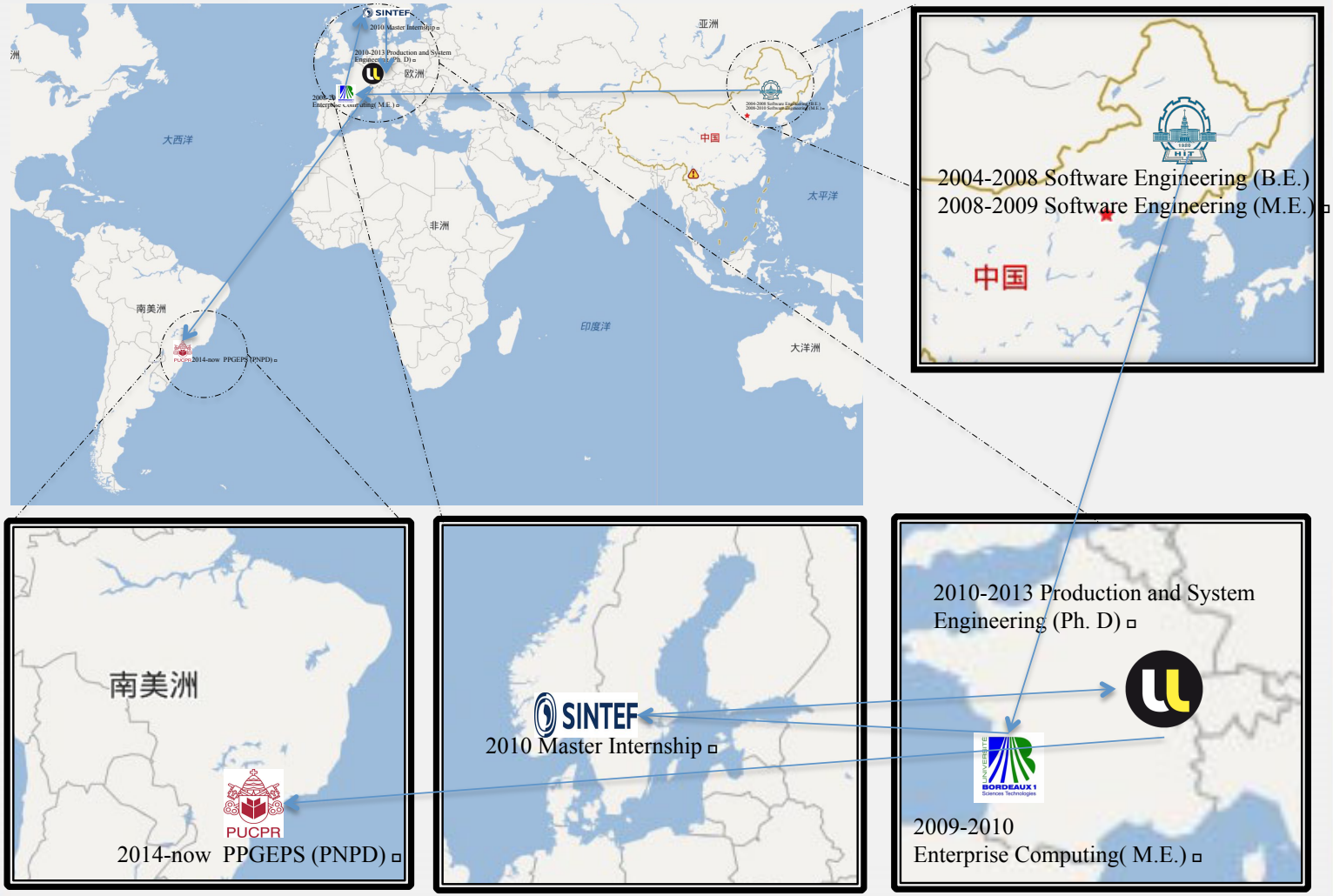
Graduate Program in Production Engineering and Systems

(PPGEPS)

An Introduction to Ontology Engineering

Dr. Yongxin Liao

Research Experience



Ontology

(in information science domain,
since 1980s)

The Famous Applications of Ontology

- Medical Science
  - E.g. Vocabulary Unification

Gene Ontology Project [1]

- Intelligence Personal Assistants
  - E.g. Semantic Matching and Disambiguation

Siri [2]

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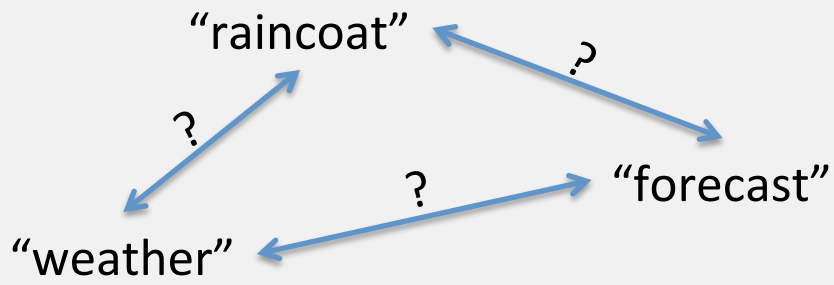
Siri - Weather

- Three Questions in the video
  - "What is the weather like today?"
  - "What is the hourly forecast?"
  - "Do I need a raincoat today?"
- How is Siri capable of understanding the meanings of the concept "weather", "forecast" and "raincoat"?
- How is Siri capable of understanding the relationships between them?



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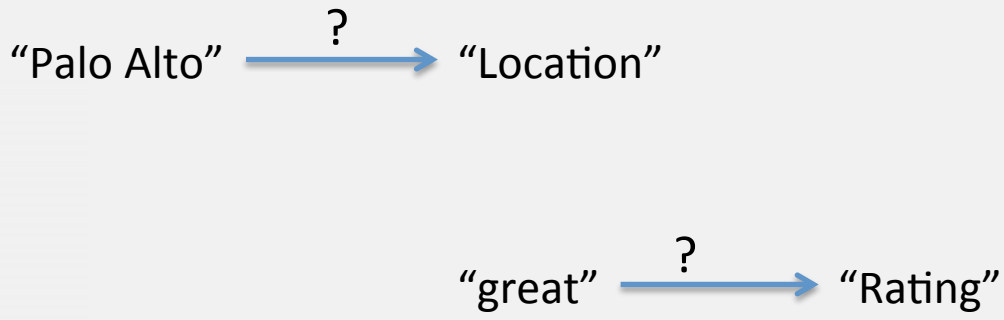
Siri - Book a Restaurant

- One question in the Video
  - "Find me a great Greek restaurant in Palo Alto."

- How is Siri capable of understanding the "Palo Alto" is a Location, and "great" is related to rating?



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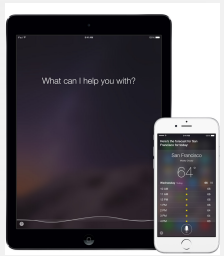
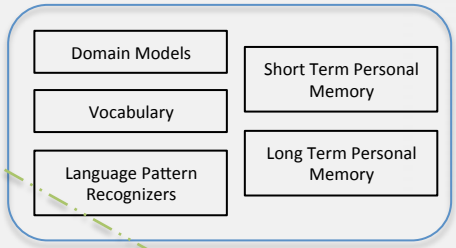
Agent (Intelligent Personal Assistant)



Mobile Devices

Siri [2]

Related Technologies
- Speech Recognition
- NL Understanding
- NL Generation
- Text-to-Speech Synthesis
- etc.

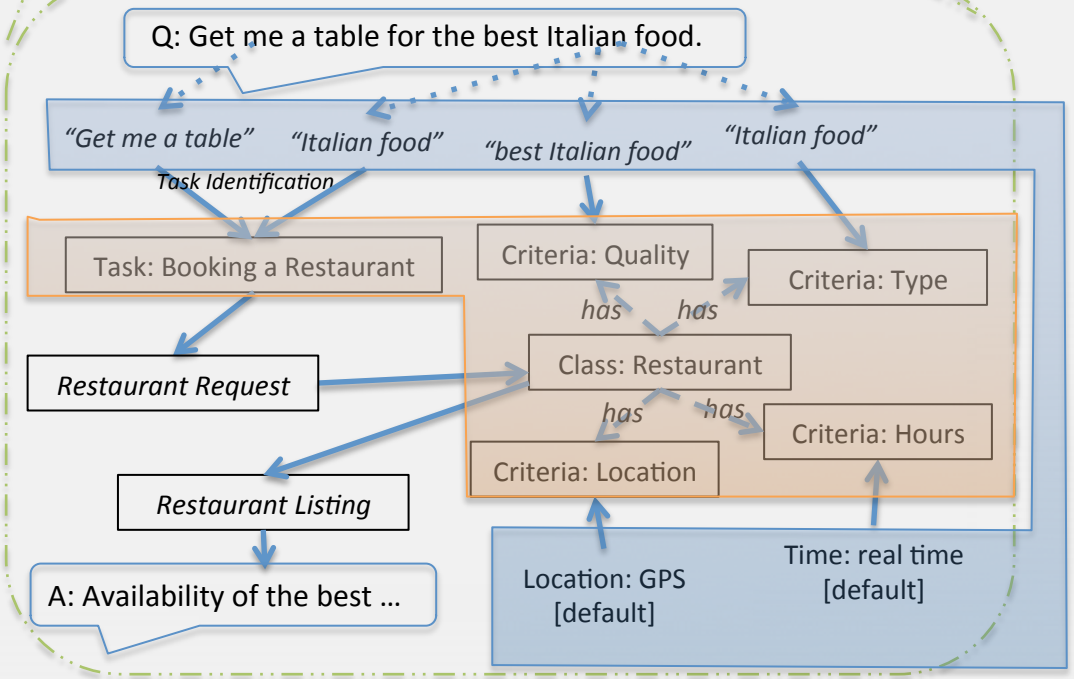


Active Ontology
(Knowledge Base)

