Einführung in Pragmatik und Diskurs

Anaphora Resolution

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Today's Plan

- Basic cases of context-dependent reference
- Anaphora: what is the problem and why is it interesting/important?
- Constraints and preferences on anaphoric relations
- Algorithms for anaphora resolution
- Challenging phenomena

Basic reading: Jurafsky and martin (2000), Chapter 3

Context-Dependent Reference

(Recall: Reference is the process in which a speaker uses a referring expression to denote an entity)

Deictic Reference (Deixis): reference to an entity in situational context of utterance, e.g., the speaker (*ich/wir, mein/unser*), hearer (*du/Sie, ihr/sie, Frau X /Herr X, Herr Professor, meine Damen und Herren*), place (*hier, da, dort*), time (*jetzt, heute, morgen, dieses Jahr*); cf. also reference relative to speaker/hearer, e.g., *rechts/links, vor, hinter*)

Anaphoric Reference (Anaphora): reference to an entity through its relationship to another entity denoted earlier, by an antecedent expression

- coreference (identity of reference): 'old' discourse entity
- bridging/association (inference): 'new' discourse entity

Example

(1) a. Cindy ist strohblond und hat braune Augen.
b. Ihr Körper ist kräftig,
c. ihr Fell schimmert in der Nachmittagssonne.
d. Als ich auf den Hof trete,
e. hebt die Haflingerstute den Kopf
f. und blinzelt mir von der Stalltür aus zu.
g. Ich gehe hinüber,
h. streichele ihr über die Stirn,
i. sie schnaubt leise
j. – das ist in der Pferdesprache ein Ausdruck von Wohlgefallen.
k. Dann knufft Cindy mir mit der Nase sanft in die Rippe.
l. Es ist Liebe auf den ersten blick.

Reference Resolution

- Task: Compute the meaning of referring expressions
- Crucial task in constructing a discourse model
  - evoke (introduce) "new" discourse referents
  - access "old" discourse referents
- Decisions involved in determining the referent:
  - Is an expression anaphoric or not?
  - Which antecedent?
  - Coreference vs. bridging?

Why Bother?

- Theoretical interest: explaining how reference works is part of explaining how communication works

- Practical importance in natural language processing applications:
  - Information extraction, question answering, summarization: resolution of anaphora in order to correctly link (and condense) information
  - Machine translation: resolution of anaphora in order to correctly translate
  - NL interfaces and dialogue systems: resolution of anaphora needed for correct interpretation, generation of anaphoric expressions needed for naturalness and efficiency

Factors in Coreference Resolution

- Syntactic and Semantic Constraints
  - Agreement
  - Syntactic constraints
  - Selectional restrictions
- Preferences
  - Recency
  - Grammatical role
  - Repeated mention
  - Parallellism
  - Verb semantics

Syntactic and Semantic Constraints on Coreference

Pronominal coreference requires agreement in number, person, gender:

(2) **Maria** hat **ein Auto**. **Sie** liebt **es**.

(3) **Maria** hat ein Auto. Das Mädchen liebt den Wagen.

Pronominal coreference must obey certain syntactic constraints

(4) Jan$_i$ kaufte sich$_i$ ein Auto.

(5) Jan$_i$ kaufte ihm$_j$ ein Auto. $[i \neq j]$

(6) Hans sagt, dass Jan$_i$ sich$_i$ ein Auto kaufte.

(7) Hans sagt, dass Jan$_i$ ihm$_j$ ein Auto kaufte. $[i \neq j]$

(8) Jan$_i$ legte die Autoschlüssel neben sich$_i$ / ?ihn$_i$.

Predicates impose selectional restrictions on their arguments:

(9) **Die Haflingerstute** blinzelt mir von **der Stalltür** aus zu. Ich gehe hinüber, streichele **ihr** und **sie schnaubt** leise.

(10) **Die Haflingerstute** blinzelt mir von **der Stalltür** aus zu. Ich gehe hinüber, streichele **das liebe Ding** und **es schnaubt** leise.

Actually, other parts of the utterance can also constrain the interpretation:

(11) **Die Haflingerstute** blinzelt mir von **der Stalltür** aus zu. Ich gehe hinüber, streichele **das liebe Ding über die Stirn**, und **es schnaubt** leise.

Selectional restrictions can be violated, e.g.:

(12) Ich habe ein Spiel instaliert. Es läuft.

