Class 11: Anaphora and co-reference resolution

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.’

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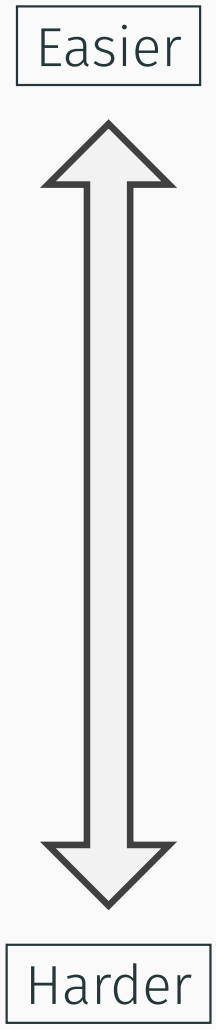
Noun phrases and reference

- 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

From the corner of the divan of Persian saddlebags on which **he** was lying, smoking, as was his custom, innumerable cigarettes, **Lord Henry Wotton** could just catch the gleam of the honey-sweet and honey-coloured blossoms of a laburnum, whose tremulous branches seemed hardly able to bear the burden of a beauty so flame-like as theirs; ...

(Oscar Wilde – The Picture of Dorian Grey)

Cataphora

С покрытого персидскими чепраками дивана, на котором лежал лорд Генри Уоттон, куря, как всегда, одну за другой бесчисленные папиросы, был виден только куст ракитника – его золотые и душистые, как мед, цветы жарко пылали на солнце, а трепещущие ветви, казалось, едва выдерживали тяжесть этого сверкающего великолепия ...

(Oscar Wilde – The Picture of Dorian Grey)

Other types of anaphora

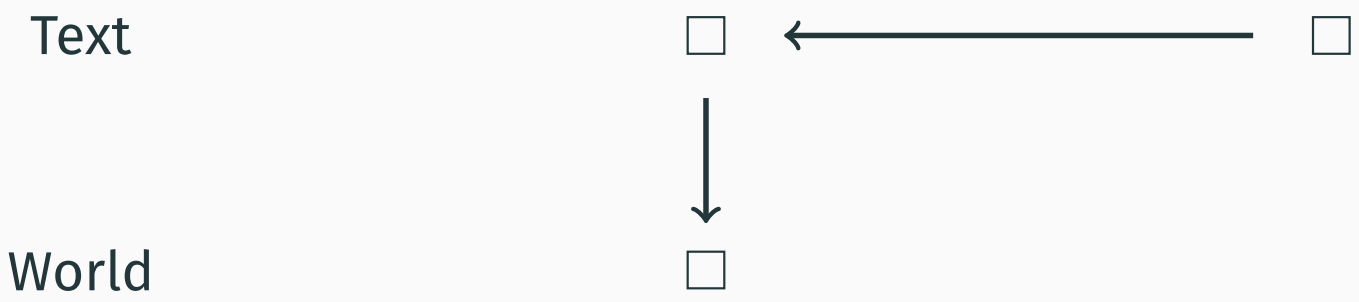
- **Bridging anaphora:**
  - This laptop is painful to use. The keyboard is half broken.
- **“Other” anaphora:**
  - Programming is hard with no `f` key. Please can I use another laptop?
- **Non-NP anaphora:** (e.g. events, propositions)
  - Даша снова не сделала домашки. Это была огромная беда.

Anaphora vs. coreference

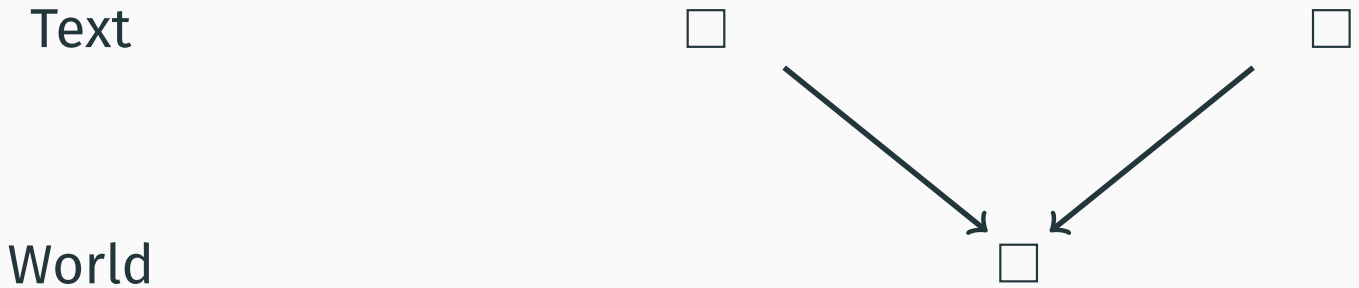
- Not all anaphoric relations are coreferential, e.g. bridging anaphora
- Multiple identical NP matches are often coreferential but not anaphoric

