LECTURE 22: ENTITIES, (CO)REFERENCE, RELATIONS

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Adapted from Julia Hockenmaier, NLP S2023 - course material
https://courses.grainger.illinois.edu/cs447/sp2023/

WHAT WE'VE COVERED SO FAR

Lexical Semantics (meaning of words)

We've mostly focused on content words

(nouns, verbs, adjectives)

Compositional Semantics (meaning of sentences)

— Principle of compositionality: The meaning of sentences depends recursively (compositionally) on the meaning of their words and constituents.

— Logically, declarative sentences correspond to propositions that can either be true or false.

WHERE WE'RE GOING NEXT

Language conveys information about (real or imagined, concrete or abstract) entities; events and facts, their properties and relations.

Entities and events may exist/take place in time and space.

What kind of information about (entities/events/time/space/…) do we need/want to represent?

How is that information expressed in language?

How can a **meaning representation capture that information**?

WHERE WE'RE GOING NEXT

So far, we have looked at… .

.. words,
… phrases,
… sentences

But we also need to understand…

… paragraphs,
… stories, articles, documents,
… dialogues

DISCOURSE: GOING BEYOND SINGLE SENTENCES

On Monday, John went to Einstein's. He wanted to buy lunch. But the cafe was closed. That made him angry, so the next day he went to Green Street instead.

'Discourse':
Any linguistic unit that consists of **multiple sentences**

Speakers describe "some situation or state of the real or some hypothetical world" (Webber, 1983)

Speakers attempt to get the **listener** to construct a similar **model of the situation**.

WHY STUDY DISCOURSE?

For natural language understanding:

Most information is not contained in a single sentence.

The system has to **aggregate** information across sentences, paragraphs or entire documents.

For natural language generation:

When systems generate text, that text needs to be easy to understand — it has to be **coherent**.

What makes text coherent?

HOW CAN WE UNDERSTAND DISCOURSE?

On Monday, John went to Einstein's. He wanted to buy lunch. But the cafe was closed. That made him angry, so the next day he went to Green Street instead.

Understanding discourse requires (among other things):

1) doing **coreference** resolution:

'the cafe' and '*Einstein's'* **refer to the same entity**	*He* and *John* refer to the same person.	*That* refers to *'the cafe was closed'*.

2) identifying **discourse ('coherence') relations**: '

He wanted to buy lunch' is the ***reason*** for	*'John went to Bevande.'*

DISCOURSE MODELS

An explicit representation of:

— the **entities, events and states** that a discourse talks about

— the **relations** between them (and to the real world).

This representation is often written in some form of logic.

What does this logic need to capture?

DISCOURSE MODELS SHOULD CAPTURE...

Entities (physical or abstract):
John, Einstein's, lunch, hope, computer science, ...

