A Brief Introduction to Semantic Web – and a Contribution to Explainable Artificial Intelligence

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Textbook

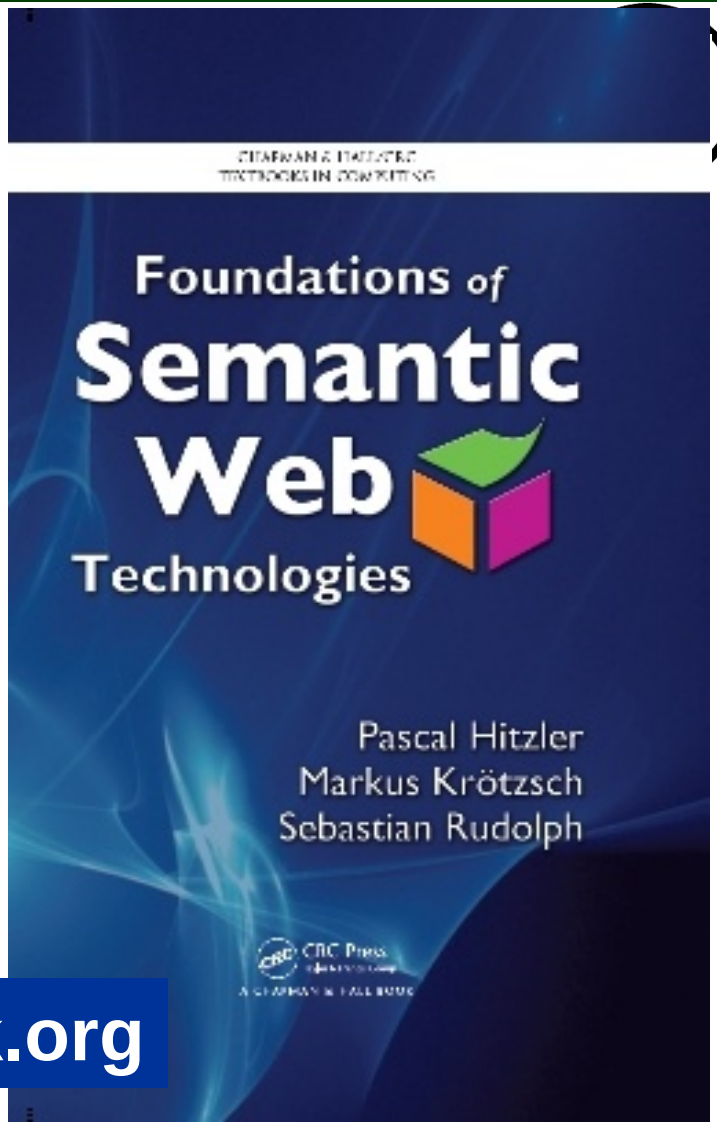
DaSe Lab

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

Foundations of Semantic Web Technologies

Chapman & Hall/CRC, 2010

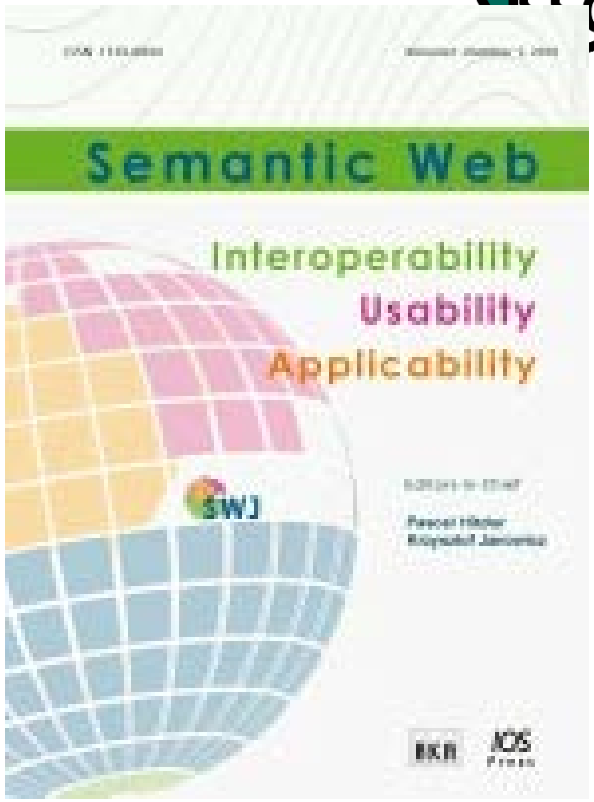
Choice Magazine Outstanding Academic Title 2010 (one out of seven in Information & Computer Science)



http://www.semantic-web-book.org

Semantic Web journal

- EiCs: Pascal Hitzler
  Krzysztof Janowicz
- Funded 2010
- 2017 Impact factor of 2.889, top (with 1.3 distance) of all journals with “Web” in the title



- We very much welcome contributions at the “rim” of traditional Semantic Web research – e.g., work which is strongly inspired by a different field.
- Non-standard (open & transparent) review process.

- **http://www.semantic-web-journal.net/**

US2TS U.S. Semantic Technologies Symposium

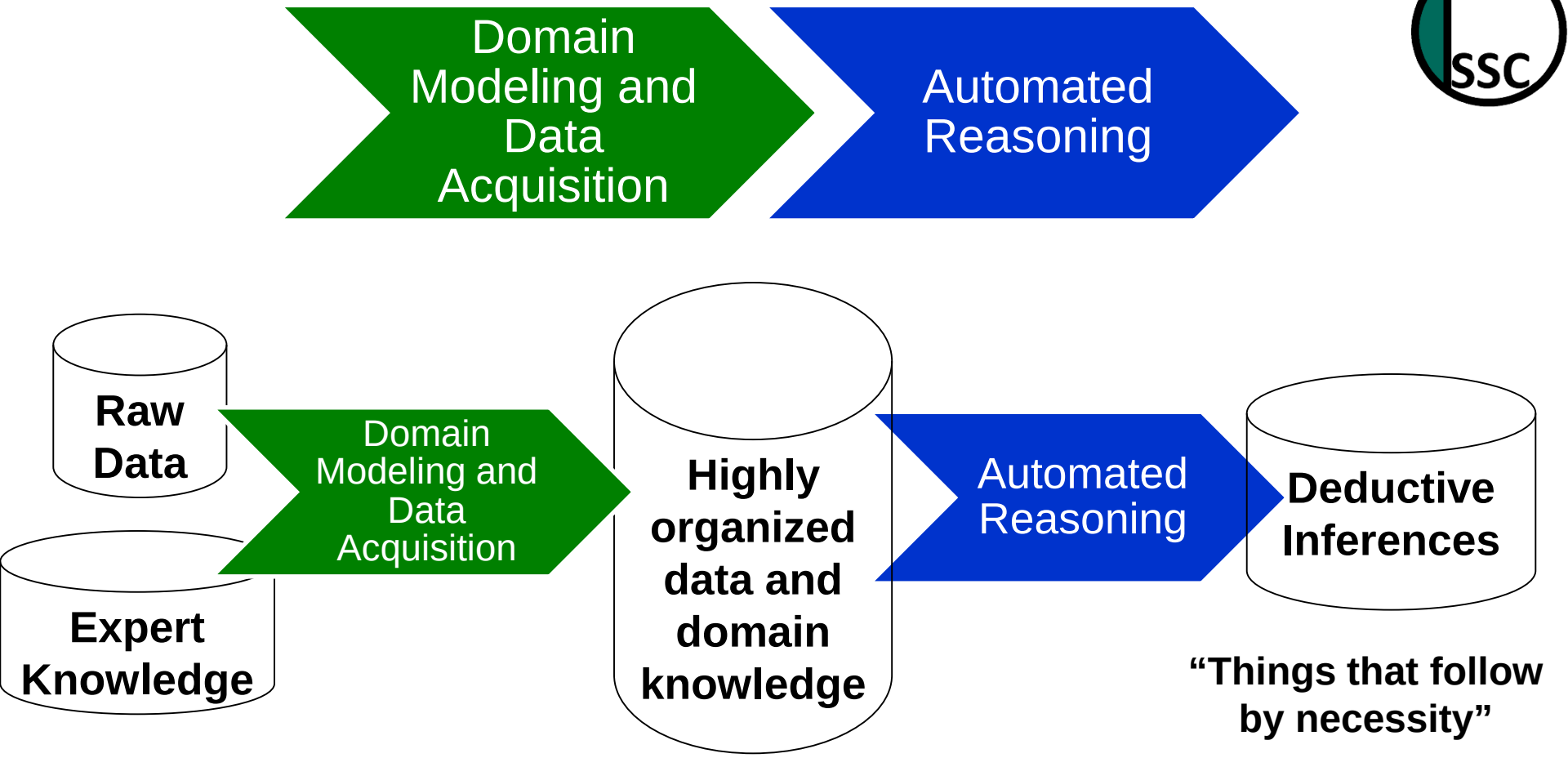
March 1-2, 2018, at Wright State University, Dayton, Ohio

