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# Natural Language Processing 1

## Lecture 8: Discourse processing

modeling  
larger text.  
eg  
paragraph,  
whole  
document

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# Outline.

Discourse structure

Learning document representations

Referring expressions and coreference

Algorithms for coreference resolution

# Document structure and discourse structure

- ▶ Most types of document are highly structured, implicitly or explicitly:
  - ▶ Scientific papers: conventional structure (differences between disciplines).
  - ▶ News stories: first sentence is a summary.
  - ▶ Blogs, etc etc
- ▶ Topics within documents.
- ▶ Relationships between sentences.

# Rhetorical relations

修辞关系

Max fell. John pushed him.

can be interpreted as:

1. Max fell **because** John pushed him.

EXPLANATION

or

- 2 Max fell **and** then John pushed him.

NARRATION

a description of how two segments of discourse are logically connected to one another.

Implicit relationship: **discourse relation** or **rhetorical relation**  
*because, and then* are examples of **cue phrases**

提示短语

## Rhetorical relations

Analysis of text with rhetorical relations generally gives a binary branching structure:

- ▶ **nucleus** (the main phrase) and **satellite** (the subsidiary phrase: e.g., EXPLANATION, JUSTIFICATION)

Max fell **because** John pushed him.

- ▶ equal weight: e.g., NARRATION

Max fell **and** Kim kept running.

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Max fell because John pushed him.

- ▶ **equal weight**: e.g., NARRATION

Max fell **and** Kim kept running.

# Coherence

Coherence in linguistics is what makes a text semantically meaningful.

Discourses have to have connectivity to be coherent:

Kim got into her car. Sandy likes apples.

Can be OK in context:

Kim got into her car. Sandy likes apples, so Kim thought she'd go to the farm shop and see if she could get some.

# Coherence

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## Coherence in interpretation

Discourse coherence assumptions can affect interpretation:

John likes Bill. He gave him an expensive Christmas present.

If EXPLANATION - 'he' is probably Bill.

If JUSTIFICATION (supplying evidence for another sentence),  
'he' is John.

## Factors influencing discourse interpretation

1. Cue phrases (e.g. *because*, *and*)
2. Punctuation (also prosody) and text structure.

韵律

Max fell (John pushed him) and Kim laughed.

Max fell, John pushed him and Kim laughed.

3. Real world content:

Max fell. John pushed him as he lay on the ground.

4. Tense and aspect.

时态

Max fell. John had pushed him.

Max was falling. John pushed him.

# Discourse parsing

**Discourse parsing:** identifying discourse structure and relations

Hard problem, much research has focused on labelling relations between pairs of sentences / clauses

1. Classification with hand-engineered features
  - ▶ e.g. punctuation, cue phrases, syntactic and lexical
2. Neural models
  - ▶ take two sentences as input
  - ▶ train a sentence encoder
  - ▶ objective: **predict the relation**

Or learn document representations in a given task

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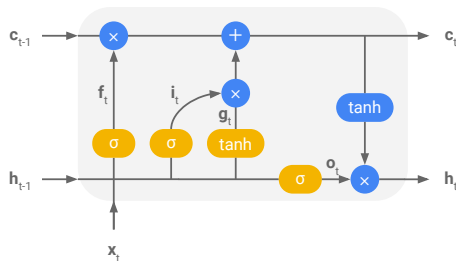
# Document representations

Document classification tasks:

- ▶ text categorization (e.g. by topic)
- ▶ sentiment analysis
- ▶ authorship attribution
- ▶ spam and phishing email filtering
- ▶ misinformation detection
- ▶ and many more

## Learning document representations

- ▶ Last time we have seen LSTMs for learning **sentence representations**

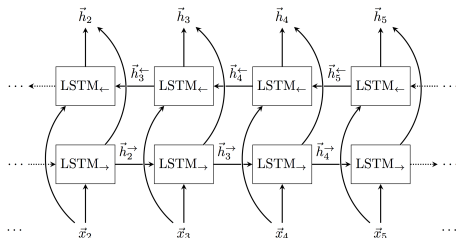


- ▶ Use these **sentence representations** to compute a **document representation**

# Bidirectional LSTM

## Bidirectional LSTM: BiLSTM

- Traverse the sentence in both directions



$$\vec{h}_t = \text{LSTM}^{\text{forward}}(\vec{h}_{t-1}, x_t)$$

$$\overleftarrow{h}_t = \text{LSTM}^{\text{backward}}(\overleftarrow{h}_{t+1}, x_t)$$

$$h_t = [\vec{h}_t, \overleftarrow{h}_t]$$

# What is the sentence representation?

Options:

why hidden state is  
the sentence  
representation?

