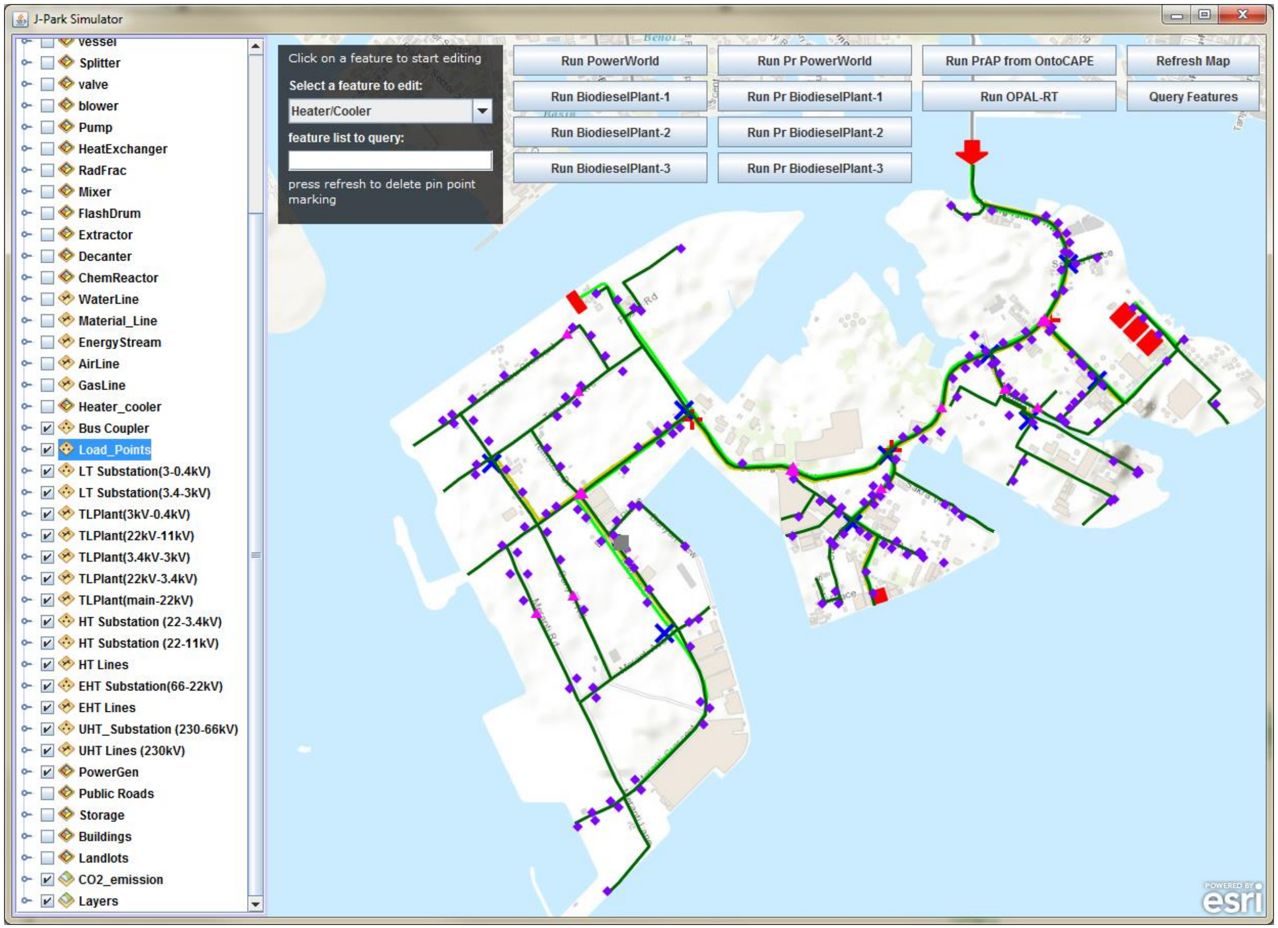
Multiple levels



www.jparksimulator.com

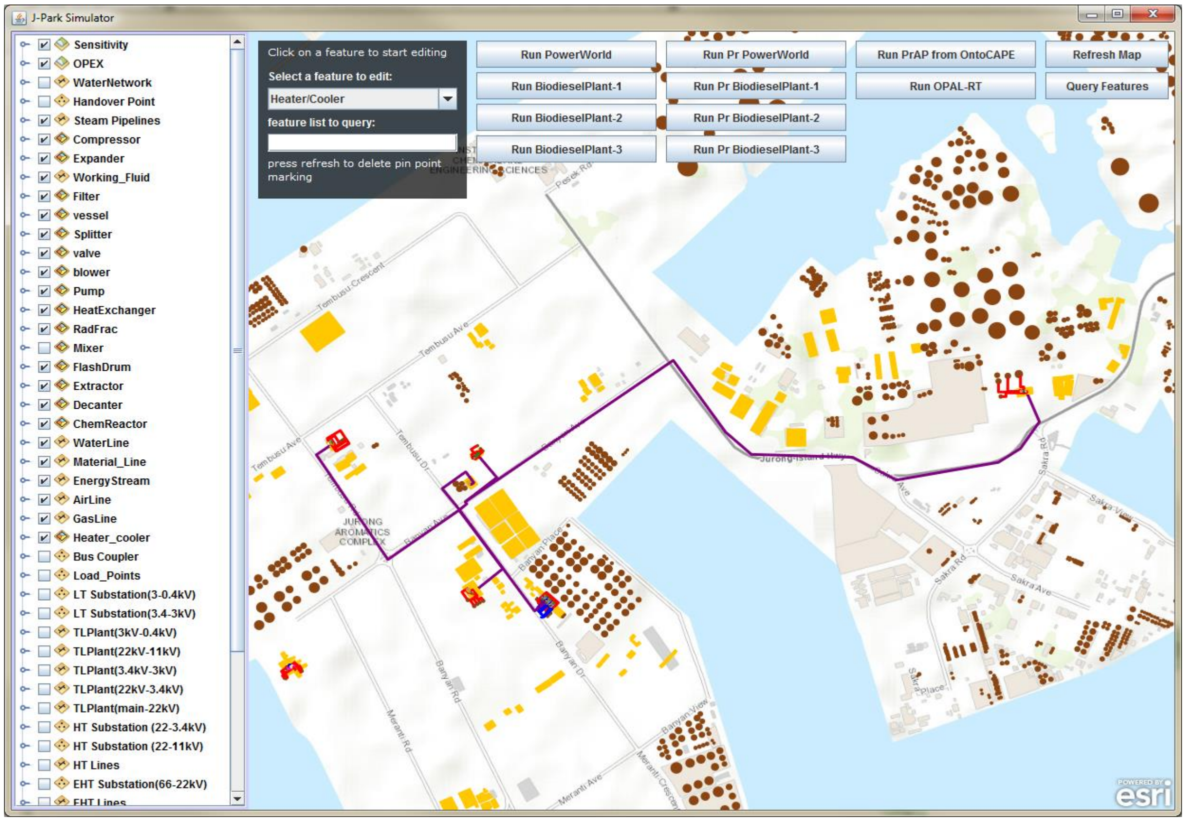
Chuan Zhang
czhang026@e.ntu.edu.sg

Electricity Grid



Chuan Zhang
czhang026@e.ntu.edu.sg

Local Steam Supply Network



Chuan Zhang
czhang026@e.ntu.edu.sg

1. Background

- **Apply Industrial 4.0 to eco-industrial park**

2. Model based intelligent expert system - JParkSimulator

- **Integrated platform for EIP energy management**

3. **Demonstration of ontology-based approach capability**

- **Process integration of waste heat power cycle**

4. Conclusion and future work

Chuan Zhang
czhang026@e.ntu.edu.sg

Demonstration of ontology-based approach

Problem

Process integration of waste heat power cycle in EIP.

