

Semantics, Science, and 10 Year Olds

Oren Etzioni, AI2

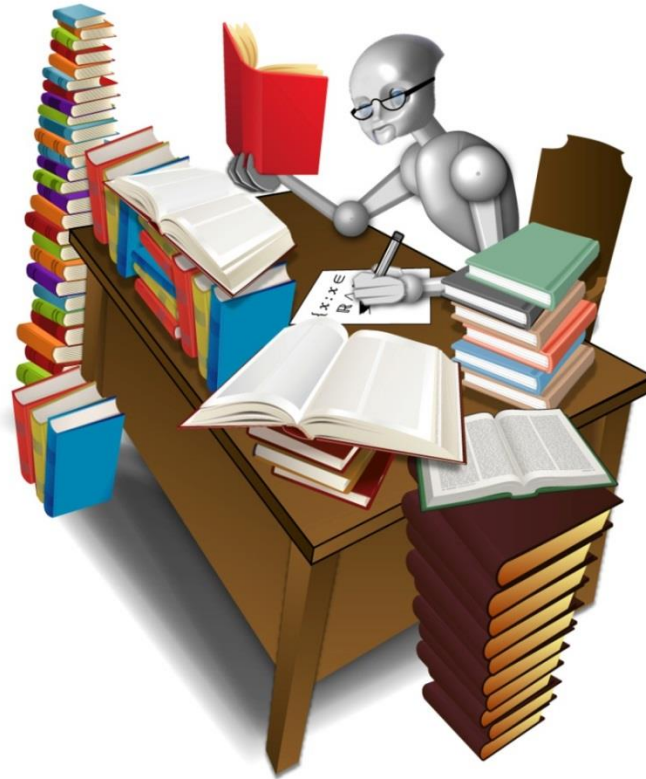


Outline

- I. Machine reading & Open IE
- II. The Allen Institute for AI (AI2)

- III. Arithmetic story problems
- IV. Diagram understanding in plane geometry
- V. Knowledge & inference in 4th grade science
- VI. Semantic literature search

I. Machine Reading (Etzioni, AAAI 2006)



Auto-Text to Knowledge

Information Extraction

IE(sentence) = [tuple, confidence]

“Edison, by all accounts, was the inventor of the light bulb.”
→ **invented(Edison, light bulb), 0.98**

Typically, IE requires:

- Pre-specified relations
- Hand-labeled training examples
- Lexicalized features/patterns

NELL Knowledge Base

categories













- relatedto
 - visualartmovement
 - personinacademy
 - generalizationof
 - athletessuchas
 - academicfields
 - chemicaltypes
 - astronautsuccess
 - automobileeng
 - airportsuchasa
 - amphibianssuc
 - aquariumssuc
 - arteriessuchas
 - animaltypephas
 - animalsuchas
 - animalsuc
 - animalsuc
 - animalsuc
 - inverseofart
 - professiontype
 - productinstan
 - booksuchasbo
 - vehicletypes
 - touristattractio
 - 5 celebritiesuch
 - archaeasuchas

obama (politician)

literal strings: [OBAMA](#), [OBama](#), [Obama](#), [obama](#)

Help NELL Learn!

NELL wants to know if these beliefs are correct.
If they are or ever were, click thumbs-up. Otherwise, click thumbs-down.

- [obama](#) is a [politician](#)  
- [obama](#) is a [male](#)  
- [obama](#) is a person who [belongs to](#) the organization [house](#) (governmentorganization)  
- [obama](#) is a person [born on](#) the date [n1961](#) (dateliteral)  
- [obama](#) is a person who [graduated from](#) the university [harvard](#) (university)  
- [obama](#) is a person who [graduated from](#) the university [harvard_law_school](#) (university)  

categories

- [politician](#)(100.0%)
 - SEAL @9 (75.0%) on 13-jan-2010 [[1](#) [2](#)] using obama
 - CPL @722 (88.0%) on 06-apr-2013 ["_ is a good president" "_ defends choice" "_ beats McCain" "massive scope" "_ is the only President" "_ is the new Hitler" "_ is half-white" "_ is an empty suit" "President" "_ is leading McCain" "McCain trails _" "Kennedy endorsed _" "_ 's Inauguration Day" "campaign" "York Times endorses _" "_ 's Inaugural Address" "more popular votes than _" "_ 's his

NELL Lexical Patterns for "haswife"

haswife metadata - Read the Web :: NELL KnowledgeBase Browser - Google Chrome
rtw.ml.cmu.edu/rtw/kbbrowser/predmeta:haswife
NELL Knowledge Base Browser
CMU Read the Web Project

- haswife
- hashusband
- husbandof
- parentofperson
- motherofperson
 - biologicalmotherofperson
- fatherofperson
 - biologicalfatherofperson
- agentcollaborateswithagent
- politicianendorsespolitician
 - politicianusendorsespolitician
- teammate
- politicianendorsesbypolitician
 - politicianusendorsesbypolitician
- agenthierarchicallybelowagent (+)
- agenthierarchicallyaboveagent
 - organizationhasagent (+)
 - coachesathlete
- agentholdsshareincompany
- companyhasshareholder
- universityhasacademicprogram
- clothingmadefromplant
- creativeworkcontributedbyagent
- moviestaractor
- moviedirectedbydirector
- bookwriter
- personhasjobposition
- jobpositionheldbyperson
- inverseofsportfansincountry
- agentcontrols
 - agentleadsorganization (+)
 - personleadscountry
 - agenthierarchicallyaboveagent (+)
- trophywonbyteam
- subpartof
 - agentbelongstoorganization (+)
 - agentparticipatedinevent
 - teamingame
 - losinggame
 - homeleamingame
 - winninggame
 - awayteamingame
 - personchargedwithcrime
 - locationlocatedwithlocation (+)
 - bodypartwithinbodypart
 - eventsubeventof
 - subfieldofacademicfield
 - iteminvolvedinevent
- agentstudiesphysiologicalcondition
- players
- issueofpoliticsgroup
- visualartistartform
- arthropodlooklikeinsect
- agriculturalproductcookedwithagriculturalteamwontrophy
- ethnicgroupofperson
- agriculturalproductcomingfromvertebrate
- shapeofobject