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

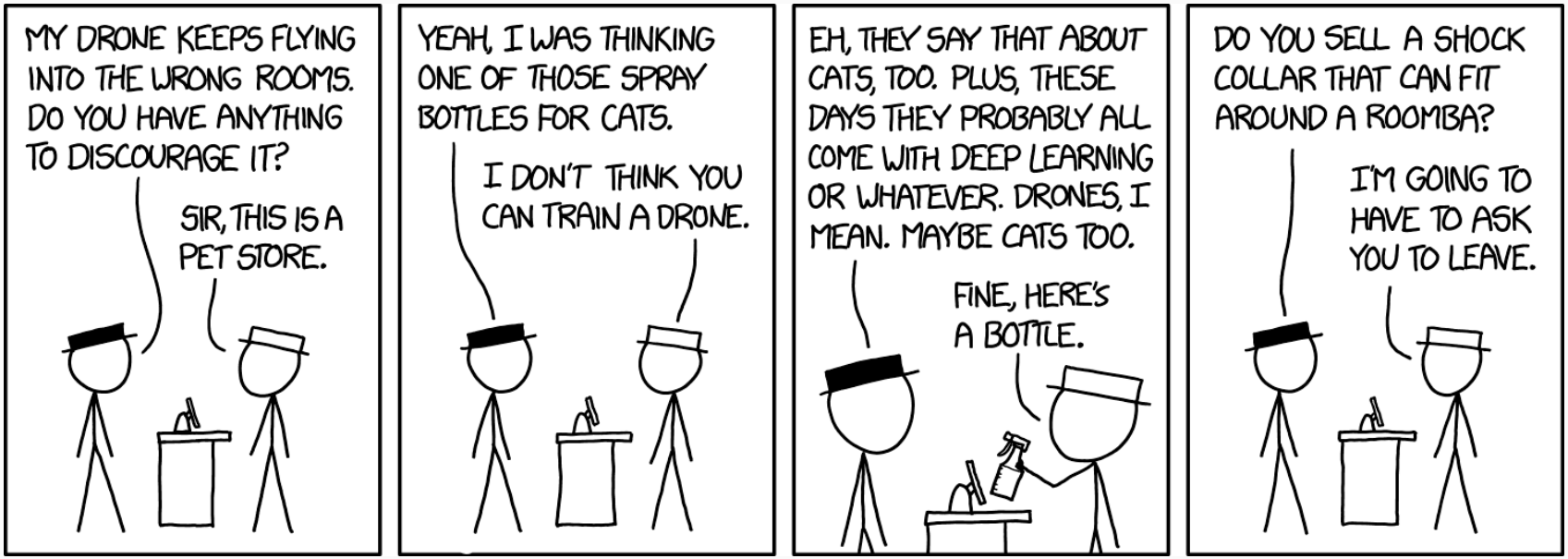
Hobbs' (1978) algorithm/1

- 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

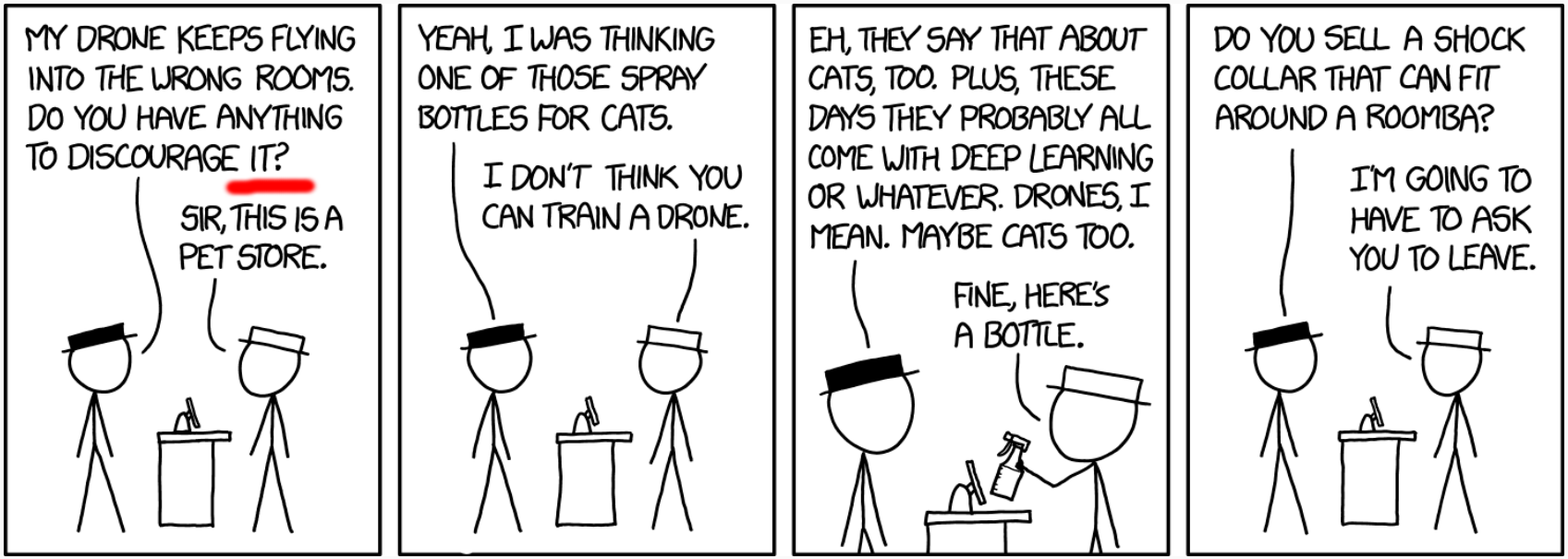
Hobbs' (1978) algorithm/2

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

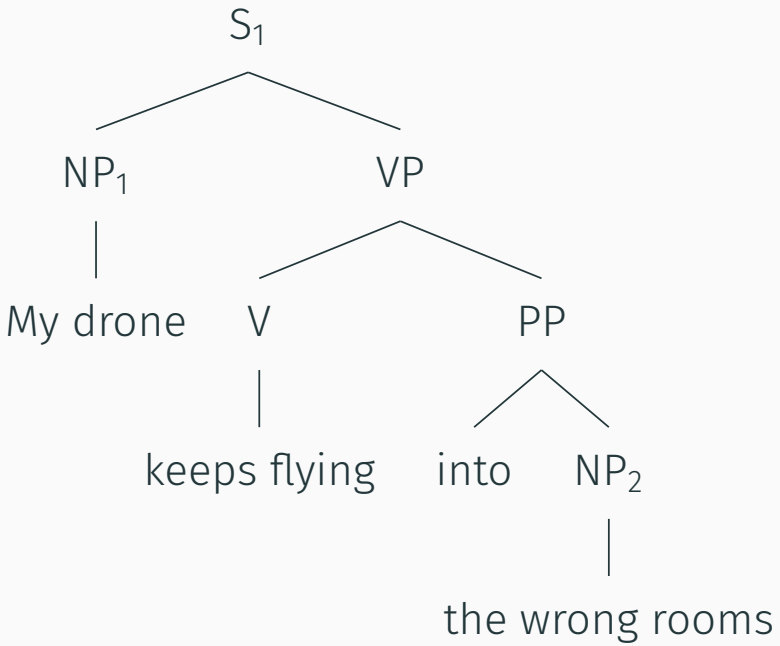
Hobbs' (1978) algorithm/3

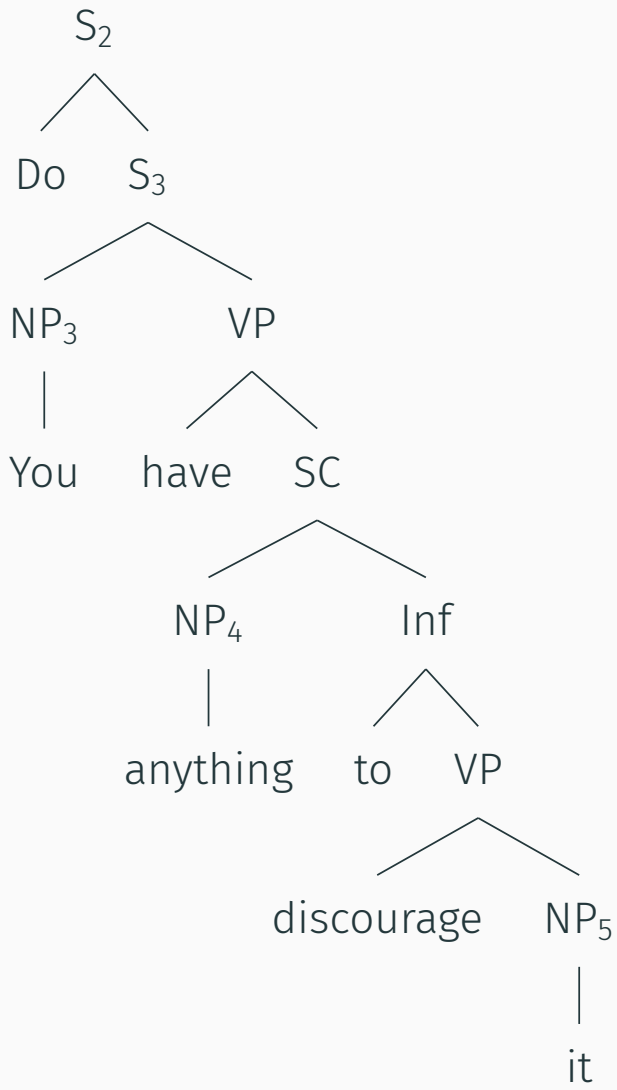


Hobbs' (1978) algorithm/3



