Knowledge Organization

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Overview Knowledge Organization

- Motivation, Objectives
- Chapter Introduction
  - New topics,Terminology
- Identification of Knowledge
  - Object Selection
  - Naming and Description
- Categorization
  - Feature-based Categorization
  - Hierarchical Categorization
- Knowledge Organization Methods
  - Natural Language
  - Ontologies
- Knowledge Organization Tools
  - Editors, visualization tools, automated ontology construction
- Examples
- Important Concepts and Terms
- Chapter Summary

Motivation and Objectives

Motivation

- effective utilization of knowledge depends critically on its organization
  - quick access
  - identification of relevant knowledge
  - assessment of available knowledge
    - source, reliability, applicability
- knowledge organization is a difficult task, and requires complementary skills
  - expertise in the domain
  - knowledge organization skills
    - librarians

Objectives

- be able to identify the main aspects dealing with the organization of knowledge
- understand knowledge organization methods
- apply the capabilities of computers to support knowledge organization
- practice knowledge organization on small bodies of knowledge
- evaluate frameworks and systems for knowledge organization

Identification of Knowledge

- Object Selection
- Naming and Description

Object Selection

- what constitutes a “knowledge object” that is relevant for a particular task or topic
  - physical object, document, concept
- how can this object be made available in the system
- example: library
  - is it worth while to add an object to the library’s collection
  - if so, how can it be integrated
    - physical document: book, magazine, report, etc.
    - digital document: file, data base, Web page, etc.

Naming and Description

- names serve two important roles
  - identification
    - ideally, a unique descriptor that allows the unambiguous selection of the object
    - often an ambiguous descriptor that requires context information
  - location
    - especially in digital systems, names are used as “address” for an object
- names, descriptions and relationships to related objects are specified in listings
  - dictionary, glossary, thesaurus, ontology, index

Knowledge Organization Methods

- Naming and Description Devices
  - index, glossary, dictionary, thesaurus, ontology
- Natural Language (NL)
  - Levels of NL Understanding
  - NL-based indexing
- Categorization
- Ontologies

Naming and Description Devices

- type
  - dictionary, glossary, thesaurus
  - ontology
  - index
- issues
  - arrangement of terms
    - alphabetical, ordered by feature, hierarchical, arbitrary
  - purpose
    - explanation, unique identifier, clarification of relationships to other terms, access to further information

Dictionary

- list of words together with a short explanation of their meanings, or their translations into another language
- helpful for the identification of knowledge objects, and their distinction from related ones
- each entry in a dictionary may be considered an atomic knowledge object, with the word as name and "entry point"
  - may provide cross-references to related knowledge objects
- straightforward implementation in digital systems, and easy to integrate into knowledge management systems

Glossary

- list of words, expressions, or technical terms with an explanation of their meanings
  - usually restricted to a particular book, document, activity, or topic
- provides a clarification of the intended meaning for knowledge objects
- otherwise similar to dictionary

Thesaurus

- collection of synonyms (word sets with identical or similar meanings)
  - frequently includes words that are related in some other way, e.g. antonyms (opposite meanings), homonyms (same pronunciation or spelling)
- identifies and clarifies relationships between words
  - not so much an explanation of their meanings
- may be used to expand search queries in order to find relevant documents that may not contain a particular word

Thesaurus Types

- knowledge-based
- linguistic
- statistical

[Liddy 2000]

Knowledge-based Thesaurus

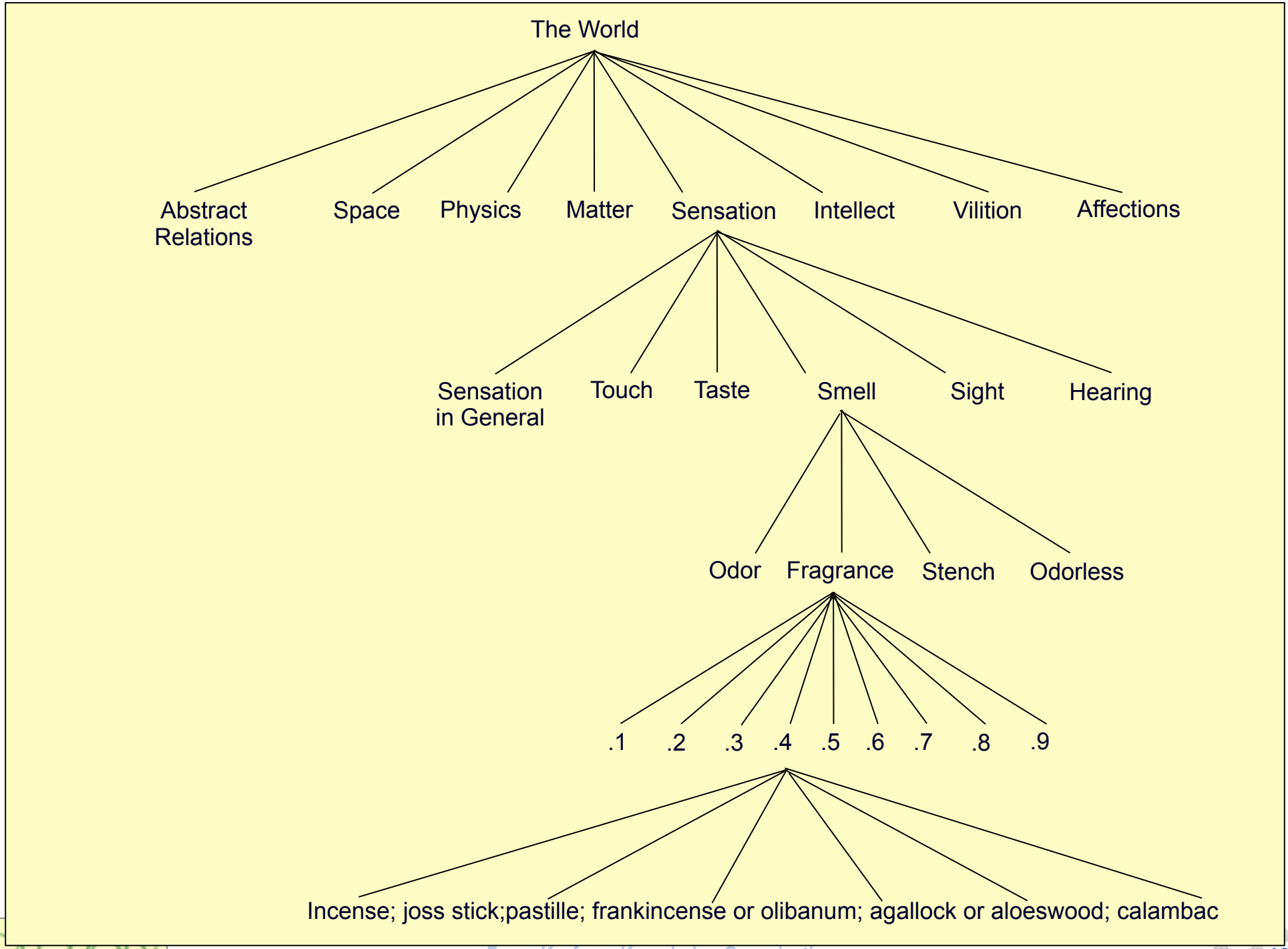
- manually constructed for a specific domain
- intended for human indexers and searchers
- contains
  - synonyms (“use for” UF)
  - more general (“broader term” BT)
  - more specific (“narrower” NT)
  - otherwise associated words (“related term” RT)
- example: “data base management systems”
  - UF data bases
  - BT file organization, management information systems
  - NT relational databases
  - RT data base theory, decision support systems

[Liddy 2000]

