CoSQL: A Conversational Text-to-SQL Challenge for Natural Language Interfaces to Databases

Tao Yu, Rui Zhang, He Yang Er, Suyi Li, Eric Xue, Bo Pang, Xi Victoria Lin, Yi Chern Tan, Tianze Shi, Zihan Li, Youxuan Jiang, Michihiro Yasunaga, Sungrok Shim, Tao Chen, Alexander Fabbri, Zifan Li, Luyao Chen, Yuwen Zhang, Shreya Dixit, Vincent Zhang, Caiming Xiong, Richard Socher, Walter Lasecki, Dragomir Radev

Yale University, Univ. of Michigan, Salesforce Research, Cornell University

EMNLP 2019

Outline

- What is NL2SQL and why **Conversational** NL2SQL?
- Task formulation
- Data collection
- Experiments

NL2SQL Task

Interface system that allows humans to use natural language to query database (DB)

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JOIN car_makers AS T3 ON
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WHERE T2.continent = 'Europe'
GROUP BY T1.country_name
HAVING COUNT(*) >= 3
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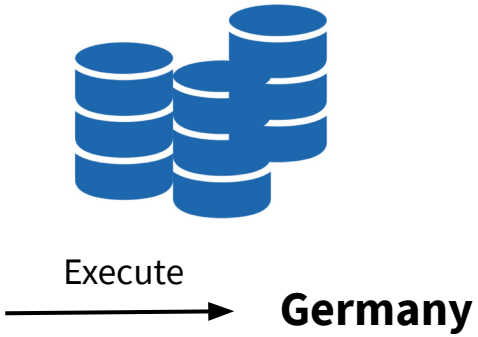

NL2SQL datasets

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- ATIS [Price, 1990; Hemphill et al. 1990; Dahl et al., 1994]
- GeoQuery [Zelle and Mooney, 1996]
- Academic [Li and Jagadish, 2014]
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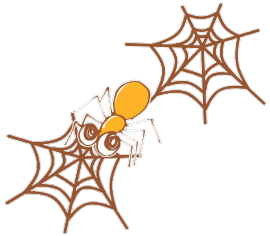

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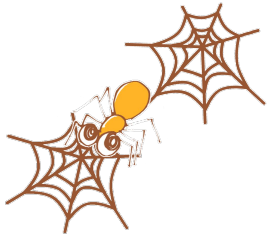

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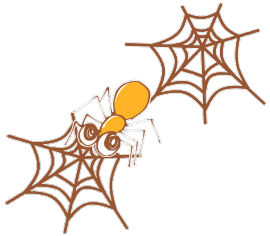

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… but assume all utterances are **single-sentence, well-formed** questions

In practice ...

Complex requests are processed through **interactions** rather than a single utterance

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- **??** “Show me Delta flights from Seattle to Boston next Monday after 7pm”

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Complex requests are processed through **interactions** rather than a single utterance

- ?? “Show me Delta flights from Seattle to Boston next Monday after 7pm”
- Instead, users would explore DB interactively

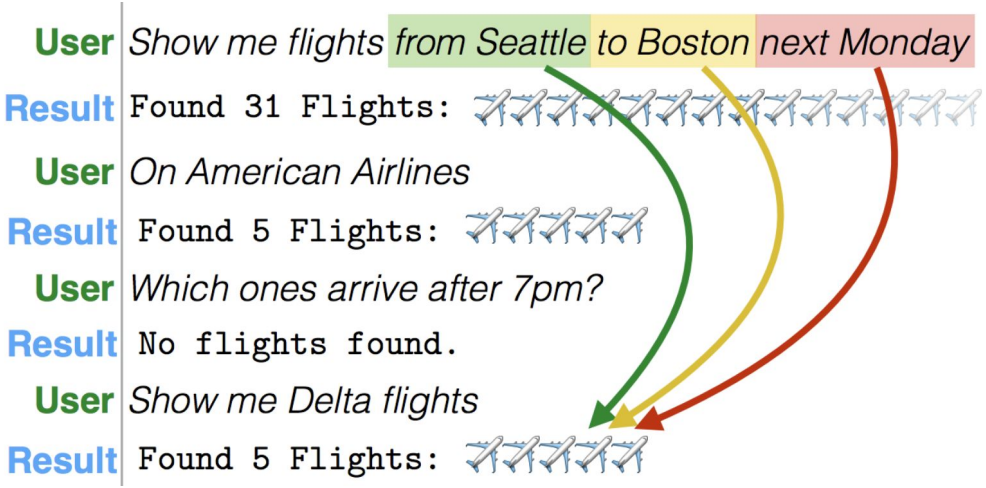

Image from [Suhr et al., 2018]

How about context-dependent NL2SQL?

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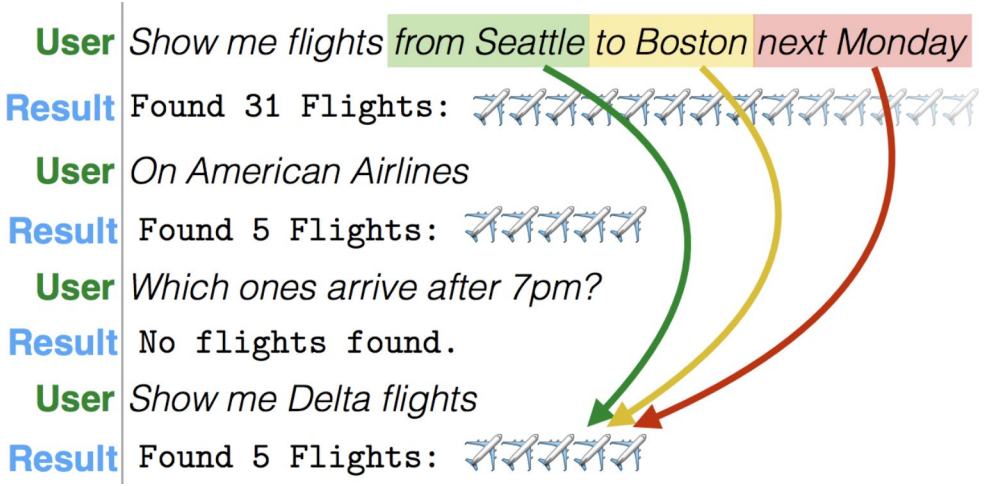

