# Class 11: Anaphora and co-reference resolution

# Things and naming things

# What is co-reference resolution?

THE prime minister has fired secretary of state Priti Patel while telling her she wishes with all her heart it was the other way around.

May confessed to Patel that although having secret meetings with the Israelis was a sackable offence, it paled in comparison to her own dire performance but “sadly nobody’s willing to pull the trigger.”

Patel said: “It was so awkward. She said ‘You don’t know how often I’ve dreamt of sitting on your side of the desk, finally being summarily dismissed for my gross incompetence.’

# What is co-reference resolution?



THE prime minister has fired secretary of state Priti Patel while telling her she wishes with all her heart it was the other way around.

May confessed to Patel that although having secret meetings with the Israelis was a sackable offence, it paled in comparison to her own dire performance but “sadly nobody’s willing to pull the trigger.”

Patel said: “It was so awkward. She said ‘You don’t know how often I’ve dreamt of sitting on your side of the desk, finally being summarily dismissed for my gross incompetence.’

# What is co-reference resolution?



THE prime minister has fired secretary of state Priti Patel while telling her she wishes with all her heart it was the other way around.

May confessed to Patel that although having secret meetings with the Israelis was a sackable offence, it paled in comparison to her own dire performance but “sadly nobody’s willing to pull the trigger.”

Patel said: “It was so awkward. She said ‘You don’t know how often I’ve dreamt of sitting on your side of the desk, finally being summarily dismissed for my gross incompetence.’

# What is co-reference resolution?



THE prime minister has fired secretary of state Priti Patel while telling her she wishes with all her heart it was the other way around.

May confessed to Patel that although having secret meetings with the Israelis was a sackable offence, it paled in comparison to her own dire performance but “sadly nobody’s willing to pull the trigger.”

Patel said: “It was so awkward. She said ‘You don’t know how often I’ve dreamt of sitting on your side of the desk, finally being summarily dismissed for my gross incompetence.’

# What is co-reference resolution?



THE prime minister has fired secretary of state Priti Patel while telling her she wishes with all her heart it was the other way around.

May confessed to Patel that although having secret meetings with the Israelis was a sackable offence, it paled in comparison to her own dire performance but "sadly nobody's willing to pull the trigger."

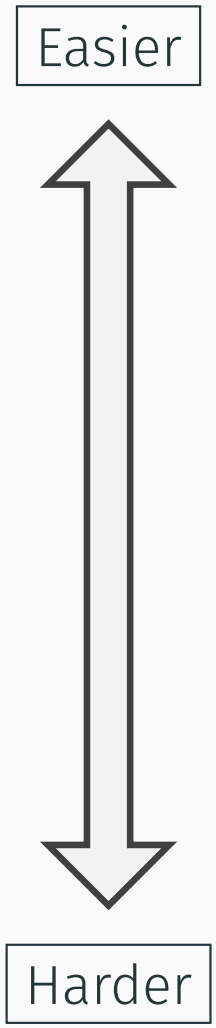
Patel said: "It was so awkward. She said 'You don't know how often I've dreamt of sitting on your side of the desk, finally being summarily dismissed for my gross incompetence.'

# Noun phrases and reference

- NPs usually refer to entities in the world
- NPs may co-refer, meaning they refer to the same entity
- They may also be nested or discontinuous

Однажды Пушкин написал письмо Рабиндранату Тагору. «Дорогой далекий друг, — писал он, — я Вас не знаю, и Вы меня не знаете. Очень хотелось бы познакомиться. Всего хорошего. Саша». Когда письмо принесли, Тагор предавался самосозерцанию. Так погрузился, хоть режь его. Его жена толкала, толкала, письмо подсовывала — не видит. Он, правда, по-русски читать не умел. Так и не познакомились.

# Kinds of reference




Interesting linguistics

**Bound variables**

She hurt *herself*
Я имею *свой* баян

**Free variables**

Maša read *her* book
*Ей* очень нравилась.

**Referring expressions**

Carles Puigdemont
the Catalan president
Puigdemont
Puchi
president of Catalonia
President Puigdemont

More frequent

# Coreference, anaphora, cataphora

- Coreference
  - Two *mentions* (NPs) refer to the same entity
  - May be identical or completely different
- Anaphora, Cataphora
  - Interpretation is in some way dependent on an antecedent
  - Traditionally the antecedent came first, but not always the case.

