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COMPUTER
SCIENCE

UNIVERSITY OF
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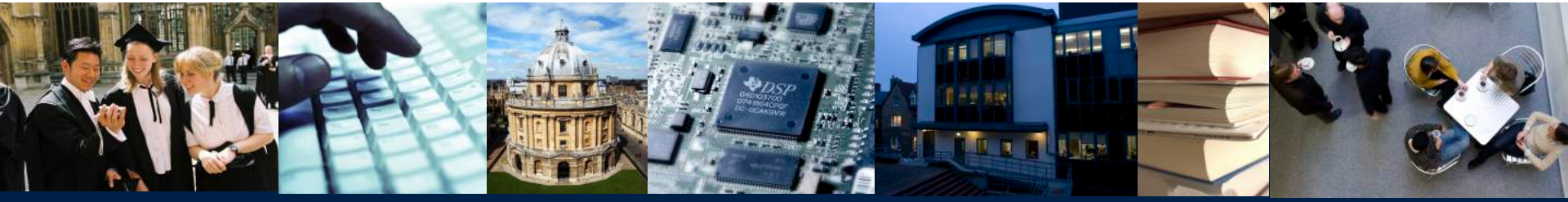


Ontologies and Reasoning

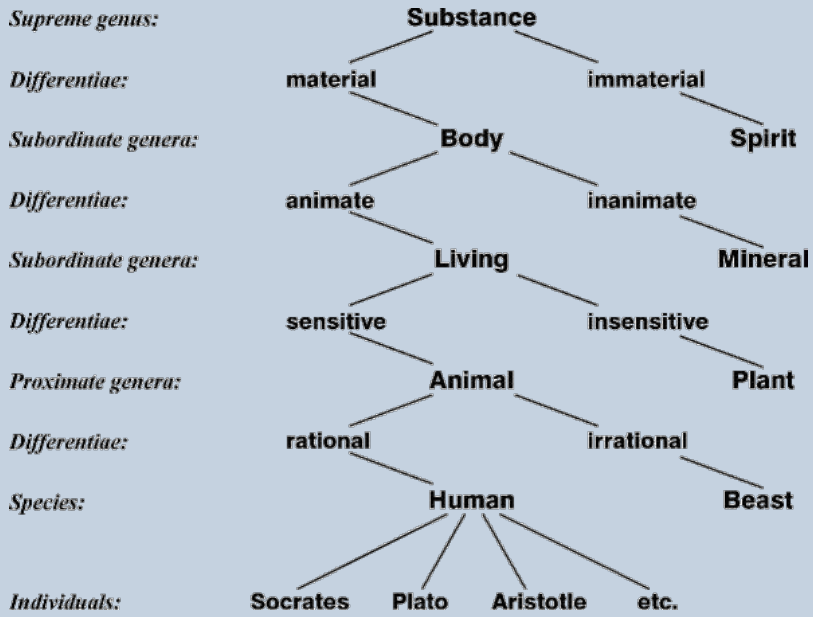
Ian Horrocks
Information Systems Group

What is an Ontology?

What is an Ontology?

A fundamental branch of **metaphysics**

- Studies “being” or “existence” and their **basic categories**
- Aims to find out what **entities** and **types of entities** exist



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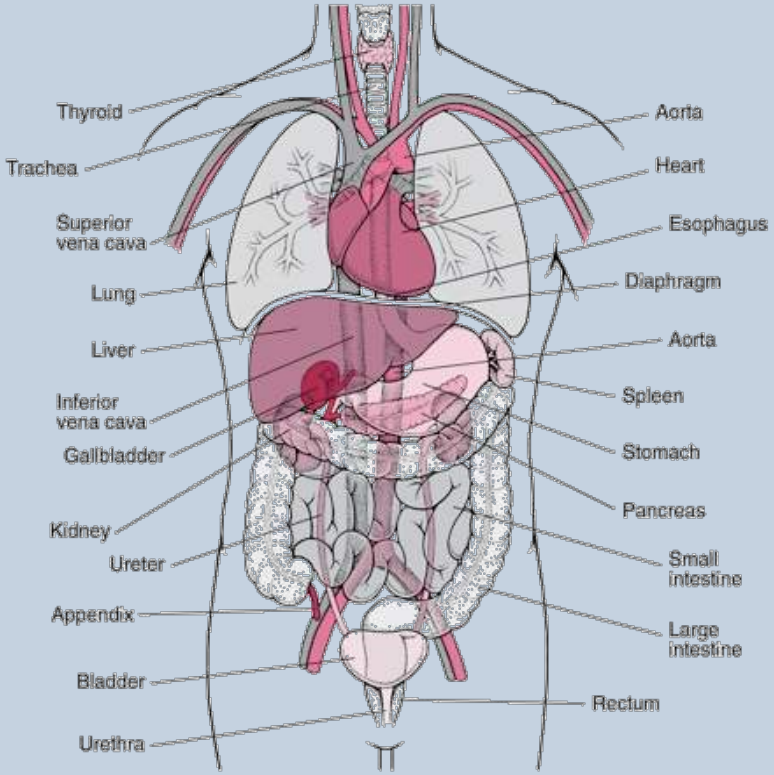

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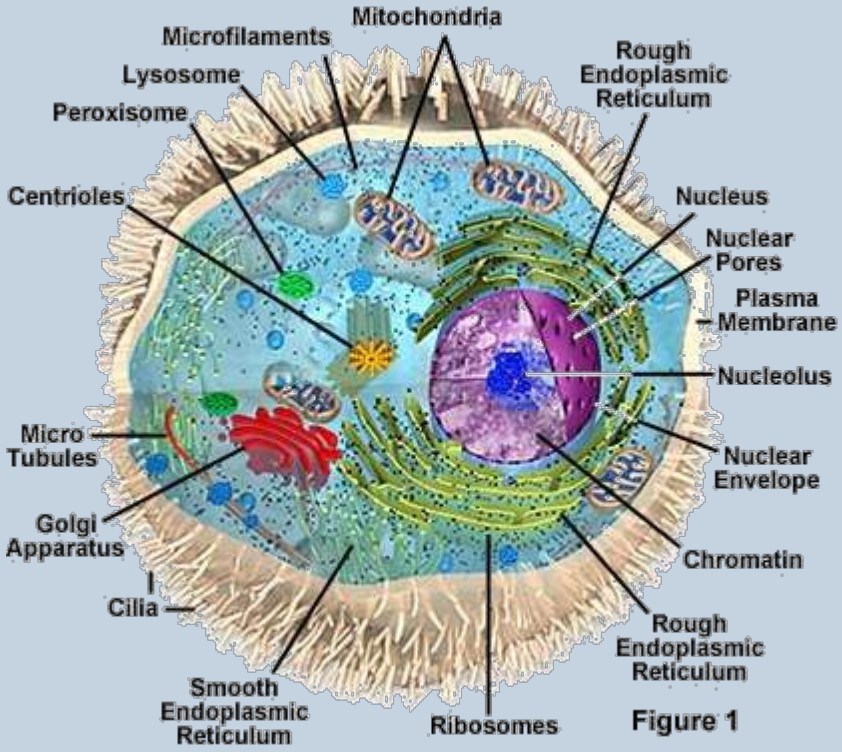