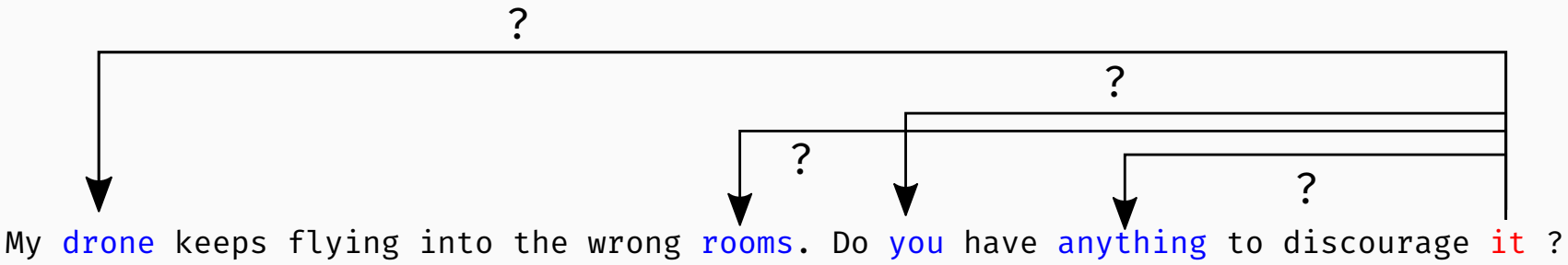
Hobbs' (1978) algorithm/4





- 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

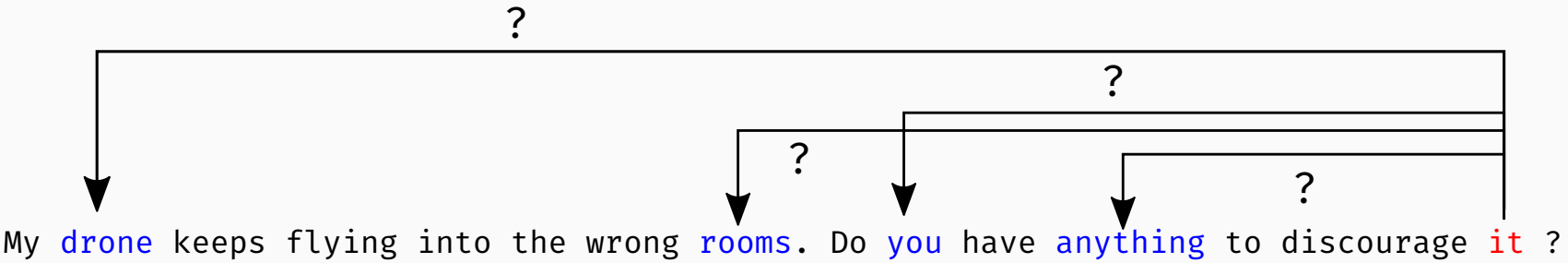
Log-linear model/1



- 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], e.g. Masc + Masc
- **compatible gender** [true, false], e.g. Masc Pro + Unknown NP
- **strict number** [true, false]
- **compatible number** [true, false]
- **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
  - Anja dyed her hair blue. Saša did too. She really liked anime.
  - **sentence distance** [0, 1, 2, ...]
  - **Hobbs distance** [0, 1, 2, ...]
- **Grammatical Role:** Entities in the subject position is more likely to be referred to than entities in the object position
  - Maša conducted scientific experiments with Daša. She was completely absorbed in her work.
- **Parallelism:**
  - Maša played D&D with Daša. Saša played table tennis with her.

