Introduction, Semantic Networks and the Others ...

Petr Křemen
petr.kremen@fel.cvut.cz

FEL ČVUT

Our plan

Course Information

Crisp Knowledge Representation

Semantic Networks

Frames

Thesauri

Topic Maps

Conceptual Graphs

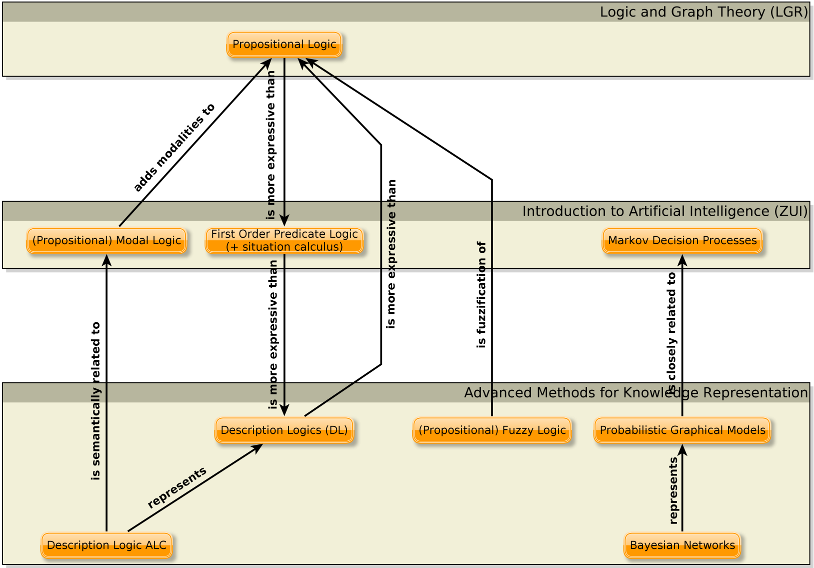
Semantic Web, Linked Data

Course Information

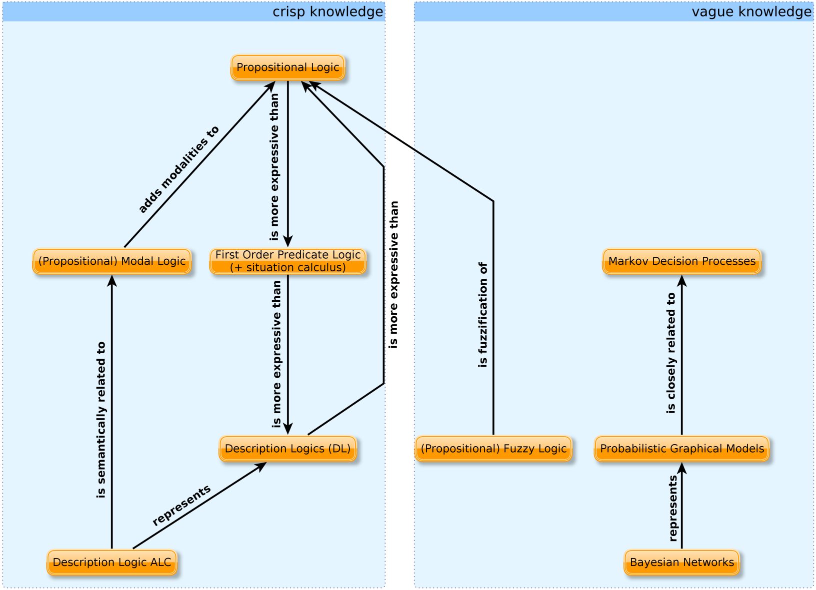
Course Information

- web page: http://cw.felk.cvut.cz/doku.php/courses/ae4m33rzn/start
- three basic topics: description logics, probabilistic models, fuzzy logic
- **Please go through the course web page carefully !!!**