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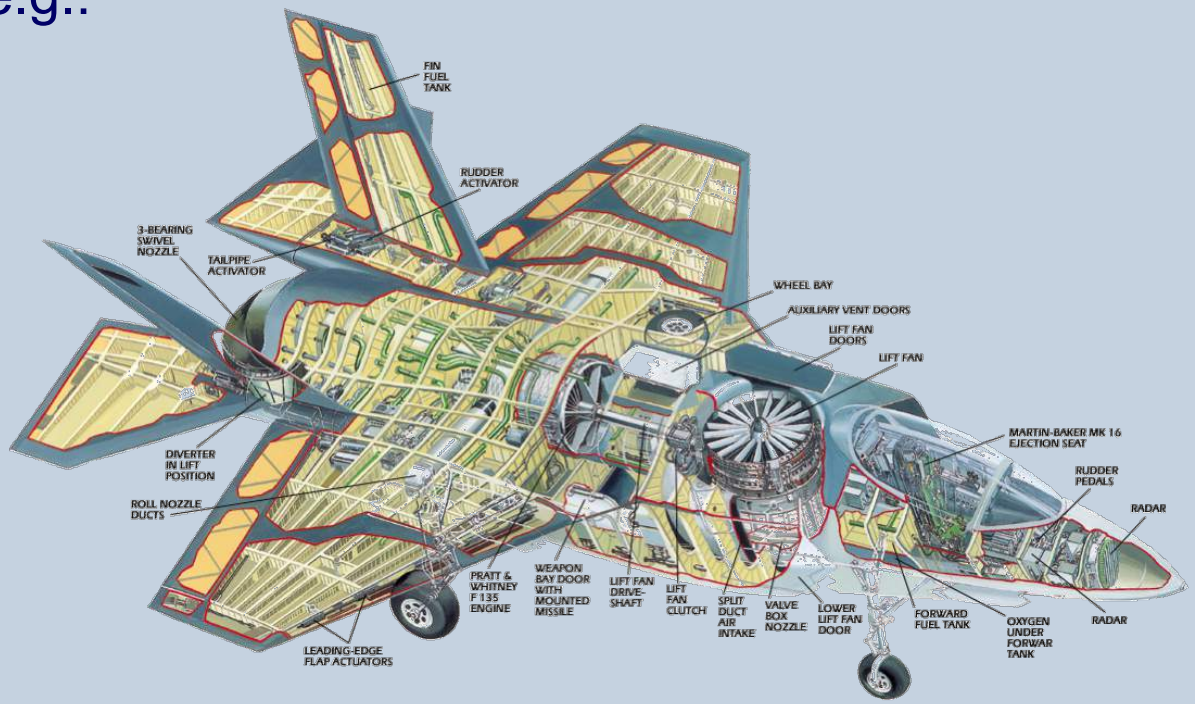
  - Aerospace



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  - Anatomy
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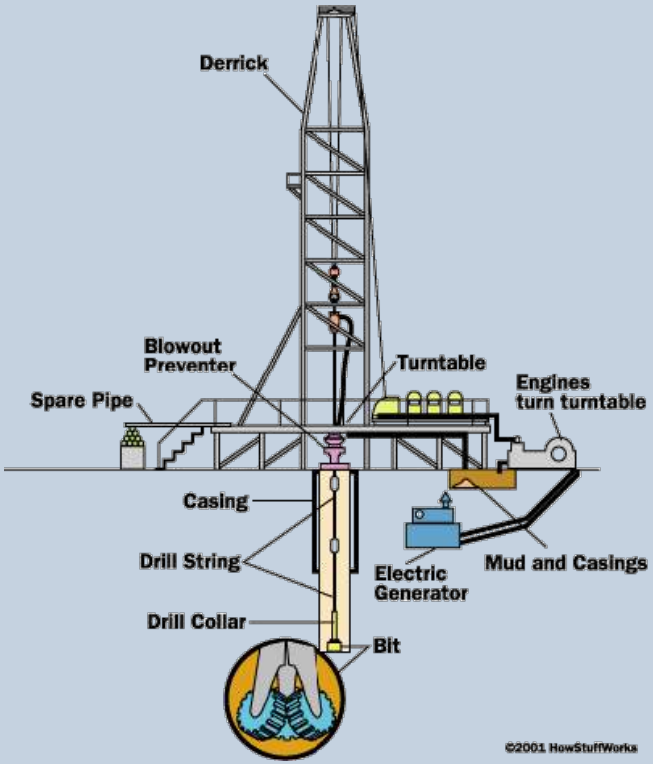
  - Oil and gas



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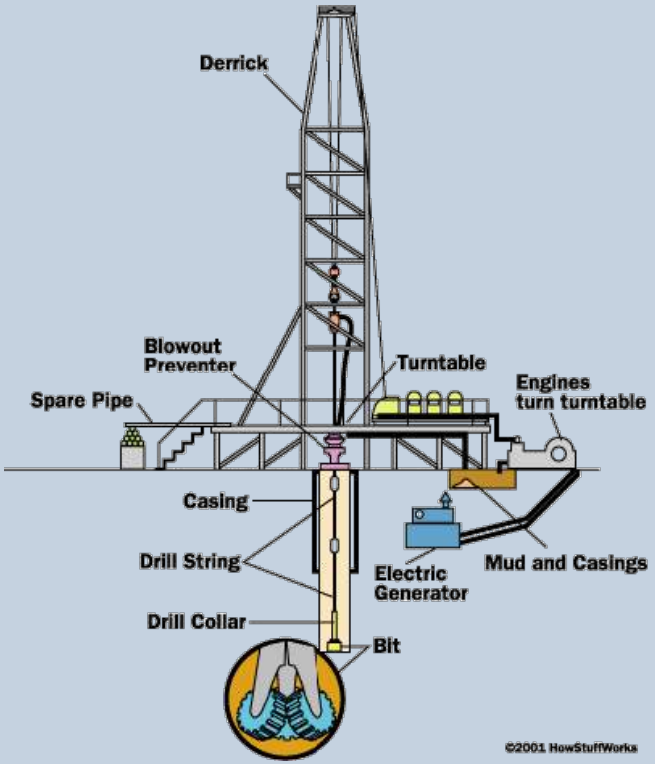
Oil pipeline is a pipeline from a facility that is an oil facility



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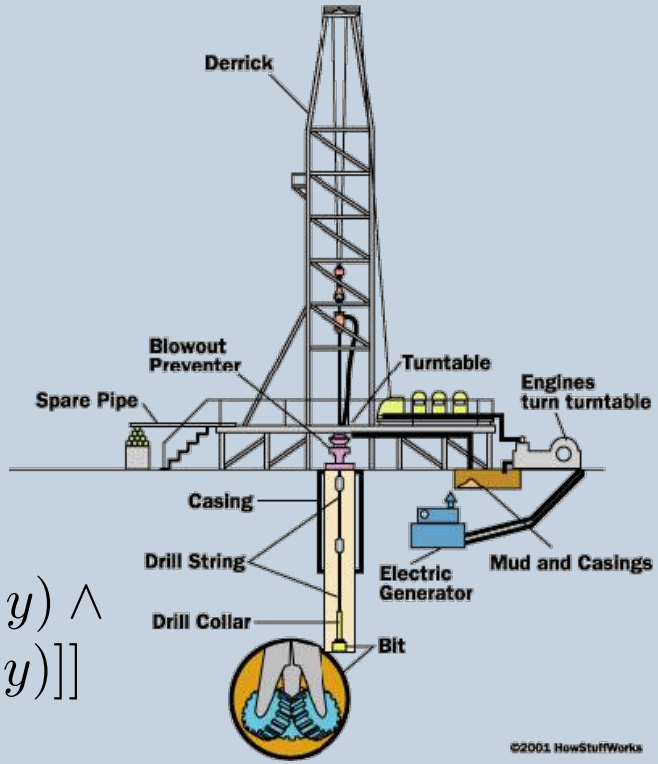
- **Formalised** using suitable logic

$$\forall x.[\text{OilPipeline}(x) \rightarrow \text{Pipeline}(x) \wedge \exists y.[\text{fromFacility}(x, y) \wedge \text{OilFacility}(y)]]$$



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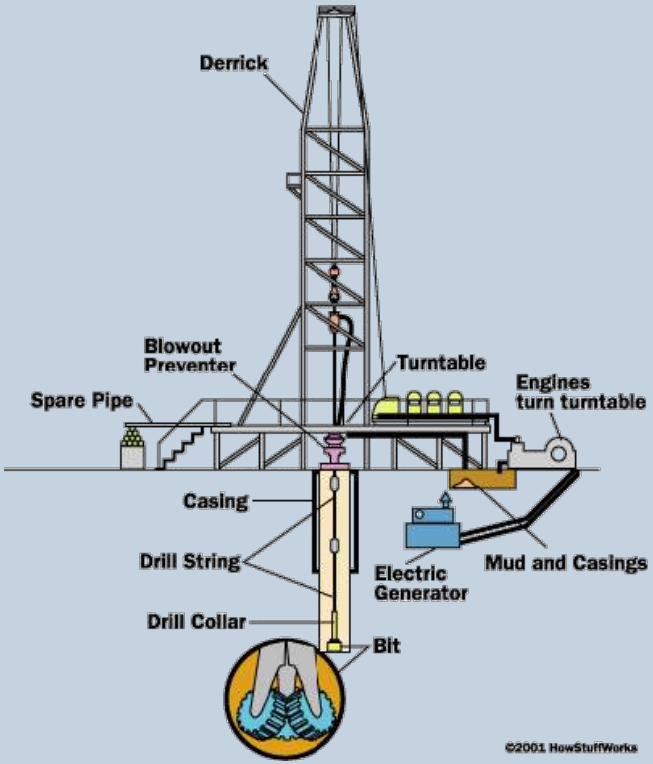