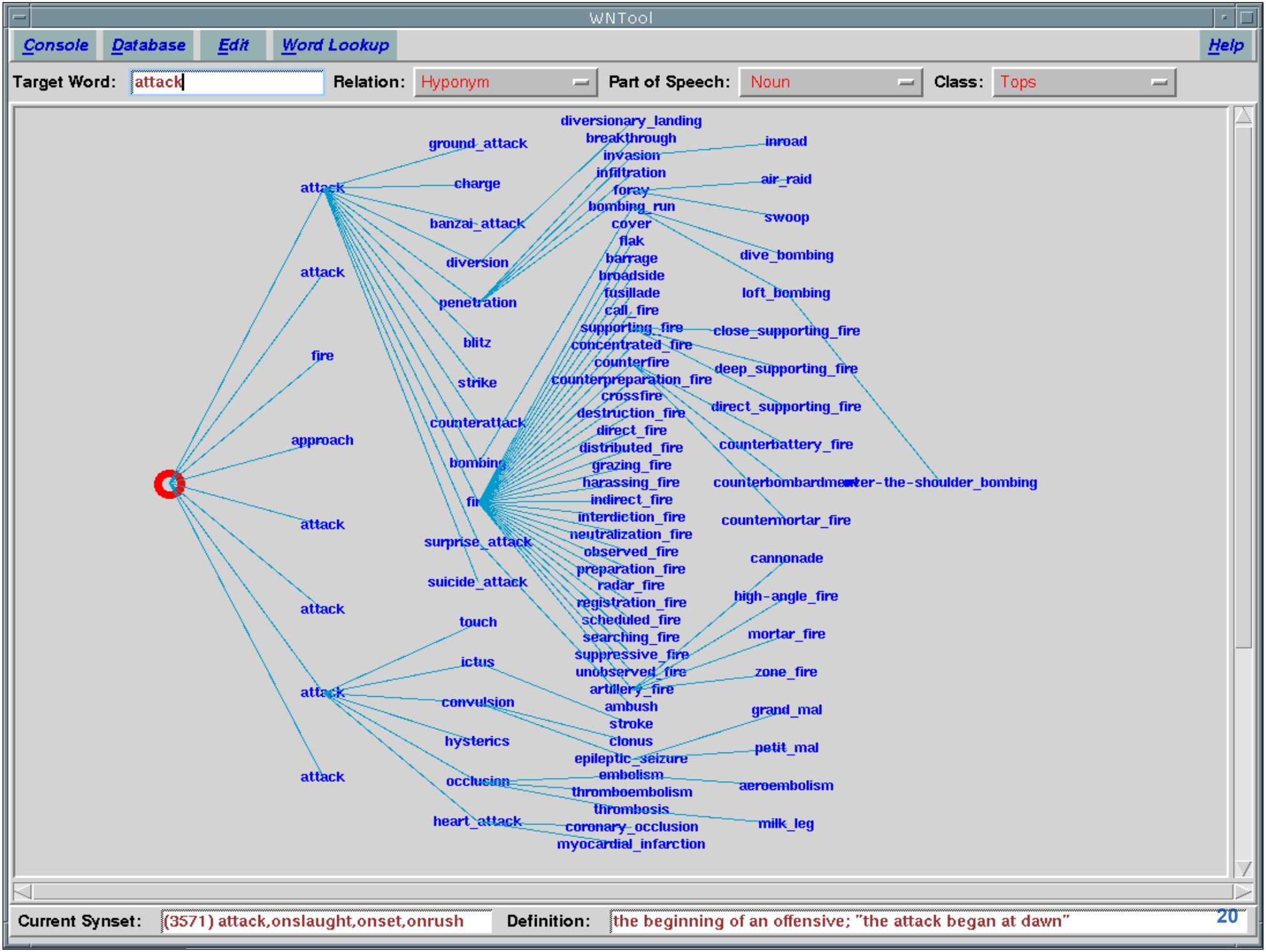
Linguistic Thesaurus

- contains explicit concept hierarchies of several increasingly specified levels
- words in a group are assumed to be (near-) synonymous
  - selection of the right sense for terms can be difficult
- examples: Roget's, WordNet
- often used for query expansion
  - synonyms (similar terms)
  - hyponyms (more specific terms; subclass)
  - hypernyms (more general terms; super-class)

[Liddy 2000]


The World
Abstract Relations
Space
Physics
Matter
Sensation
Intellect
Vilition
Affections
Sensation in General
Touch
Taste
Smell
Sight
Hearing
Odor
Fragrance
Stench
Odorless
.1
.2
.3
.4
.5
.6
.7
.8
.9
Incense; joss stick;pastille; frankincense or olibanum; agallock or aloeswood; calambac

[Liddy 2000]


WNTool
Console
Database
Edit
Word Lookup
Help
Target Word: attack
Relation: Hyponym
Part of Speech: Noun
Class: Tops
attack
attack
attack
fire
approach
attack
attack
attack
attack
ground_attack
charge
banzai_attack
diversion
penetration
blitz
strike
counterattack
bombing
fi
surprise_attack
suicide_attack
touch
ictus
convulsion
hysterics
occlusion
heart_attack
diversionary_landing
breakthrough
invasion
infiltration
foray
bombing_run
cover
flak
barrage
broadside
fusillade
call_fire
supporting_fire
concentrated_fire
counterfire
counterpreparation_fire
crossfire
destruction_fire
direct_fire
distributed_fire
grazing_fire
harassing_fire
indirect_fire
interdiction_fire
neutralization_fire
observed_fire
preparation_fire
radar_fire
registration_fire
scheduled_fire
searching_fire
suppressive_fire
unobserved_fire
artillery_fire
ambush
stroke
clonus
epileptic_seizure
embolism
thromboembolism
thrombosis
coronary_occlusion
myocardial_infarction
inroad
air_raid
swoop
dive_bombing
loft_bombing
close_supporting_fire
deep_supporting_fire
direct_supporting_fire
counterbattery_fire
counterbombardment
counternortar_fire
cannonade
high-angle_fire
mortar_fire
zone_fire
grand_mal
petit_mal
aeroembolism
milk_leg
Current Synset: (3571) attack,onslaught,onset,onrush
Definition: the beginning of an offensive; "the attack began at dawn"
20

Query Expansion in Search Engines

- look up each word in Word Net
- if the word is found, the set of synonyms from all Synsets are added to the query representation
- weigh each added word as 0.8 rather than 1.0
- results better than plain SMART
  - variable performance over queries
  - major cause of error: the use of ambiguous words' Synsets
- general thesauri such as Roget's or WordNet have not been shown conclusively to improve results
  - may sacrifice precision to recall
  - not domain specific
  - not sense disambiguated

[Liddy 2000, Voorhees 1993]

Statistical Thesaurus

- automatic thesaurus construction
  - classes of terms produced are not necessarily synonymous, nor broader, nor narrower
  - rather, words that tend to co-occur with head term
  - effectiveness varies considerably depending on technique used

[Liddy 2000]

Automatic Thesaurus Construction (Salton)

- document collection based
  - based on index term similarities
  - compute vector similarities for each pair of documents
  - if sufficiently similar, create a thesaurus entry for each term which includes terms from similar document

[Liddy 2000]

Sample Automatic Thesaurus Entries

408 dislocation
junction
minority-carrier
point contact
recombine
transition
409 blast-cooled
heat-flow
heat-transfer
410 anneal
strain

411 coercive
demagnetize
flux-leakage
hysteresis
induct
insensitive
magnetoresistance
square-loop
threshold
412 longitudinal
transverse

[Liddy 2000]

Dynamic Automatic Thesaurus Construction

- thesaurus short-cut
  - run at query time
  - take all terms in the query into consideration at once
  - look at frequent words and phrases in the top retrieved documents and add these to the query
    - = automatic relevance feedback

[Liddy 2000]

Expansion by Association Thesaurus

Query: ***Impact of the 1986 Immigration Law***

Phrases retrieved by association in corpus

- *illegal immigration*
- *amnesty program*
- *immigration reform law*
- *editorial page article*
- *naturalization service*
- *civil fines*
- *new immigration law*
- *legal immigration*
- *employer sanctions*
- *statutes*
- *applicability*
- *seeking amnesty*
- *legal status*
- *immigration act*
- *undocumented workers*
- *guest worker*
- *sweeping immigration law*
- *undocumented aliens*

[Liddy 2000]

Index

- listing of words that appear in a set of documents, together with pointers to the locations where they appear
- provides a reference to further information concerning a particular word or concept
- constitutes the basis for computer-based search engines

Indexing

- the process of creating an index from a set of documents
  - one of the core issues in Information Retrieval
- manual indexing
  - controlled vocabularies, humans go through the documents
- semi-automatic
  - humans are in control, machines are used for some tasks
- automatic
  - statistical indexing
  - natural-language based indexing

Natural Language Methods

- Natural Language Processing
- Natural Language Understanding
- NLP-based Indexing

Natural Language Processing

- a range of computational techniques for analyzing and representing naturally occurring texts
  - at one or more levels of linguistic analysis
  - for the purpose of achieving human-like language processing
  - for a range of tasks or applications

[Liddy 2000]

NLP-based Indexing

- the computational process of identifying, selecting, and extracting useful information from massive volumes of textual data
  - for potential review by indexers
  - stand-alone representation of content
  - using Natural Language Processing

[Liddy 2000]

What can NLP Indexing do?

- phrase recognition
- disambiguation
- concept expansion

Ontologies

- description
- "representational promiscuity"
- ontology types
- usage of ontologies
  - domain standards and vocabularies
- ontology development
  - development process
  - specification languages

Categorization

- Hierarchical Categorization
- Feature-based Categorization

Hierarchical Categorization

- a set of objects is divided into smaller and smaller subset, forming a hierarchical structure (tree) with the elementary objects as leaf nodes
  - typically one feature is used to distinguish one category from another
  - often constitutes a relatively stable “backbone” of a knowledge organization scheme
  - re-organization requires a major effort

Feature-based Categorization

- objects or documents are assigned to categories according to commonalties in specific features
- can be used to dynamically group objects into categories that are of interest for a particular task or purpose
  - re-organization is easy with computer support

Ontology

- examines the relationships between words, and the corresponding concepts and objects
  - in practice, it often combines aspects of thesaurus and dictionary
  - frequently uses a graph-based visual representation to indicated relationships between words
- used to identify and specify a vocabulary for a particular subject or task

The Notion of Ontology

- ontology
  explicit specification of a shared conceptualization that holds in a particular context
- captures a viewpoint on a domain:
  - taxonomies of species
  - physical, functional, & behavioral system descriptions
  - task perspective: instruction, planning

[Schreiber 2000]

Ontology Types

- domain-oriented
  - domain-specific
    - medicine => cardiology => rhythm disorders
    - traffic light control system
  - domain generalizations
    - components, organs, documents
- task-oriented
  - task-specific
    - configuration design, instruction, planning
  - task generalizations
    - problems solving, e.g. upml
- generic ontologies
  - “top-level categories”
  - units and dimensions

[Schreiber 2000]

Using Ontologies

- ontologies needed for an application are typically a mix of several ontology types
  - technical manuals
    - device terminology: traffic light system
    - document structure and syntax
    - instructional categories
  - e-commerce
- raises need for
  - modularization
  - integration
    - import/export
    - mapping