Confirmed speakers/panelists/coordinators:

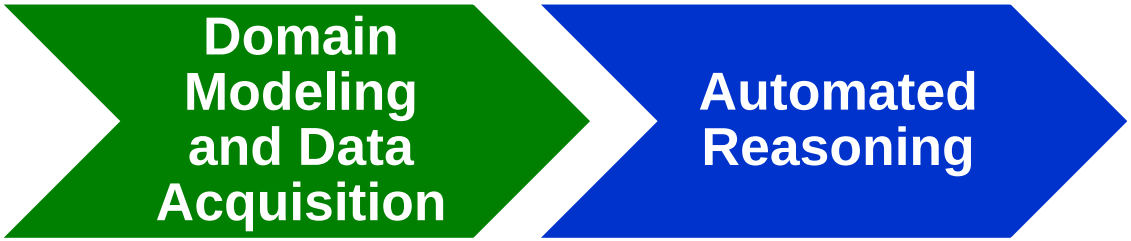
Achille Fukoue
Karl Grossner
Jim Hendler
Chris Mungall
Chaitan Baru
Dan Brickley
David Booth
Tim Finin
Peter Fox
Michael Grüninger
Melissa Haendel
Eric Kansa
Craig Knoblock
Werner Kuhn
Matt Lange
Rob Sanderson
Philip Schreur
Ryan Shaw
Brian Ulicny

Program Chair: Krzysztof Janowicz

Knowledge-based Systems



Knowledge-based Systems

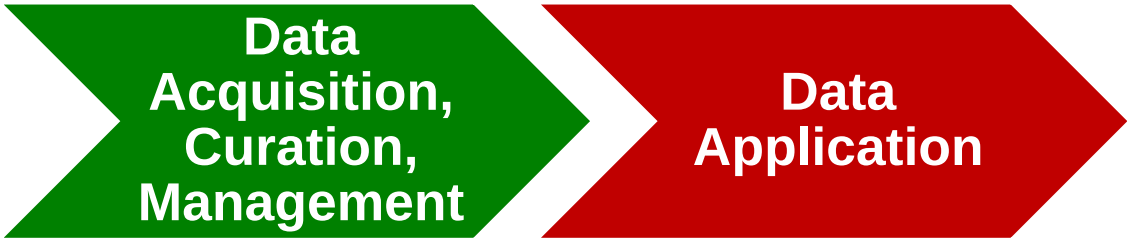


“Expert Systems” traditionally based on the logic programming paradigm.

In the wake of Semantic Web Technologies, Description Logics have emerged as alternative dominant paradigm.

Description logics underlie the W3C standard “Web Ontology Language” (OWL).

Data Applications



Semantic Web technologies provides efficient methods for

- **data sharing**
- **data reuse**
- **data integration**
- **data discovery**

for all kinds of application scenarios.

Key idea: A good data model (schema) makes a lot of a difference!

Description Logics

- Unary and binary predicates only (classes = concepts
  properties = roles)
- Conjunction, disjunction, negation and restricted quantifiers to form complex class expressions
- SubClass relationships (i.e., implications between complex classes)
- Role chains (concatenation of binary predicates)
- Variable bindings are severely restricted.

Result:

- Decidable logics, with complexities known.
- Variable-free notation.
- Some are P-complete; some are 2NExpTime
- Very efficient reasoners available.

Semantic Data Models

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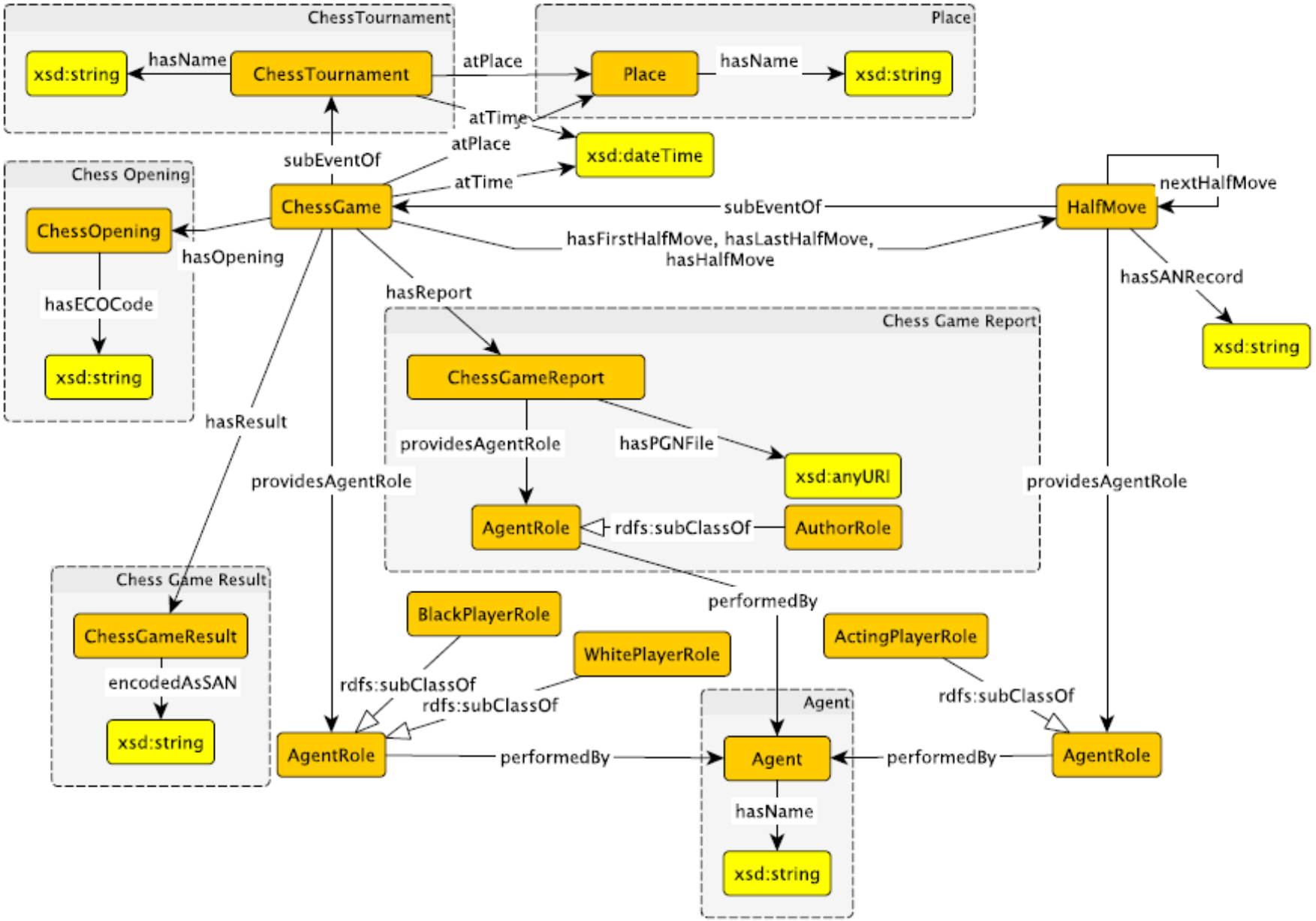


$$\mathsf{AgentRole} \sqsubseteq (=1\ \mathsf{performedBy.Agent}) \sqcap \forall \mathsf{performedBy.Agent} \tag{10.1}$$

$$\exists \mathsf{performedBy.Agent} \sqsubseteq \mathsf{AgentRole} \tag{10.2}$$

$$\top \sqsubseteq \forall \mathsf{pAR.AgentRole} \tag{10.3}$$

$$\mathsf{ChessGame} \sqsubseteq \exists \mathsf{atPlace.Place} \sqcap \forall \mathsf{atPlace.Place} \tag{10.4}$$

$$\mathsf{ChessGame} \sqsubseteq \exists \mathsf{atTime.xsd{:}dateTime} \sqcap \forall \mathsf{atTime.xsd{:}dateTime} \tag{10.5}$$

$$\mathsf{ChessGame} \sqsubseteq \exists \mathsf{pAR.BlackPlayerRole} \sqcap \exists \mathsf{pAR.WhitePlayerRole} \tag{10.6}$$

