CS 4650/7650
Information Extraction and Question Answering[1]

Jacob Eisenstein

November 12, 2013

[1]Some material from Brendan O'Connor, Claire Cardie, and the FASTUS team.

Course roadmap

- Words (WSD, classification and morphology)
- Sequences (tagging)
- Trees (parsing)
- Semantics and discourse
- **Applications**
  - Today: knowledge from text
  - Next week: machine translation

Knowledge from text

- **Information extraction**
  - input: schema of desired knowledge base
  - output: populate schema from text resources
- **Question answering**
  - input: natural language questions
  - output: natural language answers
  - intermediate representation usually includes structured knowledge base

(see wolfram alpha video)

WolframAlpha computational... knowledge engine

what are the three lightest metals?

Examples Random

Input interpretation:

3 lightest metallic elements

Results:

By atomic weight: More

1	lithium	6.941 u	
2	beryllium	9.012182 u	
3	sodium	22.98976928 u	

⋮

By density: More

1	lithium	0.535 g/cm^3	
2	potassium	0.856 g/cm^3	
3	sodium	0.968 g/cm^3	

⋮

Units »

Computed by Wolfram *Mathematica* Source information » Download page

WolframAlpha computational knowledge engine

how expensive are the three lightest metals?

Examples Random

Using closest Wolfram|Alpha interpretation: **three lightest metals**

More interpretations: expensive

Input interpretation:

3 lightest metallic elements

Results:

By atomic weight: More

1	lithium	6.941 u	
2	beryllium	9.012182 u	
3	sodium	22.98976928 u	

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By density: More

1	lithium	0.535 g/cm^3	
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WolframAlpha computational knowledge engine

what is the lightest radioactive element?

Examples Random

Input interpretation:

lightest radioactive elements

Results:

By atomic weight: More

1	technetium	98 u	
2	promethium	145 u	
3	polonium	209 u	
4	astatine	210 u	
5	radon	222 u	

By density: More

1	radon	0.00973 g/cm^3	
2	radium	5 g/cm^3	
3	promethium	7.264 g/cm^3	
4	polonium	9.196 g/cm^3	
5	actinium	10.07 g/cm^3	

WolframAlpha computational knowledge engine

what is the lightest element which is radioactive?

Examples Random

Assuming "element" is elements | Use as a class of elements instead

Input interpretation:

lightest radioactive elements

Results:

By atomic weight: More

1	technetium	98 u
2	promethium	145 u
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By density: More

1	radon	0.00973 g/cm^3
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WolframAlpha computational... knowledge engine

of all of the radioactive elements, which is the lightest?

Examples Random

Using closest Wolfram|Alpha interpretation: **the radioactive elements**

More interpretations: elements which

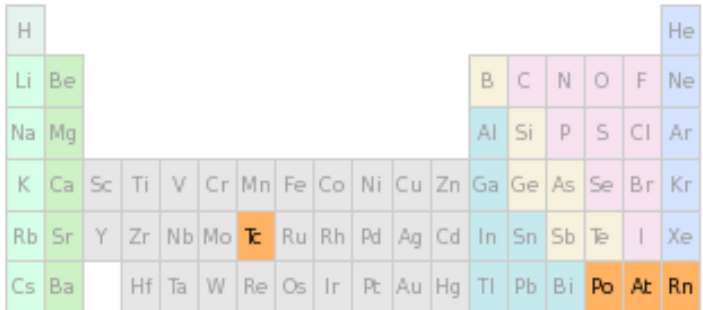
Input interpretation:

radioactive elements

Members: More

actinium | americium | astatine | berkelium | bohrium | californium | copernicium | curium | darmstadtium | dubnium | einsteinium | fermium | francium | hassium | lawrencium | meitnerium | mendelevium | neptunium | nobelium | plutonium | ... (total: 37)

Periodic table location:



Knowledge extraction in NLP

Knowledge extraction requires solving lots of NLP problems

- understand the source data (syntax, discourse, semantics)
- understand the query
- reason about how they fit together

Outline

Information Extraction
- Finding entities
- Entity linking
- Relation extraction
- Event detection

The six Ws

- Who, what, where, when, why, how?
- IE is mostly concerned with the first four.