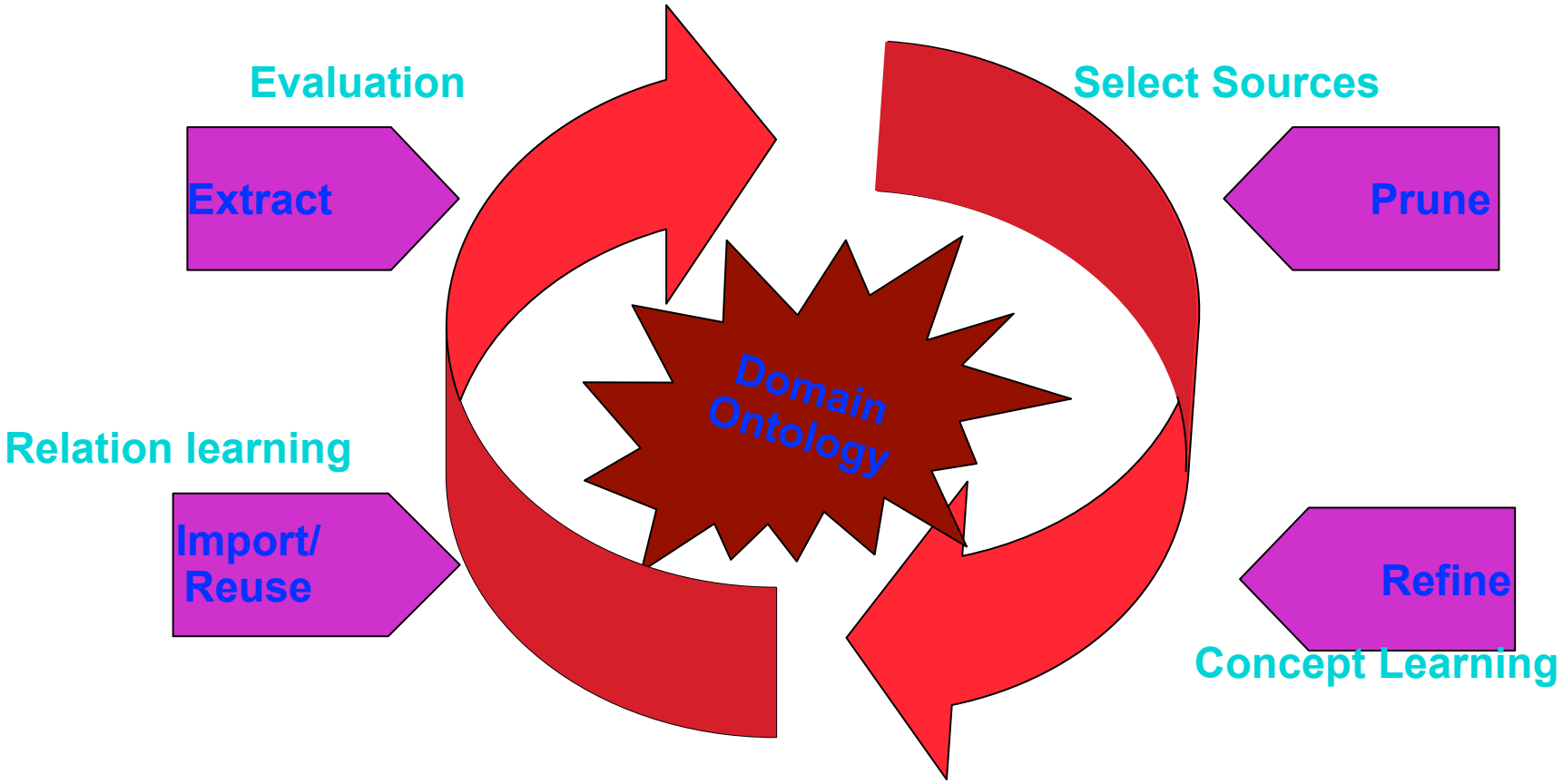
[Schreiber 2000]

Domain Standards and Vocabularies As Ontologies

- example: Art and Architecture Thesaurus (AAT)
- contains ontological information
  - AAT: structure of the hierarchy
- structure needs to be “extracted”
  - not explicit
- can be made available as an ontology
  - with help of some mapping formalism
- lists of domain terms are sometimes also called “ontologies”
  - implies a weaker notion of ontology
  - scope typically much broader than a specific application domain
  - example: domain glossaries, wordnet
  - contain some meta information: hyponyms, synonyms, text

[Schreiber 2000]

Ontology Development



Scott Patterson, CS8350

Kietz, Maedche, Voltz; A Method for Semi-Automatic Ontology acquisition from a Corporate Intranet

Maedche & Staab; Ontology Learning for the Semantic Web

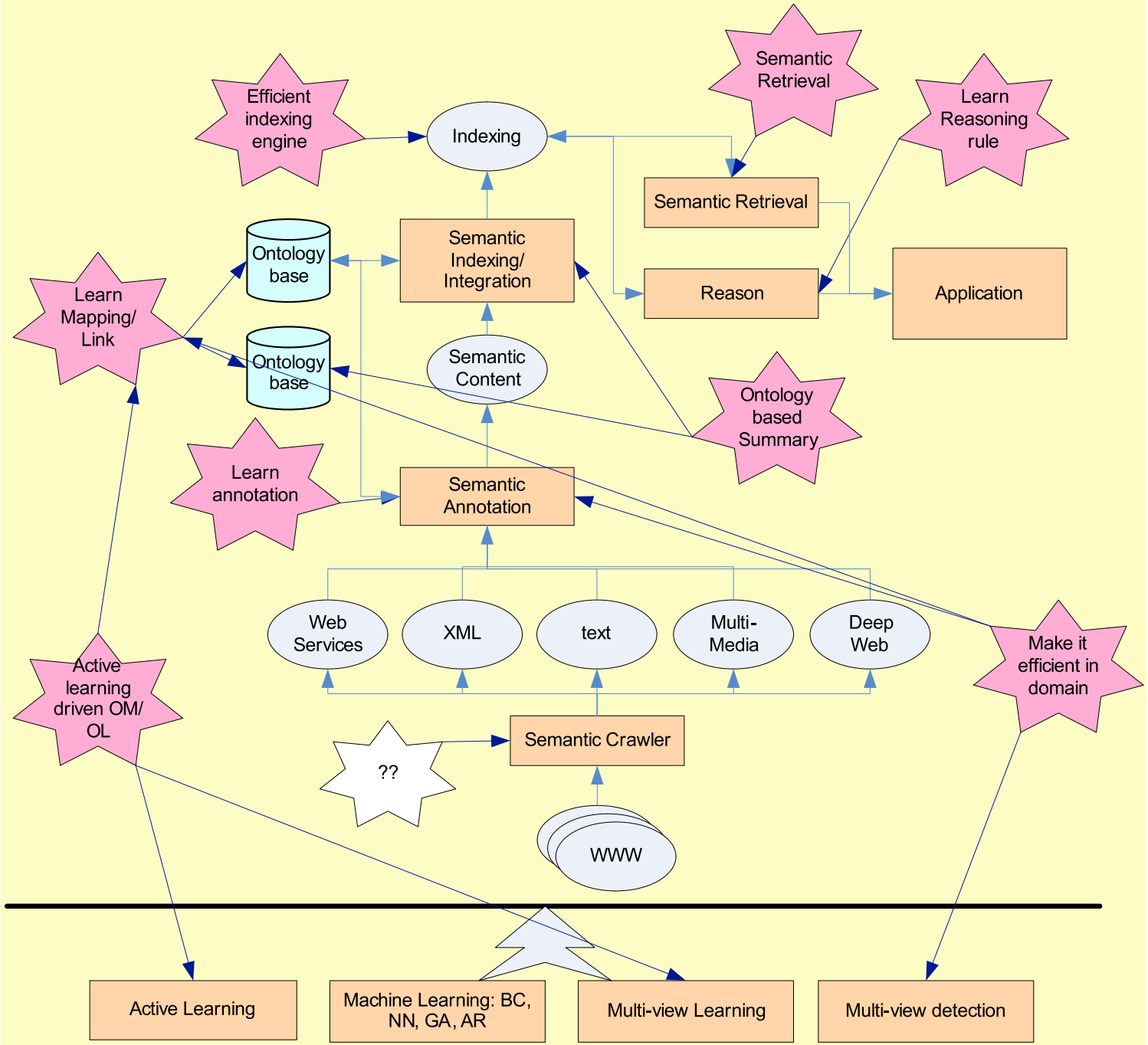
Ontology Specification

- many different languages
  - KIF
  - Ontolingua
  - Express
  - LOOM
  - UML
  - XML to the rescue: Web Ontology Language (OWL)
- common basis
  - class (concept)
  - subclass with inheritance
  - relation (slot)

[Schreiber 2000]

