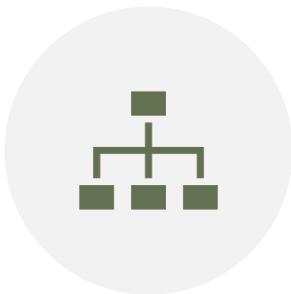


Reminders



HOMEWORK 8 DUE DATE
IS DUE BY MIDNIGHT ON
4/1.



QUIZ ON CHAPTERS 12-
14 IS DUE TONIGHT AT
11:59PM



IF DOING HW OPTION,
BE SURE TO DO IRB
TRAINING ASAP

Wrap Up: Logical Representation of Sentence Meaning

JURAFSKY AND MARTIN CHAPTER 16

Review: Desirable Properties for Meaning Representations

1. **Verifiability** – compare some meaning representation (MR) to a representation in a knowledge base (KB).
2. **Unambiguous Representations** – each ambiguous natural language meaning corresponds to a separate MR
3. **Canonical Forms** – paraphrases are collapsed to one MR
4. **Make Inferences** – draw valid conclusions based on the MR of inputs and its background knowledge in KB
5. **Match variables** – variables can be replaced by some object in the KB so an entire proposition will then match

Model-Theoretic Semantics

A **model** allows us to bridge the gap between a formal representation and the world. The model stands in for a particular state of affairs in the world.

The **domain** of a model is the set of objects that are being represented. Each distinct thing (*person, restaurant, cuisine*) corresponds to a unique element in the domain

Properties of objects (like whether a restaurant is *expensive*) in a model correspond to sets of objects.

Relations between object (like whether a restaurant *serves* a cuisine) are are sets of tuples.

Domain	$\mathcal{D} = \{a, b, c, d, e, f, g, h, i, j\}$
Matthew, Franco, Katie and Caroline	a, b, c, d
Frasca, Med, Rio	e, f, g
Italian, Mexican, Eclectic	h, i, j

Properties

Noisy $Noisy = \{e, f, g\}$

Frasca, Med, and Rio are noisy

Relations

Likes

Matthew likes the Med

Katie likes the Med and Rio

Franco likes Frasca

Caroline likes the Med and Rio

$Likes = \{\langle a, f \rangle, \langle c, f \rangle, \langle c, g \rangle,$
 $\langle b, e \rangle, \langle d, f \rangle, \langle d, g \rangle\}$

Serves

Med serves eclectic

Rio serves Mexican

Frasca serves Italian

$Serves = \{\langle f, j \rangle, \langle g, i \rangle, \langle e, h \rangle\}$

Domain

Matthew, Franco, Katie and Caroline
Frasca, Med, Rio
Italian, Mexican, Eclectic

Properties

Noisy

Frasca, Med, and Rio are noisy

Relations

Likes

Matthew likes the Med

Katie likes the Med and Rio

Franco likes Frasca

Caroline likes the Med and Rio

Serves

Med serves eclectic

Rio serves Mexican

Frasca serves Italian

$$\mathcal{D} = \{a, b, c, d, e, f, g, h, i, j\}$$

$$a, b, c, d$$

$$e, f, g$$

Katie likes Rio

Katie → c

Rio → g

likes → Likes

$$\text{Likes} = \{\langle a, f \rangle, \langle c, f \rangle, \langle c, g \rangle, \langle b, e \rangle, \langle d, f \rangle, \langle d, g \rangle\}$$

$\langle c, g \rangle \in \text{Likes}$

so *Katie likes Rio*

is True

$\} \}$

Review: First-Order Logic

FOL is a meaning representation language that satisfies the desirable qualities that we outlined. It provides a computational basis for **verifiability** and **inference**.

1. Truth conditions for logical formula involving terms and predicates like Near (Goldie, Upenn)
2. Truth conditions for multiple formula with logical connectives
3. Truth conditions for quantifiers

Review: Logical Connectives

We can conjoin formula with logical connectives like **and** (\wedge), **or** (\vee), **not** (\neg), and **implies** (\Rightarrow)

Each one has a **truth table**:

P	Q	$P \vee Q$
<i>False</i>	<i>False</i>	<i>False</i>
<i>False</i>	<i>True</i>	<i>True</i>
<i>True</i>	<i>False</i>	<i>True</i>
<i>True</i>	<i>True</i>	<i>True</i>

Review: Quantifiers and Variables

There are two quantifiers in FOL:

1. **Existential quantifier** – \exists – “There exists” – Is true if it holds at least one thing that matches the variable
2. **Universal quantifier** – \forall – “For all” – Is true if it holds true for all of the things that match the variable

Review: Existential Quantifier

There is a restaurant that serves Mexican food near Penn

We use the existential quantifier and a variable to represent the indefinite noun phrase “a restaurant”.

```
 $\exists x \text{ Restaurant}(x) \wedge \text{Serves}(x, \text{MexicanFood}) \wedge$   
 $\text{Near}(\text{LocationOf}(x), \text{LocationOf}(Penn))$ 
```

For this to be true there must be at least one object such that if we were to substitute it for the variable x, the resulting formula would be true.