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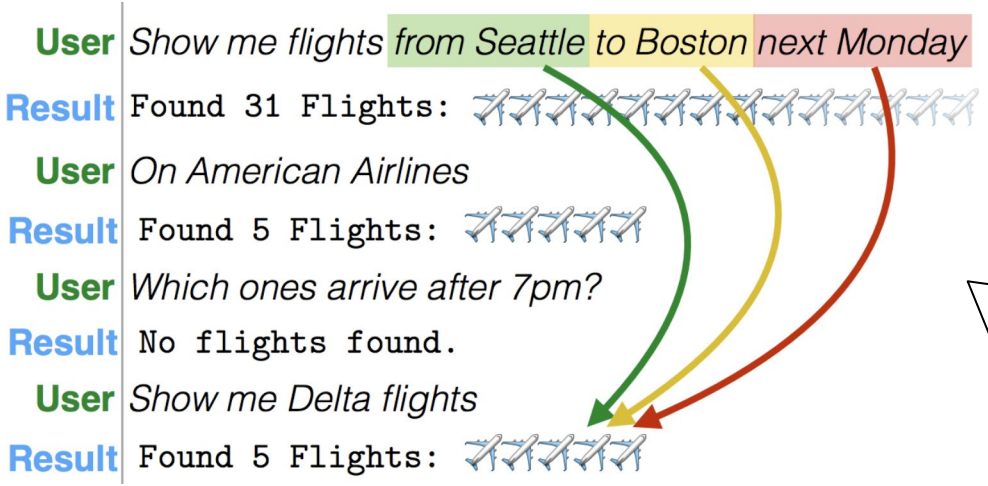

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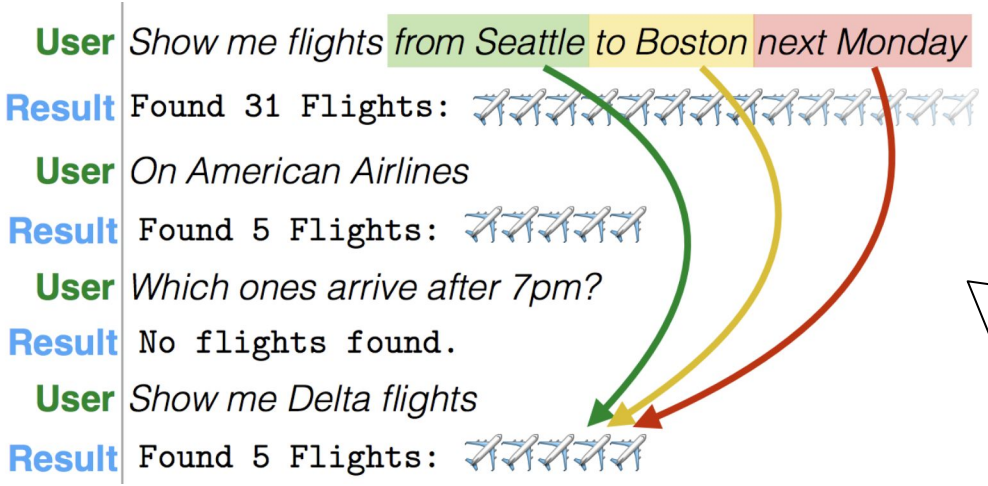

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User *Show me flights from Seattle to Boston next Monday*

Result `Found 31 Flights:` 

User *On American Airlines*

Result `Found 5 Flights:` 

User *Which ones arrive after 7pm?*

Result `No flights found.`

User *Show me Delta flights*

Result `Found 5 Flights:` 

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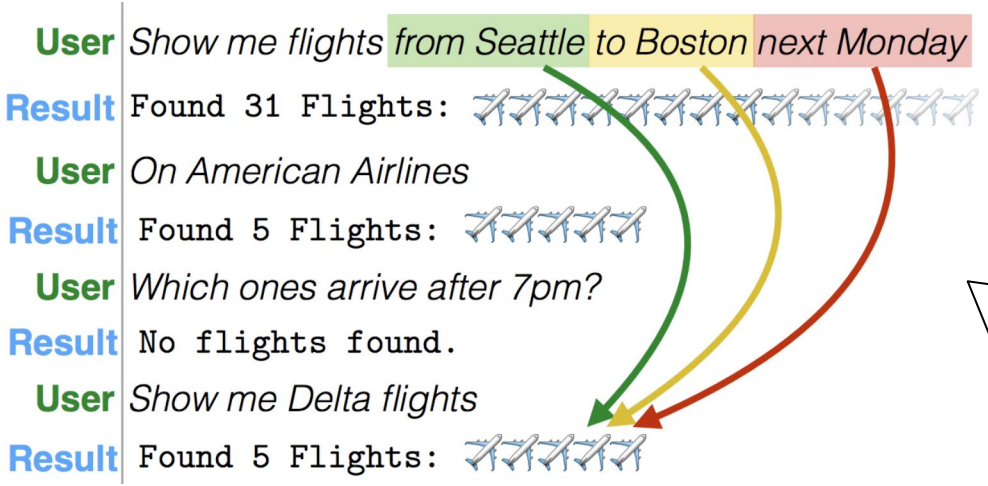

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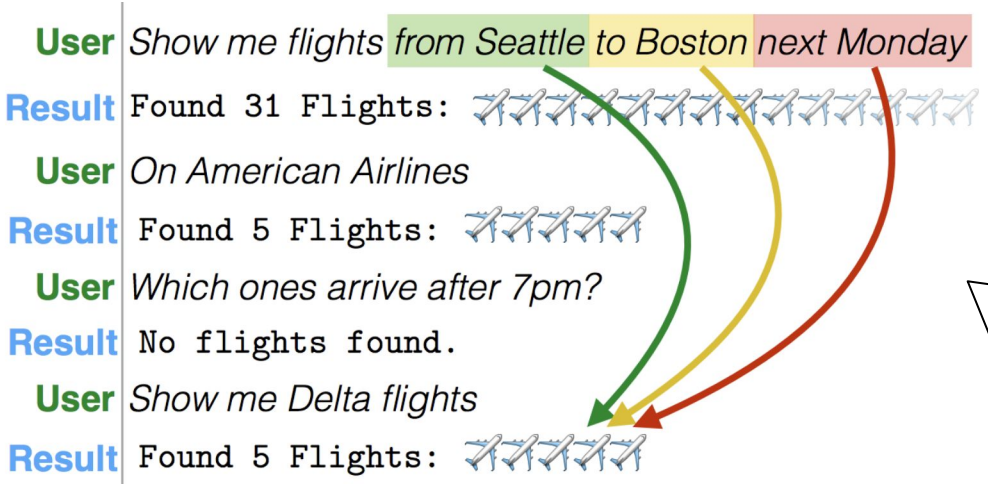

