Lecture 27:
Natural Language Generation

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Today’s lecture

Very high-level overview of (classical) NLG research, with a bit about summarization and dialog at the end.

Today’s materials are mainly taken from:

Many questions in NLG research are very domain and task specific

What is Generation?

Automatic production of natural language text, usually from underlying semantic representation
- As “natural-language front ends” used to present information in databases etc.: weather forecasts, train systems, (personalized) museum/restaurant/shopping guides,…
- In dialog systems
- In summarization systems
- In authoring aids to help people create routine documents: customer support, job ads, etc…

Example: Rail travel information system

- **Domain knowledge:** Train schedules
- **User Input:** from a graphical user interface, or in natural language: “How can I get from Aberdeen to Glasgow?”

- ** Desired output:**
  There are 20 trains each day from Aberdeen to Glasgow. The next train is the Caledonian Express; it leaves Aberdeen at 10am. It is due to arrive in Glasgow at 1pm, but arrival may be slightly delayed because of snow on the track near Stirling.
There are many dependencies between these tasks. The standard NLG system architecture consists of:

**Text planning:**
- Content determination and discourse planning

**Sentence planning:**
- Sentence aggregation, lexicalization and referring expression generation

**Linguistic realization:**
- Syntactic, morphological and orthographic processing.

### Content determination

**Input:** user input and background knowledge (database)

**Output:** a set of ‘messages’ to be communicated (here shown with gloss)

```
message-id: msg01
relation: IDENTITY
a. [arguments: [arg1: NEXT-TRAIN
arg2: CALEDONIAN-EXPRESS]]

b. The next train is the Caledonian Express
```

```
message-id: msg02
relation: DEPARTURE
a. [arguments: [departing-entity: CALEDONIAN-EXPRESS
departure-location: ABERDEEN
departure-time: 1000]]

b. The Caledonian Express leaves Aberdeen at 11am
```
Content determination

**Input:** user input and background knowledge (database)

**Output:** a set of ‘messages’ to be communicated

**User model:** User’s task, user’s level of expertise, previous interactions with system (esp. in dialog)

Need to filter, summarize and process input data

Relies often on (system-specific) heuristics (looking at corpus helps!)

Discourse planning

How should the messages be ordered?
What are the discourse relations that hold between them?
Often represented as a tree:

```
Root
  \--- Sequence
    \  \--- NextTrainInformation
         \  \  \--- [NUMBER-OF-TRAINS-IN-PERIOD] [IDENTITY] [DEPARTURE]
```

Sentence aggregation

Which messages should be conveyed in a single sentence?
_The next train leaves at 10am. It is the Caledonian Express._
_The next train, which leaves at 10am, is the Caledonian Express._

**Linguistic means to combine messages (=clauses):**
- **Relative clauses:** _The next train, which leaves at 10 am, is the Caledonian Express_
- **Coordination:** _The Caledonian Express leaves at 10am, and is the next train_
- **Subordination:** _The Caledonian Express is the next train, although it leaves only at 10am._
- **Lists:** _There are trains at 10am, at 11:30am and at 1:00pm._

Lexicalization and referring expressions

**Lexicalization:** Which words and phrases should be used to express domain concepts:
- does the train ‘leave’ or ‘depart’?
- a ‘statistical error’ is not the same as a ‘statistical mistake’

NLG systems need a domain lexicon

**Referring expression generation:**
When do you use a pronoun/a definite NP/an indefinite NP to refer to an entity?
Needs a discourse model
Linguistic realization

Generate a grammatically and orthographically correct English utterance:

```
message-id: msg03
relation: NUMBER-OF-TRAINS-IN-PERIOD
arguments:
  source: ABERDEEN
destination: GLASGOW
number: 20
period: DAILY
```

There are 20 trains each day from Glasgow to Edinburgh.

NLG evaluation

Many areas of NLP have shared task evaluations that allow comparisons of different algorithms/systems on the same data.