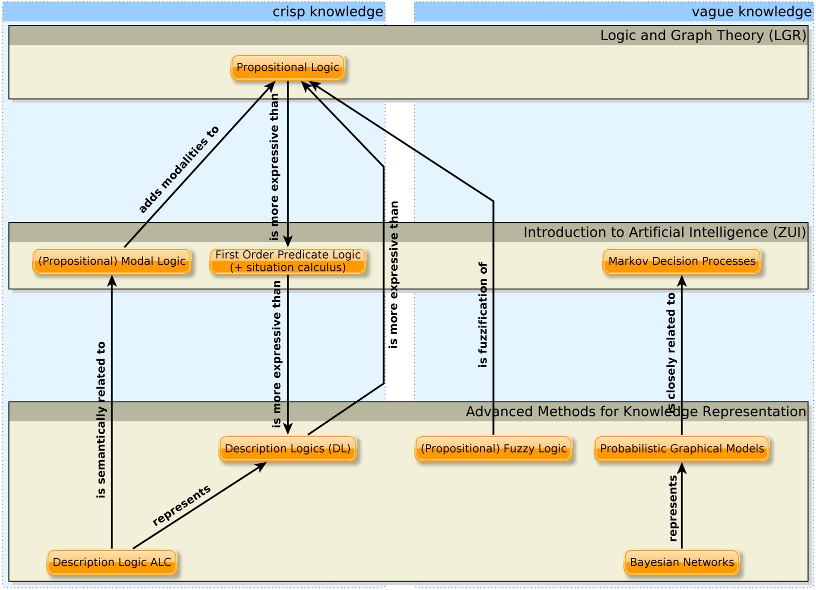
Course Roadmap



Course Roadmap



Course Roadmap



Crisp Knowledge Representation

Motivation

- Let's have the domain of a university. Each stakeholder needs different type of information:
  - Student: **"Which bachelor course should I enroll in order to get at least 6 credits ?"**
  - Teacher : **"How many hours per week am I going to teach this term ?"**
  - Dean : **"Which courses are popular among students ?"**
- **Knowledge** tries to capture relationships in the domain, so that they can be used for answering various types of queries.
  - **"Bachelor courses are courses."**
  - **"In most cases a course can be opened only if 2 or more students are enrolled."**
  - **"Every head of a department is a school employee."**

Motivation (2)

- So, two questions remain ...
  - How to formally represent knowledge ?
    - declaratively $\times$ procedurally ? – this course will deal with **declarative knowledge**. např. $(\forall P)(BachelorCourse(P) \Rightarrow Course(P))$
    - without uncertainty (crisp) $\times$ with uncertainty – this course will cover both, starting **without uncertainty**. např. $(\forall K)(Course(K) \Rightarrow (CourseWithException(K) \vee ((\exists X_1, X_2) IsEnrolledTo(X_1, K) \wedge IsEnrolledTo(X_2, K) \wedge X_1 \neq X_2))$
  - How to make use of the knowledge representation ?
    - knowledge management – search engines (databases, semantic servers, semantics web)
    - multiagent systems – content of messages sent between agents
    - machine learning – language bias
    - ... all AI branches

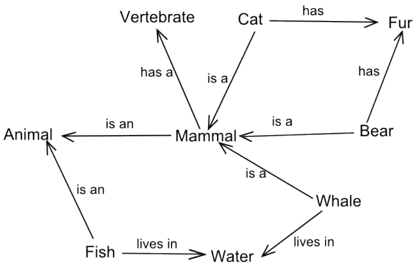
laboratory Gerstner

Declarative Knowledge Representation without Uncertainty

- semantic networks, frames,
- thesauri, topic maps
- relational databases (relational calculus)
- rule-based systems, Prolog (first-order predicate logics)
- semantic web, RDF(S), OWL, OWL 2 (**description logics**)

Semantic Networks

Semantic Networks



(©wikipedia.org)

Nodes = entities (individuals, classes),

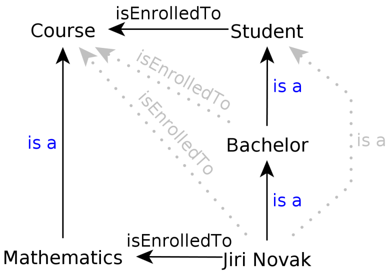
Edges = binary relations

- The only possible inferrence is *inheritance* by means of **is a** relationship.

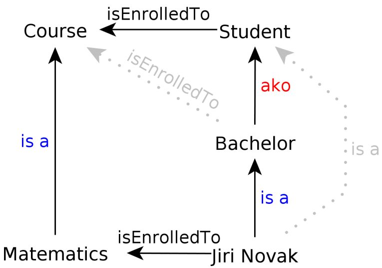
Example

Each `Cat` **has a** `Vertebrate`, since each `Cat` **is a** `Mammal`.

Semantic Networks (2)



However, this does not allow distinguishing individuals (instances) and groups (classes).



To solve this, a new relationship type “is a kind of” **ako** can be introduced and used for inheritance, while **is a** relationships would be restricted to expressing individual-group relationships.