Review: Universal Quantifier

All restaurants in Philly are closed.

```
 $\forall x \text{Restaurant}(x) \wedge \text{Is}((\text{LocationOf}(x), \\ \text{Philadelphia}) \\ \Rightarrow \text{Closed}(x))$ 
```

The \forall operator states that for the logical formula to be true, the substitution of **any object** in the knowledge base for the **universally quantified variable** should result in a true formula.

Lambda Notation

Lambda notation provides a way to abstract from fully specified FOL formulas by **matching variables**.

$$\lambda x. P(x)$$

Such expressions consist of the symbol λ , followed by one or more variables, followed by a FOL formula that makes use of those variables

This process of λ -reduction consists of a simple textual replacement of the λ variables and the removal of the λ .

$$\lambda x. P(x) (A)$$

$$P(A)$$

Lambda Example

One λ -expression can be used within another:

$$\lambda x. \lambda y. \text{Near}(x, y)$$

Apply lambda λ -reduction to x:

$$\lambda x. \lambda y. \text{Near}(x, y) \text{ (Bacaro)}$$

$$\lambda y. \text{Near}(\text{Bacaro}, y)$$

Apply lambda λ -reduction to y:

$$\lambda y. \text{Near}(\text{Bacaro}, y) \text{ (Centro)}$$

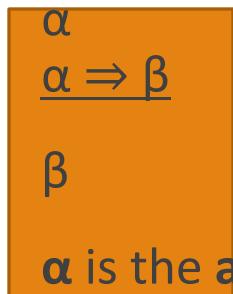
$$\text{Near}(\text{Bacaro}, \text{Centro})$$

λ -notation provides a way to incrementally gather arguments to a predicate

Inference

A meaning representation language must support inference to add valid new propositions to a knowledge base or to determine the truth of propositions not explicitly in the KB.

Modus ponens provides if-then reasoning:



α is the antecedent

β is the consequent

Inference

VegetarianRestaurant(Leaf)

$\forall x \text{VegetarianRestaurant}(x) \Rightarrow \text{Serves}(x, \text{VegetarianFood})$

Serves(Leaf ,VegetarianFood)

Here, the formula *VegetarianRestaurant(Leaf)* matches the antecedent of the rule, thus allowing us to use modus ponens to conclude *Serves(Leaf ,VegetarianFood)*.

Forward Chaining

Forward chaining systems use modus ponens whenever new individual facts are added to the KB.

All applicable implication rules are found and applied, each resulting in the addition of new facts to the knowledge base.

These new propositions can also be used to fire implication rules applicable to them. The process continues until no further facts can be deduced.

Backward Chaining

In **backward chaining**, modus ponens is run in reverse to prove specific propositions called **queries**.

1. See if the query formula is true by determining if it is present in the knowledge base.
2. If not, search for applicable implication rules present in the knowledge base.

Applicable rules are ones where the consequent matches the query formula. If there are any such rules, then the query can be proved if the antecedent of any one them can be shown to be true. This can be performed recursively.

Backward Chaining ≠ Reasoning Backwards

Backward chaining reasons from queries to **known facts**.

Reasoning backwards goes from known consequents to **unknown antecedents**.

Reasoning backwards is an **invalid**.

Sometimes it is useful for determining what is **plausible**. Plausible reasoning from consequents to antecedents is known as **abduction**.

Soundness and Completeness

Forward and backward chaining are both **sound** (meaning all inferences that we draw using them are **valid**). However, neither is **complete**.

The fact that they are not complete means that there are **valid inferences that cannot be found** by systems using these methods alone.

An alternative inference technique called **resolution** is both sound and complete, but it is far more computationally expensive, so most systems just use chaining.

Representing Events

One limitation of FOL is that it only allows events with a **fixed arity** (number of arguments).

Ideally, there would be a direct mapping from a verb's subcategorization frame onto a FOL predicate.

Leaf serves vegetarian fare

=

Serves(Leaf ,VegetarianFare)

However, **events** are more complicated since events may involve a host of participants, props, times and locations.

Representing Events

Choosing the correct number of arguments for the predicate representing the meaning of **eat** is tricky.

1. I ate.
2. I ate a turkey sandwich.
3. I ate a turkey sandwich at my desk.
4. I ate at my desk.
5. I ate lunch.
6. I ate a turkey sandwich for lunch.
7. I ate a turkey sandwich for lunch at my desk

Event variables

Event variables to allow us to make assertions about an event without using a single predicate with a fixed number of arguments.

1. **Event predicates** are refactored with an existentially quantified variable as their **only** argument.

$$\exists e \text{ Eating}(e)$$

2. We can introduce **additional predicates to represent the other information** we have about the event. These predicates take an event variable as their first argument and related FOL terms as their second argument