1. use  $h_L$  — the final hidden state of the LSTM
2. use an average of LSTM hidden states at all time steps  
(mean-pooling)
3. use max-pooling — take the maximum value in each vector component of all hidden states
4. use an attention mechanism, i.e. a weighted sum of the hidden states at all time steps



## Attention mechanism

Sentence representation as a **weighted sum of all hidden states**

- ▶ the model learns a **weight vector**  $w_\alpha$ , and computes its **dot product with the hidden state**  $h_t$  transformed by a FFNN:

$$\alpha_t = w_\alpha \cdot \text{FFNN}_\alpha(h_t)$$

- ▶ normalise the weights into a distribution via softmax

$$a_t = \frac{e^{\alpha_t}}{\sum_{k=1}^L e^{\alpha_k}}$$

- ▶ compute the sentence representation  $h_{ATT}$  as a weighted sum

$$h_{ATT} = \sum_{t=1}^L a_t \cdot h_t$$

# Building a document representation

Options:

1. Feed the whole document to an LSTM word by word
  - ▶ possibly use word-level attention to learn what are the useful words
2. Build a **hierarchical model**
  - ▶ first compute sentence representations
  - ▶ combine sentence representations into a document representation
  - ▶ using **another LSTM** and / or **attention over sentences**
  - ▶ train with a document level objective

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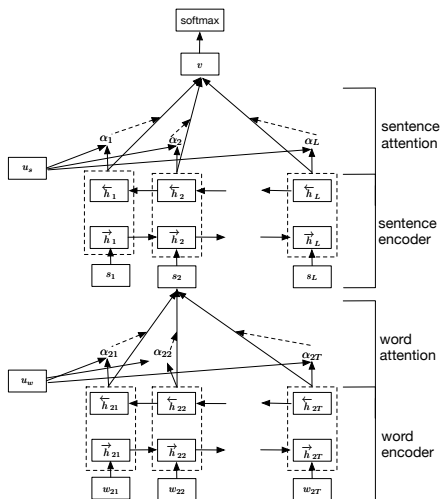
## Hierarchical attention networks

Yang et al. 2016. *Hierarchical Attention Networks for Document Classification*. NAACL.

- ▶ Take pretrained word embeddings as input
- ▶ **LSTM sentence encoder** with **word-level attention** (to construct sentence representations)
- ▶ **LSTM document encoder** with **sentence-level attention** (to construct document representations)
- ▶ trained with document-level objective

Experiments with sentiment analysis and text categorization

# Hierarchical attention network



# HAN output with attention visualised

## Sentiment analysis of Yelp reviews

GT: 4 Prediction: 4

pork belly = delicious .  
 scallops ?  
 i do n't .  
 even .  
 like .  
 scallops , and these were a-m-a-z-i-n-g .  
 fun and tasty cocktails .  
 next time i 'm in phoenix , i will go  
 back here .  
 highly recommend .

GT: 0 Prediction: 0

terrible value .  
 ordered pasta entree .  
 .  
 \$ 16.95 good taste but size was an  
 appetizer size .  
 .  
 no salad , no bread no vegetable .  
 this was .  
 our and tasty cocktails .  
 our second visit .  
 i will not go back .

Documents from Yelp 2013. Label 4 means star 5, label 0 means star 1.

# HAN output with attention visualised

## Topic classification

GT: 1 Prediction: 1

why does zebras have stripes ?  
 what is the purpose or those stripes ?  
 who do they serve the zebras in the  
 wild life ?  
 this provides camouflage - predator  
 vision is such that it is usually difficult  
 for them to see complex patterns

GT: 4 Prediction: 4

how do i get rid of all the old web  
 searches i have on my web browser ?  
 i want to clean up my web browser  
 go to tools > options .  
 then click “ delete history ” and “  
 clean up temporary internet files . ”

Documents from Yahoo Answers. Label 1 denotes Science and Mathematics and label 4 denotes Computers and Internet.