Eventualities (events or states):
— Events: On Monday, John went to Einstein's

involve entities, take place at a point in time

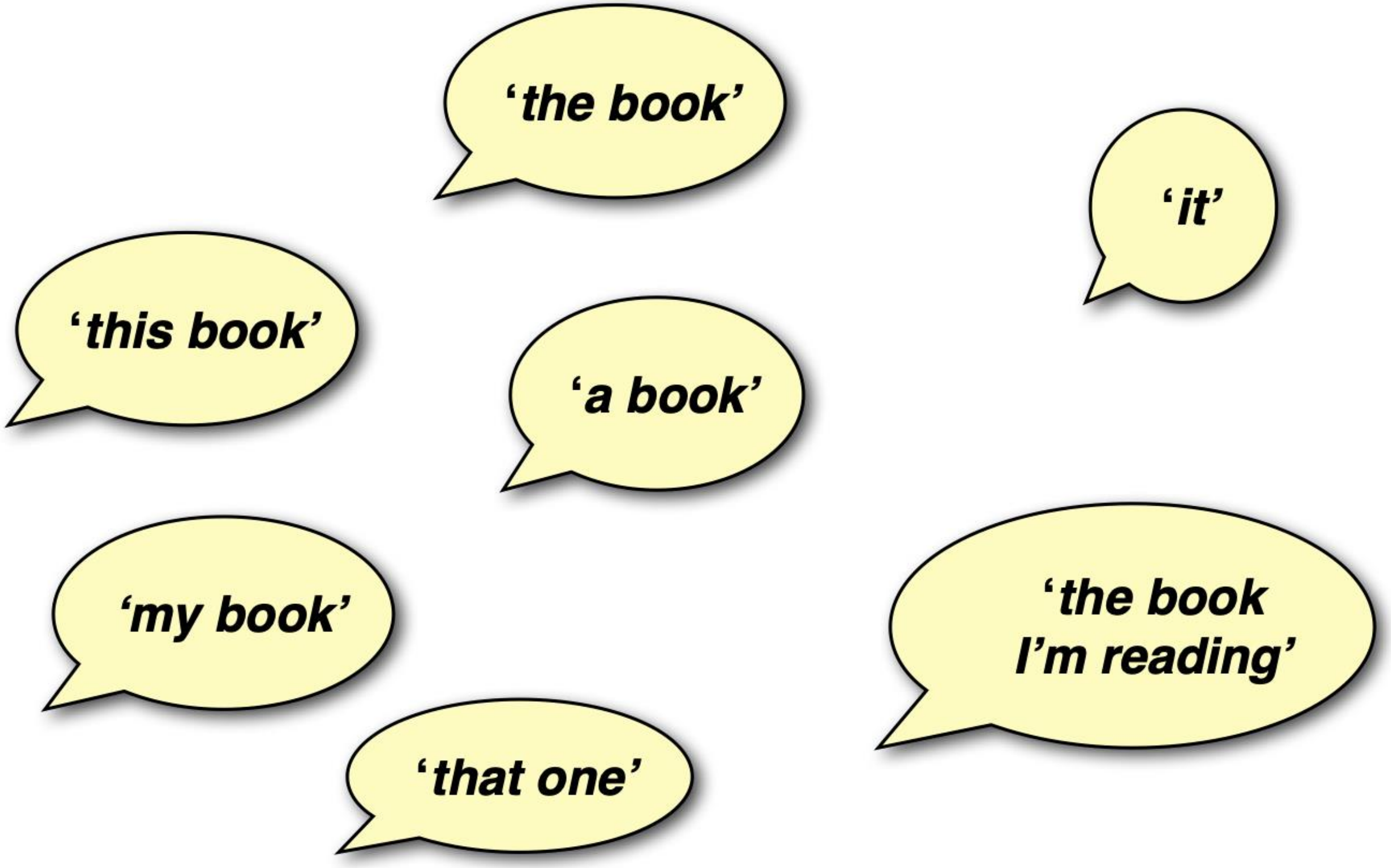
— States: It was closer. Water is a liquid.
involve entities and hold for a period of time (or are generally true)

Temporal relations between events/states afterwards, during,

Rhetorical ('discourse') **relations** between propositions so, instead, if, whereas

PART 2: REFERRING EXPRESSIONS

HOW DO WE REFER TO ENTITIES?



SOME TERMINOLOGY

Referring expressions (‘*this book*’, ‘it’) refer to some entity (e.g. a book), which is called the **referent**

Co-reference: two referring expressions that refer to the same entity **co-refer** (are co-referent).
I saw a movie last night. I think you should see it too!

The referent is **evoked** in its first mention, and **accessed** in any subsequent mention.

INDEFINITE NPS

No determiner: *I like* ***walnuts****.*

Indefinite determiner: *She sent her* ***a*** *beautiful goose*

Numerals: *I saw* ***three*** *geese.*

Indefinite quantifiers: *I ate* ***some*** *walnuts.*

(Indefinite) ***this*****:** *I saw* ***this*** *beautiful Ford Falcon today*

Indefinite NPs usually **introduce a new discourse entity**.

They can refer to a specific entity or not:

- *I'm going to buy a computer today.*
- (unclear if the speaker has a particular computer in mind (e.g. his friends' old computer), or just any computer)

DEFINITE NPS

The **definite** article (***the*** *book*), **Demonstrative articles** (***this/that*** *book*, ***these/those*** *books*),

Possessives (***my/John's*** *book*)

Definite NPs **refer to an identifiable entity** (previously mentioned or not)

Definite NPs can also consist of

- **Personal pronouns** (***I, he***)
- **Demonstrative pronouns** (***this, that, these, those***)
- Universal **quantifiers** (***all, every)***
- (unmodified) **proper nouns** ***(John Smith, Mary, Urbana)***

INFORMATION STATUS

Every entity can be classified along two dimensions:

Hearer-new vs. hearer-old
Speaker assumes entity is (un)known to the hearer

Hearer-old: *I will call Sandra Thompson*.
Hearer-new: *I will call a colleague in California* (=Sandra Thompson)

Special case of hearer-old: **hearer-inferrable**

I went to the student union. The food court was really crowded.