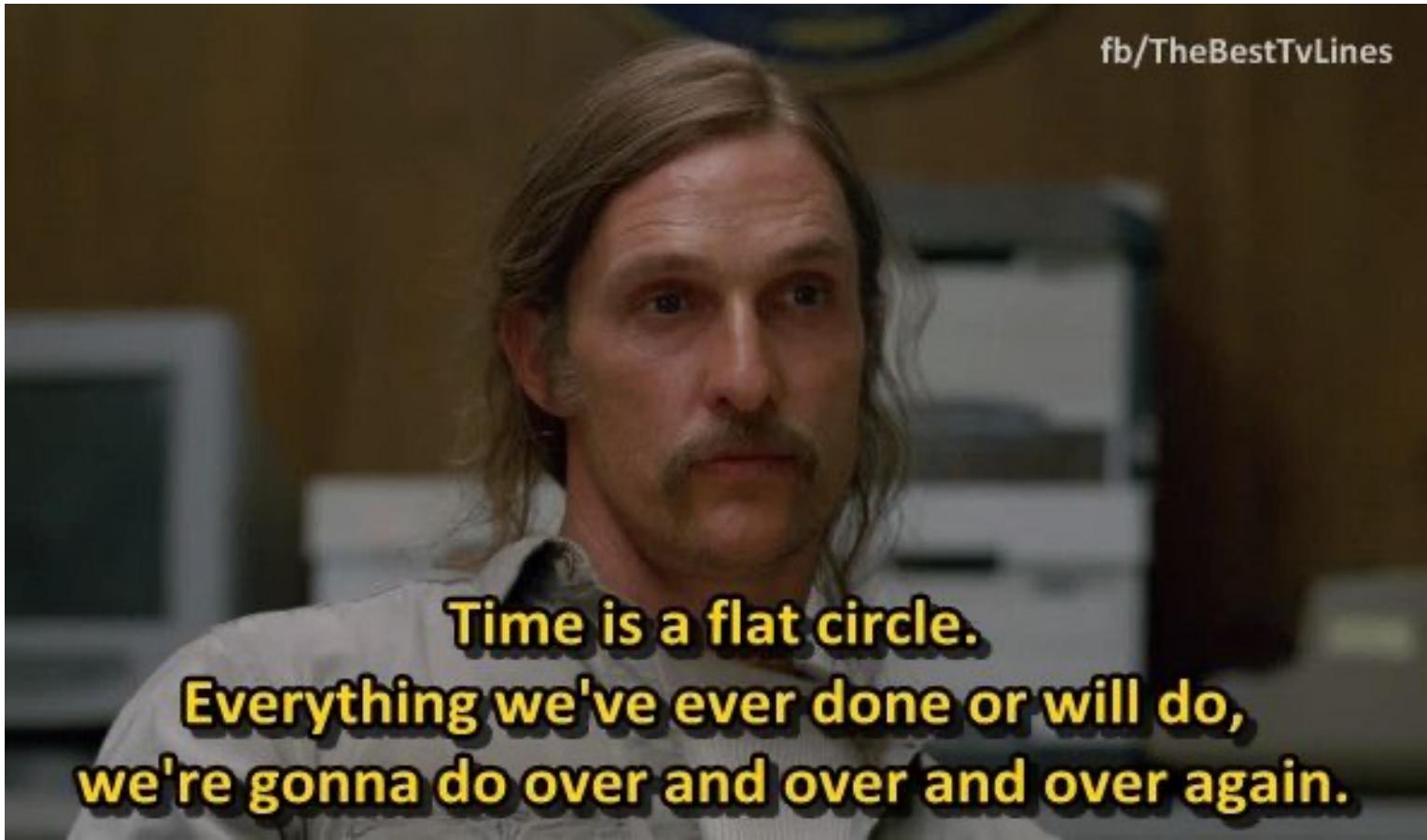
$$\exists e \text{ Eating}(e) \wedge \text{Eater}(e, \text{Speaker}) \wedge \text{Eaten}(e, \text{TurkeySandwich})$$

Neo-Davidsonian Events

1. Events are captured with predicates that take a single event variable as an argument.
2. We don't need to specify a fixed number of arguments for a FOL predicate. Instead, we can glue on as many as are provided in the input.
3. No more roles are postulated than are mentioned in the input.
4. The connections across related inputs that share the same predicate are satisfied without the need for additional inference.

Representing Time

Temporal logic gives us ways of representing when events occur.



Time is a flat circle.

**Everything we've ever done or will do,
we're gonna do over and over and over again.**

Representing Time

Temporal logic gives us ways of representing when events occur.

Time flows forward and that events are associated with either **points** or **intervals** in time, as on a timeline.

We can order distinct events by situating them on the timeline; one event precedes another if the flow of time leads from the first event to the second.

Represent the current moment in time as a point, and we can then easily define familiar notions of **past**, **present**, and **future**.

Tense

These sentences only differ in the **tense** of the verb.

1. I arrived in New York.
2. I am arriving in New York.
3. I will arrive in New York.

A Neo-Davidsonian event representation would give us:

$$\exists e \text{ Arriving}(e) \wedge \text{Arriver}(e, \text{Speaker}) \wedge \text{Destination}(e, \text{NewYork})$$

How can we represent the temporal information specified by the verb tense? By *predicating additional information about the event variable e .*

Tense

Past tense – *I arrived in NY.*

$$\exists e \text{ Arriving}(e) \wedge \text{Arriver}(e, \text{Speaker}) \wedge \text{Destination}(e, \text{NewYork}) \\ \wedge \text{IntervalOf}(e, i) \wedge \text{EndPoint}(i, n) \wedge \text{Precedes}(n, \text{Now})$$