$$\exists \mathsf{subEventOf.ChessTournament} \sqcup \exists \mathsf{hasOpening.ChessOpening} \sqsubseteq \mathsf{ChessGame} \tag{10.7}$$

$$\exists \mathsf{hasResult.ChessGameResult} \sqcup \exists \mathsf{hasReport.ChessGameReport} \sqsubseteq \mathsf{ChessGame} \tag{10.8}$$

$$\mathsf{ChessGame} \sqsubseteq \forall \mathsf{subEventOf.ChessTournament} \sqcap \forall \mathsf{hasOpening.ChessOpening} \tag{10.9}$$

$$\mathsf{ChessGame} \sqsubseteq \forall \mathsf{hasResult.ChessGameResult} \sqcap \forall \mathsf{hasReport.ChessGameReport} \tag{10.10}$$

$$\mathsf{BlackPlayerRole} \sqcup \mathsf{WhitePlayerRole} \sqsubseteq \mathsf{AgentRole} \sqcap (=1\ \mathsf{pAR}^{-}\mathsf{.ChessGame}) \tag{10.11}$$

$$\mathsf{ChessGame} \sqsubseteq (=1\ \mathsf{hasFirstHalfMove.HalfMove}) \sqcap (=1\ \mathsf{hasLastHalfMove.HalfMove}) \tag{10.12}$$

$$\mathsf{ChessGame} \sqsubseteq (=1\ \mathsf{hasLastHalfMove.HalfMove}) \tag{10.13}$$

$$\mathsf{hasHalfMove} \sqsubseteq \mathsf{subEventOf}^{-} \tag{10.14}$$

$$\mathsf{hasFirstHalfMove} \sqsubseteq \mathsf{hasHalfMove} \tag{10.15}$$

$$\mathsf{hasLastHalfMove} \sqsubseteq \mathsf{hasHalfMove} \tag{10.16}$$

$$\mathsf{HalfMove} \sqsubseteq \mathsf{Event} \sqcap \exists \mathsf{pAR.ActingPlayerRole} \sqcap (=1\ \mathsf{hasHalfMove}^{-}\mathsf{.ChessGame}) \tag{10.17}$$

$$\mathsf{ActingPlayerRole} \sqsubseteq \mathsf{AgentRole} \sqcap (=1\ \mathsf{pAR}^{-}\mathsf{.HalfMove}) \tag{10.18}$$

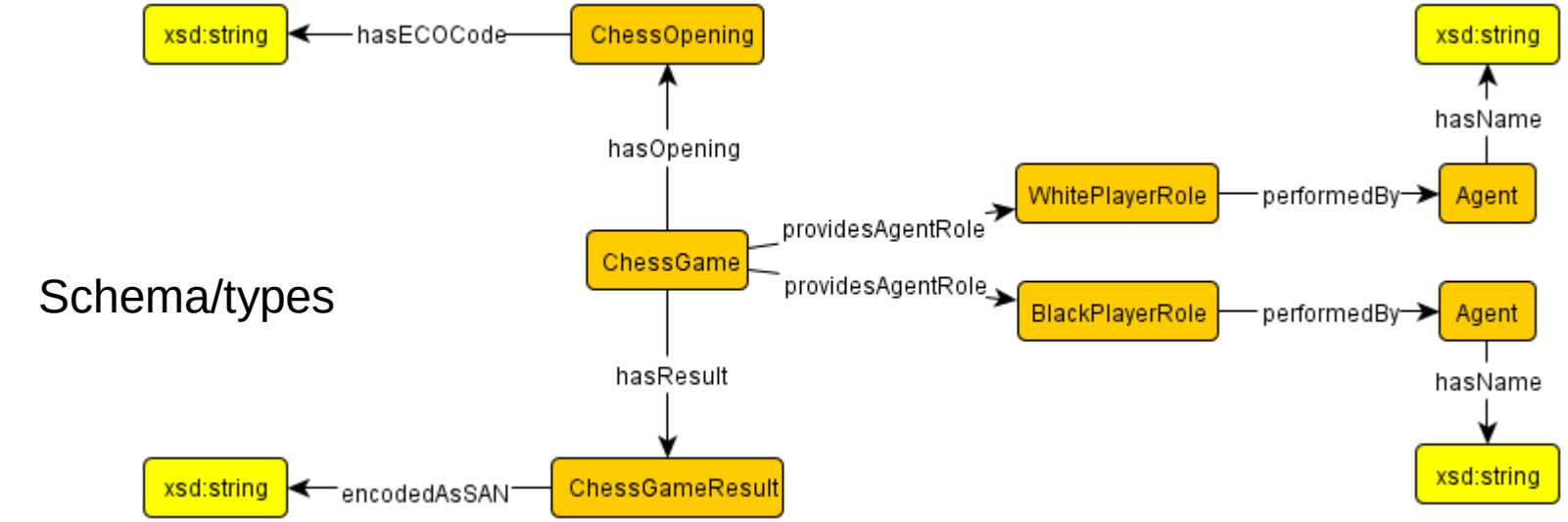
$$\mathsf{HalfMove} \sqsubseteq (\leq 1\ \mathsf{nextHalfMove.HalfMove}) \sqcap \neg \exists \mathsf{nextHalfMove.Self} \tag{10.19}$$

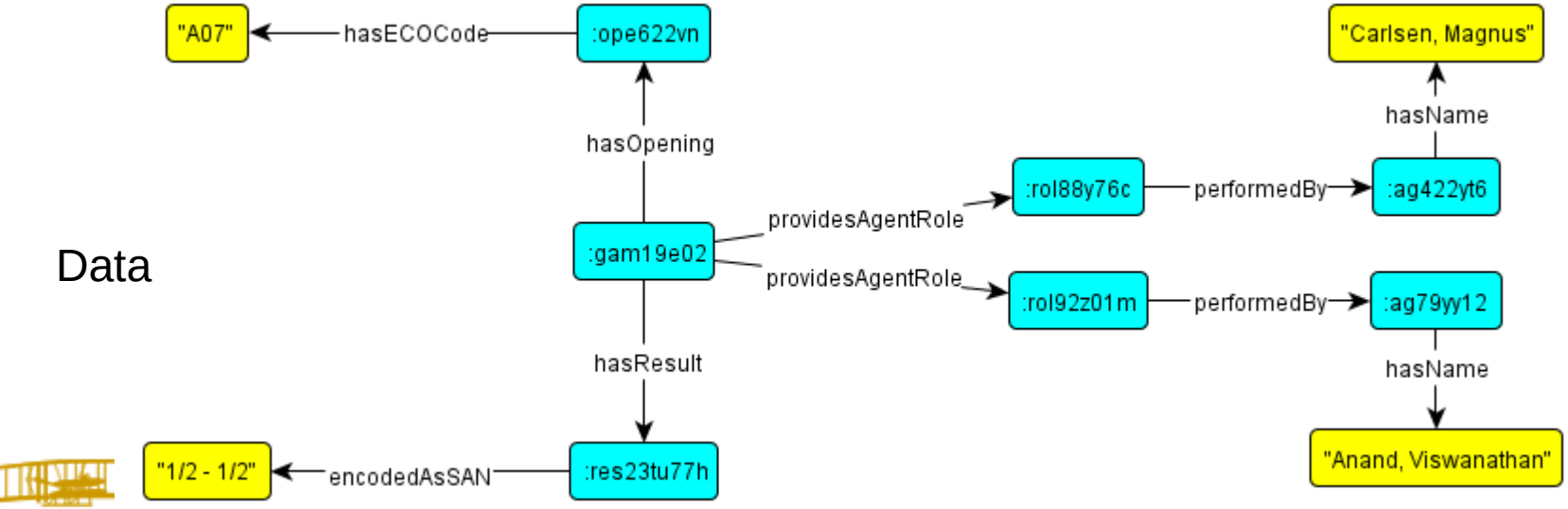
$$\exists \mathsf{subEventOf.ChessGame} \sqcup \exists \mathsf{nextHalfMove.HalfMove} \sqsubseteq \mathsf{HalfMove} \tag{10.20}$$

$$\exists \mathsf{hasSANRecord.xsd{:}string} \sqsubseteq \mathsf{HalfMove} \tag{10.21}$$

$$\mathsf{HalfMove} \sqsubseteq \forall \mathsf{subEventOf.ChessGame} \sqcap \forall \mathsf{nextHalfMove.HalfMove} \tag{10.22}$$

