

Track B Launch: Harmonizing Definitions & Formal Semantics



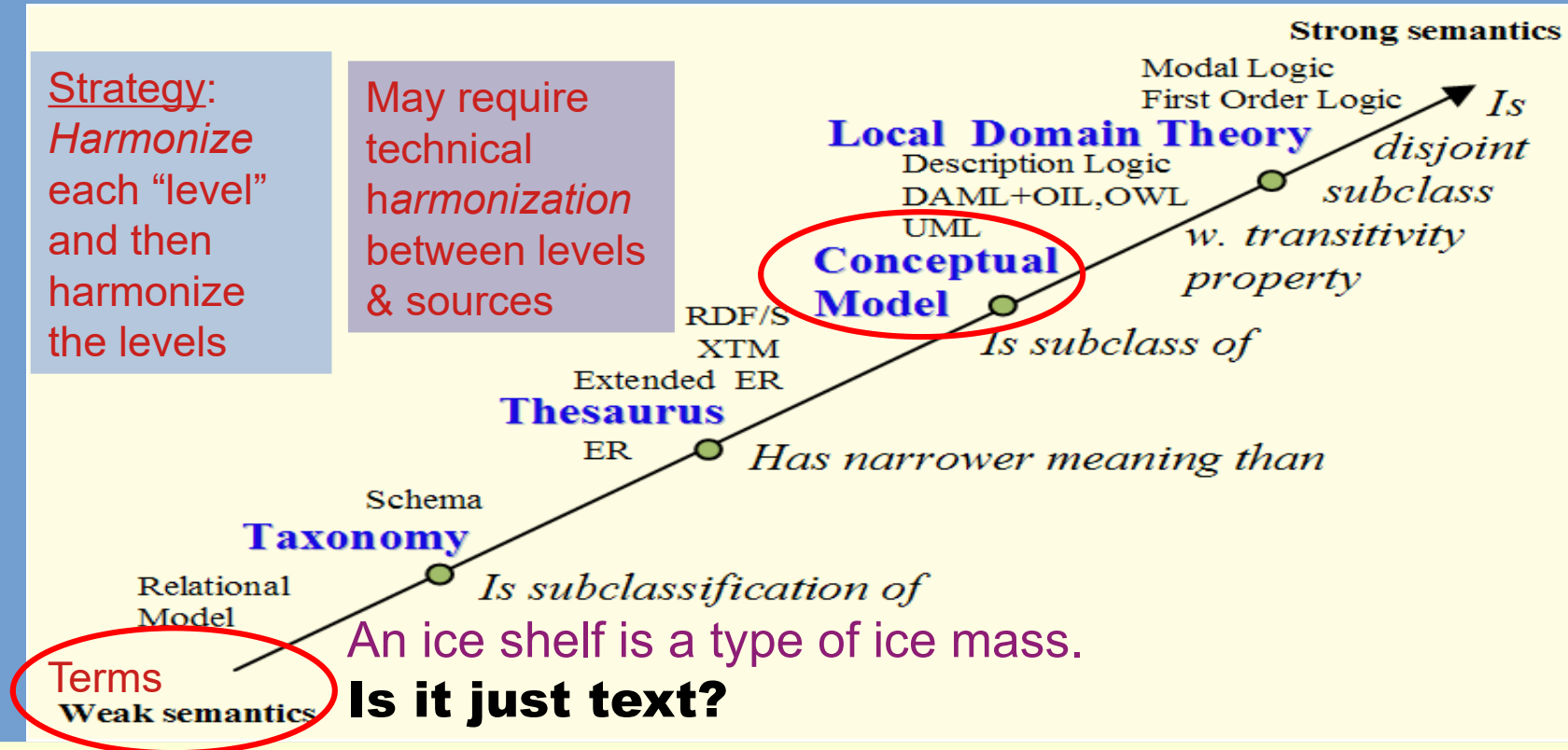
Sure would be nice to harmonize these conversations.



- Co-Chairs:
- Gary Berg-Cross (Ontolog)
 - Part 1 Harmonizing Definitions
- Part 2 Alex Shkotin: Formal Definitions

Term Definitions in a Semantic Spectrum/Gradient Context

Terms may be standardized but the *meaning* has to be too.