Semantic Networks (3)

- ☺ are simple – from the point of logics they are not much more than a binary structure + **ako** and **is a** relationships with the following semantics:

$$relation(X, Y) \wedge ako(Z, X) \Rightarrow relation(Z, Y).$$
$$isa(X, Y) \wedge ako(Y, Z) \Rightarrow isa(X, Z).$$
$$ako(X, Y) \wedge ako(Y, Z) \Rightarrow ako(X, Z).$$

- ☹ no way to express non-monotonous knowledge (like FOL).
- ☹ no easy way to express n-ary relationships (**reification** needed).
- ☹ no way to express binary relationships characteristics – transitivity, functionality, reflexivity, etc., or their hierarchies "to be a father means to be a parent", aj.,
- ☹ no way to express more complex constructs, like cardinality restrictions: "Each person has at most two legs."
- Wordnet, Semantic Wiki, aj.

Semantic Networks – Wordnet, MultiWordnet

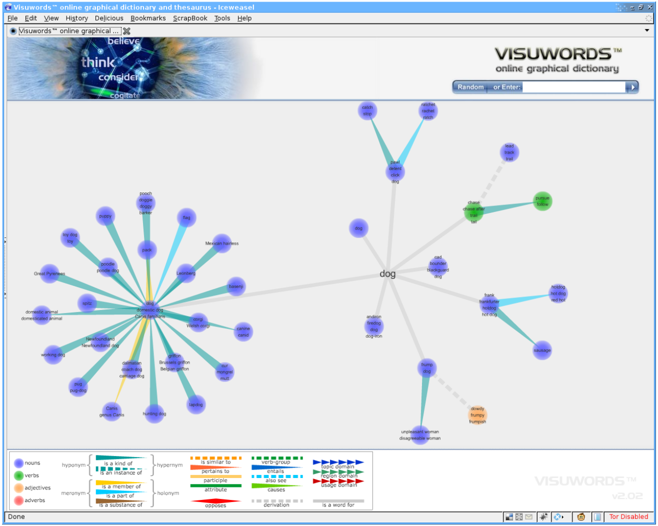
Wordnet (`http://wordnet.princeton.edu`) and MultiWordnet (`http://multiwordnet.itc.it`) are lexical databases. They are represented as semantic networks extended with a bit more semantics, e.g. :

hyponyms, hypernyms
: correspond to the **ako** relationship.

meronyms, holonyms
: denote "part-of" relationships between terms.

synonyms, antonyms
: synonyms are grouped into *synsets* – i.e. sets of terms that build up a single semantic context/meaning (e.g. $S_1 = \{\text{man}, \text{adult male}\}, S_2 = \{\text{man}, \text{human being}\}$)

Semantic Networks – http://www.visuwords.com/



laboratory Gerstner

Frames

Frames

frame: Škoda Favorit
slots:

is a: car
has engine: four-stroke engine
has transmission system: manual
has carb: *value*: Jikov
default: Pierburg

- more structured than semantic networks
- forms that contain **slots** (binary relationships).

([MvL93])

- Every slot has several **facets** (slot use restrictions), e.g. cardinality, defaults, etc.
- ☺ Facets allow non-monotonic reasoning.
- ☺ *Daemons* are triggers for actions perfomed on facets (read, write, delete). Can be used e.g for consistency checking.

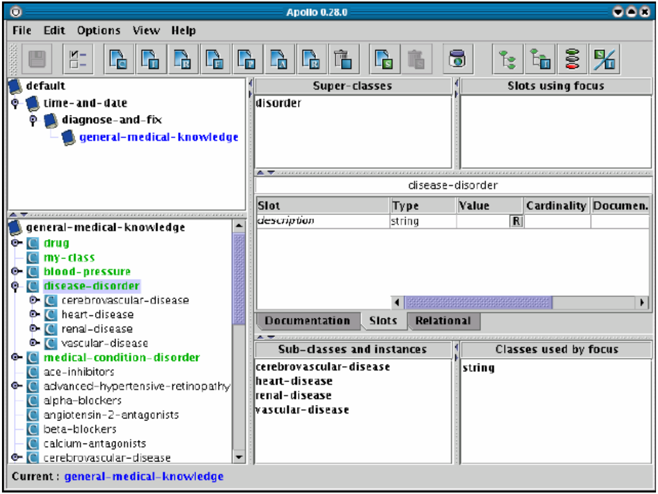
Frames (2)

Example

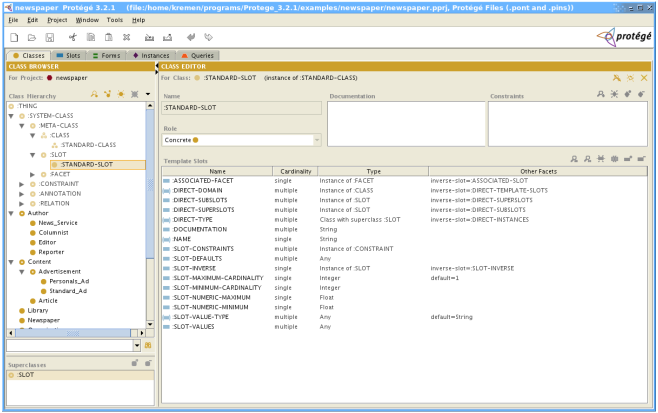
Typically, `Škoda Favorit` **has carb** of type `Pierburg`, but this particular `Škoda Favorit` **has carb** of type `Jikov`.