Ontology and Knowledge Graph

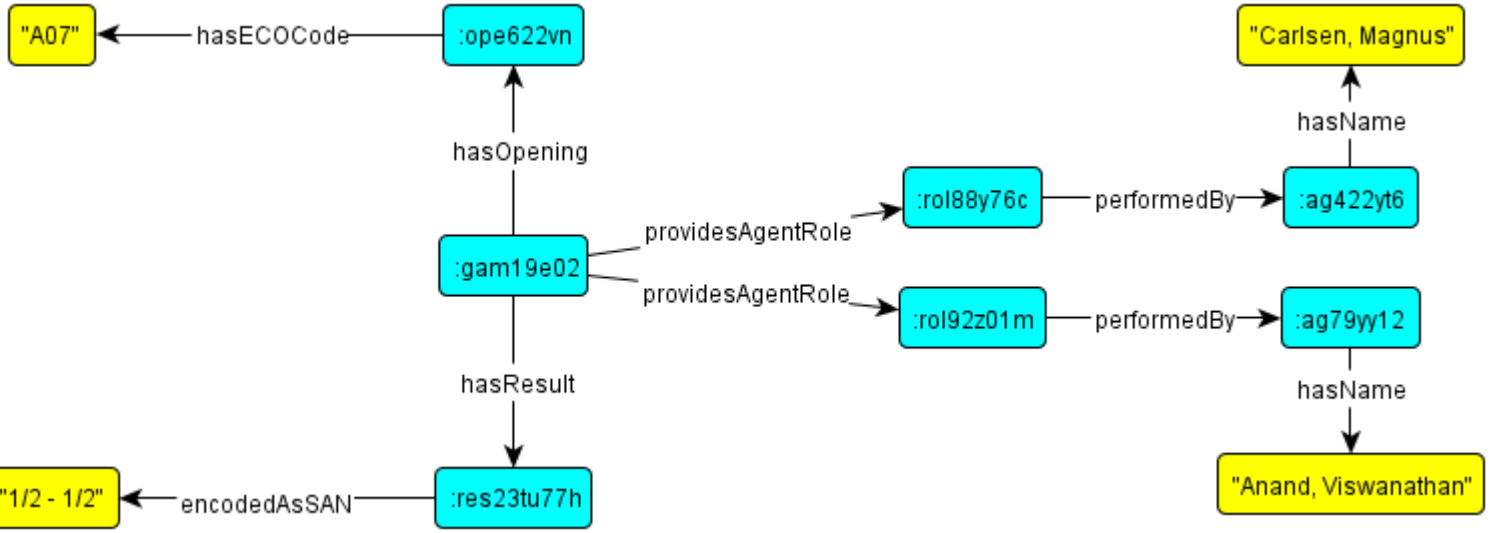




RDF Knowledge Graph

RDF uses Web-referencable identifiers.

E.g., :ag422yt6 expands to a full URI (for Magnus Carlsen).
Under best practices, it even dereferences.



Ontologies & Knowledge Graphs

Knowledge Graph	**Schema**
RDF Graph	**Ontology**
Labelled Directed Graph	**Type Logic**
Abox	**Tbox**
Facts	**Logical Theory**

Theresa May

British Prime Minister

tmay.co.uk

Theresa Mary May is a British politician who has served as Prime Minister of the United Kingdom and Leader of the Conservative Party since July 2016, the second woman to hold both positions. Wikipedia

Born: October 1, 1956 (age 60), Eastbourne, United Kingdom

Height: 5′ 8″

Party: Conservative Party

Spouse: Philip May (m. 1980)

Education: St Hugh's College, Oxford (1974–1977)

Previous offices: Home Secretary (2010–2016), MORE

Profiles

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People also search for View 15+

St Hugh's College, Oxford

College in Oxford, England

Website Directions

St Hugh's College is one of the constituent colleges of the University of Oxford. It is located on a 14.5-acre site on St Margaret's Road, to the north of the city centre. Wikipedia

Address: St Margaret's Rd, Oxford OX2 6LE, UK

Principal: Elish Angiolini

Phone: +44 1865 274900

Founder: Elizabeth Wordsworth

Founded: 1886

Named for: Hugh of Lincoln

Undergraduates: 432 (2011–2012)

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4.1/5 University Rooms · 2,310 votes

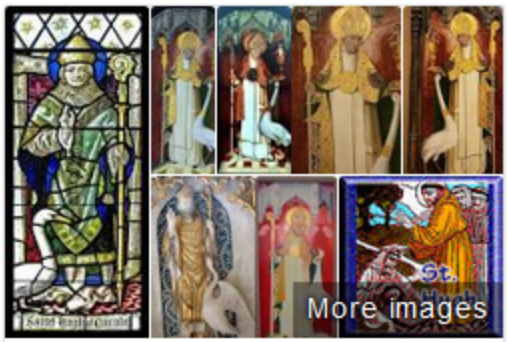
Send to your phone Send

Notable alumni View 40+


Theresa May


Aung San Suu Kyi


Barbara Castle



Hugh of Lincoln

Saint

Hugh of Lincoln, also known as Hugh of Avalon, was a French noble, Benedictine and Carthusian monk, bishop of Lincoln in the Kingdom of England, and Catholic saint. Wikipedia

Born: 1140, Avalon, France

Died: November 16, 1200, London, United Kingdom

Feast: 16 November (R.C.C.); 17 November (Anglican)

Major shrine: Lincoln Cathedral

Attributes: a white swan

Patronage: sick children, sick people, shoemakers and swans

People also search for


Little Saint Hugh of Lincoln


Thomas More


William Howard, 1st Visco...

Schema.org

- **Collaboratively launched in 2011 by Google, Microsoft, Yahoo, Yandex.**
  2011: 297 classes, 187 relations
  2015: 638 classes, 965 relations
- **Simple schema, request to web site providers to annotate their content with schema.org markup. Promise: They will make better searches based on this.**
- **2015: 31.3% of Web pages have schema.org markup, on average 26 assertions per page.**

Ramanathan V. Guha, Dan Brickley, Steve Macbeth: Schema.org: Evolution of Structured Data on the Web. ACM Queue 13(9): 10 (2015)

- TrainTrip
- Organization
  - Airline
  - Corporation
  - EducationalOrganization
    - CollegeOrUniversity
    - ElementarySchool
    - HighSchool
    - MiddleSchool
    - Preschool
    - School
  - GovernmentOrganization
  - LocalBusiness
    - AnimalShelter
    - AutomotiveBusiness
      - AutoBodyShop
      - AutoDealer
      - AutoPartsStore
      - AutoRental
      - AutoRepair
      - AutoWash
      - GasStation
      - MotorcycleDealer
      - MotorcycleRepair
    - ChildCare
    - Dentist
    - DryCleaningOrLaundry
    - EmergencyService
      - FireStation
      - Hospital
      - PoliceStation
    - EmploymentAgency
    - EntertainmentBusiness
      - AdultEntertainment
      - AmusementPark
      - ArtGallery
      - Casino
      - ComedyClub
      - MovieTheater
      - NightClub
    - FinancialService
      - AccountingService
      - AutomatedTeller
      - BankOrCreditUnion
      - InsuranceAgency
    - FoodEstablishment
      - Bakery
      - BarOrPub
      - Brewery
      - CafeOrCoffeeShop
      - FastFoodRestaurant

WIKIDATA

Main page
Community portal
Project chat
Create a new item
Recent changes
Random item
Query Service
Nearby
Help
Donate

