

# CS 4705

## Pronouns and Reference Resolution

# A Reference Joke

Gracie: Oh yeah ... and then Mr. and Mrs. Jones were having matrimonial trouble, and my brother was hired to watch Mrs. Jones.

George: Well, I imagine **she** was a very attractive woman.

Gracie: **She** was, and my brother watched **her** day and night for six months.

George: Well, what happened?

Gracie: **She** finally got a divorce.

George: Mrs. Jones?

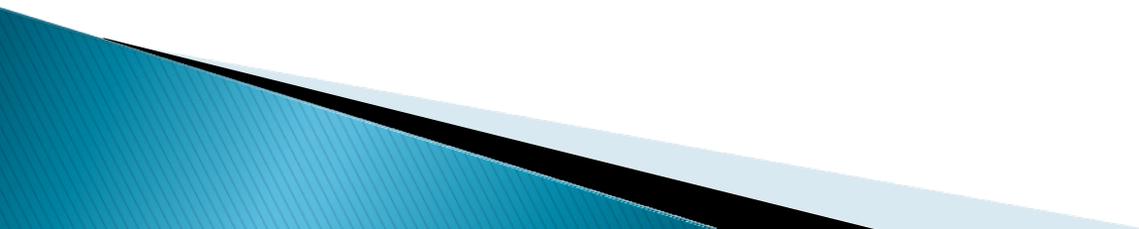
Gracie: No, my brother's wife.

# Some Terminology

- ▶ Discourse: anything longer than a single utterance or sentence
  - Monologue
  - Dialogue:
    - May be multi-party
    - May be human-machine

# Reference Resolution

- ▶ Process of associating **Bloomberg/he/his** with particular person and **big budget problem/it** with a concept  
Guiliani left Bloomberg to be mayor of a city with a big budget problem. **It's** unclear how **he'll** be able to handle **it** during **his** term.
- ▶ Referring exprs.: **Guilani, Bloomberg, he, it, his**
- ▶ **Presentational it, there**: non-referential
- ▶ Referents: the **person named Bloomberg**, the concept of a **big budget problem**

- ▶ **Co-referring** referring expressions:  
Bloomberg, he, his
  - ▶ Antecedent: Bloomberg
  - ▶ Anaphors: he, his
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# Discourse Model

- ▶ Needed to model reference because referring expressions (e.g. **Guiliani, Bloomberg, he, it budget problem**) encode information about beliefs about the referent
- ▶ When a referent is first mentioned in a discourse, a representation is evoked in the model
  - Information predicated of it is stored also in the model
  - On subsequent mention, it is accessed from the model

# Types of Reference

- ▶ Entities, concepts, places, propositions, events, ...

According to John, Bob bought Sue an Integra, and Sue bought Fred a Legend.

- But **that** turned out to be a lie. (a speech act)
- But **that** was false. (proposition)
- **That** struck me as a funny way to describe the situation. (manner of description)
- **That** caused Sue to become rather poor. (event)
- **That** caused them both to become rather poor. (combination of multiple events)

# Reference Phenomena

- ▶ Indefinite NPs

A homeless man hit up Bloomberg for a dollar.

Some homeless guy hit up Bloomberg for a dollar.

This homeless man hit up Bloomberg for a dollar.

- ▶ Definite NPs

The poor fellow only got a lecture.

- ▶ Demonstratives

This homeless man got a lecture but that one got carted off to jail.

▶ **One-anaphora**

Clinton used to have a dog called Buddy. Now he's got another one

# Pronouns

A large tiger escaped from the Central Park zoo chasing a tiny sparrow. It was recaptured by a brave policeman.

- Referents of pronouns usually require some degree of **salience** in the discourse (as opposed to definite and indefinite NPs, e.g.)
- How do items become salient in discourse?

# Saliency via Simple Recency: 'Rule of two sentences'

He had dodged the press for 36 hours, but yesterday the Buck House Butler came out of the cocoon of his room at the Millennium Hotel in New York and shoveled some morsels the way of the panting press. First there was a brief, if obviously self-serving, statement, and then, in good royal tradition, a walkabout.

