Distinction-Based and Verification-Assisted Knowledge Modeling

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Requirements Engineering

- Build mutual understanding between stakeholders
- Pitfalls – too often assume that:
  - key domain concepts are well understood
  - stakeholders share common definitions
- Basic concept definitions are overlooked
  - deemed too obvious to bother with

RE and Law

- Software engineers are not lawyers
  - Not trivial to translate the intent of a law into specific requirements
    - traceable
    - verifiable
- ex: Consent management in healthcare (Canada) :
  - At least five different laws, written at different times, with different objectives, address consent management, privacy and confidentiality of EHR

Knowledge Modeling and Law

- Laws can be modeled, structured and abstracted, using software engineering techniques
  - to simplify domain understanding for software engineers
  - to build a bridge between the legal domain and the software engineering domain
- It is very complex to model the whole text and regulations:
  - We choose to focus on essential knowledge conveyed by **Basic Concepts**

Distinction-Based Domain Modeling

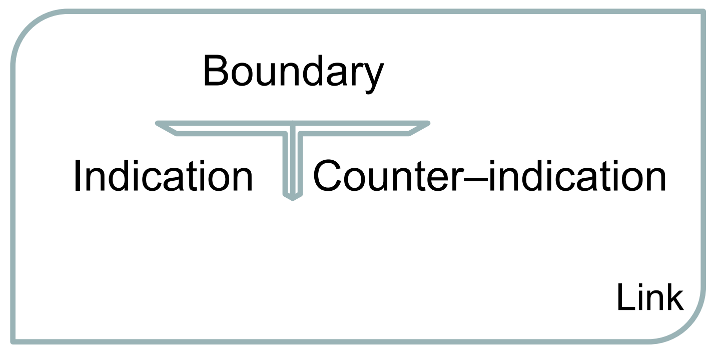
- Assumptions:
  - Clear-cut distinction is prior to definition
  - Symbols are the shortest mean to connect Meanings with total precision:
    - This is what we call “Formalization”
- Formalization allows engineering of Meanings that are computable by a machine

Calculus of distinctions

- Based on *Laws of forms - LoF*, of George Spencer Brown:
  - Lof is a formal calculus that can be interpreted as Boolean Logic
  - LoF was extended by F. Varela to deal with 3-valued logics
  - We extended LoF to deal with elements (numbers, words), bunches of elements, types of elements, and mappings

How to make Distinctions in accordance with LoF ?