Zuhadar, Leyla, Olfa Nasraoui, and Robert Wyatt. "Visual ontology-based information retrieval system." 2009 13th International Conference Information Visualisation. IEEE, 2009.

Definitions can serve as links between things on the semantic ladder...but

- Metadata/keywords/tagging
 - The word forest is commonly used, BUT there is no universally recognized precise definition. More than 800 definitions of forest used around the world.
- Linked Data
- SKOS Granularity of terms **frequently** differ (broader, narrower, ambiguous)
- Semantic Web, Populating KGs, FAIR principles
- Formal ontologies and Informal ontologies
 - Ontological term definitions of a domain-specific vocabulary used by a group of experts to communicate about entities to which a term label refer.
- Aligning definitions in different formal ontologies

Qualities of a Good Definition (not lexical)

- Depends on purpose...can be different for humans and computers.
 - How to give meaning for humans AND aligned interpretation by a computer.
 - How do we bring these together?
 - Specify the intended meaning of a term by clarifying and disambiguating
 - logical properties -necessary conditions
 - necessary conditions allows us to check whether an instance is *consistent* (and non-circular) with the classes of which it is asserted to be a member, and to infer that the instance has ALL the properties that are necessary
 - instance classification: sufficient conditions for inferences apply to a class instance entities are instances based on the definition (Everest is a Mountain);
 - taxonomic schematization: the axioms of a class's logical definition can be used as a *template* for the axioms of its subclasses, as well as for the contents of the associated textual definitions.....

Lessons from the Cryosphere Semantic Harmonization Effort

2

3

Glacier
Conceptual
Model

1

Why do we need upper-level
ontologies?

Discussion with Barry Smith and others

VoCamps

IAOA Summer Institute on Upper Ontologies, University of Toronto,
August 8-11

Ruth HVs

Class hierarchy: glacier

- chemical entity
- 'collection of specimens'
- construction
- 'environmental feature'
- 'environmental material'
- 'fiat object part'
- 'food container or wrapping'
- 'food product type'
- 'manufactured product'
- manufacturer
- 'material anatomical entity'
- 'material anatomical entity'
- 'material information bearer'
- 'molecular entity'
- 'multicellular organism'
- object
- 'astronomical object'
- glacier
 - 'alpine glacier'
 - 'cirque glacier'
 - 'ice piedmont'
 - 'ice sheet'
 - 'outlet glacier'
 - 'plateau glacier'
 - 'tidewater glacier'
 - 'tributary glacier'
 - 'valley glacier'
 - 'volcanic crater glacier'
- 'ice mass'
- meteor
- 'physical object of mesoscopic geological size'
- 'snow mass'
- 'solid objects'

Annotations: glacier

EnvO

definition [type: xsd:string]

An ice mass which is of sufficient mass that the action of gravity upon it overcomes the frictional forces holding it in place, causing it to deform and flow towards lower elevation.

database_cross_reference

<https://en.wikipedia.org/wiki/Glacier>

Glacier

rdfs:comment

The definition of glacier is highly variable. Two main issues exist: 1) Whether or not a mass of ice must currently show movement to be considered a glacier or not and 2) What is the relationship between ice sheets and glaciers (i.e., which is the parent in a parent/child relationship or whether they are distinct terms).

database_cross_reference

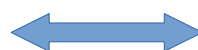
<https://orcid.org/0000-0003-4808-4736>

has_exact_synonym [type: xsd:string]

SubClass Of +

- 'composed primarily of' some (rock or ice)
- 'has part' some ice
- 'has part' some snow
- 'participates in' some 'glacial transport process'
- object