Dapper in a suit and colourfully striped tie, Paul Burrell was stinging from a weekend of salacious accusations in the British media. He wanted us to know: he had decided after his acquittal at his theft to trial to sell his story to the Daily Mirror because he needed the money to stave off "financial ruination". And he was here in America further to spill the beans to the ABC TV network simply to tell "my side of the story".

If he wanted attention in America, he was getting it. His lawyer in the States, Richard Greene, implored us to leave alone him, his wife, Maria, and their two sons, Alex and Nicholas, as they spent three more days in Manhattan. Just as quickly he then invited us outside to take pictures and told us where else the besieged family would be heading: Central Park, the Empire State Building and ground zero. The "blabbermouth", as The Sun – doubtless doubled up with envy at the Mirror's coup – has taken to calling Mr Burrell, said not a word during the 10-minute outing to Times Square. But he and his wife, in pinstripe jacket and trousers, wore fixed smiles even as they struggled to keep their footing against a surging scrum of cameramen and reporters. Only the two boys looked resolutely miserable.

# Salience via Structural Recency

E: So you have the engine assembly finished.  
Now attach **the rope**. **By the way, did you buy  
the gas can today?**

A: Yes.

E: Did **it** cost much?

A: No.

E: OK, **good**. Have you got **it** attached yet?

# Inferables

- ▶ I almost bought an Acura Integra today, but a door had a dent and the engine seemed noisy.
- ▶ Mix the flour, butter, and water. Knead the dough until smooth and shiny.

# Discontinuous Sets

- ▶ Entities **evoked** together but mentioned in different sentence or phrases

John has a St. Bernard and Mary has a Yorkie. **They** arouse some comment when **they** walk **them** in the park.

# Generics

I saw two Corgis and their seven puppies today. **They** are the funniest dogs

# Constraints on Coreference

- ▶ Number agreement

John's parents like opera. John hates it/John hates them.

- ▶ Person and case agreement

- Nominative: I, we, you, he, she, they
- Accusative: me, us, you, him, her, them
- Genitive: my, our, your, his, her, their

George and Edward brought bread and cheese. They shared them.

- ▶ Gender agreement

John has a Porsche. He/it/she is attractive.

- ▶ Syntactic constraints: **binding theory**

John bought himself a new Volvo. (himself = John)

John bought him a new Volvo (him = not John)

- ▶ Selectional restrictions

John left his plane in the hangar.

He had flown it from Memphis this morning.

# Pronoun Interpretation Preferences

- ▶ Recency

John bought a new boat. Bill bought a bigger one.  
Mary likes to sail it.

- ▶ But...grammatical role raises its ugly head...

John went to the Acura dealership with Bill. He  
bought an Integra.

Bill went to the Acura dealership with John. He  
bought an Integra.

?John and Bill went to the Acura dealership. He  
bought an Integra.

▶ And so does...repeated mention

- John needed a car to go to his new job. He decided that he wanted something sporty. Bill went to the dealership with him. He bought a Miata.
- Who bought the Miata?
- What about grammatical role preference?

▶ Parallel constructions

Saturday, Mary went with Sue to the farmer's market.

Sally went with her to the bookstore.

Sunday, Mary went with Sue to the mall.

Sally told her she should get over her shopping obsession.

▶ Verb semantics/thematic roles

John telephoned Bill. He'd lost the directions to his house.

John criticized Bill. He'd lost the directions to his house.