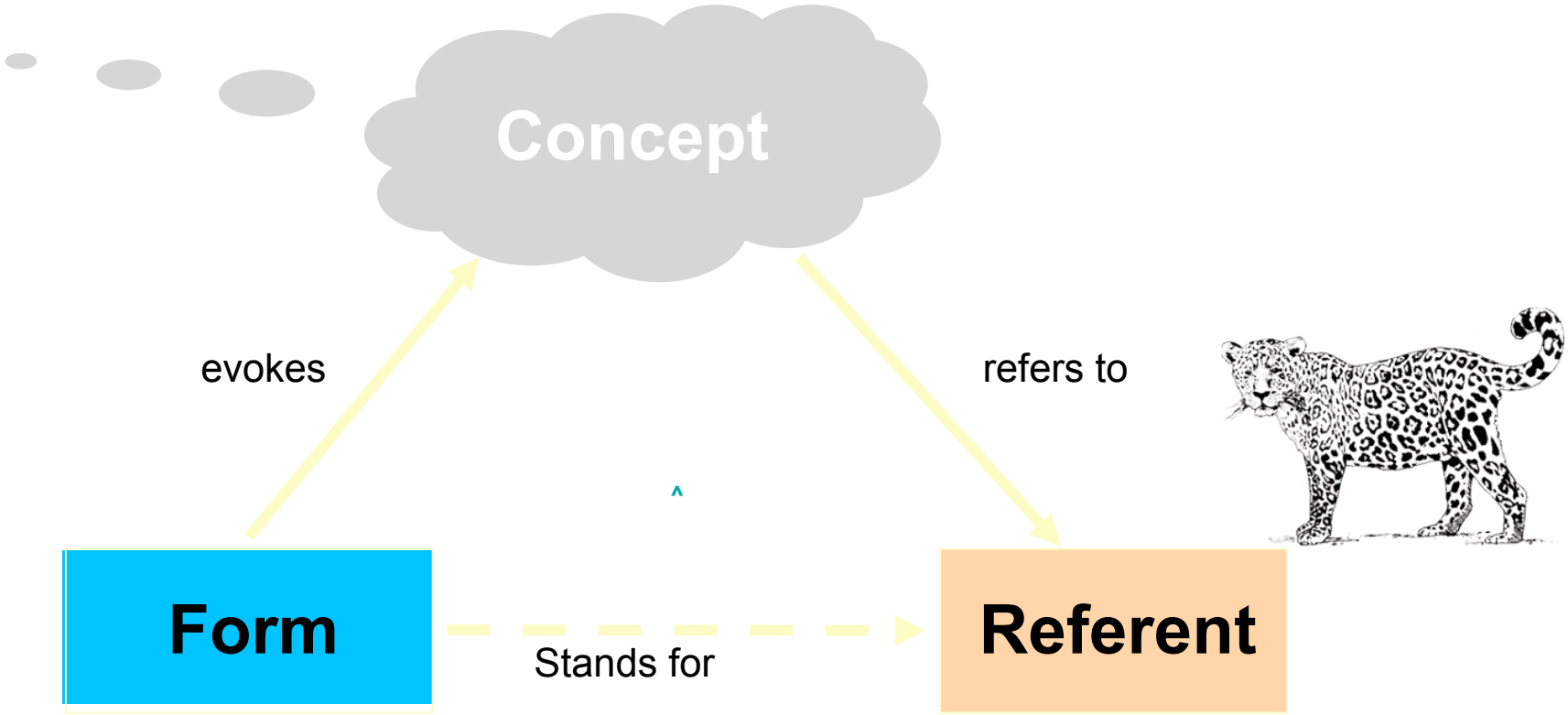
Knowledge Organization Examples

- ad-hoc via diagrams
- concept-form-referent triangle
- ontology mind map
- comparison on knowledge organization methods
  - taxonomy, thesaurus, topic map, ontology
- examples of ontologies



http://keg.cs.tsinghua.edu.cn/persons/tj/Reports/Pswmp-Jie-Tang.ppt

Communication Principle

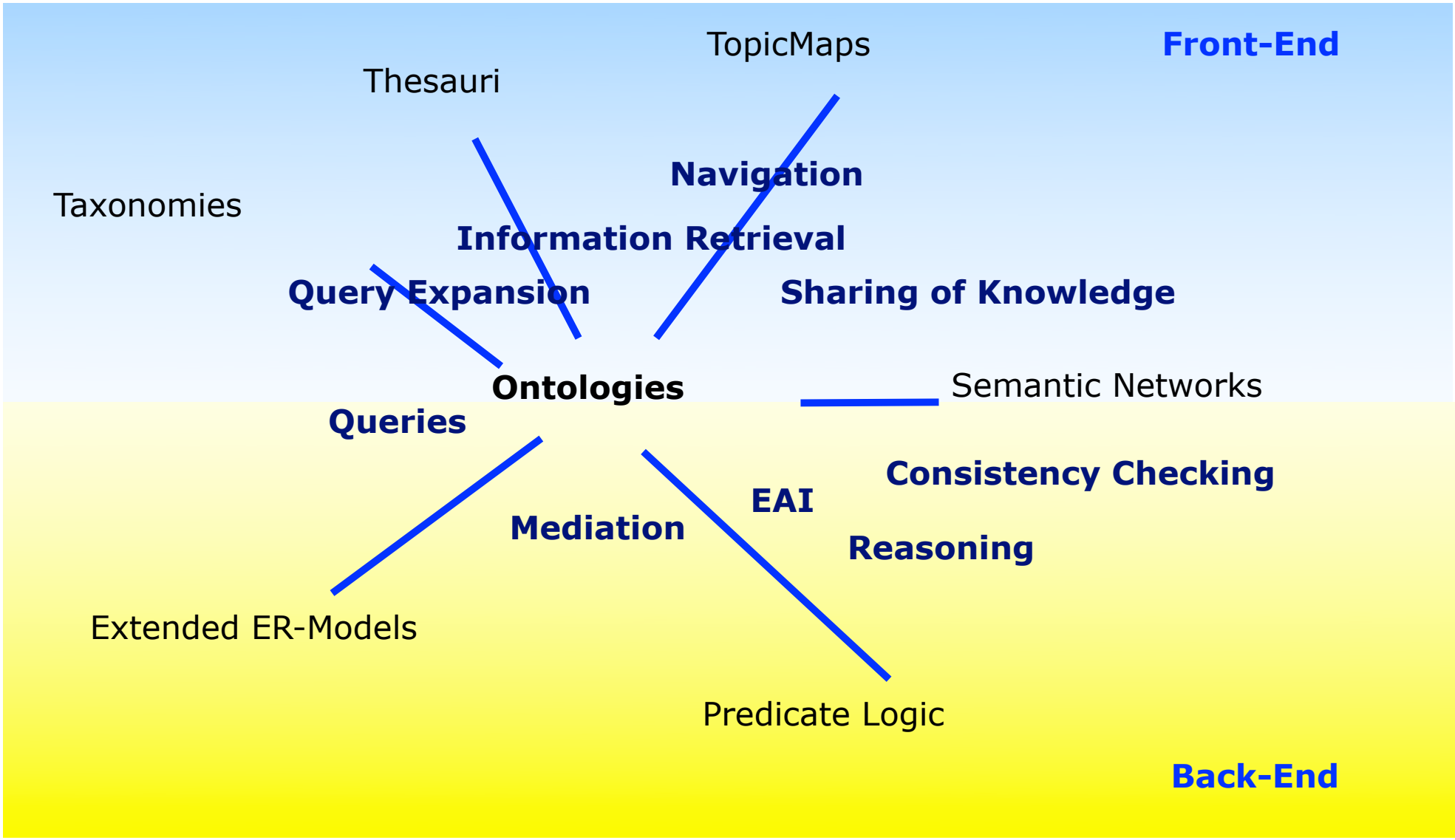


"Jaguar"

[Odwen, Richards, 1923]

[Hotho, Sure, 2003]

Views on Ontologies

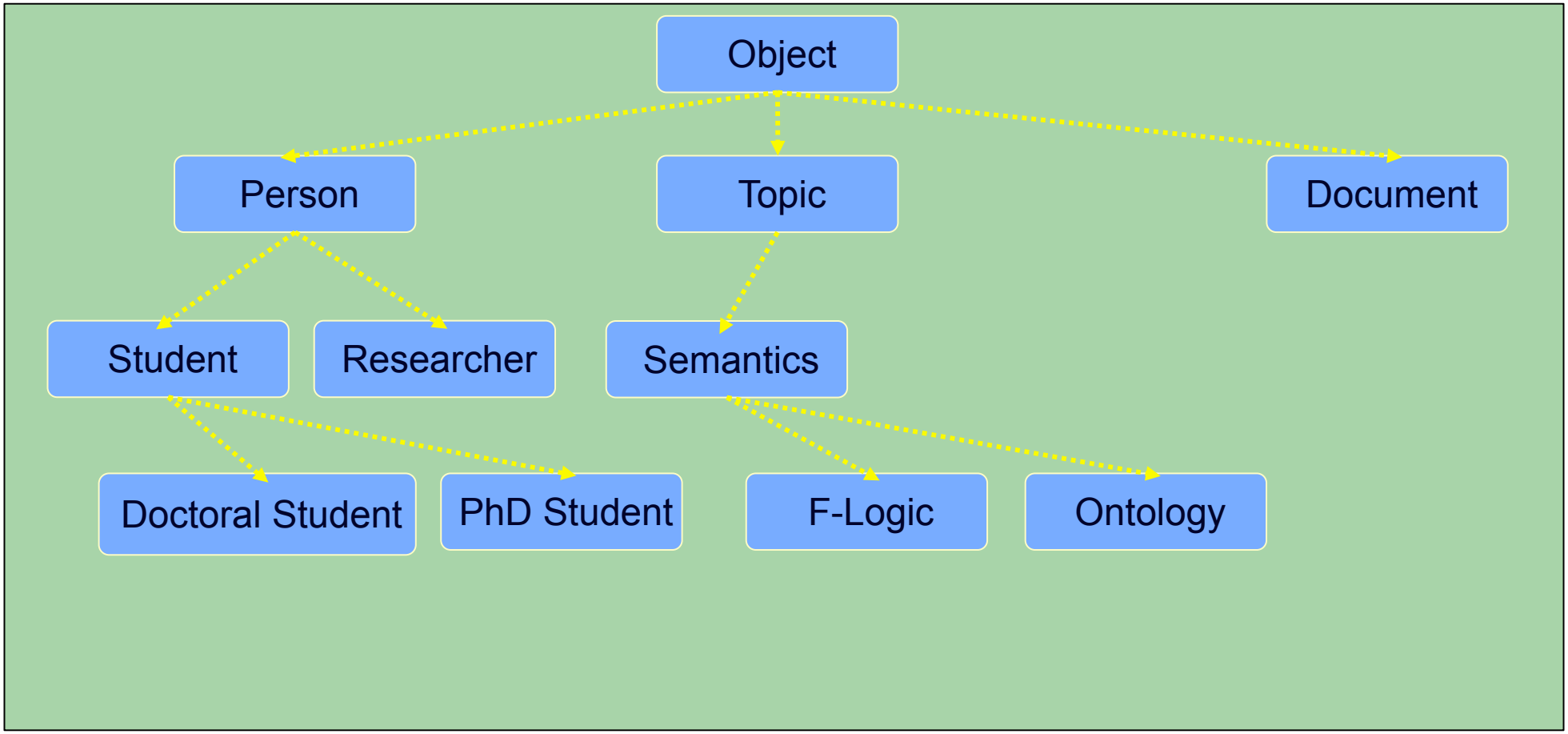


[Hotho, Sure, 2003]

