

Reference Resolution and Algorithms

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Reference Resolution Methods

- Constraints and Preferences
 - Person Agreement
 - Case Agreement
 - Gender Agreement
 - Selectional Restrictions
 - Recently Introduced References
 - Grammatical Role
 - Parallelism
 - Repeated Mention
 - Intra-sentential Syntactic Constraints
- Reference Resolution Algorithms
 - Lappin and Leass Algorithm
 - Hobbs Tree Search Algorithm
 - Centering Algorithm
 - Mitkov's Algorithm

Constraints and Preferences

- **Person Agreement** : The referent and referring expression must agree in person
 - Zuha and I bought a camera. We like capturing nature scenes. (We = I and Zuha)
 - Zuha and Prabha bought a camera. We like capturing nature scenes. (We = Zuha and Prabha : **incorrect**)
- **Case Agreement** : The position where a pronoun is used constraints its form
 - Object position : accusative case of pronouns (him, her, them)
 - Subject position : nominative case of pronouns (he, she)

Constraints and Preferences

- **Gender Agreement** : required when resolving pronominal references
 - Zuha bought a printer. She is printing now (**she = Zuha**)
 - Zuha bought a printer. It is printing now (**it = printer**)
- **Selectional Restrictions** : verbs on their agreement helps in resolving references
 - Zuha put an apple on the table. Suha is eating it.
 - **Object (eat)**: edible thing -> 'it' resolved as **apple** not table

Constraints and Preferences

- Recently Introduced References
 - Entities introduced more **recently** are considered of greater **importance** than those introduced further back in the text
 - The doctor found an old map in the captains chest. Jim found an even older map hidden on the shelf. It describe an island. (**It = Jims map**)
- Grammatical Role
 - Entity in the **subject position** can be considered more important than one in the object position
 - Suha went to market with Zuha. She bought fruits. (**she=Suha**)

Constraints and Preferences

- **Parallelism** : The structural parallelism exists in the sentence can be used to resolve the reference.
- Zuha went to Suha to the computer shop. Danish went with her to a computer institute. (**her=Suha**)
- **Repeated Mention** : entities that are **focused** in the prior discourse are more likely to continue.
- Lucid was the first among the six women to join the astronaut program. Lucid holds the international record for the most flight hours in orbit by any woman in the world.
- She spend 180 days on the Russian space station. (**she = Lucid**)

Constraints and Preferences

- **Intra-sentential Syntactic Constraints** (Binding Theory Constraints) :
 - The **reflexive** use of pronouns co-refers with the **subject** of the innermost clause.
 - John bought himself a new laptop. (**himself** = John)
 - John bought him a new laptop. (**him** ≠ John)

Reference Resolution Algorithms

- Lappin and Leass Algorithm for Anaphora Resolution
- Centering Algorithm
- Mitkov's Pronoun Resolution Algorithm

Lappin and Leass 1994

- Lappin and Leass 1994 propose a discourse model in which potential referents have degrees of salience.
- They try to resolve (pronoun) references by finding highly salient referents compatible with pronoun agreement features.
- In effect, they incorporate:
 - recency
 - syntax-based preferences
 - agreement, but no (other) semantics

Lappin and Leass 1994

- First, we assign a number of salience factors & salience values to each referring expression.
- The salience values (weights) are arrived by experimentation on a certain corpus.

Lappin and Leass 1994

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	80
Existential emphasis	70
Accusative (direct object) emphasis	50
Indirect object emphasis	40
Non-adverbial emphasis	50
Head noun emphasis	80

Lappin and Leass 1994

- Non-adverbial emphasis is to penalize “demarcated adverbial PPs” (e.g., “In his hand, ...”) by giving points to all other types.
- Head noun emphasis is to penalize embedded referents.
- Other factors & values:
 - Grammatical role parallelism: 35
 - Cataphora: -175

Lappin and Leass 1994

- The algorithm employs a simple weighting scheme that integrates the effects of several preferences:
 - For each new entity, a representation for it is added to the discourse model and **salience value** computed for it.
 - Salience value is computed as the sum of the weights assigned by a set of **salience factors**.
 - The weight a salience factor assigns to a referent is the highest one the factor assigns to the referent's referring expression.
 - Salience values are cut in half each time a new sentence is processed.

