A Network-based End-to-End Trainable Task-oriented Dialogue System

Google HQ, 23/06/2016
Tsung-Hsien (Shawn) Wen
Outline

- Intro
- Neural Dialogue System
- Wizard-of-Oz Data Collection
- Experiments
- Conclusion & Discussion
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The two paradigms

M: Hello, welcome to the Cambridge dialogue system, What kind of food would you like?
H: Yeah I want to find a restaurant that serves European food.
M: Hotel du Vin and Bistro is a nice place. It serves European food.
H: Uh what is the address and phone number?
M: Hotel du Vin and Bistro is a nice place. Their address is XXX and their phone is YYY.
H: Thank you goodbye.
M: Thank you for using this system.

[Su et al, 2016]

A: How old are you ?
B: I’m 16. Why are you asking ?
A: I thought you were 12.
B: What made you think so ?
A: I don’t know what you are talking about.
B: You don’t know what you are saying.

[Li et al, 2016]
The two paradigms

- **Task-Oriented Dialogue Systems**
  - Goal-oriented
  - Require precise understanding, hard to collect data.
  - Modular, highly handcrafted, restricted ability, but meaningful/useful systems.

- **Chat-based Conversational Agents**
  - Chit-chat (non-goal).
  - Vast amount of data (but probably not helpful).
  - End-to-end, highly data-driven, but meaningless/inappropriate responses, unreliable systems.

- Can we train a useful (complete tasks) dialogue system directly from data?
- How can we collect the data to train this model?
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Traditional Dialogue Systems

- Speech Recognition
- Language Understanding
- Language Generation
- Dialogue Manager
- Dialogue System
- KB
- Web

Text flow:
- Speech Recognition -> Language Understanding
- Language Understanding -> Language Generation
- Language Generation -> Dialogue Manager
- Dialogue Manager -> Dialogue System
- Dialogue System -> KB
- Dialogue System -> Web

Speech Synthesis

Text:
- text
Neural Dialogue Systems
Can I have \( <v.\text{food}> \)

MySQL query: "Select * where food=Korean"
Can I have <v.food>
Can I have <v.food>

Korean 0.7
British 0.2
French 0.1
...

Belief Tracker

Can I have <v.food>
Jordan RNN-CNN belief trackers

British French Korean ... Chinese

Value-specific delex. ngram placeholder

Slot delex.

Value-specific delex. ngram feature

1.3 2.3 9.7 1.2 .01 .85

[Henderson et al, 2014]

Pad zeros to have the same length

Memorise the delex. position

Delexicalised CNN

1st conv. 2nd conv. 3rd conv. max-pool avg-pool

Output layer

Hidden layer

Turn t

Input layer

sentence representation
Jordan RNN-CNN belief trackers

Delexicalised CNN

User turn $t$

System turn $t-1$

Output layer

Hidden layer

Input layer

Turn $t$

$f_{v,cnn}^t$

Sentence representation

$\text{Delexicalised CNN}$

1$\text{st}$ conv.

2$\text{nd}$ conv.

3$\text{rd}$ conv.

max-pool

avg-pool
Can I have <v.food>

Korean 0.7  
British 0.2  
French 0.1  
...

MySQL query: "Select * where food=Korean"

Database Operator

Belief Tracker

Intent Network
Can I have <v.food>

Intent Network

Policy Network

Belief Tracker

Database

MySQL query: "Select * where food=Korean"

Database Operator

Can I have <v.food>
Can I have <v.food>?

Korean 0.7
British 0.2
French 0.1

MySQL query: "Select * where food=Korean"

Database:

- Seven days
- Nirala Curry Prince
- Little Seoul
- Royal Standard

Belief Tracker

Intent Network

Generation Network

Policy Network

DB pointer
Can I have <v.food>

<table>
<thead>
<tr>
<th>Food</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korean</td>
<td>0.7</td>
</tr>
<tr>
<td>British</td>
<td>0.2</td>
</tr>
<tr>
<td>French</td>
<td>0.1</td>
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MySQL query: "Select * where food=Korean"

Policy Network

Intent Network

Generation Network

Belief Tracker

Database Operator
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Hi, I want a cheap Korean restaurant. What area are you looking for?
Hi, I want a **cheap Korean restaurant**.

What **area** are you looking for?

**Somewhere in the north.**

*Little Seoul* is nice one in the north.

<table>
<thead>
<tr>
<th>What user wants?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>Korean</td>
</tr>
<tr>
<td>Price</td>
<td>Cheap</td>
</tr>
<tr>
<td>Area</td>
<td><strong>North</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Search Table</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Seoul</td>
<td>...</td>
</tr>
</tbody>
</table>
Hi, I want a **cheap Korean restaurant**.