But most NLG systems are very domain/application specific.
- Every system starts from its own input representation
- Not a single gold standard data set
- Can we evaluate subtasks (e.g. referring expression generation)?
- How can we compare system outputs against each other/against human produced text? (metrics such as BLEU/ROUGE may not correlate highly enough with human judgments)

Some NLG systems

Cogentex’s chart explainer

http://www.cogentex.com/products/chartex/faq/bjs-sample.png
Cogentex’s Camera system

**User Input**
- I want a camera for:
  - Basic snapshots
  - Business use
  - Pro photography
- I want to view the pictures as:
  - On-screen images
  - 4x6 prints
  - Bx10 blowups
- I don’t want to pay more than:
  - $250
  - $500
  - $1000

**Generated Response**
I’ve found three cameras that match your photographic needs:

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. Resolution</th>
<th>Weight (oz)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentax Digilens 110</td>
<td>1280 x 768</td>
<td>11.3</td>
<td>$199</td>
</tr>
<tr>
<td>Kodak Zoomer 450</td>
<td>1280 x 768</td>
<td>9.9</td>
<td>$249</td>
</tr>
<tr>
<td>Nikon Flashlock Q2</td>
<td>2048 x 1360</td>
<td>13.1</td>
<td>$649</td>
</tr>
</tbody>
</table>

All of these models are easy to use, which makes them solid, predictable performers in a business context. And they all have 1280 x 768 pixels or more of resolution, which will give satisfactory print quality in smaller sizes.

The most affordable choice is the Pentax Digilens 110. The Kodak Zoomer 450 is more compact and portable, but it costs $50 more than the Digilens. Given the price difference, my choice would be the Digilens, unless you value the Zoomer’s compactness.

The Digilens is in stock for immediate shipment. The Zoomer is currently out of stock, but should ship by next Sunday, August 24. As usual, a carrying case is yours for free if you order before next Wednesday, August 27.

Edinburgh’s ILEX and M-PIRO

ILEX: a web-based virtual museum gallery and a phone-based system for an actual gallery

M-PIRO: adds an authoring tool for curators

**What is that?**
This exhibit is a lekythos, created during the archaic period. It dates from circa 500 BC. It was painted by Amasis with the red figure technique and it originates from Attica.

The COMIC system

**Conversational Multimodal Interaction with Computers**
**Dialog system for bathroom design applications**

**Sample dialog**

<table>
<thead>
<tr>
<th>User</th>
<th>Tell me about this design [click on Alt Mettlach]</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMIC</td>
<td>[Look at screen] This design is in the CLASSIC style. [circle tiles] As you can see, the colors are DARK RED and OFF WHITE. [point at tiles] The tiles are from the ALT METTLACH collection by VILLEROY and BOCH. [point at design name]</td>
</tr>
</tbody>
</table>

Summarization
Summarization

“The process of distilling the most important information from a text to produce an abridged version for a particular task and user”

- Abstract or extract?
- Generic (no specific task/user) or query-focused?
- Single-document or multi-document?

Output:
- Abstracts (of scientific papers)
- Headlines (or newspaper articles)
- Snippets (for webpages)
- Answers to complex questions (from multiple sources)

Extracts from a single document

Goal: Produce a paragraph that summarizes a document

1. Content selection:
   - Find ‘important’ (key) sentences
   - Extract key facts/phrases

2. Information ordering:
   - What order should these key facts be presented in?

3. Sentence realization:
   - Produce a coherent paragraph from the list of key facts

Centroid-based content selection

Which sentences are most central in a document?
Binary classification task: sentence -> {include, don’t include}

Method A: Central sentences = salient/informative sentences:
- a sentence is salient if it contains many salient words.
- a word is salient (=informative) in a document
  if it occurs significantly more often than expected (if -2 log \( \lambda(w) \) > 10)
Likelihood ratio \( \lambda(w) \):

\[
P_{doc}(w)/P_{English}(w)
\]

Method B: Central sentences = most similar to other s’s in doc.
- compute sentence-based TF/IDF for the words in a document
  (sentence=TF/IDF’s document, document= TF/IDF’s collection)
- distance between sentences: cosine of TD/IDF vectors of all words
- centrality of sentence i: average distance to all other sentences in document

RST-based summarization

Use a discourse parser to identify rhetorical relations between sentences/clauses in a document.