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- Who, what, where, when, why, how?
- IE is mostly concerned with the first four.
  - **who/where**: named entity extraction and coreference (we've already talked about this)
  - **what**: usually defined in terms of *relations* between entities
  - **when**
    - parsing time expressions, finding the temporal order of events
    - this is a big part of IE, but I'm not going to talk about it today

The Information Extraction pipeline

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Named entity recognition

Find and tag **mentions** of **entities** in text.

At a meeting of <ORG>the Thirteen</ORG>,
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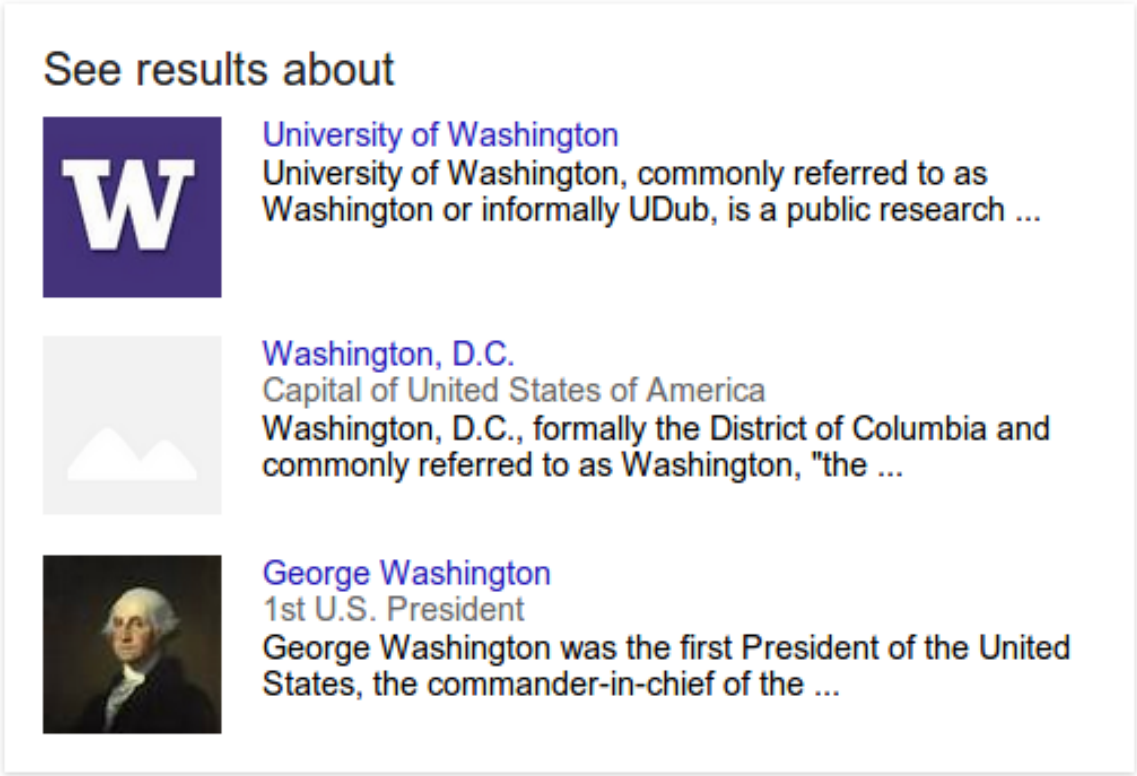
Entity linking

Goal: link entity mentions to knowledge base entries.
Like multi-document coreference resolution, but must ultimately resolve to KB entry.



Entity linking: challenges

From Rao et al (2010)

1. Name variations: Boston Symphony Orchestra vs BSO, Qaddafi vs Gadaffi, etc
2. Name polysemy: Washington (person, place, football team, US Government, ...)
3. Absence: many entities do not appear in the KB.

In combination, these challenges are especially pernicious: William Clinton is a variation of Bill Clinton, but appears in Wikipedia as two other individuals.