Present tense – *I am arriving in NY.*

$$\exists e \text{ Arriving}(e) \wedge \text{Arriver}(e, \text{Speaker}) \wedge \text{Destination}(e, \text{NewYork}) \\ \wedge \text{IntervalOf}(e, i) \wedge \text{MemberOf}(i, \text{Now})$$

Future tense – *I will arrive in NY.*

$$\exists e \text{ Arriving}(e) \wedge \text{Arriver}(e, \text{Speaker}) \wedge \text{Destination}(e, \text{NewYork}) \\ \wedge \text{IntervalOf}(e, i) \wedge \text{EndPoint}(i, n) \wedge \text{Precedes}(\text{Now}, n)$$

Temporal Expressions

Absolute	Relative	Durations
April 24, 1916	yesterday	four hours
The summer of '77	next semester	three weeks
10:15 AM	two weeks from yesterday	six days
The 3rd quarter of 2006	last quarter	the last three quarters

Lexical triggers for temporal expressions:

Category	Examples
Noun	<i>morning, noon, night, winter, dusk, dawn</i>
Proper Noun	<i>January, Monday, Ides, Easter, Rosh Hashana, Ramadan, Tet</i>
Adjective	<i>recent, past, annual, former</i>
Adverb	<i>hourly, daily, monthly, yearly</i>

Temporal normalization

- mapping a temporal expression to either normalization a specific point in time or to a duration

Other Temporal Phenomena

Order – a pair of events can *precede* or *follow* each other, they or *overlap* and may have different onset times.

Duration – we might want to model how long an event typically takes

- *I went to college to get a degree*
- *I went to the salon to get a haircut*

Frequency / periodicity

- *Presidential elections take place every 4 years*

Stationarity – permanent versus impermanent events

- *The Statue of Liberty is in New York*
- *The Coronavirus is in New York*

Conclusion

Formal meaning representations that capture the meaning-related content of linguistic inputs. These representations are intended to bridge the gap from language to common-sense knowledge of the world.

Meaning representation languages like FOL specify syntax and semantics of these representations. Many others have been used in NLP and AI.

Important elements of semantic representation including states and events can be captured in FOL.

Modelling temporal phenomena is an important challenge.

Information Extraction

JURAFSKY AND MARTIN CHAPTER 18

Information Extraction (IE)

- Information extraction (IE), turns the unstructured text information into structured data
- Populate a relational database to enable further processing, support queries

Template Filling

Citing high fuel prices, United Airlines said Friday it has increased fares by \$6 per round trip on flights to some cities also served by lowercost carriers. American Airlines, a unit of AMR Corp., immediately matched the move, spokesman TimWagner said. United, a unit of UAL Corp., said the increase took effect Thursday and applies to most routes where it competes against discount carriers, such as Chicago to Dallas and Denver to San Francisco.

FARE-RAISE ATTEMPT:	[LEAD AIRLINE:	UNITED AIRLINES]
		AMOUNT:	\$6	
		EFFECTIVE DATE:	2006-10-26	
		FOLLOWER:	AMERICAN AIRLINES	

Steps in IE

- NER and co-reference resolution
- **relation extraction**
 - spouse-of, child-of, employer-of, partof, membership-in, located-in
- event extraction
- temporal expression normalization
- template filling

Named Entity Recognition

Citing high fuel prices, [ORG United Airlines] said [TIME Friday] it has increased fares by [MONEY \$6] per round trip on flights to some cities also served by lower-cost carriers. [ORG American Airlines], a unit of [ORG AMR Corp.], immediately matched the move, spokesman [PER Tim Wagner] said. [ORG United], a unit of [ORG UAL Corp.], said the increase took effect [TIME Thursday] and applies to most routes where it competes against discount carriers, such as [LOC Chicago] to [LOC Dallas] and [LOC Denver] to [LOC San Francisco].

Type	Tag	Sample Categories	Example sentences
People	PER	people, characters	Turing is a giant of computer science.
Organization	ORG	companies, sports teams	The IPCC warned about the cyclone.
Location	LOC	regions, mountains, seas	The Mt. Sanitas loop is in Sunshine Canyon.
Geo-Political Entity	GPE	countries, states, provinces	Palo Alto is raising the fees for parking.
Facility	FAC	bridges, buildings, airports	Consider the Golden Gate Bridge.
Vehicles	VEH	planes, trains, automobiles	It was a classic Ford Falcon.

Named Entity Recognition

- Find spans of text that constitute proper names
 - Ambiguity of segmentation
 - What's an entity and what isn't
 - Where the boundaries are
 - Classify the type of the entity
 - Type ambiguity

Category Ambiguity in NER

Name	Possible Categories
<i>Washington</i>	Person, Location, Political Entity, Organization, Vehicle
<i>Downing St.</i>	Location, Organization
<i>IRA</i>	Person, Organization, Monetary Instrument
<i>Louis Vuitton</i>	Person, Organization, Commercial Product

Examples of type ambiguities in the use of the name Washington

[PER Washington] was born into slavery on the farm of James Burroughs.

[ORG Washington] went up 2 games to 1 in the four-game series.

Blair arrived in [LOC Washington] for what may well be his last state visit.

In June, [GPE Washington] passed a primary seatbelt law.