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Our goal: Conversational NL2SQL (CoSQL)

Most previous work expects user query to be well-formed and in a single sentence

But in practice,

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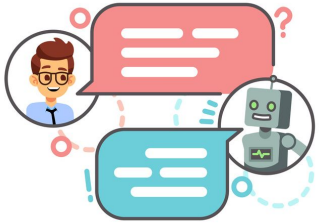
⇒ We collect real-world dialog data on Mechanical Turk

CoSQL (Desiderata & Tasks)



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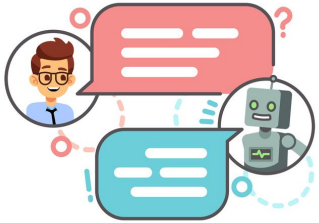

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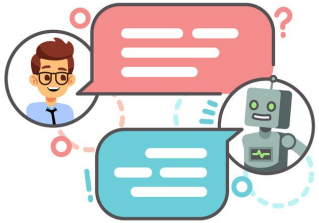
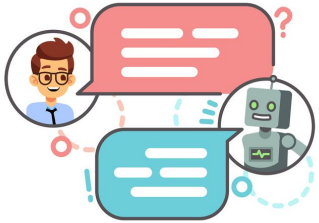


Task 1. Dialog Act Management

CoSQL (Desiderata & Tasks)



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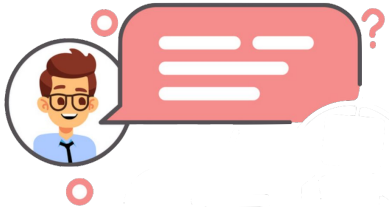
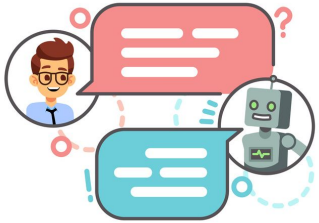
- Given user's question, the system classify it into an utterance type:



Context-dependent user question → Dialog act type

CoSQL (Desiderata & Tasks)



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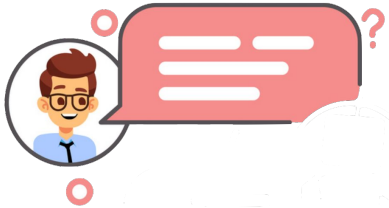
- Given user's question, the system classify it into an utterance type: "INFORM_SQL" (answerable with SQL), "AMBIGUOUS", "GREETING", "CANNOT_ANSWER", "NOT_RELATED", etc.



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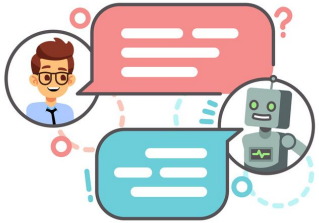
Task 1: Dialog Act Management

Some interesting dialog action types with examples:

1. INFER_SQL: if the user's question must be answered by SQL+human inference. SQL cannot directly return the answer, but we can infer the answer based on the SQL results.
   Examples: users' questions are "are they..?" (yes/no question) or "the 3rd oldest...".
   Are there more female or male students overall? Can you list all the events that happened within the last 5 years?
2. AMBIGUOUS: the user's question is ambiguous, the system needs to double check the user's intent (e.g. what/did you mean by…?) or ask for which columns to return.
3. AFFIRM: affirm something said by the system (user says yes/agree)
4. NEGATE: negate something said by the system (user says no/deny)
5. NOT_RELATED: the user's question is not related to the database, the system reminds the user
6. CANNOT_UNDERSTAND: the user's question cannot be understood by the system, the system asks the user to rephrase or paraphrase question.
7. CANNOT_ANSWER: the user's question cannot be easily answered by SQL, the system tells the user its limitation.
   Example: What is the average population across the counties? Which county has a population closest to that?

CoSQL (Desiderata & Tasks)



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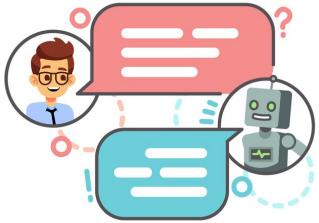

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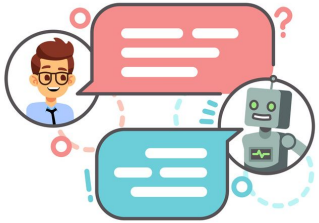

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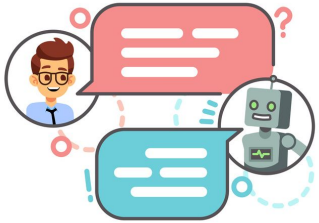

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Dialog SQL state tracking

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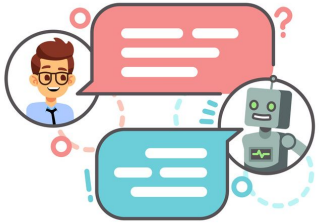

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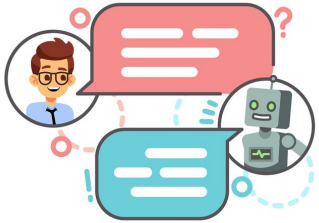

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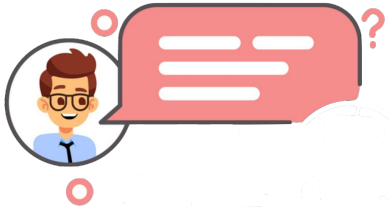

Context-dependent user question → SQL query

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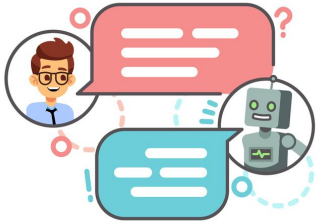

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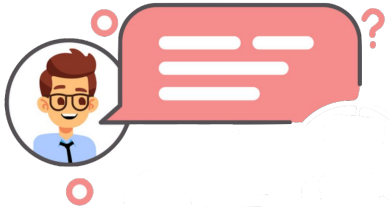
- Context-dependent semantic parsing