Entity linking: steps

Candidate identification

- Brute force: check Google Knowedge Graph for all strings that could link to an entity
- Add source document coreference resolution

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Ranking Supervised formulation (Dredze et al 2010):

$$\begin{aligned} \min_{\mathbf{w}} \quad & ||\mathbf{w}||_2^2 \\ s.t. \quad & \mathbf{w}^\mathsf{T} f(\mathbf{x}_i, y_i) > \max_{\hat{y} \neq y_i} \mathbf{w}^\mathsf{T} f(\mathbf{x}_i, \hat{y}) \end{aligned}$$

Features:

- String match
- Popularity
- Local context and entity type
- Document context (similar entities)

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Relations

A relation is a *predication* about a pair of entities.

- Davos **works for** Stannis
- King's Landing **is in** Westeros
- Joffrey's **father is** Jaime

Relations are typically permanent.

Example relations

From the Automatic Content Extraction (ACE) 2004 Task:

relation type	*subtypes*
physical	located, near, part-whole
personal-social	business, family, other
employment/membership/ subsidiary	employ-executive, employ-staff, employ-undetermined, member-of-group, partner, subsidiary, other
agent-artifact	user-or-owner, inventor-or-manufacturer, other
person-org affiliation	ethnic, ideology, other
GPE affiliation	citizen-or-resident, based-in, other
discourse	-

Relations in text

- Typically we focus on cases in which the relation and the two entities are all mentioned in the same sentence. (Exception: Robert and Cersei were married. A son was born the next year)

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- **Micro-reading**: correctly identify every relation *mention*
- **Macro-reading**: correctly identify every relation in the text

Knowledge-base population (KBP)

Extract attributes for each named person or organization:

entity	house	father	mother	position
Arya	Stark	Eddard	Catelyn	
Daenerys	Targaryen	Aerys		Mother-of-dragons
Qhorin	commoner			Knight-of-the-Watch

KBP is similar to relation extraction.

- Columns define relation types
- Rows define the left entity
- Cells define the right entity

Relations from patterns

- Early idea: lexical patterns, like regular expressions
- Possible patterns for PERSON lives-in LOCATION:
  - PERSON lives in LOCATION
  - PERSON lived in LOCATION
  - PERSON has lived in LOCATION
  - PERSON resides in LOCATION

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  - morphological analysis
  - phrase chunking

Relations from patterns

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- Possible patterns for PERSON LIVES-IN LOCATION:
  - PERSON <VGROUP SYNSET=LIVE#1> in LOCATION
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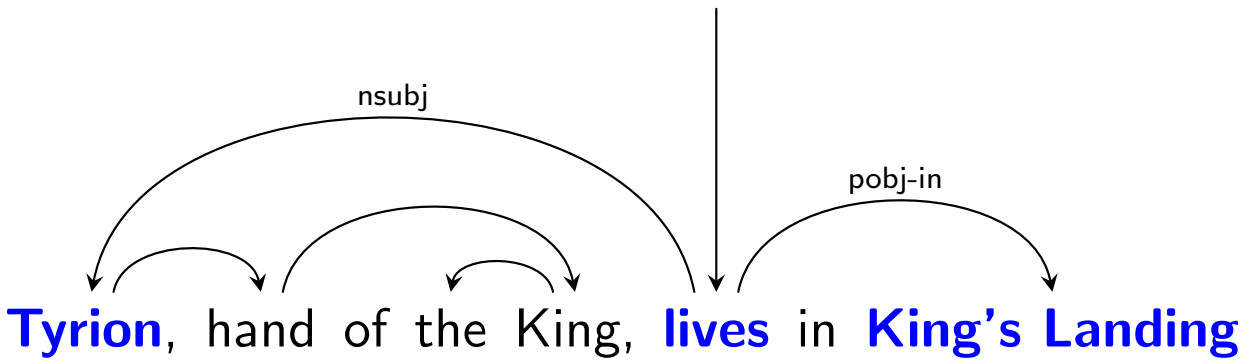
  - lexical semantics

Syntactic patterns

Given a dependency parse, we can define more flexible patterns:



Supervised relation extraction

We can develop a classifier for each relation type, or a general classifier for detecting relations of any type.