# Cataphora

(Oscar Wilde – The Picture of Dorian Grey)

# Other types of anaphora

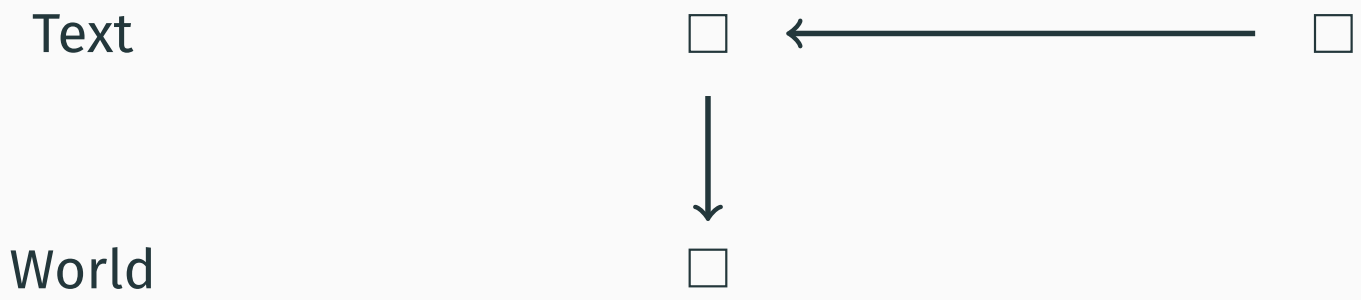
- Bridging Anaphora:
- ”Other” Anaphora:
- Non-NP Anaphora (e.g. events, propositions)

# Anaphora vs. coreference

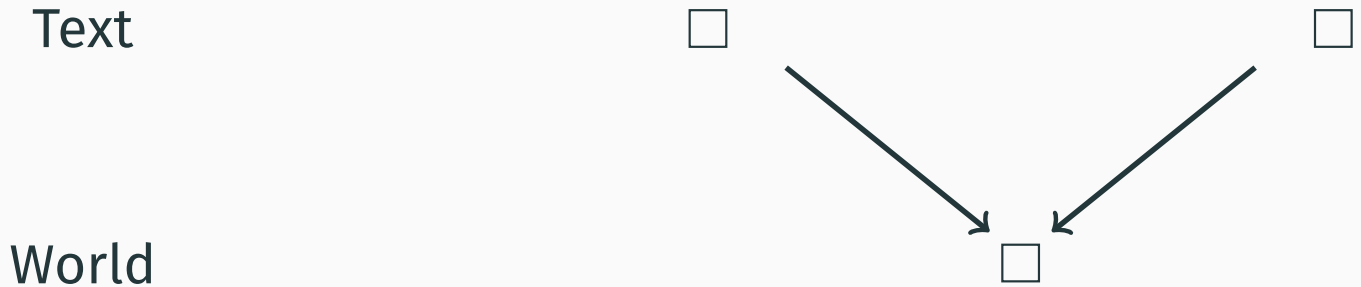
- Not all anaphoric relations are coreferential, e.g. bridging anaphora
- Multiple identical NP matches are often coreferential but not anaphoric

# Two different things

Anaphora resolution




Co-reference resolution



# Applications

## Machine translation:

- Translating pronouns like *себя* — myself, yourself, herself, ...
- Translating from languages with no gender distinction in pronouns *här — он, она*

## Text summarisation:

- [Maša]$_i$ read [Wikipedia]$_j$ with unbridled enthusiasm. [She]$_i$ spent so long reading [it]$_j$ that [she]$_i$ forget about her homework.
  - $\rightarrow$ Maša read Wikipedia and forgot about her homework.