Questions

Answers
(audible and visual)

Human



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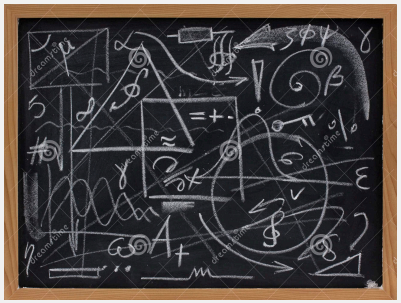
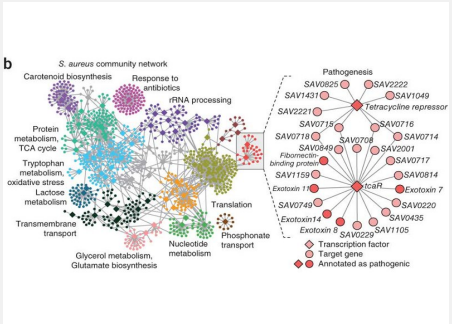
Main Objective of This Course



Real World Information

How to formally represent?

How to Inference and Query?



Ontology

Outlines of this Lecture

- What is an Ontology?
  - The Definition of Ontology
  - How Mankind and Machine Abstracts the World?
- Ontology in a PLC Context
  - A Simple Example and Issues in a PLC Context
  - Existing Ontologies for Different Stages in a PLC
- What Can You Learn From This Course?
- Schedule
- Protégé Practices

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What is an Ontology?

- Definitions (Information Science)
  - "An ontology is an explicit specification of a conceptualization" Tom Gruber [3].

(1) What is an explicit specification?

Explicit: Stated clearly and in detail (leaving no room for confusion or doubt).

Specification: A detailed description of how to make something.

(2) What is a conceptualization?

Conceptualization: A conceptualization is an abstract, simplified view of the world that we wish to represent for some purposes.

Ontology ⇨ A clear and detailed description of how to make an abstract, simplified view of the world.

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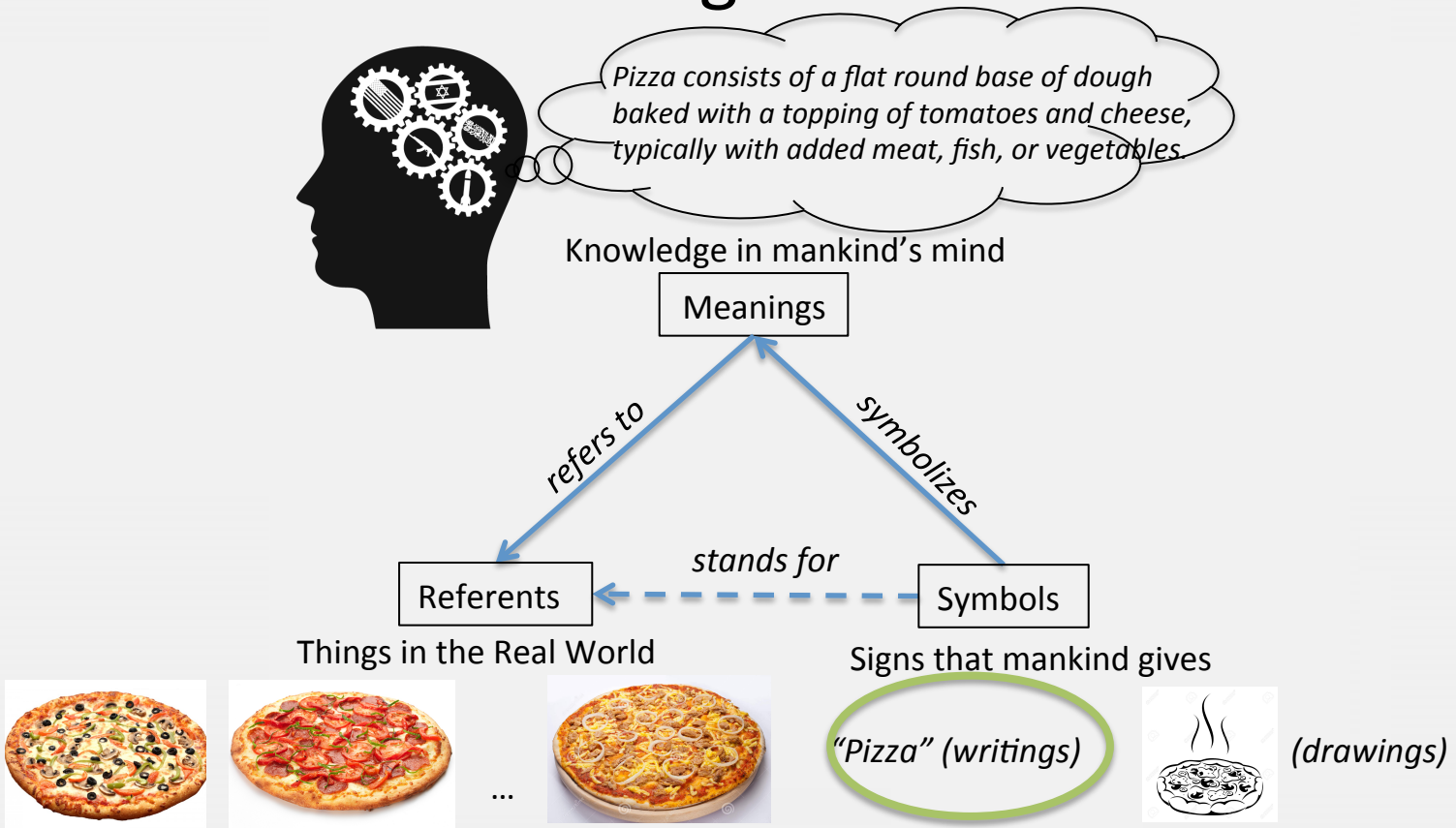
How Mankind Abstracts and Simplifies the World?

- The Semantic Triangle



By Ogden and Richards (1923) , in *The Meaning of Meaning*.