- Feature-based classification (**Features**: heads of each entity, types of each entity, distance between entities, words between entities, dependency path between entities, ...)
- Kernel-based classification
  - Kind of like K-nearest-neighbors classification
  - The label for a test instance should be based on similar training instances

Whirlwind tour of kernel-based classification

- The kernel function maps from pairs of instances to a non-negative real value.

$$K : \mathcal{X} \times \mathcal{X} \to \mathbb{R}_+$$

  - $K(x_1, x_2)$ is large for similar x_1, x_2, small if they are different
  - K can count number of shared words, etc.

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- Classification rule:

$$\hat{y}(\mathbf{x}) = \sum_i y_i \alpha_i K(\mathbf{x}, \mathbf{x}_i) + b$$

  - Each $\alpha_i \geq 0$ is a parameter, which must be learned.
  - $\#|\alpha| = \#|\mathbf{x}|$, regardless of number of features

Other training paradigms: bootstrapping

- Start with a few seed patterns
- Extract some high-confidence relations
- Induce more patterns
- Extract more relations
- ...

Other training paradigms: distant learning

- Start with a large set of known relations (e.g. from Freebase)
- Collect all sentences that include both entities in the relation. These are positive training instances.
- Sample negative training instances (for example, sentences that contain one entity in a relation but not both).
- a.k.a. multi-instance learning

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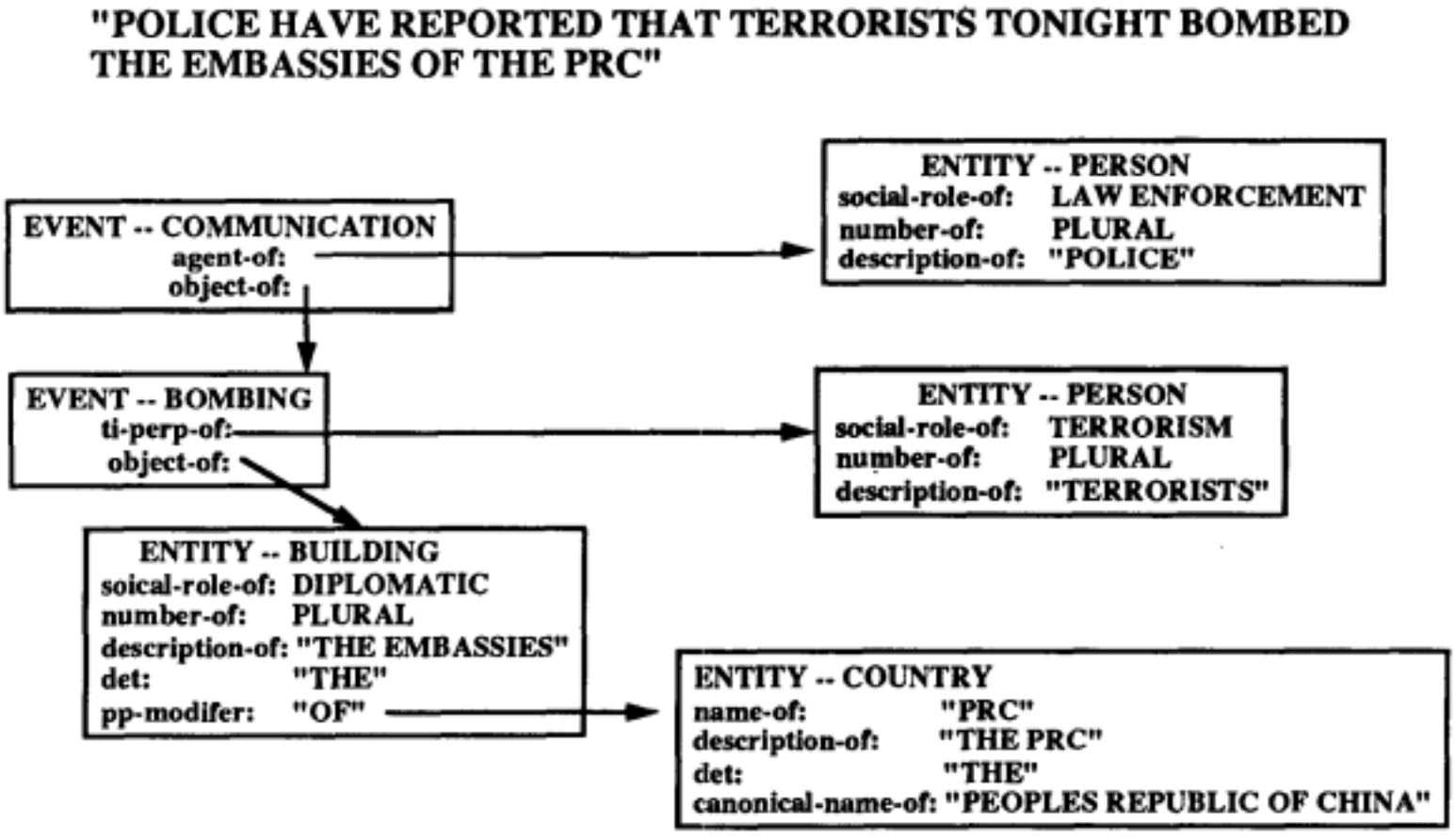
Event extraction