## Information extraction:

- What did Maša do ?
  - read Wikipedia
  - forgot about her homework

# Pronominal anaphora resolution

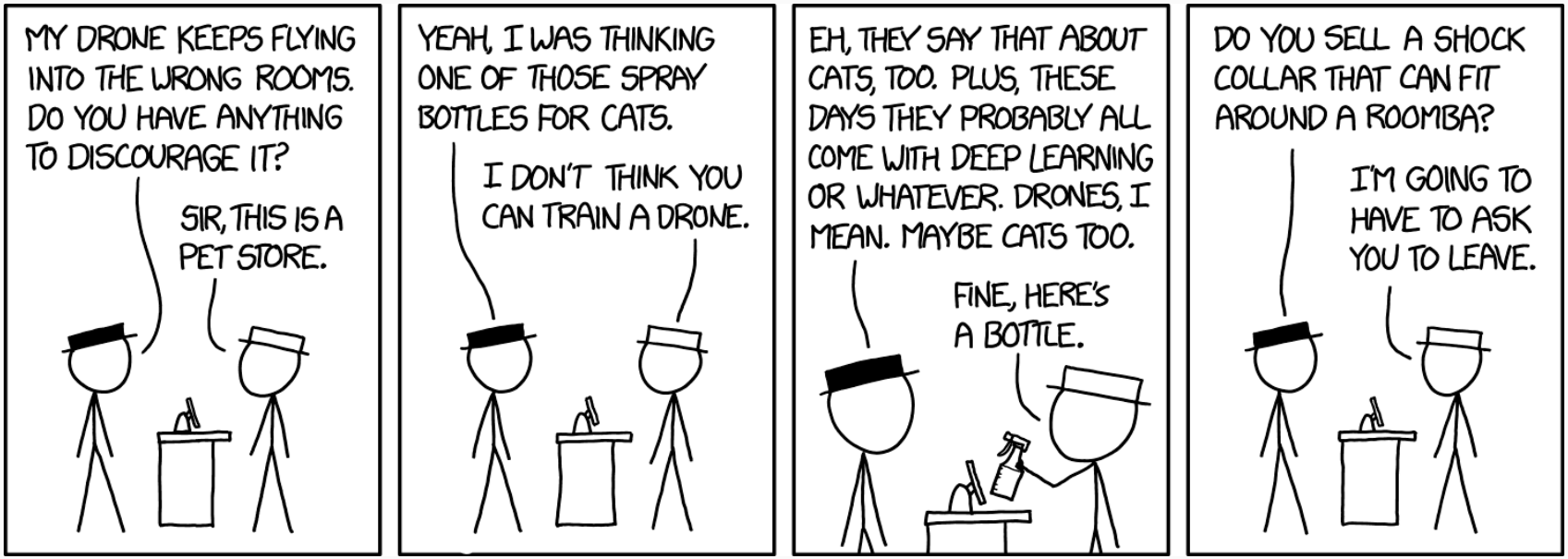
# Hobbs' (1978) algorithm/1

- Simple syntax-based algorithm for 3rd person anaphoric pronouns
- Requires:
  - Constituency parser
  - Gender and number 'checker'
    - Parsers for English rarely include gender information for nouns
- Searches current and preceding sentences in a breadth-first, left-to-right manner, stops when it finds a matching NP