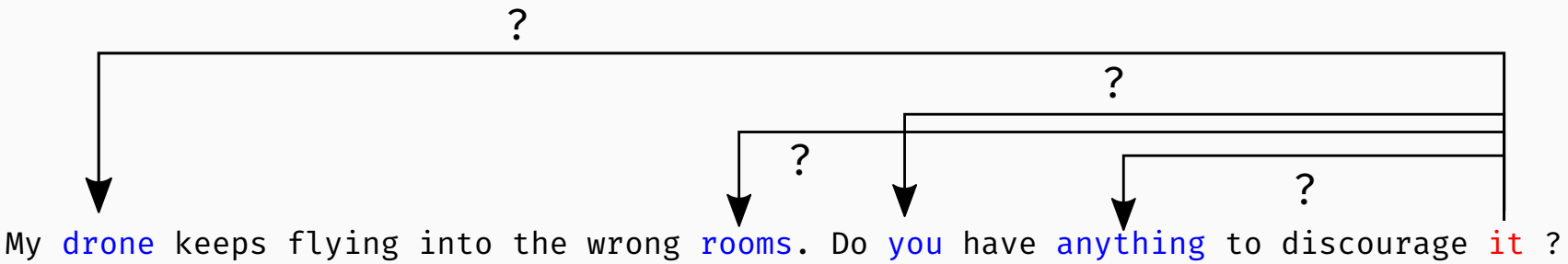
Are these cross-linguistically applicable ?

Log-linear model/5

- **Verb Semantics:** Certain verbs seem to bias whether the subsequent pronouns should be referring to their subjects or objects
  - • Maša sternly rebuked Daša. She broke her keyboard.
  - ? Maša phoned Daša. She had lost her laptop.
- **Selectional Restrictions:** Restrictions because of semantics
  - Maša got bored of Wikipedia on the train after reading it for hours.

Are these cross-linguistically applicable ?

Log-linear model/6



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

Co-reference resolution

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.

Reference models

Chains: (which bits corefer with other bits)

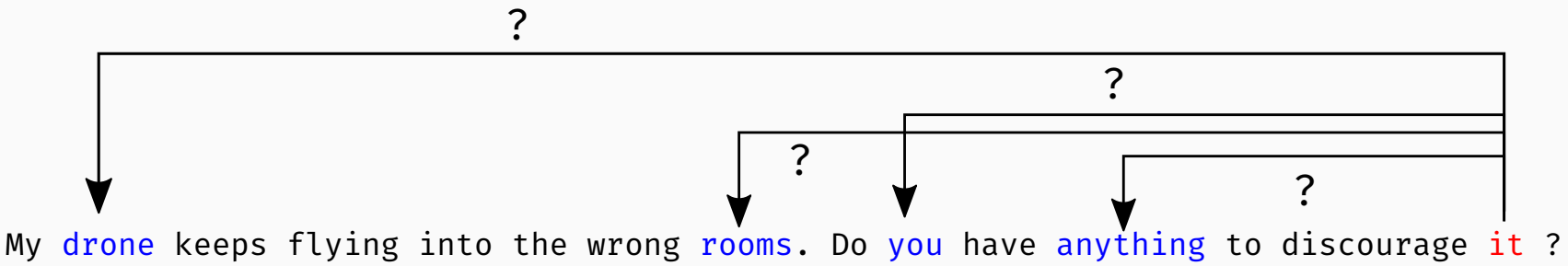
Пушкин ← он$_1$, Пушкин ← я$_1$, Пушкин ← меня$_1$, Пушкин ← Саша

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

Entity mention: (which bits refer to the same real-world entity)

Александр Пушкин	←	Пушкин, он$_1$, я$_1$, меня$_1$, Саша
Рабиндранат Тагор	←	Рабиндранату Тагору, Дорогой далекий друг, Вас$_1$, Вы$_1$, Тагор, его$_1$, Он

General algorithm



We can use the same basic algorithm that we used for anaphora resolution.

