PRODUCTION ENGINEERING LABORATORY

Ontologies’ Interoperability: Concerns and perspectives

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Interoperability

Interoperability: "Ability for two (or more) systems or components to exchange information [syntactic interoperability] and to use this information [semantic interoperability]." (IEEE Standard,1990)

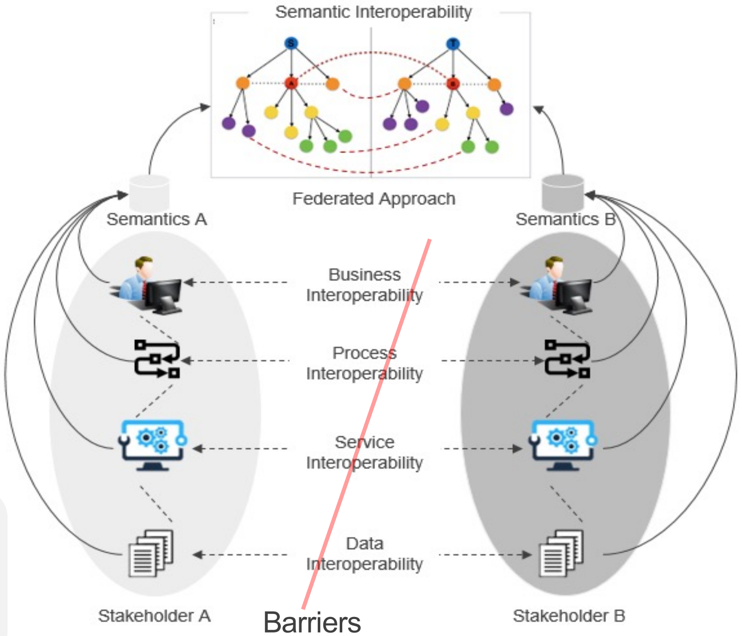
Semantic interoperability: "Ability to automatically interpret the information exchanged meaningfully and accurately in order to produce useful results as defined by the end users of both systems."

Entreprise Interoperability Framework (Chen et al., 2007):

Interoperability concerns: data, service, process (sequence of services), and business (harmonized way of work between organizations).

Interoperability barriers: incompatibility that gets in the way of information sharing and exchange (conceptual, technological, and organizational).

Interoperability approaches: the way in which these barriers are removed (integrated, unified, federated).



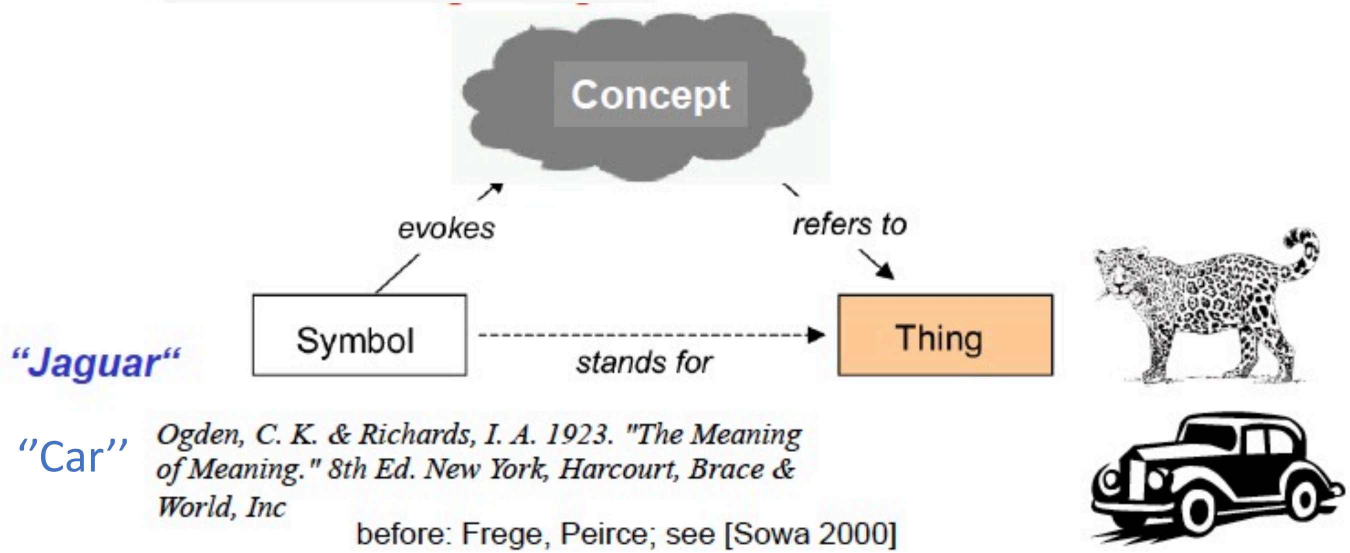
(Inspired from Zachariwic, 2017)

Sharing meaning

- **Metadata**
  - Data describing the content and meaning of resources and services.
  - But everyone must speak the same language…
- **Terminologies**
  - Shared and common vocabularies
  - For search engines, agents, curators, authors and users
  - But everyone must mean the same thing…
- **Semantic Models**
  - Shared and common understanding of a domain
  - Essential for search, exchange and discovery

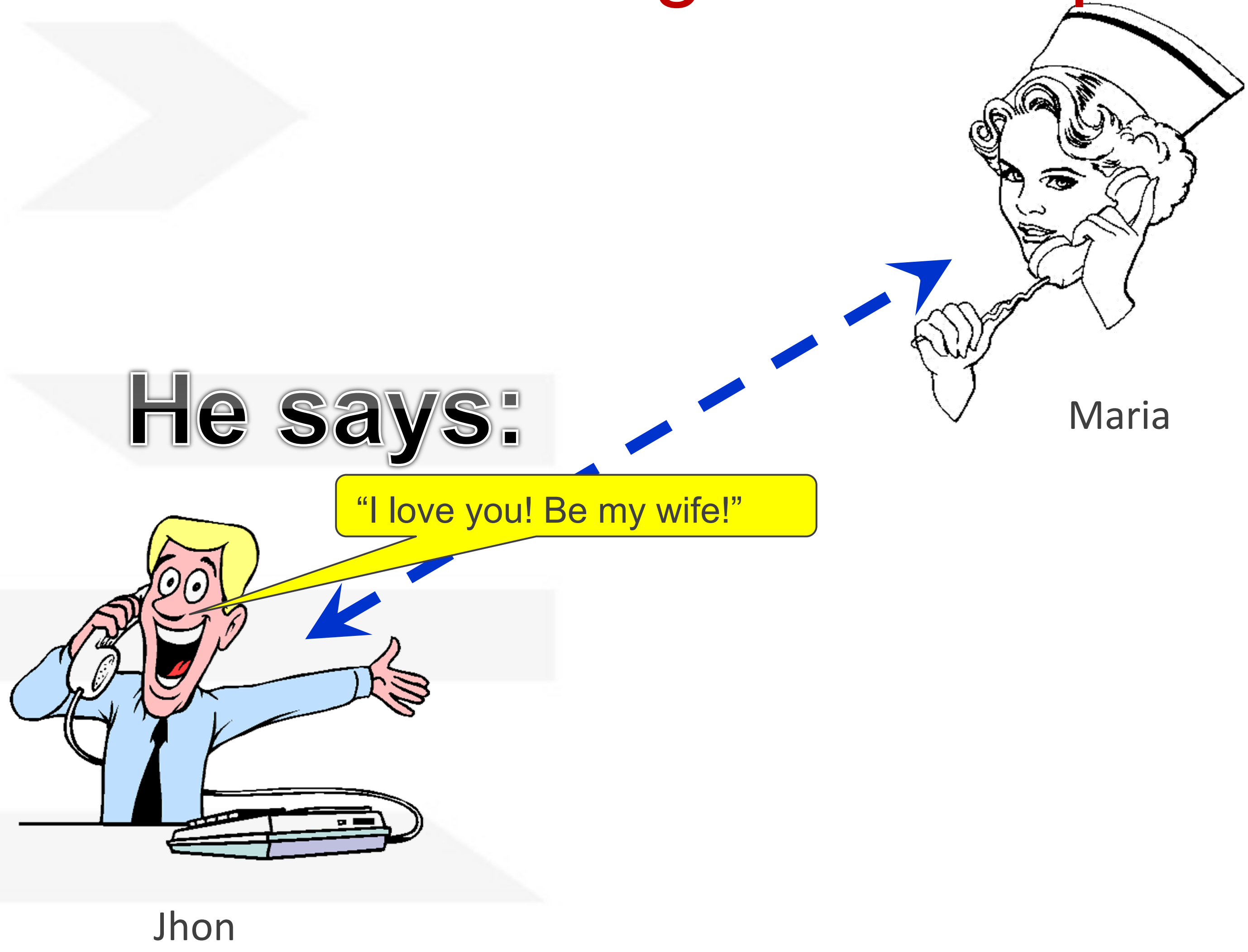
The Meaning Triangle

- Humans require words (or at least symbols) to communicate efficiently. The mapping of words to things is indirect. We do it by creating concepts that refer to things.
- The relation between symbols and things has been described in the form of the meaning triangle:



From Owen Conlan slides

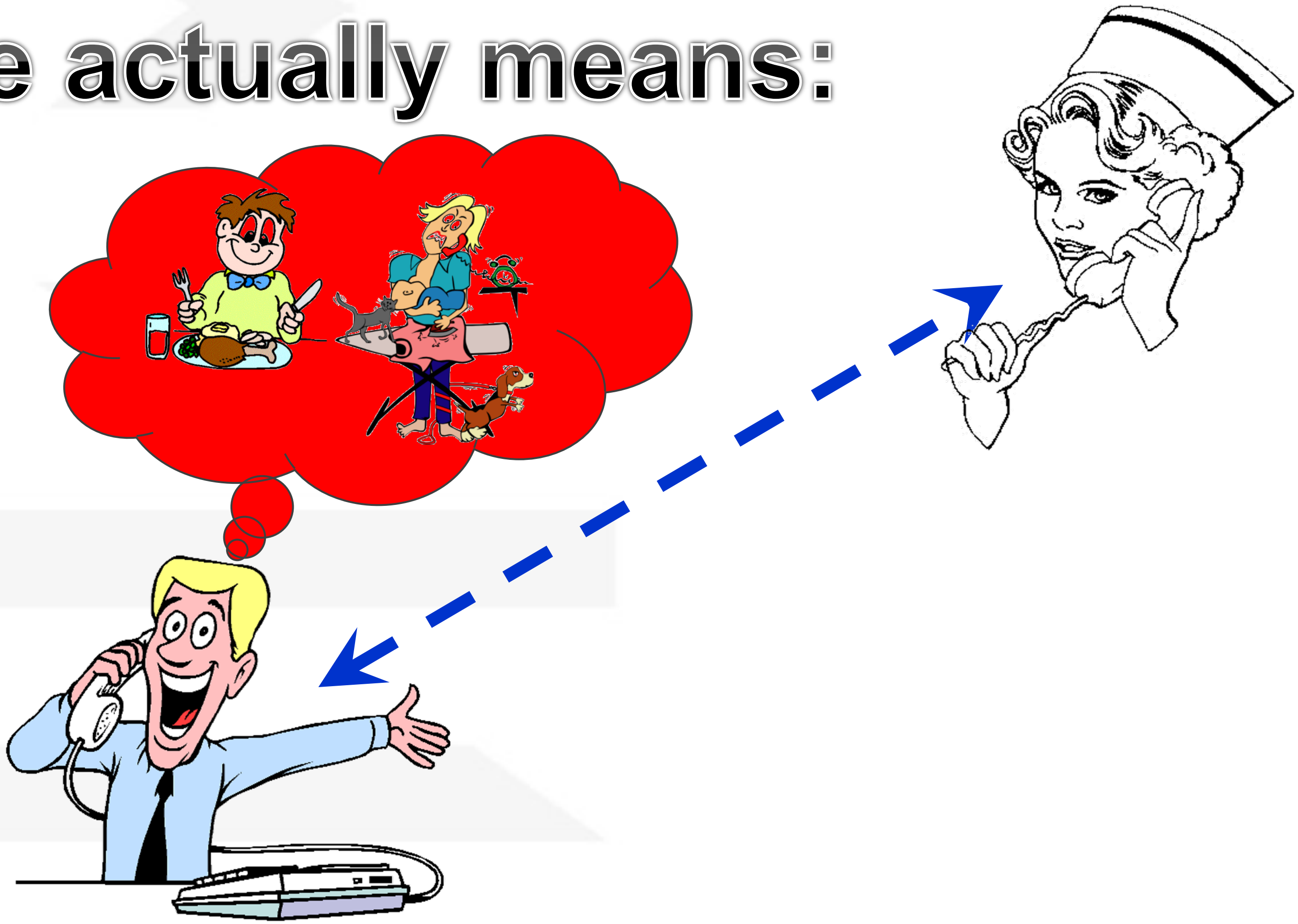
Common Understanding ! : Example 1/13



Example from Vagan Terziyan slides

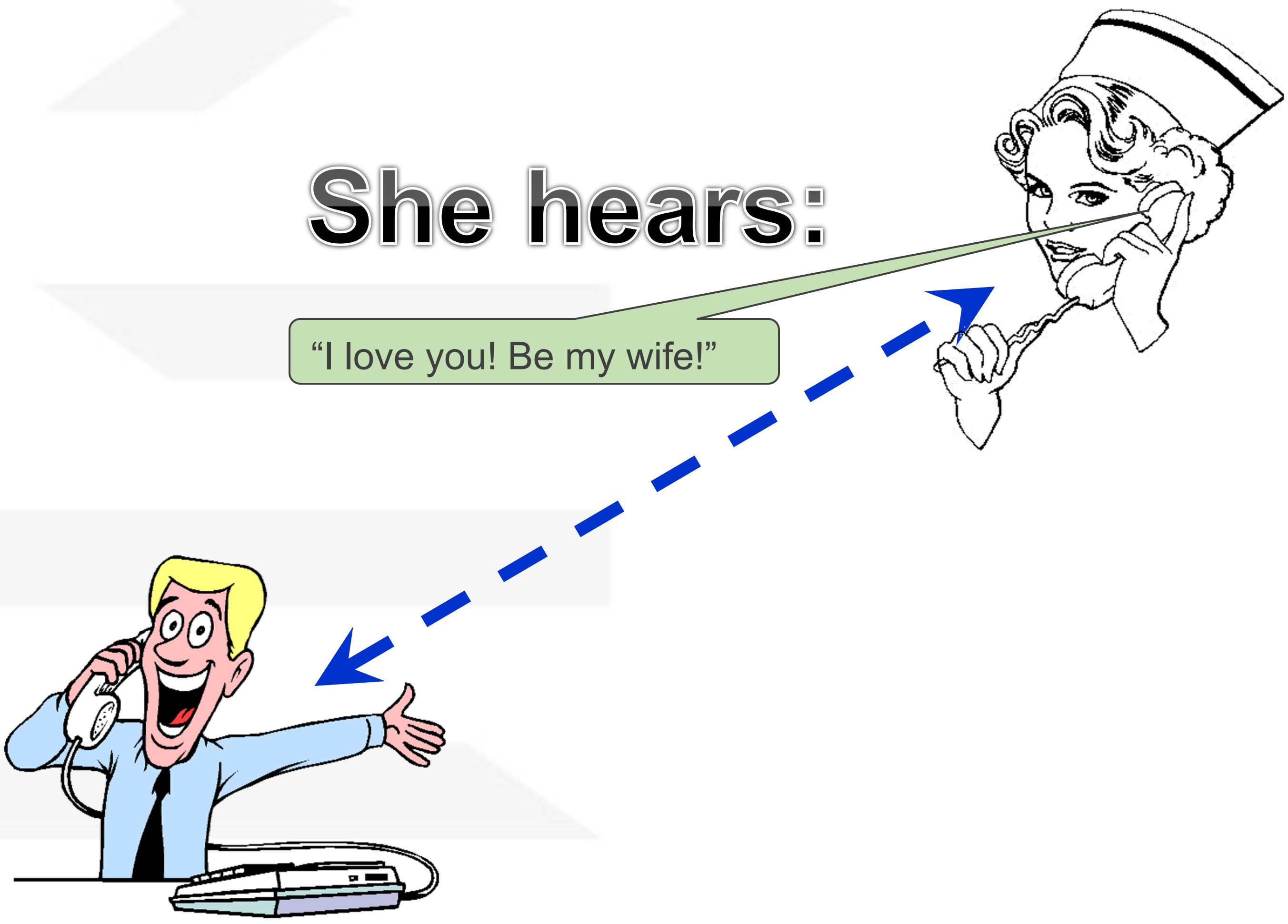
Common Understanding ! : Example 2/13

He actually means:



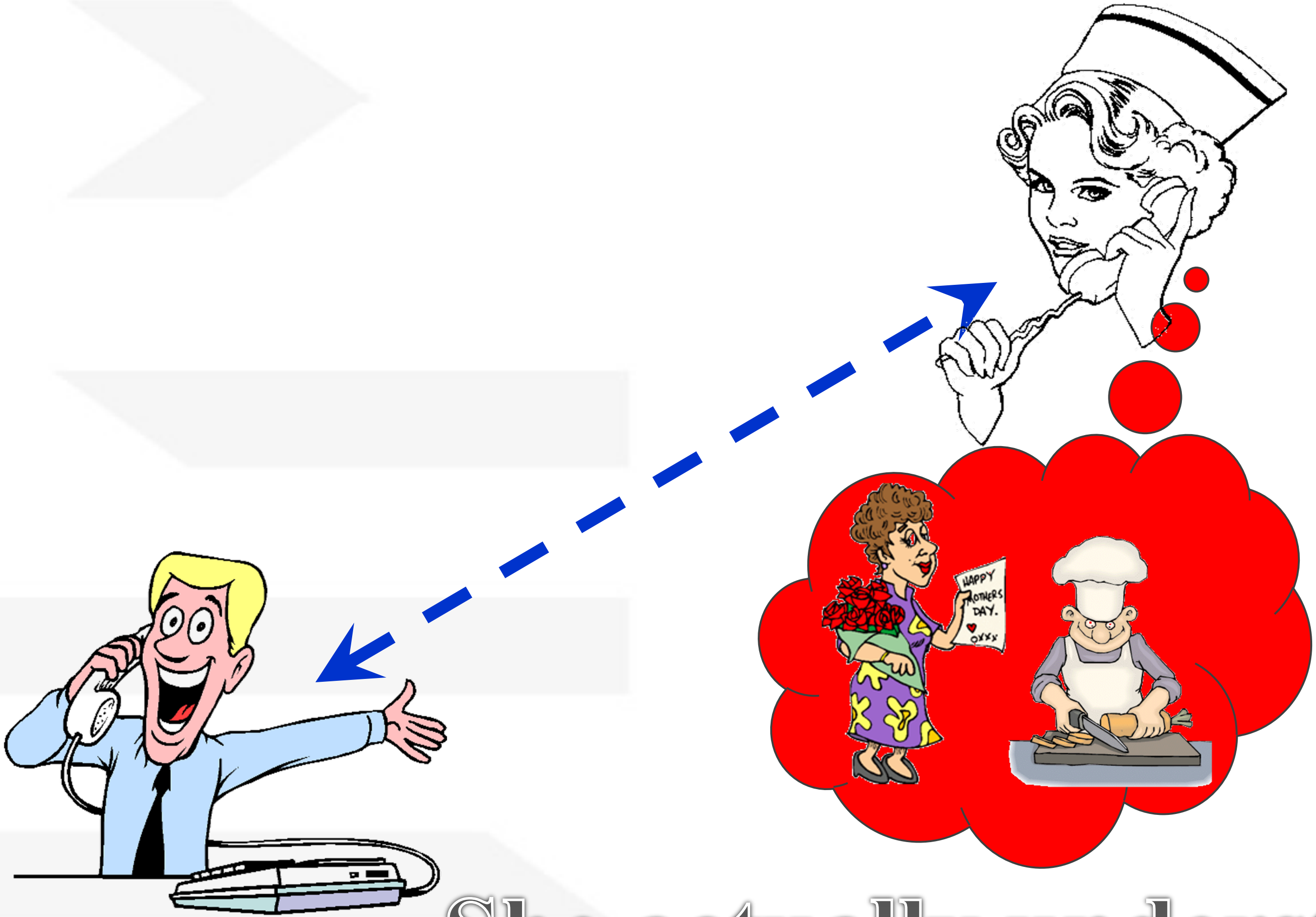
Example from Vagan Terziyan slides

Common Understanding ! : Example 3/13



Example from Vagan Terziyan slides

Common Understanding ! : Example 4/13



She actually understands:

Example from Vagan Terziyan slides

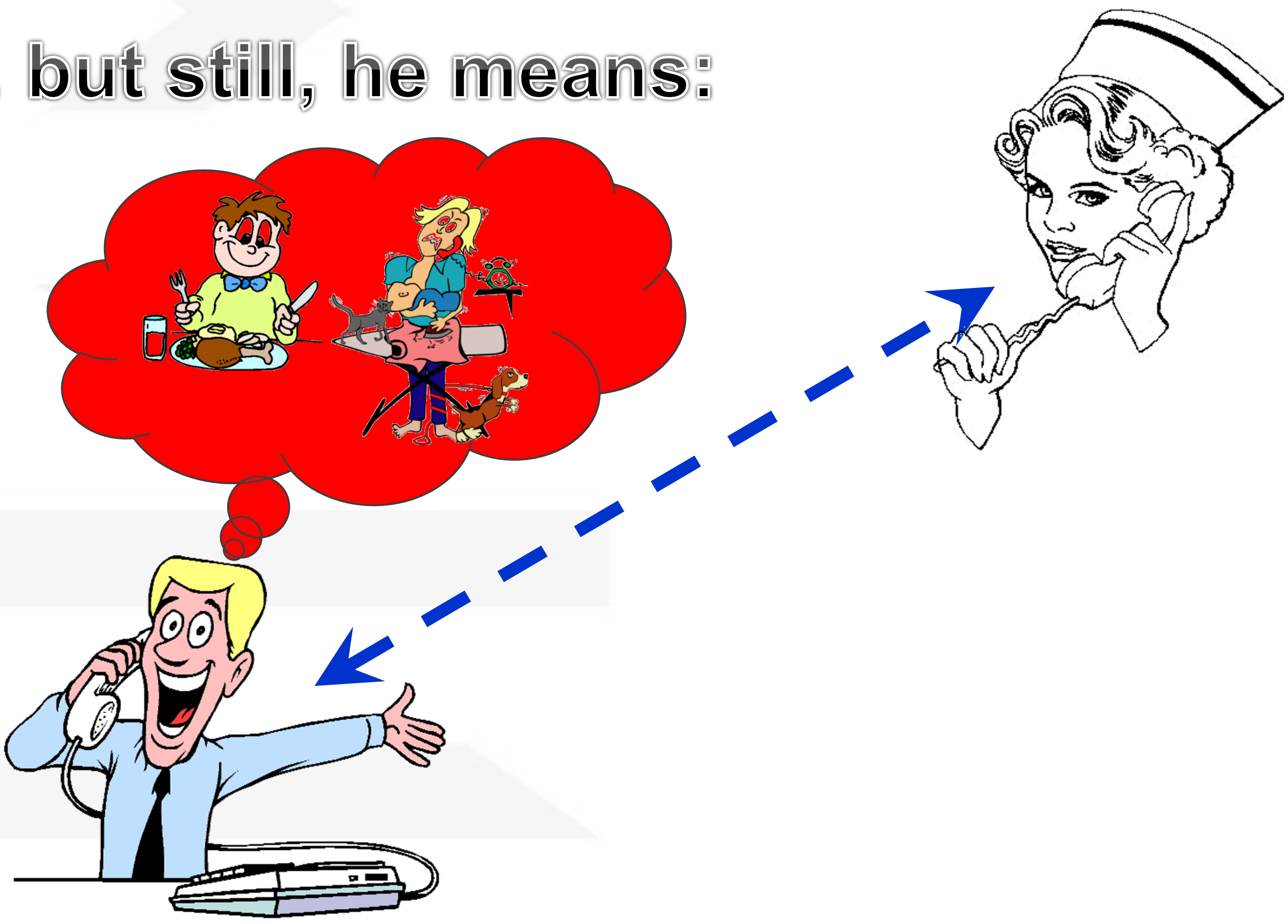
Common Understanding ! : Example 5/13

He may say it in many ways:

Example from Vagan Terziyan slides

Common Understanding ! : Example : 6/13

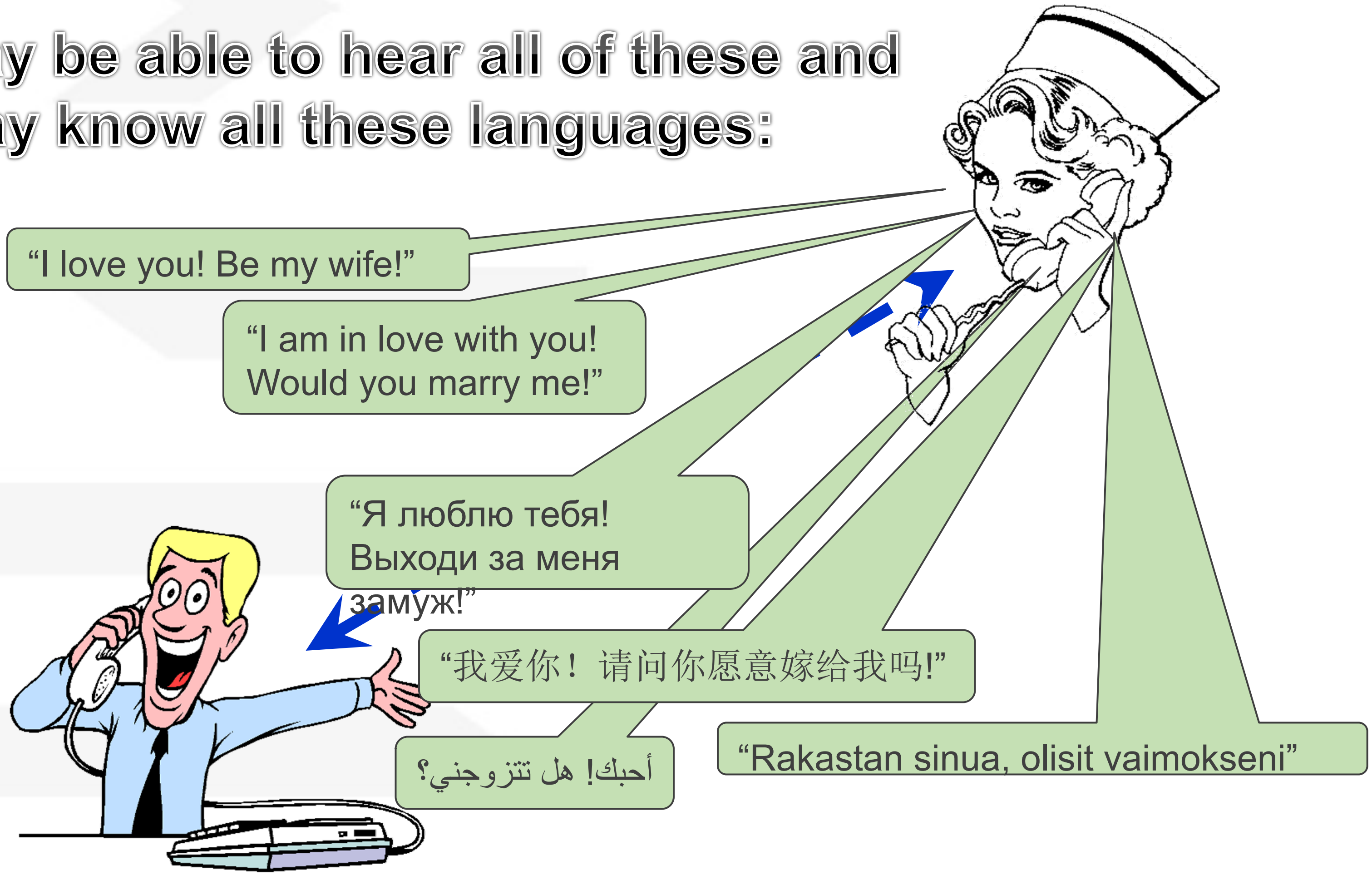
... but still, he means:



Example from Vagan Terziyan slides

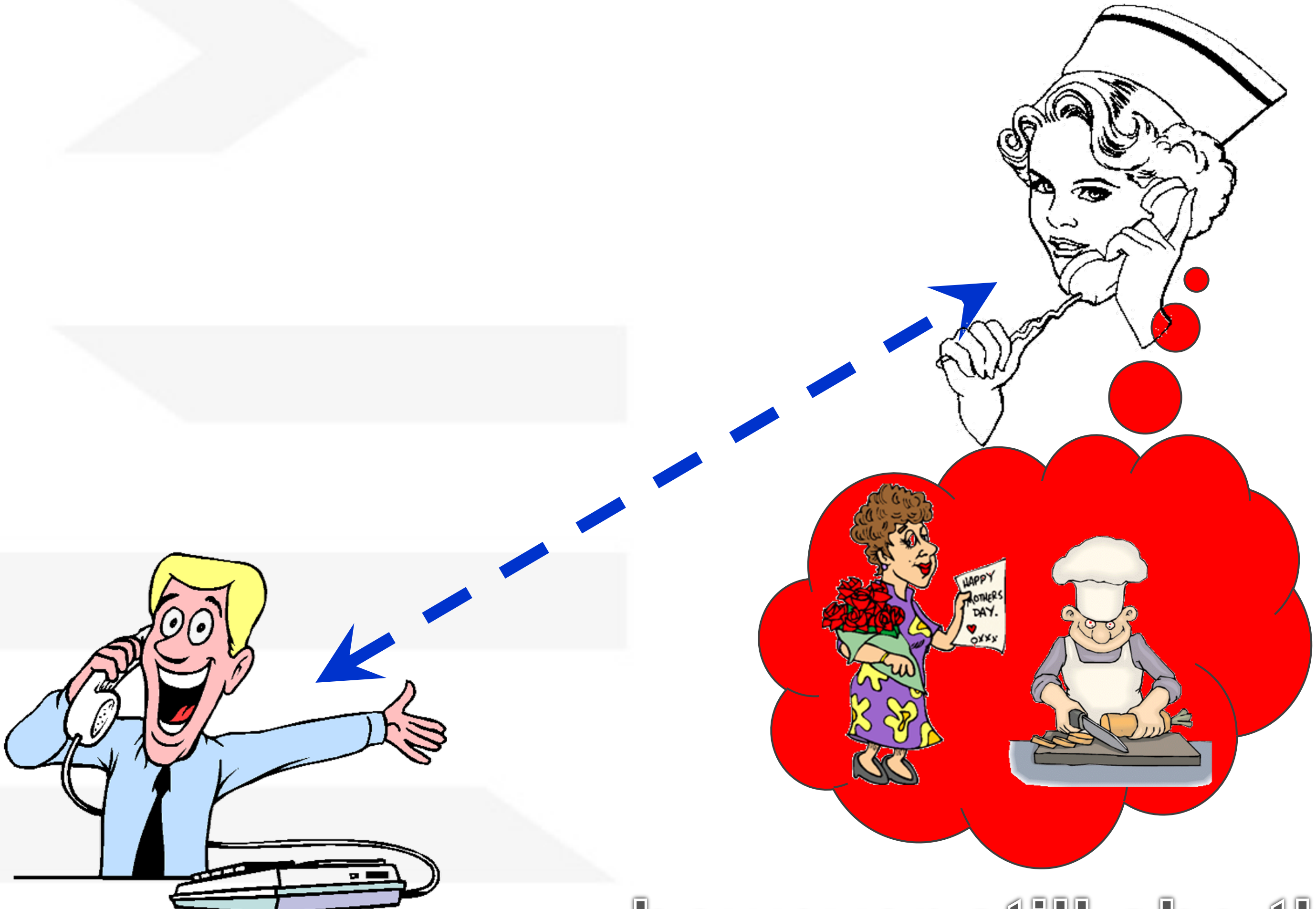
Common Understanding ! : Example 7/13

She may be able to hear all of these and may know all these languages:



Example from Vagan Terziyan slides

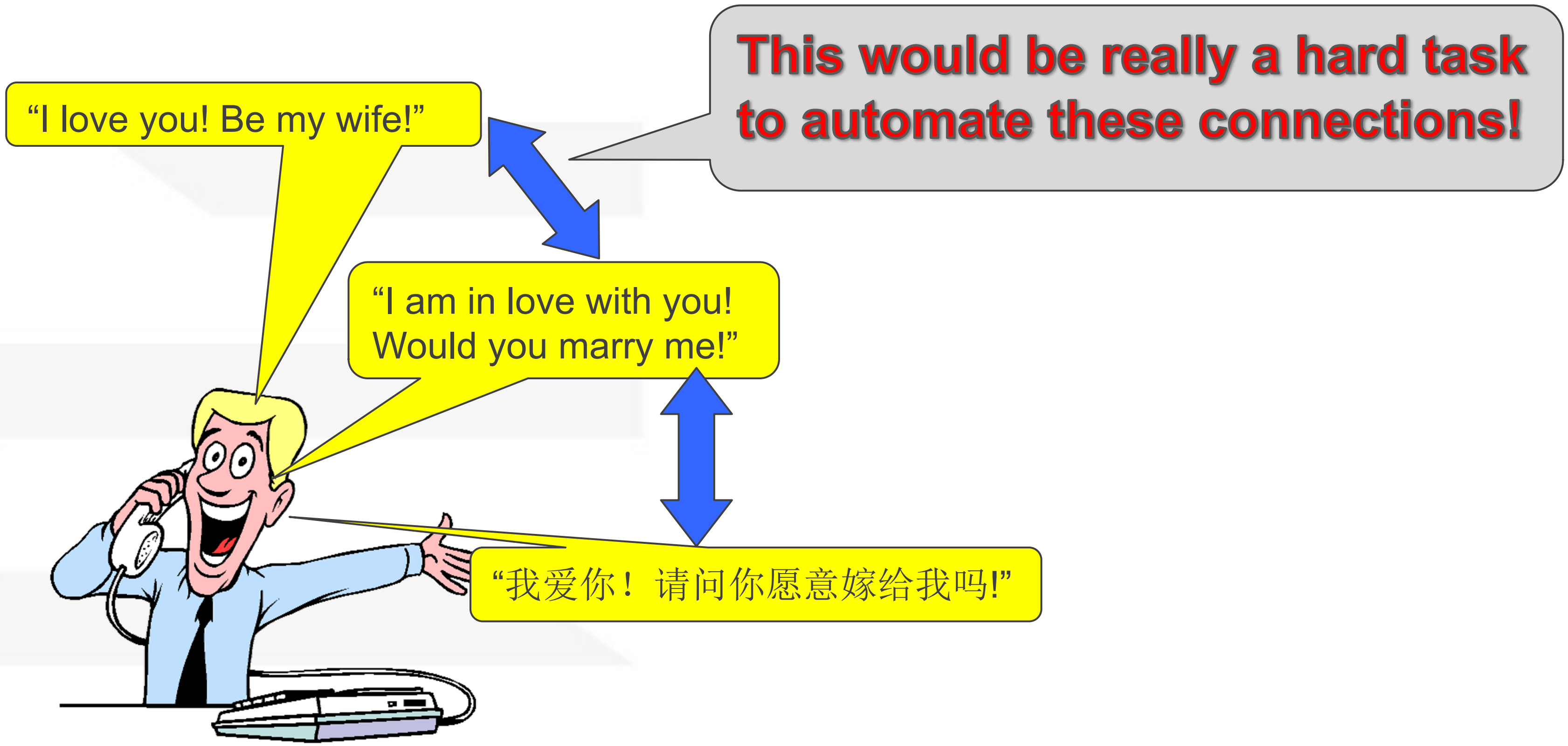
Common Understanding ! : Example 8/13



...however still she thinks:

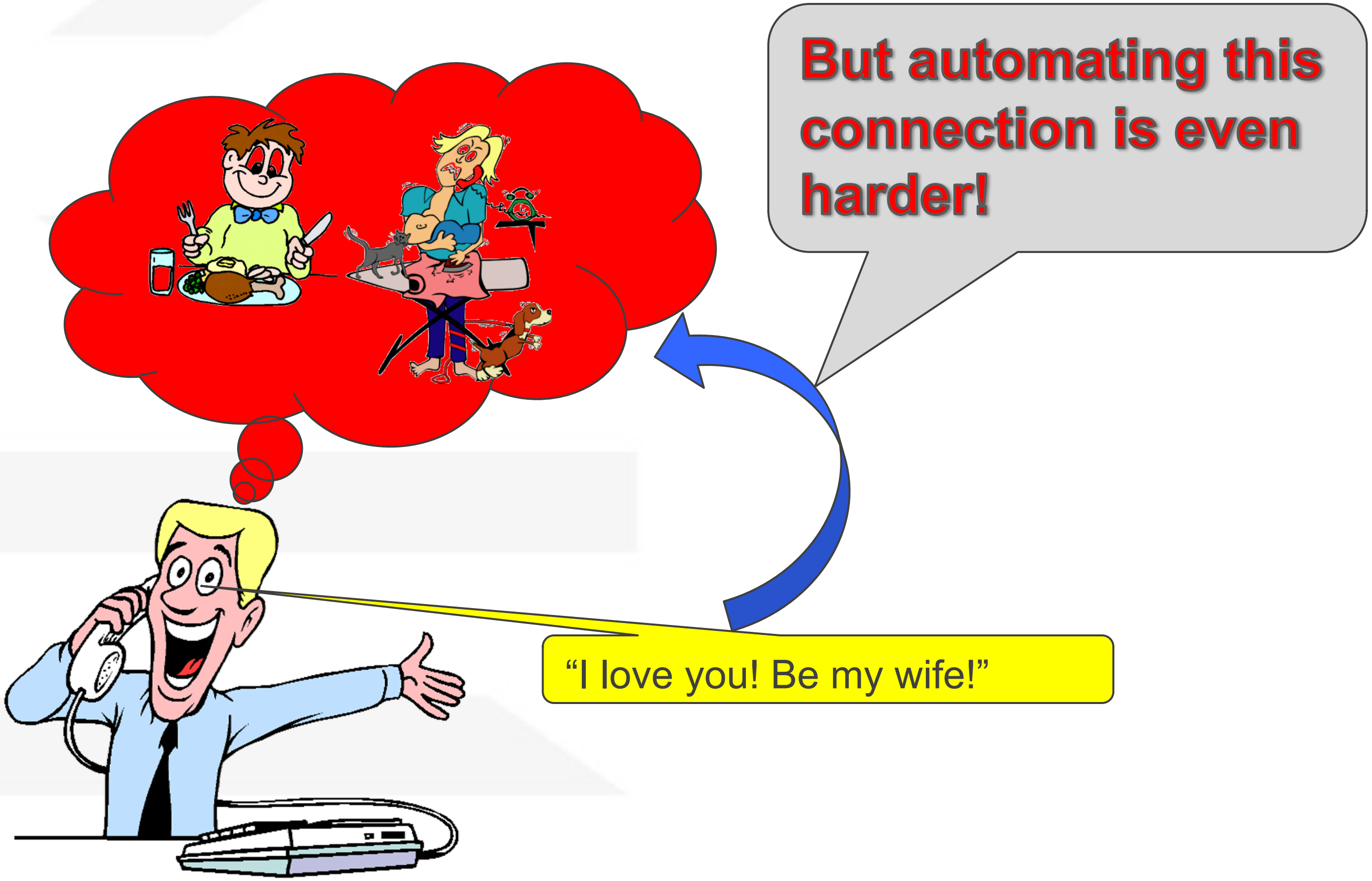
Example from Vagan Terziyan slides

Common Understanding ! : Example 9/13



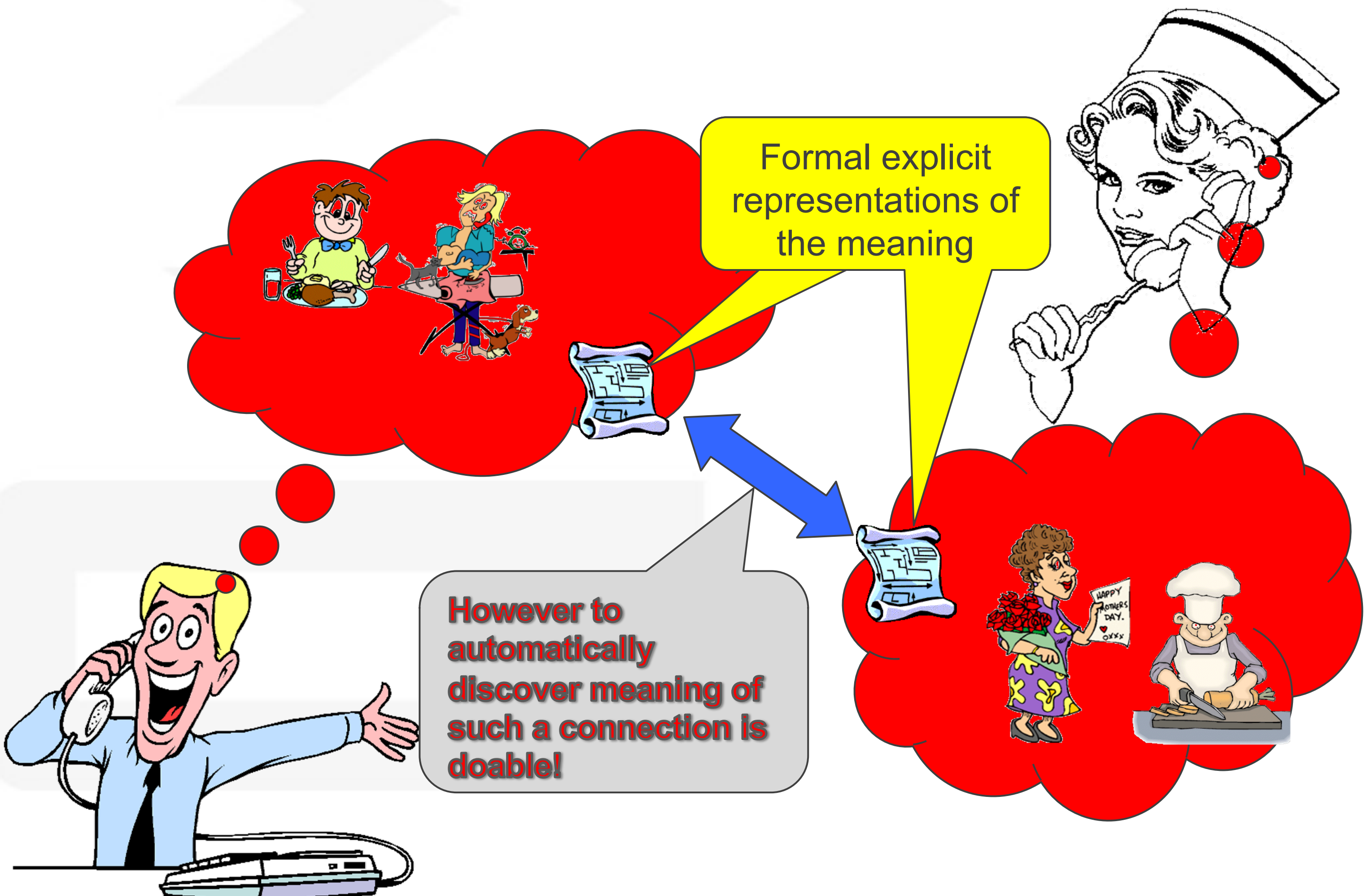
Example from Vagan Terziyan slides

Need for Semantics Example 10/13



Example from Vagan Terziyan slides

Common Understanding ! : Example 11/13



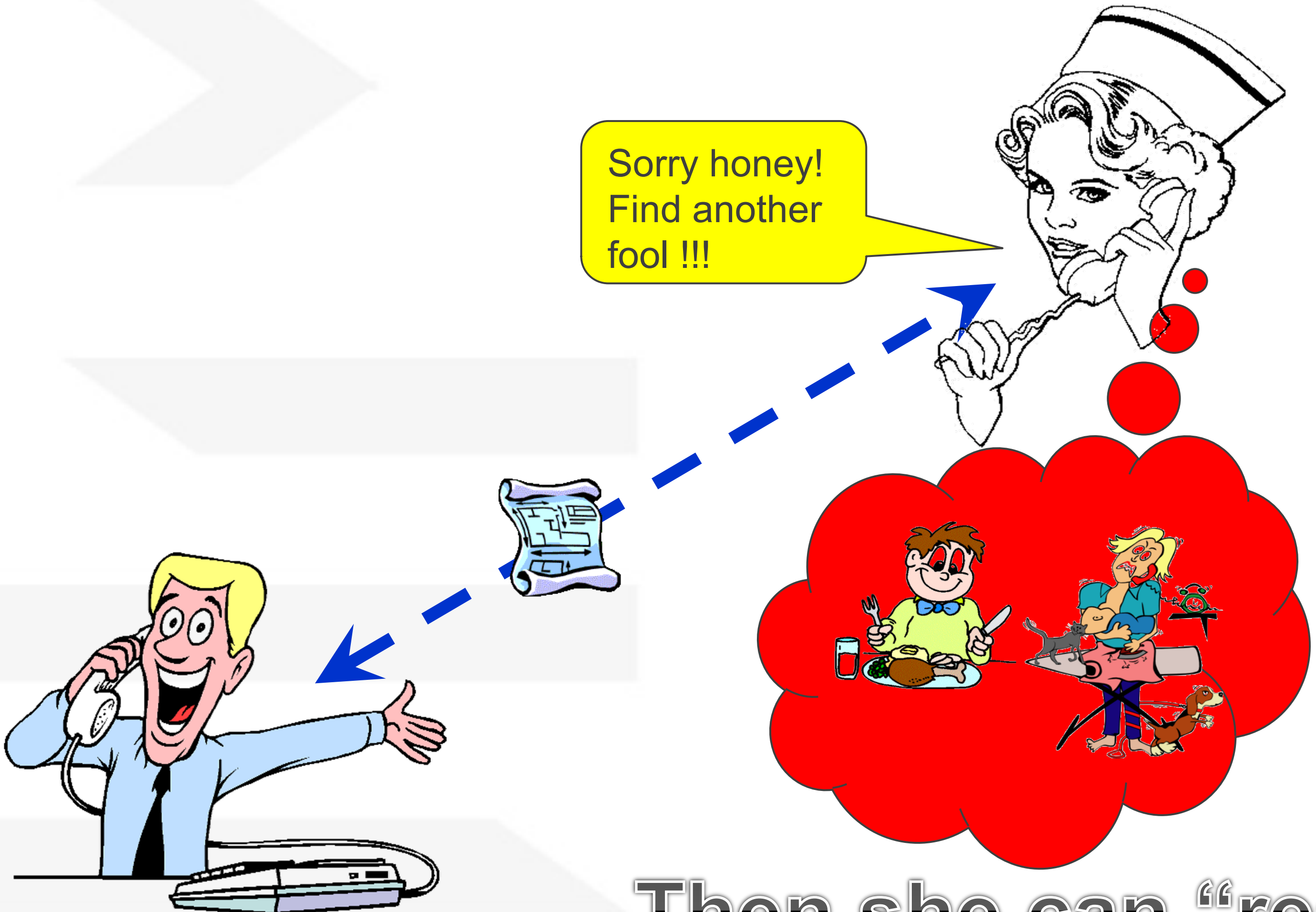
Example from Vagan Terziyan slides

Common Understanding ! : Example 12/13

Now if he is explicit!