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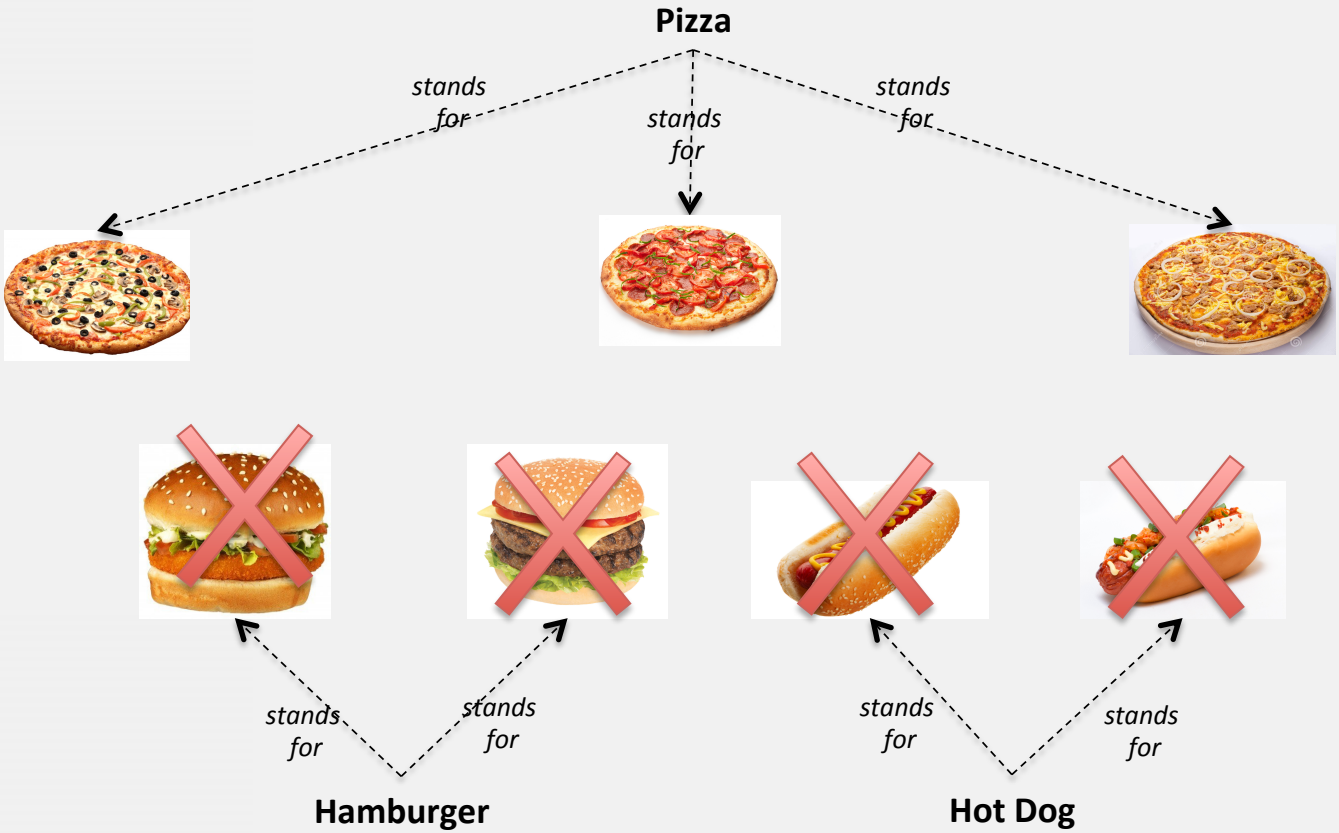
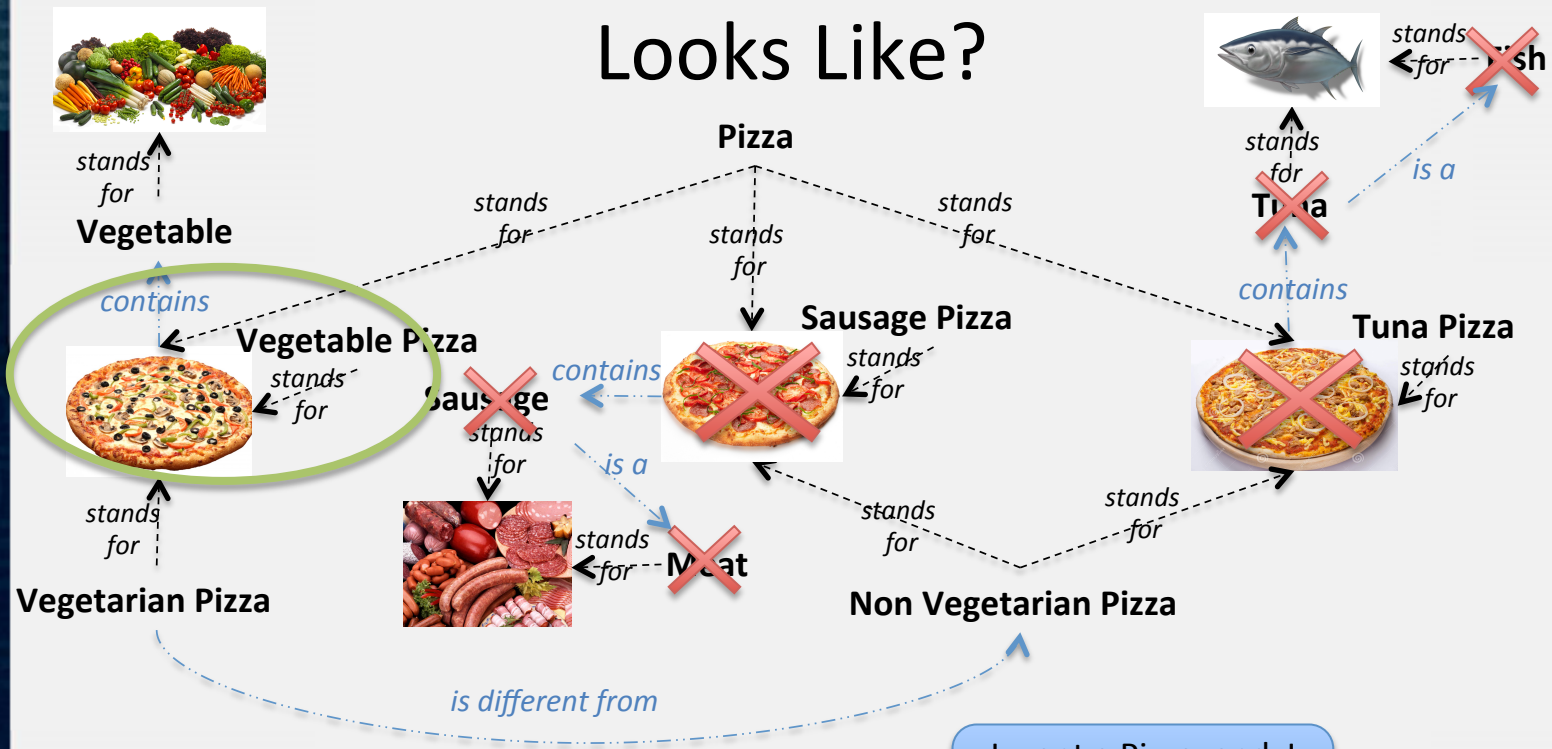
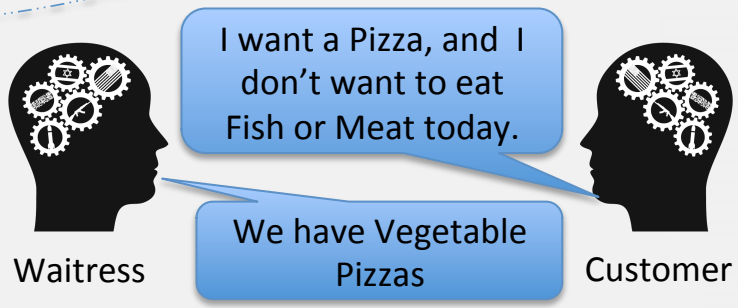
How This Abstracted and Simplified View Looks Like?



How This Abstracted and Simplified View Looks Like?



How this abstracted and simplified view looks like:
(1) Using Concepts to classify things in the world;
(2) Describing the relationships between Concepts;
(3) Use (1) and (2) to do Logical Inference .



Pizza *consists of a flat round base of dough baked with a topping of tomatoes and cheese, typically with added* ***meat***, ***fish***, *or* ***vegetables***.

What is an Ontology?

conceptualization

This abstract and simplified view of the world is represented as "a set of **Concepts** and **Relationships** that can exist for an agent or a community of agents" by Tom Gruber [3]

Ontology is a clear and detailed description of how to make this conceptualization, which

(1) introduces the **Concepts** relevant to a domain of interest

- e.g. "Pizza", "Hot Dog", "Hamburger", "Meat", "Fish", "Vegetable", "Sausage", "Tuna", "Vegetable Pizza", "Sausage Pizza", "Tuna Pizza", "Vegetarian Pizza", "Non Vegetarian Pizza", and so on.

(2) and specifies the **Relationships** between those Concepts

- e.g. "Vegetarian Pizza" *is different from* "Non Vegetarian Pizza"
  "Vegetable Pizza" *contains* "Vegetable"
  "Vegetable Pizza" does not *contain* "Meat" or "Fish"
  "Sausage Pizza" *contains* "Sausage"
  "Tuna Pizza" *contains* "Tuna"

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What is an Ontology?

This abstract and simplified view of the world is represented as "a set of **Concepts** and **Relationships** that can exist for an agent or a community of agents" by Tom Gruber [3]

The one who commits to this conceptualization

Engineering Domain

"Model"

