COMP9414: Artificial Intelligence

Lecture 7b: Semantics and Pragmatics

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This Lecture

- Semantics
  - Features and Augmented Grammars
  - Semantic Interpretation
- Pragmatics
  - Discourse Structure
  - Speech Act Theory
  - Dialogue Management

Agreement

- Number agreement
  - Which country borders France?
  - Which countries border France?
  - *Which country border France?
  - *Which countries borders France?
- Case
  - I saw him
  - *Him saw I
- To capture these facts, need lexical knowledge

Noun Features

Pronoun	Person	Number	Gender	Case
I	first	sing		nom
you	second	sing/plural		nom/acc
we	first	plural		nom
us	first	plural		acc
he	third	sing	masculine	nom
she	third	sing	feminine	nom
it	third	sing	neuter	nom/acc
him	third	sing	masculine	acc
her	third	sing	feminine	acc
they	third	plural		nom
them	third	plural		acc

Verb Forms

Verb	Form	Example
cry	base	
cries	simple present	He cries
cried	simple past	He cried
crying	present participle	He is crying
cried	past participle	He has cried

Tense	Verb sequence	Example
future	will + infinitive	He will cry
present perfect	has + past participle	He has cried
future perfect	will + have + past participle	He will have cried
past perfect	had + past participle	He had cried

Verb Forms

Progressive	Verb sequence	Example
present	is + present participle	He is crying
past	was + present participle	He was crying
future	will + be + past participle	He will be crying
present perfect	has + been + pres participle	He has been crying
future perfect	will + have + been + past participle	He will have been crying
past perfect	had + been + pres participle	He had been crying

Subcategorization

[]	Jack laughed
[NP]	Jack found a key
[NP, NP]	Jack gave Sue the paper
[VP(inf)]	Jack wants to fly
[NP, VP(inf)]	Jack told the man to go
[VP(ing)]	Jack keeps hoping for the best
[NP, VP(ing)]	Jack caught Sam looking at his desk
[NP, VP(base)]	Jack watched Sam look at his desk

Determines mandatory sentence constituents

Augmented Context Free Grammars

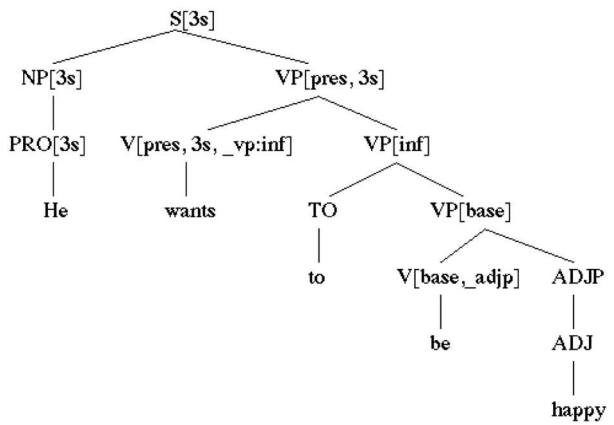
- Each symbol has a collection of features
- Grammar rules constrain feature values
  - Use unification to enforce constraints, as in Prolog
- Features (mainly) derived from lexical items
- Some also from grammar rules (e.g. Case)
- Simple example
  - S(number: N) $\rightarrow$ NP(number: N) VP(number: N)
  - Enforce number agreement by unification (matching)

Typical (Small) Grammar

S(Agr) → NP(Agr), VP(VForm, Agr)
NP(Agr) → ART(Agr), N(Agr)
NP(Agr) → PRO(Agr)
VP(VForm, Agr) → V(VForm, Agr, []) # subcat feature
VP(VForm, Agr) → V(VForm, Agr, [NP]), NP(Agr)
VP(VForm, Agr) → V(VForm, Agr, [VP(inf)]), VP(inf, _)
VP(VForm, Agr) → V(VForm, Agr, [ADJP]), ADJP
VP(inf, Agr) → to, VP(base, Agr)
ADJP → ADJ([])
ADJP → ADJ([VP(inf)], VP(inf, _)

Convention is to unify (match) arguments in rule with same name
Note: _ is a variable that matches anything

Example



Note: Not all arguments are specified on tree nodes

Semantic Interpretation

- Logical form (LF) captures underlying "meaning"
  - Depends on purpose – no one "true" meaning
- Logical form should resolve semantic ambiguity
- Compute LF of sentence from LF of constituents
- Treat logical form as another feature
- Example: John sold a car to Mary
  event(e, Sell) ∧ occur(e, past) ∧ agent(e, John) ∧ co-agent(e, Mary) ∧ object(e, $\{c$: car$\}$)

Thematic Roles

- Agent (intentional actor)
- Object/Theme (object on which action performed)
- Patient (animate object affected psychologically)
- Co-agent
- Instrument
- Beneficiary
- Location
- Source
- Destination

Often hard to distinguish!