The [VEH Washington] had proved to be a leaky ship, every passage I made...

NER Algorithms & Evaluations

- Word to word sequence labelling
 - Capture boundary and type
 - Feature based
 - Neural
-
- Precision, Recall, F1
 - Segmentation component can cause problems

Relation Extraction

- A relation consists of a set of ordered tuples over elements of a domain
- The domain elements corresponds to the named entities

Domain

United, UAL, American Airlines, AMR

Tim Wagner

Chicago, Dallas, Denver, and San Francisco

$$\mathcal{D} = \{a, b, c, d, e, f, g, h, i\}$$

$$a, b, c, d$$

$$e$$

$$f, g, h, i$$

Classes

United, UAL, American, and AMR are organizations

Tim Wagner is a person

Chicago, Dallas, Denver, and San Francisco are places

$$Org = \{a, b, c, d\}$$

$$Pers = \{e\}$$

$$Loc = \{f, g, h, i\}$$

Relations

United is a unit of UAL

American is a unit of AMR

Tim Wagner works for American Airlines

United serves Chicago, Dallas, Denver, and San Francisco

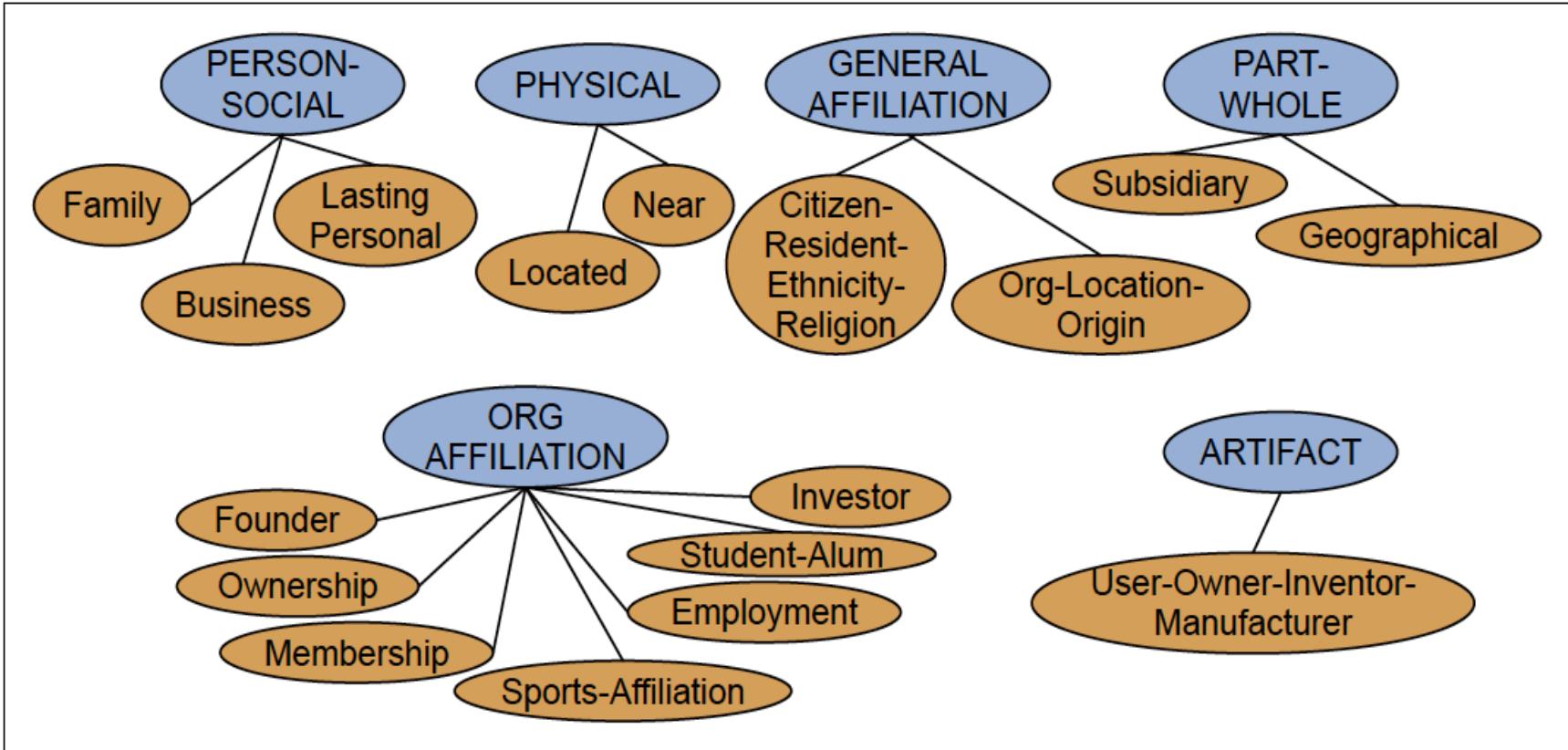
$$PartOf = \{\langle a, b \rangle, \langle c, d \rangle\}$$

$$OrgAff = \{\langle c, e \rangle\}$$

$$Serves = \{\langle a, f \rangle, \langle a, g \rangle, \langle a, h \rangle, \langle a, i \rangle\}$$

Citing high fuel prices, [ORG **United Airlines**] said [TIME **Friday**] it has increased fares by [MONEY **\$6**] per round trip on flights to some cities also served by lower-cost carriers. [ORG **American Airlines**], a unit of [ORG **AMR Corp.**], immediately matched the move, spokesman [PER **Tim Wagner**] said. [ORG **United**], a unit of [ORG **UAL Corp.**], said the increase took effect [TIME **Thursday**] and applies to most routes where it competes against discount carriers, such as [LOC **Chicago**] to [LOC **Dallas**] and [LOC **Denver**] to [LOC **San Francisco**].