- frames can be grouped into *scenarios* that represent typical situations, e.g. going into a restaurant. [MvL93]
- OKBC - http://www.ai.sri.com/ okbc
- Protégé - http://protege.stanford.edu/overview/protege-frames.html
- Apollo - http://apollo.open.ac.uk
- Apollo CH - http://labe.felk.cvut.cz/ falc/Apollo

Frames (3) - Apollo CH



Frames (4) - Protégé



laboratory Gerstner

Frames and Semantics Networks – Summary

- ☺ very simple structures for knowledge representation,
- ☺ nonmonotonic reasoning,
- ☹ ad-hoc reasoning procedures, that complicates (and broadens ambiguity during) translation to First Order Predicate Logic (FOPL),
- ☹ problems – querying, debugging.
- ... but semantic networks are basis for other technologies:
  - **thesauri**
  - **topic maps**

Thesauri

Thesauri

thesaurus is a taxonomy (hierarchy of terms) enriched with new types of relationships, e.g.:

BT/NT (broader/narrower term) = term hierarchy.

Example

beef → NT → meat

SN (scope note) explains meaning of a given term.

Example

school → SN → institution for education

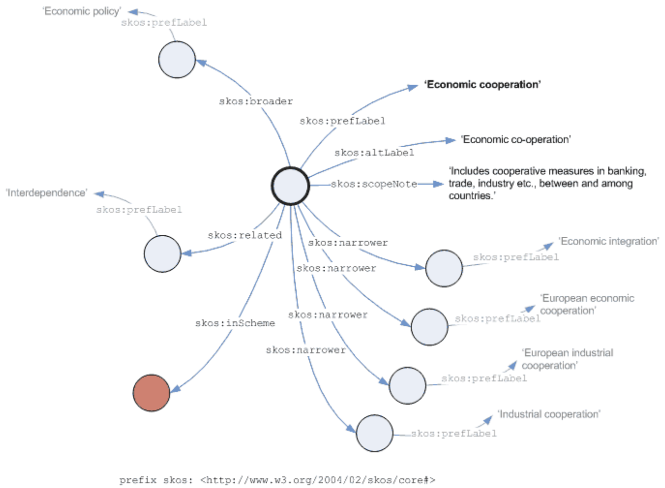
RT (related term) describes general term relationships (excluding BT/NT, USE, ...).

Příklad

topic maps → RT → knowledge management.

SKOS `http://www.w3.org/2004/02/skos`

Thesauri – Example



http://metadaten-twr.org/2011/01/19/skos-simple-knowledge-organisation-system, cit. 16.9.2012

Thesauri – Summary

- two ISO standards: single-language thesauri (ISO 2788:1986) or multiple-language thesauri (ISO 5964:1985).
- ☺ simple, easy-to-use by non-experts in knowledge engineering
- ☹ problems in formal semantics:

Example

BT relationships can be used in several meanings:

subsumption , e.g. fruit BT apple,
instance of , e.g. man BT David,
part of , e.g. auto BT wheel.
...

- semantic search, disambiguation, NLP

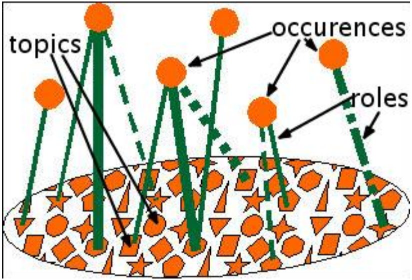
Topic Maps

Topic Maps – Topics

- ISO standard – ISO/IEC 13250:2003
- three types of objects : **topics**, their **occurences** and mutual **associations**.
- topics
  - represent concepts – classes, instances, properties, etc.
  - topics can have several **topic types**. The relationship "has type" build up a hierarchy of topics (analogy to *isa* relationships in semantics networks, or property *rdf:type* in RDF(S)).
  - each topics can have one or more **names** (e.g. nick, formal name, login name, etc.), each of which in different **variants** (e.g. visualization vs. sorting).

Topic Maps – Occurences

- occurences
  - represent "links" from topics to real documents/information resources.
  - a topic is connected with an occurence by means of a **role**, that determines the occurence type (web page, article, book, etc.)