- **Relations** are predications involving two arguments.
- **Events** are predications involving arbitrary numbers of arguments.

Event type	Subtypes
Life	Be-born, Marry, Divorce, Injure, Die
Movement	Transport
Transaction	Transfer-ownership, Transfer-money
Business	Start-org, Merge-org, Declare-bankruptcy, End-org
Conflict	Attack, Demonstrate
Personnel	Start-position, End-position, Nominate, Elect
Justice	Arrest-jail, Release-parole, Trial-hearing Charge-indict, Sue, Convict, Sentence, Fine, Execute, Extradite, Acquit, Appeal, Pardon

Representing events



Event templates

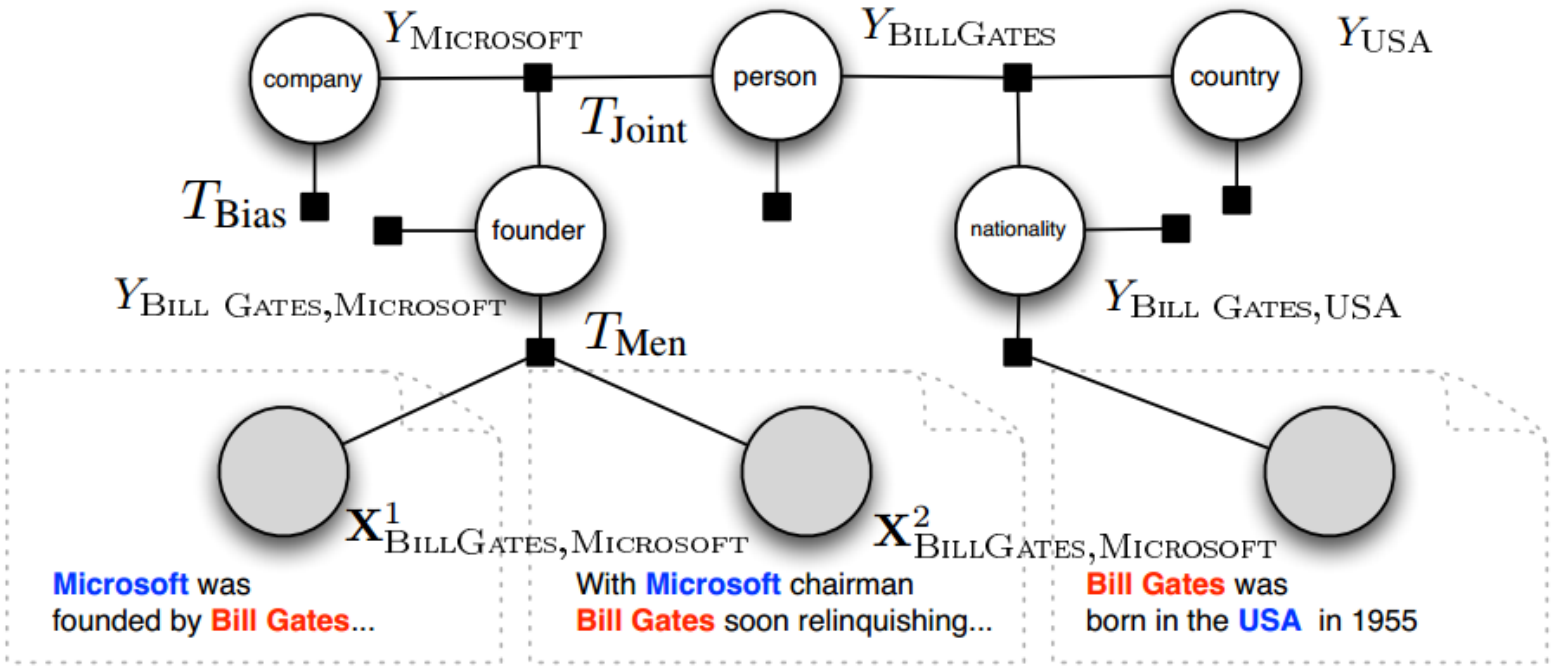
In supervised event extraction, each event type has a template of relevant attributes.