Tim Wagner [**is a spokesman**] for American Airlines.
United [**is a unit of**] UAL Corp.
American [**is a unit of**] AMR.



Relations	Types	Examples
Physical-Located	PER-GPE	He was in Tennessee
Part-Whole-Subsidiary	ORG-ORG	XYZ, the parent company of ABC
Person-Social-Family	PER-PER	Yoko's husband John
Org-AFF-Founder	PER-ORG	Steve Jobs, co-founder of Apple...

Unified Medical Language System

Entity	Relation	Entity
Injury	disrupts	Physiological Function
Bodily Location	location-of	Biologic Function
Anatomical Structure	part-of	Organism
Pharmacologic Substance	causes	Pathological Function
Pharmacologic Substance	treats	Pathologic Function

Given a medical sentence like:

Doppler echocardiography can be used to diagnose left anterior descending artery stenosis in patients with type 2 diabetes

Extract the UMLS relation:

Echocardiography (Doppler) **Diagnoses** Acquired stenosis

Wikipedia info boxes

Barack Obama



44th President of the United States

In office

January 20, 2009 – January 20, 2017

Vice President [Joe Biden](#)

Preceded by [George W. Bush](#)

Succeeded by [Donald Trump](#)

**United States Senator
from Illinois**

In office

January 3, 2005 – November 16, 2008

Preceded by [Peter Fitzgerald](#)

Succeeded by [Roland Burris](#)

**Member of the Illinois Senate
from the 13th district**

In office

January 8, 1997 – November 4, 2004

Preceded by [Alice Palmer](#)

Succeeded by [Kwame Raoul](#)

Personal details

Born Barack Hussein Obama II
August 4, 1961 (age 58)
[Honolulu, Hawaii, U.S.](#)

Political party Democratic

RDF Triples

- Resource Description Framework
- **RDF triple** is a tuple of
 - Entity-relation-entity, aka
 - Subject-predicate-object expression
- **Subject**: University of Pennsylvania
- **Predicate**: location
- **Object**: Philadelphia, PA



Zachary G. Ives

FOLLOW

Professor of Computer and Information Science, [University of Pennsylvania](#)

Verified email at cis.upenn.edu - [Homepage](#)

Databases data integration distributed systems web data management

TITLE	CITED BY	YEAR
Dbpedia: A nucleus for a web of open data S Auer, C Bizer, G Kobilarov, J Lehmann, R Cyganiak, Z Ives The semantic web, 722-735	2950	2007

DBpedia is a community effort to extract structured information from Wikipedia and to make this information available on the Web. DBpedia allows you to ask sophisticated queries against datasets derived from Wikipedia and to link other datasets on the Web to Wikipedia data. We describe the extraction of the DBpedia datasets, and how the resulting information is published on the Web for human-and machine-consumption. We describe some emerging applications from the DBpedia community and show how website authors can facilitate DBpedia content within their sites. Finally, we present the current status of interlinking DBpedia with other open datasets on the Web and outline how DBpedia could serve as a nucleus for an emerging Web of open data.

Freebase, WordNet, other ontologies

- Freebase relations:
 - people/person/nationality
 - location/location/contains
 - people/person/place-of-birth
 - biology/organism classification
- WordNet relations:
 - is-a, instance-of
 - hypernyms/hyponyms
 - Giraffe is-a ruminant is-a ungulate is-a mammal is-a vertebrate is-a animal...

Strategies for relation extraction

- hand-written patterns
- supervised machine learning
- semi-supervised machine learning
 - Bootstrapping
 - Distant supervision
- unsupervised machine learning

Hearst Patterns

Agar is a substance prepared from a mixture of red algae, such as Gelidium, for laboratory or industrial use.

- She suggests that the following lexico-syntactic pattern

$$NP_0 \text{ such as } NP_1 \{, NP_2 \dots, (\text{and/or}) NP_i\}, \ i \geq 1$$

- implies the following semantics

$$\forall NP_i, i \geq 1, \text{hyponym}(NP_i, NP_0)$$

- allowing us to infer

$$\text{hyponym}(\text{Gelidium, red algae})$$

$NP \{, NP\}^* \{, \}$ (and or) other NP_H	temples, treasures, and other important civic buildings
NP_H such as $\{NP,\}^* \{(or and)\} NP$	red algae such as Gelidium
such NP_H as $\{NP,\}^* \{(or and)\} NP$	such authors as Herrick, Goldsmith, and Shakespeare
$NP_H \{, \}$ including $\{NP,\}^* \{(or and)\} NP$	common-law countries , including Canada and England
$NP_H \{, \}$ especially $\{NP,\}^* \{(or and)\} NP$	European countries , especially France, England, and Spain