Assigning Thematic Roles

- (Semantic) selection restrictions given by verb
  - e.g. agent of 'break' is animate
- Prepositions indicate likely role
  - e.g. 'with' implies instrument or co-agent
  - e.g. 'by' implies location or agent
- Problem examples
  - The window broke
  - My car drinks petrol

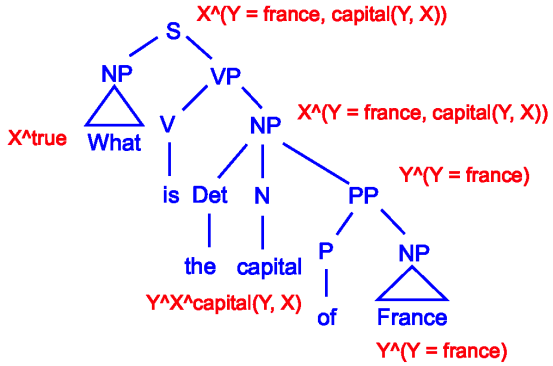
Simple method but doesn't always work ⇒ probabilities

Logical Form (Chat-80)

- Logical Form (LF) is just another feature
  - Formulae of the form XˆF where X is a variable and F is a formula
  - Read "the X such that F"
- May need more than matching to compute logical forms

Example Logical Form

What is the capital of France?



Example Grammar

S(Xˆ(VPForm ∧ NPForm)) → NP(XˆNPForm), VP(XˆVPForm)
NP(Form) → N(Form)
NP(Xˆ(PPForm ∧ NForm)) → ART, N(YˆXˆNForm), PP(YˆPPForm)
N(Xˆtrue) → what
N(Xˆ(X = france)) → france
N(XˆYˆ(capital(X,Y))) → capital
VP(Form) → V(be), NP(Form)
PP(Form) → P(of), NP(Form)

Summary

- Disambiguation is central problem in NLP
- Use logical form language to resolve semantic ambiguity
- Augmented grammars can capture agreement and logical form
  - Focus on lexical knowledge
- No one "right" logical form language
  - Case frames, First-order logic, ···

Pragmatics

- Discourse Processing
  - Reference Resolution
  - Discourse Structure
- Speech as Rational Action
  - Speech Act Theory
  - Spoken Dialogue Systems

Reference Resolution

Jack lost his wallet in his car.
He looked for it for several hours.

Jack forgot his wallet.
Sam did too.

Jack forgot his wallet.
He looked for someone to borrow money from.
Sam did too.

I found a red pen and a pencil.
The pen didn't work.

I saw two bears.
Bill saw some too.

Reference Resolution

We bought a desk.
The drawer was broken.

Reserve a flight to Brisbane for me.
Reserve one for Norman too.

John gave Mary five dollars.
It was more than he gave Sue. One of them was counterfeit.

Each girl took a handout.
Then she threw it away.

John didn't marry a Swedish blonde.
She was Danish/She had brown hair/She's living with him.

Discourse Entities

- The possible antecedents of pronouns
  - Noun phrases explicitly mentioned in recent discourse
  - A set of (implied) discourse entities
    - e.g. the handouts each girl took, the set of girls
  - An object related to (evoked by) a discourse entity
    - e.g. the drawer of the desk
  - Fillers of roles in stereotypical scenarios
    - e.g. waiters in restaurants
- Assume discourse is divided into "local contexts"

Focus Hypothesis

- At any time, there is a discourse entity that is the preferred antecedent for pronouns in the current local context – the discourse focus
  1. If any object in the local context is referred to by a pronoun in the current sentence, then the focus of the current sentence must also be pronominalized
  2. The focus is the most preferred discourse entity in the local context that is referred to by a pronoun
  3. Maintaining the focus is preferred to changing the focus
- Order possible antecedents subject > object > rest

Example

Jack left for the party late. (focus = Jack)
When he arrived, Sam met him at the door. (focus = he/Jack)
He decided to leave early. (focus = he/Jack)

Jack saw him in the park. (focus = him)
He was riding a bike. (focus = he/him)

While Jack was walking in the park, he met Sam. (focus = he/Jack)
He invited him to the party. (focus = Jack or Sam)

Discourse Structure

E: So you have the engine assembly finished.
Now attach the rope to the top of the engine.
By the way, did you buy petrol today?
A: Yes. I got some when I bought the new lawnmower wheel.
I forgot to take my can with me, so I bought a new one.
E: Did it cost much?
A: No, and I could use another anyway.
E: OK. Have you got it attached yet?