haswife
(relation: inverse of [wifeof](#))
See [learned instances](#) of haswife

- Metadata**
- **antireflexive**
 - "true"
 - **antisymmetric**
 - "true"
 - **description**
 - "person has a wife"
 - **domain**
 - [person](#)
 - **domainWithinRange**
 - "false"
 - **extractionPatterns**
 - "arg1 a bad influence of and actress Angelina ar arg2" "arg1 and fiance World arg2" "arg1 and and her lover arg2" "ar arg2" "arg1 and his for arg2" "arg1 and his for arg2" "arg1 and his wor arg2" "arg1 and Sarah to arg2" "arg1 Appears bought his wife arg2" "cheated on arg2" "arg1 committed adultery with "arg1 endeavors to kee "arg1 gal pal arg2" "arg with arg2" "arg1 had an arg2" "arg1 has annou married to arg2" "arg1 "arg1 is banging arg2" arg2" "arg1 leaves to g arg2" "arg1 married the affair with arg2" "arg1 separated after arg2" "arg1 set to marry arg2" "arg1 shirtless and arg2" "arg1 showed up and told arg2" "arg1 sinned with arg2" "arg1 son by arg2" "arg1 splashes out on arg2" "arg1 still pining for arg2" "arg1 takes wife arg2" "arg1 the husband of arg2" "arg1 then married arg2" "arg1 to banish arg2" "arg1 to bring his wife arg2" "arg1 to cast out arg2" "arg1 to have a child by arg2" "arg1 to have a child with arg2" "arg1 to have sex with arg2" "arg1 to pop the question to arg2" "arg1 to send him and arg2" "arg1 to sex with arg2" "arg1 to star with arg2" "arg1 to tie the knot arg2" "arg1 took his wife arg2" "arg1 toted arg2" "arg1 used to kiss arg2" "arg1 VIII and arg2" "arg1 VIII married arg2" "arg1 was actually married to arg2" "arg1 was joined by his wife arg2" "arg1 was making out with arg2" "arg1 was married to arg2" "arg1 was never married to arg2" "arg1 was not married to arg2" "arg1 was not present when arg2" "arg1 was once married to arg2" "arg1 was photographed holding arg2" "arg1 was secretly married to arg2" "arg1 was sexually involved with arg2" "arg1 Wentz and arg2" "arg1 were a reality arg2" "arg1 who affirmed that arg2" "arg1 will break up with arg2" "arg1 with his new love arg2" "arg1 with love to arg2" "arg1 yong arg2" "arg2 Adams and David arg1" "arg2 admits that she and arg1" "arg2 and actor Brad arg1" "arg2 and baby daddy arg1" "arg2 and Barack Obama to arg1" "arg2 and beau arg1" "arg2 and boyfriend arg1" "arg2 and Brad arg1" "arg2 and Brad Pitt arg1" "arg2 and country music star arg1" "arg2 and country singer arg1" "arg2 and dad is arg1" "arg2 and david arg1" "arg2 and David arg1" "arg2 and debutant arg1" "arg2 and estranged husband arg1" "arg2 and ex husband arg1" "arg2 and fianc arg1" "arg2 and fiance arg1" "arg2 and Fiance arg1" "arg2 and gal pal arg1" "arg2 and girlfriend arg1" "arg2 and Good Charlotte rocker arg1" "arg2 and guy arg1" "arg2 and Guy arg1" "arg2 and her beau arg1" "arg2 and her BF arg1" "arg2 and her boyfriend arg1" "arg2 and her children with arg1" "arg2 and her daughter by arg1" "arg2 and her ex arg1" "arg2 and her fianc arg1" "arg2 and her fiance arg1" "arg2 and her former husband arg1" "arg2 and her gal pal arg1" "arg2 and her girlfriend arg1" "arg2 and her hubby arg1" "arg2 and her husband arg1" "arg2 and her husband Guy arg1" "arg2 and her husband Tom arg1" "arg2 and her longtime boyfriend arg1" "arg2 and her man arg1" "arg2 and her new boyfriend arg1" "arg2 and her new hubby arg1" "arg2 and her new husband arg1" "arg2 and her partner arg1" "arg2 and her partner Brad arg1" "arg2 and her relationship to arg1" "arg2 and her rocker boyfriend arg1" "arg2 and her rocker husband arg1" "arg2 and her spouse arg1" "arg2 and hottie arg1" "arg2 and hubble arg1" "arg2 and hubby arg1" "arg2 and husband arg1" "arg2 and husband Guy arg1" "arg2 and husband Tom arg1" "arg2 and its spinoff arg1" "arg2 and Jack Lemmon in arg1" "arg2 and longtime boyfriend arg1" "arg2 and Mary the mother of arg1" "arg2 and Mary the Mother of arg1" "arg2 and new boyfriend arg1" "arg2 and new husband arg1" "arg2 and other half arg1" "arg2 and partner Brad arg1" "arg2 and Prince Harry arg1" "arg2 and rocker arg1" "arg2 and stepdaughter of arg1" "arg2 and suri arg1" "arg2 and the Claim arg1" "arg2 and the first season of arg1" "arg2 and the last episode of arg1" "arg2 and Tom arg1" "arg2 and tom arg1" "arg2 Angelina Jolie and arg1" "arg2 announced her engagement to arg1" "arg2 anointed the feet of arg1" "arg2 as being closer to arg1" "arg2 as the companion of arg1" "arg2 as the receptacle of arg1" "arg2 bare unto arg1" "arg2 became engaged to arg1" "arg2 became pregnant by arg1" "arg2 became pregnant with arg1" "arg2 became the bride of arg1" "arg2 became the wife of arg1" "arg2 Beckham and David arg1" "arg2 began a relationship with arg1" "arg2 breaking up with arg1" "arg2 broke up with arg1" "arg2 bullock arg1" "arg2 came to the tomb of arg1" "arg2 cheat on arg1" "arg2 Cheating on arg1" "arg2 could return with arg1" "arg2 eloped with arg1" "arg2 Engaged to arg1" "arg2 esposa arg1" "arg2 Fergie and arg1" "arg2 filed for divorce from arg1" "arg2 files for divorce from arg1" "arg2 Files for Divorce from arg1" "arg2 gal pal arg1" "arg2 gave birth to her and arg1" "arg2 gets engaged to arg1" "arg2 getting engaged to arg1" "arg2 got engaged to arg1" "arg2 got married to arg1" "arg2 had a child by arg1" "arg2 had no hand in arg1" "arg2 had to kill

Top patterns include:
A bad influence on
A child through
Abusive to
And actress Angelina
...
Commits adultery with

Question: can we leverage regularities in language to extract information in a relation-independent way?

Relations often:

- anchored in verbs
- exhibit simple syntactic form

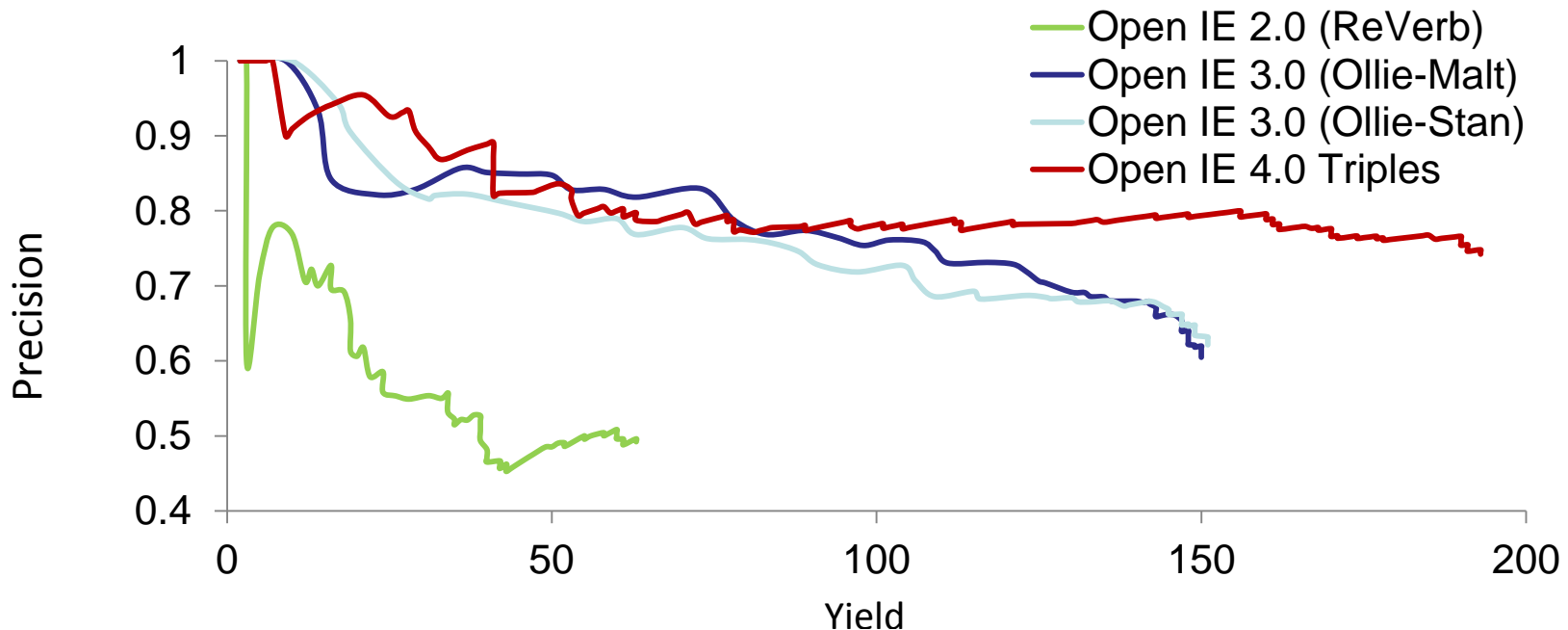


Virtues:

- No hand-labeled data
- “No sentence left behind”
- Exploit redundancy & serendipity of Web
- Robust to parser errors

History of Open IE

- 2007: 1.0 (TextRunner, auto-labeled examples, CRF)
- 2011: 2.0 (ReVerb, simple model of verb-based relations)
- 2012: 3.0 (Ollie, parser, verbs + nouns)
- 2013: 4.0 (semantic role labeling, n-ary relations)



Open Information Extraction



Argument 1: Relation: Argument 2: All

408 answers from 11543 sentences (cached)

Do you mean...

Apple Inc. (345)



Apple Inc. (NASDAQ: AAPL; formerly Apple Computer, Inc.) is an American multinational corporation that designs and sells consumer electronics, computer software, and personal computers. The company's best-known hardware products are the Macintosh line of computers, the iPod, the iPhone and the iPad. Its software includes the Mac OS X operating system; the iTunes media browser; the iLife suite of multimedia and creativity software; the iWork suite of productivity software; Aperture, a...[read more](#)

Apple (14)



The apple is the pomaceous fruit of the apple tree, species *Malus domestica* in the rose family (Rosaceae). It is one of the most widely cultivated tree fruits, and the most widely known of the many members of genus *Malus* that are used by humans. Apples grow on small, deciduous trees. The tree originated in Western Asia, where its wild ancestor, *Malus sieversii*, is still found today. Apples have been grown for thousands of years in Asia and Europe, and were brought to North America by...[read more](#)

iPad (4)



The iPad (/ ˈaɪpæd/ EYE-pad) is a line of tablet computers designed and marketed by Apple Inc., primarily as a platform for audio-visual media including books, periodicals, movies, music, games, apps and web content. Its size and weight fall between those of contemporary smartphones and laptop computers. The iPad runs on iOS, the same operating system used on Apple's iPod Touch and iPhone, and can run its own applications as well as iPhone applications. Without modification or a developer...[read more](#)

Apple Store (1)



The Apple Retail Store is a chain of retail stores owned and operated by Apple Inc., dealing in computers and consumer electronics. The stores sell Macintosh personal computers, software, iPods, iPads, iPhones, third-party accessories, and other consumer electronics such as Apple TV. Many stores feature a Theatre for presentations and workshops and a Studio for training with Apple products; all stores offer a Genius Bar for technical support and repairs, as well as free workshops available...[read more](#)



Open Information Extraction

Argument 1: Relation: Argument 2:

All ▾

289 answers from 2008 sentences (results truncated)

Apple



The apple is the pomaceous fruit of the apple tree, species *Malus domestica* in the rose family (Rosaceae). It is one of the most widely cultivated tree fruits, and the most widely known of the many members of genus *Malus* that are used by humans. Apples grow on small, deciduous trees. The most common variety is *Malus domestica*. *Malus sieversii*, is still found in the mountains of Central Asia.

Open IE is scalable but shallow!

all ingredient (37) food (33) ...

are tender (263)

fall to the ground (68)

are in bloom (68)

grow on **Tree** (58)contain **Pectin** (53)are a good source of **Dietary fiber** (40)produces **Apple** (34)are rich in **Pectin** (33)

are in season (32)

are high in **Dietary fiber** (30)fall from **Tree** (24)

is cut in half (22)

II. The Allen Institute for AI (AI2)

“In order to be truly intelligent, computers must understand— that is probably the critical word. It is one thing to feed *The Tale of Two Cities* into a computer. It’s another to have the computer understand what’s being said.”

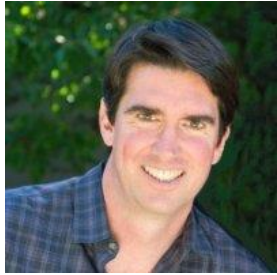
Source: (**Paul Allen**, Microcomputer Interface, **1977**)



ALLEN INSTITUTE
for ARTIFICIAL INTELLIGENCE

Mission: *contribute to the world through high-impact AI research and engineering, with emphasis on reasoning, learning, and reading capabilities.*

Scientific Advisory Board (SAB)



Adam Cheyer

Co-founder and VP Engineering at Siri, Inc.



Dan Roth

Professor at University of Illinois Urbana-Champaign, fellow of ACM, AAI, and ACL, Associate Editor in Chief of JAIR



Eric Horvitz

Director of Microsoft Research (Redmond), fellow of AAI and AAAS, AAI President (2007-09)



Dan Weld

Professor at University Washington, fellow of ACM and AAI



Tom Mitchell

Chair of Machine Learning Department, Carnegie-Mellon, fellow of AAI and AAAS, AAI Distinguished Service Award

AI2 Overview (Nonprofit Research Institute)

- Experimental science projects
- Sample of Research collaborations
 - Chris Manning, Stanford
 - Luke Zettlemoyer, UW
 - Andrew McCallum, Umass
 - Dan Roth, UIUC
- Open source initiatives
 - Open AI Resources

Discover & Discuss Open Source AI

OPEN AI Resources

Discover and Discuss the World's Open-source Artificial Intelligence Software & Data



[HOME](#) [ABOUT US](#) [FAQ](#) [FORUM](#) [SIGN IN](#)

[SUBMIT A RESOURCE](#)

RECENT ACTIVITY

- [MOST COMMENTED](#)
- [MOST LIKED](#)
- [MOST VIEWED](#)
- [MOST DISLIKED](#)