This gives a discourse tree with hierarchical nucleus-satellite relations between clauses

This discourse tree defines a salience ranking: the highest nuclei in the tree are the most salient
Information ordering and Sentence Realization

In which order should the key phrases be presented?
Simplest case: order in which they appear in document
Finding the optimal solution is NP-complete, but we can approximate

Use centering theory to measure coherence
Use coreference resolution and parsing to produce an ‘entity grid’
(which entities occur in which sentence, and in which role),
then find good sequences of transitions

Sentence realization may require some rephrasing:
Use longer descriptions to introduce entities, shorter ones to refer back
“Bush met Putin today. **George W. Bush** said…”
=> “**George W. Bush** met Putin today. Bush said…”

Conversational Agents

AKA:
Spoken Language Systems
Dialogue Systems
Speech Dialogue Systems

Applications:
Travel arrangements (Amtrak, United airlines)
Telephone call routing
Tutoring
Communicating with robots
Anything with limited screen/keyboard

Conversational Agents (Chapter 24)

A travel dialog: Communicator

<table>
<thead>
<tr>
<th>S1:</th>
<th>Hello, You’ve reached the [Communicator]. Tell me your full name</th>
</tr>
</thead>
<tbody>
<tr>
<td>U2:</td>
<td>hi i’d like to fly to seattle tuesday morning</td>
</tr>
<tr>
<td>S3:</td>
<td>Traveling to Seattle on Tuesday, August eleventh in the morning. Your full name?</td>
</tr>
<tr>
<td>U4:</td>
<td>[John Doe]</td>
</tr>
<tr>
<td>S5:</td>
<td>Hello, [John], I’m glad to hear from you again. You can now ask me for help.</td>
</tr>
<tr>
<td>S6:</td>
<td>OK. Let’s see I have a United flight departing Pittsburgh at ten forty five a.m. arriving into Seattle at one fifty seven p.m. Is that OK?</td>
</tr>
<tr>
<td>U7:</td>
<td>Yes</td>
</tr>
<tr>
<td>S8:</td>
<td>Will you return to Pittsburgh from Seattle?</td>
</tr>
<tr>
<td>U9:</td>
<td>no i will go to Los Angeles</td>
</tr>
<tr>
<td>S10:</td>
<td>Traveling to Los Angeles. on what date</td>
</tr>
<tr>
<td>U11:</td>
<td>Sorry can we go back to talk about the previous leg again</td>
</tr>
<tr>
<td>S12:</td>
<td>For the first leg, you are on a United flight 1446 departing Pittsburgh at ten forty five A.M. tomorrow, arriving in Seattle at one fifty seven P.M. Do you want to take that?</td>
</tr>
<tr>
<td>U13:</td>
<td>actually i want to leave on wednesday</td>
</tr>
<tr>
<td>S14:</td>
<td>a flight on wednesday</td>
</tr>
<tr>
<td>S15:</td>
<td>I have a flight departing Pittsburgh at ten forty five a.m., arrives Seattle at one fifty seven p.m. Is that OK?</td>
</tr>
<tr>
<td>U16:</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Figure 19.1** The travel domain: a fragment from a successful conversation between a user (U) and the Communicator system (S) of Xu and Rudnicky (2000).
Call routing: ATT HMIHY

S: How may I help you?
U: *can you tell me how much it is to tokyo?*
S: You want to know the cost of a call?
U: *yes that’s right*
S: Please hold on for rate information.

S: How may I help you?
U: *what’s the area code for chicago?*
S: You want an area code.
U: *(silence)*
S: The area code for Chicago is 312.