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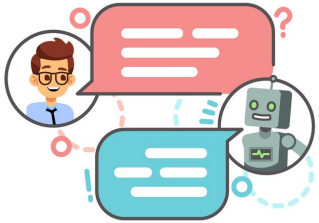

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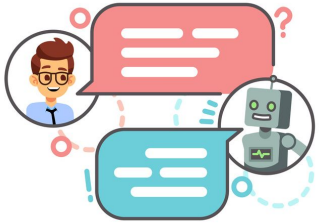

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V. Describe how it got the result and what the result means

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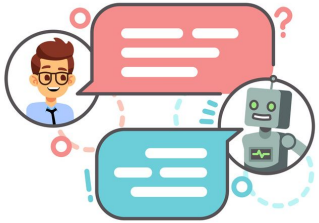

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System response generation

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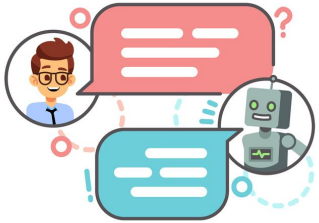

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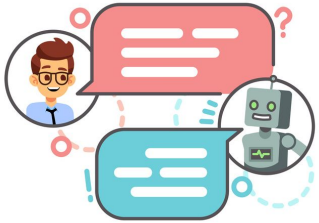
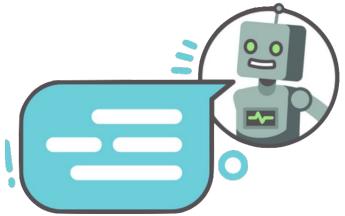


Task 3. System response generation

- SQL query and execution results → generate a NL response that describes the query and returned results

SQL query & execution result → System response (NL description)



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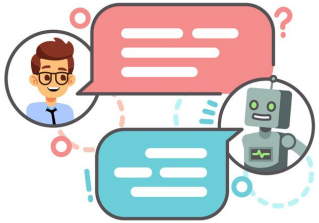

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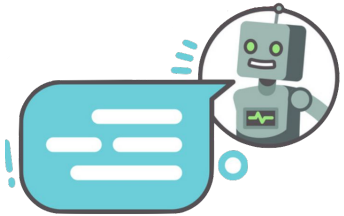
- SQL query and execution results → generate a NL response that describes the query and returned results
- Allow users to verify if the result answers their questions.

SQL query & execution result → System response (NL description)



CoSQL (Example)

D_1 : Database about student dormitories containing 5 tables

Database

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Q_1 : What are the names of all the dorms? INFORM_SQL

Database

User Question

CoSQL (Example)

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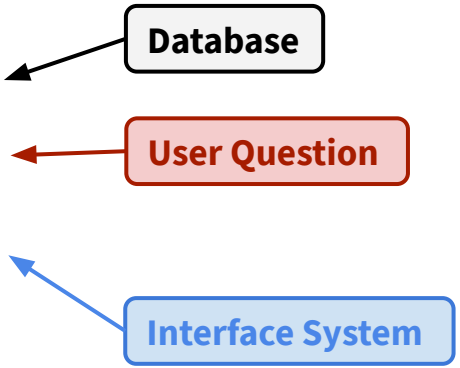
S_1 : `SELECT dorm_name FROM dorm`

A_1 : (Result table with many entries)

R_1 : This is the list of the names of all the dorms. CONFIRM_SQL



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S_1 : `SELECT dorm_name FROM dorm`

A_1 : (Result table with many entries)

R_1 : This is the list of the names of all the dorms. **CONFIRM_SQL**

Q_2 : Which of those dorms have a TV lounge? **INFORM_SQL**

CoSQL (Example)

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A_2 : (Result table with many entries)

R_2 : This shows the names of dorms with TV lounges. **CONFIRM_SQL**

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R_3 : Do you mean among those with TV Lounges? **CLARIFY**

Q_4 : Yes. **AFFIRM**

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A_4 : Fawlty Towers

R_4 : Fawlty Towers is the name of the dorm that has a TV lounge but not a study room as an amenity. **CONFIRM_SQL**

CoSQL (Example)

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A_4 : Fawlty Towers

R_4 : Fawlty Towers is the name of the dorm that has a TV lounge but not a study room as an amenity. **CONFIRM_SQL**

...

Q_8 : Thanks! **THANK_YOU**

R_8 : You are welcome. **WELCOME**

System Response Generation (example)

Examples

1. If the returned result can be combined with the SQL description, combine them together to generate the response. For example:

   Given SQL: `SELECT avg(salary) FROM instructor`

   Result Returned: 200k

System Response Generation (example)

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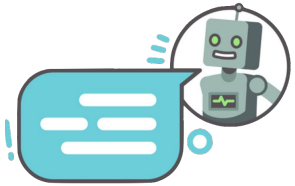
1. If the returned result can be combined with the SQL description, combine them together to generate the response. For example:

   Given SQL: `SELECT avg(salary) FROM instructor`

   Result Returned: 200k

   Response: The average salary of all instructors is 200k.



System Response Generation (example)

Examples

2. If the returned result is too large and cannot be combined with the SQL description, describe them separately. For example:

   Given SQL:
   ```
   SELECT avg(T1.salary), T1.department_id
   FROM instructor as T1 JOIN department
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   ```
   Result Returned: a long table

System Response Generation (example)

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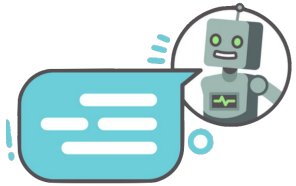
   GROUP BY T1.department_id
   ```

   Result Returned: a long table

   Response: Here is the result table that shows the average salary in each department.
   For example, the average of CS professors is 250k.