# Pragmatics

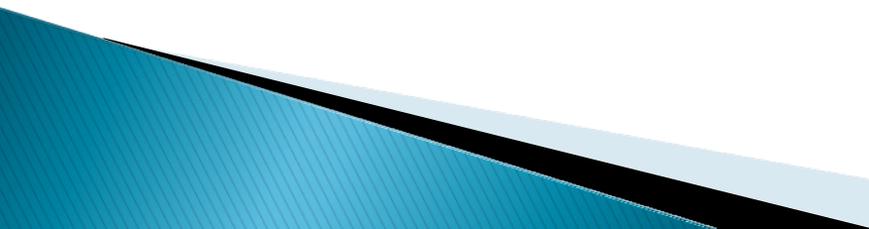
- ▶ Context-dependent meaning

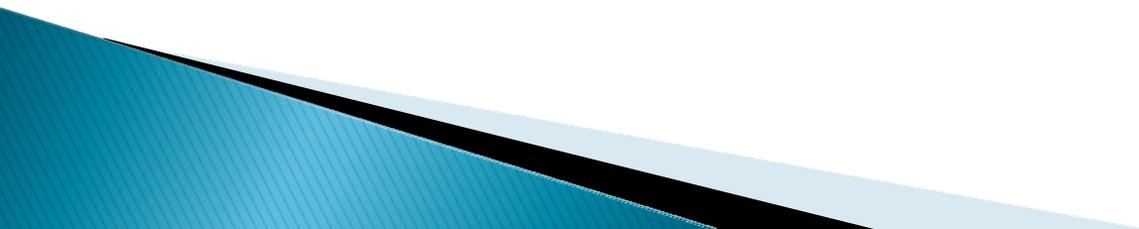
Jeb Bush was helped by **his** brother and so was Frank Lautenberg. (Strict vs. Sloppy)

Mike Bloomberg bet George Pataki a baseball cap that **he could/couldn't** run the marathon in under 3 hours.

Mike Bloomberg bet George Pataki a baseball cap that **he could/couldn't** be hypnotized in under 1 minute.

# Sum: What Factors Affect Reference Resolution?

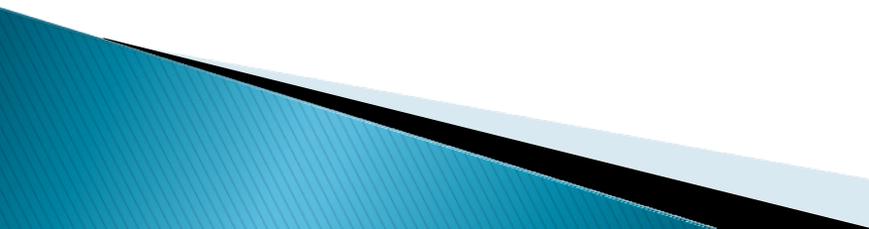
- ▶ Lexical factors
    - Reference type: Inferrability, discontinuous set, generics, one anaphora, pronouns,...
  - ▶ Discourse factors:
    - Recency
    - Focus/topic structure, digression
    - Repeated mention
  - ▶ Syntactic factors:
    - Agreement: gender, number, person, case
    - Parallel construction
    - Grammatical role
- 

- Selectional restrictions
  - ▶ **Semantic/lexical factors**
    - Verb semantics, thematic role
  - ▶ **Pragmatic factors**
- 

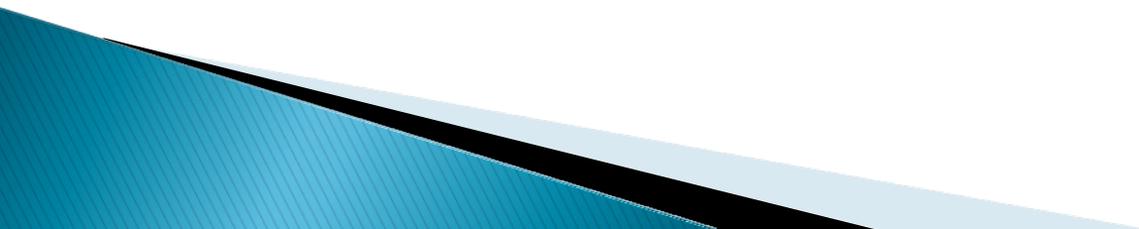
# Reference Resolution

- ▶ Given these types of constraints, can we construct an algorithm that will apply them such that we can identify the correct referents of anaphors and other referring expressions?