Print/export
Create a book
Download as PDF
Printable version

In other projects
Wikimedia Commons
MediaWiki
Meta-Wiki
Wikispecies
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Wikipedia
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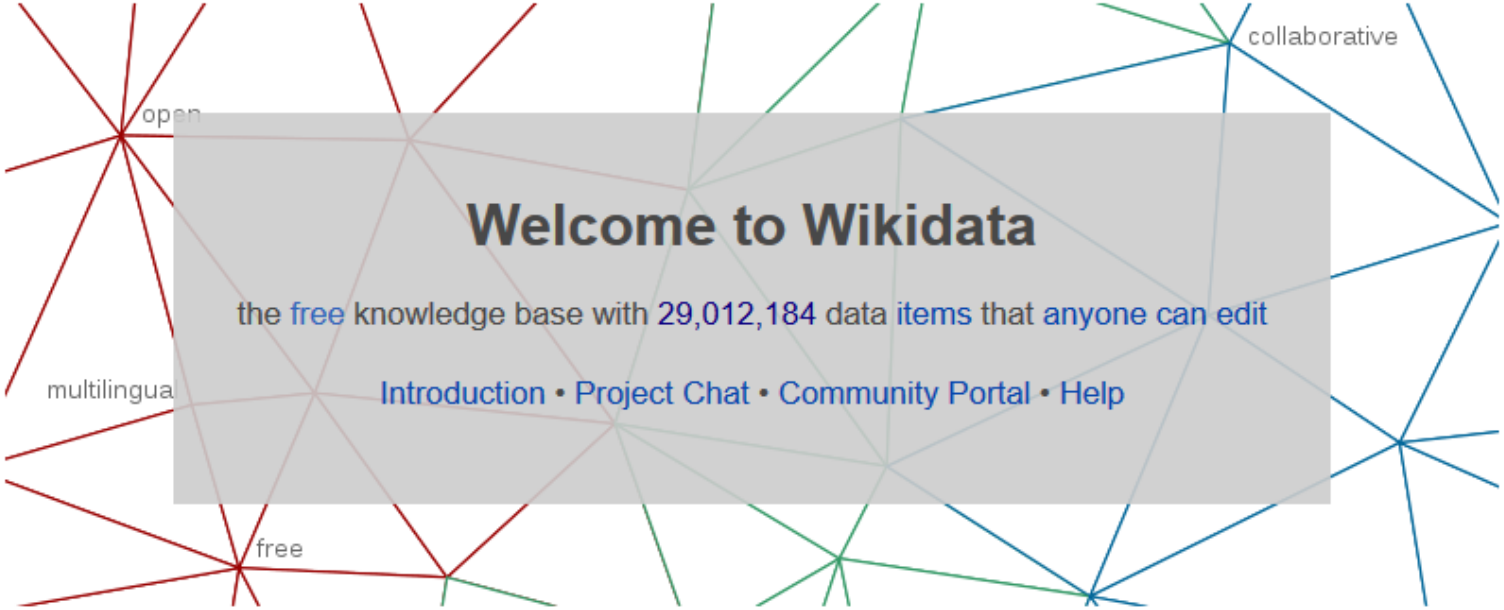
Wikisource
Wikiversity
Wikivoyage
Wiktionary

Tools
What links here



Welcome to Wikidata

the free knowledge base with 29,012,184 data items that anyone can edit

Introduction • Project Chat • Community Portal • Help

Welcome!

Wikidata is a free and open knowledge base that can be read and edited by both humans and machines.

Wikidata acts as central storage for the **structured data** of its Wikimedia sister projects including Wikipedia, Wikivoyage, Wikisource, and others.

Wikidata also provides support to many other sites and services beyond just Wikimedia projects! The content of Wikidata is available under a free license, exported using standard formats, and can be interlinked to other open data sets on the linked data web.

Learn about data

New to the wonderful world of data? Develop and improve your data literacy through content designed to get you up to speed and feeling comfortable with the fundamentals in no time.

Linked Data

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SSC

A bit older but somewhat more expressive: Linked Data on the Web

Number of Datasets	**2017-01-26**	**1,146**
	2014-08-30	570
	2011-09-19	295
	2010-09-22	203
	2009-07-14	95
	2008-09-18	45
	2007-10-08	25
	2007-05-01	12

38.606.408.854 triples and counting!

LOD Laundromat

DBpedia: LOTR page

dbpedia-owl:thumbnail	▪ http://upload.wikimedia.org/wikipedia/commons/thumb/6/62/Jrrt_lotr_cover_design.jpg/200px-Jrrt_lotr_cover_design.jpg
dbpedia-owl:wikiPageExternalLink	▪ http://lotr.wikia.com ▪ http://www.glyphweb.com/arda/ ▪ http://www.tolkienlibrary.com/ ▪ http://www.tolkien.co.uk/ ▪ http://www.houghtonmifflinbooks.com/features/lordoftheringstrilogy/
dbpprop:author	▪ dbpedia:J._R._R._Tolkien
dbpprop:books	▪ dbpedia:The_Two_Towers ▪ dbpedia:The_Return_of_the_King ▪ dbpedia:The_Fellowship_of_the_Ring ▪ "Volumes:"
dbpprop:country	▪ England
dbpprop:expiry	▪ 20 (xsd:integer)
dbpprop:genre	▪ dbpedia:Adventure_novel ▪ dbpedia:High_fantasy
dbpprop:hasPhotoCollection	▪ http://www4.wiwiss.fu-berlin.de/flickrwrappr/photos/The_Lord_of_the_Rings
dbpprop:imageCaption	▪ Tolkien's own cover designs for the three volumes
dbpprop:language	▪ English
dbpprop:mediaType	▪ Print
dbpprop:name	▪ The Lord of the Rings
dbpprop:pages	▪ 1216 (xsd:integer)
dbpprop:precededBy	▪ dbpedia:The_Hobbit
dbpprop:pubDate	▪ 21 (xsd:integer)
dbpprop:publisher	▪ dbpedia:Allen_&_Unwin
dbpprop:small	▪ yes
dbpprop:wikiPageUsesTemplate	▪ dbpedia:Template:Infobox_book_series ▪ dbpedia:Template:Pp-vandalism
dcterms:subject	▪ category:Monomyths ▪ category:High_fantasy_novels ▪ category:Middle-earth_books ▪ category:British_fantasy_novels ▪ category:Fantasy_books_by_series ▪ category:1950s_fantasy_novels ▪ category:Sequel_novels ▪ category:The_Lord_of_the_Rings ▪ category:English_novels