Task-oriented dialog task v.s. CoSQL

Task-oriented dialog: dialog state-tracking with pre-defined slots and values

```
Topic:'food'  Cuisine:'Chinese'
Neighborhood:'Palo Alto'
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CoSQL: cover **more diverse & complex** semantics of practical user questions with SQL

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GROUP BY T1.department_id
HAVING avg(T1.salary) > (SELECT avg(salary) FROM instructor)
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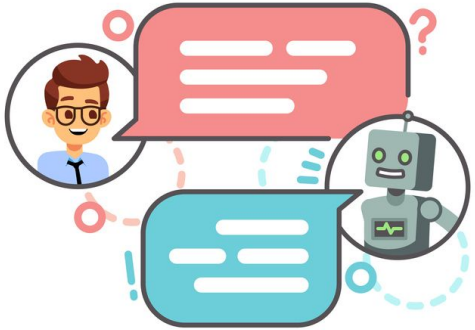
Data Collection

- **Wizard of Oz method:** Real-time dialog between two players (user & system)

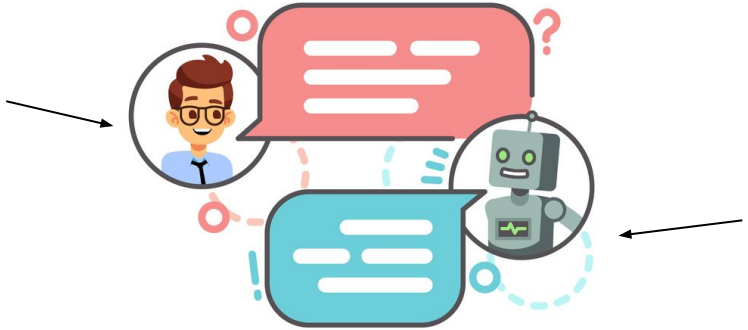


Data Collection

- **Wizard of Oz method:** Real-time dialog between two players (user & system)

DB User: Crowd Workers

Interface System:
CS students with SQL skill

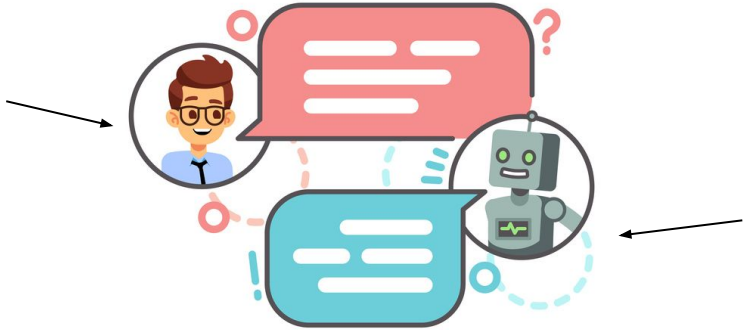


Data Collection

- **Wizard of Oz method:** Real-time dialog between two players (user & system)
- Take each question from *Spider* as user's dialog goal.

DB User: Crowd Workers

Interface System:
CS students with SQL skill



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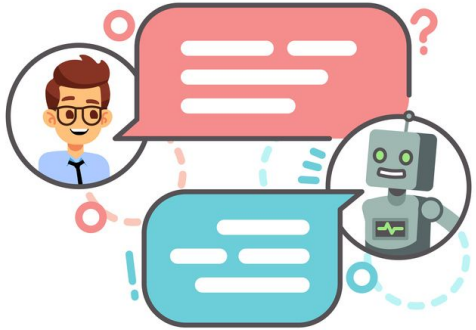

Interface System:
CS students with SQL skill

Data Collection

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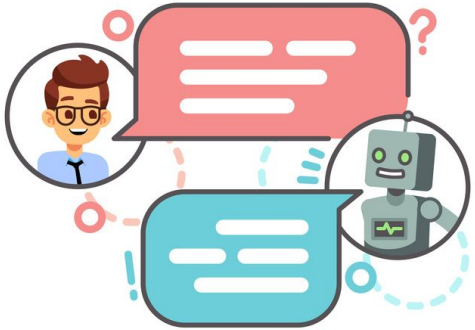


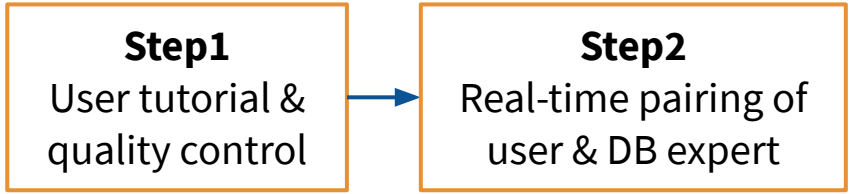