Extending Taxonomies to Ontologies

- Taxonomy
  - strict hierarchy
- Thesaurus
  - hierarchy plus synonyms and other relations between words
- Topic Map
  - additional relations between concepts
    - across the hierarchy
  - properties of concepts
- Ontology
  - rules specifying the structure of the concept space
  - instances of concepts

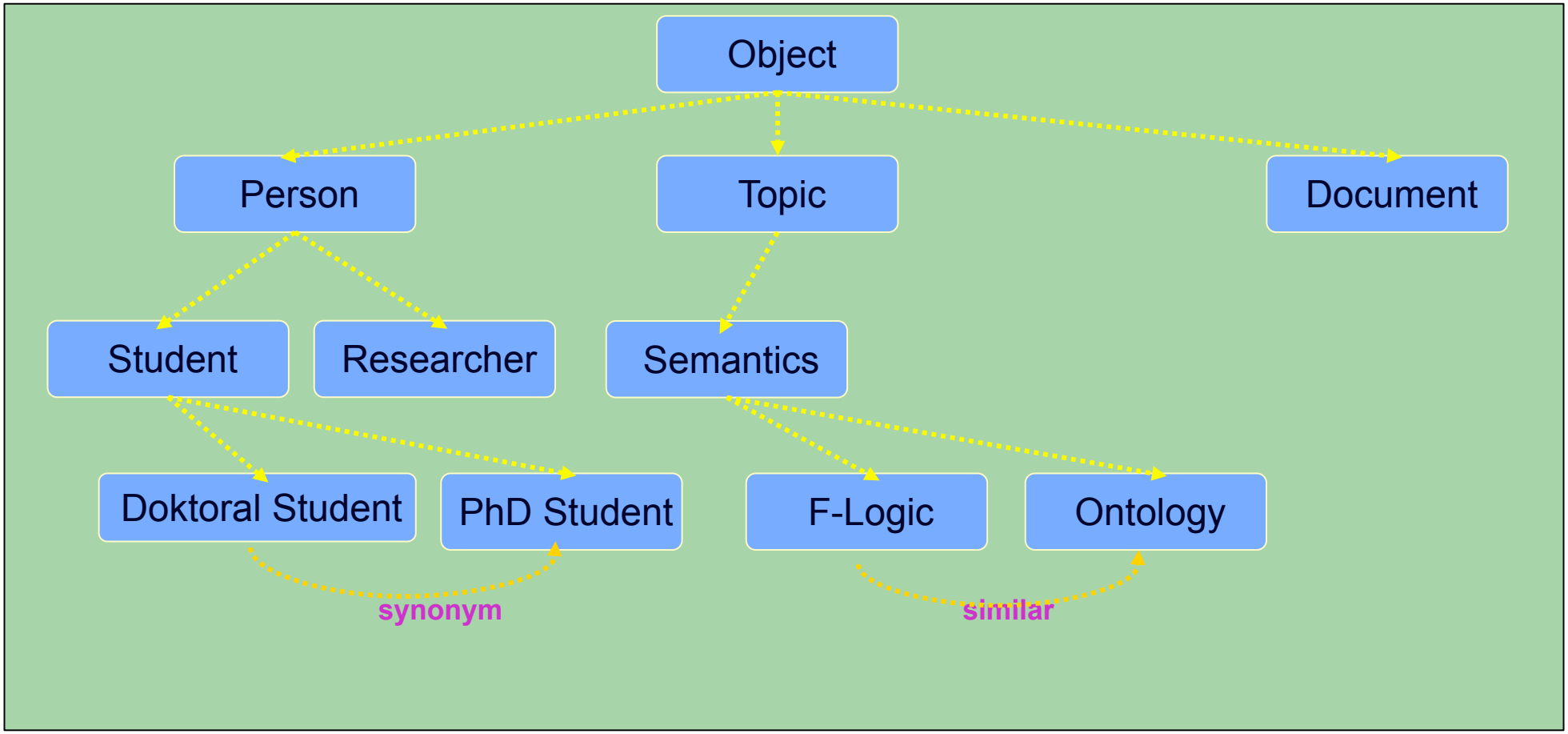
Taxonomy



Taxonomy: Segmentation, classification and ordering of elements into a classification system according to their relationships between each other

[Hotho, Sure, 2003]

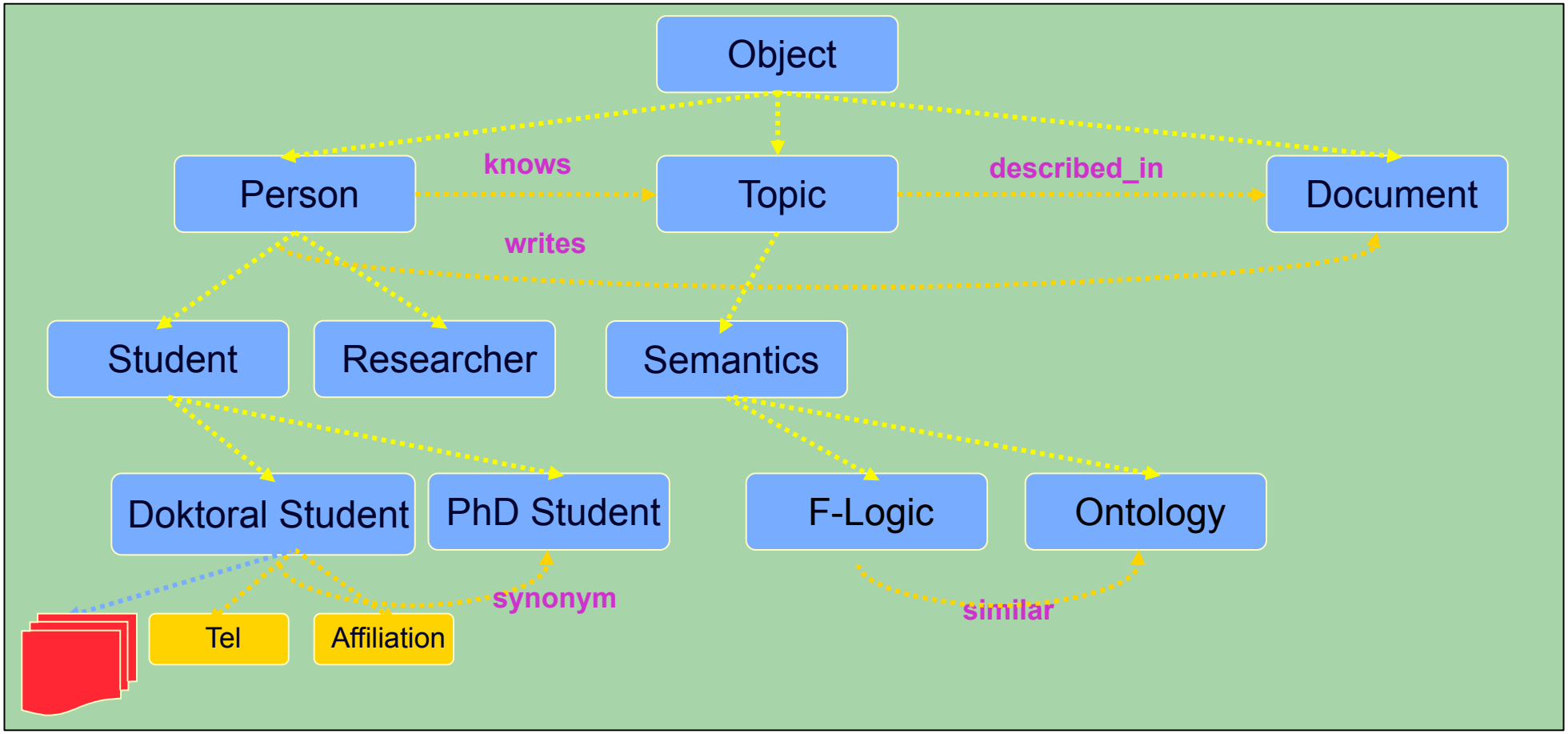
Thesaurus



- Terminology for specific domain
- Graph with primitives, 2 fixed relationships (similar, synonym), sometimes additional relationships (antonym, homonym, ...)
- originated from bibliography

[Hotho, Sure, 2003]