0.	MESSAGE ID	TST1-MUC3-0099
1.	TEMPLATE ID	1
2.	DATE OF INCIDENT	- 25 OCT 89
3.	TYPE OF INCIDENT	BOMBING
4.	CATEGORY OF INCIDENT	TERRORIST ACT
5.	PERPETRATOR: ID OF INDIV(S)	"TERRORISTS"
6.	PERPETRATOR: ID OR ORG(S)	-
7.	PERPETRATOR CONFIDENCE	-
8.	PHYSICAL TARGET: ID(S)	"THE EMBASSIES"
9.	PHYSICAL TARGET: TOTAL NUM	PLURAL
10.	PHYSICAL TARGET: TYPE(S)	DIPLOMAT OFFICE OR RESIDENCE: "THE EMBASSIES"
11.	HUMAN TARGET: ID(S)	-
12.	HUMAN TARGET: TOTAL NUM	-
13.	HUMAN TARGET: TYPE(S)	-
14.	TARGET: FOREIGN NATIONS	-
15.	INSTRUMENT: TYPE(S)	*
16.	LOCATION OF INCIDENT	EL SALVADOR: SAN ISIDRO (TOWN)
17.	EFFECT ON PHYSICAL TARGET	SOME DAMAGE: "THE EMBASSIES"
18.	EFFECT ON HUMAN TARGET	NO INJURY: "-"

Typical approach: train classifiers for each slot in the template

Collective relation extraction

Joint reasoning about both language understanding and the underlying semantics.



(Yao, Riedel, and McCallum, 2010)

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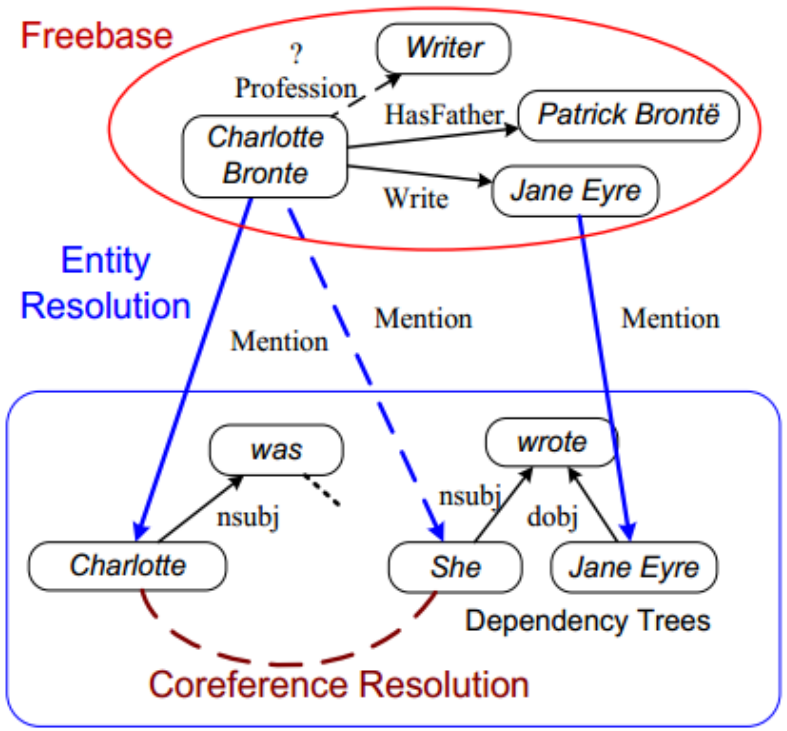