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# Co-reference and referring expressions

Niall Ferguson  
Stephen I  
being cha

指示代词coreference occurs when two or more expressions in a text refer to the same person or thing; they have the same referent

多产的高薪的穿着时尚的

and a snappy dresser.  
until he spent an hour  
word study.

**referent** a real world entity that some piece of text (or speech) refers to. **the actual Prof. Ferguson**

**referring expressions** bits of language used to perform reference by a speaker. **'Niall Ferguson', 'he', 'him'**

**antecedent** the text initially evoking a referent. **'Niall Ferguson'**

**anaphora** the phenomenon of referring to an antecedent.

**cataphora** pronouns appear before the referent (rare)

What about *a snappy dresser*?

def  
<https://en.wikipedia.org/wiki/Coreference#:~:>

# Pronoun resolution

- ▶ Identifying the referents of pronouns
- ▶ **Anaphora resolution**: generally only consider cases which refer to antecedent noun phrases.

Niall Ferguson is prolific, well-paid and a snappy dresser.  
Stephen Moss hated him — at least until he spent an hour  
being charmed in the historian's Oxford study.

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## Coreference resolution as supervised classification

- ▶ **instances**: potential pronoun/antecedent pairings
- ▶ **class** is TRUE/FALSE
- ▶ **training data** labelled with correct pairings
- ▶ candidate antecedents are all NPs in current sentence and preceeding 5 sentences (excluding pleonastic pronouns)

Niall Ferguson is prolific, well-paid and a snappy dresser.  
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## Hard constraints: Pronoun agreement

- ▶ A little girl is at the door — see what she wants, please?
- ▶ My dog has hurt his foot — he is in a lot of pain.
- ▶ \* My dog has hurt his foot — it is in a lot of pain.

### Complications:

- ▶ I don't know who the new lecturer will be, but I'm sure **they**'ll make changes to the course.
- ▶ The team played really well, but now **they** are all very tired.
- ▶ Kim and Sandy are asleep: **they** are very tired.

## Hard constraints: Reflexives

自生代词。myself, himself

- ▶ John<sub>i</sub> cut himself<sub>i</sub> shaving. (himself = John, subscript notation used to indicate this)
- ▶ # John<sub>i</sub> cut him<sub>j</sub> shaving. ( $i \neq j$  — a very odd sentence)

**Reflexive pronouns** must be coreferential with a preceding argument of the same verb, non-reflexive pronouns cannot be.

## Hard constraints: Pleonastic pronouns



没有实际意义的代词

**Pleonastic pronouns** are semantically empty, and don't refer:

- ▶ **It** is snowing
- ▶ **It** is not easy to think of good examples.
- ▶ **It** is obvious that Kim snores.
- ▶ **It** bothers Sandy that Kim snores.



# Soft preferences: Saliency

显著性

代词所指代的那个词

- ▶ **Recency**: **More recent** antecedents are preferred. They are more accessible.

*Kim has a big car. Sandy has a smaller one. Lee likes to drive **it**.*

it refers to smaller car, instead of big car. this is the rule for human language

- ▶ **Grammatical role**: Subjects > objects > everything else:

**Fred** went to the shopping centre with Bill. He bought a CD.

He refers to Fred, instead of Bill. 上一句的主语，而不是宾语

- ▶ **Repeated mention**: Entities that have been mentioned more frequently are preferred.

代词指代的往往是前文中最常出现的词，而不是少出现的词

## Soft preferences: Saliency

- ▶ **Parallelism** Entities which **share the same role** as the pronoun in the same sort of sentence are preferred:

*Bill went with Fred to the lecture. Kim went with him to the bar. Him=Fred*

相同的句子结构，him指的是同语法结构中的那个词

- ▶ **Coherence effects**: The pronoun resolution may depend on the rhetorical / discourse relation that is inferred.