Tracking focus isn't enough

Discourse Segments

- Recency-based technique for reference resolution
- Fixed time and location or simple progression
- Fixed set of speakers/hearers
- Fixed set of background assumptions
- Intentional view
  - Segment elements contribute to same discourse purpose
- Informational view
  - Segment elements are related temporally, causally, etc.

Hierarchical Structure

SEG1

Jack and Sue went to buy a new lawnmower since their old one was stolen.

SEG2

Sue had seen the man who took it and she had chased them down the street, but they'd driven away in a truck.

After looking in the store, they realized they couldn't afford one.

SEG3

By the way, Jack lost his job last month so he's been short of cash recently. He has been looking for a new one, but so far hasn't had any luck.

Anyway, they finally found a used one at a garage sale.

Attentional Stack

- Stack corresponding to segment hierarchy at point in time
  - e.g. [SEG1, SEG2] or [SEG1, SEG3]
- Stack update on starting SEG3
  - Either push new segment
    - giving [SEG1, SEG2, SEG3]
  - Or close current segment and push new segment
    - giving [SEG1, SEG3]

Managing the Attentional Stack

- Extending a segment
  - All references can be resolved in current segment
  - Same tense or same tense without perfect aspect
- Creating a new segment
  - Change in tense (progression of discourse)
  - Cue phrase indicating digression
- Closing a segment
  - Discourse purpose of new segment part of immediate parent

Speech Acts

- Speech as goal-directed rational activity
  - e.g. promise, threaten, warn, order, advise, state request, inform, assert, deny, apologize, thank, greet, criticize, dare, hope, congratulate, welcome, bless, curse, toast, challenge, announce, declare, question, . . .
- Sometimes explicit in utterances, use of so-called performative verbs

Speech act type is utterance's illocutionary force

Actions Involved in Speech Acts

- Locutionary act
  - Physical act of saying something
- Illocutionary act
  - Speech act performed in making utterance
- Perlocutionary act
  - Effect on hearers' actions thoughts, beliefs, etc.

Communication involves intention recognition

Characterizing Illocutionary Acts

	request	warn
propositional content	Future act A of H	Future event or state E
preparatory conditions	H able to do A S believes H able to do A Not obvious to both S, H that H will do A anyway	S has reason to believe E will occur and is not in H's interest Not obvious to both S, H that E will occur
sincerity conditions	S wants H to do A	S believes E not in H's best interest
essential conditons	Counts as an attempt to get H to do A	Counts as undertaking to the effect that E not in H's best interest

Heavily oriented towards speaker's intentions

Indirect Speech Acts

- Use of one kind of illocutionary act to perform another
  - Can you pass the salt?
  - Do you know the time?
  - You are standing on my foot
  - Why don't you leave now?
  - Would you like a game of tennis?
  - If I were you, I'd sell that car
  - Now would you mind getting off my foot!
- Even harder to recognize speaker's intention

Spoken Dialogue Systems

- Feasible now with good speech recognition
  - Speaker dependent or domain specific
- Based on limiting possible dialogue structure
  - Frames with slots that need filling
  - Graphs representing possible transitions
  - Rules for defining actions based on prior context
  - Limited range of subdialogues (e.g. clarification)