Plant 1 with waste heat @ 150ºC

ORC 1 with demand @ 120ºC

Plant 2 with waste heat @ 180ºC

ORC 2 with demand @ 140ºC

Plant 3 with waste heat @ 100ºC

ORC 3 with demand @ 160ºC

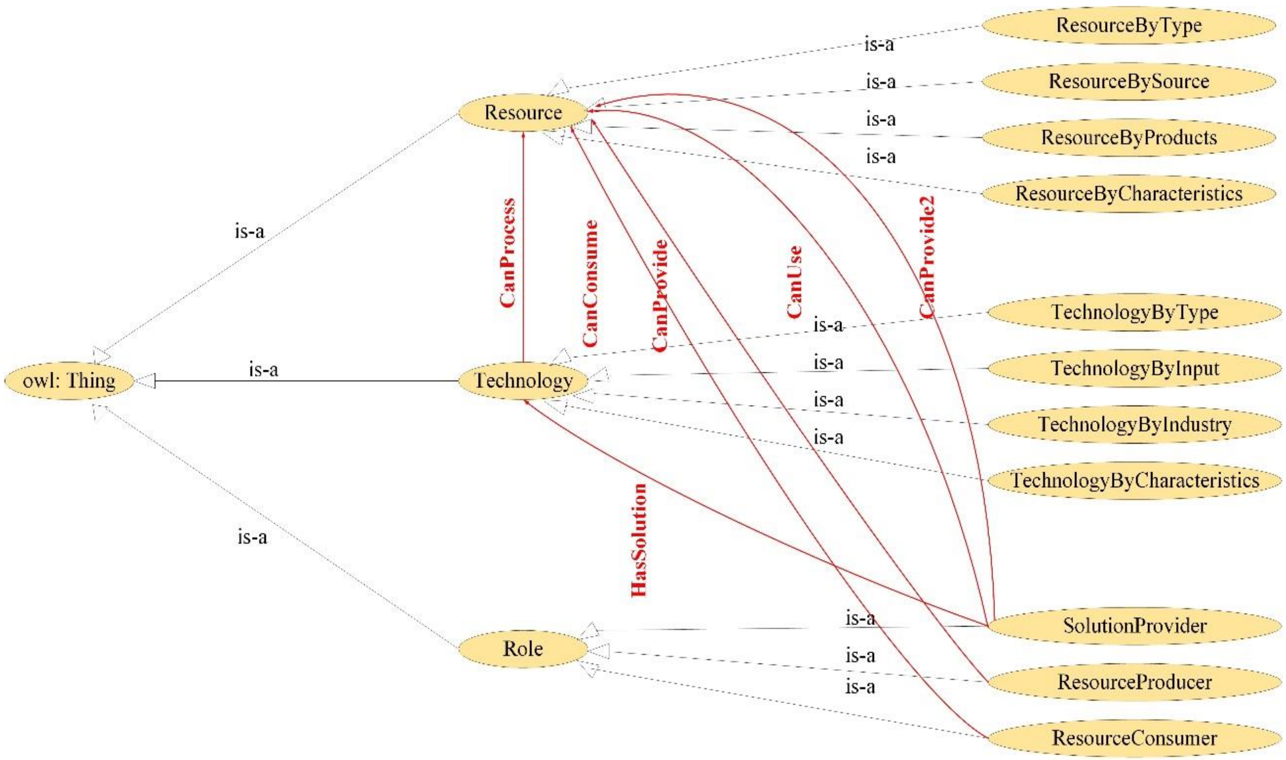
Challenge

1. Ontology-based system must know "ORC" can utilize waste heat from plant.

2. Each entity must be exactly and uniquely interfiled.

Chuan Zhang
czhang026@e.ntu.edu.sg

Demonstration of ontology-based approach

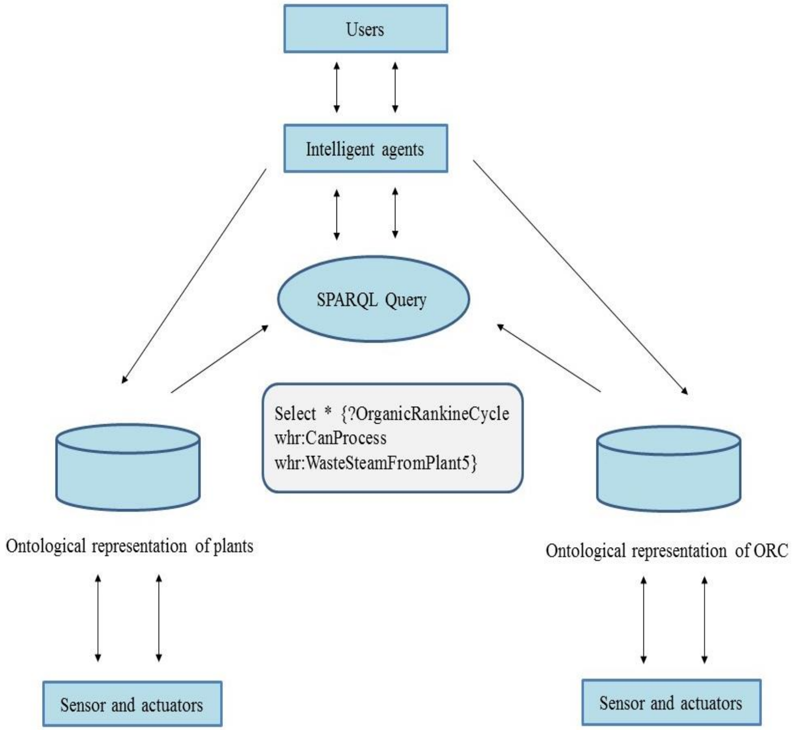


The ontology framework

Chuan Zhang
czhang026@e.ntu.edu.sg

Demonstration of ontology-based approach

Solution



Can be easily involved into natural language query.

Uniform Resource Identifier for each entity.

Information retrieval in SPAQRL language

Chuan Zhang
czhang026@e.ntu.edu.sg

1. Background

- **Apply Industrial 4.0 to eco-industrial park**

2. Model based intelligent expert system - JParkSimulator

- **Integrated platform for EIP energy management**

3. Demonstration of ontology-based approach capability

- **Intelligent query and data fusion**

4. Conclusion and future work

Chuan Zhang
czhang026@e.ntu.edu.sg

Conclusion

1. An ontology-based approach for eco-industrial park energy management is proposed in this paper.

2. Ontology can be expressed in machine-readable language, it will greatly facilitate the knowledge share between machines and software agents.