(13) Zwei Öpfer wurden gefangen. Sie sind gegessen worden.

Coreference Preferences (Salience)

- Recency (distance): resolve to a more recently mentioned entity

  (14) Jan hat ein Kanninchen. Hans hat ein Pferd. Maria futtert es.

- Grammatical role: resolve to the entity mentioned in a grammatical role that assigns higher salience (e.g., subject over other roles)

  (15) Jan besuchte die Messe mit Hans. Er kaufte ein Computerspiel.

- Parallellism: resolve to entity mentioned in a grammatical role parallel to that of the pronoun

  (16) Jan kaufte Hans ein Computerspiel. Maria kaufte ihm ein Buch.

- Verb semantics: verbs differ in which of their arguments they make more salient

  (17) Jan rufte Hans an. Er hat ein Buch verloren.

  (18) Jan critisierte Hans. Er hat ein Buch verloren.

- Repeated mention: entities referred to over and over are more salient (cf. the exercise example about Georg Philipp Schmitt)

It is not entirely clear how these preferences apply to (or differ for) other types of anaphoric expressions than personal pronouns!
e.g.,

(19) Jan besuchte die Messe mit Hans. Der kaufte ein Computerspiel.

(20) Jan besuchte die Messe mit Hans. Der Kerel kaufte ein Computerspiel.

Syntactic-Tree Search Algorithm for Pronominal Coreference (Hobbs 1978)

- pronoun resolution based on syntactic representation, implemented as traversing syntactic tree containing the pronoun and preceding trees:
- syntactic binding constraints incorporated
- preferences for antecedent in subject position incorporated
- preferences about distance incorporated in direction of search
- no semantics, but requires full syntactic analysis
- depends on syntactic theory

Syntactic-Tree Search Algorithm for Pronominal Coreference (Hobbs 1978)

1. Begin at the NP node immediately dominating the pronoun.

2. Go up the tree to the next NP or S node. Call it X.

3. Traverse all branches to the left below X in left-to-right breadth-first order. Propose as antecedent any compatible NP node which has an NP or S node between it and X.

4. If X is the highest node in the sentence, traverse the trees of the previous sentences starting from the more recent ones. Each tree is traversed left-to-right, breadth-first.
   If X is not the highest node, continue with step 5.

5. From node X, go up the tree to the first NP or S node encountered. Call it X.

6. If X is an NP node and if the path to X did not pass through the nominal node that X immediately dominates. propose X as antecedent.

7. Traverse all branches below X to the left in left-to-right, breadth-first order. Propose any compatible NP node as the antecedent.

8. If X is an S node, traverse all branches of node X to the right in left-to-right, breadth-first order, but do not go below any NP or S node encountered. Propose any compatible NP node as the antecedent.

9. Go to step 4.

Syntactic-Tree Search Algorithm for Pronominal Coreference (Hobbs 1978)

Examples:

(21) The castle in camelot remained **the residence** of the king until 536, when he moved **it** to London.

(22) a driver in his truck

(23) a driver of his truck (illustrates when rule 6 blocks a candidate)

Centering-Based Algorithm (Brennan et al. 1987)

Pronominal anaphora resolution based on preferences due to the relation between center of attention and choice of referring expressions, as predicted by the centering theory

1. Generate all possible C_b-C_f combinations for all each possible set of referent assignments

2. Filter by constraints

3. Rank by transition preferences

Centering Theory (Grosz, Joshi and Weinstein 1995)

- each utterance has one backward looking center C_b and an ordered set of forward looking centers C_f
- proposed C_f ordering $Subj < Obj < Other$
  (various other proposals considered in the literature)
- the most highly ranked item on C_f is the C_p, i.e., the preferred C_b for the next utterance
- types of center-transitions depending on whether backward looking center is maintained or changed: continuation, retaining, shift

- Rule 1: If any item is pronominalized, then the C_b is pronominalized
- Rule 2: preference for sequences of center continuation, or smooth (=gradual) shift

Centering transition types:

	$C_b(U_i) = C_b(U_{i-1})$	$C_b(U_i) \neq C_b(U_{i-1})$
$C_b(U_i) = C_p(U_i)$	Continue	Smooth Shift
$C_b(U_i) \neq C_p(U_i)$	Retain	Rough Shift

$C_b(U_k)$ — backward looking center of utterance U_k
$C_f(U_k)$ — (partially) ordered list of forward looking centers of utterance U_k
$C_p(U_k)$ — highest ranked item on $C_f(U_k)$, the preferred (next) center

Centering-Based Pronominal Coreference Resolution

Examples:

(24) a. Brennan drives an Alfa Romeo.
b. She drives too fast.
c. Friedman races her on weekends.
d. She often beats her.

