Lecture 7: Formal Concept Analysis

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Contents

1 Introduction to Concepts

Concepts

Definition 1 (Knowledge)**.** Justified *true* belief. Can be justified by facts (Nonaka & Takeuchi, 1995).

- Beliefs and propositions are described in terms of *concepts* or ideas related to each other.
- Concepts represent classes or *categories* or objects.

Definition 2 (Concept)**.** describes a set of objects or instances which occur in the application domain and which share similar characteristics. (Schreiber et al., 1999, p. 92)

Example 3. Space, planets, society, country, transport, education, knowledge

Extent and Intent of a Concept

Definition 4 (Extent)**.** is the set of all *objects* that belong to a concept.

Definition 5 (Intent)**.** is the set of all *attributes* shared by the objects in a concept.

- A concept is determined by its *extent* and *intent*.

- It is usually impossible to list all the objects or name all the attributes of a concept.
- Fixing a *context* is fixing the set of objects and attributes.

Definition 6 (Context)**.** consists of set G of objects, set M of *attributes* and a correspondence (a cross-table) relating objects with values of the attributes.

Example: A Context for Planets

	size			dist. from sun		moon	
	small	medium	large	near	far	yes	no
Mercury	x			x			x
Venus	x			x			x
Earth	x			x		x	
Mars	x			x		x	
Jupiter			x		x	x	
Saturn			x		x	x	
Uranus		x			x	x	
Neptune		x			x	x	
Pluto	x				x	x	

Objects : planets (Mercury, Venus, Earth,...)

Attributes : properties relating to size, distance, satellite.

Example 7.
1. Consider the set of all attributes of Earth: $B = \{\text{Small}, \text{Near}, \text{Yes}\}$
2. Consider the set of all similar objects: $A = \{\text{Earth}, \text{Mars}\}$
3. Then the pair (A, B) is a concept in this context.

2 Ordering of Concepts

Ordering of Concepts by Abstraction

Question 1.
- *Construct a concept starting from Venus.*
- *Construct a concept starting from Moon=No.*
- *Construct a concept starting from Earth and Pluto*
- Concept (A_1, B_1) is more general than (A_2, B_2) if and only if the *extent* A_1 contains A_2:

$$(A_1, B_1) \geq (A_2, B_2) \quad \Longleftrightarrow \quad A_1 \supseteq A_2$$

- This is equivalent to the *intent* B_1 contained in B_2:

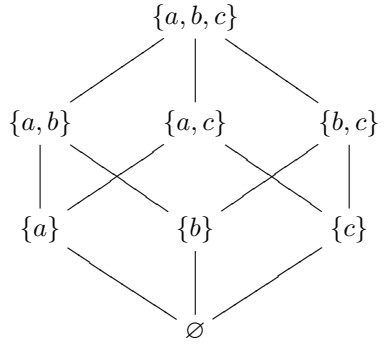
$$(A_1, B_1) \geq (A_2, B_2) \quad \Longleftrightarrow \quad B_1 \subseteq B_2$$

Example 8.
- $A_1 = \{\text{Earth}, \text{Mars}, \text{Pluto}\}$, $B_1 = \{\text{Small}, \text{Yes}\}$
- $A_2 = \{\text{Earth}, \text{Mars}\}$, $B_2 = \{\text{Small}, \text{Near}, \text{Yes}\}$

Taxonomy

- Taxonomy originated in biology as classification of species, their organisation of into a hierarchical classification.
- Non-biological taxonomy is classification of objects into categories and subcategories.

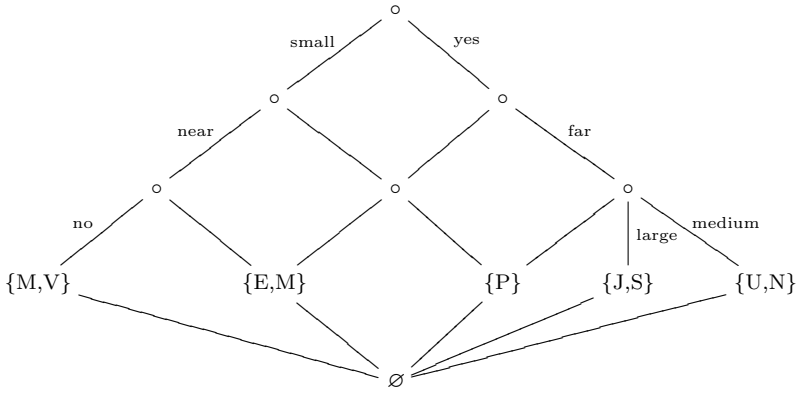
Example 9. A *power set* 2^A of set $A = \{a, b, c\}$:



Concept Lattice

- Concepts can be categorised and organised into a *concept lattice*.
- The concept lattice visually depicts the relation between concepts.

Example 10 (Concept lattice for planets).



3 Concept Analysis Technique

Concept Analysis Techniques

- It is highly recommended to undertake concept analysis exercise in an organisation (Dalkir, 2011).
- Concept analysis involves three dimensions of a given concept:
  1. A list of key attributes.
  2. A list of illustrative examples.
  3. A list of illustrative non-examples.

Concept Name		
Key Attributes	Examples	Non-examples
1...	1...	1...
2...	2...	2...
3...	3...	3...
⋮	⋮	⋮

Automatic Formal Concept Analysis

- Formal Concept Analysis (FCA) can be performed automatically by FCA algorithms in computer programs.
- It can be used not only for a basic concept analysis, but also as a data-mining technique on large datasets.
- Examples of FCA applications:
  1. FCA for MS Excel `http://www.fca.radvansky.net/`
  2. Galicia `http://www.iro.umontreal.ca/~galicia/`
  3. Camelis `http://www.irisa.fr/LIS/ferre/camelis/`
  4. Coron `http://coron.loria.fr/site/index.php`
  5. FCA demo `http://www.upriss.org.uk/fca/fcademo.html`

Summary

- Concepts represent categories or classes of objects (extent) sharing common attributes (intent).
- Concepts can be organised and classified into a hierarchy (taxonomy).
- A concept lattice is based on ordering of concepts by generality.
- Automatic methods based on Formal Concept Analysis can help in the process of organising and representation of knowledge.

Additional Reading

- Read the article '*Formal conceptualisation as a basis for a more procedural knowledge management*' by Andradea et al. (2007).

References

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Schreiber, G., Hoog, R. de, Akkermans, H., Anjewierden, A., Shadbolt, N., Velde, W. V. de, et al. (1999). *Knowledge engineering and management: The CommonKADS methodology*. The MIT Press.