Linked Data: Volume

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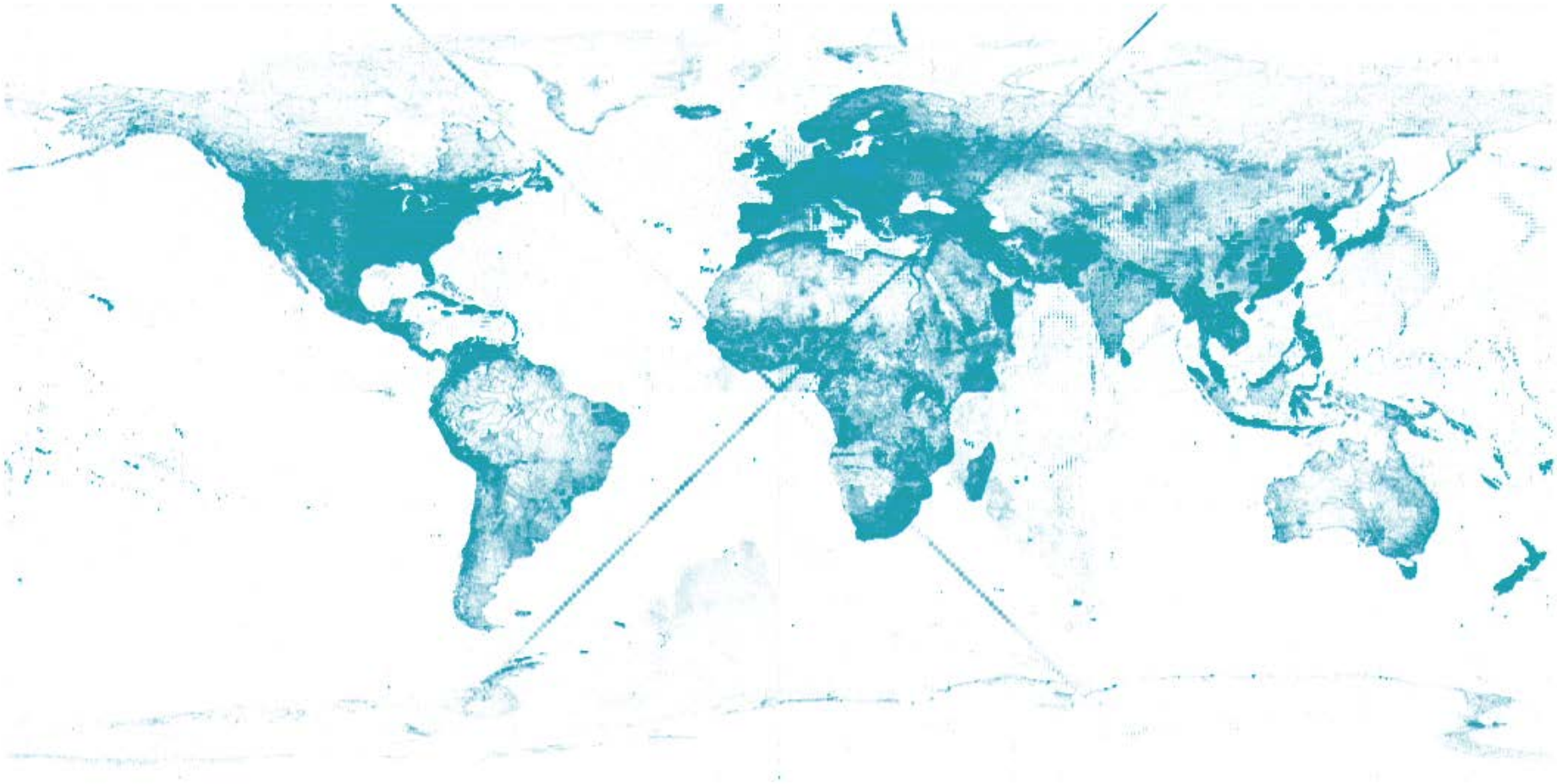
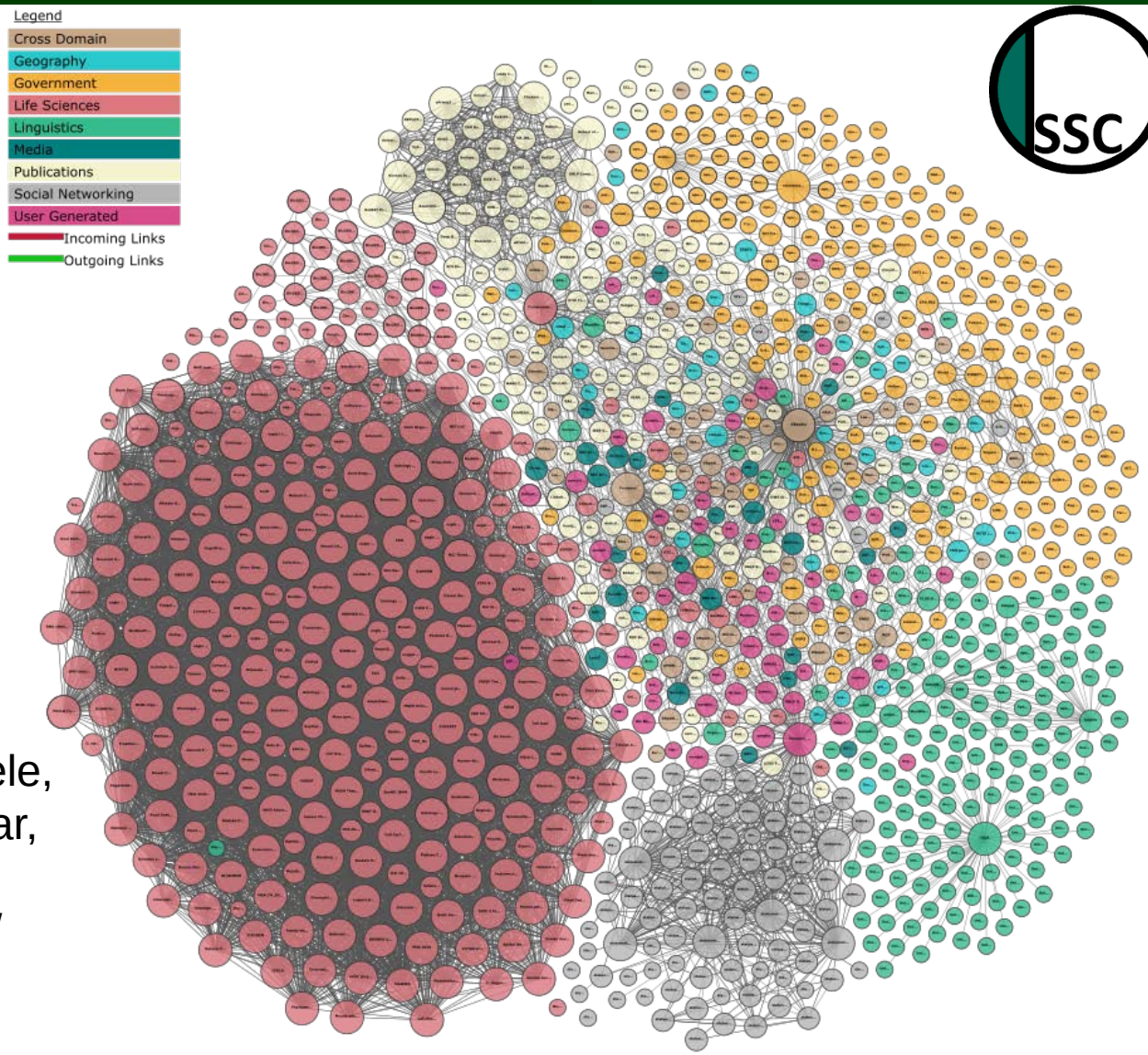
Geoindexed Linked Data – courtesy of Krzysztof Janowicz, 2012

http://stko.geog.ucsb.edu/location_linked_data

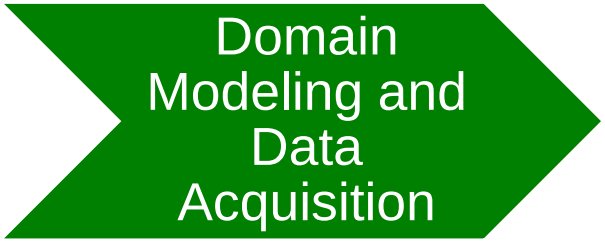


Some Linked Datasets 2017



Linking Open Data cloud diagram 2017, by Andrejs Abele, John P. McCrae, Paul Buitelaar, Anja Jentzsch and Richard Cyganiak. http://lod-cloud.net/

Semantic Data Management



Data *management*: SWT promises:

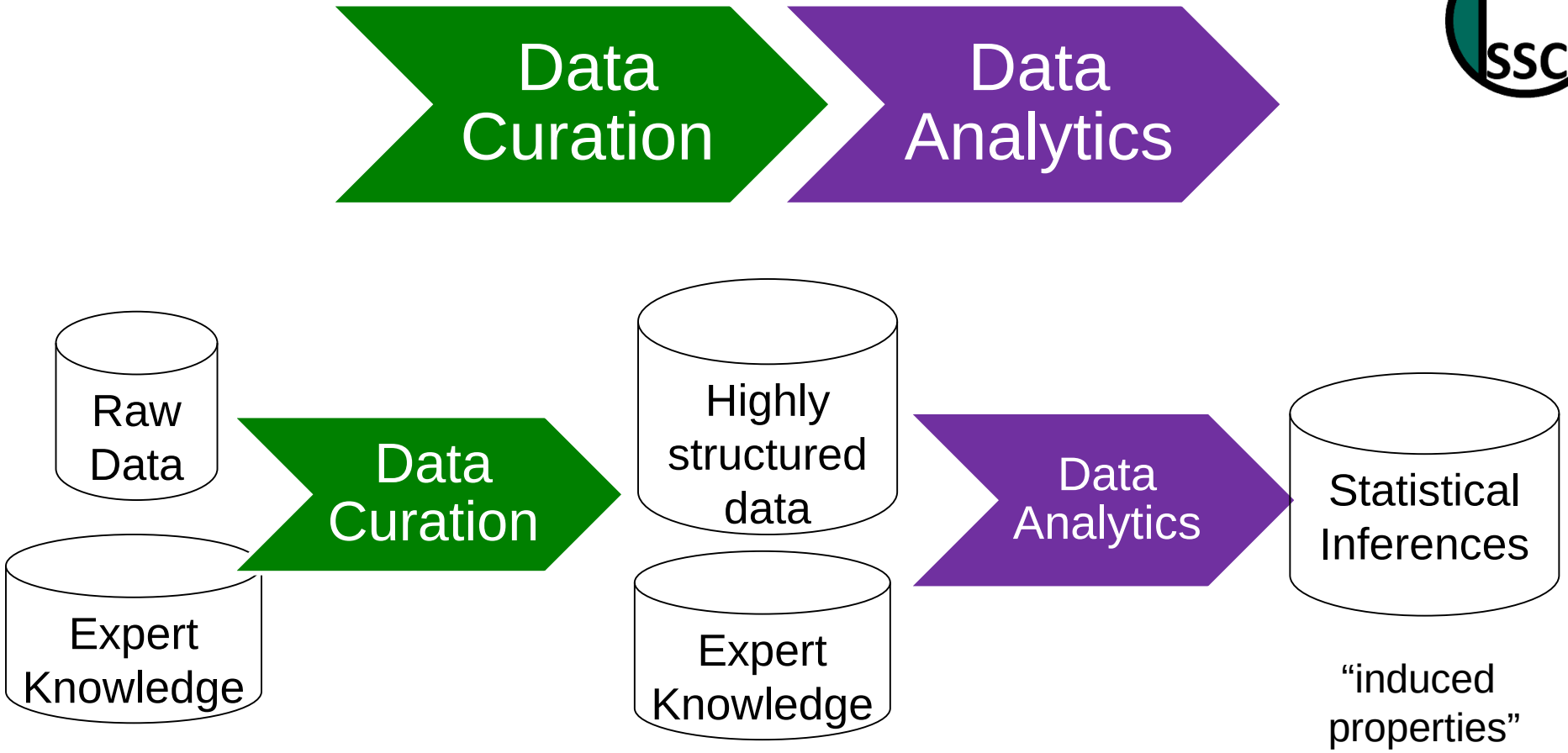
If information is structured *well*, then this significantly reduces data management cost (discovery, reuse, repurposing, integration, revision).