Fashion Domain

Production Engineers

Fashion Designers

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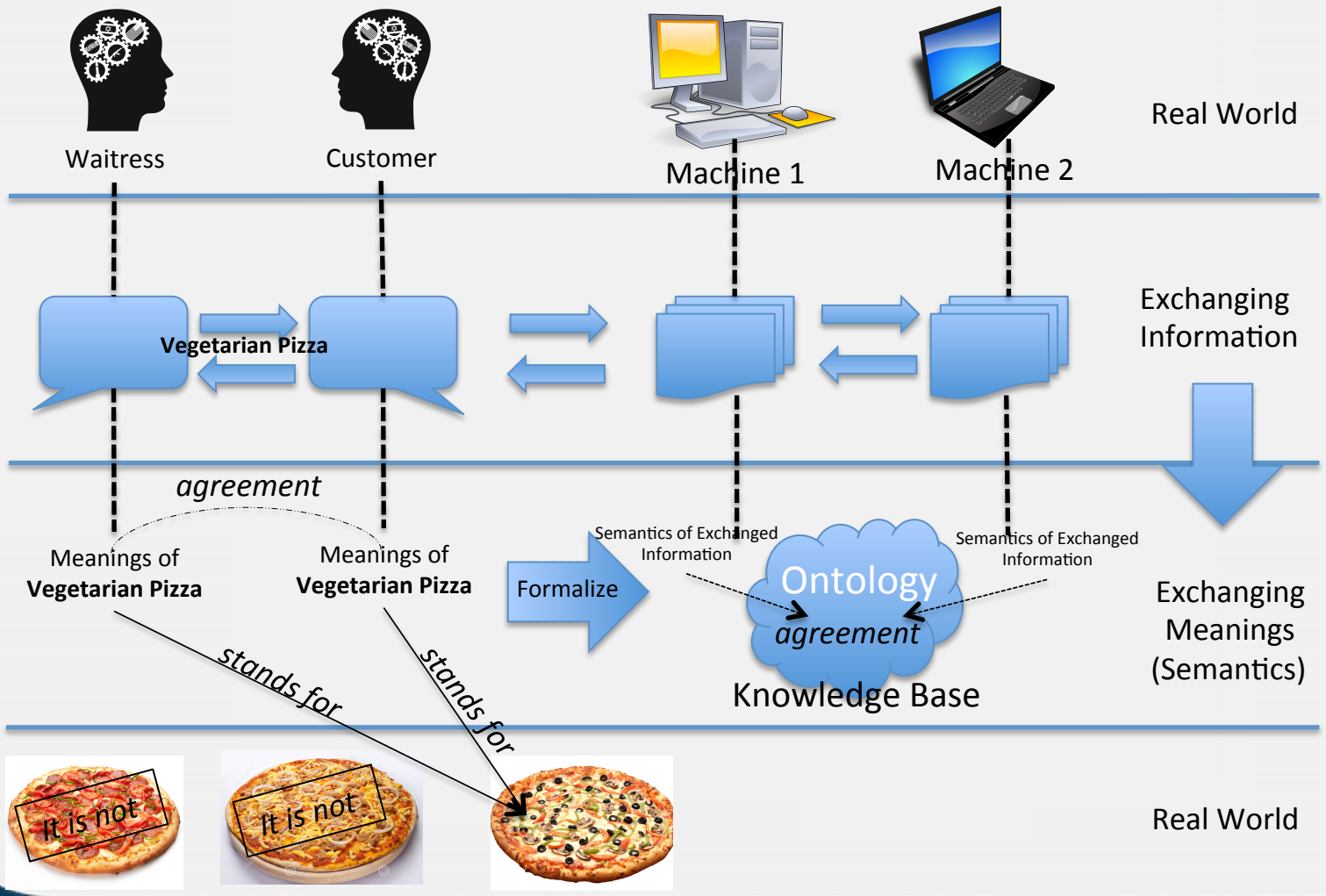
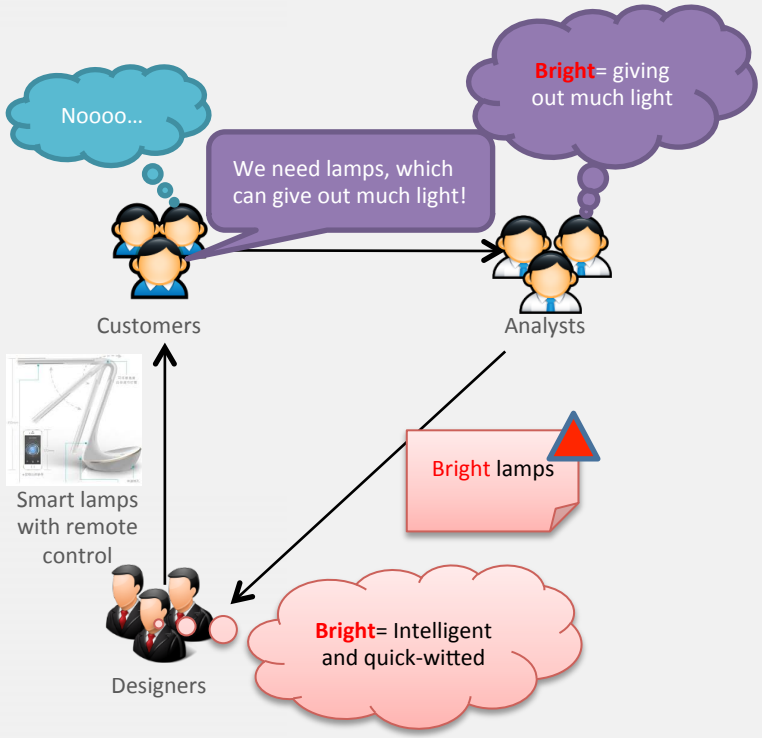
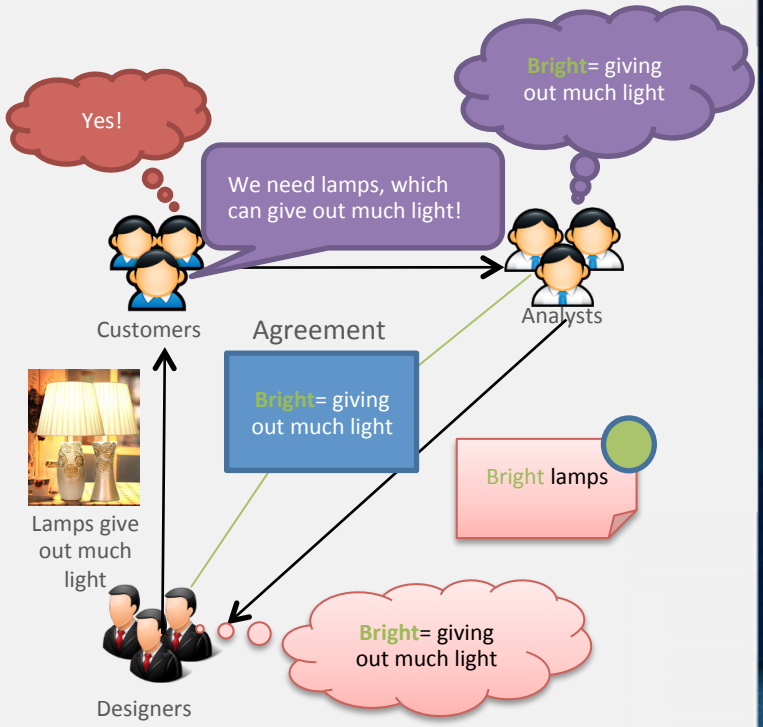
From Mankind to Machine



A Simple Example of using a concept without or with agreement



Without an agreement in the concept "Bright"



With an agreement in the concept "Bright"

Oxford Dictionary=> Bright: (1) giving out much light
(2) Intelligent and quick-witted

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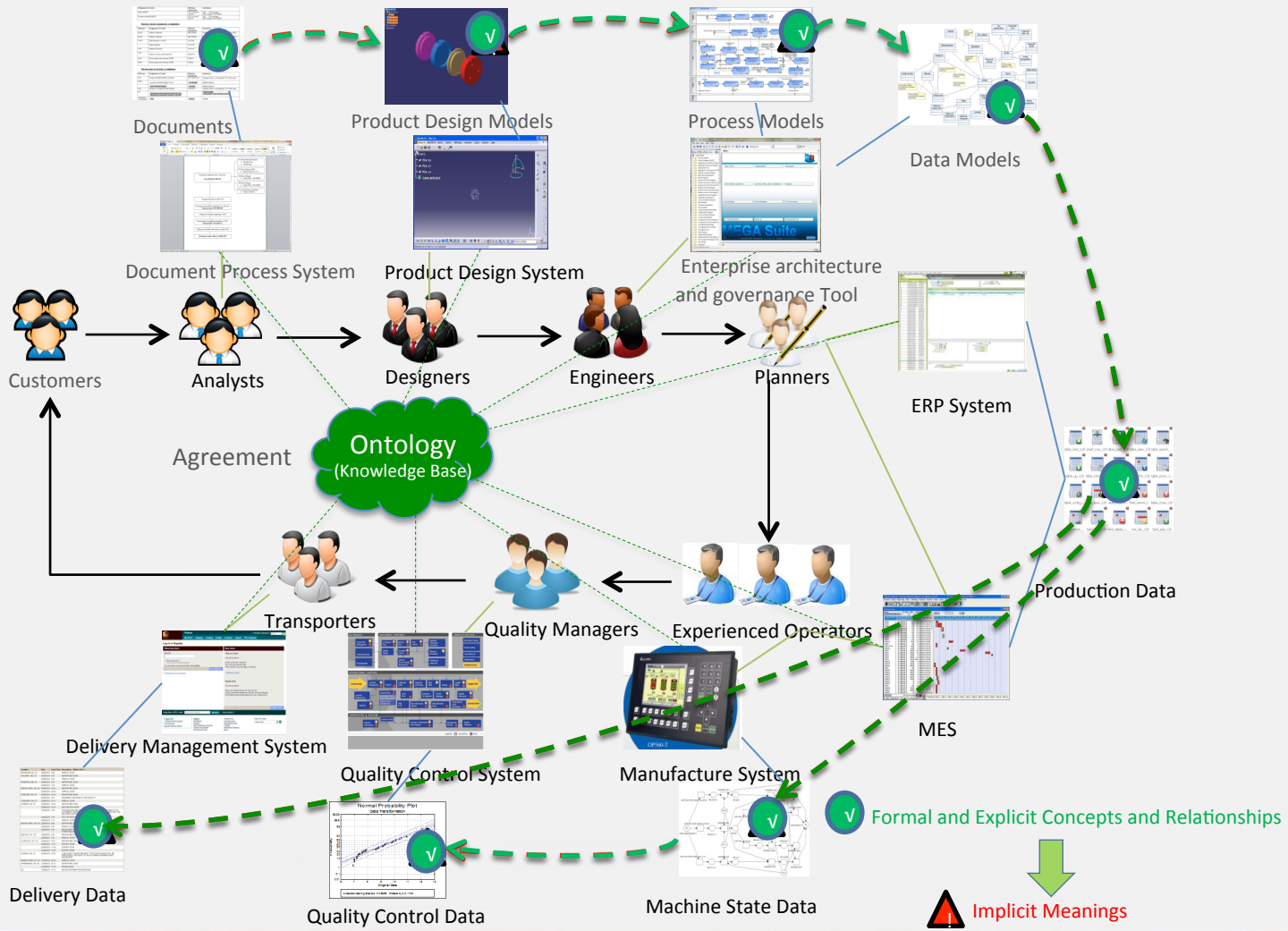
Agreement in a Product Life Cycle (PLC)Context