(Lao, Subramanya, Pereira, and Cohen, 2012)

Special cases: time

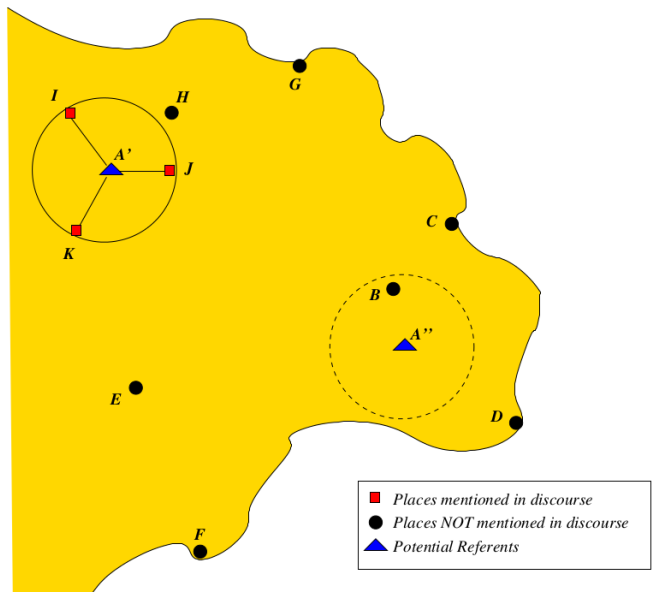
Expression	*Type*	*Value*
October of 1963	DATE	1963-10
October	DATE	2011-10
last Friday	DATE	2011-09-16
next weekend	DATE	2011-W39-WE
the day after tomorrow	DATE	2011-09-21
the nineties	DATE	199X
winter of 2000	DATE	2000-WI
5th century B.C.	DATE	-05XX
now	DATE	PRESENT_REF
Saturday morning	TIME	2011-09-24TMO
4 p.m. Tuesday	TIME	2011-09-20T16:00

- SUTIME is a rule-based system for parsing time expressions.
- Recent work (Agneli et al) has focused on statistical parsing.

Special cases: space

Location descriptions also have a structure that is hierarchical and complex, yet arguably tractable.

- the first gas station after you cross under the 85 on Peachtree Road in Vinings
- on the left after you come up stairs in TSRB
- in the bottom of a drawer in the cabinet opposite the green bookcase



The problem of resolving place names is **toponym resolution**.

Next steps: beliefs and evidence

- Possibly factual: United States may extend its naval quarantine to Jordans Red Sea port of Aqaba.
- Possibly counter-factual: They may not have enthused him for their particular brand of political idealism.
- Source-specific facuality: Izvestiya **said** that the G-7 leaders **pretended** everything was OK in Russia's economy.
- Epistemic marking: He saw the gunman, The WSJ editorial page speculated ...

FactBank is a corpus of factuality annotations (Saurí and Pustejovsky 2009).

	Positive (+)	Negative (−)	Underspecified (u)
Certain (CT)	Fact: <CT,+>	Counterfact: <CT,−>	Certain but unknown output: <CT,u>
Probable (PR)	Probable: <PR,+>	Not probable: <PR,−>	(NA)
Possible (PS)	Possible: <PS,+>	Not certain: <PS,−>	(NA)
Underspecified (U)	(NA)	(NA)	Unknown or uncommitted: <U,u>