Machine learning techniques

- **Supervised:** training corpus annotated with manually annotated with fixed set of relations and entities
- **Semi-supervised:** high-precision seed patterns, or seed tuples, are used to bootstrap more examples
- **Distant supervision:** start with a huge number of seeds, learn noisy pattern fields (e.g. 100k examples of birth-place-of from infoboxes, help learn the corresponding text patterns)

Semisupervised Relation Extraction

function `BOOTSTRAP(Relation R)` **returns** *new relation tuples*

tuples \leftarrow Gather a set of seed tuples that have relation *R*

iterate

sentences \leftarrow find sentences that contain entities in *tuples*

patterns \leftarrow generalize the context between and around entities in *sentences*

newpairs \leftarrow use *patterns* to grep for more tuples

newpairs \leftarrow *newpairs* with high confidence

tuples \leftarrow *tuples* + *newpairs*

return *tuples*

Bootstrapping proceeds by taking the entities in the seed pair, and then finding sentences (on the web, or whatever dataset we are using) that contain both entities.

Example

- Task: Create airline/hub pairs
- Seed: Ryanair has a hub at Charleroi
 - use this seed fact to discover new patterns by finding other mentions of this relation in our corpus
- Sentences found:
 - Budget airline Ryanair, which uses Charleroi as a hub, scrapped all weekend flights out of the airport.
 - All flights in and out of Ryanair's Belgian hub at Charleroi airport were grounded on Friday...
 - A spokesman at Charleroi, a main hub for Ryanair, estimated that 8000 passengers had already been affected.
- Patterns extracted:
 - / [ORG], which uses [LOC] as a hub /
 - / [ORG]'s hub at [LOC] /
 - / [LOC] a main hub for [ORG] /

Distant Supervision

function DISTANT SUPERVISION(*Database D, Text T*) **returns** *relation classifier C*

foreach relation *R*

foreach tuple (e_1, e_2) of entities with relation *R* in *D*

sentences \leftarrow Sentences in *T* that contain e_1 and e_2

$f \leftarrow$ Frequent features in *sentences*

observations \leftarrow *observations* + new training tuple (e_1, e_2, f, R)

C \leftarrow Train supervised classifier on *observations*

return *C*

R: place of birth

(e1, e2): <Edwin Hubble, Marshfield>, <Albert Einstein, Ulm>, etc

Sentences: Hubble was born in Marshfield; Einstein, born (1879),
Ulm; Hubble's birthplace in Marshfield..., etc

Open IE

- Unsupervised relation extraction
- Find all strings of words that satisfy the triple relation.
 - United has a hub in Chicago, which is the headquarters of United Continental Holdings.
 - r1: <United, has a hub in, Chicago>
 - r2: <Chicago, is the headquarters of, United Continental Holdings>

Evaluation of Relation Extraction

- Supervised
 - Test sets with human annotated, gold-standard relations and computing precision, recall, and F-measure
- Semi and Unsupervised
 - Human evaluations
 - Compute precision at different levels of recall

Temporal Expression Extraction

Absolute	Relative	Durations
April 24, 1916	yesterday	four hours
The summer of '77	next semester	three weeks
10:15 AM	two weeks from yesterday	six days
The 3rd quarter of 2006	last quarter	the last three quarters

Lexical triggers for temporal expressions:

Category	Examples
Noun	<i>morning, noon, night, winter, dusk, dawn</i>
Proper Noun	<i>January, Monday, Ides, Easter, Rosh Hashana, Ramadan, Tet</i>
Adjective	<i>recent, past, annual, former</i>
Adverb	<i>hourly, daily, monthly, yearly</i>

- Temporal expression recognition
- Temporal normalization
 - mapping a temporal expression to either normalization a specific point in time or to a duration

Event Extraction

[EVENT Citing] high fuel prices, United Airlines [EVENT said] Friday it has [EVENT increased] fares by \$6 per round trip on flights to some cities also served by lower-cost carriers. American Airlines, a unit of AMR Corp., immediately [EVENT matched] [EVENT the move], spokesman Tim Wagner [EVENT said]. United, a unit of UAL Corp., [EVENT said] [EVENT the increase] took effect Thursday and [EVENT applies] to most routes where it [EVENT competes] against discount carriers, such as Chicago to Dallas and Denver to San Francisco.

In English events are typically expressed verbs like exploded, and sometimes nouns like explosion.

Temporal ordering of events

Delta Air Lines earnings soared 33% to a record in the fiscal first quarter, bucking the industry trend toward declining profits.

- Soaring_{e1} is included in the fiscal first quarter_{t58}
- Soaring_{e1} is simultaneous with the bucking_{e3}
- Declining_{e4} includes soaring_{e1}

Template Filling

- Scripts are common, stereotypical situations
- Templates represent scripts with a fixed set of slots that take slot-filler values
- Train two separate supervised systems
 - Template recognition
 - Role-filler extraction
- Most earlier systems were based on handwritten regular expressions and grammar rules.