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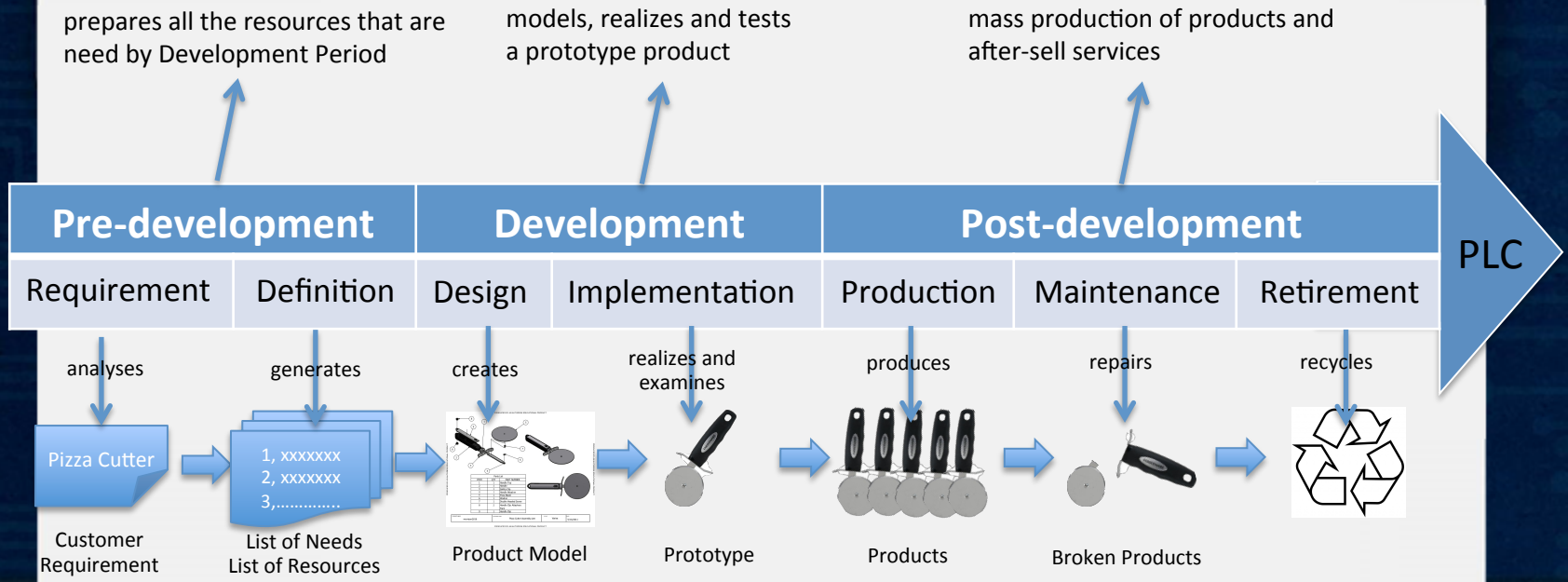
Different Stages in a Product Life Cycle (PLC)



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Ontology Application Examples in a Product Life Cycle (PLC)

PLC Periods	PLC Phases	Ontology Application Examples
Pre-development	Requirement	E.g. For identifying the inconsistencies among requirements
	Definition	
Development	Design	E.g. For Integrating multi-domain knowledge to assist product design
	Implementation	
Post-development	Production	E.g. For Supporting System Interoperability and Knowledge Sharing
	Maintenance	
	Retirement	

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Ontology Application – During the Product Design Phase

- Keyword Explanation

Inconsistency: The fact or state of being inconsistent *(Oxford Dictionary)*

In other words, It is the conflict among two or more descriptions about one common object.

An example:

This pizza is a vegetarian pizza.

Inconsistent

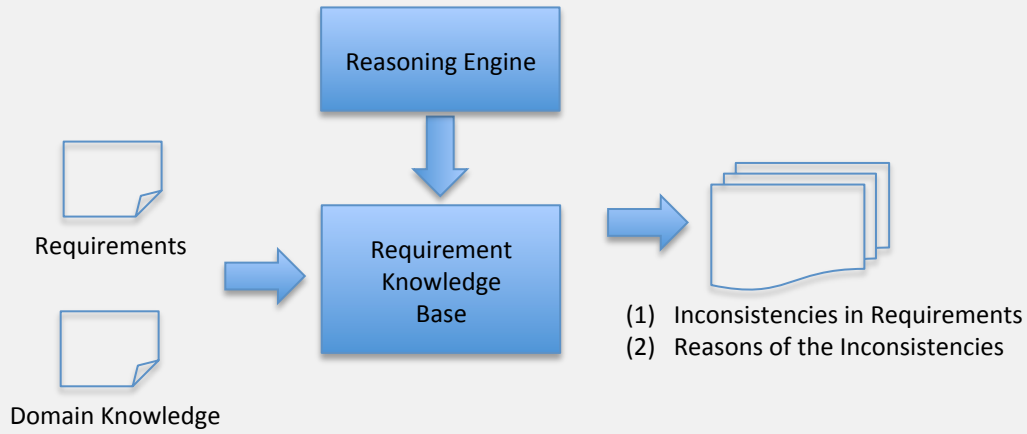
Consistent

This pizza contains meats.

This pizza contains vegetable.

Ontology Application – During the Pre-Development Period

- One of the Research Questions
  - How to identify the inconsistencies among the product requirements?
- A Brief Introduction of One Proposed Solution [4]



Ontology Application – During the Pre-Development Period

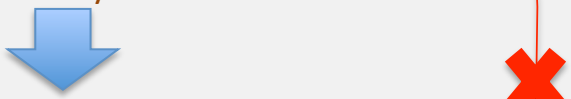
- An Example (Straightforward Explanation)

Requirement Examples:

1. The system supports Photo Upload
2. Photos must not exceed 3Mb in size
3. Photos must support bitmaps of at most 1280 * 960 pixels

Domain Knowledge Example:

1. Bitmaps can require a color-depth of up to 24 bits per pixel (1,4,8,16,24 bits)
2. The size of a bitmap approximately equal to its pixels multiplied by its bits and divided by 8388608
   (1 Mb= 1024 Kb= 1024*1024 bytes= 8*1024*1024bits=8388608bits)



	(1bits/pixel)	(8bits/pixel)	(24bits/pixel)
Bitmap Examples			
In case of 1280*960 pixels	≈0.14Mb	≈1.17Mb	≈3.51Mb

=> Requirement 2 and Requirement 3 are inconsistent with each other.

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Ontology Application – During the Pre-Development Period

- An Example (Technical Explanation)

Step 1 Domain Knowledge => OWL Expression

Domain Knowledge Example:

1. Bitmaps can require a color-depth of up to 24 bits per pixel (1,4,8,16,24 bits)
2. The size of a bitmap approximately equal to its pixels multiplied by its bits and divided by 8388608
   (1 Mb= 1024 Kb= 1024*1024 bytes= 8*1024*1024bits=8388608bits)

Web Ontology Language (OWL) Expression of Domain Knowledge

Classes: Bitmap

Properties: hasSizeInMb, hasLengthPixels, hasWidthPixels, hasBits

Axioms: Bitmap hasBits exactly 1 {1,4,8,16,24}
Bitmap hasLengthPixels exactly 1 integer
Bitmap hasWidthPixels exactly 1 integer

Rules: Bitmap(?x), hasBits(?x, ?b), hasLengthPixels(?x, ?l), hasWidthPixels(?x, ?w), multiply(?lw, ?l, ?w), multiply(?lwb, ?lw, ?b), divide(?mb, ?lwb, 8388608) -> hasSizeInMb(?x, ?mb)

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Ontology Application – During the Pre-Development Period

- An Example (Technical Explanation)

Step 2 Requirements => OWL Expression

Requirement Examples:

1. The system supports Photo Upload
2. Photos must not exceed 3Mb in size
3. Photos must support bitmaps of at most 1280 * 960 pixels

Web Ontology Language (OWL) Expression of Requirement

Classes: System, Photo, Bitmap, PhotoUpload, BitmapAtMost1280x960

Properties: hasSizeInMb, hasLengthPixels, hasWidthPixels, supportFeature

Axioms: System supportFeature PhotoUpload

Photo hasSizeInMb exactly 1 decimal[<= "3.0"^^decimal]

Bipmap subClassOf Photo

BitmapAtMost1280x960 subClassOf Bitmap

BitmapAtMost1280x960 hasLengthPixels exactly 1 integer[<= 1280]

BitmapAtMost1280x960 hasWidthPixels exactly 1 integer[<= 960]

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Ontology Application – During the Pre-Development Period

- An Example (Technical Explanation)

Step 3 Reasoning

Web Ontology Language (OWL) Expression of Requirement and Domain Knowledge

Classes: System, Photo, Bitmap, PhotoUpload, BitmapAtMost1280x960,

Properties: hasSizeInMb, hasLengthPixels, hasWidthPixels, supportFeature, hasBits

Axioms: System supportFeature PhotoUpload

Photo hasSizeInMb exactly 1 decimal[<= "3.0"^^decimal]

Bipmap subClassOf Photo

BitmapAtMost1280x960 hasLengthPixels exactly 1 integer[<= 1280]

BitmapAtMost1280x960 hasWidthPixels exactly 1 integer[<= 960]

BitmapAtMost1280x960 subClassOf Bitmap

Bitmap hasBits exactly 1 {1,4,8,16,24}

Bitmap hasLengthPixels exactly 1 integer

Bitmap hasWidthPixels exactly 1 integer

Rules: Bitmap(?x), hasBits(?x, ?b), hasLengthPixels(?x, ?l), hasWidthPixels(?x, ?w), multiply(?lw, ?l, ?w), multiply(?lwb, ?lw, ?b), divide(?mb, ?lwb, 8388608) -> hasSizeInMb(?x, ?mb)