Applications: HCLS

- **OBO foundry** includes more than 100 biological and biomedical ontologies
- **Siemens** “actively building OWL based clinical solutions”
- **SNOMED-CT** (Clinical Terms) ontology
  - used in healthcare systems of more than 15 countries, including Australia, Canada, Denmark, Spain, Sweden and the UK
  - also used by major US providers, e.g., Kaiser Permanente
  - ontology provides common vocabulary for recording clinical data

Applications: Energy Supply Industry

- **EDF Energy** offer personalised energy saving advice to every customer

- **OWL ontology** used to model relevant environmental factors

- **Oxford's HermiT reasoner** used to match customer circumstances with relevant pieces of advice

Applications: Intelligent Mobile Platform

- **Samsung** developing Intelligent Moblile Platform to support context-aware applications
- IMP monitors environment via **sensor data** (GPS, compass, accelerometer, ...)
- **OWL ontology** used to model environment and **infer context** (e.g., coffee with friends)
- Applications exploit context to enable more **intelligent behaviour**

Applications: Oil and Gas Industry

- **Statoil** use data to inform production and exploration management
  - Large and complex data sets are difficult and time consuming to use
- Using ontologies to **improve access** to relevant data

Barriers to Wider Adoption

- **Ontology engineering** (methodological)
  - Extensive tool support (editing, reasoning, explanation, modularity)
  - Carefully designed “upper ontologies”
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  - Carefully designed “upper ontologies”
  - But it’s still hard
- **Ontology reasoning** (computational)
  - Highly optimised OWL reasoners
  - OWL profiles and specialised reasoners
  - But it’s still hard

Ontology Engineering: Case Study

SNOMED is **BIG** – over **400,000 concepts**

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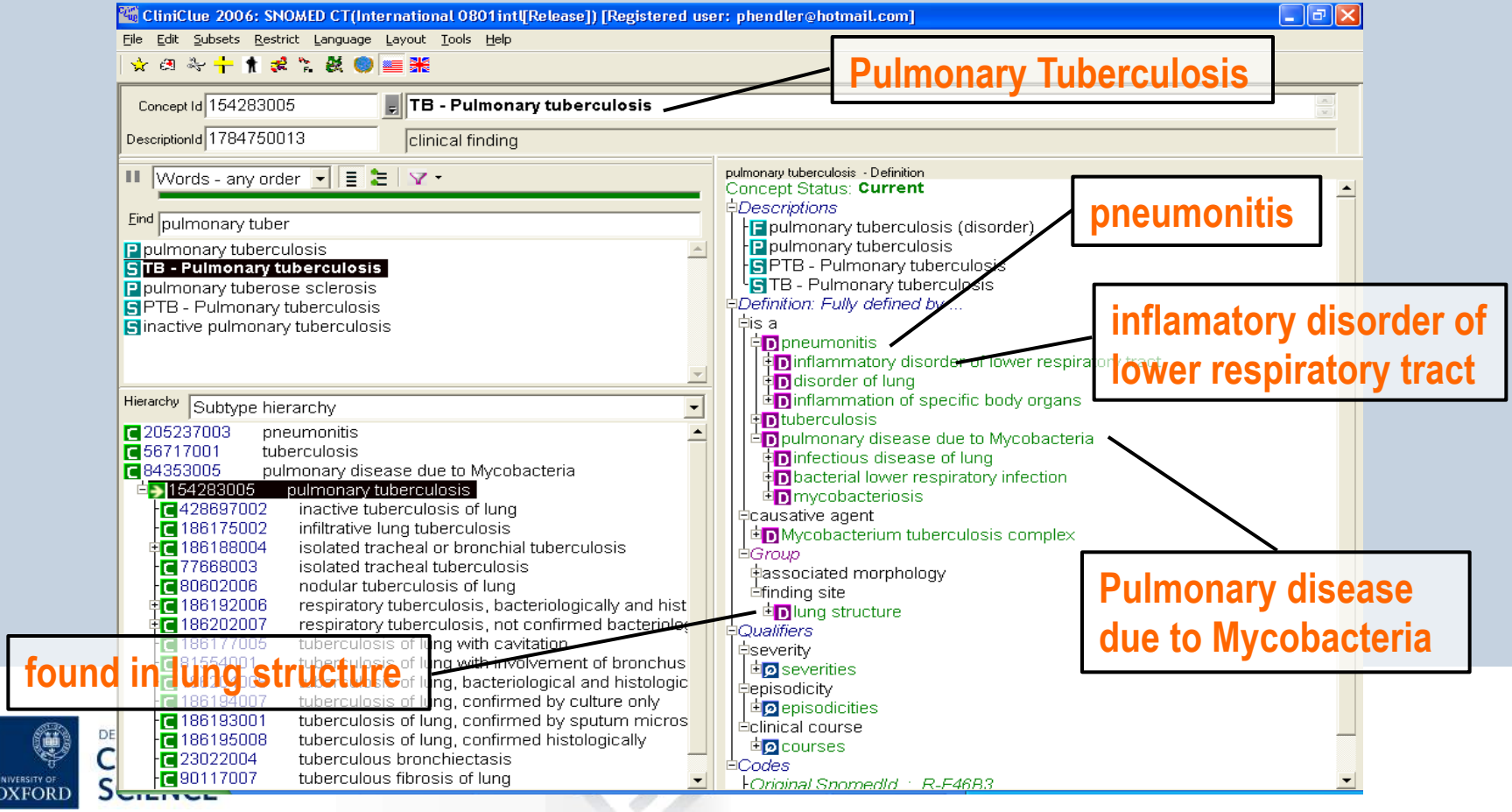

Ontology Engineering: Case Study

- **Kaiser Permanente** extending SNOMED to express, e.g.:
  - *non-viral pneumonia* (negation)
  - *infectious pneumonia* is caused by a *virus* or a *bacterium* (disjunction)
  - *double pneumonia* occurs in two *lungs* (cardinalities)
- This is easy in **SNOMED-OWL**
  - but reasoner failed to find expected subsumptions, e.g., that *bacterial pneumonia* is a kind of *non-viral pneumonia*
- Ontology highly **under-constrained**: need to add disjointness axioms (at least)
  - *virus* and *bacterium* must be disjoint

Ontology Engineering: Case Study

- Adding disjointness led to **surprising results**
  - many classes become inconsistent, e.g., *percutanious embolization of hepatic artery using fluoroscopy guidance*
- Cause of **inconsistencies** identified as class *groin*
  - *groin* asserted to be subclass of both *abdomen* and *leg*
  - *abdomen and leg* are disjoint
  - modelling of *groin* (and other similar "junction" regions) identified as incorrect

Ontology Engineering: Case Study

- Correct modelling of groin is quite complex, e.g.:
  - groin has a part that is part of the abdomen, and has a part that is part of the leg (***inverse properties***)

$$\begin{aligned} \mathsf{Groin} &\sqsubseteq \exists \mathsf{hasPart}.(\exists \mathsf{isPartOf}.\mathsf{Abdomen}) \\ \mathsf{Groin} &\sqsubseteq \exists \mathsf{hasPart}.(\exists \mathsf{isPartOf}.\mathsf{Leg}) \\ \mathsf{hasPart} &\equiv \mathsf{isPartOf}^{-} \end{aligned}$$

  - all parts of the groin are part of the abdomen or the leg (**disjunction**)

$$\mathsf{Groin} \sqsubseteq \forall \mathsf{hasPart}.(\exists \mathsf{isPartOf}.(\mathsf{Abdomen} \sqcup \mathsf{Leg}))$$

  - ...