Lappin and Leass 1994

The steps taken to resolve a pronoun are as follows:

- Collect potential referents (four sentences back);
- Remove potential referents that don't semantically agree;
- Remove potential referents that don't syntactically agree;
- Compute salience values for the rest potential referents;
- Select the referent with the highest salience value.

Lappin and Leass 1994

- Salience factors apply per NP, i.e., referring expression.
- However, we want the salience for a potential referent.
 - So, all NPs determined to have the same referent are examined.
- The referent is given the sum of the highest salience factor associated with any such referring expression.
- Salience factors are considered to have scope over a sentence
 - so references to the same entity over multiple sentences add up
 - while multiple references within the same sentence don't.

Example (from Jurafsky and Martin)

- John saw a beautiful Acura Integra at the dealership.
- He showed it to Bob.
- He bought it.

Example

- John saw a beautiful Acura Integra at the dealership.

Referent	Phrases	Value
John	{ John }	?
Integra	{ a beautiful Acura Integra }	?
dealership	{ the dealership }	?

John

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	80
Existential emphasis	
Accusative emphasis	
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

Example

- John saw a beautiful Acura Integra at the dealership.

Referent	Phrases	Value
John	{John}	310
Integra	{a beautiful Acura Integra}	?
dealership	{the dealership}	?

Integra

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	
Existential emphasis	
Accusative emphasis	50
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

Example

- John saw a beautiful Acura Integra at the dealership.

Referent	Phrases	Value
John	{John}	310
Integra	{a beautiful Acura Integra}	280
dealership	{the dealership}	?

dealership

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	
Existential emphasis	
Accusative emphasis	
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

Example

- John saw a beautiful Acura Integra at the dealership.

Referent	Phrases	Value
John	{ John }	310
Integra	{ a beautiful Acura Integra }	280
dealership	{ the dealership }	230

Example

- He showed it to Bob.

Referent	Phrases	Value
John	{ John }	310/2
Integra	{ a beautiful Acura Integra }	280/2
dealership	{ the dealership }	230/2

Referent	Phrases	Value
John	{ John }	155
Integra	{ a beautiful Acura Integra }	140
dealership	{ the dealership }	115

He

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	80
Existential emphasis	
Accusative emphasis	
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

310

Example

- He showed it to Bob.

Referent	Phrases	Value
John	{John, he ₁ }	465
Integra	{a beautiful Acura Integra}	140
dealership	{the dealership}	115

It

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	
Existential emphasis	
Accusative emphasis	50
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

280

Example

- He showed it to Bob.

Referent	Phrases	Value
John	{ John, he ₁ }	465
Integra	{ a beautiful Acura Integra }	140
dealership	{ the dealership }	115

Since “Integra” is more salient than “dealership” (140>115):

- “it” refers to “Integra”

Example

- He showed it to Bob.

Referent	Phrases	Value
John	{ John, he ₁ }	465
Integra	{ a beautiful Acura Integra, it ₁ }	420
dealership	{ the dealership }	115

Bob

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	
Existential emphasis	
Accusative emphasis	
Indirect object emphasis	40
Non-adverbial emphasis	50
Head noun emphasis	80

270

Example

- He showed it to Bob.

Referent	Phrases	Value
John	{John, he ₁ }	465
Integra	{a beautiful Acura Integra, it ₁ }	420
Bob	{Bob}	270
dealership	{the dealership}	115

Example

- He bought it.

Referent	Phrases	Value
John	{ John, he ₁ }	465/2
Integra	{ a beautiful Acura Integra, it ₁ }	420/2
Bob	{ Bob }	270/2
dealership	{ the dealership }	115/2

Referent	Phrases	Value
John	{ John, he ₁ }	232.5
Integra	{ a beautiful Acura Integra, it ₁ }	210
Bob	{ Bob }	135
dealership	{ the dealership }	57.5

He

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	80
Existential emphasis	
Accusative emphasis	
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

310

Example

- He bought it.