Discourse-new vs. discourse-old:
Speaker introduces new entity into the discourse, or refers to an entity that has been previously introduced.

Discourse-old: *I will call her/Sandra now.*
Discourse-new: *I will call my friend Sandra now.*

ANAPHORIC PRONOUNS

Anaphoric pronouns refer back to some previously introduced entity/discourse referent:

- ***John*** *showed* ***Bob*** *his car.* ***He*** *was impressed.*
- *John showed Bob his car.* ***This*** *took five minutes.*

The **antecedent** of an anaphor is the previous expression that refers to the same entity.

There are number/gender/person **agreement constraints:** ***girls*** can't be the antecedent of ***he***

Usually, we need some form of **inference** to identify the antecedents.

SALIENCE/FOCUS

Only some recently mentioned entities can be referred to by pronouns:

- *John went to Bob's party and parked next to a classic Ford Falcon.*
- *He went inside and talked to Bob for more than an hour.*
- *Bob told him that he recently got engaged.*
- *He also said he bought it (???)/ the Falcon yesterday.*

Key insight (also captured in Centering Theory)

- Capturing which entities are salient (in focus) reduces the amount of search (inference) necessary to interpret pronouns!

PART 3: COREFERENCE RESOLUTION

THE COREFERENCE RESOLUTION TASK

Victoria Chen, Chief Financial Officer of Megabucks Banking Corp since 2004, saw her pay jump 20%, to $1.3 million, as the 37-year-old also became the Denver-based financial services company's president. It has been ten years since she came to Megabucks from rival Lotsabucks.

Return **Coreference Chains**

(sets of mentions that refer to the same entities)

1. {Victoria Chen, Chief Financial Officer...since 2004, her, the 37-year-old, the Denver-based financial services company's president}
2. {Megabucks Banking Corp, Denver-based financial services company, Megabucks}
3. {her pay}
4. {rival Lotsabucks}

SPECIAL CASE: PRONOUN RESOLUTION

Task: Find the antecedent of an anaphoric pronoun in context

1. ***John*** *saw* ***a beautiful Ford Falcon*** *at* ***the dealership****.*

2. ***He*** *showed* ***it*** *to* ***Bob****.*

3. ***He*** *bought* ***it****.*

$\mathbf{he_2}$, $\mathbf{it_2}$ = John, Ford Falcon, or dealership?
$\mathbf{he_3}$, $\mathbf{it_2}$ = John, Ford Falcon, dealership, or Bob?

COREF AS BINARY CLASSIFICATION

- Represent each NP-NP pair (+context) as a feature vector.
- **Training:**
  - Learn a binary classifier to decide whether NPi is a possible antecedent of NPj
- **Decoding** (running the system on new text):
  - — Pass through the text from beginning to end
  - — For each NPi:
    Go through NPi-1...NP1 to find best antecedent NPj.
    Corefer NPi with NPj.
    If the classifier can't identify an antecedent for NPi, it's a new entity.

EXAMPLE FEATURES FOR COREF RESOLUTION

What can we say about each of the two NPs?

- Head words, NER type, grammatical role, person, number, gender, mention type (proper, definite, indefinite, pronoun), #words, ...

How similar are the two NPs?

- — Do the two NPs have the same head noun/modifier/words?
- — Do gender, number, animacy, person, NER type match?
  — Does one NP contain an alias (acronym) of the other?
  — Is one NP a hypernym/synonym of the other?
- — How similar are their word embeddings (cosine)?

What is the likely relation between the two NPs?

- — Is one NP an appositive of the other?
- — What is the distance (#sentences, #words, #mentions) between the two NPs?