Ontology Engineering: Case Study

What we learned:

- Ontology engineering is **error prone**
  - errors of omission (e.g., disjointness) and commission (e.g., modelling of groin)
- **Expressive features** of OWL are sometimes needed
- Sophisticated tool support is **essential**
  - handling ontologies of this size is challenging
  - domain experts (and logicians!) often need help to understand the (root) cause of both inconsistencies and non-subsumptions
  - surprising and unexplained (non-) inferences are frustrating for users and may cause them to lose faith in the ontology and/or reasoner

Ontology Deployment: **OBDA**

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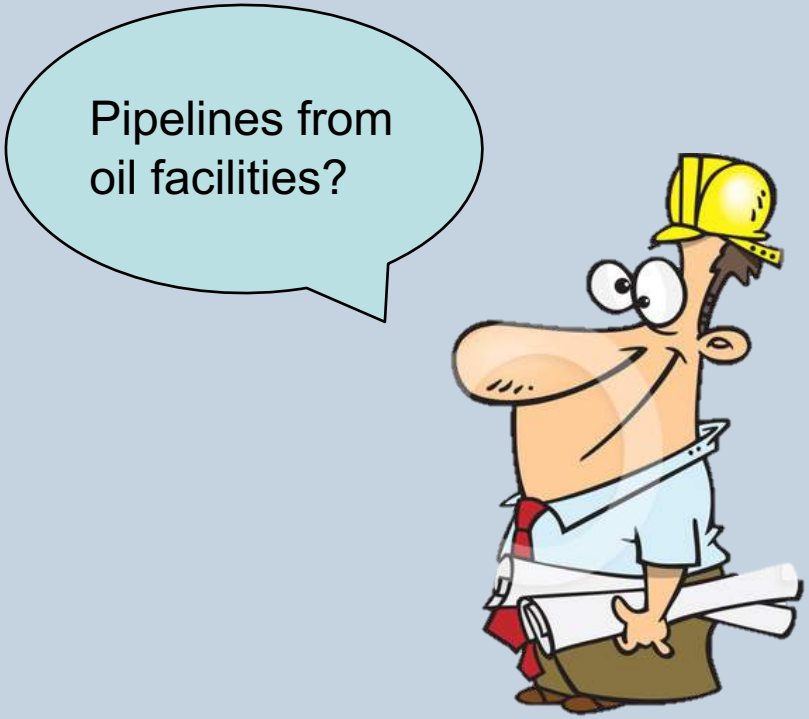

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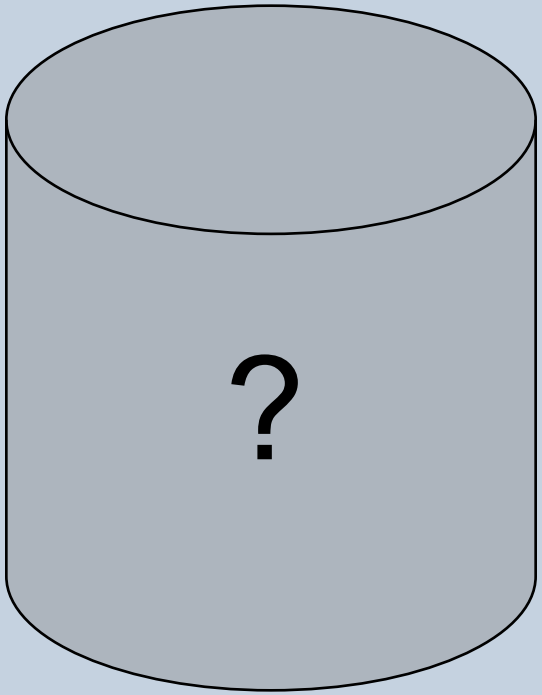

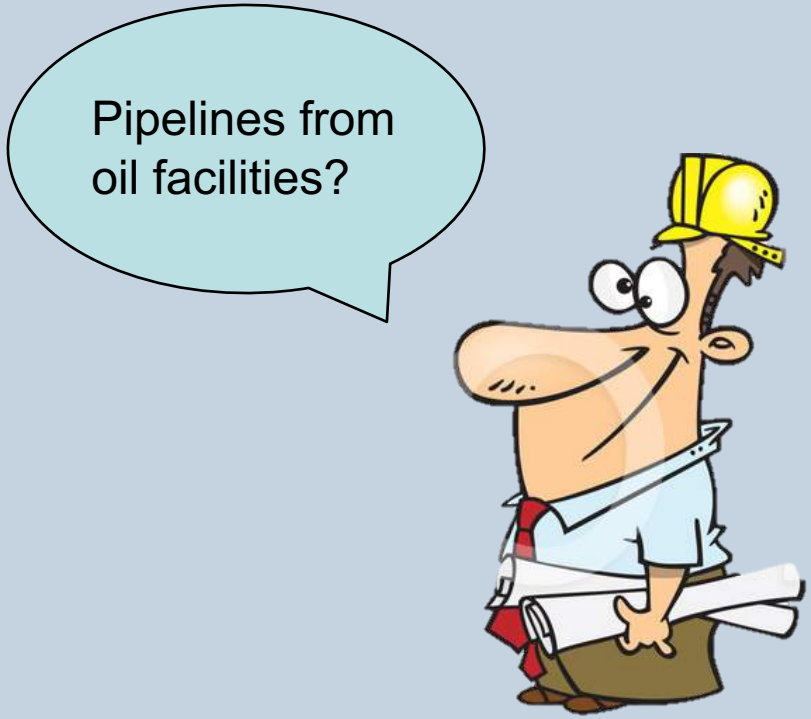

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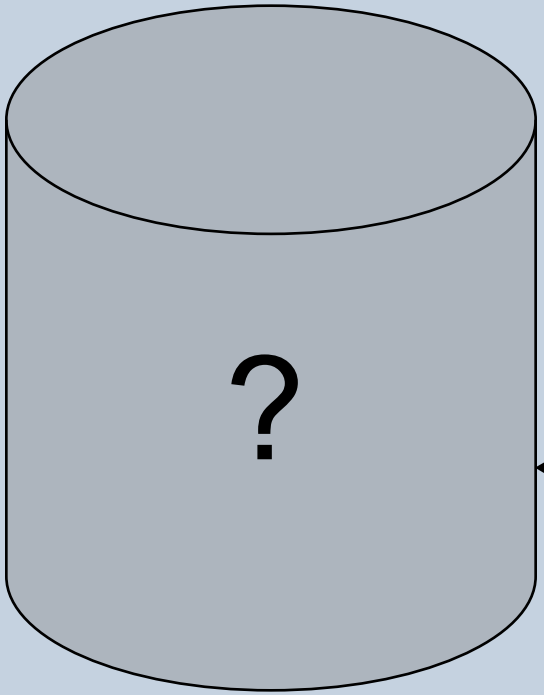

Pipelines from oil facilities?

$$Q(x) \leftarrow \text{Pipeline}(x) \wedge \text{fromFacility}(x, y) \wedge \text{OilFacility}(y)$$

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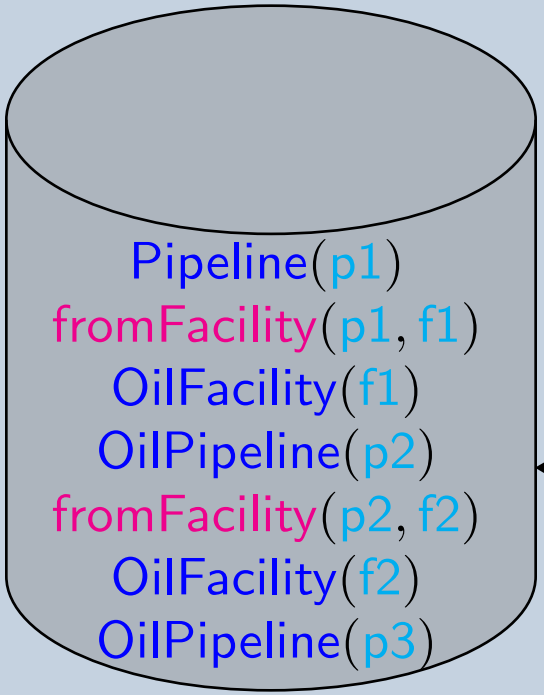

