Natural Language Understanding

Ling575
Spoken Dialog Systems
April 17, 2013

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    - Augmented with semantic attachments in FOPC
    - Producing a general lambda calculus representation
- What about spoken dialog systems?

NLU for SDS

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- Why not?

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- Why not?
  - Examples of travel air speech input (due to A. Black)
    - Eh, I wanna go, wanna go to Boston tomorrow
    - If its not too much trouble I'd be very grateful if one might be able to aid me in arranging my travel arrangements to Boston, Logan airport, at sometime tomorrow morning, thank you.
    - Boston, tomorrow

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  - Speech recognition:
    - Error-prone, perfect full analysis difficult to obtain

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    - Open prompt: **"How may I direct your call?''**
    - Responses: may I have consumer lending?,
      - I'd like my checking account balance, or
      - "ah I'm calling 'cuz ah a friend gave me this number and ah she told me ah with this number I can buy some cars or whatever but she didn't know how to explain it to me so I just called you you know to get that information."

Call Routing

- General approach:
  - Build classification model based on labeled training data, e.g. manually routed calls
    - Apply classifier to label new data

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    - (Dimensionality reduction by singular value decomposition)
  - Compute cosine similarity for new call & training examples

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- Frame:
  - Domain-dependent information structure
  - Set of attribute-value pairs
  - Information relevant to answering questions in domain

Natural Language Understanding

- Most systems use frame-slot semantics
  Show me morning flights from Boston to SFO on Tuesday

  - SHOW:
  - FLIGHTS:
    - ORIGIN:
      - CITY: Boston
      - DATE:
        - DAY-OF-WEEK: Tuesday
      - TIME:
        - PART-OF-DAY: Morning
    - DEST:
      - CITY: San Francisco

Another NLU Example

- Sagae et 2009
- Utterance (speech): we are prepared to give you guys generators for electricity downtown
- ASR (NLU input): we up apparently give you guys generators for a letter city don town
- Frame (NLU output):
  - **<s>.mood declarative**
  - **<s>.sem.agent kirk**
  - **<s>.sem.event deliver**
  - **<s>.sem.modal.possibility can**
  - **<s>.sem.speechact.type offer**
  - **<s>.sem.theme power-generator**
  - **<s>.sem.type event**

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  - Integrated parsing and semantic analysis
    - E.g. semantic grammars
  - Classification or sequence labeling approaches
    - HMM-based, MaxEnt-based

Grammars

- Formal specification of strings in a language
- A 4-tuple:
  - A set of terminal symbols: Σ
  - A set of non-terminal symbols: N
  - A set of productions P: of the form A -> α
  - A designated start symbol S
- In regular grammars:
  - A is a non-terminal and α is of the form {N} Σ^*
- In context-free grammars:
  - A is a non-terminal and α in (Σ U N)*

Simple Air Travel Grammar

- LIST -> show me | I want | can I see|…
- DEPARTTIME -> (after|around|before) HOUR| morning | afternoon | evening
- HOUR -> one|two|three…|twelve (am|pm)
- FLIGHTS -> (a) flight|flights
- ORIGIN -> from CITY
- DESTINATION -> to CITY
- CITY -> Boston | San Francisco | Denver | Washington

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    - can -> ε
    - * Boston -> Boston

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  - Employed by some speech toolkits, e.g. CSLU
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  - LIST -> show me | I want | can I see|…
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    - can -> ε
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- Simple, but…
  - VERY limited, assumes direct correspondence

Semantic Grammars

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- Syntactic structure:
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- Frames can be nested
- Widely used: Phoenix NLU (CU, CMU), vxml grammars

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    - Can associate probabilities with parse & analysis
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  - Domain- and application-specific
    - Hard to port

Learning Probabilistic Slot Filling

- Goal: Use machine learning to map from recognizer strings to semantic slots and fillers

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- Motivation:
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- Many alternative classifier models
  - HMM-based, MaxEnt-based