*Bill likes Fred. He has a great sense of humour.*

we human knows he refer to Fred, not Bill

Although I phone her every week, my mother still complains that I don't keep in touch often enough.

Her refers to

代词必须与人称的单复数保持一致 When you use a singular subject of the sentence, the verb that you use must also be singular. These should always agree with one another.

The book was and I didn't

Example: The man walked to his car. "man" is a singular, male noun, so "his" is the appropriate pronoun to replace the noun.

Example: Students need to bring their own lunch. "students" is a plural noun, and "their" is the appropriate plural pronoun to replace the noun.

true or false

## Features

Cataphoric Binary: t if **pron**

Number agreement Binary: antecedent.

Gender agreement Binary: t if gender agreement.

Same verb Binary: t if the **pronoun and the candidate antecedent** are arguments of **the same verb**.

Sentence distance Discrete: { 0, 1, 2 ... }

Grammatical role Discrete: { subject, object, other } **The role of**

**the potential antecedent** of candidate antecedent. is antecedent a proper noun, definite noun (eg a boy), indefinite noun (eg the boy), or pronoun

被指代的那个词 是主语还是宾语还是谓语

Parallel Binary: **antecedent and the pronoun share the same grammatical role**.

Linguistic form Discrete: { proper, definite, indefinite, pronoun }

# Feature vectors

Niall Ferguson is prolific, well-paid and a snappy dresser.  
 Stephen Moss hated him — at least until he spent an hour  
 being charmed in the historian's Oxford study.

candidate  
antecedent

Cataphoric

parallel

pron	ante	cat	num	gen	same	dist	role	par	form
him	Niall F.	f	t	t	f	1	subj	f	prop
him	Ste. M.	f	t	t	t	0	subj	f	prop
him	he	t	t	t	f	0	subj	f	pron
he	Niall F.	f	t	t	f	1	subj	t	prop
he	Ste. M.	f	t	t	f	0	subj	t	prop
he	him	f	t	t	f	0	obj	f	pron

him is objective

ste.M is subjective

Apply any classifier, e.g. SVM, random forests etc.

## Problems with simple classification model

- ▶ Cannot implement 'repeated mention' effect.
- ▶ Cannot use information from previous links.

Not really pairwise: need a **discourse model** with real world entities corresponding to clusters of referring expressions.

## Neural end-to-end coreference resolution

Lee et al. 2017. *End-to-end Neural Coreference Resolution*. EMNLP.

- ▶ Mention-ranking paradigm, i.e. output a probability distribution over candidate mentions
- ▶ considers all text spans of certain length (e.g. bigrams, trigrams) as possible mentions
- ▶ coreference of all mentions considered (not only pronouns)
- ▶ end-to-end trainable neural architecture, based on an LSTM sentence encoder

## Task definition

**Assign** each span  $i$  **an antecedent**  $y_i$

- ▶ out of all possible spans in  $Y_i = \{1, \dots, i-1, \epsilon\}$
- ▶ empty token  $\epsilon$  is included to indicate the span  $i$  is non-referential or discourse-new

To do this, **for each pair of spans**  $i$  and  $j$

- ▶ the model **assigns a score**  $s(i, j)$  for their coreference link
- ▶ and computes a distribution  $P(y_i)$  over the antecedents of  $i$

$$P(y_i) = \frac{e^{s(i, y_i)}}{\sum_{y' \in Y(i)} e^{s(i, y')}}$$

## Computing the score $s$

The score  $s(i, j)$  includes three factors:

- ▶  $m(i)$ : whether span  $i$  is a mention
- ▶  $m(j)$ : whether span  $j$  is a mention
- ▶  $c(i, j)$ : whether  $j$  is the antecedent of  $i$

$$s(i, j) = m(i) + m(j) + c(i, j)$$

$s(i, \epsilon)$  is set to 0, i.e. the model predicts the antecedent with the highest positive score or abstains