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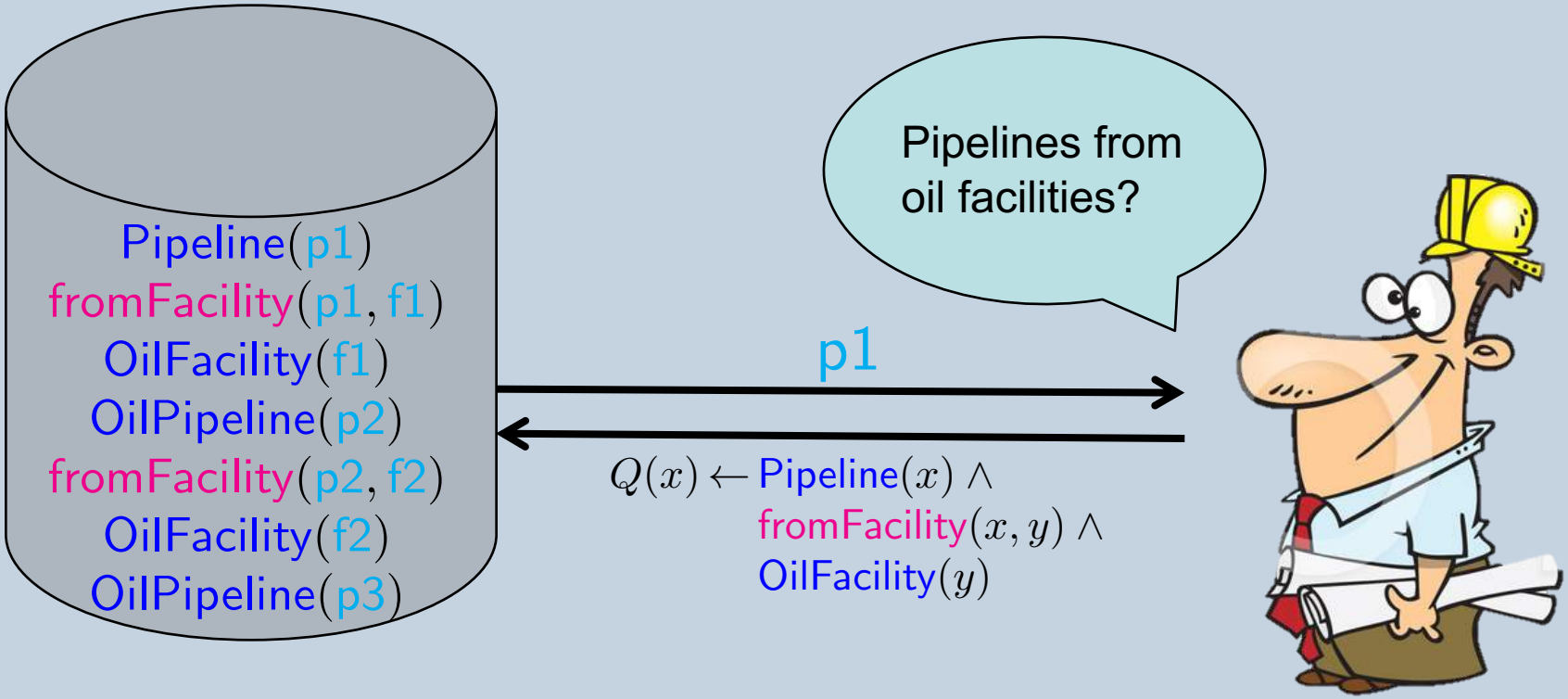

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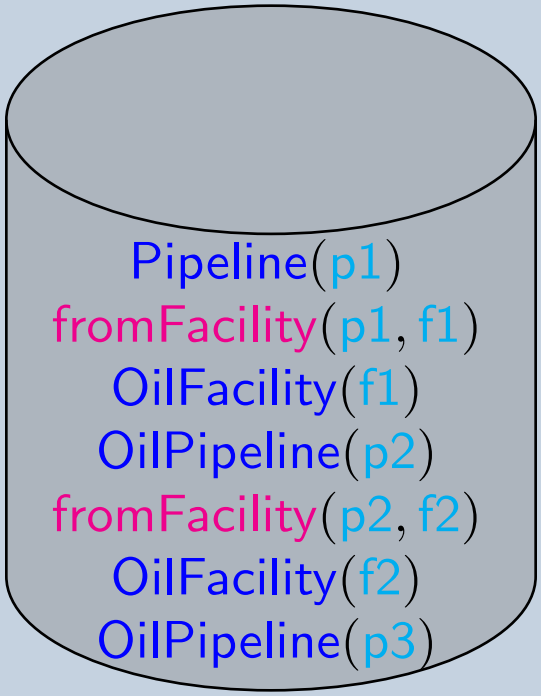

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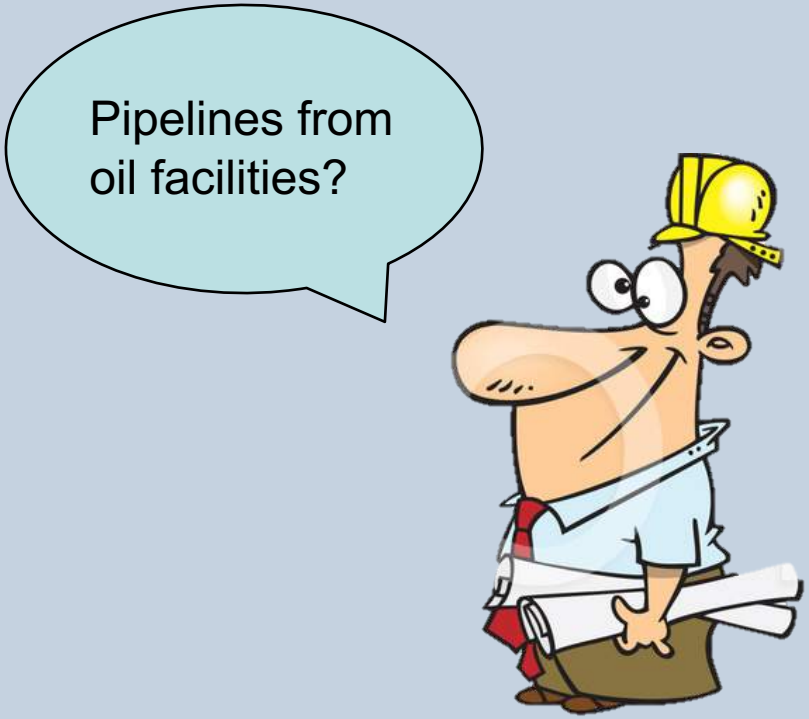

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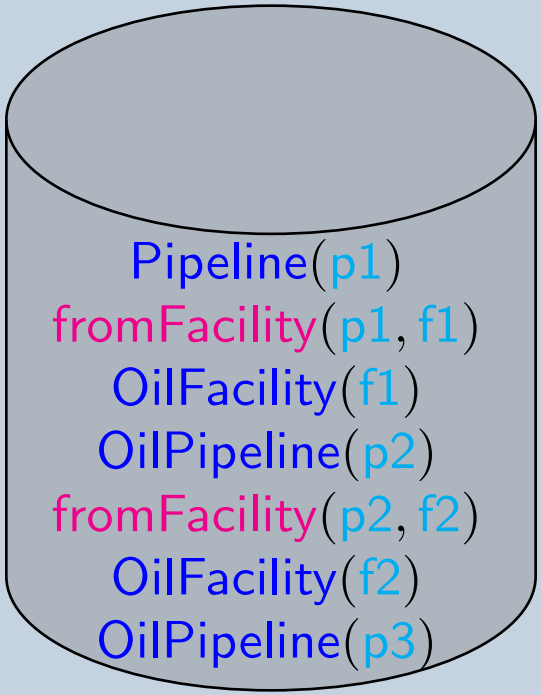