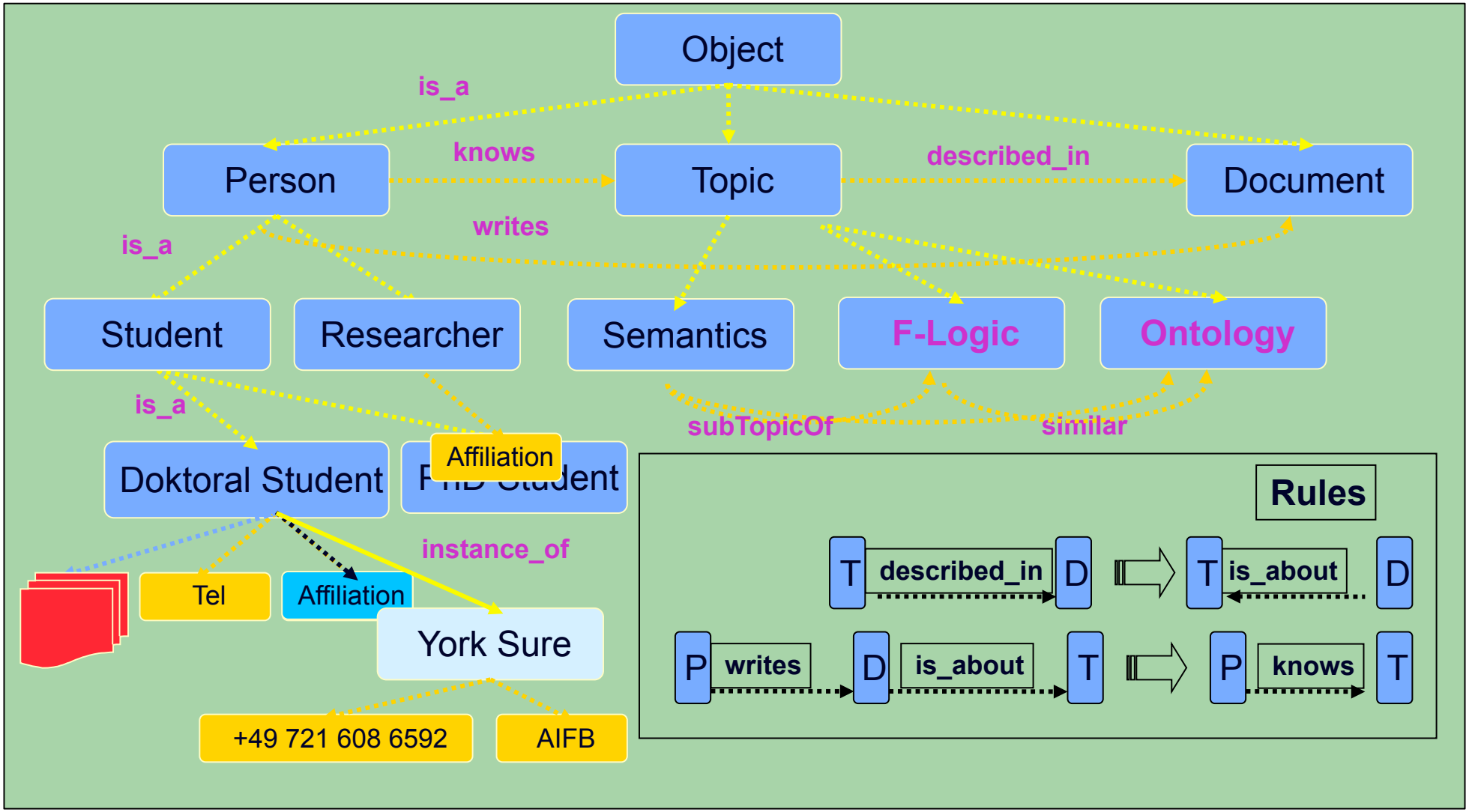
Topic Map



- Topics (nodes), relationships and o*ccurrences* (to documents)
- ISO-Standard
- typically for navigation and visualization

[Hotho, Sure, 2003]

Ontology

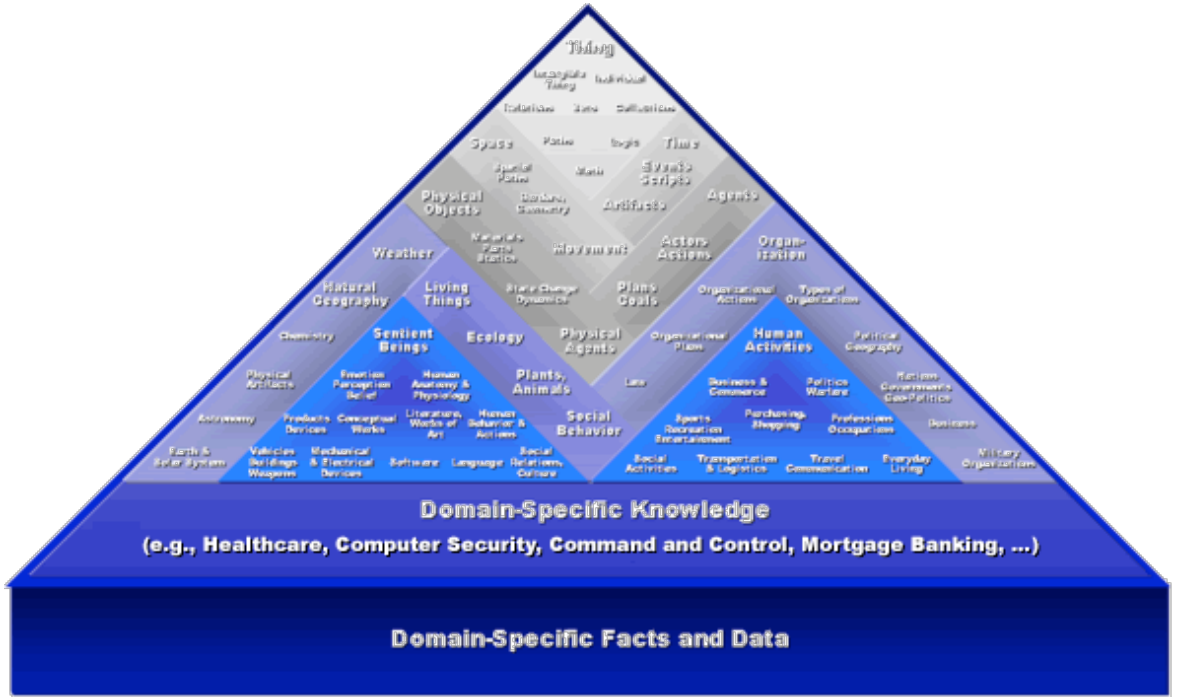


- Representation Language: Predicate Logic (F-Logic)
- Standards: RDF(S); OWL

[Hotho, Sure, 2003]

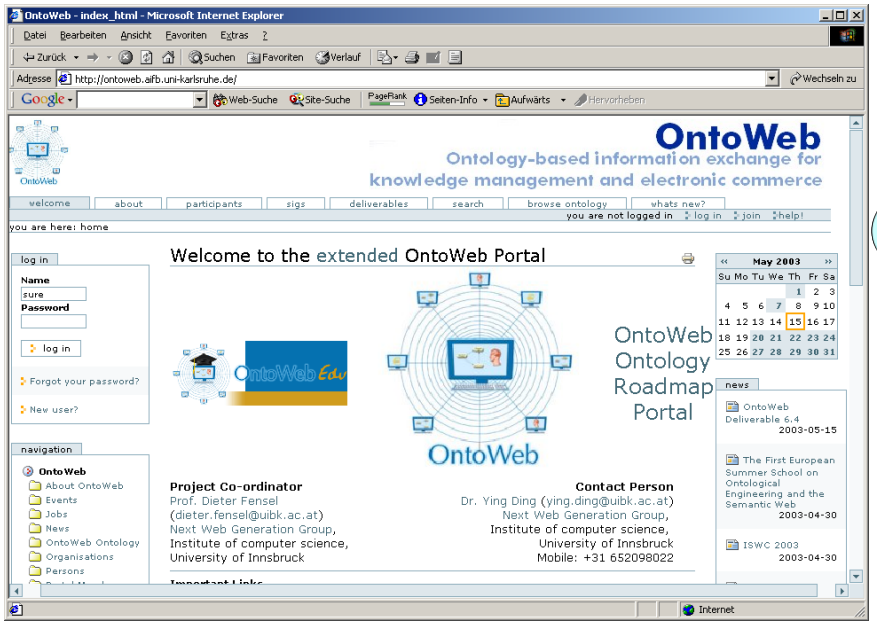
Knowledge Organization Examples

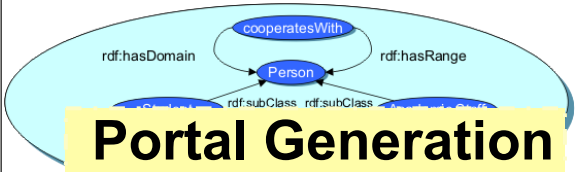
Cyc Knowledge Base Structure



Follow the link below for an interactive version that shows more information about the categories (requires JavaScript, and may not work in all browsers):
http://www.cyc.com/cyc/images/cyc/technology/whatiscyc_dir/whatdoescycknow