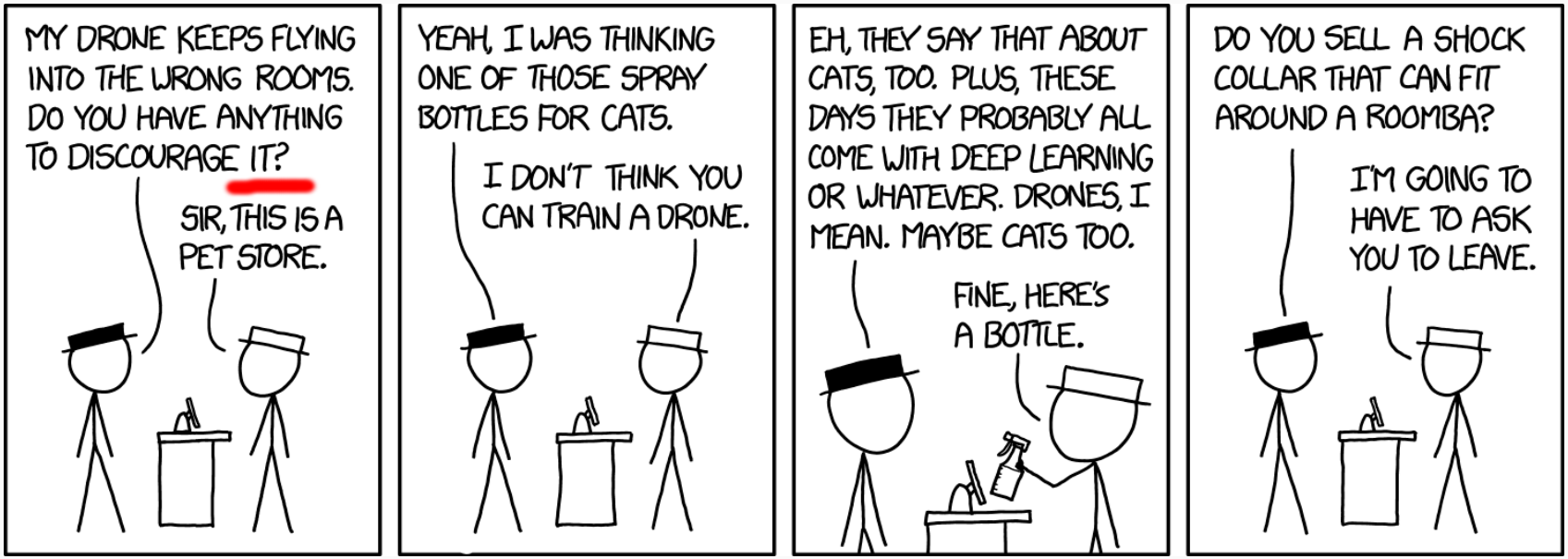
# Hobbs' (1978) algorithm/2

- Right to left search in current sentence
- If not valid antecedent fine, try previous sentence
    - Left to right breadth-first search