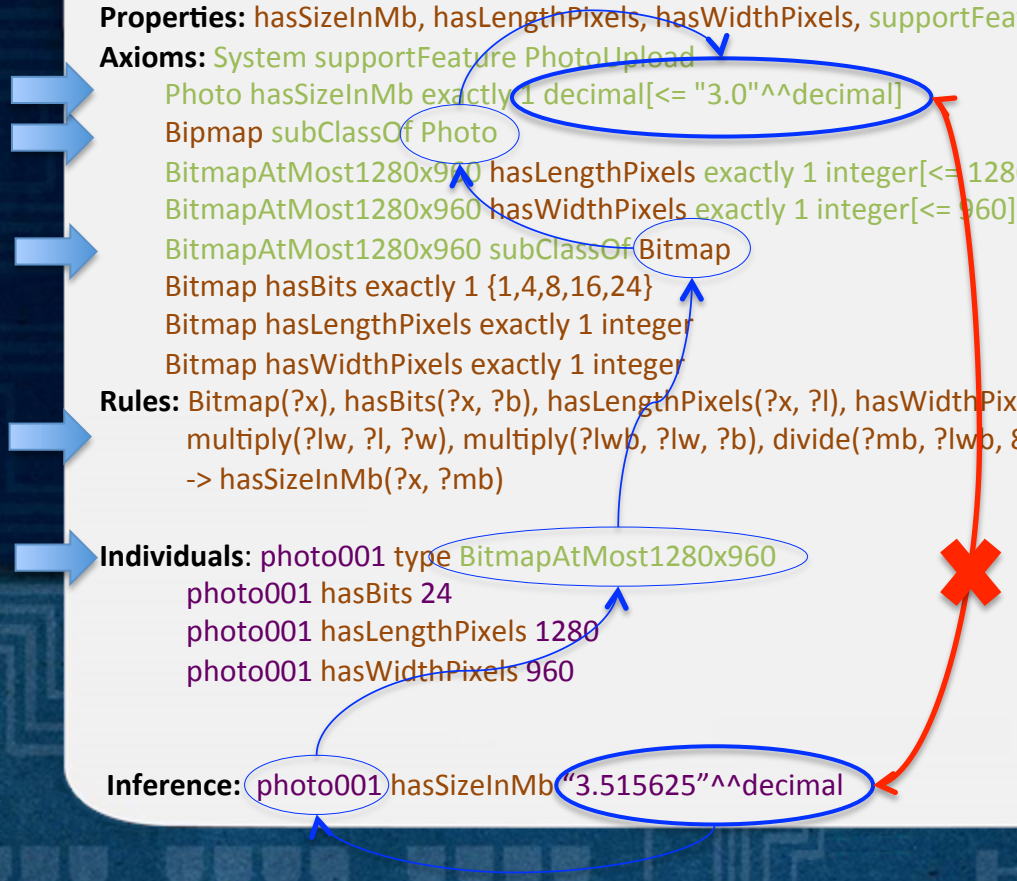
Individuals: photo001 type BitmapAtMost1280x960

photo001 hasBits 24

photo001 hasLengthPixels 1280

photo001 hasWidthPixels 960

Inference: photo001 hasSizeInMb "3.515625"^^decimal



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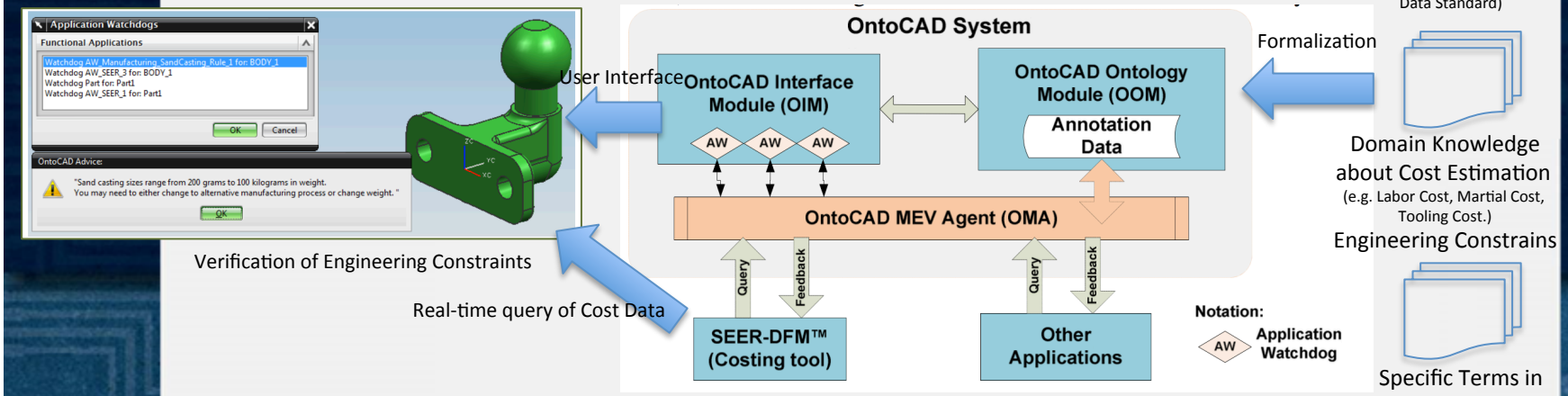
Ontology Application – During the Development Period

- One of the Research Questions
  - How to represent, share and reuse of existing knowledge to assist Product Design?
- A Brief Introduction of One Proposed Solution [5]



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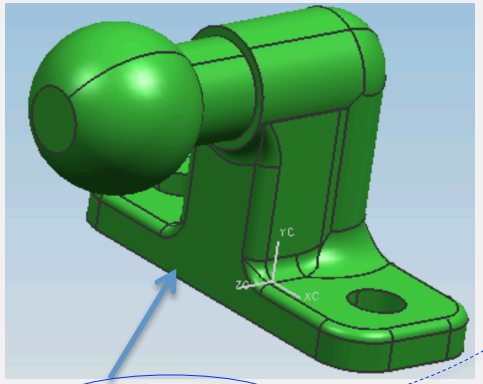
Ontology Application – During the Development Period

- An Example (Straightforward Explanation)

A CAD Model



Domain Knowledge

(1) Ductile cast iron is a material. This raw material costs $0.6325 per Kg.
(Based on the real time query of Cost Estimation System: SEER-DFM™)

SEER Cost Estimation System

Material: *Ductile Cast Iron*

Data automatically populated from CAD model

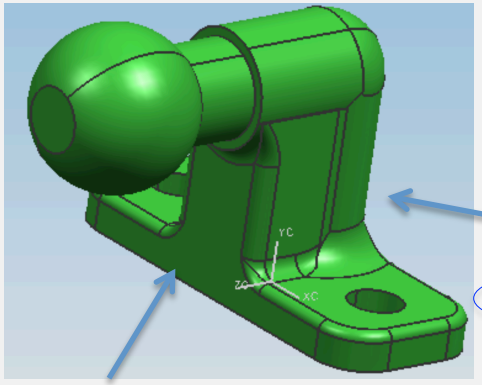
Weight: 1.98 kilograms

Cost: $1.25

Ontology Application – During the Development Period

- An Example (Straightforward Explanation)

A CAD Model



Domain Knowledge

(1) Ductile cast irons is a material. This raw material costs $0.6325 per Kg. (Based on the real time query of Cost Modelling System: SEER-DFM™)

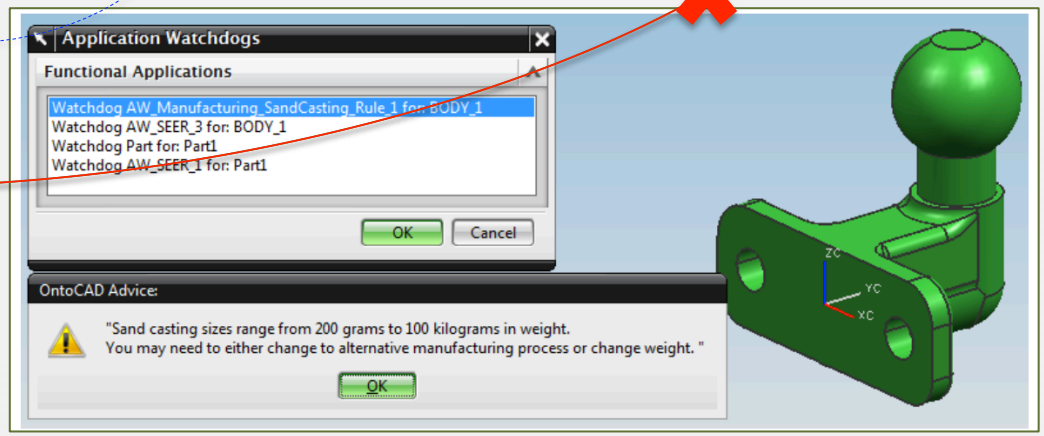
(2) Sand Casting Process is a manufacturing process. The size range for manufacturing process of sand casting can be applied from 200 grams to 100 kilograms in weight.