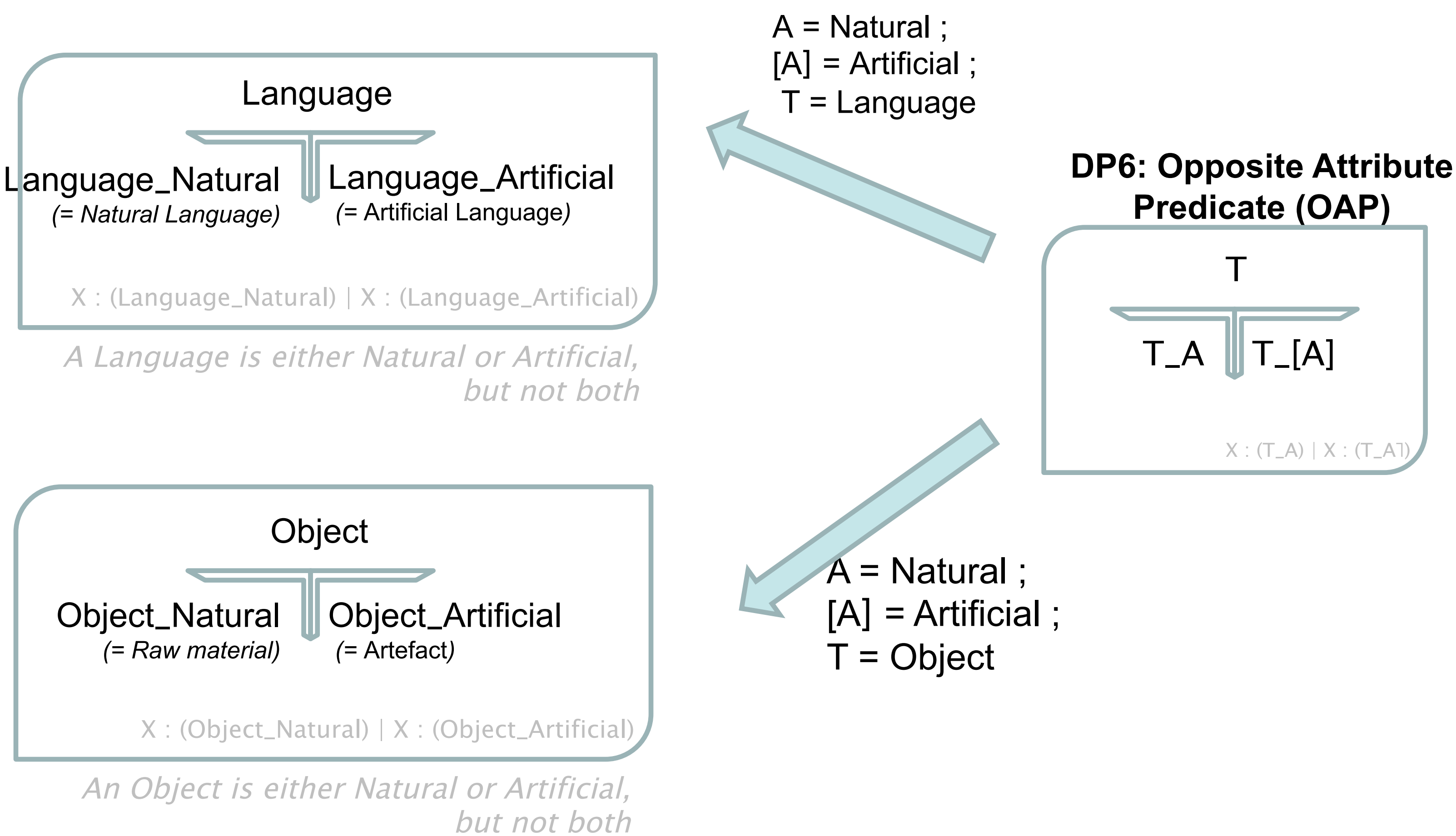
- A Distinction can be made by instantiating a Distinction Pattern :
  - In a Distinction Pattern,
    - the drawn boundary represents the distinction
    - the 2 drawn mutually exclusive sides represent the 2 indications:
      - The inside represents the indication (atomic)
      - The outside represents the counter-indication
    - the link, encompassing the indication and the counter-indication, identify the Distinction as a whole



Distinction Patterns in action! (1)

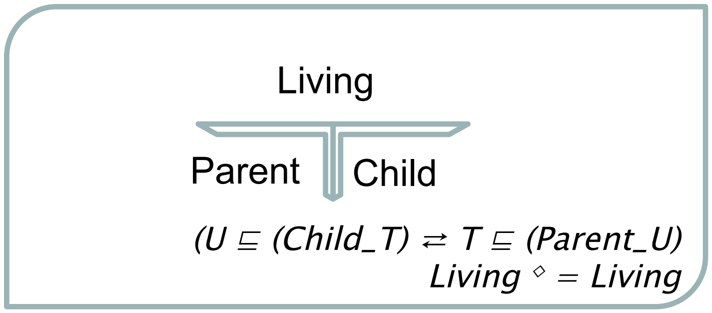
Instanciations

Pattern

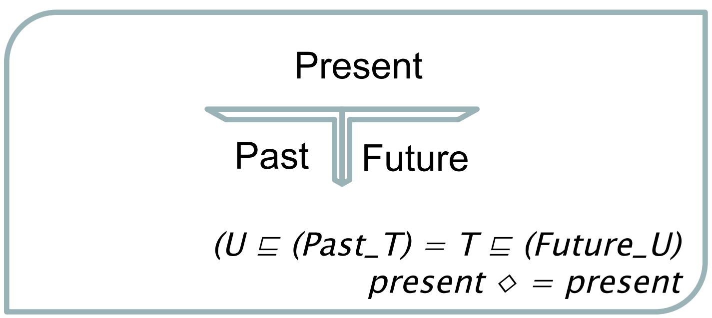


Distinction Patterns in action! (2)