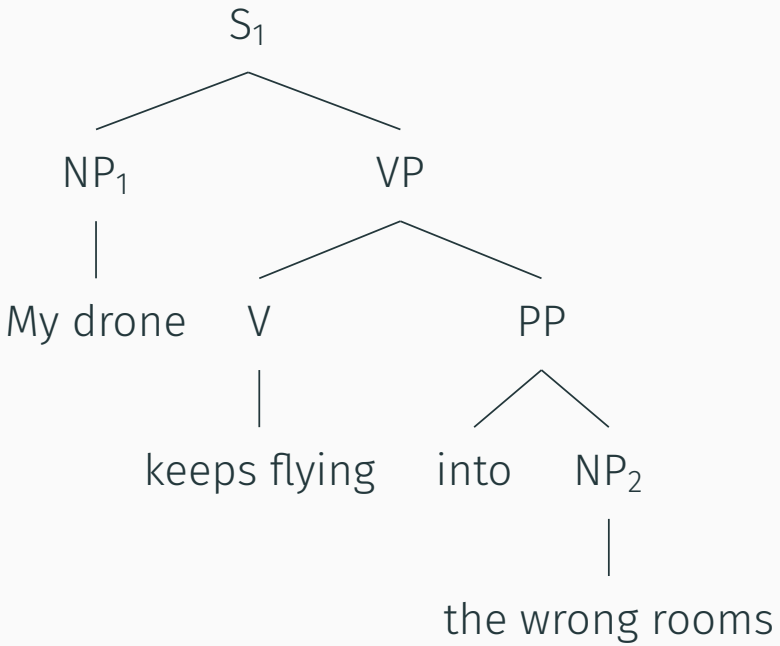
# Hobbs' (1978) algorithm/3

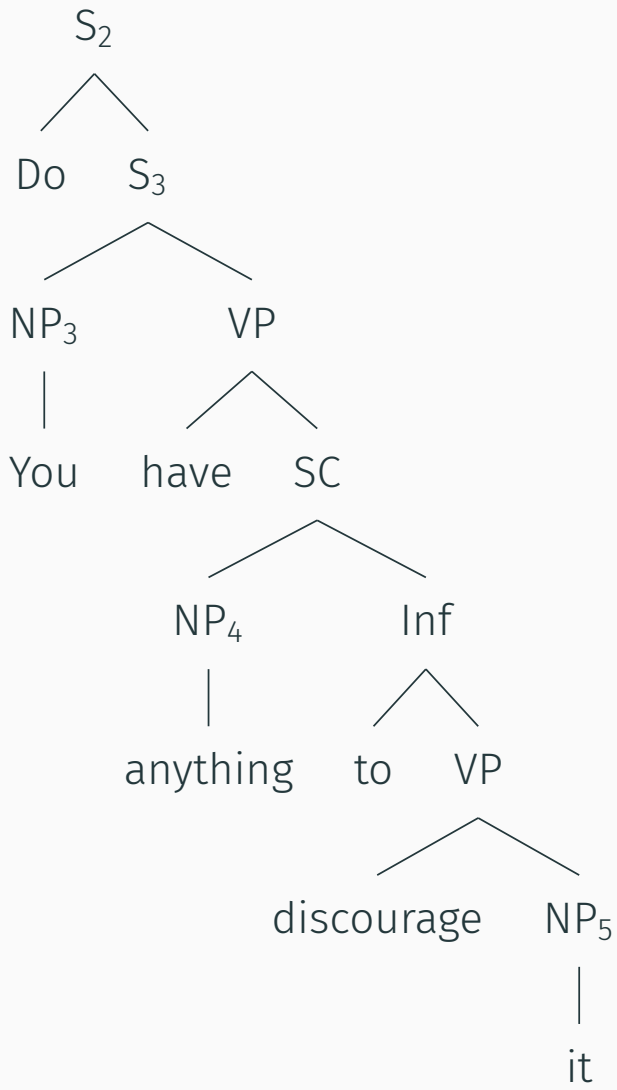


# Hobbs' (1978) algorithm/3



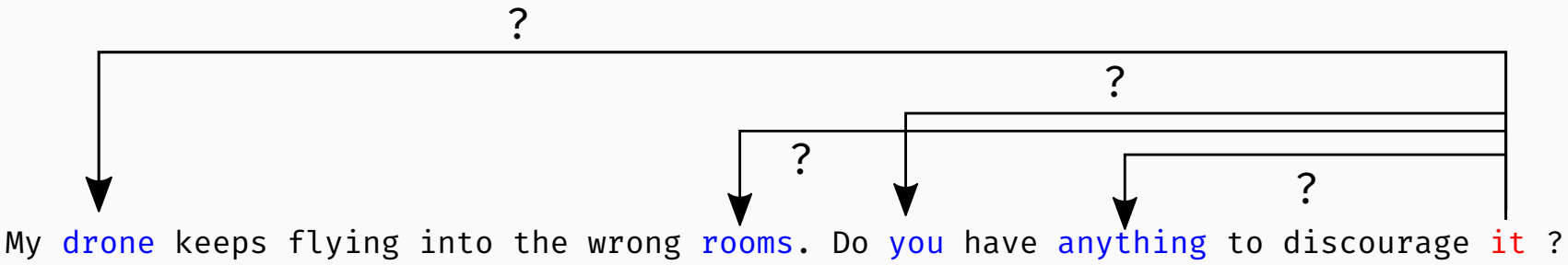
# Hobbs' (1978) algorithm/4




- Start search in $NP_5$ in $S_2$
- Reject $NP_4$, no intervening NP
- Reject $NP_3$, feature mismatch
- Move to $S_1$
- Accept $NP_1$

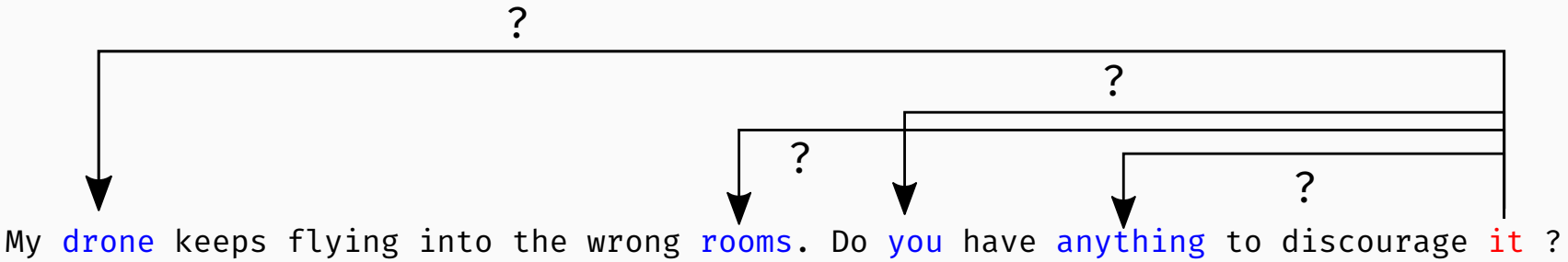
# Log-linear model/1




- Supervised machine learning approach
- Requires corpus where each pronoun has been linked with its antecedent