Example from Vagan Terziyan slides

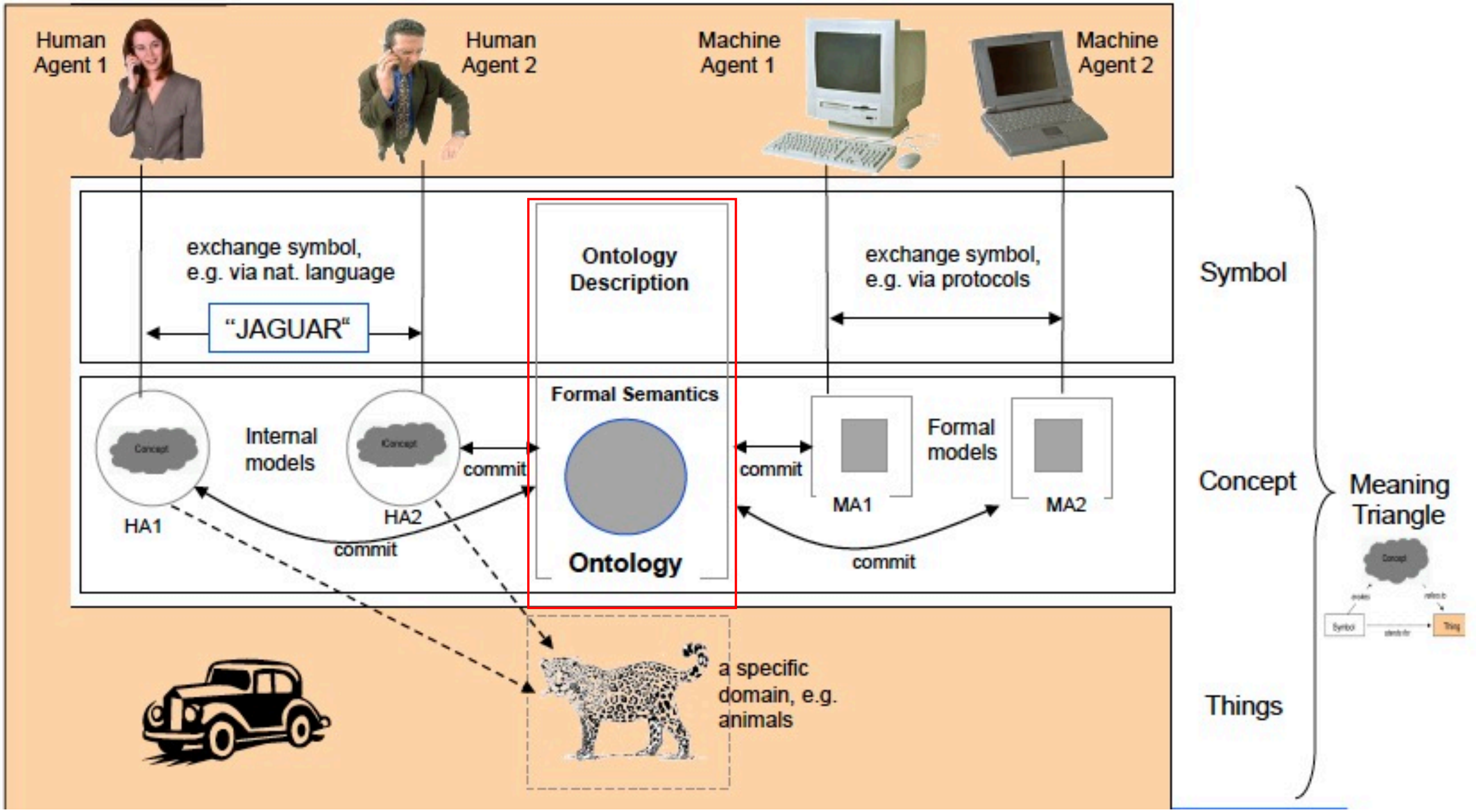
Common Understanding ! : Example 13/13



Then she can "really" understand!

Example from Vagan Terziyan slides

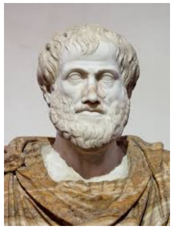
Human and machine communication



From Owen Conlan slides

[Maedche et al., 2002]

ONTOLOGY



A representation of "what exists" is an ontology. (From philosophy)

Studer(98): Formal, explicit specification of a shared conceptualization

- Formal → Machine readable
- explicit specification → Concepts, properties, functions, axioms are explicitly defined
- shared → Consensual knowledge
- conceptualization → Abstract model of some domain

A set of objects, relations, concepts, and properties formally (logically) described so that software agents can interpret them.

What is an Ontology?

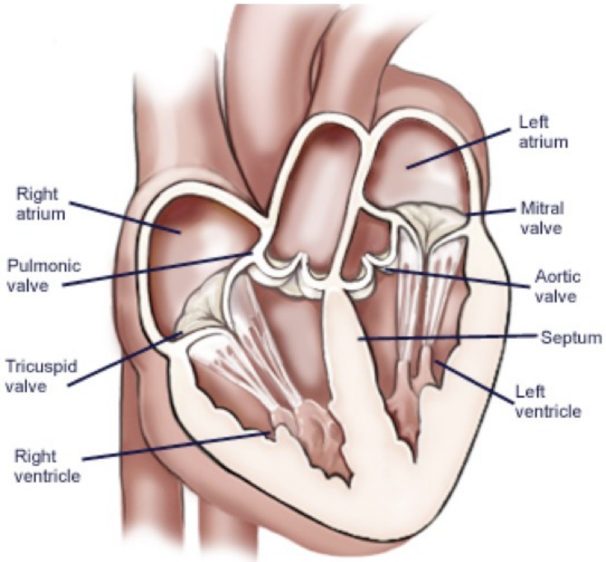
A model of (some aspect of) the world

- Introduces **vocabulary** relevant to domain
- Specifies **meaning** of terms

  Heart is a muscular organ that
  is part of the circulatory system

- **Formalised** using suitable logic

$$\forall x.[\mathsf{Heart}(x) \rightarrow \mathsf{MuscularOrgan}(x) \wedge \exists y.[\mathsf{isPartOf}(x,y) \wedge \mathsf{CirculatorySystem}(y)]]$$



From: Ian Horrocks "OWL 2: The Next Generation"

Ontologies in Philosophy Vs Computer science

Ontology perspective

- **Representation** of entities, ideas, and events, their properties and relations, according to **a system of categories**.
- The **same** in Computer science and Philosophy.

Ontology focus

- In computer science, is about establishing fixed, controlled vocabularies.
- In philosophy, is more on the perception and the representation of the world.

In **computer science** and engineering area: **focusing** on the **formats of the vocabularies** (OWL, JSON, UML, etc.) and the **capacities to process** them.

WARNING

Missing the most important part: The semantic disambiguation of the vocabulary.

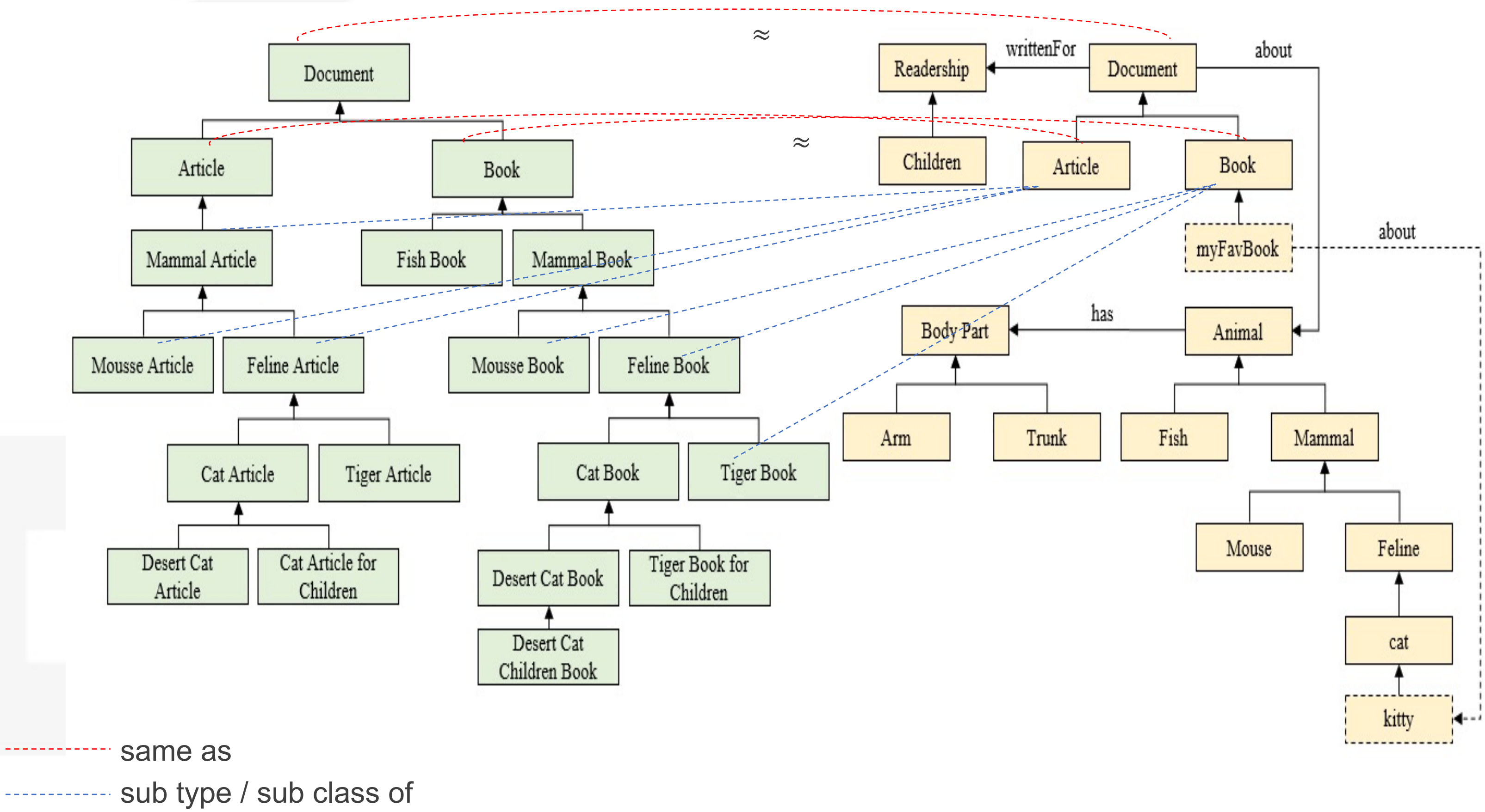
Necessity to make the ***balance*** between the ***utility*** of use and the ***philosophical*** vision to represent the world when building ontologies.

Monolithic and Pluralistic Approaches

- **Monolithic approach <u>: Only one ontology</u>** may exist or may be conceptualised for the same domain.

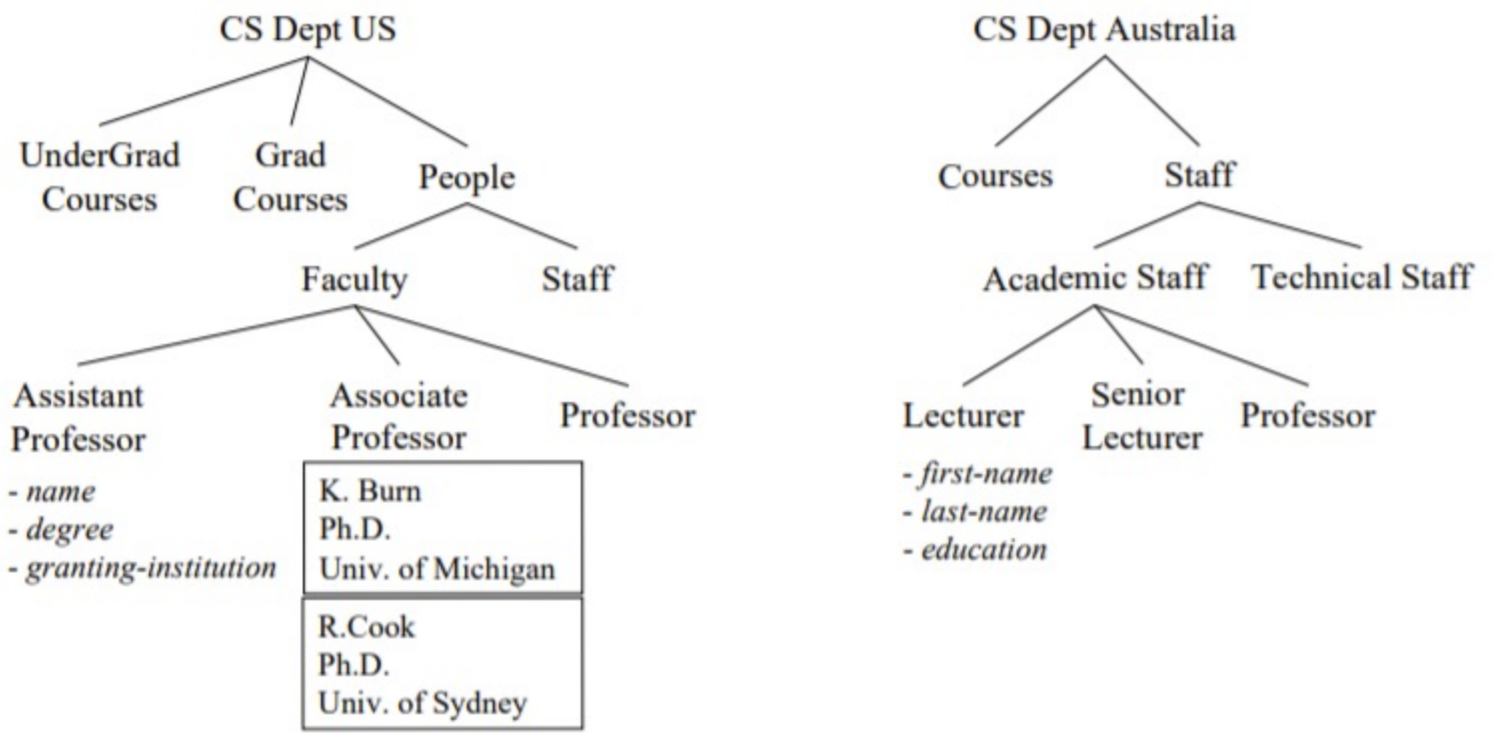
- **Pluralistic approach <u>: more than one ontology</u>** for the same domain may exist or may be conceptualised .