Instanciations



Note: Identity$_{Living}$ and Living (Being) are identified

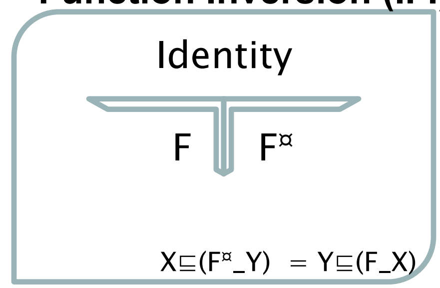


F = Parent;
F ¤ = Child;
Id = Id$_{Living}$ Being;

F = Past ;
F ¤ = Future ;
T = Present ;

Pattern

DP7: irreflexive Function Inversion (IFI)

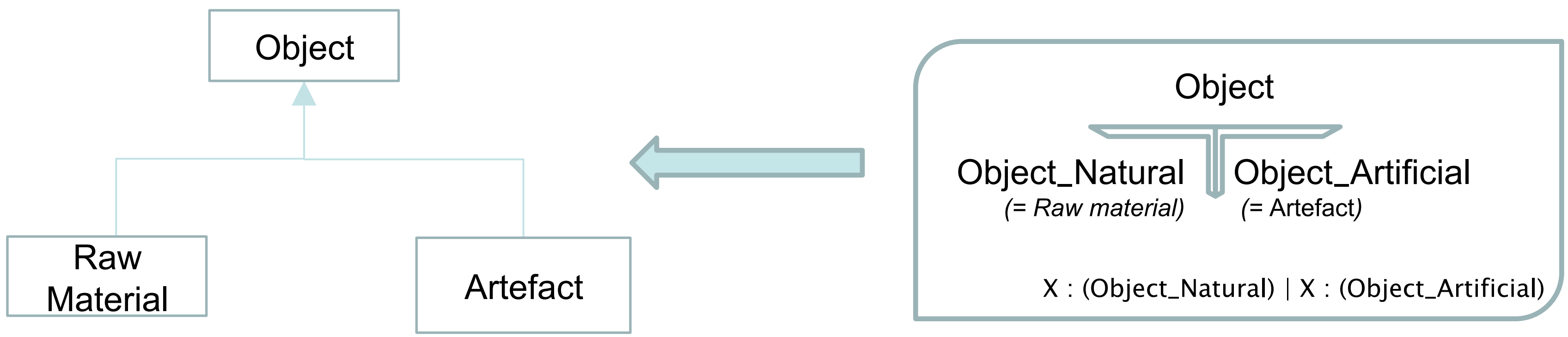


Note: Identity$_M$ may be identified with M

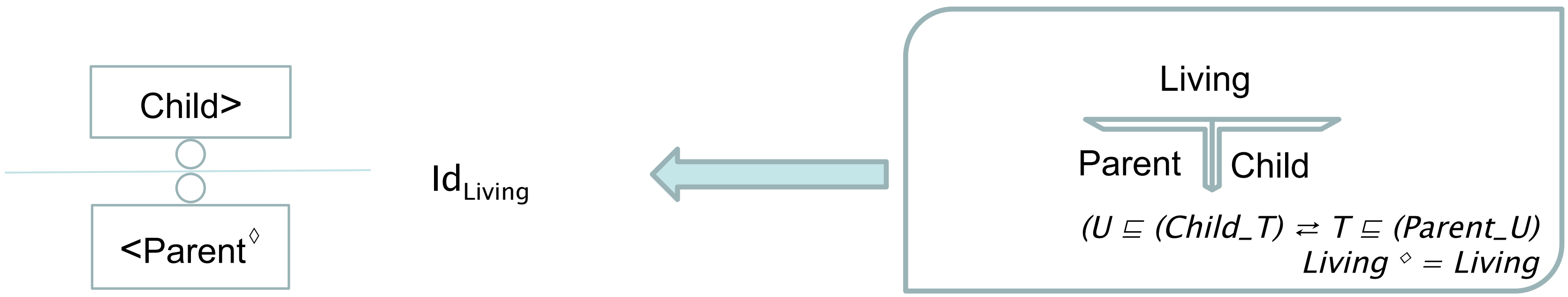
Graphical presentation

- We use « UML-like » notations for explaining distinguished words-meaning relations to IT people :
  - « A picture is worth a 1000 words »

Typing modelling



Inverse Associations modeling



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Finally : What is a Distinction?