General class axioms +



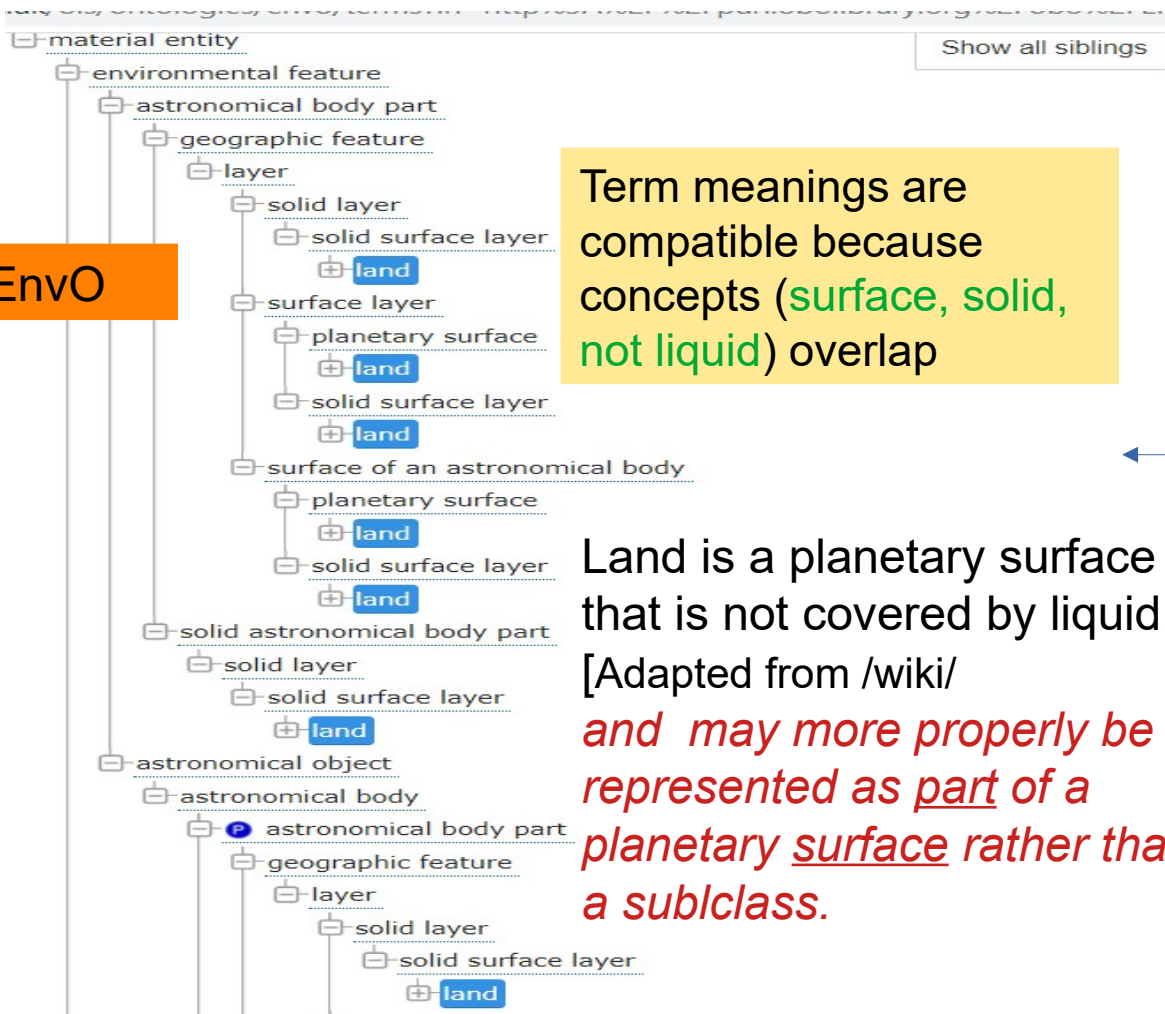
SWEET

But there is an explosion of Domain Definitions

Ablation – Ruth Durr’s graphic illustration of the problem!