Same terms / Different conceptualisation

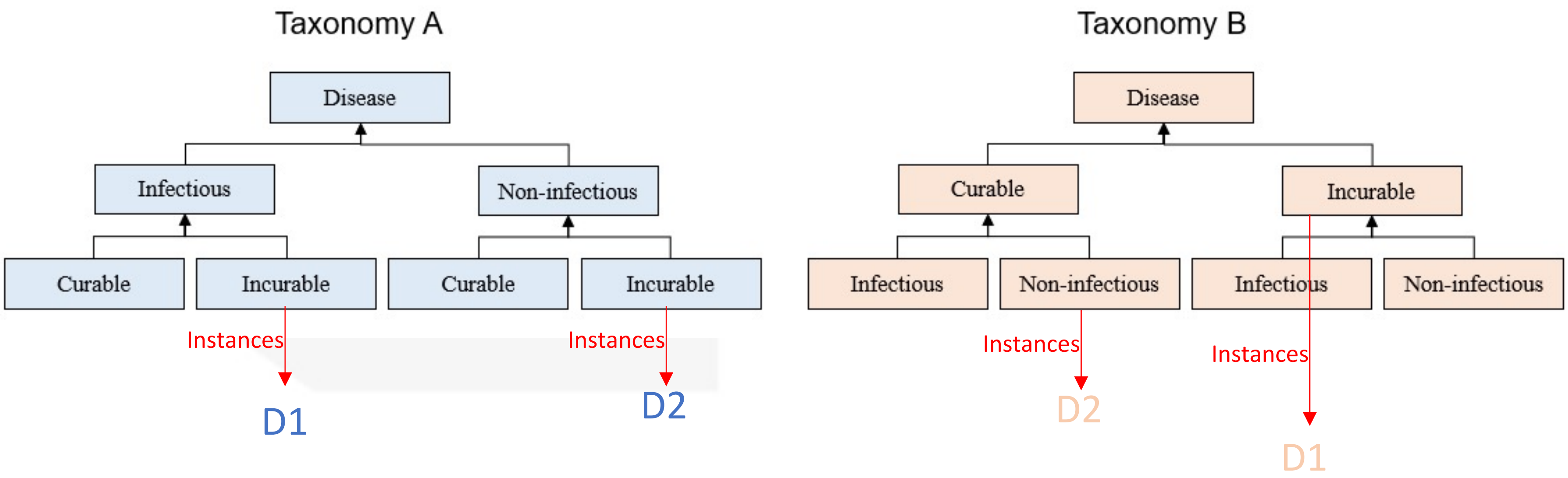


Same terms / Different conceptualisation

- Difficult to get an exact match (correct!) among concepts.



Same terms / Different conceptualisation



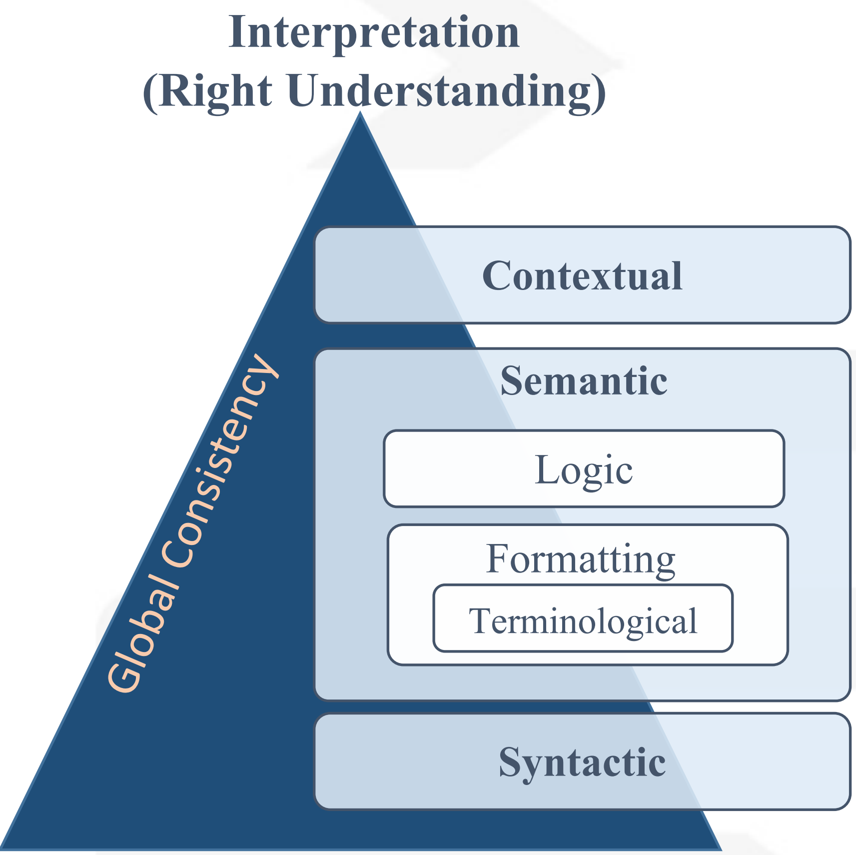
Taxonomy A and *Taxonomy B* include the same terms, but the structure is different in each one. Each structure is valid according the point of view in the mind of its modeler.

Fact!

Ontology was presented as valuable solution for interoperability

But
Ontologies are not-interoperable

Concerns of ontology interoperability (factors)



- Concerns the perspective, surroundings, circumstances, or environment that specify, the meaning of an occurrence depending to the stakeholder, organization, etc., and their needs and intents.
- Concerns the set of logical propositions of the ontology (classification, relations, and axioms defining ontologies concepts.
- Concerns labelling of classes, their definition and the annotations, by using existing annotations standards or best practices.
- Concerns concept names used by ontologies (e.g. car, automobile and motor refer to the same entity).
- Concerns ontology languages with different amount of expressivity (e.g. OWL-DL, RDFS).

Syntax and Terminology (complementary)

- Terminology may be same but different syntax makes interoperability harder to achieve without further mapping.

<price> <value> **1** </value> <currency> **GBP** </currency> </price>	price(**1**,**GBP**)

- Syntax may be same but different terminology makes interoperability harder to achieve without further mapping.

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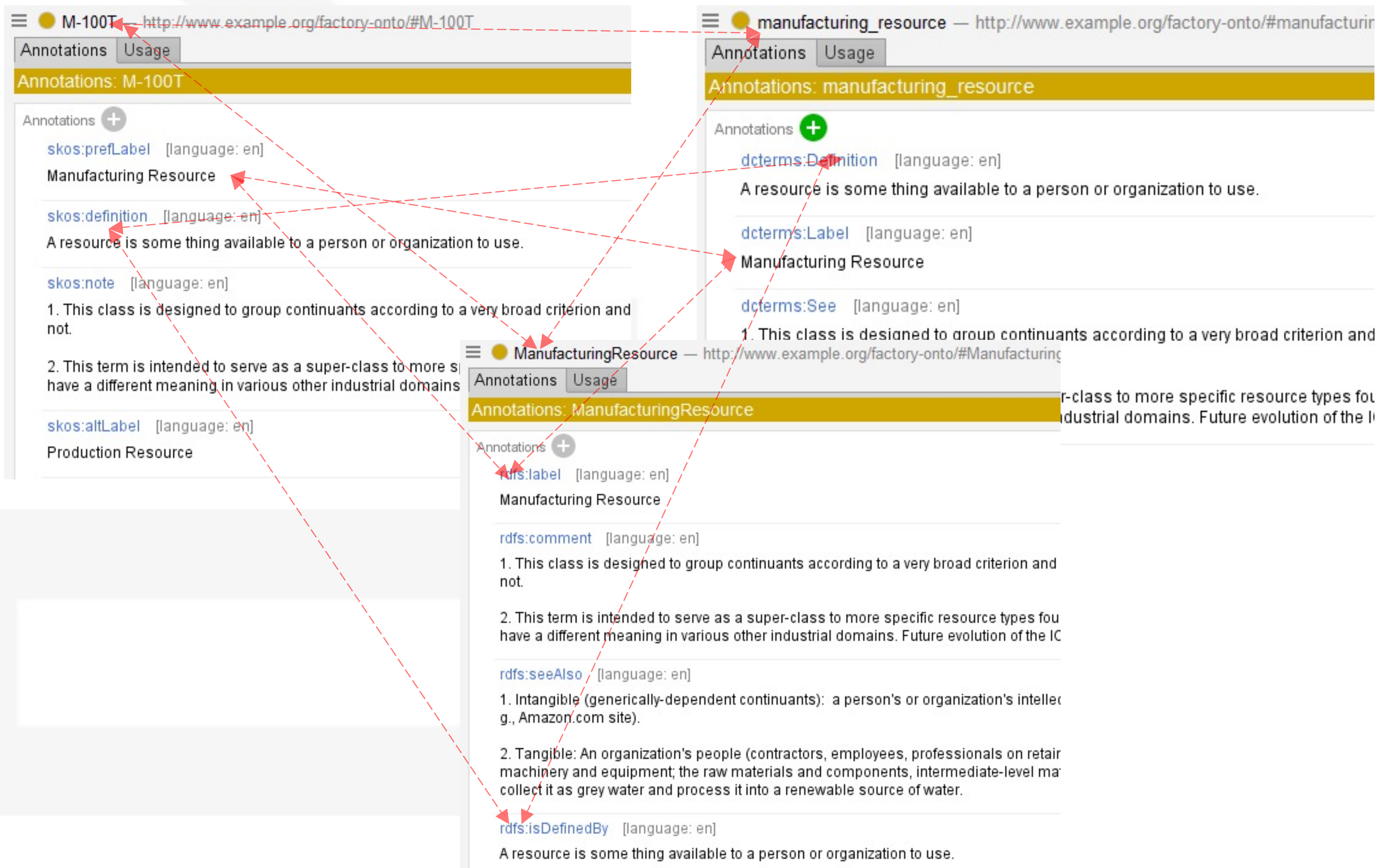
Terminological and Formatting Interoperability



Logical Interoperability

- Ontology 1: $Boring = \forall\, succeeds.Drilling \sqcup \forall\, precedes.Reaming$
- Ontology 2: $Boring = \forall\, isSuccededBy.Reaming \sqcup \forall\, isPrecededBy.Drilling$

→ Both statement has same semantic but logically not interoperable without additional axioms $succeed^{-} = isSuccededBy$ and $precedes^{-} = isPrecededBy$

Semantic Interoperability

- Ontology 1: $Product = \exists\ canBePurchasedBy.Customer$
- Ontology 2: $Product = \exists\ hasIdentifier.SerialNumber$
- Ontology 3: $Product = \ \forall\ hasRole.ProductRole$

→ Semantically they are for not interoperable due to the difference in conceptualization.

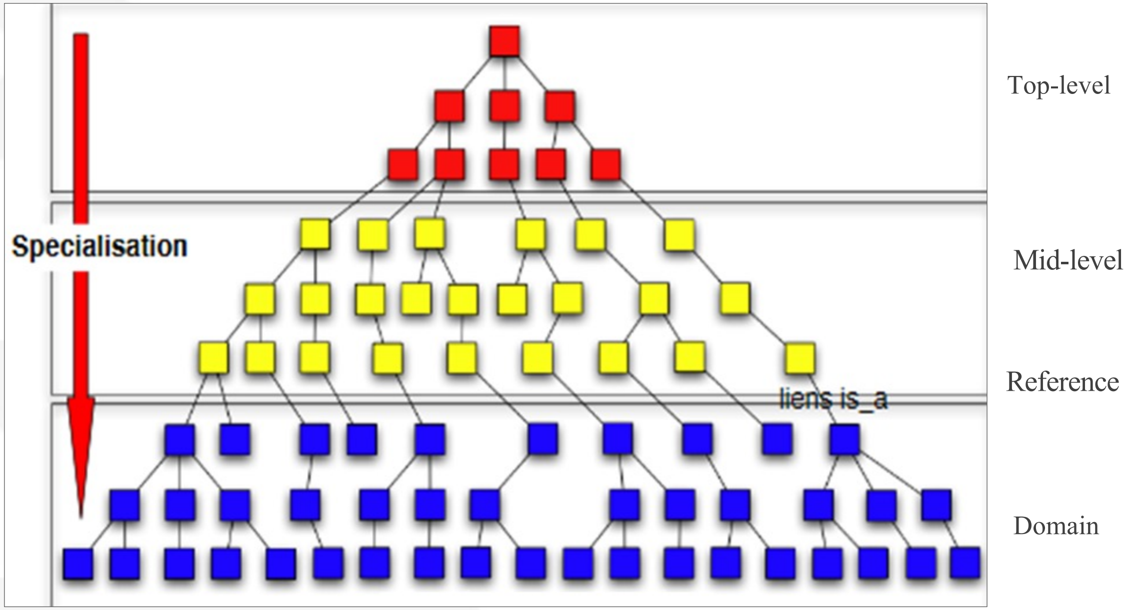
Contextual Interoperability

- Ontology 1: $Agent \sqsubseteq Person \sqcap Organization$
- Ontology 2: $Agent \sqsubseteq (Organism \sqcap System) \sqcup \exists\, hasIntention.Intention$

→ Ontology 1 refers to only human being or group of human being. (narrower sense).