- A **Distinction** is a single intentional thought that arrives embodied in two mutually incompatible ideas :
  - Distinction Making is a conscious activity of human beings :
    - It produces a clear-cut and well definable <u>indication</u> in the actor's language
- A Distinction is mental :
  - It must not be confused with its drawing

Distinction-Based Reasoning

- Describing concepts using formulas and operators (symbols)
- Reasoning about concepts to validate definitions
- Calculus on words-meaning is conducted
  - by substituting and replacing into language constructs
    - well defined indications by the body of their definition
  - By example:

$$\frac{\begin{array}{ll} \text{father\_bart} \approx \text{homer} & \text{parent} \approx \text{father, mother} \\ \text{mother\_bart} \approx \text{marge} & (F, G)\_X \approx (F\_X), (G\_X) \end{array}}{\text{parents\_bart} \approx (\text{homer, marge})}$$

Calculus of Distinctions Operators

Boolean expressions

A : B reads "A is a B”

A || B reads "A and B are disjoint"

Terms (word expressions)

[A] reads "the opposite of A"

A_B reads "A has quality B"

A | B reads “A or B”

A & B reads “A and B”

Properties of *IsA*

transitivity

$$\alpha_1 : \alpha_2 \wedge \alpha_2 : \alpha_3 \Rightarrow \alpha_1 : \alpha_3$$

WorkProduct : Artefact and Artefact : Object

$\Longrightarrow$

WorkProduct : Object

Opposite attributes

natural = [artificial]

natural is the opposite of artificial

natural *can be substituted by* [artificial]
and vice-versa

Disjointness

$$\alpha \parallel \beta \Leftrightarrow \forall x \cdot \neg(x : \alpha \wedge x : \beta)$$

two types are disjoint iff they have no common subtypes

$$\alpha\_\beta \parallel \alpha\_[\beta]$$

having opposite qualities makes two concepts distinct

RawMaterial = Object_natural

Artefact = Object_artificial *imply* RawMaterial || Artefact

natural = [artificial]

Combining qualities

Service = Product_(intangible & nonStorable);

A service is an intangible and non-storable product

Good = Product_(tangible | storable)

a good is a tangible or storable product

Are services and goods distinct?

Application and IsA

- A_B : A
  - An A with quality B is an A

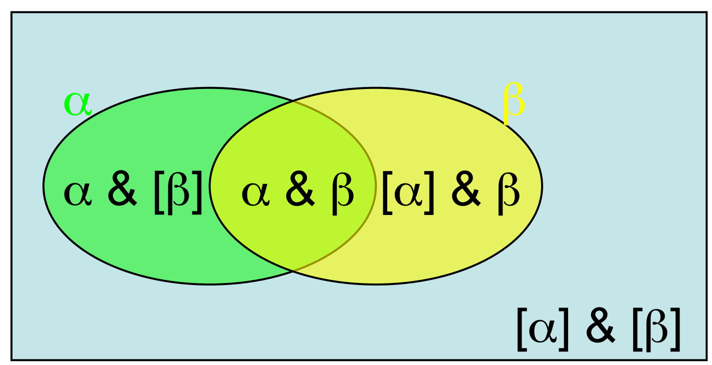
- Service = Product_(intangible & nonStorable)
  - A service is a product

Reasoning about combinations

$$[\alpha \,\&\, \beta] = ([\alpha] \,\&\, \beta) \mid (\alpha \,\&[\beta]) \mid ([\alpha] \,\&[\beta])$$