Referent	Phrases	Value
John	{ John, he ₁ }	232.5
Integra	{ a beautiful Acura Integra, it ₁ }	210
Bob	{ Bob }	135
dealership	{ the dealership }	57.5

Since “John” is more salient than “Bob” (232.5>135):

■ “he” refers to “John”

Example

- He bought it.

Referent	Phrases	Value
John	{ John, he_1, he_2 }	542.5
Integra	{ a beautiful Acura Integra, it_1 }	210
Bob	{ Bob }	135
dealership	{ the dealership }	57.5

It

Salience Factor	Salience Value
Sentence recency	100
Subject emphasis	
Existential emphasis	
Accusative emphasis	50
Indirect object emphasis	
Non-adverbial emphasis	50
Head noun emphasis	80

280

Example

- He bought it.

Referent	Phrases	Value
John	{ John, he ₁ , he ₂ }	542.5
Integra	{ a beautiful Acura Integra, it ₁ }	210
Bob	{ Bob }	135
dealership	{ the dealership }	57.5

Since “Integra” is more salient than “dealership” (210>57.5):

- “it” refers to “Integra”

Example

- He bought it.

Referent	Phrases	Value
John	{ John, he ₁ , he ₂ }	542.5
Integra	{ a beautiful Acura Integra, it ₁ , it ₂ }	490
Bob	{ Bob }	135
dealership	{ the dealership }	57.5

We should have added 35 for grammatical role parallelism, but we ignore this.

Try: Suha saw a laptop in the shop. She enquired about it. She bought it.

Centering Theory

Basic ideas:

- A discourse has a focus, or center.
- The center typically remains the same for a few sentences, then shifts to a new object.
- The center of a sentence is typically pronominalized.
- Once a center is established, there is a strong tendency for subsequent pronouns to continue to refer to it.

Centering Theory

Sample Discourse:

John saw a beautiful Acura Integra at the dealership. (U_1)

He showed it to Bob. (U_2)

He bought it. (U_3)

Think of each sentence as an Utterance (U_n).

Task: Build up a *Discourse Model* and resolve the pronouns.

Centering Theory

Assumptions:

Each Utterance has a *discourse center* (broadly equivalent to the idea of topic).

This center tends to be the *preferred antecedent* for a pronoun in a following utterance.

The first utterance in a discourse has an undefined discourse center (i.e., one needs to be established “on the fly”).

Centering Theory

Definitions:

Backward Looking Center (C_b): current center of discourse.

Forward Looking Centers (C_f): ordered list of entities mentioned in previous utterance (U_n) which are candidates for the center of discourse in the current utterance (U_{n+1}).

Preferred Center (C_p) for current utterance (U_{n+1}): highest forward looking center (C_f) in this utterance (U_{n+1})

Centering Theory

Discourse Transitions: Based on these definitions, one can now define a number of relations which hold between sentences and which model how successful/acceptable transitions *between* utterances are.

This discourse is not smooth:

John saw a beautiful Acura Integra at the dealership. (U_1)

Mary showed a watch to Bob. (U_2)

He bought it. (U_3)

Discourse Transitions

	$C_b(U_{n+1})=C_b(U_n)$ or undefined $C_b(U_n)$	$C_b(U_{n+1})\neq C_b(U_n)$
$C_b(U_{n+1})=C_p(U_{n+1})$	CONTINUE	SMOOTH-SHIFT
$C_b(U_{n+1})\neq C_p(U_{n+1})$	RETAIN	ROUGH-SHIFT

(from J&M:692)

Utterances should be linked by these transitions and rough shifts should be dispreferred.

The Centering Algorithm

Basic Rules:

1) If an element was realized as a pronoun, keep referring to it as a pronoun.

2) The Transition states are ordered:

Continue > Retain > Smooth-Shift > Rough-Shift

The Centering Algorithm

Basic Steps:

- 1) Generate possible C_b - C_f combinations.
- 2) Filter the possible combinations by the basic rules, morphological/syntactic constraints and whatever else one may have defined.
- 3) Rank by Transition Orderings

Applying the Algorithm

John saw a beautiful Acura Integra at the dealership. (U_1)

He showed it to Bob. (U_2)

He bought it. (U_3)

John saw a beautiful Acura Integra at the dealership. (U_1)