Interface System:
CS students with SQL skill

1. Dialog act management
2. SQL translation
3. Response generation
4. Inform of ambiguous/unanswerable questions

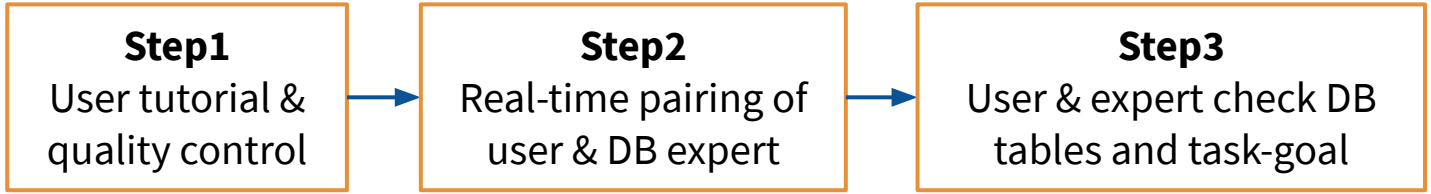
Data Collection (MTurk Process)

Step1
User tutorial &
quality control

Data Collection (MTurk Process)



Data Collection (MTurk Process)



Data Collection (MTurk Process)

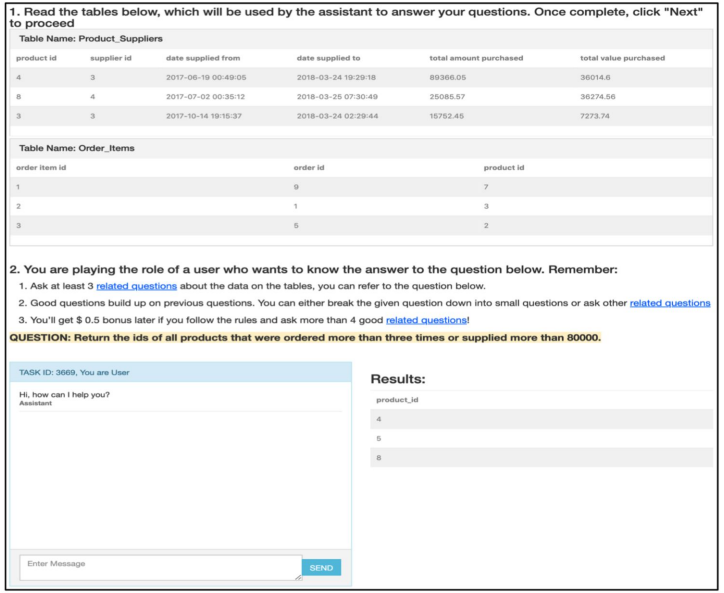
Step1
User tutorial & quality control

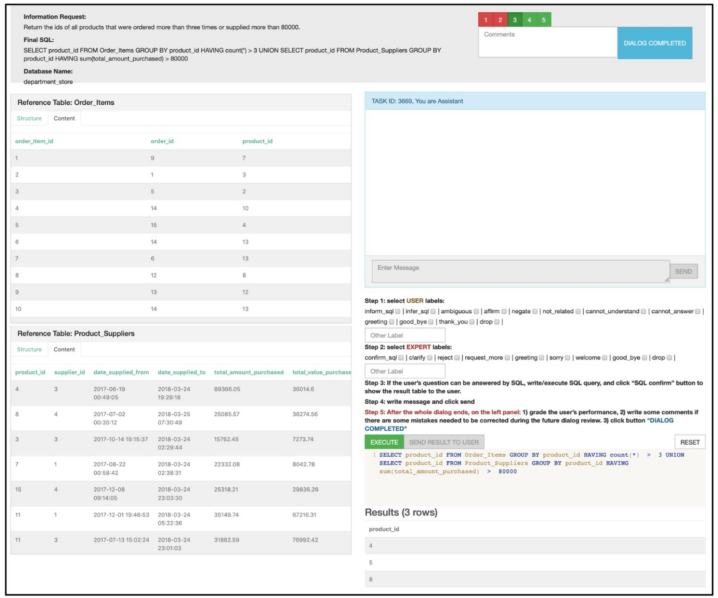
→

Step2
Real-time pairing of user & DB expert

→

Step3
User & expert check DB tables and task-goal





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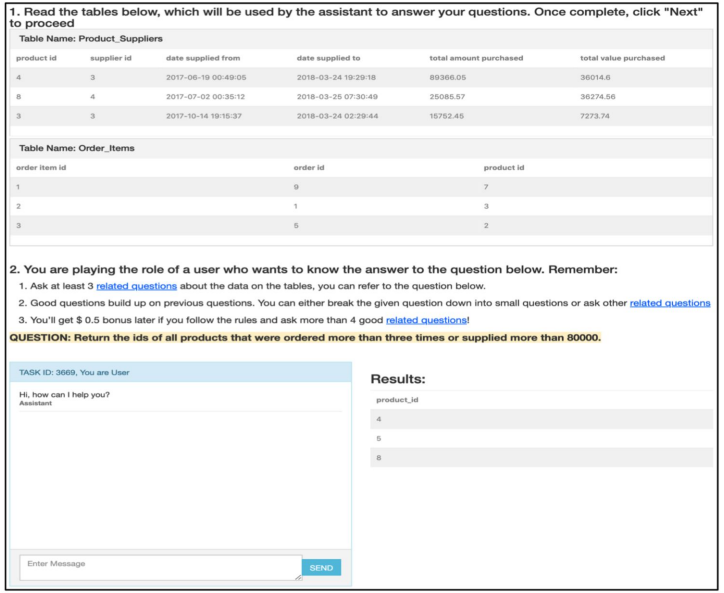
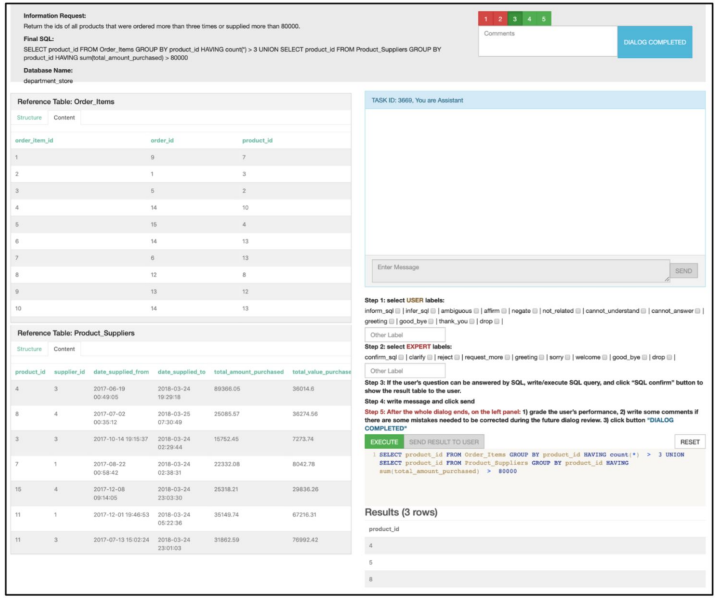
Step4
Real-time chat

User side



System side



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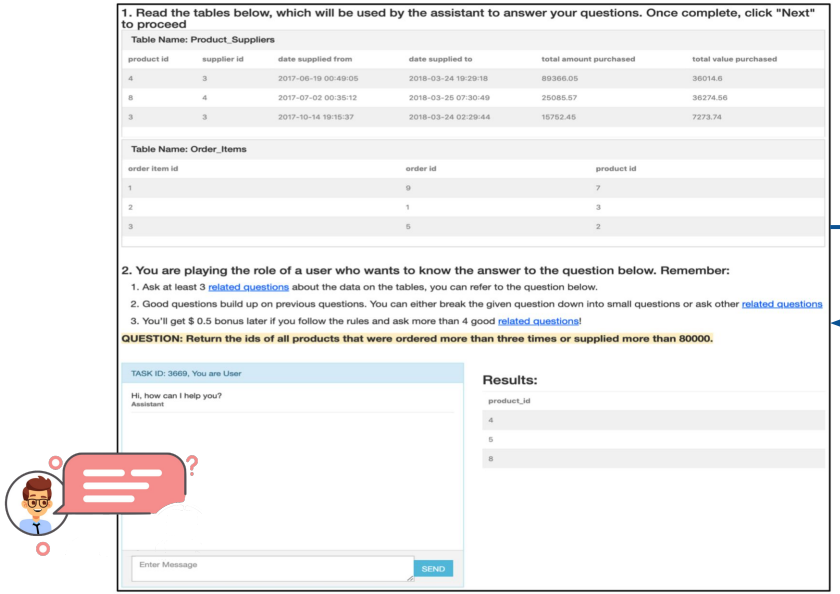

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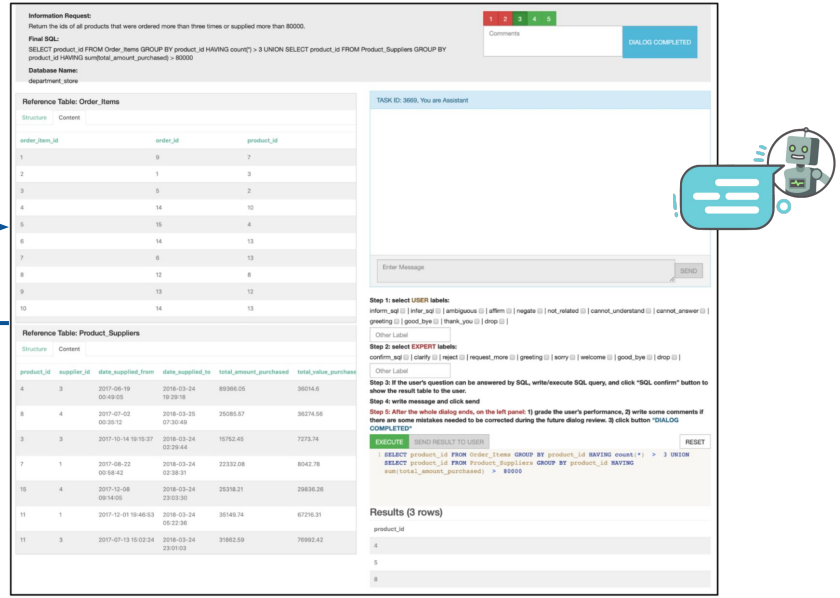

Dataset Statistics

CoSQL v.s. context-dependent NL2SQL

	ATIS	**CoSQL**
# Q sequence	1658	3,007
# user questions	11,653	15,598*
# databases	1	200
# tables	27	1020
Avg. Q len	10.2	11.2
Vocab	1582	9,585
Avg. # Q turns	7.0	5.2
Unanswerable Q	✗	✓
User intent	✗	✓
System response	✗	✓

Dataset Statistics

CoSQL v.s. context-dependent NL2SQL ⇒ **More practically useful & interpretable**

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Dataset Statistics

