

Class 11: Anaphora and co-reference resolution

What is co-reference resolution?

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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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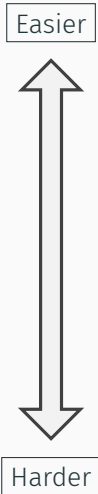
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Noun phrases and reference

- 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
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по-русски читать не умел. Так и не познакомились.

Kinds of reference

 <div>Easier</div> <div>Harder</div>	Interesting linguistics	
	Bound variables	She hurt <i>herself</i> Я имею <i>свой</i> баян
	Free variables	Maša read <i>her</i> 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.

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)

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)

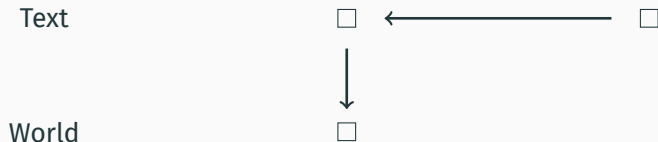
- Даша снова не сделала домашки. **Это** была огромная беда.

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



Machine translation:

- Translating pronouns like *себя* — myself, yourself, herself, ...
- Translating from languages with no gender distinction in pronouns *hän* — *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.
→ Maša read Wikipedia and forgot about her homework.

Information extraction:

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

Pronominal anaphora resolution

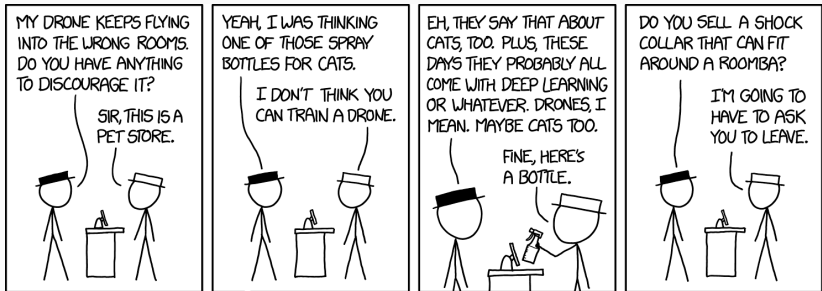
Hobbs' (1978) algorithm/1

- 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

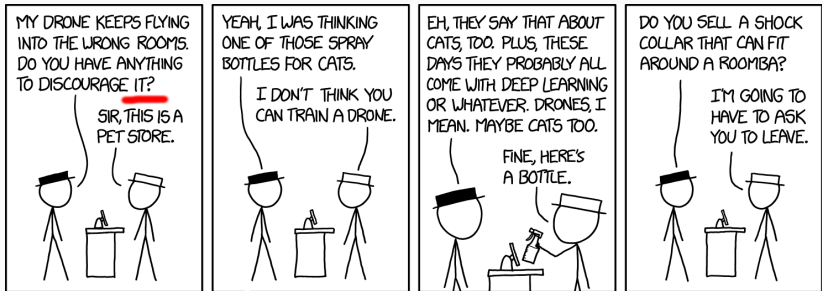
Hobbs' (1978) algorithm/2

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

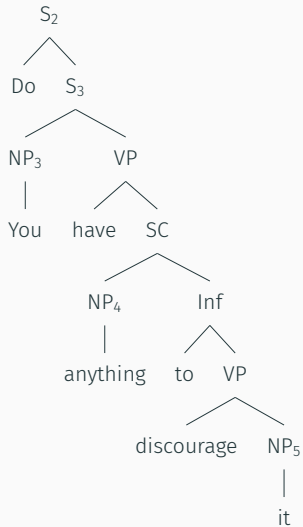
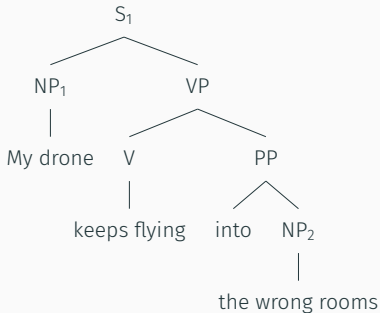
Hobbs' (1978) algorithm/3



Hobbs' (1978) algorithm/3

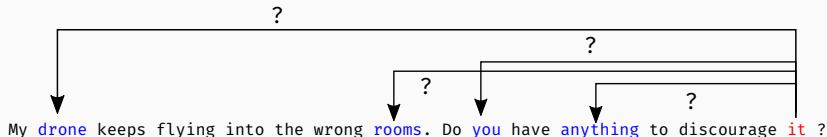


Hobbs' (1978) algorithm/4



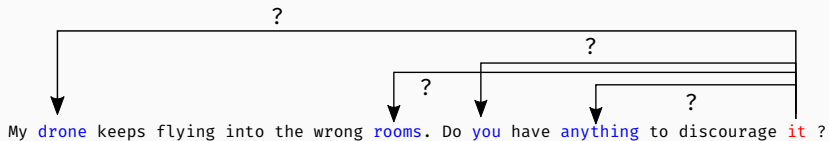
- Start search in NP₅ in S₂
- Reject NP₄, no intervening NP
- Reject NP₃, feature mismatch
- Move to S₁
- Accept NP₁

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)

- **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 ?