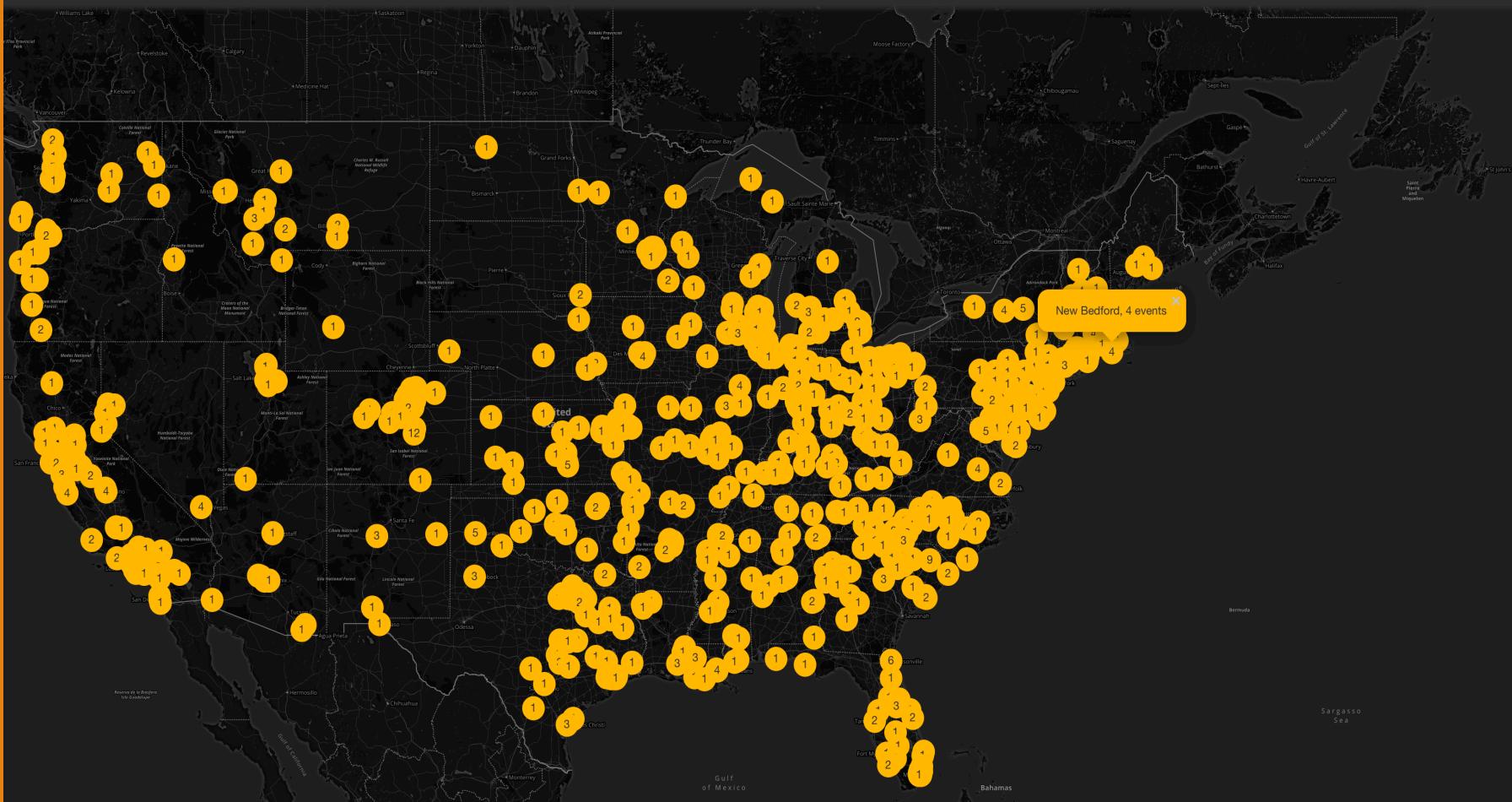
FARE-RAISE ATTEMPT:	[LEAD AIRLINE:	UNITED AIRLINES]
		AMOUNT:	\$6	
		EFFECTIVE DATE:	2006-10-26	
		FOLLOWER:	AMERICAN AIRLINES	

The Gun Violence Database

Gun Violence
DATABASE

BROWSE MAP ABOUT PROJECT WORK ON TASKS DOWNLOAD DATA

Chris Callison-Burch ▾



Ellie Pavlick and Chris Callison-Burch, University of Pennsylvania

Goals of the GVDB

Collect data about gun violence in the US to
facilitate public health research.

Draw sample from local newspapers and television
stations that publish online.

Use machine learning and crowdsourcing to **extract
structured data from text.**

GVDB Template

Chicago Police release Laquan McDonald shooting video | National News

Three seconds. On a dashcam video clock, that's the amount of time between the moment when two officers have their guns drawn and the point when Laquan McDonald falls to the ground. The video, released to the public for the first time late Tuesday, is a key piece of evidence in a case that's sparked protests in Chicago and has landed an officer behind bars. The 17-year-old McDonald was shot 16 times on that day the video shows in October 2014. Chicago police Officer Jason Van Dyke was charged Tuesday with first-degree murder....

Incident #1053

City	
Date	
Shooter	
Victim	
Victim Killed	

Person #1014

Name	
Gender	
Age	
Race	