BROWSE CATEGORIES

- [APPLICATIONS \(132\)](#)
- [ARCHITECTURES AND LANGUAGES \(84\)](#)
- [EDUCATION \(7\)](#)
- [GAMES & PUZZLES \(109\)](#)
- [INTERFACES \(19\)](#)
- [MACHINE LEARNING \(280\)](#)
- [NATURAL LANGUAGE \(430\)](#)
- [REPRESENTATION AND REASONING \(233\)](#)
- [ROBOTICS \(55\)](#)
- [SENSING AND VISION \(115\)](#)
- [UNCATEGORIZED \(199\)](#)
- [WEB \(70\)](#)
- [ALL CATEGORIES \(1522\)](#)



AI2 Chronology

Key Events

AI2 launched	Jan. 2014
\$8M AI ADI Program launched	March 2014
Team of 20	April 2014
Summer Intern Program	June 2014
Machine Vision Workshop	August 2014
Team of ~50	Dec. 2015



Talent + Mission = Impact





Project Methodology:

1. Externally-defined challenge tasks
2. Training data + **unseen** test data (“as is”)
3. Measurable progress, clear focus

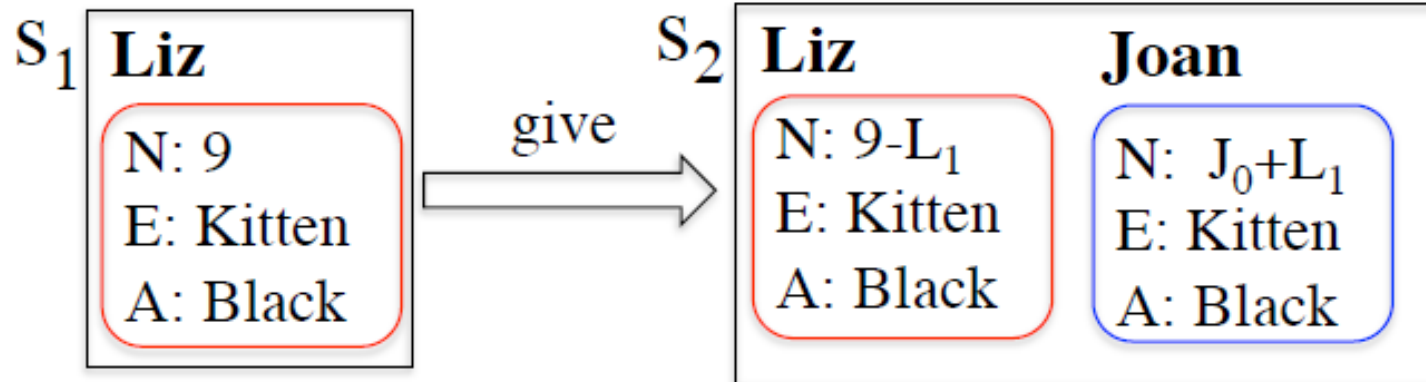
Key differences with Watson:

1. Deeper semantics & inference
2. Open model: publish, collaborate, open source

Arithmetic word Problem

Liz had 9 black kittens. She gave some of her kittens to Joan. Joan now has 11 kittens. Liz has 5 kittens left and 3 have spots. How many kittens did Joan get?

State Transition



Liz gave some of her kittens to **Joan**.

Equation: $9 - x = 5$

Solution: $x = 4$ kittens

Verb Categorization Approach (submitted)

Category	Example
Observation	There were 28 <u>bales</u> of hay in the <i>barn</i> .
Positive	<i>Joan</i> went to 4 football <u>games</u> this year.
Negative	<i>John</i> lost 3 of the violet <u>balloons</u> .
Positive Transfer	<i>Mike's dad</i> borrowed 7 <u>nickels</u> from <i>Mike</i> .
Negative Transfer	<i>Jason</i> placed 131 <u>erasers</u> in the <i>drawer</i> .
Construct	<i>Karen</i> added 1/4 of a cup of <u>walnuts</u> to a <i>batch</i> of trail mix.
Destroy	The <i>rabbits</i> ate 4 of <i>Dan's</i> <u>potatoes</u> .

Table 1: Examples for different verb categories in sentences. Entities are underlined; *containers* are italic, and verbs are bolded.

81% categorization accuracy; 77% of test problems solved

IV. First Steps in the Geometry Domain

Combines vision, NLP, and simple semantics

Data set: 100 9th grade geometry problems

To Appear in AAAI '14 (*Seo, Hajishirzi, Farhadi*, Etzioni)

In the diagram, AB intersects circle O at D , AC intersects circle O at E , $AE = 4$, $AC = 24$, and $AB = 16$. Find AD .

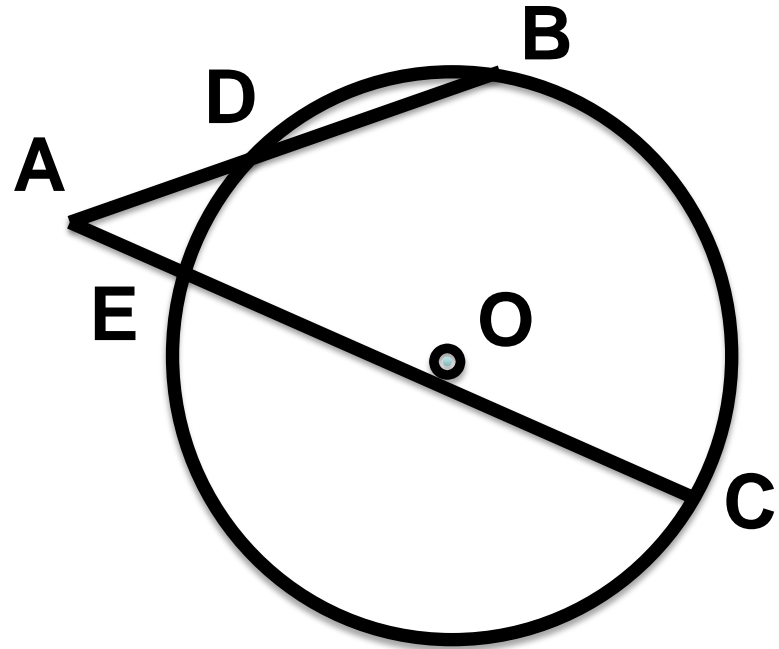


Diagram Understanding

- **Problem:** identify visual elements, their locations, their equations
- Couple with text

In the diagram, **secant AB** intersects **circle O** at **D**, **secant AC** intersects **circle O** at **E**, $AE = 4$, $AC = 24$, and $AB = 16$. Find AD .