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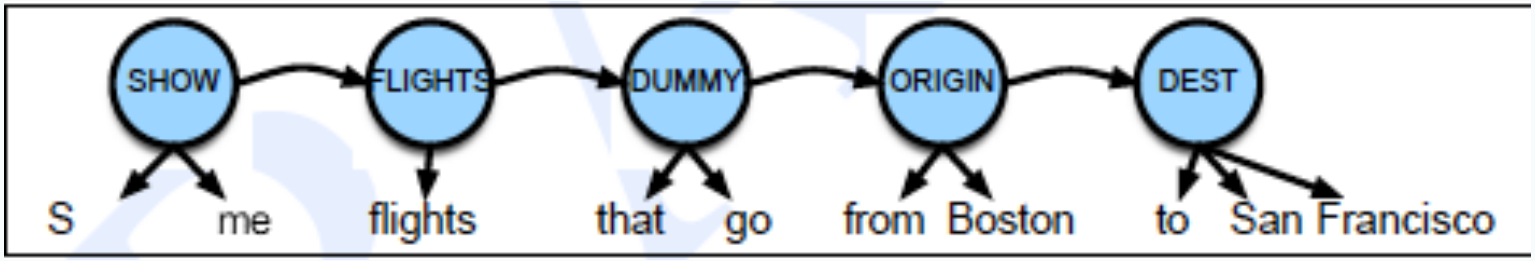
- = argmax P(W|C)P(C)
- Assume limited M-concept history, N-gram words
  - = $$\prod_{i=2}^{N} P(w_i \mid w_{i-1} \ldots w_{i-N+1}, c_i) \prod_{i=2}^{N} P(c_i \mid c_{i-1} \ldots c_{i-M+1})$$

Probabilistic Slot Filling

- Example HMM



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  - XML-based ‘programming’ framework for speech systems
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    - Structures voice interaction
    - Can incorporate Javascript for functionality

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  - Support for sub-dialog call-outs

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    - Grammars
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    - Domain managers: credit card nos etc
- TTS:
  - <ssml> markup language
  - Allows choice of: language, voice, pronunciation
  - Allows tuning of: timing, breaks

Simple VoiceXML Example

- Minimal form:

```
<form>
  <field name="transporttype">
     <prompt>
        Please choose airline, hotel, or rental car.
     </prompt>
     <grammar type="application/x=nuance-gsl">
       [airline hotel "rental car"]
     </grammar>
  </field>
  <block>
    <prompt>
     You have chosen <value expr="transporttype">.
    </prompt>
  </block>
</form>
```

Basic VXML Document

- Main body: <form></form>
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    - Specify grammar to recognize/interpret user input
      - <grammar>[airline hotel "rental car"]</grammar>

Other Field Elements

- Context-dependent help:
  - <help>Please select activity.</help>

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- Action to be performed on input:
  - <filled>
    - <prompt>You have chosen <value exp="transporttype">.
    - </prompt></filled>

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- Guards:
  - Default: Skip field if slot value already entered

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  - Pick prompts for conditions
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  - No speech timeout
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  - Speech, but nothing valid recognized
- <help>:
  - General system help prompt

Complex Interaction

- Preamble, grammar:

```
<noinput>    I'm sorry, I didn't hear you.  <reprompt/>  </noinput>

<nomatch> I'm sorry, I didn't understand that.  <reprompt/> </nomatch>

<form>
   <grammar type="application/x=nuance-gsl">
    <![ CDATA[
    Flight (  ?[
              (i [wanna (want to)] [fly go])
              (i'd like to [fly go])
              ([(i wanna)(i'd like a)] flight)
           ]
           [
             ( [from leaving departing] City:x) {<origin $x>}
             ( [(?going to)(arriving in)] City:x) {<destination $x>}
             ( [from leaving departing] City:x
               [(?going to)(arriving in)] City:y) {<origin $x> <destination $y>}
           ]
           ?please
    )
    City [ [(san francisco) (s f o)] {return( "san francisco, california")}
           [(denver) (d e n)] {return( "denver, colorado")}
           [(seattle) (s t x)] {return( "seattle, washington")}
    ]
    ]]> </grammar>

 <initial name="init">
    <prompt> Welcome to the consultant. What are your travel plans?  </prompt>
 </initial>
```