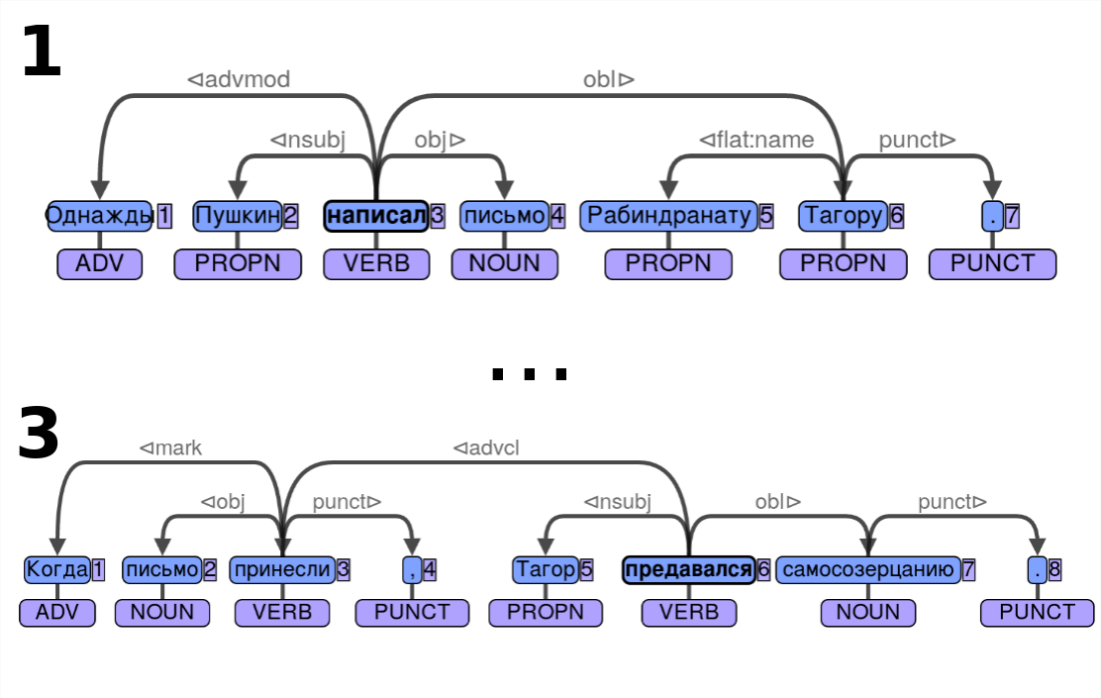
- For each NP,
  - For each other NP we have seen so far,
    - Classify if NP is coreferent

Additional features

We can use all the same features that we use for pronominal anaphora resolution, but some others may be helpful

- Gazeteers (giving semantic classes — `abstract`, `person`, etc.)
- Name correspondence classes (e.g. Маша–Мария)
- …

Rule-based models/1



Constraint-based, rules like:

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

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

Rule-based models/2

Example rules:

- Mark full-text proper noun matches as coreferent
- Two 1st person pronouns in the same quoted speech corefer
  - **я** Вас не знаю и Вы **меня** не знаете.
- A surname matching a previous firstname + surname corefers
  - Рабиндранату Тагору ...Тагор

Evaluation

Model-Theoretic coreference scoring/1

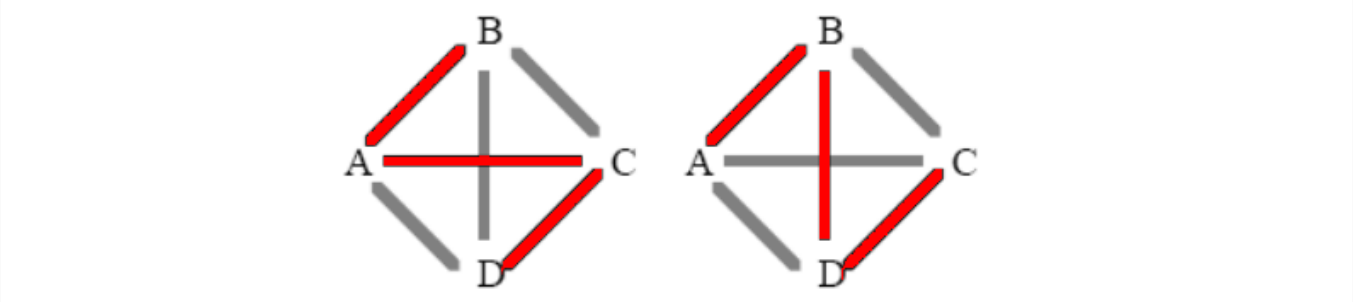
Used in the MUC series of shared tasks

Requires:

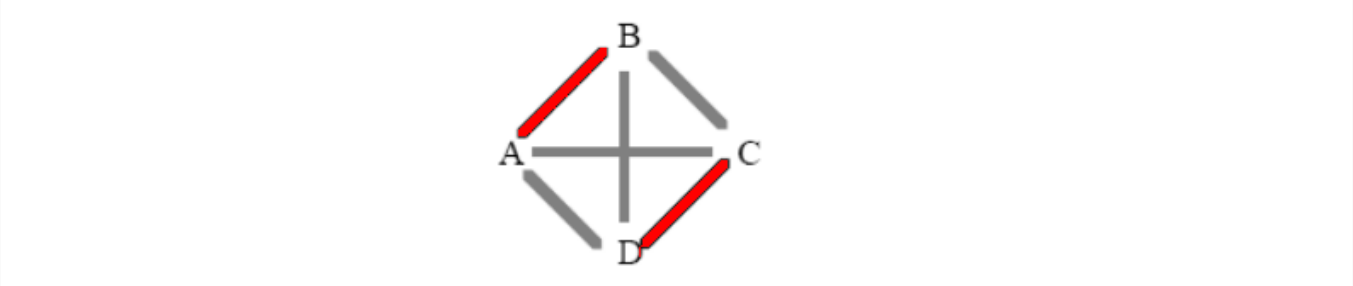
- A KEY (the gold standard)
- A RESPONSE (system output)