$C_f(U_1): \{\text{John, Integra, dealership}\}$

$C_p(U_1): \{\text{John}\}$

$C_b(U_1): \{\text{undefined}\}$

Applying the Algorithm

He showed it to Bob. (U_2)

Possibility 1 for U_2 : $C_f(U_2): \{\text{John, Integra, Bob}\}$
 $C_p(U_2): \{\text{John}\}$
 $C_b(U_2): \{\text{John}\}$

Transition: Continue ($C_p(U_2)=C_b(U_2)$; $C_b(U_1)$ undefined)

Possibility 2 for U_2 : $C_f(U_2): \{\text{John, dealership, Bob}\}$
 $C_p(U_2): \{\text{John}\}$
 $C_b(U_2): \{\text{John}\}$

Transition: Continue ($C_p(U_2)=C_b(U_2)$; $C_b(U_1)$ undefined)

Applying the Algorithm

Possibilities 1 and 2 are equally likely in terms of the discourse transitions. We could decide to slightly prefer Possibility 1 because of the initial ordering in U_1 .

$C_f(U_1)$: {John, Integra, dealership}

Applying the Algorithm

He bought it. (U_3)

Possibility 1 for U_3 : $C_f(U_3): \{\text{John, Acura}\}$

$C_p(U_3): \{\text{John}\}$

Preferred

$C_b(U_3): \{\text{John}\}$

Transition: Continue ($C_p(U_3)=C_b(U_3)=C_b(U_2)$)

Possibility 2 for U_3 : $C_f(U_3): \{\text{Bob, Acura}\}$

$C_p(U_3): \{\text{Bob}\}$

$C_b(U_3): \{\text{Bob}\}$

Transition: Smooth-Shift ($C_p(U_3)=C_b(U_3); C_b(U_3) \neq C_b(U_2)$)

Applying the Algorithm

Continue > Retain > Smooth-Shift > Rough-Shift

Prefer Possibility 1

John saw a beautiful Acura Integra at the dealership. (U_1)

John showed Integra to Bob. (U_2)

John bought Integra. (U_3)

Try: Suha saw a laptop in the shop. She enquired about it. She bought it.

Mitkov's Algorithm

- 1) Examine current sentence and 2 preceding ones (if available). Look for NPs to the left of the anaphor.
- 2) Select from set of NPs only those with gender/number compatibility.
- 3) Apply **antecedent indicators** to each candidate NP and assign scores. Propose candidate with highest score.
 - if equal score, compare immediate reference score
 - if still no resolution, compare collocational score
 - if still no resolution, compare indicating verbs score
 - if still no resolution, go for most recent NP

Mitkov's Antecedent Indicators

- 1) First NP gets +1 (generally topic)
- 2) NPs immediately following an *indicating verb* get +1
 - Examples: *assess, check, cover, define, describe*
 - Empirical evidence suggests that these NPs have high salience.
- 3) Lexical Iteration: If an NP is repeated twice or more in paragraph, do +2. For single repetition, do +1.
- 4) Collocation Match: If NP has an identical collocation pattern to that of the pronoun, do +2 (weak preference).
 - Example: Press **the key** down and turn the volume up... Press **it** again.

Mitkov's Antecedent Indicators

5) Immediate reference gets +2. Restricted to certain contexts: (You) V NP CONJ (you) V it.

- Example: *you can stand the printer up or lay it flat*

6) Sequential instructions get +2

- Example: *To turn on the printer, ... To program it...*

7) Term Preference: if NP is a term typical of the text genre, do +1.

8) Indefinite NPs get -1 (tend not to be antecedents).

9) NPs in PPs get -1 (tend not to be antecedents).

10) Referential distance: NPs in previous clause but same sentence +2, in previous sentence +1, etc.

An Example

Raise the original cover. Place the original face down on the original glass so that *it* is centrally aligned.

original cover

$1(\text{first NP}) + 1(\text{term preference}) + 1(\text{referential distance}) = 3$

original face

Preferred

$1(\text{first NP}) + 1(\text{term preference}) + 2(\text{referential distance}) = 4$

original glass

$1(\text{term preference}) - 1(\text{PP}) + 2(\text{referential distance}) = 2$

Try: Suha saw a laptop in the shop. She enquired about it. She bought it.