Case analysis rule : the opposite of being $\alpha \,\&\, \beta$
is being at least the opposite of either α *or* β

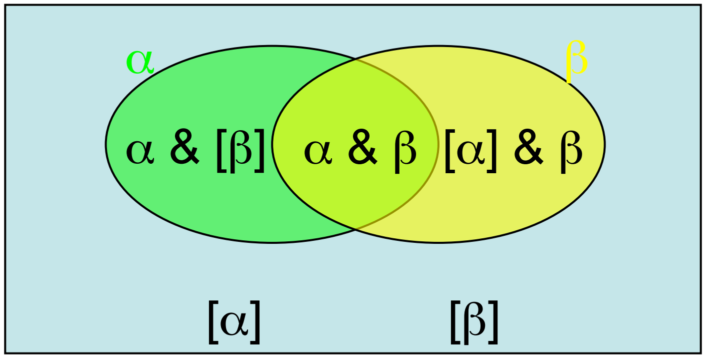
	β	[β]
α	α & β	α & [β]
[α]	[α] & β	[α] & [β]



Why not use plain set theory?

$$\overline{\alpha \cap \beta} = \overline{\alpha} \cup \overline{\beta}$$

The most common de Morgan's law in set theory reduces three cases to two overlapping cases



We simply use a less common law

$$\overline{\alpha \cap \beta} = (\overline{\alpha} \cap \beta) \cup (\alpha \cap \overline{\beta}) \cup (\overline{\alpha} \cap \overline{\beta})$$

Complement of qualities

$$[\alpha\_\beta] = \alpha\_[\beta]$$

The opposite of α *having quality* β

is α *having the opposite of quality* β

it is a relative complement

Reasoning on services

$$
\begin{array}{ll}
 & [\text{service}] \\
= & \hfill \langle \text{definition of service} \rangle \\
 & [\text{Product\_}(\text{intangible} \,\&\, \text{nonStorable})] \\
= & \hfill \langle (5) \rangle \\
 & \text{Product\_}[(\text{intangible} \,\&\, \text{nonStorable})] \\
= & \hfill \langle (4) \rangle \\
 & \text{Product\_}(\\
 & \quad ([\text{intangible}] \,\&\, \text{nonStorable}) \qquad \text{Flowware} \\
 & \quad | \\
 & \quad (\text{intangible} \,\&\, [\text{nonStorable}]) \qquad \text{Software} \\
 & \quad | \\
 & \quad ([\text{intangible}] \,\&\, [\text{nonStorable}]) \qquad \text{Hardware} \\
 &)
\end{array}
$$