→ Ontology 2 refers to a all organism and even some "software agent" (broader sense).

Ontology's levels of abstraction



- **Top level ontology** is a domain independent ontology that describes very general concepts.
- **Middle level ontology** define general modules like space and time.
- **Reference ontology** which is richer than a mid-level ontology and less specific than domain ontology.
- **Domain ontology** describe concepts of a domain of interest in a very specific way.

Role of top-level ontologies (TLO)

- Provides domain independent semantics
- « God's eye view »
- Collection of many metaphysical topics that already found consensus.
- Common starting point (top down approach)
- Off-the-shelf roots for taxonomies.
- Interoperability among domain ontologies using same TLO.

Example: How TLO is useful ?

How the **Marketing Team** see it?

This is a « **Product** ».

How the **Maintenance Team** see it?

This is a « **Maintainable Item** ».

Marketing Team

Maintenance Team

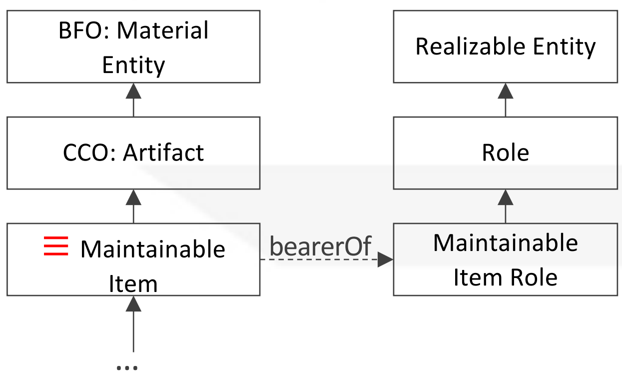
PLC & ROMAIN interoperability check

- ☑ Same top-level ontology (BFO)
- ☑ Same mid-level ontologies (CCO)
- ☑ Same syntax (OWL)
- ☑ Same terminology
- ☑ Same logics (OWL-DL)
- ☑ Same domain (Product Life Cycle)
- ☑ Same development process
- **Different development teams!!**

Does this difference impacts the **interoperability** of the two ontologies?

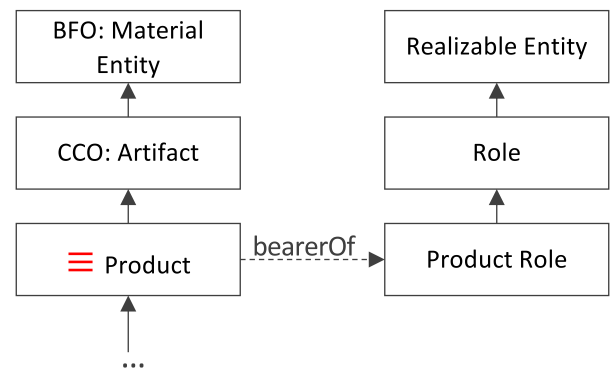
Use case ROMAIN-PLC: The added value of defined classes

ROMAIN Ontology



∀x, y [Maintainable Item (x) ≡ Artifact(x) Λ y(Maintainable Item Role(y) Λ x bearerOf y)]

PLC Ontology



∀x, y [Product(x) ≡ Artifact(x) Λ y(Asset Role(y) Λ x bearerOf y)]

- The Artifact « CAR » that has Maintainable Item Role and Product Role is considered as product and Maintainable Item in the same time
- Marketing and Maintenance teams can exchange information about the same Artifact CAR even if their considerations are totally different

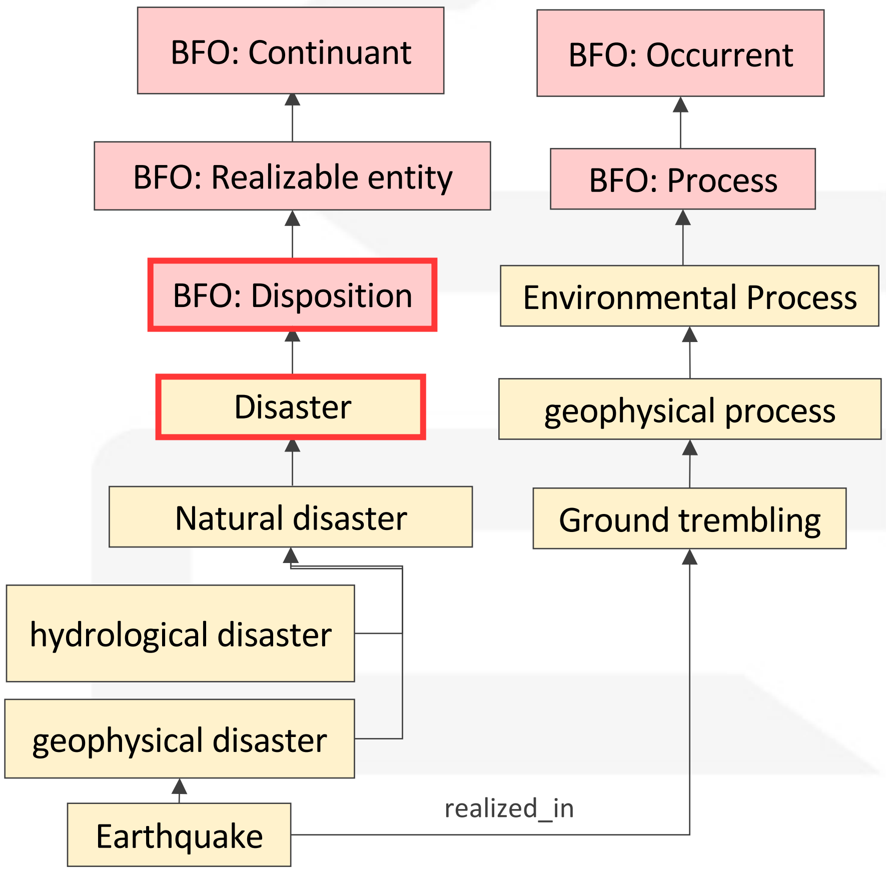
POLARISCO & MEMOn interoperability check

- ☑ Same top-level ontology (BFO)
- ☑ Same mid-level ontologies (CCO)
- ☑ Same syntax (OWL)
- ☑ Same terminology
- ☑ Same logics (OWL-DL)
- ☑ Same domain (Disaster management)
- ☑ Same development process
- ☑ Same development team
- ⛔ **Different perspective and context !!**

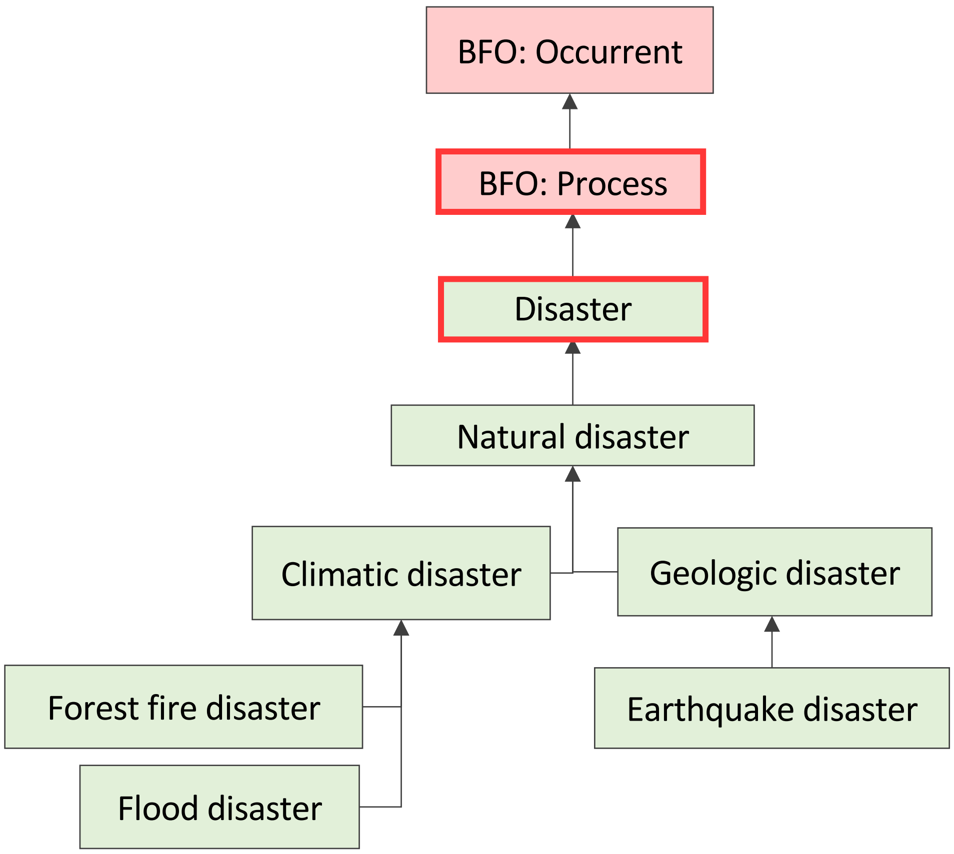
Does this difference impacts **interoperability** of the two ontologies?

Integration & Consistency check

(a) MEMOn



(b) POLARISCO



Consistency check

Different perspectives → logical inconsistency

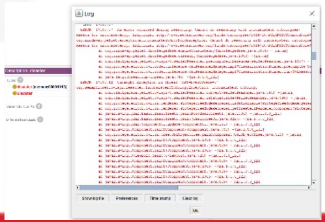
POLARISCO

- A "disaster" is defined as a subcategory of the class **"bfo: process"**.
- A process is an occurrent entity that exists in time by occurring or happening has temporal parts and always depends on at least one material entity.
- This choice was made according to the USDHS definition of disaster: any event, natural or manmade, that results in extraordinary levels of mass casualties, damage affecting the population, infrastructure, environment, economy, and/or government functions.