CoSQL v.s. task-oriented dialogue datasets

	DSTC2	WOZ 2.0	KVRET	MultiWOZ	**CoSQL**
# dialogs	1,612	600	2,425	8,438	2,164
Total # turns	23,354	4,472	12,732	115,424	22,422
Total # tokens	199,431	50,264	102.077	1,520,970	22.8197
Avg. # turns/dialog	14.49	7.45	5.25	13.68	10.36
Avg. # tokens/turn	8.54	11.24	8.02	13.18	11.34
Total # unique tokens	986	2,142	2,842	24,071	7,502
# databases	1	1	1	7	140
# Slots #	8	4	13	25	3,696
# Values #	212	99	1,363	4,510	>1,000,000

Dataset Statistics

CoSQL v.s. task-oriented dialogue datasets ⇒ **Semantically diverse**

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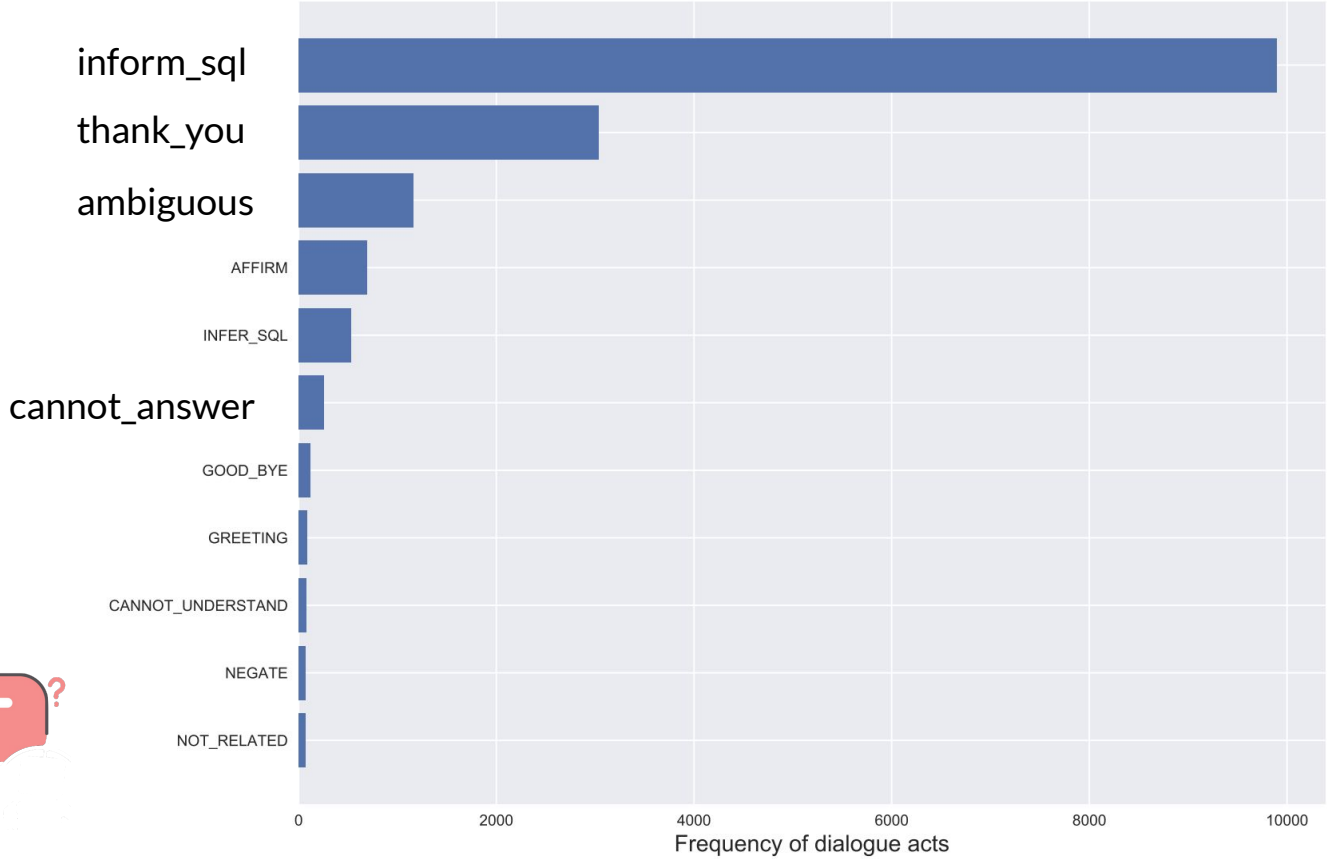
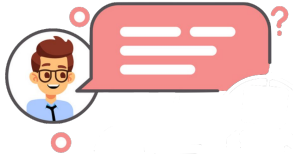
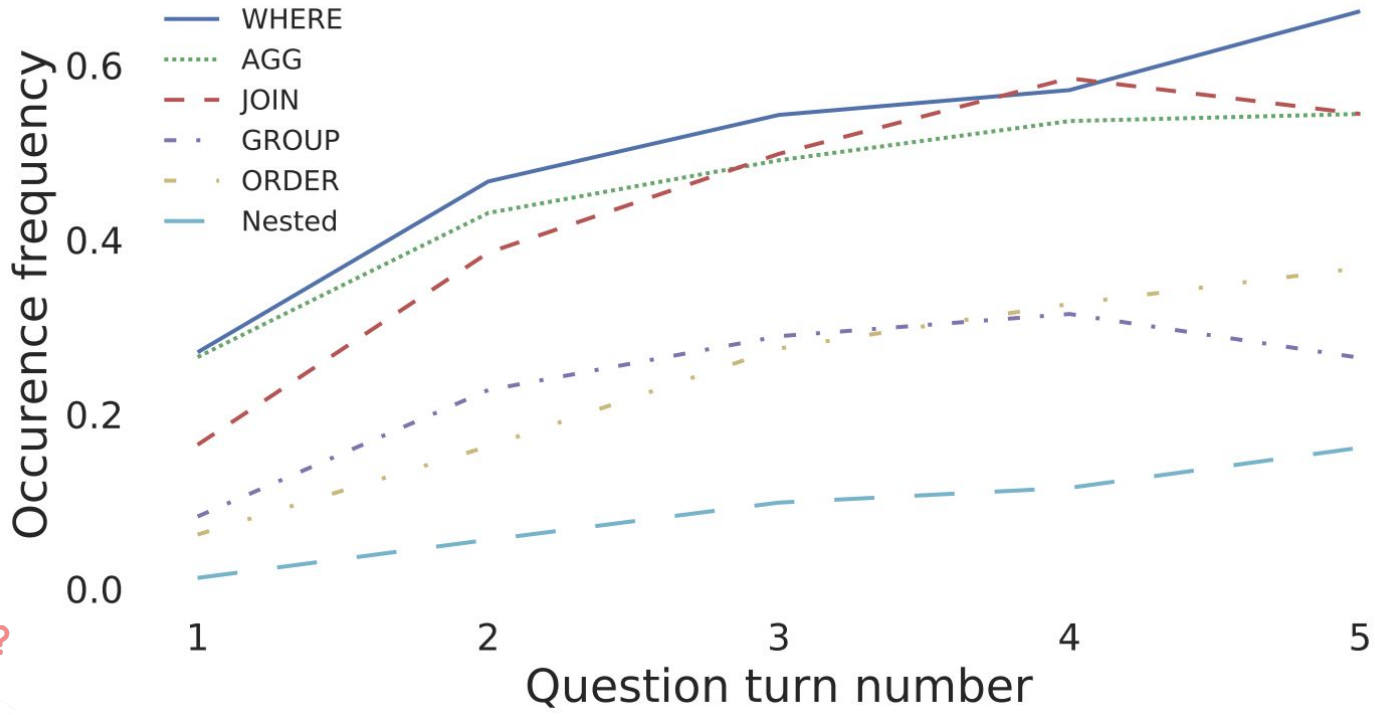
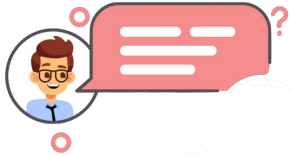
Dialog act distribution





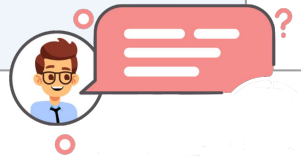
Semantic change by turns





User follow-up question characteristics

	Coreference	Change constraint	Different attribute of same topic	Same attribute for different topic	Question about the answer
Previous Q	How many female students are in the class?				
Follow up Q					



User follow-up question characteristics

	Coreference	Change constraint	Different attribute of same topic	Same attribute for different topic	Question about the answer
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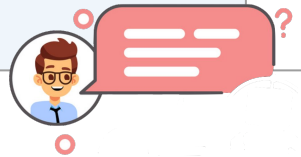
Follow up Q	What are **their** names?				