- Extract positive and negative examples
- Train binary classifier
  - True: is co-referent
  - False: is not co-referent

# Log-linear model/2




Positive example:

- (it, my drone)

Negative examples:

- (it, anything)
- (it, you)
- (it, the wrong rooms)

# Log-linear model/3

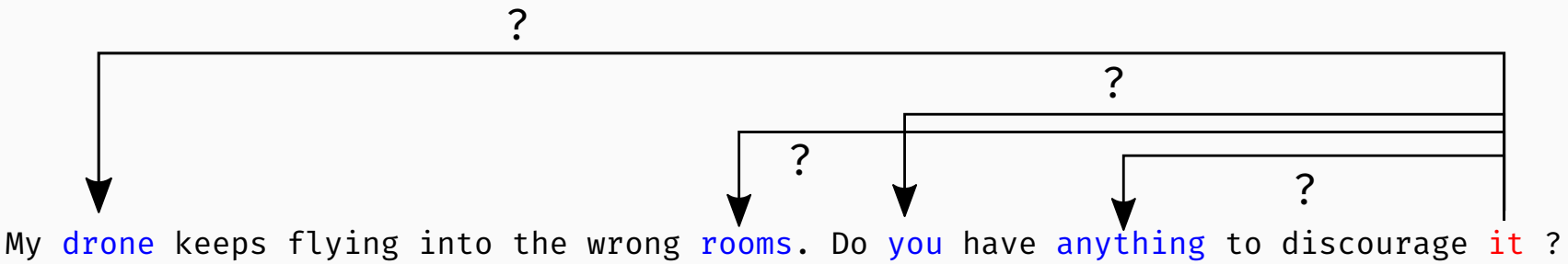
- **strict gender** [true, false]
- **compatible gender** [true, false]
- **strict number** [true, false]
- **compatible number** [true, false]
- **sentence distance** [0, 1, 2, ...]
- **Hobbs distance** [0, 1, 2, ...]
- **linguistic form** [proper, def, indef, pronoun]

Can you think of some other useful features ?

# Log-linear model/4

- **Recency:** More recently mentioned entities are more likely to be referred to
- **Grammatical Role:** Entities in the subject position is more likely to be referred to than entities in the object position
- **Parallelism:**
- **Verb Semantics:** Certain verbs seem to bias whether the subsequent pronouns should be referring to their subjects or objects
- **Selectional Restrictions:** Restrictions because of semantics

# Log-linear model/5




- For each pronoun,
  - For each NP we have seen so far,
    - Classify if NP is an antecedent of the pronoun

# Co-reference resolution

# Reference models

Однажды Пушкин написал письмо Рабиндранату Тагору. «Дорогой далекий друг, — писал он, — я Вас не знаю, и Вы меня не знаете. Очень хотелось бы познакомиться. Всего хорошего. Саша». Когда письмо принесли, Тагор предавался самосозерцанию. Так погрузился, хоть режь его. Его жена толкала, толкала, письмо подсовывала — не видит. Он, правда, по-русски читать не умел. Так и не познакомились.

Пушкин, он$_1$, я$_1$, меня$_1$

Рабиндранату Тагору, Дорогой далекий друг, Вас$_1$, Вы$_1$, Тагор, его$_1$, Он

# General algorithm

# Additional features

# Rule-based models/1

Input is a sequence of dependency trees representing the document.

Constraint-based, rules like:

$C =< ANA, ANT, DIST, PROP >$

- ANA, ANT = constraints on the anaphor and antecedent
- DIR = direction (e.g. forward, backwards)
- DIST = how far to look (in sentences)
- PROP = should features (e.g. gender) be propagated?