Term	Definition	Source
Ablation	The process by which ice and snow dissipate owing to melting and evaporation.	NOAA Glossary of Hydrologic Terms
Ablation	(1) ~~combined processes (such as sublimation, fusion or melting, evaporation) which remove snow or ice from the surface of a glacier or from a snow-field; also used to express the quantity lost by these processes~~ (2) ~~reduction of the water equivalent of a snow cover by melting, evaporation, wind and avalanches.~~	NSIDC accessed 2016
Ablation	(1) ~~All processes that reduce the mass of the glacier.~~ (2) ~~The mass lost by the operation of any of the processes of sense 1, expressed as a negative number.~~ The main processes of ablation are melting and calving (or, when the glacier nourishes an ice shelf, ice discharge across the grounding line). On some glaciers sublimation, loss of windborne snow and avalanching are significant processes of ablation. 'Ablation', unqualified, is sometimes used as if it were a synonym of surface ablation, although internal ablation, basal ablation, and frontal ablation, especially calving, can all be significant in some contexts.	Cogley et al. IACS-UNESCO Glacier Mass Balance 2011
Ablation	Ablation refers to all processes by which snow, ice, or water in any form are lost from a glacier. Ablation is the loss of snow or ice by evaporation and melting. The rate at which ablation occurs depends on the atmospheric conditions present, such as air moisture content, solar radiation, temperature, and the reflectivity (Albedo) of the snow or ice surface. Fresh snow has a high albedo (0.7 to 0.9), indicating that 70 to 90 percent of the radiation received is reflected; glacier ice has a lower albedo of 0.2 to 0.4. Therefore, more radiation may be absorbed by glacier ice than by snow. Glaciers around the mountain receive different amounts of sunlight, so each glacier has its own characteristic ablation pattern.	Molnia USGS 2004
Ablation	The loss of ice and snow from a glacier system. This occurs through a variety of processes including melting and runoff, sublimation, evaporation, calving, and wind transportation of snow out of a glacier basin.	Molnia USGS 2004
Ablation	~~All processes that remove snow, ice, or water from a snowfield, glacier, etc., that is typically melt, evaporation, sublimation as well as wind erosion, avalanches, calving, etc.; in this sense, the opposite of accumulation. In many publications before 1980, ablation did not include mechanical removal of either snow or ice, i.e., wind erosion, avalanches, calving, etc.~~	Fierz et al. IACS-UNESCO Seasonal Snow on the Ground 2009

Some Concepts are easier to “Align” between Ontologies.. but..



Term meanings are compatible because concepts (**surface**, **solid**, **not liquid**) overlap

Land is a planetary surface that is not covered by liquid.

[Adapted from /wiki/
and may more properly be represented as part of a planetary surface rather than a subclass.

SWEET

Realm...

planetary realm

--atmosphere

-coastal

?

-coastal region (not in EnvO)

-continental (continental crust?)

-critical zone

-geologic feature? (Geographic Feature)

-geosphere

-glacial region

-hydrosphere

-hydrosphere feature

--ice cap

-ocean region

--planetary structure

--ring

-solid earth (“solid material” not in EnvO)

--geologic structure not in EnvO

--land

A February Panel

- Discussion of Qualities of a Good Definition
- Lessons from the Cryosphere work
- Principles
- Panel discussion as time allows.



Presenters: Pier Luigi Buttigieg, Ruth Duerr, Mark Schildhaue, Kai Blumberg, Gary Berg-Cross

Track B Cont.: Advantages of Formal Definitions



Sure would be **useful** to **formalize** these conversations.



A March Panel. Advantages of Formal Definitions

- **Selja Seppälä.** Systematizing definitions in ontologies.
- **Andrea Westerinen.** Experiences with Foundational, Domain and Application Ontologies in OWL2.
- **Caitlin Woods** and **Emily Low.** Representing ontologies in Natural Language and First-Order Logic: Why do we need both?
- Panel discussion as time allows.

Natural vs Formal languages

- Different forms and the same meaning

We use some formal languages just not recognizing it.

- (1) “**one hundred twenty one**” and **121** means the same. While decimal notation is very formal language having Regular Grammar. **Advantages**: algorithms of summarizing and multiplication we learned at school.

Sublanguage of English for numbers is formal too, and has it's own grammar rules.

- (2) “**twice two equals four**” and “**2 * 2 = 4**” mean the same thing. the syntax of arithmetic expressions is known from programming languages.

Advantages: algorithms for the equivalent transformation of an expression with preserving its meaning: expansion of brackets, rearrangement of operands of operations +, * etc.

Natural vs Formal languages (cont.)

- Different forms and the same meaning

(3) "**Mary is a woman**" and "**ClassAssertion(:Woman :Mary)**"
means the same, but the language OWL2/FS just not commonly used.

Advantage: algorithms for processing sentences as knowledge.