(25) a. The sentry was not dead.
b. He was, in fact, showing signs of reviving.
c. He was partially uniformed in a cavalry tunic.
d. Mike stripped this from him and donned it.
e. He tied and gagged the man.

Heuristics-Based Pronominal Coreference Resolution (Lappin&Leass 1994)

- Combines salience factors using weights
- Incorporates constraints: morphological agreement, pleonastic pronouns, syntactic binding constraints
- No semantics, no extra-linguistic knowledge
- Good results
- Relies on syntactic structure, but has been reimplemented with just POS and NP-chunking

Heuristics-Based Pronominal Coreference Resolution (Lappin&Leass 1994)

Salience Factors	Weights
Sentence recency	100
Subject emphasis	80
Existential emphasis	70
Accusative (direct object) emphasis	50
Indirect object and oblique complement emphasis	40
Non-adverbial emphasis	50
Head noun emphasis	80

Heuristics-Based Pronominal Coreference Resolution (Lappin&Leass 1994)

To resolve a pronoun:

1. Collect potential referents up to 4 sentences back.

2. Remove candidates that do not satisfy constraints

3. Compute the total salience value of each candidate by adding any applicable values to the previously computed value

4. Select the candidate with the highest salience value. In case of ties, select the closest candidate. Update discourse model.

At the end of processing each sentence, reduce the salience values by half.

Heuristics-Based Pronominal Coreference Resolution (Lappin&Leass 1994)

Example:

(26) a. John saw an Acura Integra at the dealership.
b. He showed it to Bob.
c. He bought it.

Anaphora Resolution

- **syntactic search** vs. semantic approach **Hobbs 1978**
- salience-based approaches, using focussing/**centering** or similar ideas: Grosz 1977, **Brennan et al. 1987**, Hajičová et al 1990; Sidner 1993; Grosz et al. 1995, Strube& Hahn 1997; papers in (Walker 1998); Strube 1998
- parallellism: Kameyama 1986; Hobbs & Kehler 1997
- combination of criteria using **heuristics**: **Lappin&Leass 1994**, Hajičová et al. 1992, Kennedy&Boguraev 1996, Kameyama 1997, Mitkov 1998, Palomar et al. 2001, Vieira&Poesio 2000, etc.;
- comparisons: Kennedy & Boguraev 1996, Tetrault 1999, etc.
- machine learning approaches e.g., McCarty&Lehnert 1995, Ge et al. 1998, Soon et al. 1999, 2001, Strube et al 2002, Cardie and Wagstaff 1999, Mueller et al. 2002, etc.

Coreference Resolution Results

Results achieved to date, based on recent publications by various authors:

NP form	Precision	Recall	F-measure
All	83%	53%	65%
Definite NPs	66%	21%	33%
Proper names	94%	62%	75%
Demonstrative NPs	23%	23%	23%
Personal pronouns	85%	85%	85%
Possessive pronouns	80%	85%	82%

Challenges

- Coreference and bridging involving lexical/conceptual relations
- Anaphors with split antecedents
- Vague anaphors
- Pleonastic pronouns (not anaphoric)
- Non-nominal antecedents
- Non-nominal anaphors
  - e.g., adverbs, discourse connectives
  - Verb substitution end ellipsis
  - Tense and mood
- Beyond text (written monologue):
  - dialogue
  - multimodal context
  - speech

Lexical/Conceptual Relations

Synonymy The semantic relation that holds between words/expressions that can (in a given context) express the same meaning.

Hyponymy The semantic relation of being subordinate or belonging to a lower rank or class.

Hyperonymy The semantic relation of being superordinate or belonging to a higher rank or class.