# Rule-based models/2

Example rules:

- Mark full-text matches as coreferent
- Two 1st person pronouns in the same quoted speech corefer
- A surname matching a previous firstname + surname corefers

# Evaluation

# Model-Theoretic coreference scoring/1

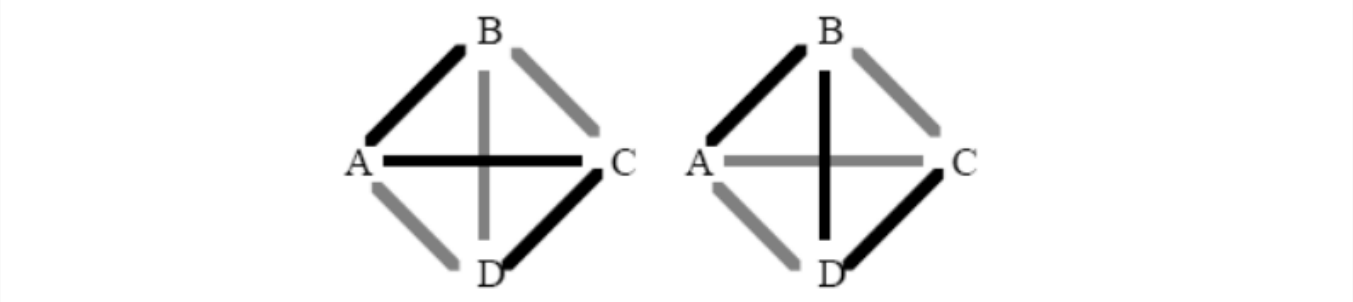
Used in the MUC series of shared tasks

Requires:

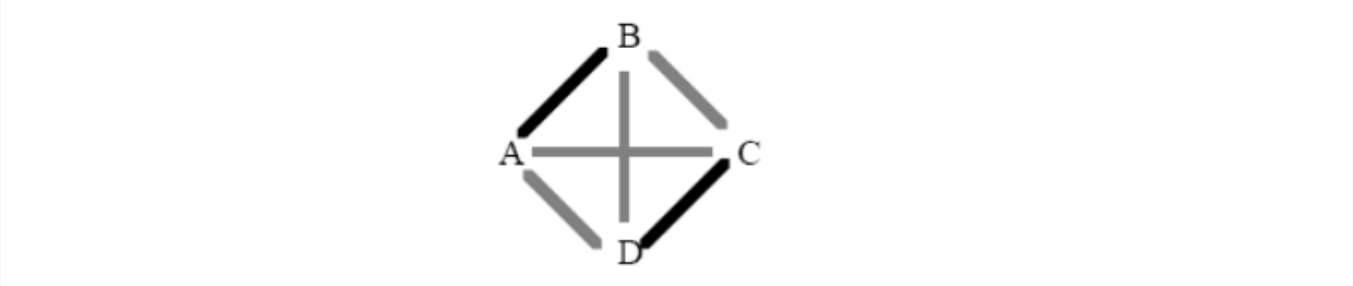
- A KEY (the gold standard)
- A RESPONSE (system output)

# Model-Theoretic coreference scoring/2

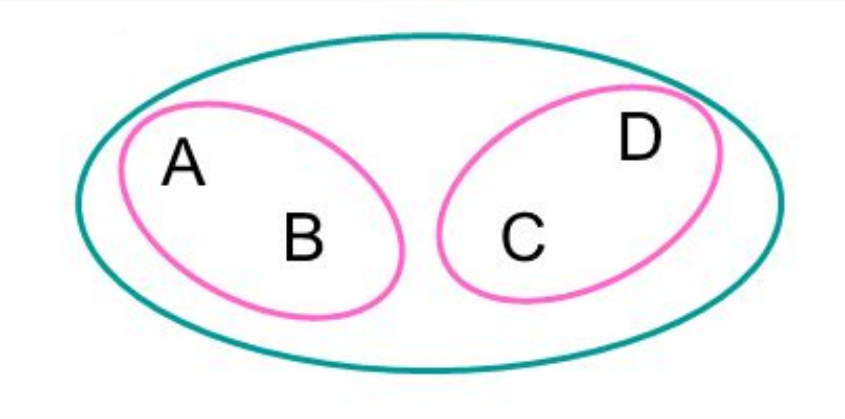
Given that A,B,C and D are part of a coreference chain in the KEY, treat as equivalent the two responses:




And as superior to:



# Model-Theoretic coreference scoring/3




- KEY: [A, B, C, D]
- RESPONSE: [A, B] [C, D]