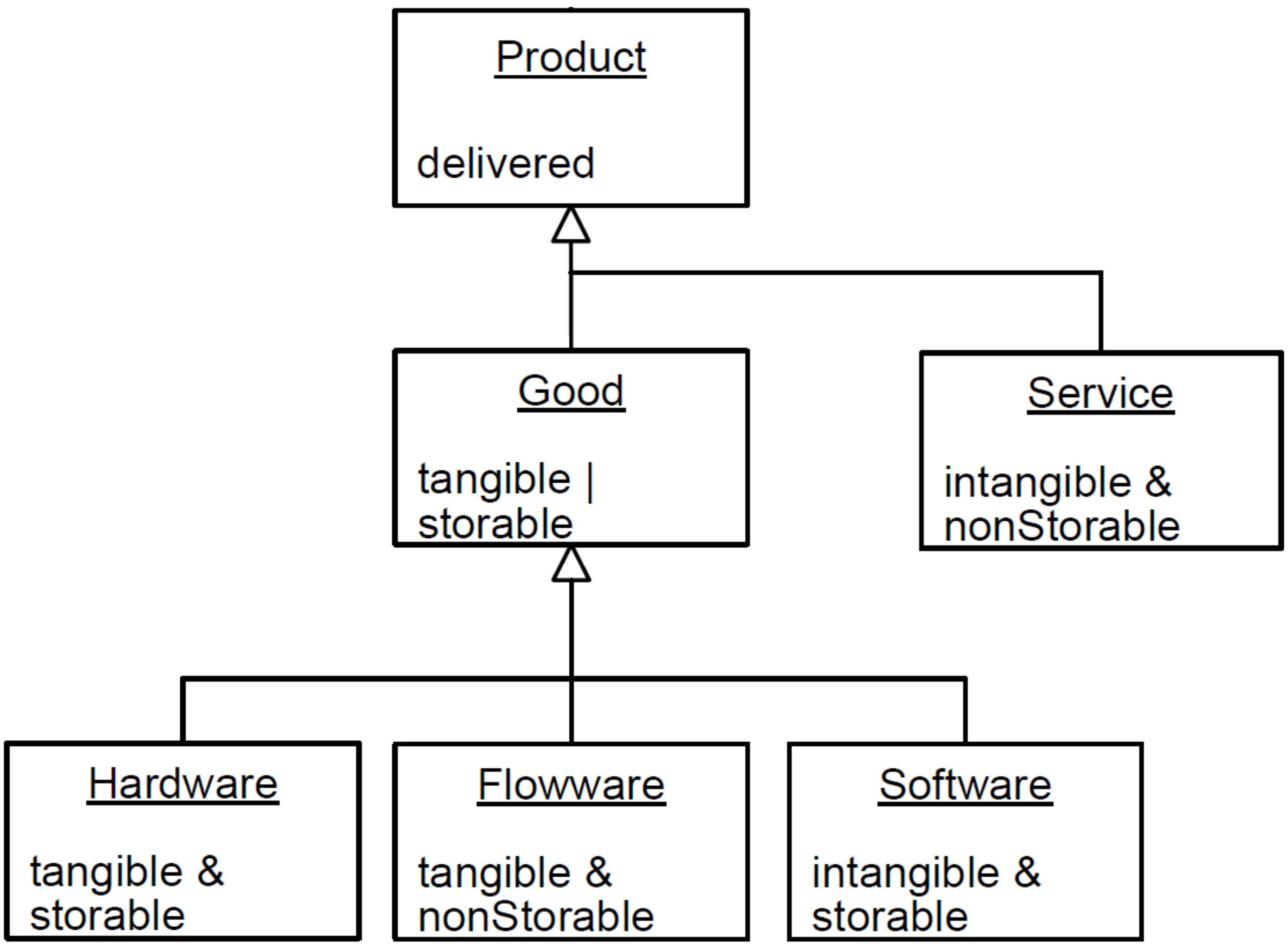
IsA based on qualities

$$
\begin{aligned}
\beta_1 \,\&\, \beta_2 \quad &: \quad \beta_1 \\
\beta_1 \quad &: \quad \beta_1 \mid \beta_2 \\
\beta_1 : \beta_2 \quad &\Rightarrow \quad \alpha\_\beta_1 : \alpha\_\beta_2
\end{aligned}
$$