Model-Theoretic coreference scoring/2

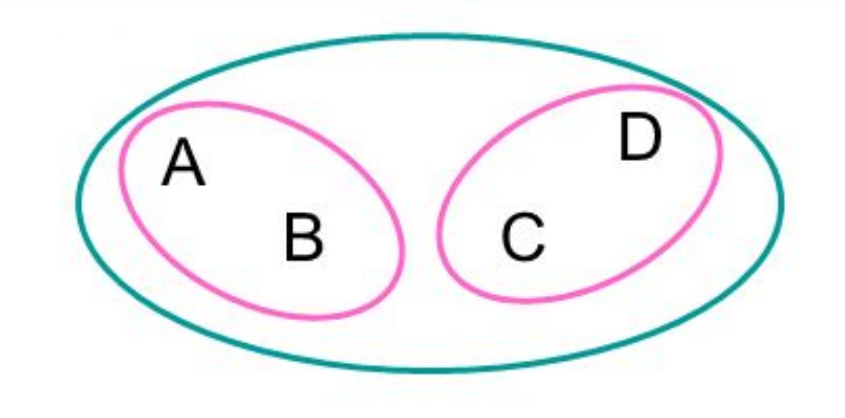
Given that A,B,C and D are part of a coreference chain in the KEY, treat as equivalent the two responses:



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 = $\frac{2.\frac{2}{3}*1}{\frac{2}{3}.1} = 0.79$

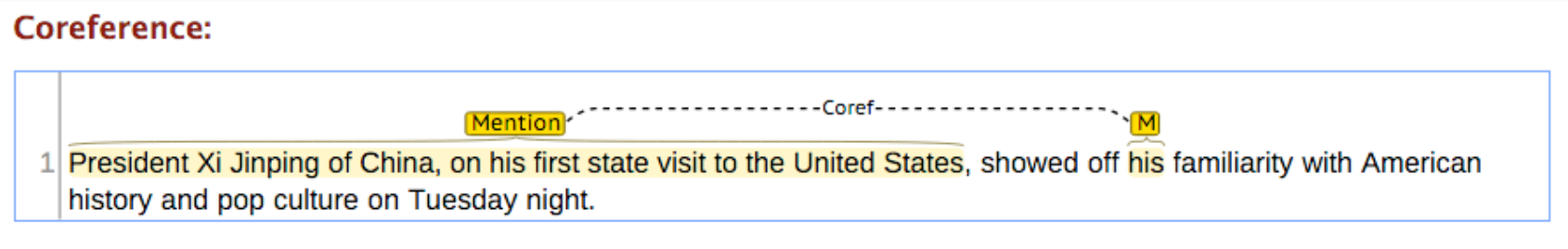
Where does the 2 come from ? The number of partitions of the key in the response.

Other metrics

- Standard precision/recall (for anaphora resolution)
- B^3 scoring: compute averages for precision and recall for each pair, and then use these averaged values
- CEAF: requires aligning the chains in the KEY and RESPONSE.

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/1

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)

xrenner/2

An example rule:

```
# ANA, ANT, DIST, PROP
form="proper"; form="proper"&lemma=$1; 100; nopropagate
```

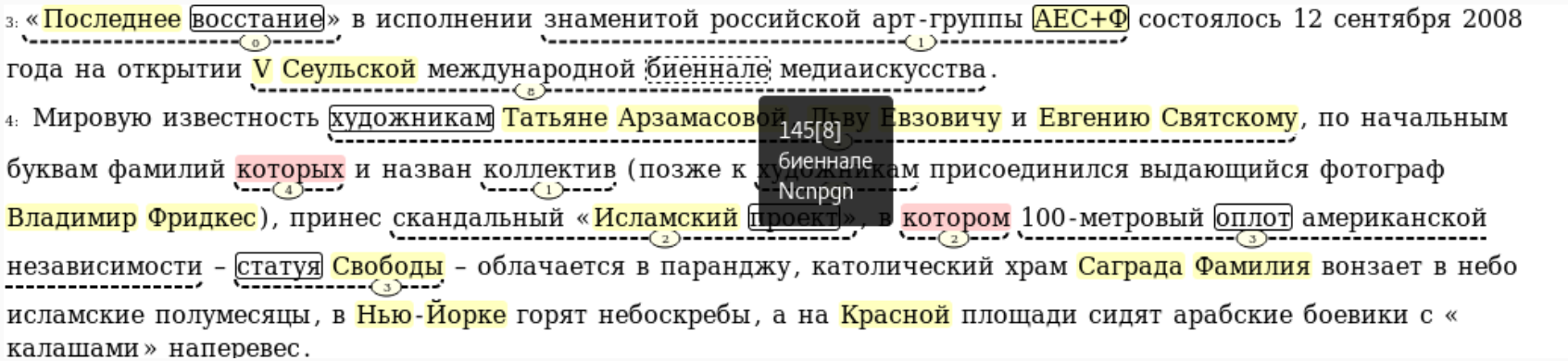
Constraints:

- Anaphor must be a proper name
- Antecedent must be a proper name with the same lemma as the anaphor
- Search up to 100 sentences backwards
- Do not propagate features from the antecedent to the anaphor.

Other stuff

- ruCoref, `https://github.com/max-ionov/rucoref`
- BART, `http://www.bart-coref.org/index.html`

RuCor



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

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

Shared tasks

Message Understanding Conference (MUC)

- Run by ARPA in the US, 1992–1997
- First big initiative in Information Extraction
- Important in NLP for:
  - Datasets for named-entity extraction and coreference.
  - Size of dataset (318 full WSJ) made it possible to apply ML methods
- Developed first methods for evaluating anaphora resolution systems
- Subsequent work based on this

SemEval 2010

- 6 participants
- Multilingual: Catalan, Dutch, English, German, Italian, Spanish
- Questions:
  - To what extent is it possible to implement a general system that is portable to the three languages?
  - How much language-specific tuning is necessary?
  - Are there significant differences between Germanic and Romance languages? And between languages of the same family?
- Used non-free OntoNotes corpus, approx. 120k tokens (English)

RuEval-2014

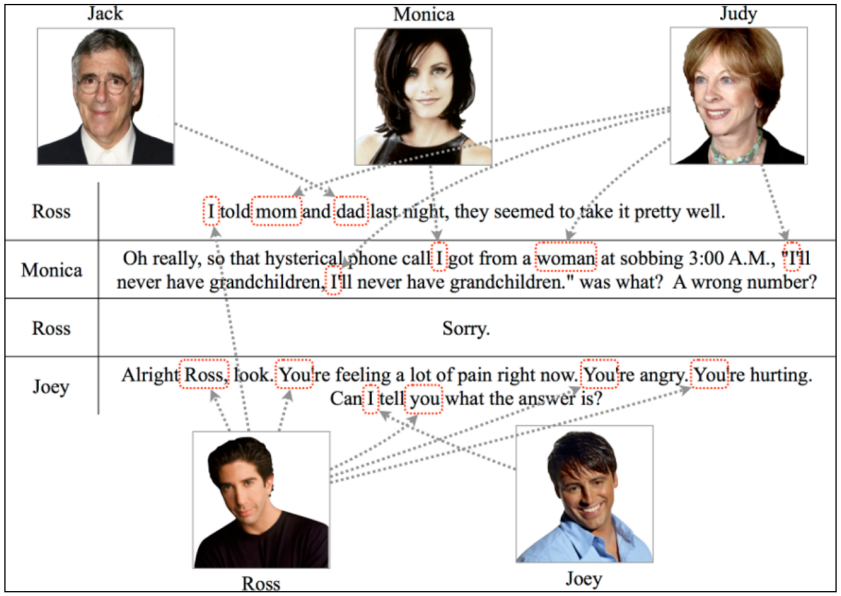
Two tracks:

- 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)

Teams:

- ABBYY, rule-based
- `mail.ru`, rule-based + ML

SemEval 2016: Character identification on multiparty dialogues



								Speaker		Entity ID
0	0	He	PRP	(TOP(S(NP*)	he	-	-	Monica_Geller	*	(284)
0	1	's	VBZ	(VP*	be	-	-	Monica_Geller	*	-
0	2	just	RB	(ADVP*)	just	-	-	Monica_Geller	*	-
0	3	some	DT	(NP(NP*	some	-	-	Monica_Geller	*	-
0	4	guy	NN	*)	guy	-	-	Monica_Geller	*	(284)
0	5	I	PRP	(SBAR(S(NP*)	I	-	-	Monica_Geller	*	(248)
0	6	work	VBP	(VP*	work	-	-	Monica_Geller	*	-
0	7	with	IN	(PP*))))))	with	-	-	Monica_Geller	*	-
0	8	!	.	*))	!	-	-	Monica_Geller	*	-

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`