**What area** are you looking for?

Somewhere in the **north**.

**Little Seoul** is nice one in the north.

**What is the phone number?**

Its phone number is **01223456789**.

<table>
<thead>
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<th></th>
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</tr>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Seoul</td>
<td></td>
</tr>
</tbody>
</table>
Hi, I want a cheap Korean restaurant.

What area are you looking for?

Somewhere in the north.

Little Seoul is nice one in the north.

What is the phone number?

Its phone number is 01223456789.

Thank you very much, good bye.

Thank you for using the system.
Hi, I want a cheap Korean restaurant.

What area are you looking for?

Somewhere in the north.

Little Seoul is nice one in the north.

What is the phone number?

Its phone number is 01223456789.

Thank you very much, good bye.

Thank you for using the system.

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<tr>
<td>Area</td>
</tr>
<tr>
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</tr>
<tr>
<td>Cheap</td>
</tr>
<tr>
<td>North</td>
</tr>
</tbody>
</table>
Wizard of Oz Data Collection

- Online parallel version of WOZ on MTurk
- Randomly hire a worker to be user/wizard.
- Task: Enter an appropriate response for one turn.
- Repeat the process until all dialogues are finished.

Example user page

Task 02004: You are looking for and it should serve gastropub food. You don't care about the price range. You want to know the address.

Info Desk: Hello, welcome to the Cambridge restaurant system. You can ask for restaurants by area, price range or food type. How may I help you?
Customer: I want a gastropub food
Info Desk: There are 4 restaurants serving gastropub food, what price range do you want?

[Submit the HIT]
## Wizard of Oz Data Collection

### Example wizard page

<table>
<thead>
<tr>
<th>Name</th>
<th>Food</th>
<th>Area</th>
<th>Price Range</th>
<th>Phone</th>
<th>Address</th>
<th>Postcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>backstreet bistro</td>
<td>gastropub</td>
<td>centre</td>
<td>expensive</td>
<td>01223 308306</td>
<td>2 Burton Street City Centre</td>
<td>C.B 1, 2 Q.A</td>
</tr>
<tr>
<td>royal standard</td>
<td>gastropub</td>
<td>east</td>
<td>expensive</td>
<td>01223 247877</td>
<td>260 Mill Road City Centre</td>
<td>C.B 1, 3 N.L</td>
</tr>
<tr>
<td>the cow pizza kitchen and bar</td>
<td>gastropub</td>
<td>centre</td>
<td>moderate</td>
<td>01223 308871</td>
<td>Corn Exchange Street</td>
<td>C.B 2, 3 Q.F</td>
</tr>
<tr>
<td>the slug and lettuce</td>
<td>gastropub</td>
<td>centre</td>
<td>expensive</td>
<td>--</td>
<td>34 - 35 Green Street</td>
<td>C.B 2, 3 J.U</td>
</tr>
</tbody>
</table>

Next turn? | Finish |

I would recommend backstreet bistro, a great gastropub restaurant in the centre. do you want their phone number? end-of-dialogue? Submit the HIT
Data Statistics

- **Ontology:**
  - Cambridge restaurant domain, 99 venues.
  - 3 informable slots: area, price range, food type
  - 3 requestable slots: address, phone, postcode

- **Dataset**
  - 676 dialogues, ~2750 turns
  - 3000 HITS, takes 3 days, costs ~400 USD
  - Data cleaning takes 2-3 days for one person
Outline

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- **Experiments**
- Conclusion & Discussion
Experiments

- **Experimental details**
  - Train/valid/test: 3/1/1
  - SGD, l2 regularisation, early stopping, gradient clip=1
  - Hidden size = 50, Vocab size: ~500

- **Two stage training:**
  - Training trackers with label cross entropy
  - Training other parts with response cross entropy

- **Decoding**
  - Beam search w/ beam width 10
  - Decode with average word likelihood
# Response Generation Task

<table>
<thead>
<tr>
<th>Model</th>
<th>Match (%)</th>
<th>Success (%)</th>
<th>BLEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seq2Seq [Sutskever et al, 2014]</td>
<td>-</td>
<td>-</td>
<td>0.1718</td>
</tr>
<tr>
<td>HRED [Serban et al, 2015]</td>
<td>-</td>
<td>-</td>
<td>0.1861</td>
</tr>
<tr>
<td>Our model w/o req. trackers</td>
<td>89.70</td>
<td>30.60</td>
<td>0.1799</td>
</tr>
<tr>
<td>Our full model</td>
<td>86.34</td>
<td>75.16</td>
<td>0.2313</td>
</tr>
<tr>
<td>Our full model + attention</td>
<td>90.88</td>
<td>80.02</td>
<td>0.2388</td>
</tr>
</tbody>
</table>
## Human evaluation