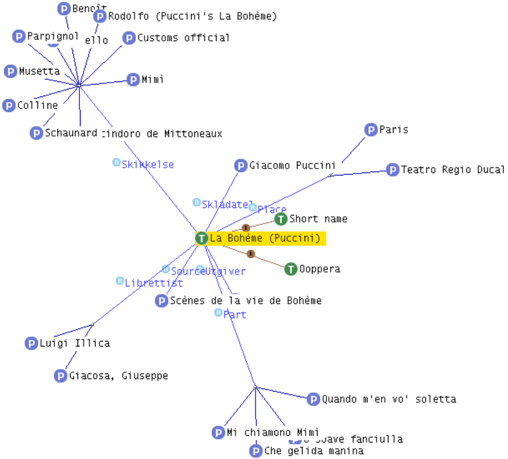


(http://www.ontopia.net/topicmaps/materials/tao.html)

Topic Maps – Asociations

- asociations
  - represent relationships between topics – analogy of n-ary relationships,
  - an *association type* (which is a topic) is assigned to an association (topic type is a special association type),
  - topics have so called **association roles** when connected to associations,
  - each association role is assigned **association role type**, which is a topic, in turn.

Topic Maps – Example

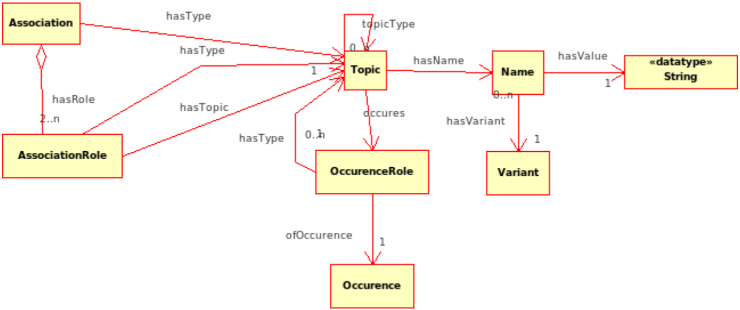


T ... topics

P ... partially expanded topics (except topic types)

R ... associations

Topic Maps – Model



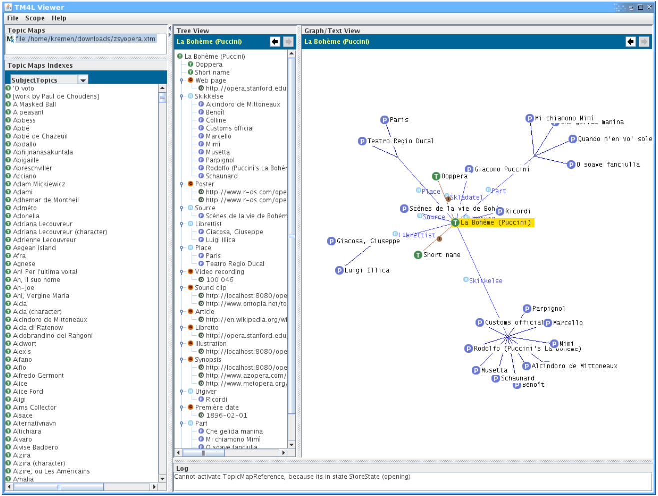
Topic Maps – Contexts, Queries

- additionally, topic maps can be grouped into **contexts** (scopes,themes).
- querying using
  - TMQL
  - tolog (syntactically similar to SQL)

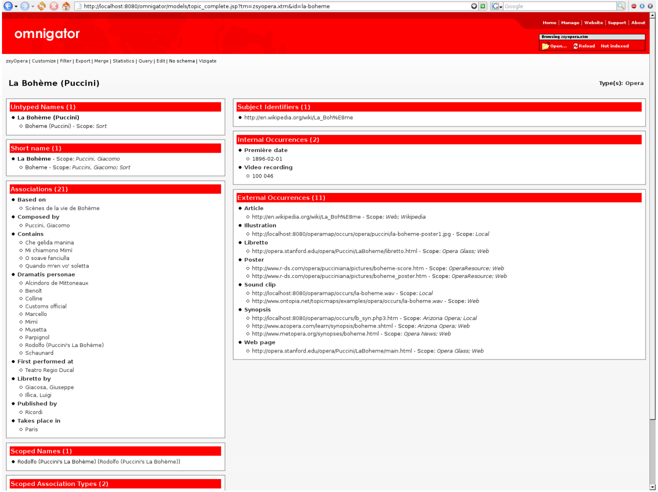
Topic Maps – Tools and Links

- selected tools:
  - Ontopia (Ontopoly, Omnigator,Vizigator) – main stakeholder in Topic Maps
  - TM4L
  - TM4J
- links:
  - http://www.ontopia.net/topicmaps/materials/tm-vs-thesauri.html
  - http://www.kosek.cz/xml/tmtut/