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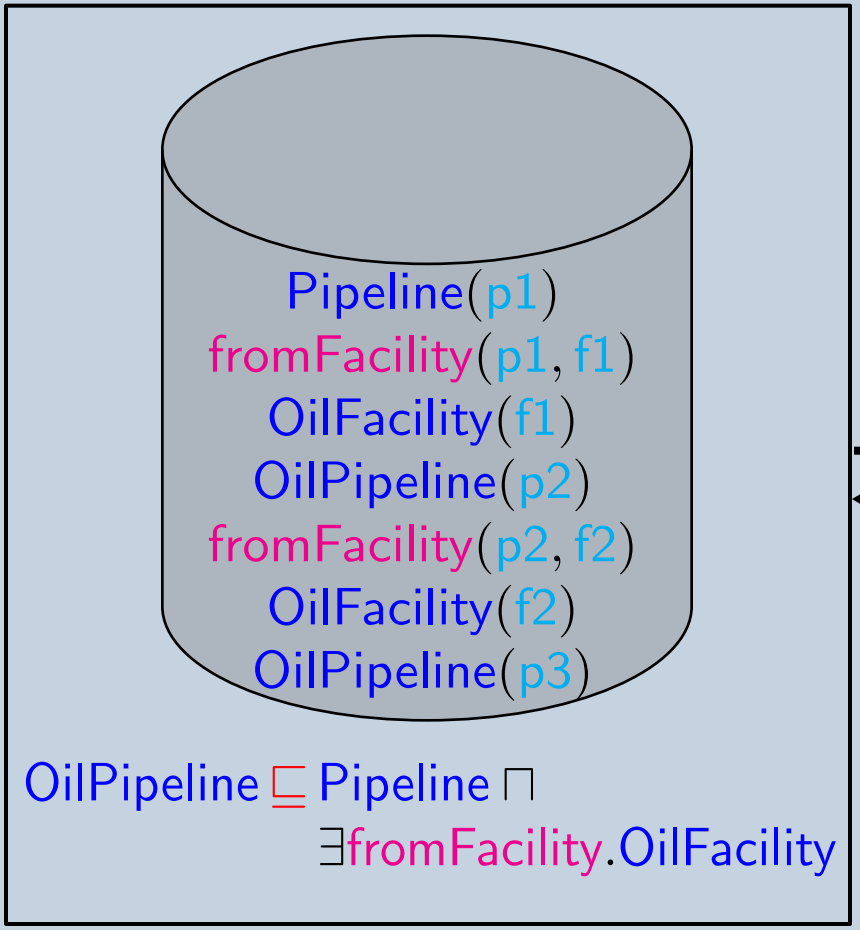

Pipelines from oil facilities?

p1, p2, p3

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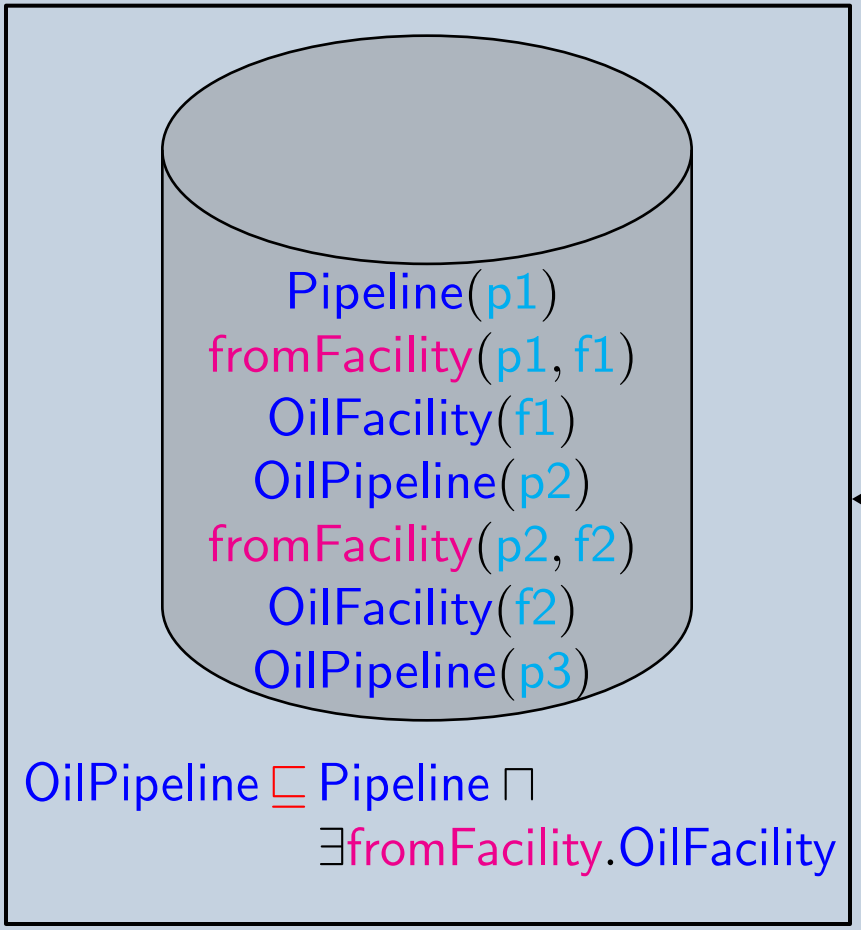

Is an oil pipeline a kind of pipeline?

$\forall x.[\mathsf{Pipeline}(x) \rightarrow \mathsf{OilPipeline}(x)]$?

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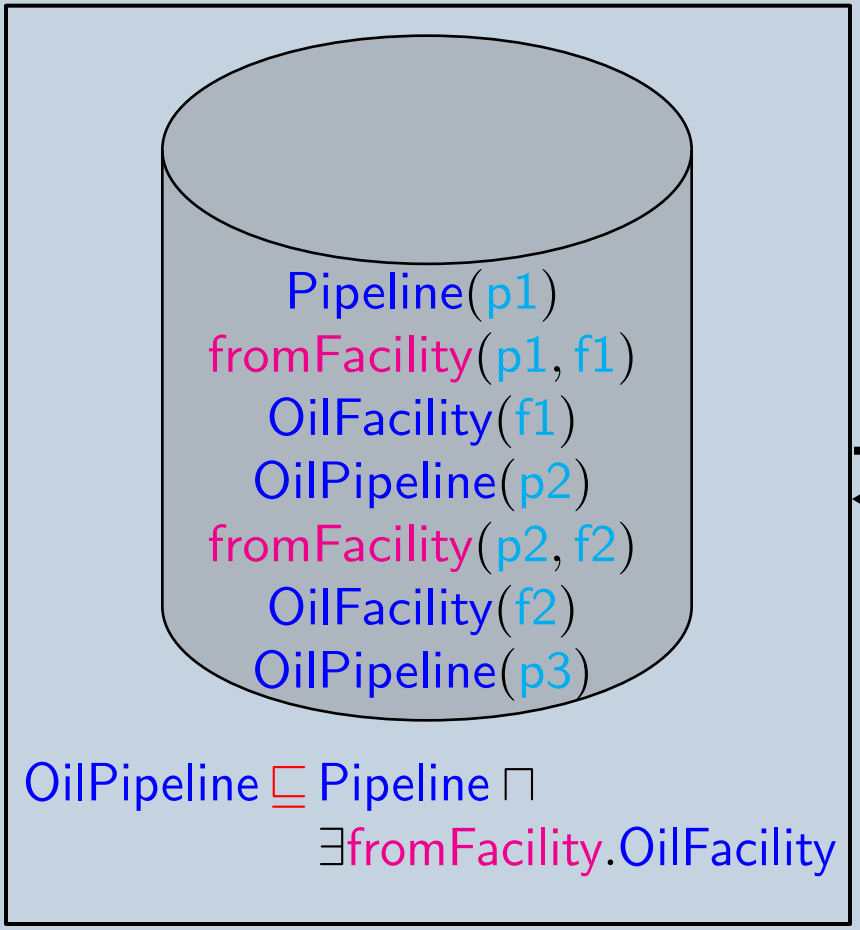