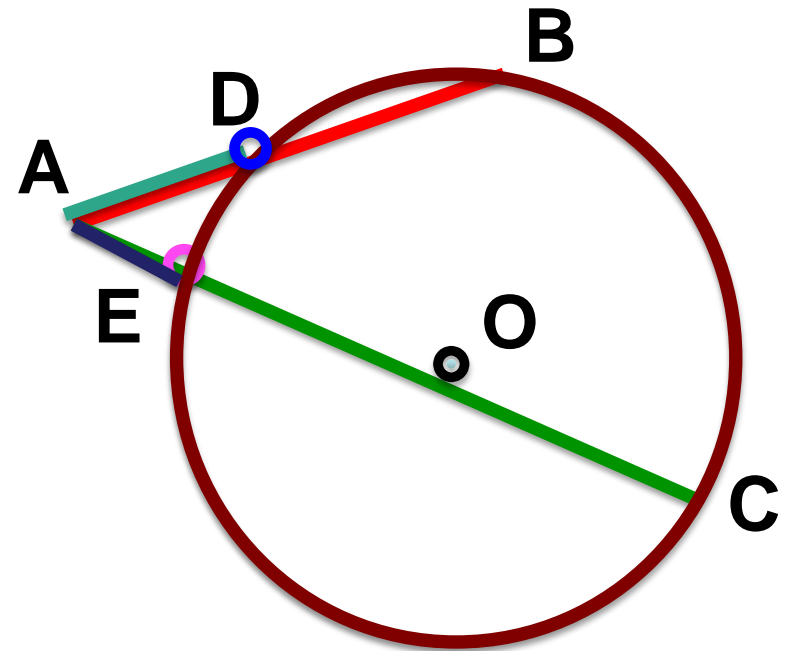


Diagram Understanding as Optimization

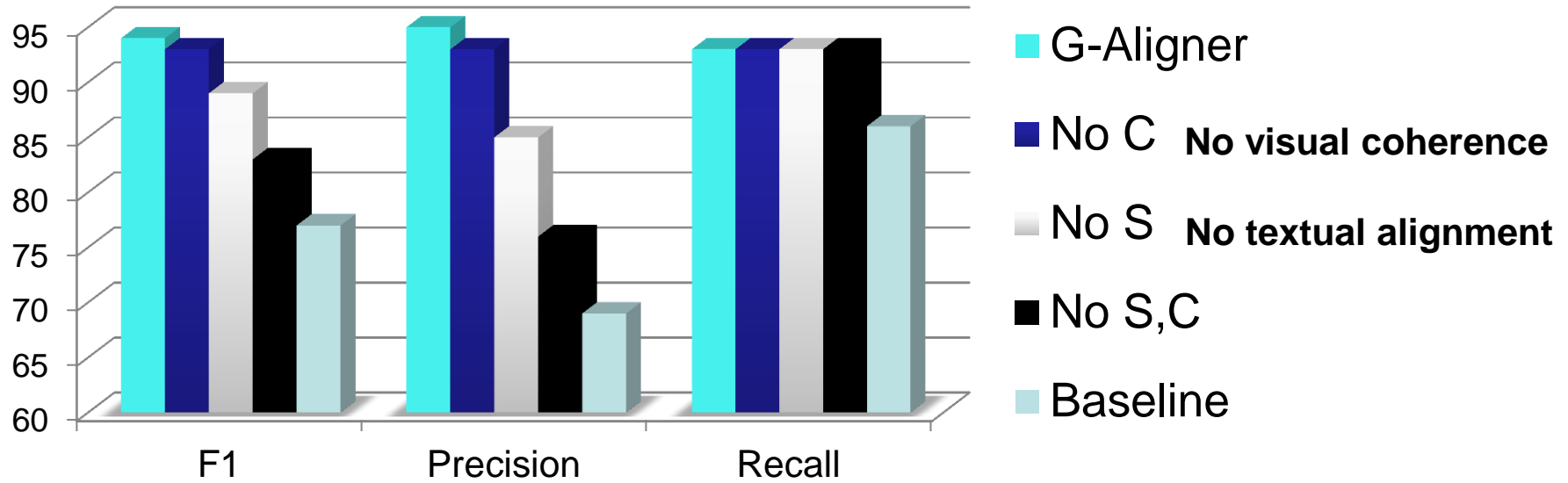
Objective function:

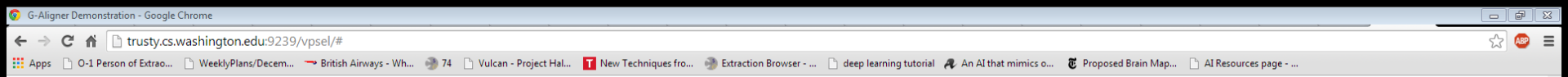
$$\hat{L} = \operatorname{argmax}_L F(\hat{L}, D, T) =$$
$$P(D, \hat{L}) \quad \text{Coverage}$$
$$+ C(C, \hat{L}) \quad \text{Visual Coherence}$$
$$+ S(T, \hat{L}) \quad \text{Text Alignment}$$

- **Bad news:** optimization requires 2^L operations
- **Good news:** function F is “submodular”

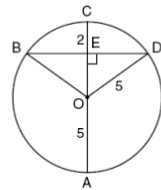
We have an algorithm that returns a $(1-1/e)$ approximation of the optimal solution!

Ablation Study



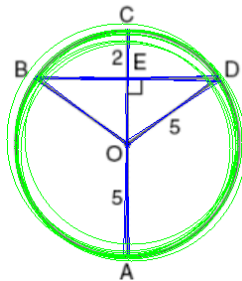


Problem Definition

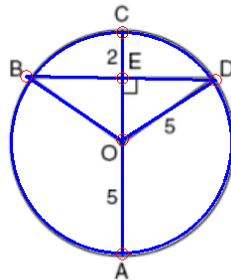


In the diagram at the left, circle O has a radius 5, and $CE = 2$. Diameter AC is perpendicular to chord BD at E. What is the length of BD?

Baseline Solution (Hough Transform)



G-Aligner Solution



In the diagram at the left, circle O has a radius 5, and $CE = 2$. Diameter AC is perpendicular to chord BD at E. What is the length of BD?

THE UNIVERSITY OF THE STATE OF NEW YORK

GRADE 4

ELEMENTARY-LEVEL SCIENCE TEST

WRITTEN TEST

JUNE 3, 2013

12 Which force causes a bicycle to slow down when the brakes are used?

- A friction
- B electricity
- C gravity
- D magnetism

More Example Questions

1 Which example describes an organism taking in nutrients?

- A a dog burying a bone
- B a girl eating an apple
- C an insect crawling on a leaf
- D a boy planting tomatoes in a garden

28 When a baby shakes a rattle, it makes a noise. Which form of energy was changed to sound energy?

- A electrical
- B light
- C mechanical
- D heat

Retrieval-based Approach (Baseline)

1 Which example describes an organism taking in nutrients?

- A a dog burying a bone
- B a girl eating an apple
- C an insect crawling on a leaf
- D a boy planting tomatoes in a garden



H_D A boy planting tomatoes in a garden is an example of an organism taking in nutrients?

Retrieval-based Approach Fails

1 Which example describes an organism taking in nutrients?

- A a dog burying a bone
- B a girl eating an apple
- C an insect crawling on a leaf
- D a boy planting tomatoes in a garden



H_D A boy **planting** tomatoes in a garden is an example **of** an organism **taking in nutrients**?



Best
matching
sentence

The roots **of** the **plant take in** water and **nutrients**.



Answer is D 

Another Example

27 Fourth graders are planning a roller-skate race. Which surface would the best for this race?

A gravel

B sand

C blacktop

D grass



**World knowledge
necessary for NLP!**

I. Winograd Schemas and Knowledge (1972)

The city councilmen refused the demonstrators a permit because **they** [feared/advocated] violence.

They = ?