TM4L Viewer


TM4L Viewer
File Scope Help
Topic Maps
file:/home/kremen/downloads/zsyopera.xtm
Topic Maps Indexes
SubjectTopics
'O voto
[work by Paul de Choudens]
A Masked Ball
A peasant
Abbess
Abbé
Abbé de Chazeuil
Abdallo
Abhijnanasakuntala
Abigaille
Abreschviller
Acciano
Adam Mickiewicz
Adami
Adhemar de Montheil
Admèto
Adonella
Adriana Lecouvreur
Adriana Lecouvreur (character)
Adrienne Lecouvreur
Aegean island
Afra
Agnese
Ah! Per l'ultima volta!
Ah, il suo nome
Ah-Joe
Ahi, Vergine Maria
Aida
Aida (character)
Alcindoro de Mittoneaux
Alda di Ratenow
Aldobrandino dei Rangoni
Aldwort
Alexis
Alfano
Alfio
Alfredo Germont
Alice
Alice Ford
Aligi
Alms Collector
Alsace
Alternativnavn
Altichiara
Alvaro
Alvise Badoero
Alzira
Alzira (character)
Alzire, ou Les Américains
Amalia
Tree View
La Bohème (Puccini)
La Bohème (Puccini)
Ooppera
Short name
Web page
http://opera.stanford.edu
Skikkelse
Alcindoro de Mittoneaux
Benoît
Colline
Customs official
Marcello
Mimì
Musetta
Parpignol
Rodolfo (Puccini's La Bohèr
Schaunard
Poster
http://www.r-ds.com/ope
http://www.r-ds.com/ope
Source
Scènes de la vie de Bohèm
Librettist
Giacosa, Giuseppe
Luigi Illica
Place
Paris
Teatro Regio Ducal
Video recording
100 046
Sound clip
http://localhost:8080/ope
http://www.ontopia.net/to
Article
http://en.wikipedia.org/wi
Libretto
http://opera.stanford.edu
Illustration
http://localhost:8080/ope
Synopsis
http://localhost:8080/ope
http://www.azopera.com/
http://www.metopera.org/
Utgiver
Ricordi
Première date
1896-02-01
Part
Che gelida manina
Mi chiamono Mimì
O soave fanciulla
Graph/Text View
La Bohème (Puccini)
Paris
Teatro Regio Ducal
Mi chiamono Mimì
manina
Quando m'en vo' sole
O soave fanciulla
Giacomo Puccini
Ooppera
Place
Skladatel
Part
Scènes de la vie de Boh
Ricordi
Source
La Bohème (Puccini)
Librettist
Giacosa, Giuseppe
Short name
Luigi Illica
Skikkelse
Parpignol
Customs official
Marcello
Mimì
Rodolfo (Puccini's La
Alcindoro de Mittoneaux
Musetta
Schaunard
Benoît
Log
Cannot activate TopicMapReference, because its in state StoreState (opening)