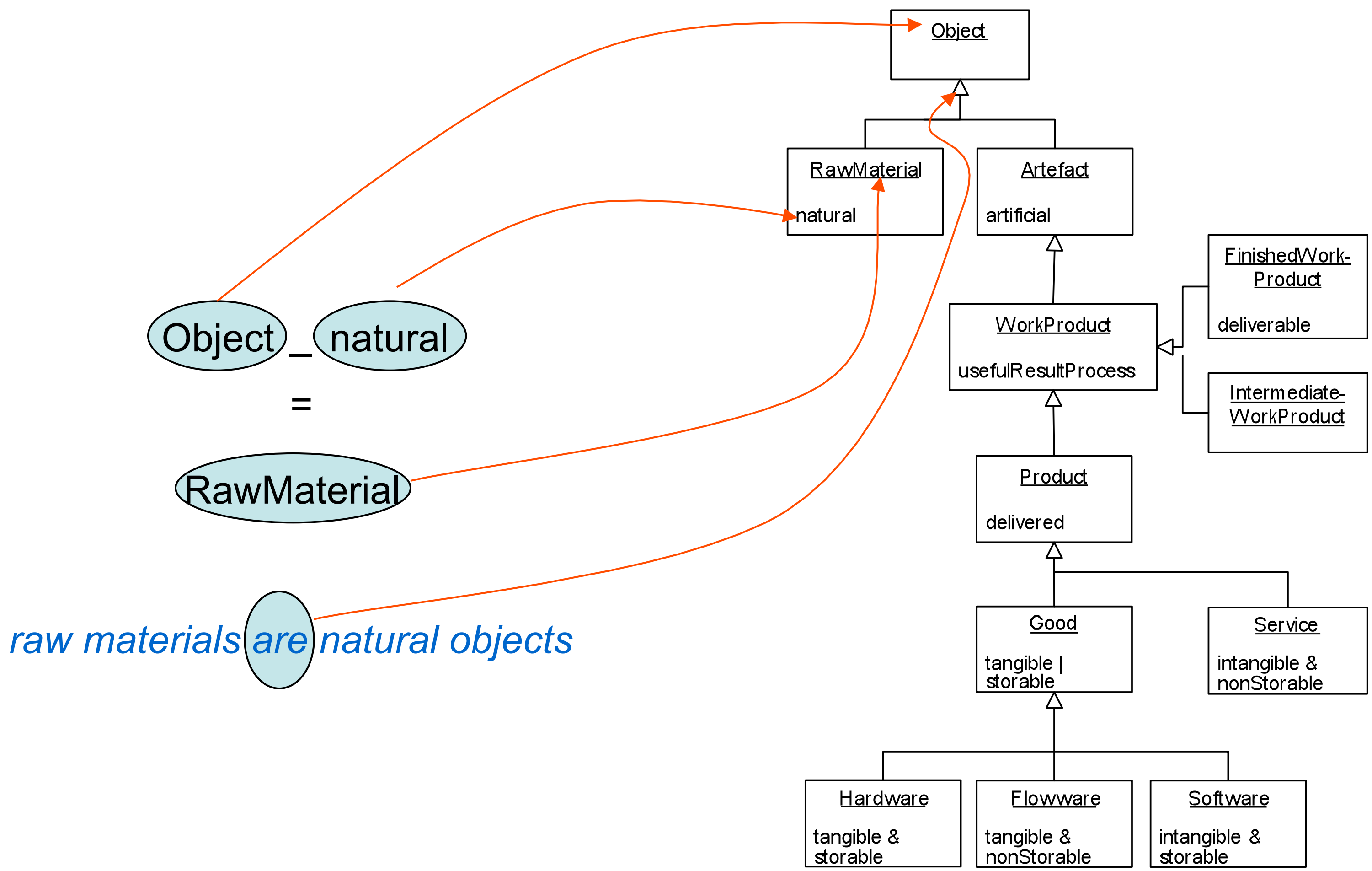
distinction based on IsA

$$\alpha : \beta_1 \;\wedge\; \beta_1 \;\|\; \beta_2 \;\Rightarrow\; \alpha \,\|\, \beta_2$$

Distinctions on products



Graphical Presentation



Set theoretic interpretation

- word = set
- _ = $\cap$
- [ ] = $\overline{\quad}$ (* complément *)
- & = $\cap$
- | = $\cup$
- A : B $\Leftrightarrow$ $A \subseteq B$
- A || B $\Leftrightarrow$ $A \cap B = \emptyset$

Set theoretic interpretation

- Object_natural = RawMaterial

  can be seen as

  "the set of objects that are natural are the raw materials"

  $Object \cap natural = RawMaterial$

Validation of models using Alloy

- Alloy is symbolic model checker for first-order logic with relations
  - FOF encoded into propositional formula
  - reuses common SAT solvers
  - only two data types
    - signatures (to define basic types)
    - finite subset of the integers
  - Object-oriented in style

What Alloy can do for us

- verify the consistency of models
  - check that definitions contain no contradiction
- check properties of models
  - state properties and check that they are entailed by the definitions

Conclusion

- Calculus of words
  - Words are indications in distinctions of a domain
  - Simple operators intended to represent and manipulate concepts of a domain
- Reason about words
  - Confirm distinctions
  - Check consistency with Alloy
  - Make deductions based on assertions about words