- Any NL-statement may be formalized keeping the same meaning.
But we will lose aesthetics and understandability.
- Controlled Natural Language (CNL) is a formal language [N. Fuchs, Project Attempto]

Definitions in sciences, technologies and law

- “The system of sciences.” [G.W. F. Hegel]

We take particular parts of Science or Technology and find out it's a **system of definitions**, as **definition is an element of theory**. So, *formal definition* is an element of formal theory.

- The idea of full definition – contextless

It is a *hard task* for knowledge engineers to persuade a domain expert to give a full definition!

- Definition – from recommendation to requirement

In science, technology and law, definitions are recommendations, agreements or requirements.

For example, in the Geology of igneous rocks, there are IUGS recommendations on what to count as a particular rock.

Definition for knowledge acquisition (math.)

In **mathematics**, the definition introduces a **new term** into the theory, which usually denotes a specific **object**, **property** of an object, **concept**, **relation**, **operation**.

We start by specifying what objects we are working with and how they are interconnected.

In **graph theory**, as soon as we understand what **nodes**, **arcs** and what the **graph** itself is, we get the opportunity to introduce new terms, defining exactly what they mean in a given subject area.

- For example:

- the **degree of a vertex** is the **number of ends of arcs incident to it**,
i.e. the number of **loops** incident to it multiplied by two, plus the number of **normal arcs** incident to it.

Note that in graph theory **natural numbers are used but not studied**.

Formal theory (structure)

- Primary terms

mostly measurable (**olivine** and other **minerals** are primary concepts when we are in Formal Geology)

- Definitions

A sample is a piroxen iff it is orthopyroxene or clinopyroxene.

$Px(x:\text{sample}) \stackrel{\text{def}}{=} Opx(x) \text{ or } Cpx(x)$. -- Formal Geology

- Axioms

for any **sample** a **volume percentage content** of **biotite** is between 0 and 100.

$(\forall x:\text{sample } 0 \leq VPC(\text{biotite})(x) \leq 100)$. -- Formal Geology

Example of more interesting axioms from [Stratigraphy](#), waiting formalization

- “the [law of superposition](#), the [principle of original horizontality](#) and the [principle of lateral continuity](#)”
- Hypothesis, Proofs, Theorems – just to be mentioned.

Formal definition processing algorithms(1)

- **Derivation rules** (Modus Ponens is most famous)
- **Substitution** of definition of symbol of function in the place of usage
- **Instantiation** – assigning instance to concept
direct calculation of definition on instances for query answering (we need no reasoner to check that $2 > 1$)
- **Satisfiability** – definition of concept is not contradictory
- **Consistency** – whole system of definitions and axioms is consistent i.e. there is some model.
- **Subsumption** – deriving class-subclass relation of two concept
(**Classifying** - all class hierarchies are derivable)
- **Equivalence** of two definitions

Formal definition processing algorithms(2)

Example of definition equivalence

гарцбургит(x) =def
40 < ОПС_оливин(x) < 90 and
10 < ОПС_ортопироксен(x) < 60 and
0 < ОПС_клинопироксен(x) < 10 and
0 < ОПС_хромшпинелид(x) < 5.

harzburgite(x) =def
40 < MMC_Ol(x) < 90 and
10 < MMC_Opx(x) < 60 and
0 < MMC_Cpx(x) < 5 and
5 ≤ MMC_Cpx(x) < 10 and
0 < MMC_Chr(x) < 5.

Description: harzburgite

Equivalent classes +

(MMC_Cpx some decimal[< "10"^^integer, > 5] or MMC_Cpx some decimal[<= "5"^^integer, > 0])
and MMC_Ol some decimal[> "40"^^integer, < "90"^^integer]
and MMC_Opx some decimal[> "10"^^integer, < "60"^^integer]
and MMC_Chr some decimal[> "0"^^integer, < "5"^^integer]

гарцбургит

Summa summarum

- Any NL-statement may be formalized keeping the *same* meaning.
- Formal definition is an element of formal theory.
- **Today ontologies are loosely formalized and well-documented formal theories.**
- **We need *more* formal definitions in ontologies.**
- Algorithms of formal knowledge processing are great (from tableau algorithm of DL, to proof assistants like Coq, HOL4, SAT reasoner).
- Luckily, **models** of our formal theories are finite, but unfortunately huge (KG).