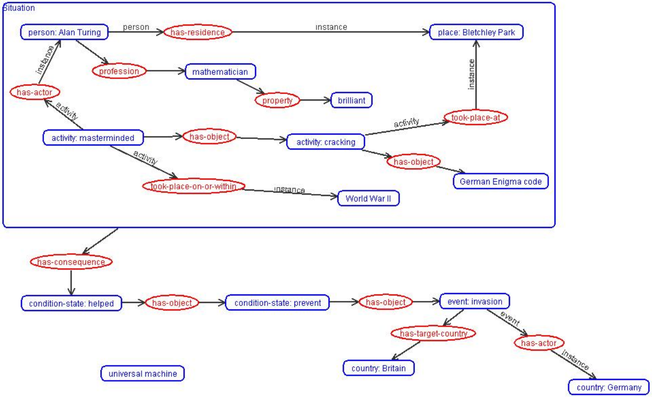
Omnigator



http://localhost:8080/omnigator/models/topic_complete.jsp?tm=zsyopera.xtm&id=la-boheme
omnigator
Home | Manage | Website | Support | About
Browsing zsyopera.xtm
Open... Reload Not indexed
zsyOpera | Customize | Filter | Export | Merge | Statistics | Query | Edit | No schema | Vizigate
La Bohème (Puccini)
Type(s): Opera
Untyped Names (1)
La Bohème (Puccini)
Boheme (Puccini) - Scope: Sort
Short name (1)
La Bohème - Scope: Puccini, Giacomo
Boheme - Scope: Puccini, Giacomo; Sort
Associations (21)
Based on
Scènes de la vie de Bohème
Composed by
Puccini, Giacomo
Contains
Che gelida manina
Mi chiamono Mimi
O soave fanciulla
Quando m'en vo' soletta
Dramatis personae
Alcindoro de Mittoneaux
Benoît
Colline
Customs official
Marcello
Mimi
Musetta
Parpignol
Rodolfo (Puccini's La Bohème)
Schaunard
First performed at
Teatro Regio Ducal
Libretto by
Giacosa, Giuseppe
Illica, Luigi
Published by
Ricordi
Takes place in
Paris
Scoped Names (1)
Rodolfo (Puccini's La Bohème) (Rodolfo (Puccini's La Bohème))
Scoped Association Types (2)
Subject Identifiers (1)
http://en.wikipedia.org/wiki/La_Boh%E8me
Internal Occurrences (2)
Première date
1896-02-01
Video recording
100 046
External Occurrences (11)
Article
http://en.wikipedia.org/wiki/La_Boh%E8me - Scope: Web; Wikipedia
Illustration
http://localhost:8080/operamap/occurs/opera/puccini/la-boheme-poster1.jpg - Scope: Local
Libretto
http://opera.stanford.edu/opera/Puccini/LaBoheme/libretto.html - Scope: Opera Glass; Web
Poster
http://www.r-ds.com/opera/pucciniana/pictures/boheme-score.htm - Scope: OperaResource; Web
http://www.r-ds.com/opera/pucciniana/pictures/boheme_poster.htm - Scope: OperaResource; Web
Sound clip
http://localhost:8080/operamap/occurs/la-boheme.wav - Scope: Local
http://www.ontopia.net/topicmaps/examples/opera/occurs/la-boheme.wav - Scope: Web
Synopsis
http://localhost:8080/operamap/occurs/lb_syn.php3.htm - Scope: Arizona Opera; Local
http://www.azopera.com/learn/synopsis/boheme.shtml - Scope: Arizona Opera; Web
http://www.metopera.org/synopses/boheme.html - Scope: Opera News; Web
Web page
http://opera.stanford.edu/opera/Puccini/LaBoheme/main.html - Scope: Opera Glass; Web

Conceptual Graphs

Example



Situation
person: Alan Turing
person
has-residence
instance
place: Bletchley Park
instance
profession
mathematician
property
brilliant
has-actor
activity
took-place-at
activity: masterminded
has-object
activity: cracking
has-object
German Enigma code
activity
took-place-on-or-within
instance
World War II
has-consequence
condition-state: helped
has-object
condition-state: prevent
has-object
event: invasion
event
has-target-country
has-actor
instance
country: Britain
country: Germany
universal machine

Conceptual Graphs

conceptual graph is a bipartite graph with two types of nodes (1) **concepts** a (2) **relations**.

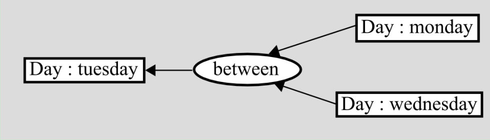
concept has the form **concept type : referent**.

Example (Quantifier type)

dog : Lucky	dog	dog : ∀	dog : {*}
Dog Lucky	Some dog	All dogs	Set of dogs
$\exists x Dog(x) \wedge Name(x, Lucky) \ldots$	$\exists x Dog(x) \ldots$	$\forall x Dog(x) \rightarrow \ldots$	☹ no FOPL

relation $=$ predicate of arbitrary arity > 0.

Example (Ternary relation)

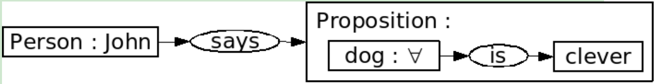


Conceptual Graphs (2)

referent consists of **quantifier** (existential, or defined (universal, collective, etc.)), **designator** (instance identifier, e.g. name) and possibly **descriptor** (conceptual graph describing the concept).

context is a concept with empty descriptor

Example (Context)



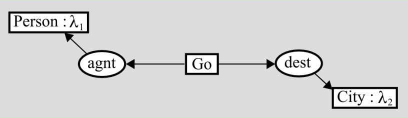
"John says, that all dogs are clever."

☹ no FOL

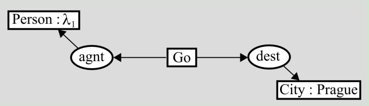
Conceptual Graphs (3)

lambda expressions correspond to "macros" – they allow defining relations by means of a "pattern" of the conceptual graph. Placeholders are denoted by λ_i symbols.

Example (lambda expressions)



def. binary relation "Go".