# Anaphora resolution

- ▶ Finding in a text all the referring expressions that have one and the same denotation
    - Pronominal anaphora resolution
    - Anaphora resolution between named entities
    - Full noun phrase anaphora resolution
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# Issues

- ▶ Which constraints/features can/should we make use of?
  - ▶ How should we order them? I.e. which override which?
  - ▶ What should be stored in our discourse model? I.e., what types of information do we need to keep track of?
  - ▶ How to evaluate?
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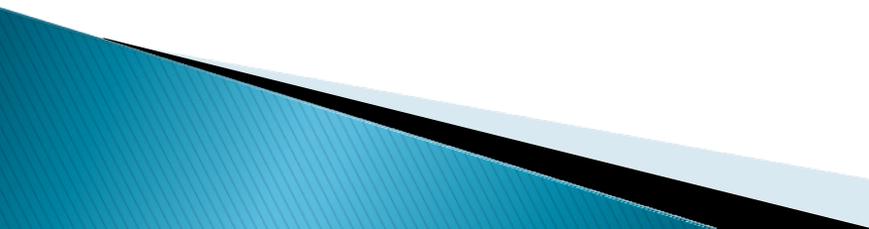
# Two Algorithms

- ▶ Lappin & Leas '94: weighting via **recency** and **syntactic** preferences
- ▶ Hobbs '78: **syntax** tree-based referential search

# Lappin & Leass '94

- ▶ Weights candidate antecedents by recency and syntactic preference (86% accuracy)
- ▶ Two major functions to perform:
  - **Update the discourse model** when an NP that evokes a new entity is found in the text, computing the salience of this entity for future anaphora resolution
  - **Find most likely referent** for current anaphor by considering possible antecedents and their salience values
- ▶ Partial example for 3P, non-reflexives

# Saliency Factor Weights

- ▶ Sentence recency (in current sentence?) 100
  - ▶ Subject emphasis (is it the subject?) 80
  - ▶ Existential emphasis (existential prednom?) 70
  - ▶ Accusative emphasis (is it the dir obj?) 50
  - ▶ Indirect object/oblique comp emphasis 40
  - ▶ Non-adverbial emphasis (not in PP,) 50
  - ▶ Head noun emphasis (is head noun) 80
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▶ Implicit ordering of arguments:

subj/exist pred/obj/indobj-  
oblique/dem.advPP

On the sofa, the cat was eating bonbons.

sofa:  $100 + 80 = 180$

cat:  $100 + 80 + 50 + 80 = 310$

bonbons:  $100 + 50 + 50 + 80 = 280$

▶ Update:

- Weights accumulate over time
- Cut in half after each sentence processed
- Saliency values for subsequent referents accumulate for equivalence class of co-referential items (exceptions, e.g. multiple references in same sentence)

The bonbons were clearly very tasty.

sofa:  $180/2=90$

cat:  $310/2=155$

bonbons:  $280/2 + (100+80+50+80)=450$

- Additional salience weights for **grammatical role parallelism** (35) and **cataphora** (-175) calculated when pronoun to be resolved
- Additional constraints on gender/number agrmt/syntax

They were a gift from an unknown admirer.

sofa:  $90/2=45$

cat:  $155/2=77.5$

bonbons:  $450/2=225 (+35) = 260....$

# Reference Resolution

- ▶ Collect potential referents (up to four sentences back): {sofa, cat, bonbons}
- ▶ Remove those that don't agree in number/gender with pronoun {bonbons}
- ▶ Remove those that don't pass intra-sentential syntactic coreference constraints  
*The cat washed it.* (it≠cat)
- ▶ Add applicable values for role parallelism (+35) or cataphora (-175) to current salience value for each potential antecedent
- ▶ Select referent with highest salience; if tie, select **closest** referent in string

# Evaluation

- ▶ Walker '89 manual comparison of Centering vs. Hobbs '78
  - Only 281 examples from 3 genres
  - Assumed correct features given as input to each
  - Centering 77.6% vs. Hobbs 81.8%
  - Lappin and Leass' 86% accuracy on test set from computer training manuals
- ▶ Type of text used for the evaluation
  - Lappin and Leass' computer manual texts (86% accuracy)
  - Statistical approach on WSJ articles (83% accuracy)
  - Syntactic approach on different genres (75% accuracy)

# New School

- ▶ Reason over all possible coreference relations as sets (within-doc)
  - Culotta, Hall and McCallum '07
- ▶ Reasoning over proper probabilistic models of clustering (across doc)
  - Haghighi and Klein '07