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A tutorial dialogue: ITSPKE

S: I didn’t understand. What force acts on all objects within close proximity to earth?
U: *uh the force of gravity*
S: Fine. Besides the Earth’s gravitational force, are there any other forces acting on the person, keys, and elevator after the release?
U: *no*
S: Yep. Thus, keep in mind that after the release, the only force on the person, keys, and elevator is the force of gravity. If gravity is the only force acting on an object, will it be moving or staying still?
U: *it will be moving*
S: Fine. Not only are the person, keys, and elevator moving, they have only gravitational forces on them. When an object is falling and has only gravitational force on it, it is said to be in what?
U: *freefall*

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Dialogue System Architecture

NLU with frame/slot semantics

There are many ways to represent the meaning of sentences. For speech dialogue systems, most common is “Frame and slot semantics”:

*Show me morning flights from Boston to SF on Tuesday.*

**SHOW:**

**FLIGHTS:**

| ORIGIN:     | CITY: Boston |
| DATE:       | Tuesday     |
| TIME:       | morning     |
| DEST:       | CITY: San Francisco |
Dialogue Manager

Controls the architecture and structure of dialogue
Takes input from ASR (speech recognizer)/NLU components
Maintains some sort of internal state
Interfaces with Task Manager
Passes output to NLG/TTS modules

Four architectures for dialogue management

Finite State
Frame-based
Information State
Markov Decision Processes
AI Planning

Finite-state dialogue managers

System completely controls the conversation with the user:
- It asks the user a series of questions
- It may ignore (or misinterpret) anything the user says that is not a direct answer to the system’s questions

Systems that control conversation like this are system initiative or single initiative.
“Initiative”: who has control of conversation
In normal human-human dialogue, initiative shifts back and forth between participants.
Single initiative + universals

We can give users a little more flexibility by adding universal commands

Universals: commands you can say anywhere

As if we augmented every state of FSA with these

Help
Start over
Correct

This describes many implemented systems
But still doesn’t allow user to say what they want to say

Mixed Initiative

Conversational initiative can shift between system and user

Simplest kind of mixed initiative: use the structure of the frame itself to guide dialogue

Slot                Question
ORIGIN             What city are you leaving from?
DEST                Where are you going?
DEPT DATE           What day would you like to leave?
DEPT TIME           What time would you like to leave?
AIRLINE             What is your preferred airline?

True Mixed Initiative

C1: . . . I need to travel in May.
A1: And, what day in May did you want to travel?
C2: OK uh I need to be there for a meeting that’s from the 12th to the 15th.
A2: And you’re flying into what city?
C3: Seattle.
A3: And what time would you like to leave Pittsburgh?
C4: Uh hmm I don’t think there’s many options for non-stop.
A4: Right. There’s three non-stops today.
C5: What are they?
A5: The first one departs PGH at 10:00am arrives Seattle at 12:05 their time. The second flight departs PGH at 5:55pm, arrives Seattle at 8pm. And the last flight departs PGH at 8:15pm arrives Seattle at 10:28pm.
C6: OK I’ll take the 5ish flight on the night before on the 11th.
C7: OK.

Information-State and Dialogue Acts

If we want a dialogue system to be more than just form-filling, it needs to be able to:

- Decide when the user has asked a question, made a proposal, rejected a suggestion
- Ground a user’s utterance, ask clarification questions, suggest plans

This suggests that:

- Conversational agent needs sophisticated models of interpretation and generation
- In terms of speech acts and grounding
- Needs more sophisticated representation of dialogue context than just a list of slots
Grounding

Dialogue is a **collective act** performed by speaker and hearer

**Common ground**: set of things mutually believed by both speaker and hearer.

To achieve common ground, hearer must **ground** or **acknowledge** speaker’s utterance.

Clark (1996):
- Principle of closure. Agents performing an action require evidence, sufficient for current purposes, that they have succeeded in performing it
- Need to know whether an action succeeded or failed

Clark and Schaefer: Grounding

**Continued attention**: B continues attending to A

**Relevant next contribution**: B starts in on next relevant contribution

**Acknowledgement**: B nods or says continuer like uh-huh, yeah, assessment (great!)

**Demonstration**: B demonstrates understanding A by paraphrasing or reformulating A’s contribution, or by collaboratively completing A’s utterance

**Display**: B displays verbatim all or part of A’s presentation