Meronymy The semantic relation that holds between a part and the whole - part to whole relation

Metonymy Substituting the name of an attribute or feature for the name of the thing itself (as in 'they counted heads')

Coreference

(27)	Peter bought a Ferrari. It is red.	
(28)	Peter bought a new Ferrari. The Ferrari is red.	(Partial) Identity
(29)	Peter bought a car. The vehicle is red.	Synonymy
(30)	Peter bought a Ferrari. The car is red.	Hyperonymy
(31)	Peter bought a car. The Ferrari is red.	Hyponymy (is-a)
(32)	We have two customers.	
	a. The bold head came an hour ago.	Meronymy
	b. The ham-sandwich came an hour ago.	Metonymy
(33)	Peter bought a Ferrari. The beast is red.	Metaphor

Bridging Anaphoric Reference

(34) Peter bought a Ferrari.
A door has a dent and the engine stops. (part-whole)

(35) Papers were reviewed by a committee.
The chair was female. (set-member)

(36) Mix the flour, butter, eggs and milk.
a. Kneed the dough until smooth and shiny.
b. Spread the paste in the baking form.
c. Stir the batter until all lumps are gone.
d. Let it rest. (result/outcome of a process)

(37) Peter crashed against a wall.
The noise woke up the neighbours. (cause-effect)

(38) Peter is reading. The book is exciting. (pred-arg)

Plural Anaphors with Split Antecedents

(39) John and Peter love their cars. They drive them every day.

(40) John has a Ferrari and Peter has a Beatle. They drive them every day.

$\Rightarrow$ Sets of entities evoked by discontinuous expressions in text. Note also that sometimes there is an ambiguity between the "set-reading" ("collective") and a "distributed" reading.

Long Distance Anaphors

(41) A.63 I think it really depends a lot on the child, because **our daughter** is, was just a lot more levelheaded about her proc-, the process.

B.64 Luckily I still have thwelve more years to worry about it.

A.65 Yeah [laughter]

. . .

B.96 . . . the University of Virginia. How much did it en-, end up costing?

A.97 Uh [bretahing], I think, uh, on a yearly basis, I'm trying to think. I would just make it a rough figure about, uh, with, with the travel expenses and so on, although **she** didn't come home that much, uh, actually.

(sw3117)

Vague Anaphors

(42) A. I mean, the baby is like seventeen months and she just screems.
B. Uh-uh.
A. Well even if she knows thhat they're fixing to get ready to go over there. The're not there yet–
B. Uh-uh.
A. –you know.
B. Yeah. **It**'s hard.

(sw4877)

⇒ Not all anaphor-like expressions have any clear antecedent in text. Perhaps they are related to "discourse topic". But also, it is not always clear what precisely these expressions mean (refer to).

Pleonastic/Expletive Pronouns

(43) It's hard to realize that there are places that are just so, uh, bare on the shelves as there.

(44) When it comes to trucks, though, I would probably think to go American.

(45) It is raining.

(46) Es gibt zwei Möglichkeiten.

$\Rightarrow$ Some pronouns do not function anaphorically, they are just grammatical "slot-fillers".

Anaphors with Non-Nominal Antecedents

e.g., discourse deixis:

(47) A. . . . we never know what they are thinking.
B. **that**'s right. I don't trust them, maybe I guess **it**'s because of what happened over there with their own people, how they threw them out of power . . .

(sw3241)

(48) Now why she didn't take him over there with her? No, she didn't do **that**.

(sw4877)

⇒ speech act, proposition, event/state, etc.

Non-nominal Anaphors

Expressions of other categories than "nominal" have been argued to be anaphoric (because they behave like or similar to anaphors):

- spatial and temporal anaphors ('there', 'then')
- tense/mood

  (49) Peter entered the room. He turned on the light.

  (50) A wolf might come. He would eat you.

- discourse connectives, discourse markers

  (51) If there is a red light, stop.

  a. Otherwise, you can go on.

  b. Otherwise, you might get a fine.

Summary

- Language use is rife with anaphoric reference
- Anaphoric reference resolution is crucial for discourse interpretation (and generation)
- Most approaches share core underlying assumptions and use similar factors
- A range of factors interplay
- Surface-level morphological and syntactic features play an important role
- Although world knowledge is important, automatic anaphora resolution achieves reasonable results without it for a considerable part
- Pronominal coreference and the simpler cases of defNP coreference can be handled robustly on a large scale (precision and recall cca 85%)
- Some types of anaphors have not been tackled much (e.g., demonstrative pronouns)
- Some reference phenomena remain a challenge

References