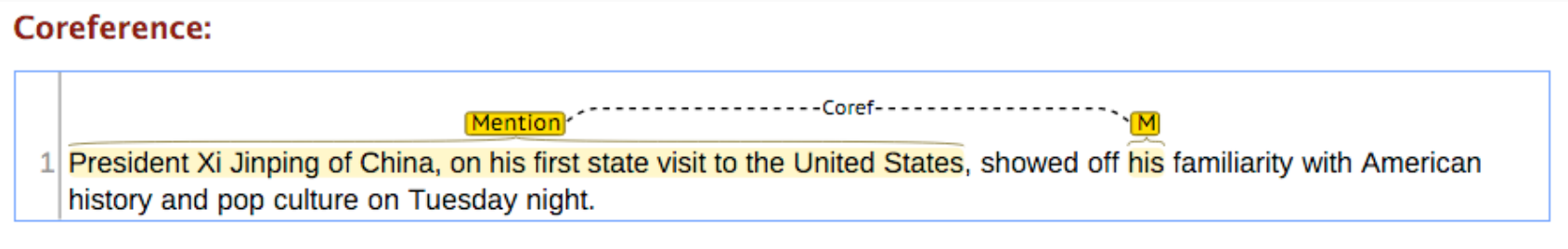
- Recall = $\frac{4-2}{3} = 0.66$
- Precision = $\frac{4-1}{4-1} = 1.0$
- F-score = $\frac{2.\frac{2}{3}*1}{\frac{2}{3}.1} = 0.79$

# Other metrics

- $B^3$ scoring
- CEAF

# Tools and resources

# Stanford CoreNLP




`https://stanfordnlp.github.io/CoreNLP/index.html`

- includes coreference for English + Chinese
- rule-based, statistical and neural models
- based on Java
- very “heavy” ($>$ 1G for code + model)

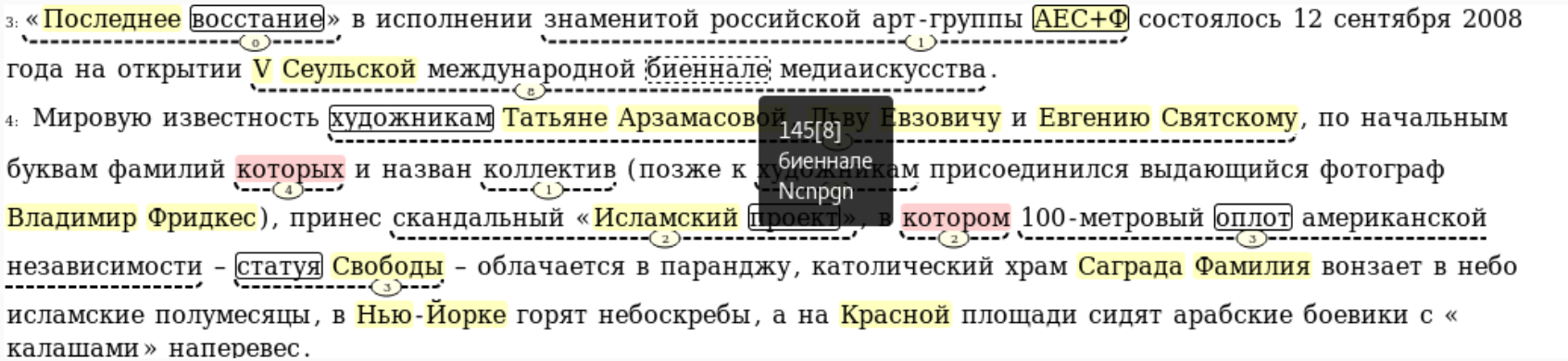
# xrenner


eXternally configurable REference and Non Named Entity Recogniser

`https://github.com/amir-zeldes/xrenner`

- based on Python
- Rule-based (constraints)
- Functioning model for English
- (relatively) small footprint ($<$ 100M)

# RuCor




http://ant1.compling.net/res03/ant1.php

- Corpus of Russian annotated for co-reference
- 156,636 tokens

# Shared tasks

# Message Understanding Conference (MUC)

# SemEval 2010

# RuEval-2014

Two tracks:

- Pronominal anaphora resolution (8 teams)
  - personal, possessive, relative and reflexive pronouns
  - antecedent should be in the gold-standard coreference chain
- Co-reference resolution (3 teams)

# Practical

# Practical

For the practical, select a short paragraph or document and write some coreference rules using Xrenner.

Further instructions:

`https://ftyers.github.io/028-komp-ling/classes/11.html`