Define the Manufacturing Process:
Sand Casting

Material: *Ductile Cast Iron*

Data automatically populated from CAD model

Weight: 150 grams



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Ontology Application – During the Production Phase

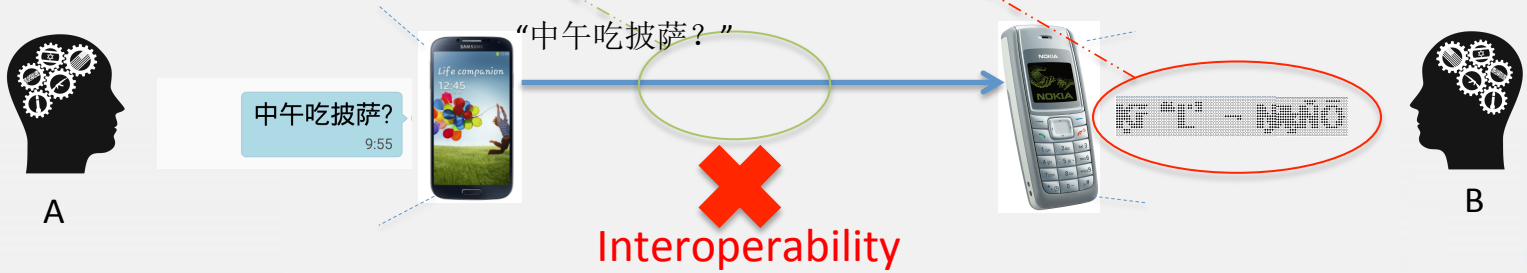
- Keyword Explanation (1/2)

Interoperability: The ability of two or more systems or components to **exchange** information and to **use** the information that has been exchanged *(IEEE standard computer glossaries)*

Not able to display correct text messages

Exchange text messages

An Example:



Ontology Application – During the Production Phase

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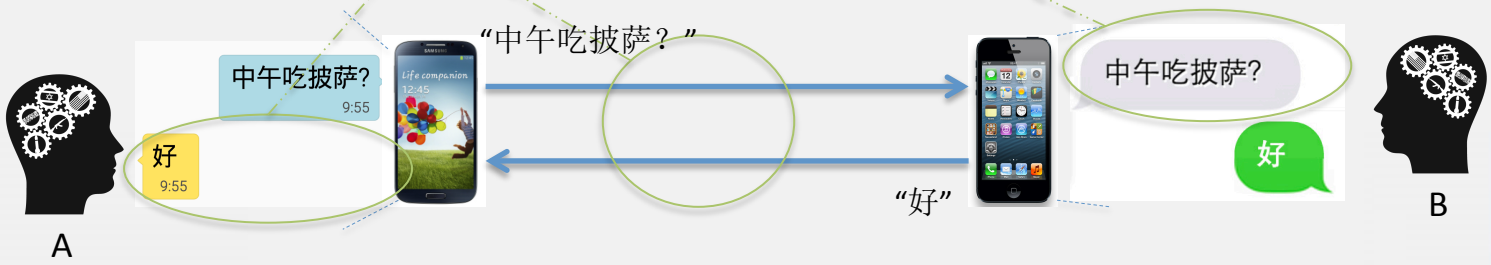

Syntactic Interoperability: E.g. Two systems exchange and display “中午吃披萨？” and “好”

Ontology

Semantic Interoperability: E.g. Two systems share the meanings of “中午吃披萨？” (Pizza for lunch?) and “好” (Ok).

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Ontology Application – During the Production Phase

- Keyword Explanation (2/2)

Data Structure: A logical relationship among data elements, designed to support specific data manipulation functions. *(IEEE standard computer glossaries)*

In other words, a particular way of organizing data in a computer so that it can be used efficiently.

An Example:

C0739 Curitiba C0799

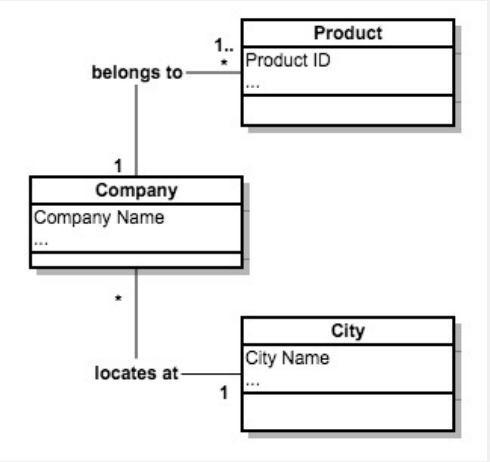
C0778 Ochakovo

Brahma

Harbin Beer

Harbin Moscow

Data



Data Model

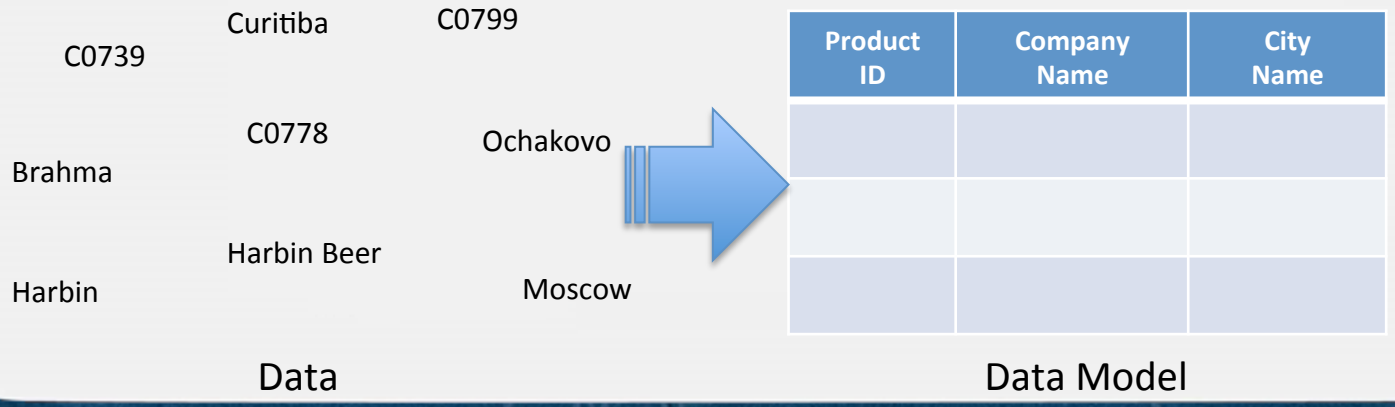
Ontology Application – During the Production Phase

- Keyword Explanation (2/2)

Data Structure: A logical relationship among data elements, designed to support specific data manipulation functions. *(IEEE standard computer glossaries)*

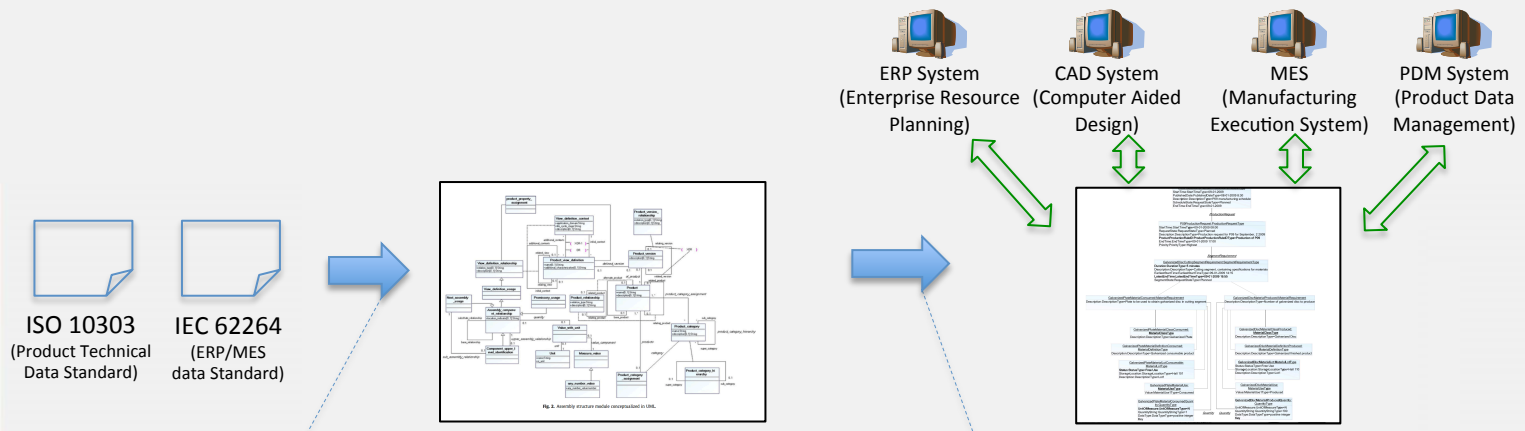
In other words, a particular way of organizing data in a computer so that it can be used efficiently.