Use of standards.

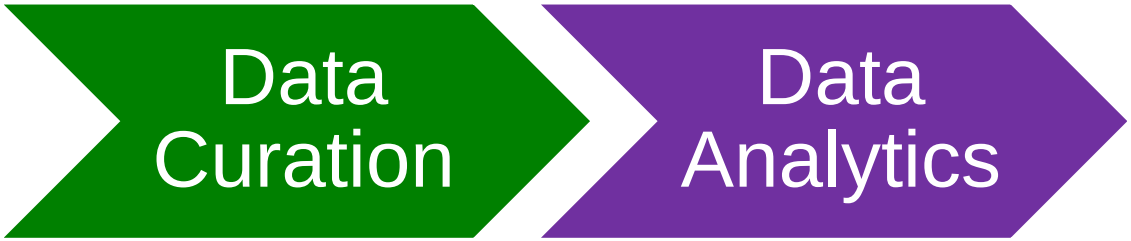
Best practices.

Data and ontology quality principles.

Data Science



Data Science



Semantic Web Technologies simplify the data curation part.

- **Easier integration of different sources.**
- **Clearer relationship between data organization and expert knowledge (i.e., data easier to understand).**
- **Easier discovery of relevant data.**

Explainable AI

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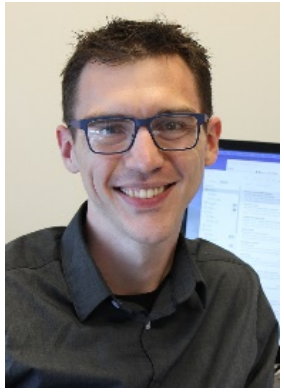
SSC

Joint work with

Md Kamruzzaman Sarker, Derek Doran, Ning Xie, Mike Raymer

WRIGHT STATE UNIVERSITY

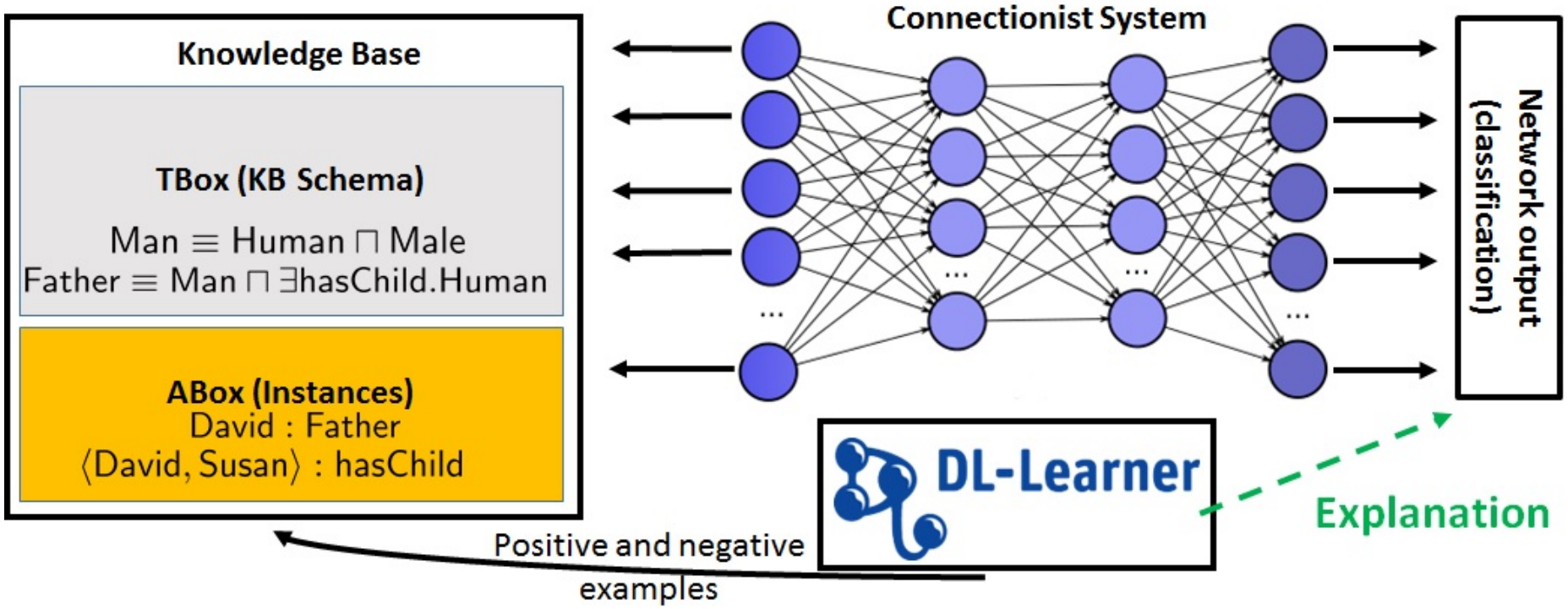
DL Extraction from ANNs

- **Explain input-output behavior of trained (deep) NNs.**

- **Idea:**
  - **Use background knowledge in the form of linked data and ontologies to help explain.**
  - **Link inputs and outputs to background knowledge.**
  - **Use a symbolic learning system (e.g., DL-Learner) to generate an explanatory theory.**

- **We're just starting on this, I report on very first experiments.**

DL Extraction from ANNs

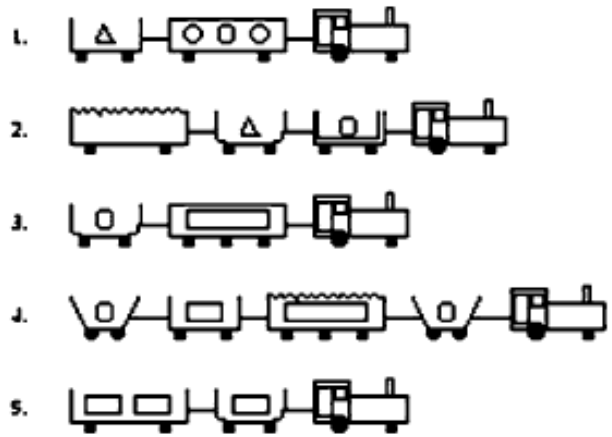


DL-Learner

Approach similar to inductive logic programming, but using Description Logics (the logic underlying OWL).

Positive examples:

negative examples:

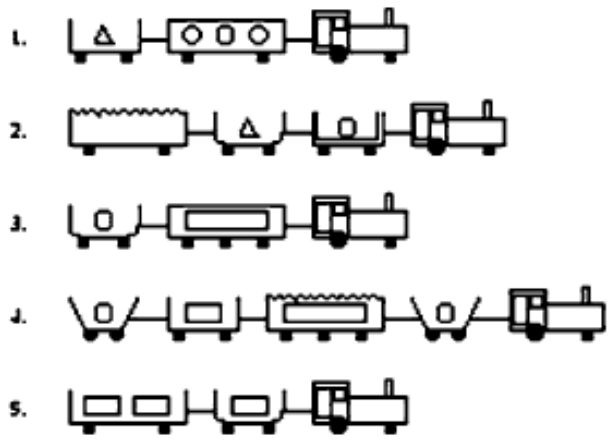


Task: find a class description (logical formula) which separates positive and negative examples.