Aim is to perform as little reasoning as possible

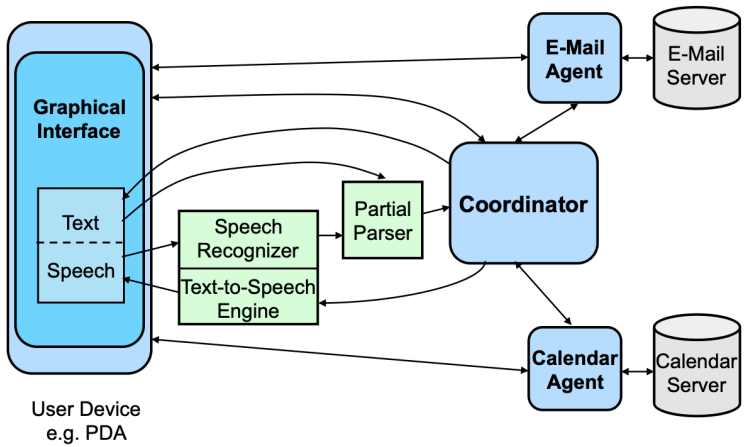
Initiative

- System Initiative
  - System "controls" dialogue by prompting user for information
  - Useful for specific tasks
    - Booking flights, Ordering pizza, Placing bets
- User Initiative
  - User "controls" dialogue by questions, commands
  - Useful for simple tasks, e.g. web search, training and simulation
- Mixed Initiative
  - Mixture of system initiative and user initiative

Smart Personal Assistant

- Integrated collection of personal (task) assistants
- Each assistant specializes in a task domain
  - E-mail and calendar management
- Users interact through a range of devices
  - PDAs, desktops, iPhone?
- Focus on usability
  - Multi-modal natural language dialogue
  - Adapt to user's device, context, preferences

System Architecture



Partial Parsing

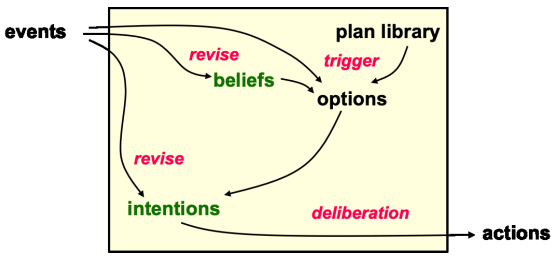
- Full parsing is inappropriate
  - Limited accuracy of speech recognition
  - Regular use of short-form expressions
  - Unconstrained language vocabulary
    - e.g. “Are there any new messages from . . . ”
- Shallow syntactic frame

clause

clause	
connective	Expresses the relation of the clauses
type	Question, declaration, imperative, ...
subject	Syntactic subject
predicate	Main verb
direct object	Main object of the predicate
indirect object	Possible second object
complement phrase	Other information e.g. time, location

BDI Agent Architecture

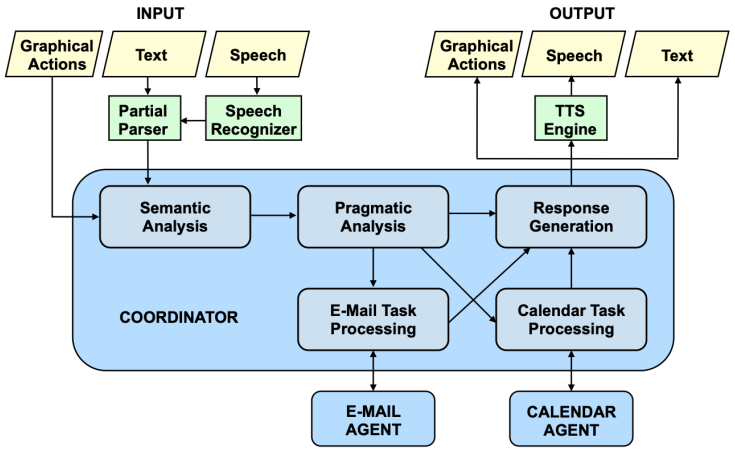
- Beliefs, desires, intentions explicit
  - Predefined plans for achieving goals
- Interpreter cycle – PRS (Procedural Reasoning System)
  - Event-driven selection and execution of plans



Dialogue Management Beliefs

- Dialogue model
  - Discourse history (stack of conversational acts)
  - Salient list (ranked list of recently mentioned objects)
- Domain knowledge
  - Supported tasks (for each task assistant)
  - Domain-specific vocabularies for task interpretation
- User model
  - User context information (device, modalities, . . .)

Dialogue Management Plans



Summary

- Dialogue systems are current “hot” topic
- Feasible because of high-quality speech recognition
  - Questions over accuracy, usability of Siri, Alexa, etc.
- Industry impetus is automation of routine interactions to reduce costs
  - Lot of hype compared to actual deployed systems
- Simple dialogue management techniques include graphs of dialogue actions and rules based on dialogue context
  - Current possible interactions not very sophisticated