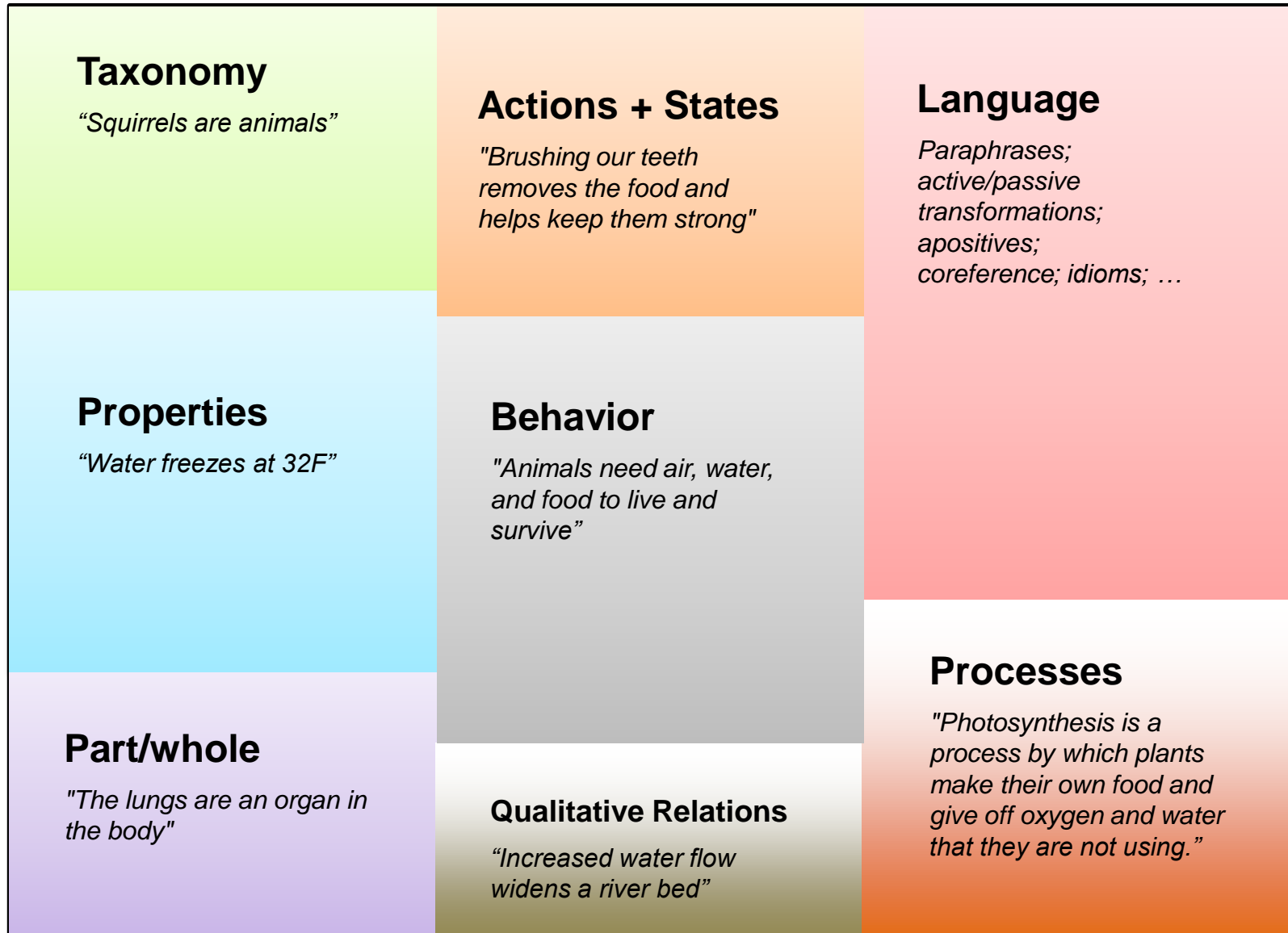
The large ball crashed right through the table because **it** was made of *styrofoam*.

It = table

The large ball crashed right through the table because **it** was made of *steel*.

It = ball

Factual Knowledge for 4th Grade Science



Sample Co-reference Challenges

Some birds fly south before winter each year. **This** is an example of (A) migration (B) hibernation (C) germination (D) evaporation

A student has a ball of clay that sinks when placed in a pan of water. **Which property** should he change to make the clay float? (A) color (B) texture (C) mass (D) shape

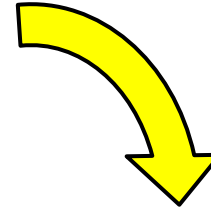
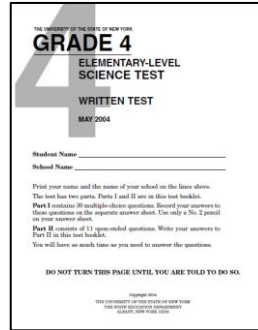
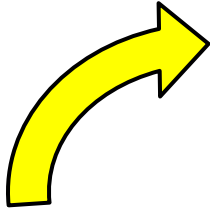
The diagram below shows an electrical circuit. The purpose of **the copper wire** is to (A) conduct electricity (B) produce electricity (C) store electricity (D) stop the flow of electricity

Entailment Challenges

- Absorb → take in
- 24 hours → day
- Lunch → Dinner
- Blue eyes → color of your eyes
- Disappear → evaporate
- Cold → decrease in temperature
- Gas → gaseous state
- Good health habit → be healthy
- **Verb synonym**
- **Phrase synonym**
- **“Siblings”**

Current Methodology

Give Aristo an exam



Mixture of:

Lexical Inference Logical Inference

{move, object, Earth}

move(X, to(Earth))



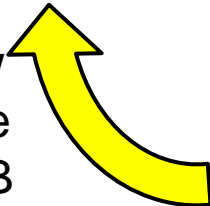
{fall, ball, ground}

fall(X, to(ground))

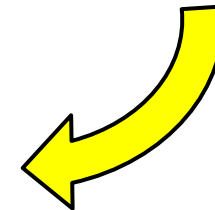
- 1. ● B C D
- 2. A B ● D ✗
- 3. A ● C D
- 4. A ● C D
- 5. A B C ● ✗

Identify where correct answer was not selected (inference path too weak)

Inject new knowledge into the KB



Identify missing knowledge



Is it all “about” Knowledge?

What about semantics?

Semantics: Treatment of Generics:

Fruits contain seeds = ?

- Two big issues: quantifier **scope** and **strength**
 - All (most? many?) fruits contain a seed?
 - All (most? many?) seeds are contained in a fruit?
 - All fruits contain all? some? seeds?
 - ...
- Pragmatic approximation:
 - Take the most common (forall-exists) interpretation, and the reverse
 - a. If it's a **fruit**, it contains a **seed** (with some confidence)
 - b. If it's a **seed**, it's contained in a **fruit** (with some confidence)

Formal representation:

∇ Fruit isa(Fruit,"fruit") → ∃ Seed isa(Seed,"seed"), contain(Fruit,Seed) @ weight 1.0

∇ Seed isa(Seed,"seed") → ∃ Fruit isa(Fruit,"fruit"), contain(Fruit,Seed) @ weight 1.0

Semantics: (Word Senses)

What do words mean? “animal”, “cat”, “bank”, ...