3. Ontology can overcome data heterogeneity through its own reasoning ability, which is crucial for increasing knowledge interoperability;

4. Ontology can make intelligent decision from remote databases, which implies the possibility of self-optimization without human intervention in the scenario of Internet of Things.

5. The prospective application of ontology-based approach can unleash the potential of artificial intelligence in eco-industry park energy management.

Chuan Zhang
czhang026@e.ntu.edu.sg

Acknowledgements

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE
Research . Innovation . Enterprise

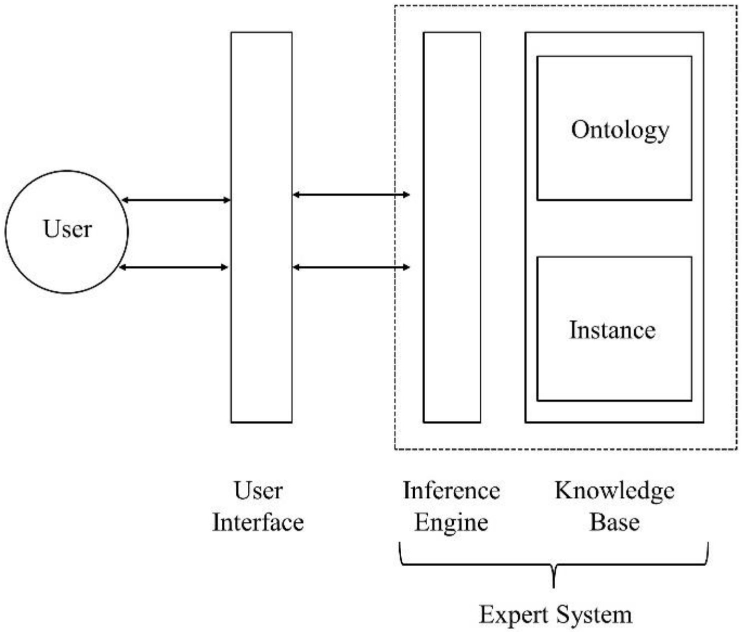
CREATE
Campus for Research Excellence And Technological Enterprise

Chuan Zhang
czhang026@e.ntu.edu.sg

Thanks & Questions?

Chuan Zhang
czhang026@e.ntu.edu.sg

Knowledge-based system: Software Infrastructure of Industrial 4.0



Architecture of a typical knowledge based system

A Knowledge-Based System (KBS) is defined as "a computer program that reasons and uses a knowledge base to solve complex problems".

The knowledge base needs to be well structured and organized, so that it can be accessed easily through a computer.

Ontologies have been used extensively by information technologists to systematically represent the knowledge in a domain.

Ontology is the backbone of knowledge based system.

Chuan Zhang
czhang026@e.ntu.edu.sg