### Quality assessment

<table>
<thead>
<tr>
<th>Metric</th>
<th>N2N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success</td>
<td>98%</td>
</tr>
<tr>
<td>Comprehension</td>
<td>4.11</td>
</tr>
<tr>
<td>Naturalness</td>
<td>4.05</td>
</tr>
<tr>
<td># of dialogues:</td>
<td>245</td>
</tr>
</tbody>
</table>

### System Comparison

<table>
<thead>
<tr>
<th>Metric</th>
<th>N2N</th>
<th>Modular</th>
<th>Tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subj. Success</td>
<td>96.95%</td>
<td>95.12%</td>
<td>-</td>
</tr>
<tr>
<td>Avg. # of Turn</td>
<td>3.95</td>
<td>4.54</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Comparisons(%)  

<table>
<thead>
<tr>
<th></th>
<th>N2N</th>
<th>Modular</th>
<th>Tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naturalness</td>
<td>46.95*</td>
<td>25.61</td>
<td>27.44</td>
</tr>
<tr>
<td>Comprehension</td>
<td>45.12*</td>
<td>21.95</td>
<td>32.93</td>
</tr>
<tr>
<td>Preference</td>
<td>50.00*</td>
<td>24.39</td>
<td>25.61</td>
</tr>
<tr>
<td>Performance</td>
<td>43.90*</td>
<td>25.61</td>
<td>30.49</td>
</tr>
</tbody>
</table>

* p <0.005, # of comparisons: 164
Example dialogues

Human : Restaurant in any area that serves Vietnamese food
Machine : thanh binh serves vietnamese food type . is there anything else i can help you with ?
Human : What is the phone number and post code
Machine : the number is 01223 362456 and the area code is c.b 3, 0 a.f . is there anything else i can do for you ?
Human : Good bye
Machine : thank you for using the cambridge restaurant system .

Human : Hi, I’m hungry for some Indonesian food
Machine : i am sorry , there are no indonesian restaurants . would you like a different food ?
Human : Oh no. How about Indian?
Machine : there are 9 restaurants serving indian types of food . do you have a preference on side of town ?
Human : East side please
Machine : sitar tandoori is a indian restaurant in the east side of town . would you like their information ?
Human : Yes, the address and phone number please
Machine : sitar tandoori is located at 43 high street cherry hinton cherry hinton and their phone number is 01223 249955 .
Human : Okay, thank you
Machine : thank you , goodbye .
Example dialogues

<table>
<thead>
<tr>
<th>Human</th>
<th>hello</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>what cuisine would you like?</td>
</tr>
<tr>
<td>Human</td>
<td>afghan</td>
</tr>
<tr>
<td>Machine</td>
<td>i am sorry, there are no afghan restaurants. would you like something else?</td>
</tr>
<tr>
<td>Human</td>
<td>korean</td>
</tr>
<tr>
<td>Machine</td>
<td>little seoul serves korean food, it is located at 108 regent street city centre.</td>
</tr>
<tr>
<td>Human</td>
<td>is it expensive?</td>
</tr>
<tr>
<td>Machine</td>
<td>little seoul serves korean food and is in the expensive price range.</td>
</tr>
<tr>
<td>Human</td>
<td>what area is that</td>
</tr>
<tr>
<td>Machine</td>
<td>little seoul is located in the centre area of town. would you like their number?</td>
</tr>
<tr>
<td>Human</td>
<td>yes</td>
</tr>
<tr>
<td>Machine</td>
<td>the telephone number is 01223 308681. is there anything else i can help you with today?</td>
</tr>
<tr>
<td>Human</td>
<td>no goodbye</td>
</tr>
<tr>
<td>Machine</td>
<td>thank you for using the cambridge restaurant system, goodbye.</td>
</tr>
</tbody>
</table>
Visualising action embedding
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Conclusion & Discussion

- An end-to-end trainable task-oriented dialogue system architecture is proposed.
- A complementary WOZ data collection is also proposed (no latency, parallel, cheap).
- Results show that it can learn from human-human conversations and help users to complete tasks.
- Explicit language grounding is crucial, but what is the best way to represent semantics?
The paper

References

Thank you! Questions?

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