Mixed Initiative

- With guard defaults

```
<field name="origin">
   <prompt> Which city do you want to leave from?  </prompt>
   <filled>
      <prompt> OK, from <value expr="origin"> </prompt>
   </filled>
</field>
<field name="destination">
   <prompt> And which city do you want to go to?  </prompt>
   <filled>
      <prompt> OK, to <value expr="destination"> </prompt>
   </filled>
</field>
<block>
   <prompt> OK, I have you are departing from  <value expr="origin">
            to  <value expr="destination">.  </prompt>
  send the info to book a flight...
</block>
</form>
```

Complex Interaction

- Preamble, external grammar:

```
<?xml version="1.0"?>
<vxml version = "2.0">

<form id="F1">

  <field name="F_1">
      <grammar src="NameGram.xml"
type="application/grammar-xml" />
      <prompt>
      Please tell me your full name so I can verify you
      </prompt>
  </field>

  <filled mode="all" namelist="F_1">
      <prompt>
        Your name is <value expr="F_1"/>
        <break strength="medium"/>
      </prompt>
    </filled>
</form>
</vxml>
```

Multi-slot Grammar

```
<?xml version= "1.0"?>
 <grammar xml:lang="en-US" root = "TOPLEVEL">
  <rule id="TOPLEVEL" scope="public">
    <item>

  <!-- FIRST NAME RETURN -->

      <item repeat="0-1">
        <ruleref uri="#FIRSTNAME"/>
        <tag>out.firstNameSlot=rules.FIRSTNAME.firstNameSubslot;</tag>
      </item>
  <!-- MIDDLE NAME RETURN -->

      <item repeat="0-1">
        <ruleref uri="#MIDDLENAME"/>
        <tag>out.middleNameSlot=rules.MIDDLENAME.middleNameSubslot;</tag>
      </item>
  <!-- LAST NAME RETURN -->

        <ruleref uri="#LASTNAME"/>
        <tag>out.lastNameSlot=rules.LASTNAME.lastNameSubslot;</tag>
      </item>

 <!-- TOP LEVEL RETURN-->
    <tag> out.F_1= out.firstNameSlot + out.middleNameSlot + out.lastNameSlot; </tag>
  </rule>
```

Multi-slot Grammar II

```
<rule id="FIRSTNAME" scope="public">
 <one-of>
  <item> matt<tag>out.firstNameSubslot="matthew";</tag></item>
  <item> dee <tag> out.firstNameSubslot="dee ";</tag></item>
  <item> jon <tag> out.firstNameSubslot="jon ";</tag></item>
  <item> george <tag>out.firstNameSubslot="george ";</tag></item>
  <item> billy <tag> out.firstNameSubslot="billy ";</tag></item>
 </one-of>
 </rule>

 <rule id="MIDDLENAME" scope="public">
 <one-of>
  <item> bon <tag>out.middleNameSubslot="bon ";</tag></item>
  <item> double ya <tag> out.middleNameSubslot="w ";</tag></item>
  <item> dee <tag> out.middleNameSubslot="dee ";</tag></item>
 </one-of>
 </rule>

 <rule id="LASTNAME" scope="public">
 <one-of>
  <item> henry <tag> out.lastNameSubslot="henry "; </tag></item>
  <item> ramone <tag> out.lastNameSubslot="dee ";  </tag></item>
  <item> jovi <tag> out.lastNameSubslot="jovi ";  </tag></item>
  <item> bush <tag> out.lastNameSubslot=""bush ";  </tag></item>
  <item> williams <tag> out.lastNameSubslot="williams "; </tag></item>
 </one-of>
 </rule>

</grammar>
```

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- Pass input to other web services
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- Access web-based audio for prompts