LEE ET AL.'S NEURAL MODEL FOR COREF RESOLUTION

Joint model for mention identification and coref resolution:

Use word embeddings + LSTM to get a vector $\mathbf{g}_i$ for each span i
i = START(i)…END(i) in the document (up to a max. span length L)

Use $\mathbf{g}_i$ + neural net NN_m to get a mention score $m(i)$ for each i
(used to identify most likely mention spans at inference time)

Use $\mathbf{g}_i$, $\mathbf{g}_j$ + NN_c to get antecedent scores $c(i,j)$ for all span pairs i, j<i

Compute overall score $s(i,j) = m(i)+m(j)+c(i,j)$ for all span pairs i,j<i
and set overall score $s(i,\varepsilon) = 0$ [score for i being discourse-new]

Identify the most likely antecedent for each span i according to

$$y_i^* = \text{argmax}_{y_i \in \{1,\ldots,i-1,\epsilon\}} P(y_i) \quad \text{with} \quad P(y_i) = \frac{\exp(s(i, y_i))}{\sum_{y' \in \{1,..i-1,\epsilon\}} \exp(s(i, y'))}$$

Perform a forward pass over all (most likely) spans
to identify their most likely antecedents

LEE ET AL.'S NEURAL MODEL FOR COREF RESOLUTION

Span representation $\mathbf{g}_i$:

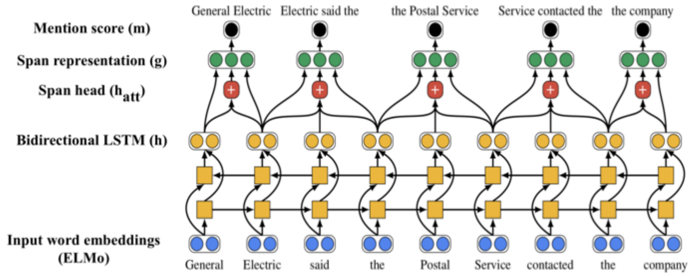
Computed by a biLSTM over word embeddings:

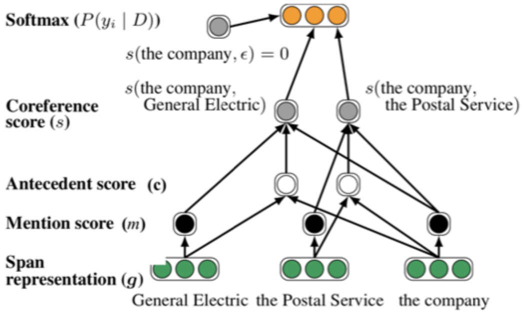
LSTM's hidden state of i's first word,

LSTM's hidden state of i's last,

weighted avg of word embeddings in span i; length of span

$[\mathbf{h}_{\text{START}(i)}, \mathbf{h}_{\text{END}(i)}, \mathbf{h}_{\text{ATT}(i)}, \varphi(i)]$





Scoring function $s(i,j)$:

a) for $j=\varepsilon$ (i has no antecedent): $s(i,\varepsilon) = 0$

b) for $j\neq\varepsilon$: $s(i,j) = m(i) + m(j) + c(i,j)$

$m(i)$: is span i a mention?

binary classifier (feedforward net) with $\mathbf{g}_i$ as input

$c(i,j)$: is j an antecedent of i?

input: $\mathbf{g}_i$, $\mathbf{g}_j$, $\mathbf{g}_i \circ \mathbf{g}_i$ [element-wise multiplication]

EVALUATION METRICS FOR COREF RESOLUTION

Compare hypothesis H against (gold) reference R by:

MUC score:

- — Precision/Recall over #coref links
- — Ignores singleton mentions
  — Rewards long coref chains/clusters

B^3 score:

- — Precision/Recall over mentions in same cluster
- — May count same mention multiple times

CEAF score:

- — Precision/Recall, based on mention alignments

CoNLL F1: combines MUC, B3, CEAF

Challenge: How to handle predicted mentions (whose span may differ from gold mentions)?

THE IMPORTANCE OF WORLD KNOWLEDGE

- Coreference resolution often needs **world (“commonsense”) knowledge.**
- Compare:
  - **The city councilme**n refused **the demonstrators** a permit because **they feared violence**.
  - **The city councilmen** refused **the demonstrators** a permit because **they advocated violence.**
- CF: The Winograd Schema Challenge https://cs.nyu.edu/faculty/davise/papers/WinogradSchemas/WS.html

WORLD KNOWLEDGE MAY CAPTURE BIAS

Preferred attachments (both by humans and systems) often reflect stereotypes (e.g. about occupations and gender)

A man and his son get into a terrible car crash. The father dies, and the boy is badly injured. In the hospital, the surgeon looks at the patient and exclaims, "I can't operate on this boy, he's my son!" https://www.aclweb.org/anthology/N18-2002/