DL-Learner

Positive examples:

negative examples:



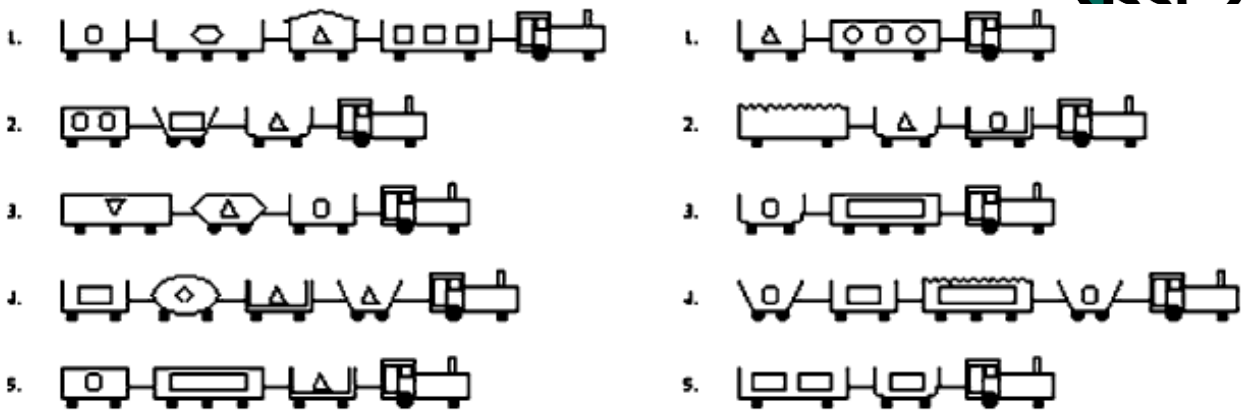
DL-Learner result: $\exists \mathtt{hasCar}.(\mathtt{Closed} \sqcap \mathtt{Short})$

In FOL:

$$\{x \mid \exists y(\mathrm{hasCar}(x, y) \wedge \mathrm{Closed}(y) \wedge \mathrm{Short}(y))\}$$

DL-Learner

DL-Learner uses refinement operators to construct ever better approximations of a solution.



$\top$

Train – covers all examples.

$\exists \text{hasCar}.\top$

$\exists \text{hasCar}.\text{Closed}$ – covers all positives, two negatives

$\exists \text{hasCar}(\text{Closed} \sqcap \text{Short})$ – solution

Proof of Concept Experiment

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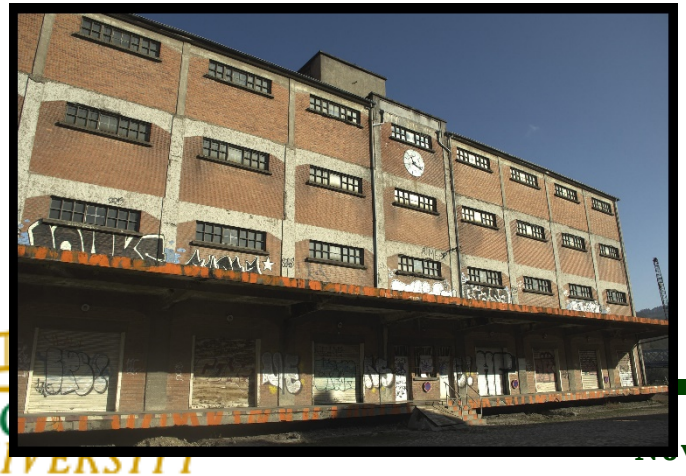
SSC

Positive:



Negative:

Images

Come from the MIT ADE20k dataset
http://groups.csail.mit.edu/vision/datasets/ADE20K/
They come with annotations of objects in the picture:

```
001 # 0 # 0 # sky # sky # ""
002 # 0 # 0 # road, route # road # ""
005 # 0 # 0 # sidewalk, pavement # sidewalk # ""
006 # 0 # 0 # building, edifice # building # ""
007 # 0 # 0 # truck, motortruck # truck # ""
008 # 0 # 0 # hovel, hut, hutch, shack, shanty # hut # ""
009 # 0 # 0 # pallet # pallet # ""
011 # 0 # 0 # box # boxes # ""
001 # 1 # 0 # door # door # ""
002 # 1 # 0 # window # window # ""
009 # 1 # 0 # wheel # wheel # ""
```

Mapping to SUMO

Simple approach: for each known object in image, create an individual for the ontology which is in the appropriate SUMO class:

contains road1
contains window1
contains door1
contains wheel1
contains sidewalk1
contains truck1
contains box1
contains building1

SUMO

- **Suggested Merged Upper Ontology**
  http://www.adampease.org/OP/

- **Approx. 25,000 common terms covering a wide range of domains**

- **Centrally, a relatively naïve class hierarchy.**

- **Objects in image annotations became individuals (constants), which were then typed using SUMO classes.**

DL-Learner input

Positive:

- **img1:** road, window, door, wheel, sidewalk, truck, box, building
- **img2:** tree, road, window, timber, building, lumber
- **img3:** hand, sidewalk, clock, steps, door, face, building, window, road

Negative:

- **img4:** shelf, ceiling, floor
- **img5:** box, floor, wall, ceiling, product
- **img6:** ceiling, wall, shelf, floor, product

DL-Learner results include:

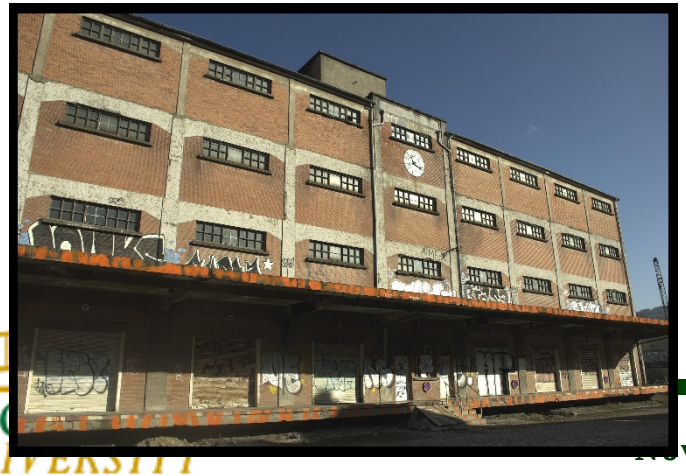
$$\exists \text{contains}.\text{Transitway}$$

$$\exists \text{contains}.\text{LandArea}$$

Proof of Concept Experiment

DaSe Lab

Positive:



Negative:

$\exists contains.Transitway$

$\exists contains.LandArea$

First 10 DL-Learner responses

$\exists$contains.Window	(1)	$\exists$contains.LandTransitway	(6)
$\exists$contains.Transitway	(2)	$\exists$contains.LandArea	(7)
$\exists$contains.SelfConnectedObject	(3)	$\exists$contains.Building	(8)
$\exists$contains.Roadway	(4)	$\forall$contains.$\neg$Floor	(9)
$\exists$contains.Road	(5)	$\forall$contains.$\neg$Ceiling	(10)

Experiment 2

DaSe Lab

SSC

Positive (selection):

Negative (selection):

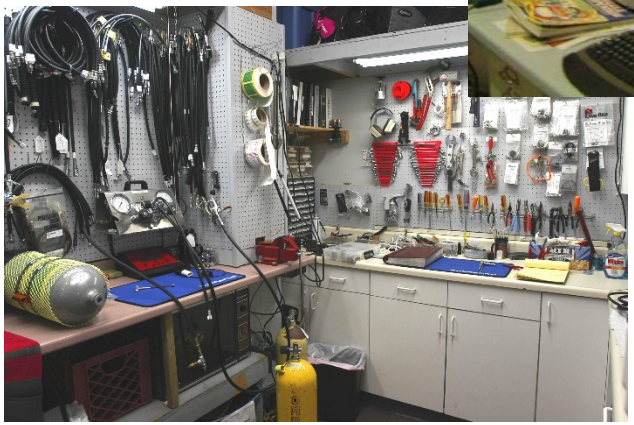
$$\exists \text{contains}.(\text{DurableGood} \sqcap \neg \text{ForestProduct})$$

Experiment 3

DaSe Lab

Positive:

Negative:



$$\forall contains.(\neg Furniture \sqcap \neg IndustrialSupply)$$

Experiment 4

DaSe Lab

SSC

Positive (selection):

Negative (selection):

$\exists$contains.SentientAgent

Experiment 5

Positive:




$\exists$contains.BodyOfWater

Negative (selection):



Next steps

- **Utilize more sophisticated ontology.**
- **Utilize more sophisticated mappings.**

- **Explain hidden neurons.**

- **Tune DL-Learner better to the specific task.**

Explaining hidden neurons

Collaborators Derek Doran and Ning Xie (Web and Complex Systems Lab)

They explore how to determine groups of hidden neurons which often fire together and thus may indicate the "detection" of certain features.

We plan to apply the above mentioned DL-Learner approach also to these groups of hidden neurons, in order to determine which features they detect.

Thanks!

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