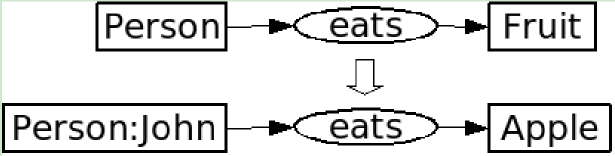


def. unary relation "Go to Prague".

Conceptual Graphs – Inference

- inference makes use of several forward chaining rules[1] (graph generalization, specialization, equivalent changes).
- querying is performed using **projection** that looks for a conceptual graph pattern in another conceptual graph making use of the conceptual type hierarchy and conceptual relations.

Example – Projection



[1] http://www.jfsowa.com/cg/cgstandw.htm

Conceptual Graphs – Tools

CharGer – CG editor
(http://sourceforge.net/projects/charger)

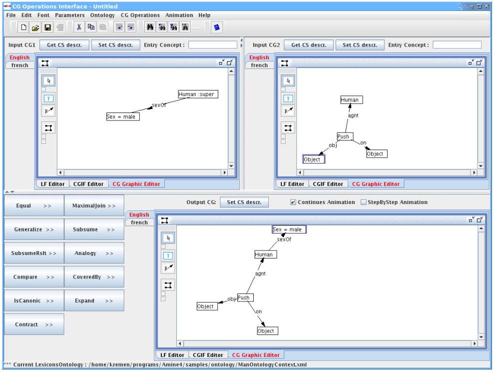
Notio – Java library + API for CG manipulation
(http://backtrack.uwaterloo.ca/CG/projects/notio)

Prolog+CG – inference engine for CG in Prolog
(http://prologpluscg.sourceforge.net)

Amine – newer version of Prolog+CG
(http://amine-platform.sourceforge.net)

DNA – annotation tool that visualizes the knowledge base using CG
(http://labe.felk.cvut.cz/ uhlir/DNATWeb/DNAThome.html)

Amine4



- editing/viewing ontologies
- editing/viewing conceptual graphs
- CG operations – e.g.: JOIN
- CG+Prolog inference
- multiagent systems

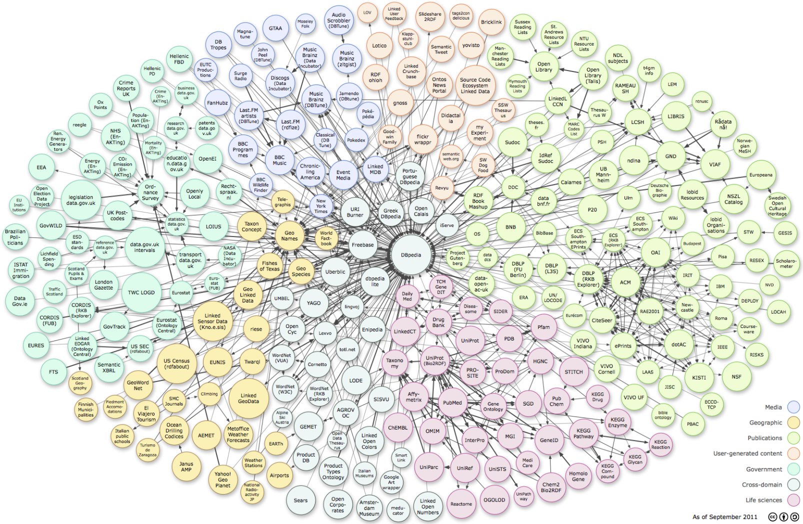
laboratory Gerstner

Conceptual Graphs – Summary

- CG's (J.F. Sowa 80's) are representatives of formal (machine readable) and at the same time well readable, intuitive languages,
- are based on Pierce existential graphs [Sow00], [**?**],
- are more expressive than FOPL – undecidability,
- to keep things decidable, so called *simple graphs* (J.F. Sowa 80's), were defined. They restrict the form of referents and prohibit contexts.

Semantic Web, Linked Data

LOD Cloud



Linking Open Data cloud diagram, by Richard Cyganiak and Anja Jentzsch. `http://lod-cloud.net`, accessed 12/04/2012

Summary

- we only quickly flew through the most important milestones in the crisp knowledge representation during last decades,
- ☹ most of these approaches have poorly defined semantics, which is a necessary condition for automated processing of large datasets,
- in this course we will focus on **description logics** – formally precise decidable logic-based knowledge representation languages.
- those interested in deeper understanding of semantic web, linked data, thesauri, etc. are welcome to enroll in the summer term our new course **Ontologies and Semantic Web** (AE0M33OSW), see general information at `https://kbss.felk.cvut.cz/web/portal/osw` and detailed syllabus at `http://bilakniha.cvut.cz/cs/predmet2876906.html`.