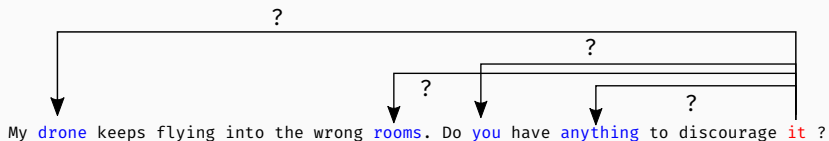
- **Recency:** More recently mentioned entities are more likely to be referred to
 - **Anja** dyed her hair blue. **Saša** did too. **She** really liked anime.
 - **sentence distance** [0, 1, 2, ...]
 - **Hobbs distance** [0, 1, 2, ...]
- **Grammatical Role:** Entities in the subject position is more 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 ?

- **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
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Reference models

Chains: (which bits corefer with other bits)

Пушкин \leftarrow он₁, Пушкин \leftarrow я₁, Пушкин \leftarrow меня₁,

Пушкин \leftarrow Саша

Рабиндранату Тагору \leftarrow Дорогой далекий друг,

Дорогой далекий друг \leftarrow Вас₁, Дорогой далекий друг

\leftarrow Вы₁, Рабиндранату Тагору \leftarrow Тагор, Тагор \leftarrow его₁,

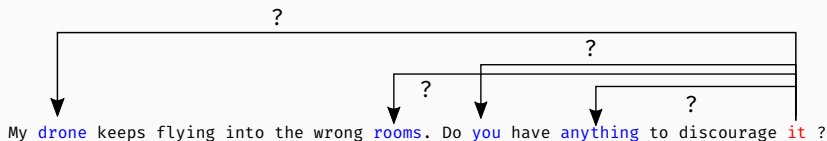
Тагор \leftarrow Он

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

Александр Пушкин \leftarrow Пушкин, он₁, я₁, меня₁, Саша

Рабиндранат Тагор \leftarrow Рабиндранату Тагору, Дорогой далекий друг, Вас₁, Вы₁, Тагор, его₁, 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

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

- Gazetteers (giving semantic classes — **abstract**, **person**, etc.)
- Name correspondence classes (e.g. Маша–Мария)
- ...

Input is a sequence of dependency trees representing the document.

Constraint-based, rules like:

$C = \langle ANA, ANT, DIST, PROP \rangle$

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

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 знаешь.
- A surname matching a previous firstname + surname corefers
 - Рабиндранату Тагору ...Тагор

Evaluation

Model-Theoretic coreference scoring/1

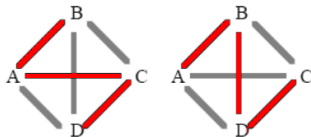
Used in the MUC series of shared tasks

Requires:

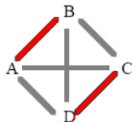
- A KEY (the gold standard)
- A RESPONSE (system output)

Model-Theoretic coreference scoring/2

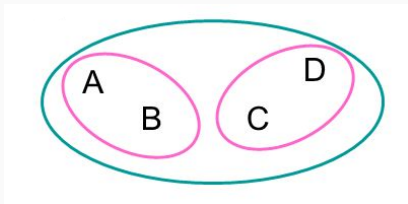
Given that A,B,C and D are part of a coreference chain in the KEY, treat as equivalent the two responses:



And as superior to:



Model-Theoretic coreference scoring/3



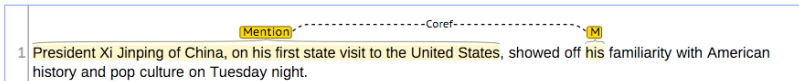
- KEY: [A, B, C, D]
- RESPONSE: [A, B] [C, D]
- Recall = $\frac{4-2}{3} = 0.66$
- Precision = $\frac{4-1}{4-1} = 1.0$
- F-score = $\frac{2 \cdot \frac{2}{3} * 1}{\frac{2}{3} + 1} = 0.79$

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

- Standard precision/recall (for anaphora resolution)
- B³ 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

Coreference:



<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)



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)

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

- 3: «Последнее восстание» в исполнении знаменитой российской арт-группы АЕС+Ф состоялось 12 сентября 2008 года на открытии V Сеульской международной биеннале медиаискусства.
- 4: Мировую известность художникам Татьяне Арзамасовой ^{145[8]} Андрею Евзовичу и Евгению Святскому, по начальным буквам фамилий которых и назван коллектив (позже к биеннале Ncnpgn присоединился выдающийся фотограф Владимир Фридкис), принес скандальный «Исламский проект», в котором 100-метровый оплот американской независимости – статуя Свободы – облачается в паранджу, католический храм Саграда Фамилия вонзает в небо исламские полумесяцы, в Нью-Йорке горят небоскребы, а на Красной площади сидят арабские боевики с «калашами» наперевес.

<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

- 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)

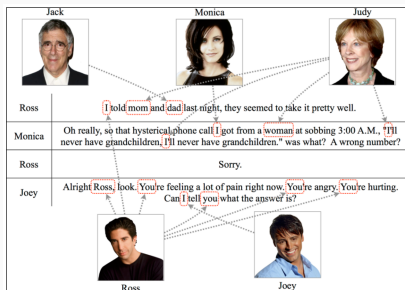
Two tracks:

- 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

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>