OntoWeb.org



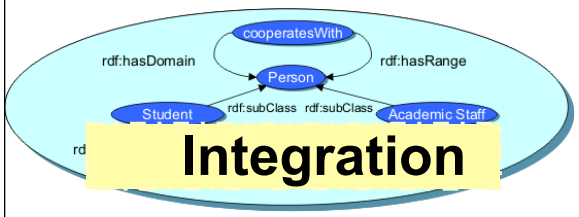


Portal Generation

Navigation

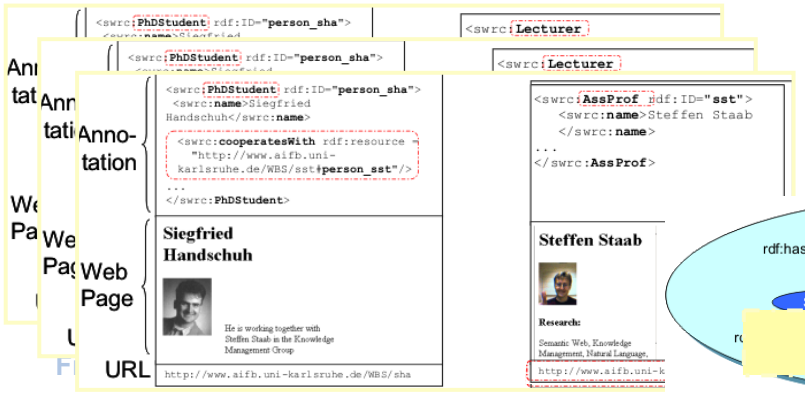
Query/Serach

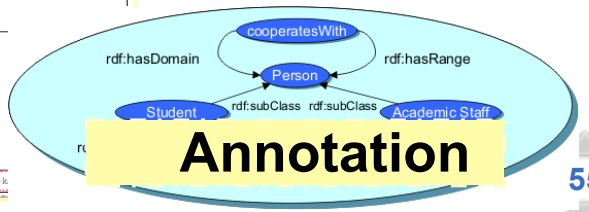
Content



Integration

Collect metadata from participating partners



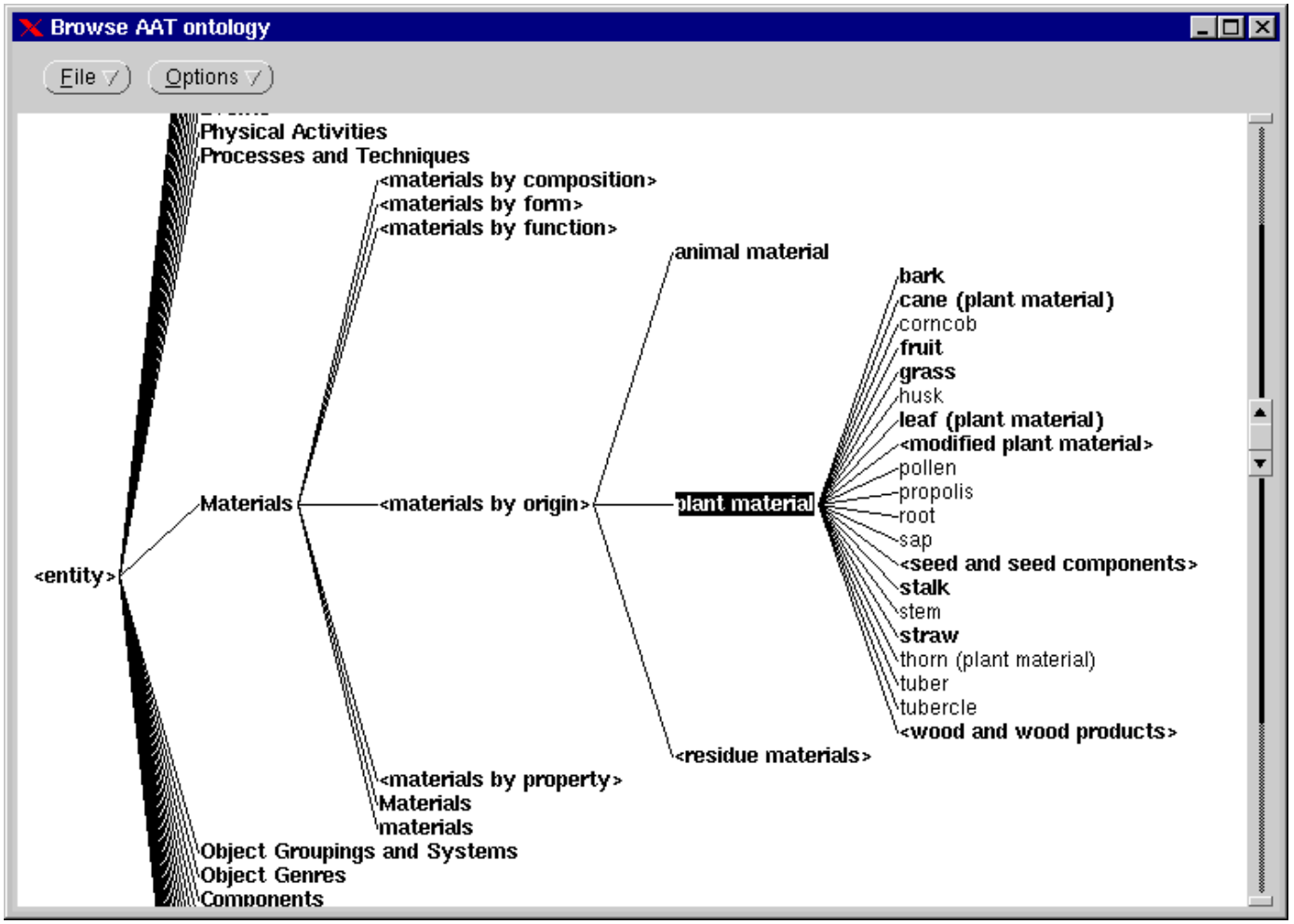


Annotation

[Hotho, Sure, 2003]

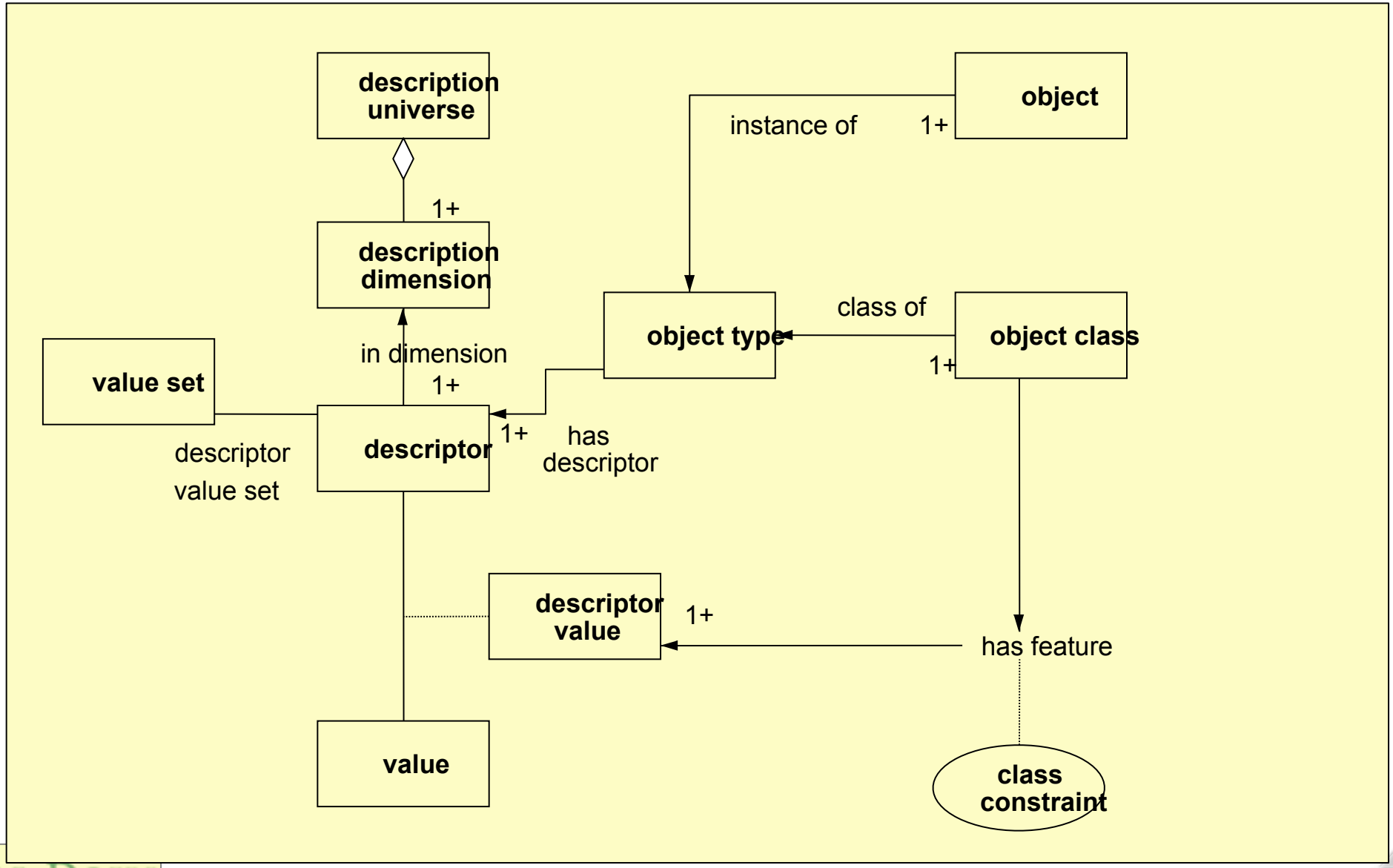
Art & Architecture Thesaurus

used for indexing stolen art objects in European police databases



[Schreiber 2000]