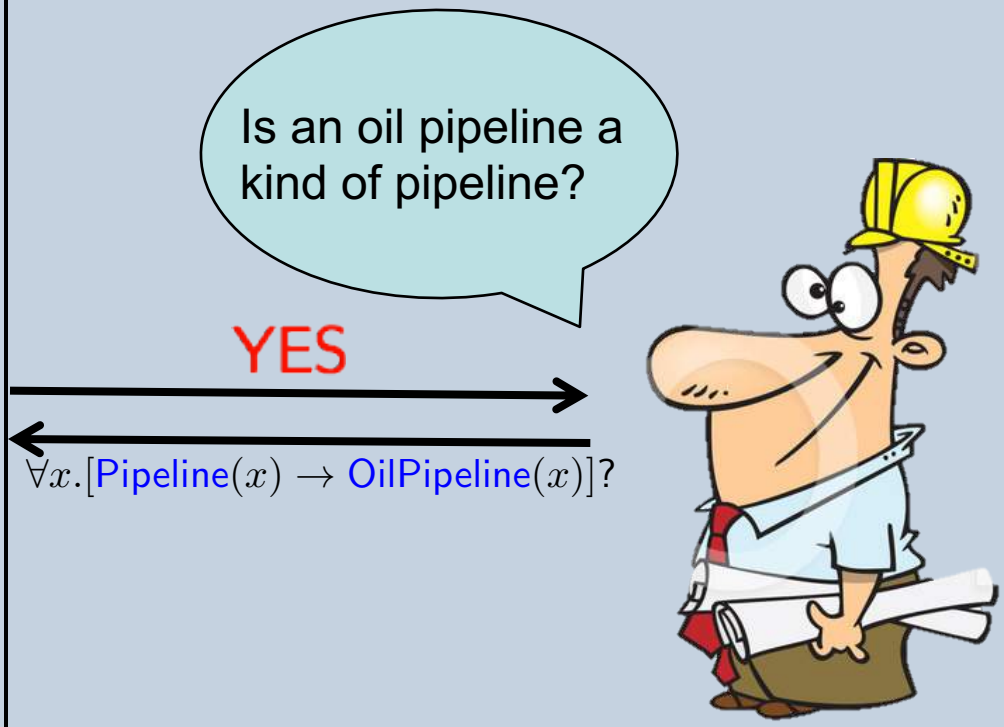

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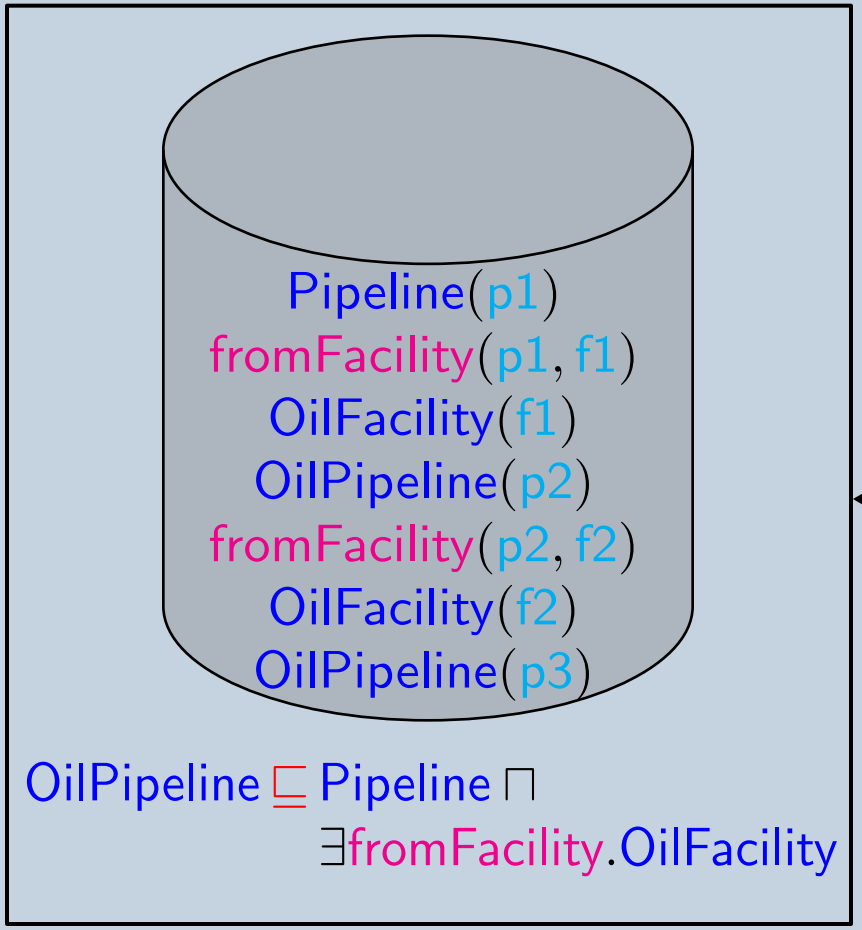

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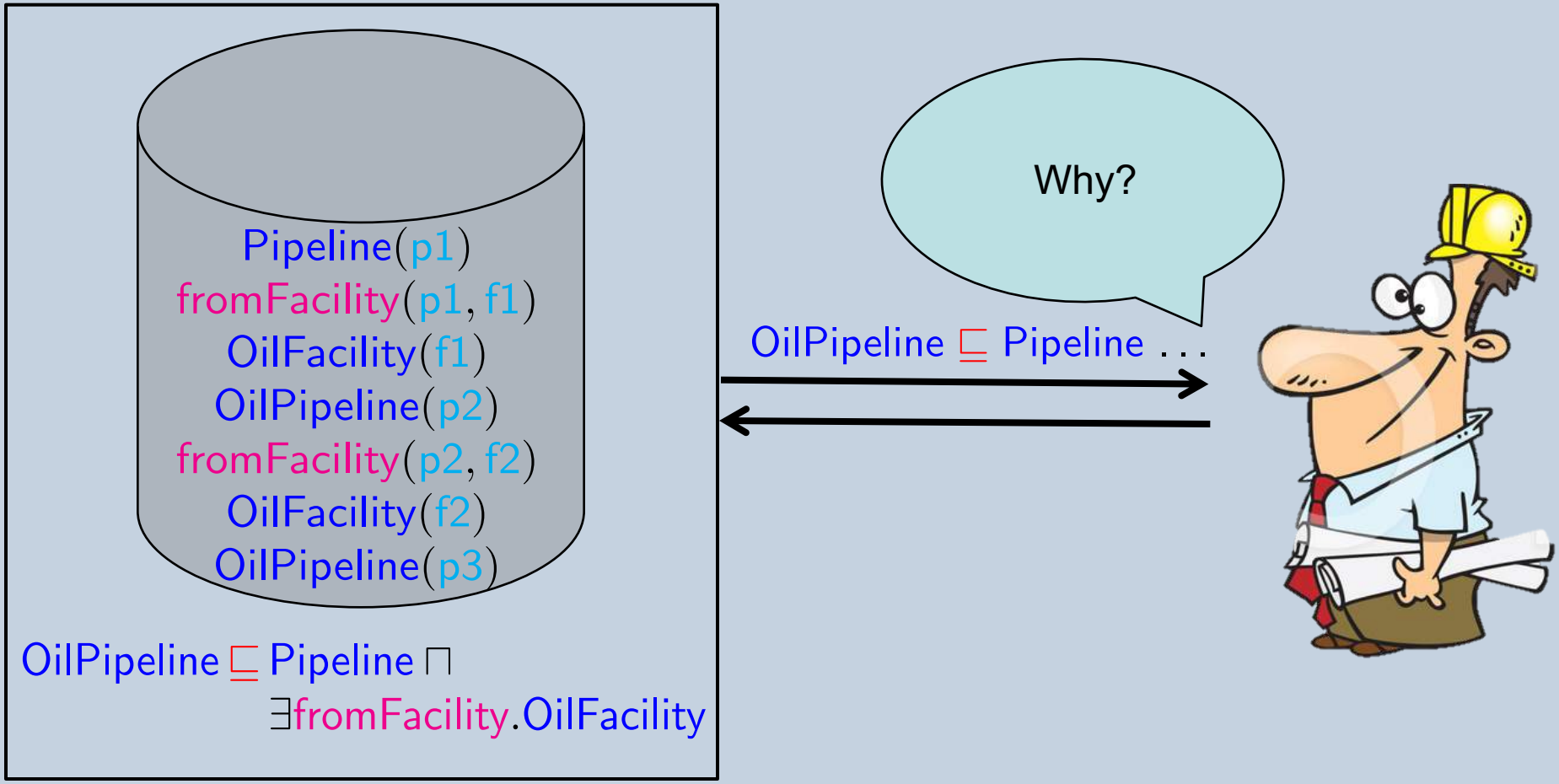