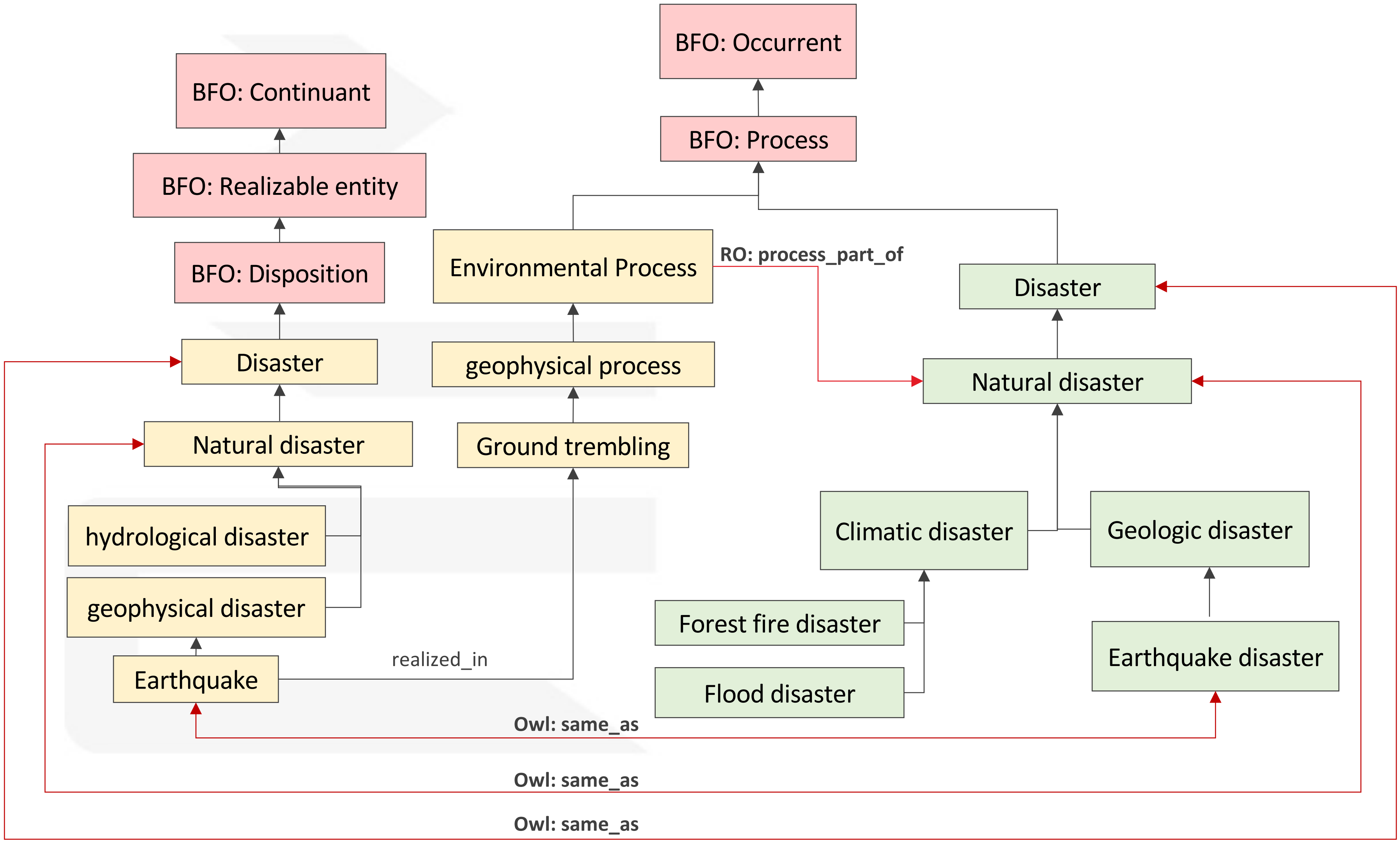
MEMOn

- A "disaster" is defined as a subcategory of the class **"bfo: disposition"** .
- A disposition is a realizable entity in virtue of which a process occurs in the independent continuant in which the disposition inheres.
- This choice was made to emphasize the difference between environmental processes and natural disasters.

BFO occurrent $\not\equiv$ **BFO continuant**



Inconsistencies resolution



Consistency of the ontology is then validated !

Conclusions and perspectives

- Choose between the Interoperability by design and by interoperability by alignment
- Consider the added value from Top level ontology driven approach (Top down)
- Specific perspectives and context remain a major factor of inconsistency of ontologies interoperability
- Need of ECOSYSTEM for ontologies interoperability

Ontologies interoperability initiatives for Industry

ONTO COMMONS
ONTOLOGY-DRIVEN DATA DOCUMENTATION FOR INDUSTRY COMMONS

Horizon 2020
European Union Funding
for Research & Innovation

www.ontocommons.eu

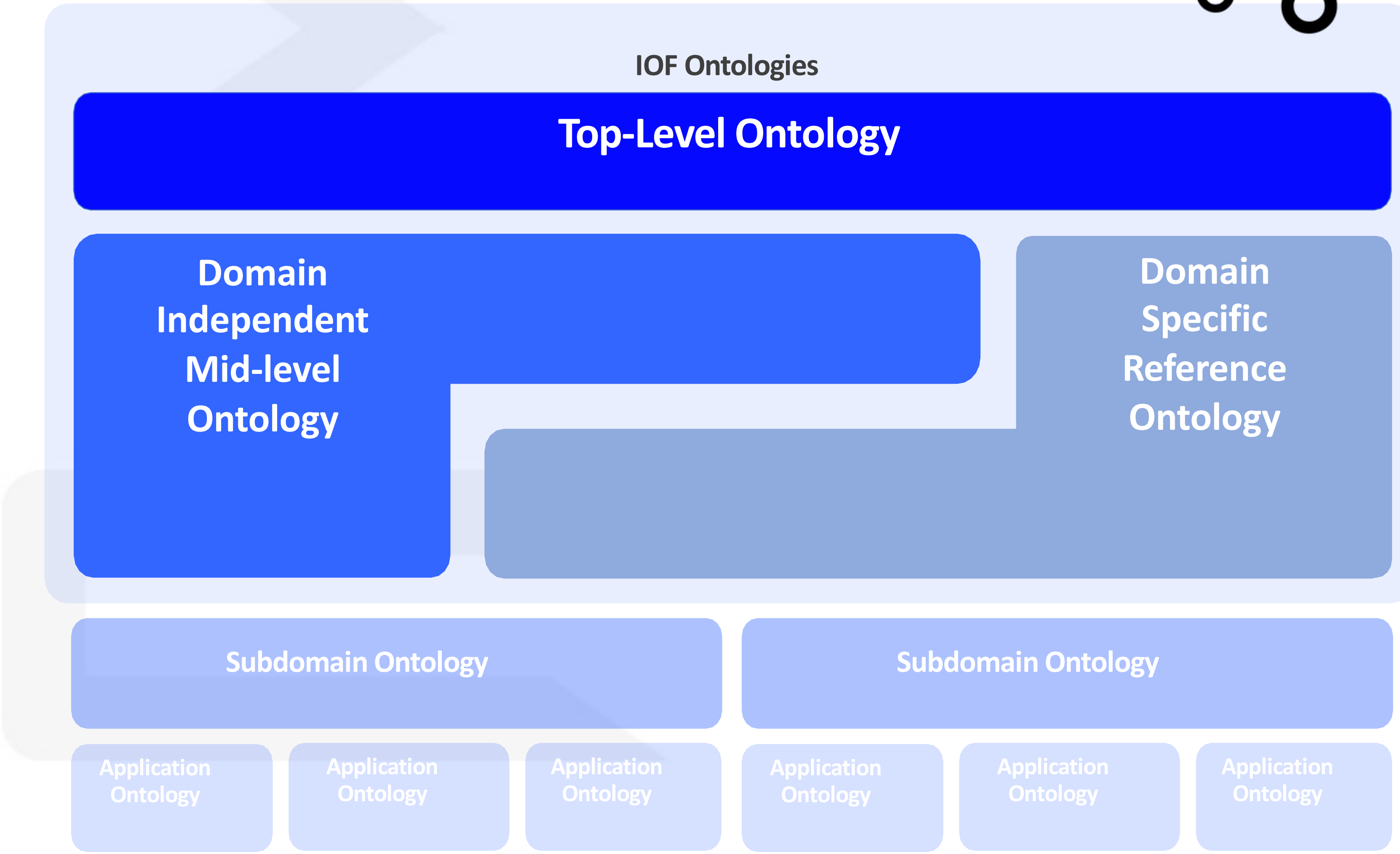
Pluralistic approach

The Industrial Ontologies Foundry (IOF)

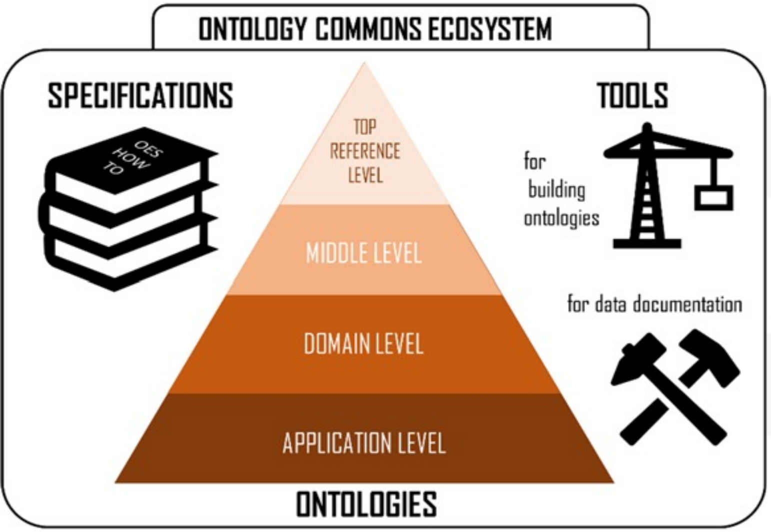
www.industrialontologies.org

Monolithic approach

IOF Ontology Architecture



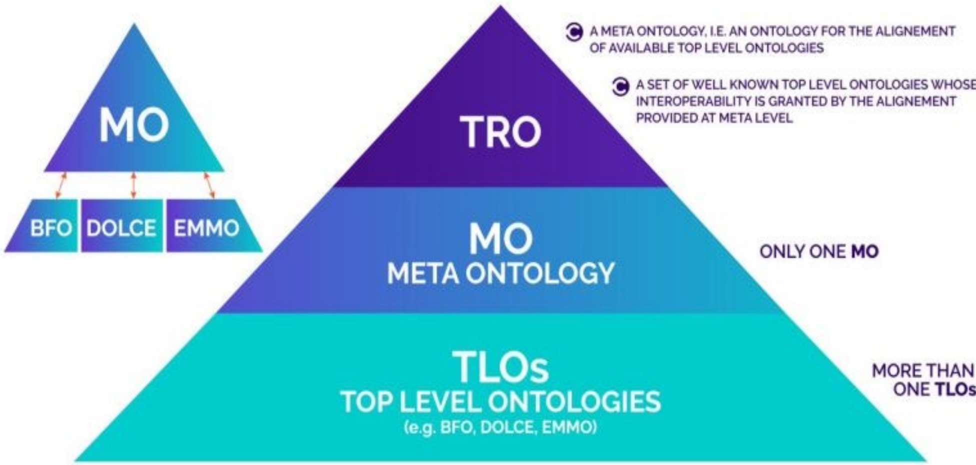
Ontology Commons EcoSystem (OCES)

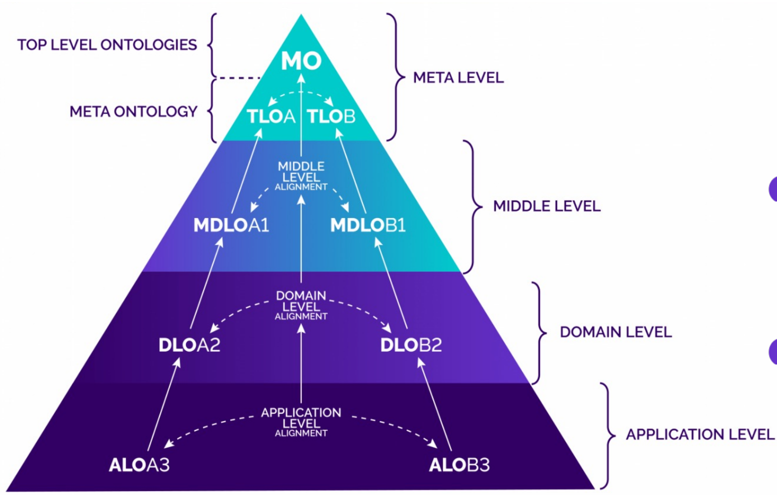


- ***a hierarchy of networked ontologies*** of different levels of generality (from top-level to application level) for which multiple forms of interoperability will be provided
- ***a set of tools and methodologies***, selected from the available state of the art, covering the full range of OntoCommons activities, from ontology development (e.g. editors) to reasoning (e.g. reasons) and database integration.
- ***a set of specifications for ontologies*** that will provide full compatibility between tools and ontologies.

OCES will be driven by FAIR principals

Ontologies harmonisation





OntoCommons will provide harmonisation between ontologies, through Top Reference Ontology through a multilevel alignement:

- ***Syntactic*** alignment (OWL, FOL, etc.) for all the ontologies that will be part of the OES.
- **Terminological** alignment enabling a minimum taxonomical interoperability between ontologies, by pasting a sub-branch of one ontology under another ontology.
- **Semantic** alignment will be targeted primarily by OntoCommons only within TLO branches,.
- **Formatting** alignment including e.g. labelling of classes, the definition of terms and the annotations.

The OCES will adopt a **pluralist approach** for the ontological representation of a domain of interest, meaning that **more than one ontology for the same domain** may be hosted.

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