▪ **Traditional approach:**

- map words/phrases to an ontology at reading time:

- “animal” → **Animal**
- “cat”, “kitty” → **Cat**
- ...

- **but:** requires *anticipating all the needed distinctions* up front, before a particular task is encountered

▪ **Deferred decisions** (a lesson from Watson):

- *preserve words/phrases* in the representation itself

∇ Fruit isa(Fruit, "fruit") → ∃ Seed isa(Seed, "seed"), contain(Fruit, Seed)

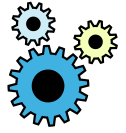


- make ontology decisions as needed at runtime *in context*

- “person” isa “animal”?
- “water” isa “basic need”?
- “shiny crimson” isa “bright color”?

Summary of our Approach

1. Knowledge + tractable reasoning is necessary for AI



2. Knowledge acquisition has to be highly automated



3. **Large** bodies of **high-quality** knowledge can be acquired from text (“machine reading”)



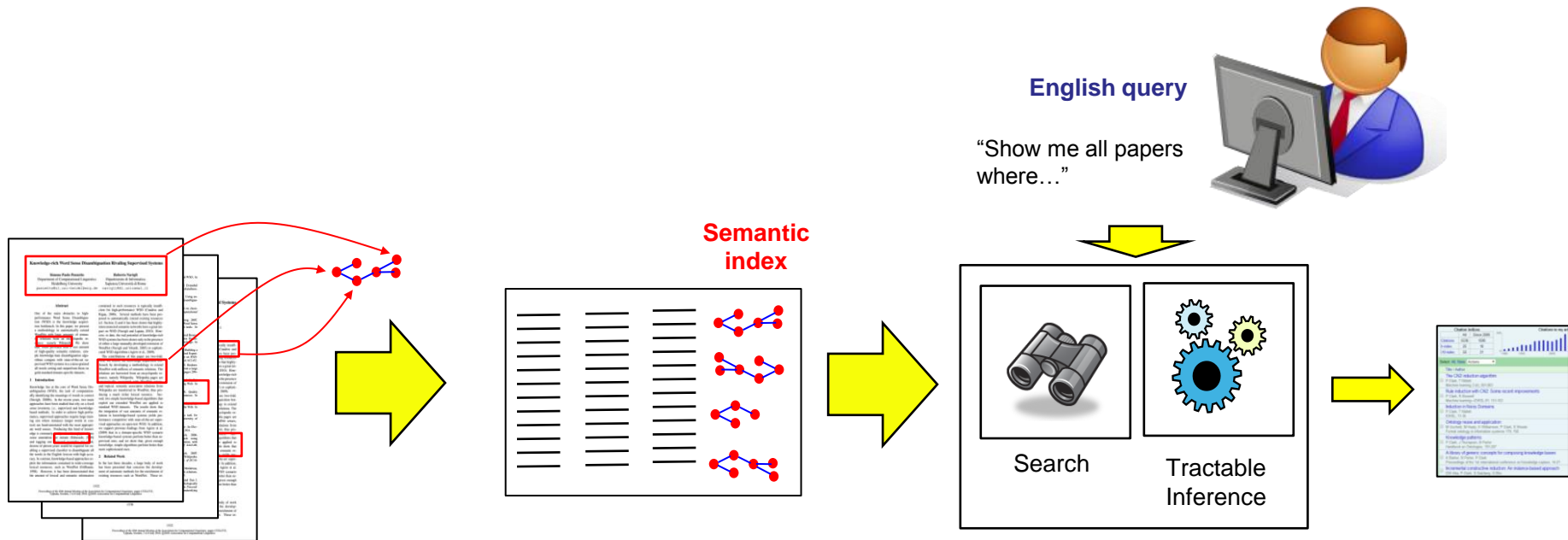
4. Aristo is tested on unseen, standardized, multiple choice tests in science, arithmetic, and geometry



Semantic challenges everywhere...

VI. Semantic Scholar Project

"Show all papers where x is implicated in y where the levels of z are elevated"...



"lift all scientific boats"

[Search](#)
[Show advanced](#)
[List](#)
[Map](#)
[Table of Contents](#)

Filter results

CLASSIFICATION

 [Introductory](#)

 [Survey](#)

 [Empirical](#)

 [Theoretical](#)

 [Application](#)

GROUP

[CMU](#)

[Bayesians](#)

[Mueller](#)

[See more](#)

TOPIC

[Model Construction](#)

[Deep Learning](#)

[Story Understanding](#)

[Machine Learning](#)

[Multi Representation](#)

[See more](#)

  **Story Understanding Through Multi-representation Model Construction**

12 References Cited by 34 Erik T. Mueller 2003

We present an implemented model of story understanding and apply it to the understanding of ...

MODEL CONSTRUCTION ▾ DEEP LEARNING ▾

  **Automatic Analysis of Plot for Story Rewriting**

18 References Cited by 28 Harry Halpin, Johanna D. Moore, Judy Robertson 2011

We argue that understanding a story consists of building multirepresentation models of the story ...

MODEL CONSTRUCTION ▾ DEEP LEARNING ▾ STORY GENERATION ▾ INFORMATION EXTRACTION ▾

  **A News Story Categorization System**

27 References Cited by 20 Philip J. Hayes, Laura E. Knecht, Monica J. Cellio 2001

We present a computer program that contains multiple representations of commonsense knowledge...

NATURAL LANGUAGE ▾ DISCOURSE ANALYSIS ▾ MESSAGE UNDERSTANDING ▾

  **A Modular Approach to Story Generation**

13 References Cited by 53 Lyn Pemberton 1999

We transform the narrative and representations of commonsense knowledge into a satisfiability ...

STORY GENERATION ▾ INFORMATION EXTRACTION ▾ NATURAL LANGUAGE PROCESSING ▾ DISCOURSE ANALYSIS ▾ MESSAGE UNDERSTANDING ▾ AUTOSLOG ▾ TERRORISM ▾

  **Deep Sentence Understanding in a Restricted Domain**

11 References Cited by 54 Pierre Zweigenbaum, Marc Cavazza 1990

We present an approach for understanding goal-based stories that combines model finding and ...

DEEP LEARNING ▾ INFORMATION EXTRACTION ▾

  **Computing Story Trees**

7 References Cited by 13 Alfred Correia 1980

We present an algorithm that takes narrated actions, narrated properties, and a domain description