## Computing the scoring functions $m$ and $c$

- ▶ Compute  $m(i)$ ,  $m(j)$  and  $c(i, j)$  based on the vectors  $g_i$  and  $g_j$ , which represent the spans  $i$  and  $j$
- ▶ span representations are constructed from hidden states of the LSTM encoder:

$$g_i = [h_{START(i)}, h_{END(i)}, h_{ATT(i)}, \phi(i)],$$

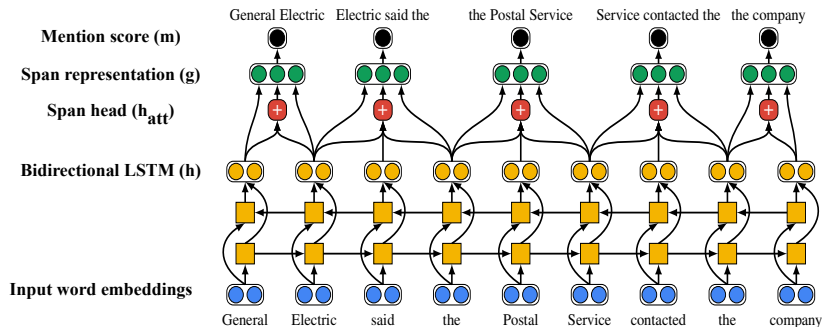
where  $\phi(i)$  is a single feature: the length of the span

$$m(i) = w_m \cdot \text{FFNN}_m(g_i)$$

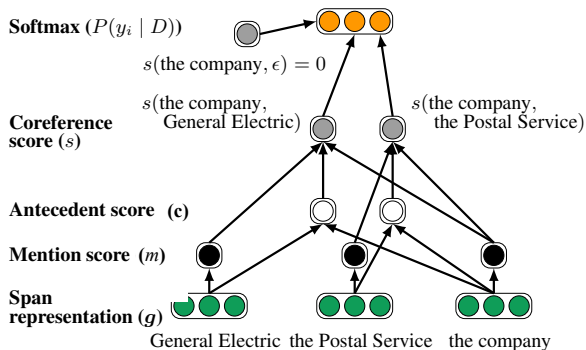
$$c(i, j) = w_c \cdot \text{FFNN}_c([g_i, g_j, g_i \odot g_j, \phi(i, j)])$$

$\phi(i, j)$  – distance between the spans in text

# Learning span representations

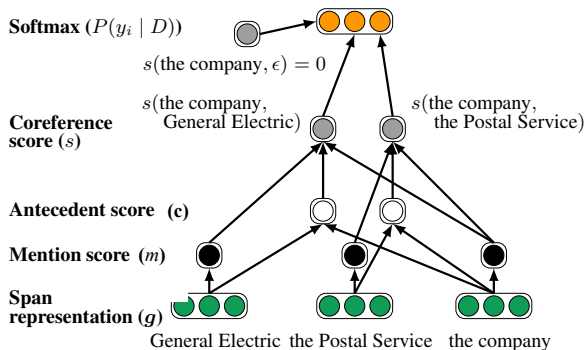


# Computing the score



Train to maximize probabilities of valid mention pairings

# Computing the score



Train to maximize probabilities of valid mention pairings

## Model output with attention visualised

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(A **fire** in a **Bangladeshi garment factory**) has left at least 37 people dead and 100 hospitalized. Most of the deceased were killed in the crush as workers tried to flee (**the blaze**) in the four-story building.

1 A fire in (a **Bangladeshi garment factory**) has left at least 37 people dead and 100 hospitalized. Most of the deceased were killed in the crush as workers tried to flee the blaze in (**the four-story building**).

2 We are looking for (a **region** of central Italy bordering the Adriatic Sea). (The **area**) is mostly mountainous and includes Mt. Corno, the highest peak of the Apennines. (**It**) also includes a lot of sheep, good clean-living, healthy sheep, and an Italian entrepreneur has an idea about how to make a little money of them.

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## Examples of errors

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3 (The flight attendants) have until 6:00 today to ratify labor concessions. (The pilots') union and ground crew did so yesterday.

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4 (Prince Charles and his new wife Camilla) have jumped across the pond and are touring the United States making (their) first stop today in New York. It's Charles' first opportunity to showcase his new wife, but few Americans seem to care. Here's Jeanie Mowth. What a difference two decades make. (Charles and Diana) visited a JC Penney's on the prince's last official US tour. Twenty years later here's the prince with his new wife.

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# Acknowledgement

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