An Example:



Ontology Application – During the Production Phase

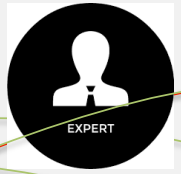
- One of the Research Questions
  - Each enterprise application within a factory has its own data structure, how to enable the interoperability among different applications?
- A Brief Introduction of One Proposed Solution [6]



Ontology Application – During the Product Design Phase

- Traditional Data Exchange Scenario

Domain Knowledge:
A City is located in a Country
Brazil, China, Russia are countries
Curitiba is a city in Brazil
Harbin is a city in China
Moscow is a city in Russia

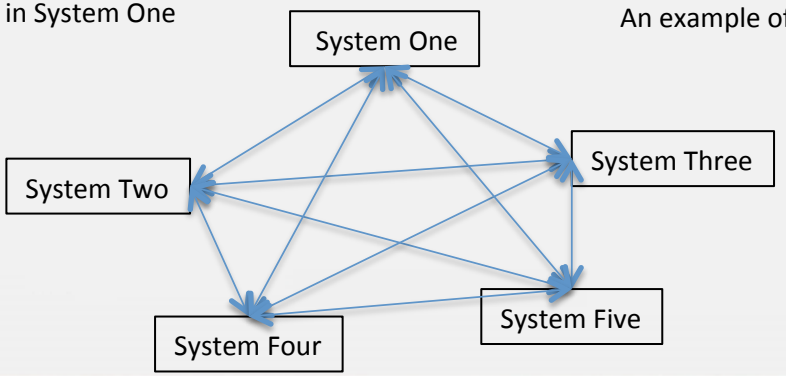


Product ID	Company Name	City Name
C0739	Brahma	Curitiba
C0778	Harbin Beer	Harbin
C0799	Ochakovo	Moscow

An example of data model in System One

Product ID	Industry Name	Country Name
C0739	Brahma	Brazil
C0778	Harbin Beer	China
C0799	Ochakovo	Russia

An example of data model in System Two



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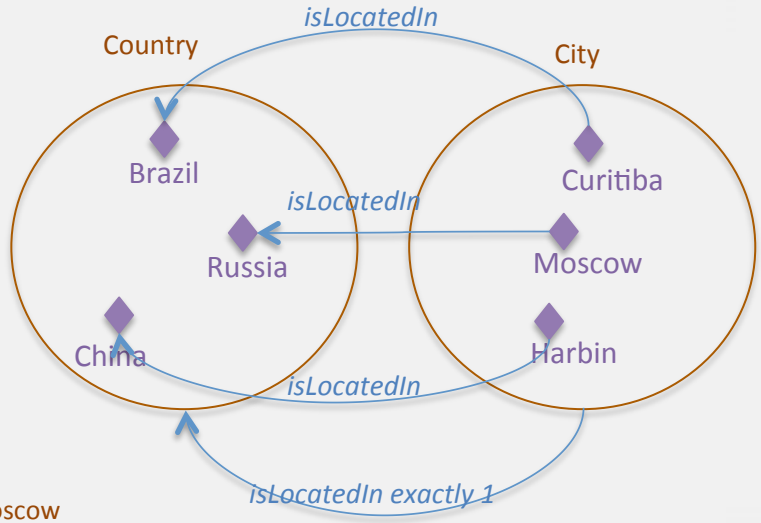
Ontology Application – During the Product Design Phase

- Domain Knowledge => Domain Ontology

Domain Knowledge:
A City is located in a Country
Brazil, China, Russia are countries
Curitiba is a city in Brazil
Harbin is a city in China
Moscow is a city in Russia

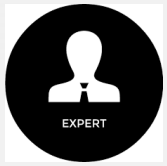
Domain Ontology:
Class: City, Country
Properties: *isLocatedIn*
Individuals: Brazil, China, Russia, Curitiba, Harbin, Moscow
Axioms: City *isLocatedIn exactly 1* Country
Brazil *type* Country
China *type* Country
Russia *type* Country
Curitiba *type* City
Herbin type City
Moscow *type* City
Curitiba *isLocatedIn* Brazil
Harbin *isLocatedIn* China
Moscow *isLocatedIn* Russia



Graphical Explanation

Ontology Application – During the Product Design Phase

- Proposed Solution: Data Exchange based on Ontology



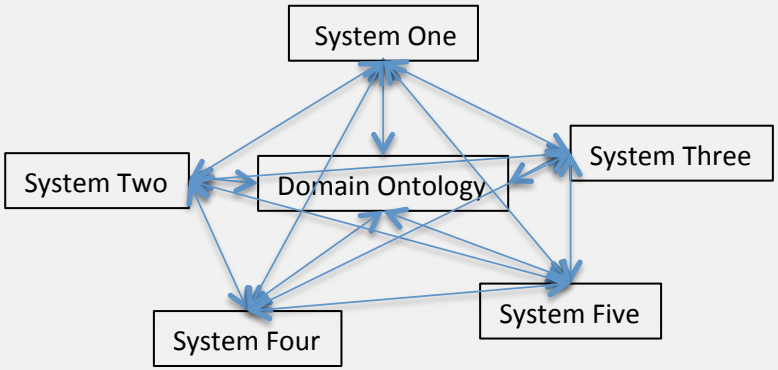
Product ID	Company Name	City Name
C0739	Brahma	Curitiba
C0778	Harbin Beer	Harbin
C0799	Ochakovo	Moscow

An example of data model in System One

Domain Ontology:
Class: City, Country
Properties: *isLocatedIn*
Individuals: Brazil, China, Russia, Curitiba, Harbin, Moscow
Axioms: City *isLocatedIn exactly 1* Country
Brazil *type* Country
China *type* Country
Russia *type* Country
Curitiba *type* City
Herbin type City
Moscow *type* City
Curitiba *isLocatedIn* Brazil
Harbin *isLocatedIn* China
Moscow *isLocatedIn* Russia

Product ID	Industry Name	Country Name
C0739	Brahma	Brazil
C0778	Harbin Beer	
C0799	Ochakovo	

An example of data model in System Two



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The Conclusion of An Ontology in the PLC?

- Ontology can :
  - Formally Represent Knowledge
  - Support the Reuse and Sharing of that Knowledge
  - Assist the Identification of Inconsistencies
  - Support the Interoperability
  - Discover New Knowledge

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What Can You Learn From This Course?

- For students who want to have a research career.
  - A Method to Formally Represent Knowledge
  - A Solution to Share and Reuse Knowledge
  - The Basis Principles to Support Them: Such as OWL 2 Syntax
- For students who want to have a engineering career.
  - An Approach to Support Interoperability
  - The New Skill to Formalize Knowledge.
  - A Tutorial of Protégé Ontology Editor
    - How to build an ontology through Protégé ?
    - How to use a reasoning engine to perform reasoning and querying?

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Course Outlines

- What is an Ontology? (1 Lecture)
- Important Terms in Ontology (7 Lectures)
  - Axioms
  - Concepts
  - Relationships
  - Complex Class Expressions
  - Data Ranges
  - Reasoning Rules
  - Knowledge Base (T-box and A-box)
  - SPARQL Query

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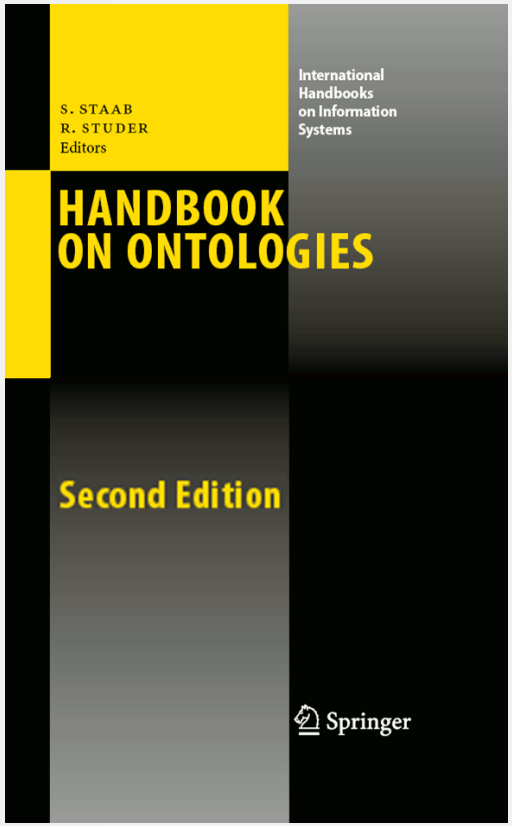
A Ontology Handbook



Title: HANDBOOK ON ONTOLOGIES
Editors: Staab, Steffen, Studer, Rudi (Eds.)
Publisher: Springer
ISBN: 978-3-540-92673-3

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Contact

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Protégé Practices

- What is Protégé?
  - It is a knowledge-modeling environment
  - It is a free, open-source software
  - It is developed at Stanford University
  - It has a large user community (more than 240,000 registered users)

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Protégé Practices

- Installation and Browse
  - Installing the Protégé Ontology Editor
    - http://protege.stanford.edu/
  - Downloading One Ontology from Ontology Library
    - http://protegewiki.stanford.edu/wiki/Protege_Ontology_Library
  - Loading the Ontology into Protégé
    - Open Protégé Desktop
    - Clicking “File”-> “Open”-> The Ontology of interest
  - Using Protégé to browse the contents in the Ontology

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[3] T. R. Gruber. A translation approach to portable ontologies. Knowledge Acquisition, 5(2):199-220, 1993.

[4] T. H. Nguyen, B. Q. Vo, M. Lumpe, and J. Grundy, "KBRE: A framework for knowledge-based requirements engineering," *Softw. Qual. J.*, vol. 22, no. 1, pp. 87–119, 2014

[5] Li, C.: Ontology-Driven Semantic Annotations for Multiple Engineering Viewpoints in Computer Aided Design, PhD Thesis (2012).

[6] H. Panetto, M. Dassisti, and A. Tursi, "ONTO-PDM: Product-driven ONTOlogy for Product Data Management interoperability within manufacturing process environment," Adv. Eng. Informatics, vol. 26, no. 2, pp. 334–348, 2012.

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Thank you
for your attention!

Any Questions?

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