Semantic Technologies

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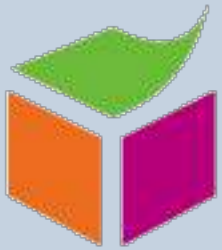

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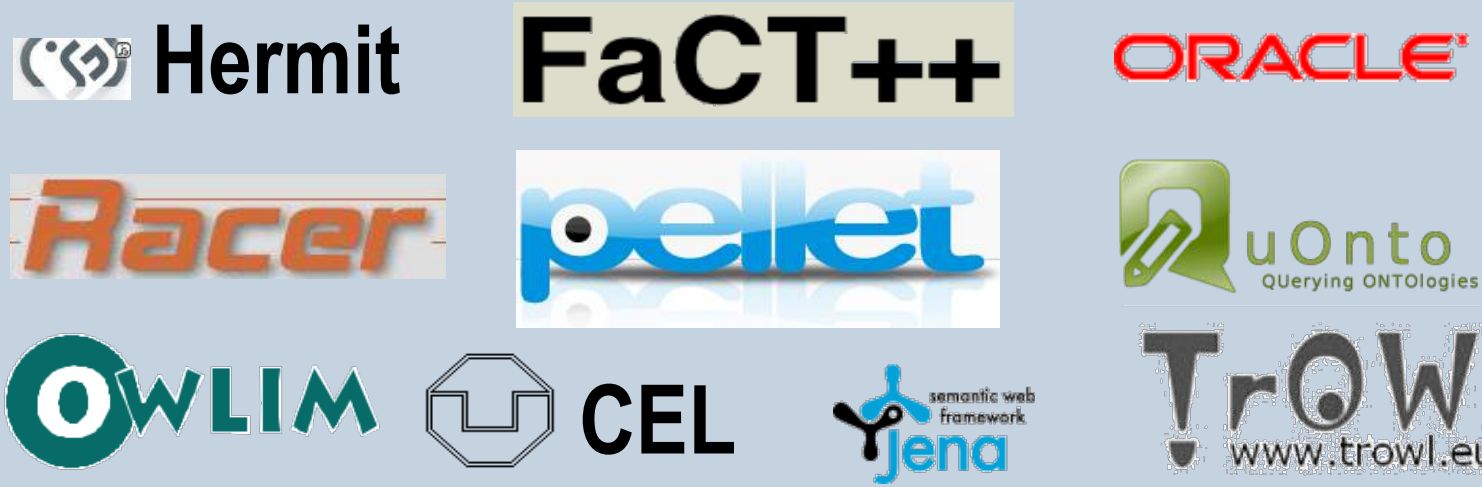

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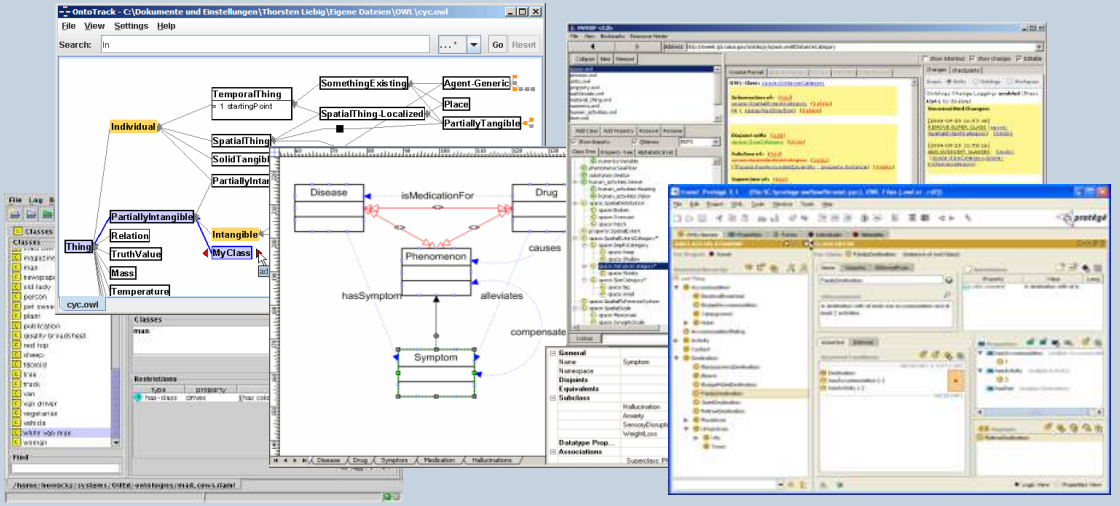


Semantic Technologies

- SemWeb motivated development of **robust infrastructure**:
  - Languages
  - Storage reasoning and query answering
  - Development tools
- Increasingly used as part of “Intelligent Information Systems


THE END?

Ongoing Research

- Query answering
  - [Motik et al], [Kontchakov et al], [Konev et al], [Baader et al], …
- Diagnosis and repair
  - [Horridge et al], [Peñaloza et al], …
- Extensions
  - [Motik et al], [Artale et al], …
- Optimisation/Profiles
  - [Kazakov], [Glimm et al], [Faddoul et al], [Savo et al], …
- Parallelization/Distribution/HPC
  - [Motik et al], [Gurajada et al], [Neumann et al], [Wu et al], …

Acknowledgements

EPSRC Engineering and Physical Sciences Research Council

SIXTH FRAMEWORK PROGRAMME

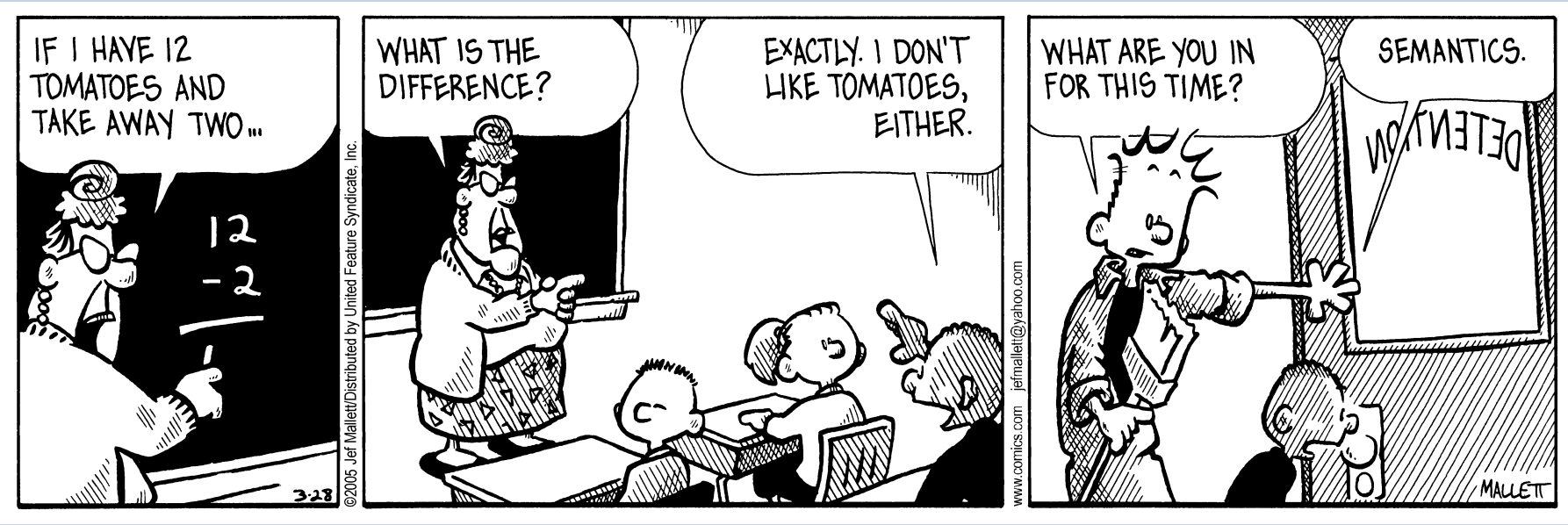
SEVENTH FRAMEWORK PROGRAMME

DARPA

UNIVERSITY OF OXFORD DEPARTMENT OF COMPUTER SCIENCE

Information Systems Group

Thank you for listening



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