COMPUTING ▾ MACHINE LEARNING ▾

deep learning applied to story understanding

Search

Show advanced

List **Map** Table of Contents

Filter results

CLASSIFICATION

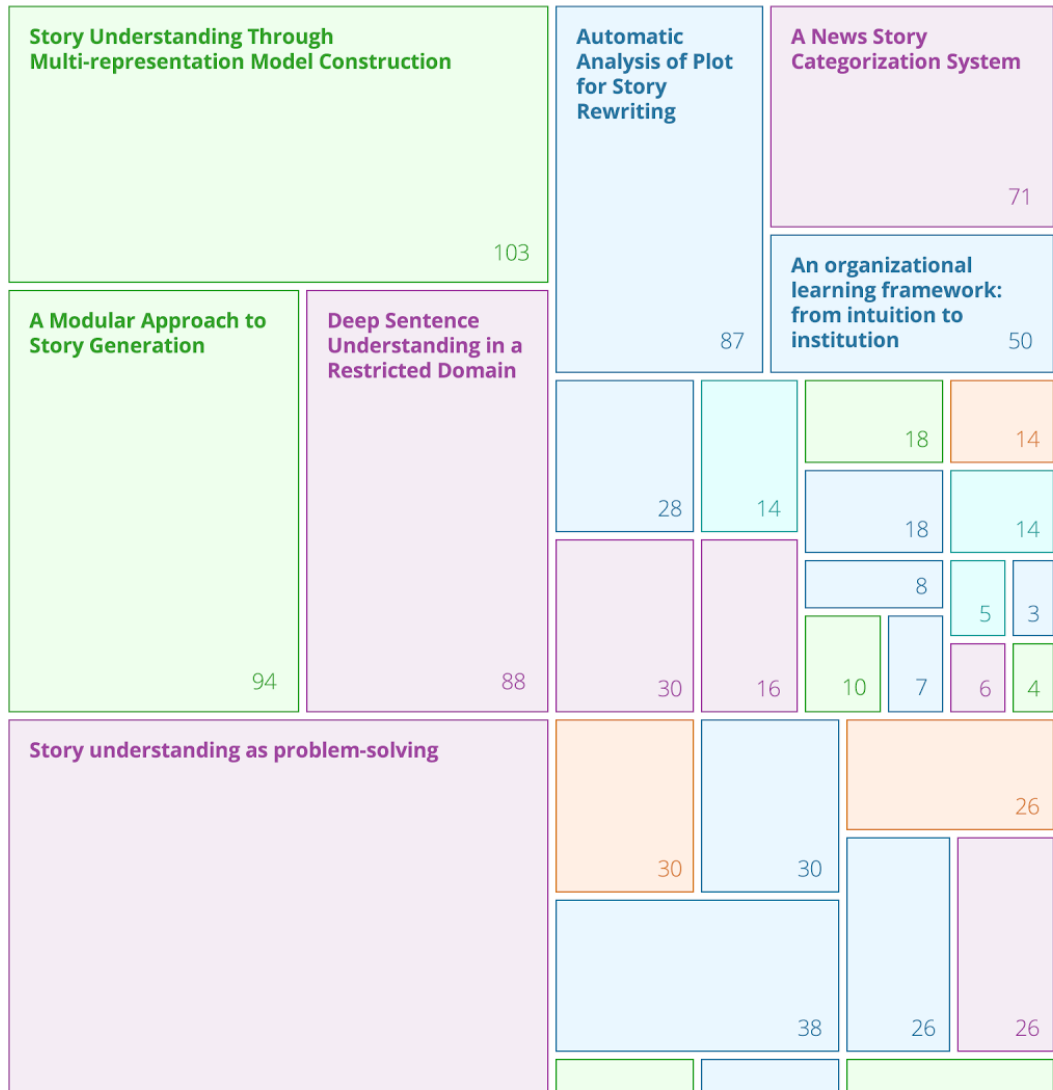
- Introductory
- Survey
- Empirical
- Theoretical
- Application

GROUP

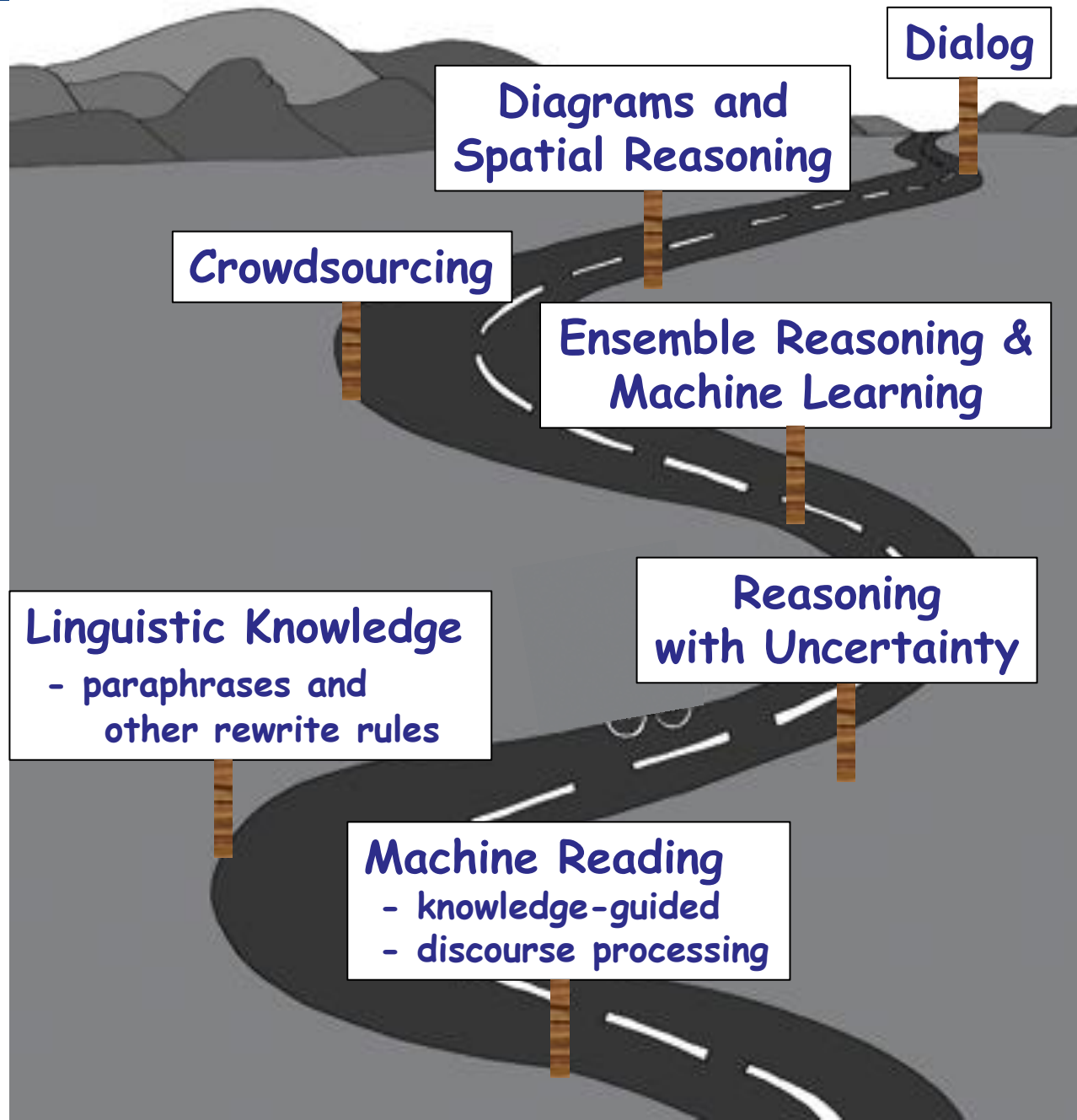
- CMU
- Bayesians
- Mueller
- See more ▾

TOPIC

- Model Construction
- Deep Learning
- Story Understanding
- Machine Learning
- Multi Representation
- See more ▾



Technologies on our Roadmap



Conclusion: Join us!