AAT Ontology

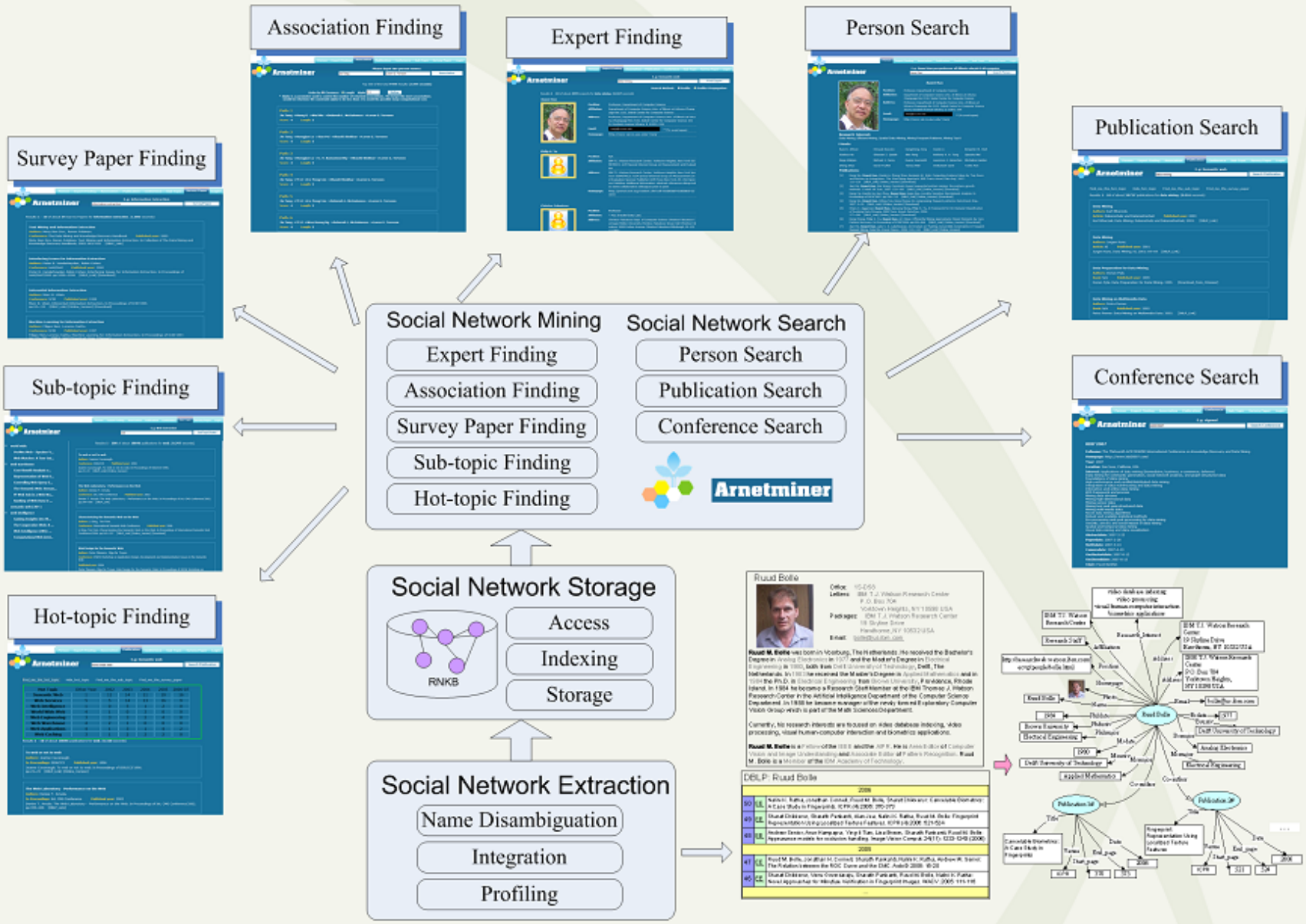


[Schreiber 2000]

ArnetMiner.org— Academic Researcher Social Network

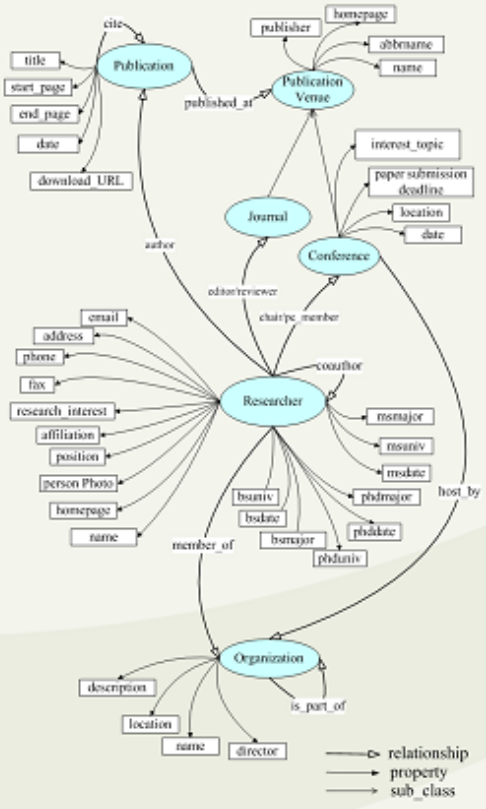
Jie Tang, Jing Zhang, Limin Yao, Duo Zhang, and Mingcai Hong
Knowledge Engineering Group, DCST, Tsinghua University
{tangjie, zhangjing, ylm, zhangduo, hmc}@keg.cs.tsinghua.edu.cn

Arnetminer
Http://www.arnetminer.org



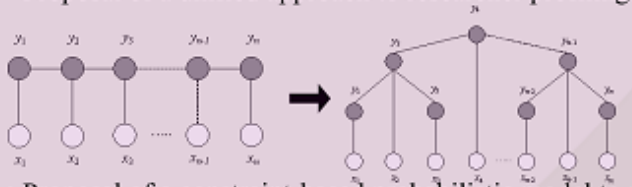
Technique Issues

Metadata



ArnetMiner advances four points:

- Proposal of a unified approach to researcher profiling based on conditional random fields.



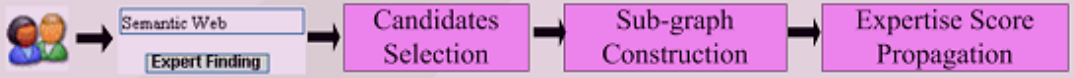
$$p(y|x)=\frac{1}{Z(x)}\exp\left(\sum_{e\in E,k}\lambda_k f_k(e,y|_e,x)+\sum_{v\in V,k}\mu_k s_k(v,y|_v,x)\right)$$

- Proposal of a constraint-based probabilistic model to name disambiguation.

$$p(y|x)=\frac{1}{Z(x)}\exp\left(\sum_{i,k}D(x_i,y_k)+\sum_{i,j\neq i}\{D(x_i,x_j)\sum_{c_k\in C}[w_k c_k(x_i,x_j)]\}\right)$$

C_k	W_k	Constraint Name	Description
c_1	w_1	CoOrg	$a_i^{(3)}.affiliation = a_j^{(3)}.affiliation$
c_2	w_2	CoAuthor	$\exists p, p\neq\emptyset, a_i^{(2)}\in p \wedge a_j^{(2)}\in p$
c_3	w_3	Citation	p_i cites p_j or p_j cites p_i
c_4	w_4	CoEmail	$a_i^{(3)}.email = a_j^{(3)}.email$
c_5	w_5	Feedback	Constraints from user feedback
c_6	w_6	t-CoAuthor	one common author in t extension

- Proposal of a score-and-propagate approach to expert finding

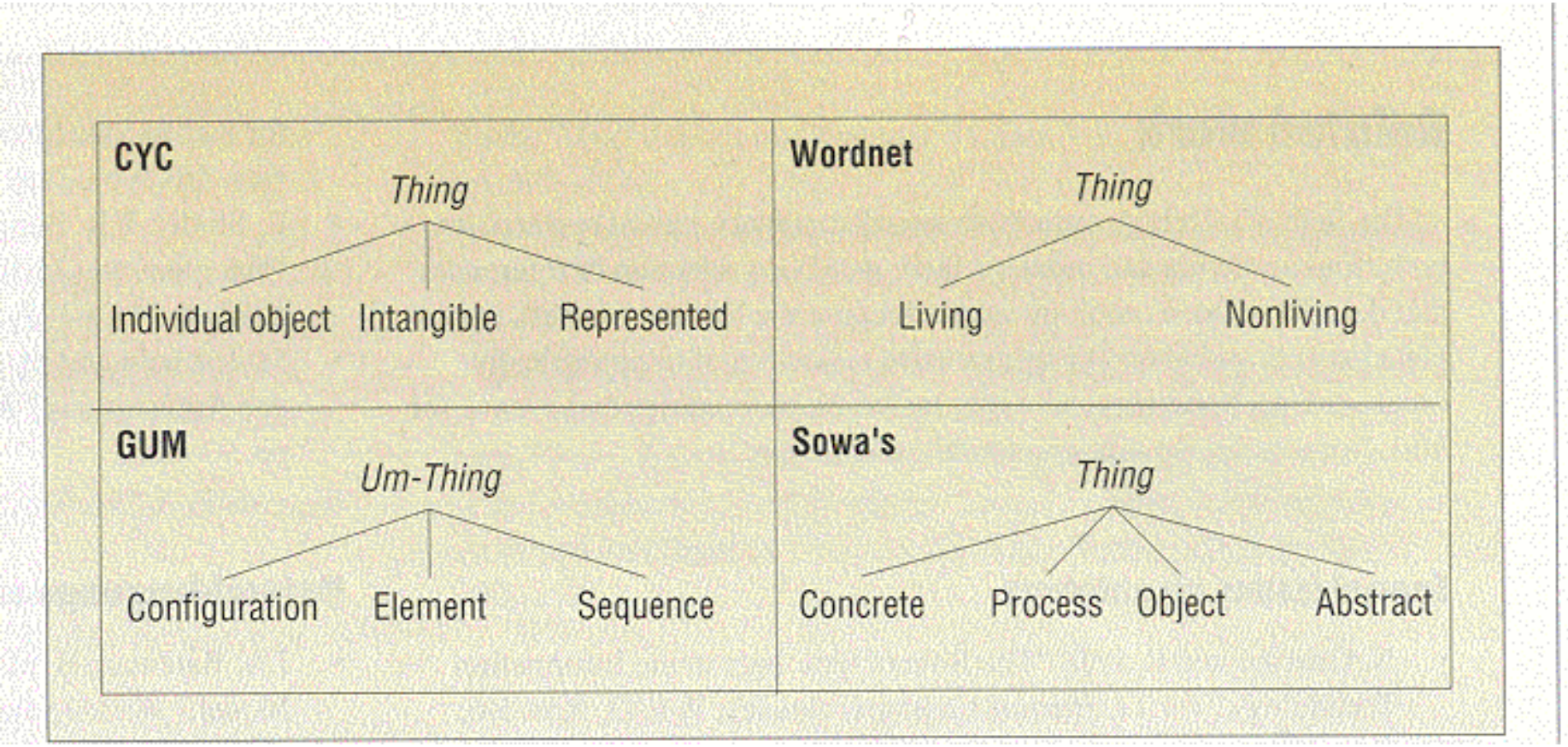


- Proposal of an efficient approach to association search.

* Other features are developed based on NLP and Text Mining, for example: Key-Phrase Extraction (e.g., research interest finding), Classification based ranking (e.g., survey paper finding), Hierarchical clustering (e.g., sub-topic finding), etc.

KEG, TSINGHUA, CHINA

Top-level Categories: Many Different Proposals



Chandrasekaran et al. (1999)

Important Concepts and Terms

- automated reasoning
- belief network
- cognitive science
- computer science
- deduction
- frame
- human problem solving
- inference
- intelligence
- knowledge acquisition
- knowledge representation
- linguistics
- logic
- machine learning
- natural language
- ontology
- ontological commitment
- predicate logic
- probabilistic reasoning
- propositional logic
- psychology
- rational agent

Summary