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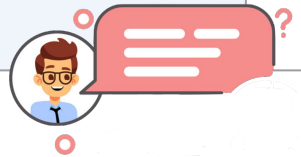
Follow up Q	What are their names?	How about in the summer?			



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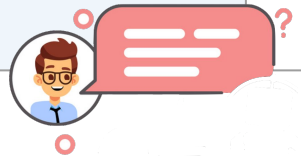

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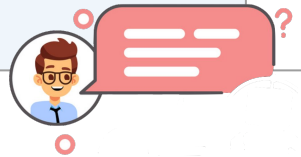
Follow up Q	What are their names?	How about in the summer?	What is the time?	And a swiss roll?	



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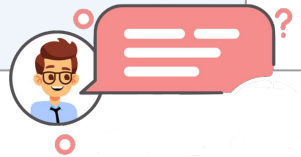
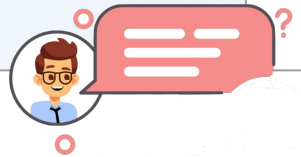
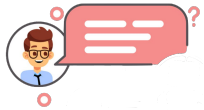


User follow-up question characteristics

	Coreference	Change constraint	Different attribute of same topic	Same attribute for different topic	Question about the answer
Previous Q	How many female students are in the class?	Show me courses taught in the winter	Where is the location of the conference?	What is the price of a bagel?	What is the highest rated college in CT? Answer: Yale
Follow up Q	What are their names?	How about in the summer?	What is the time?	And a swiss roll?	How many departments does Yale have?

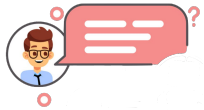


Tasks & Experiments



Context-dependent user question → Dialog act type

Tasks & Experiments



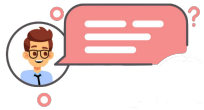
Context-dependent user question → Dialog act type

Context-dependent user question → SQL query

Tasks & Experiments

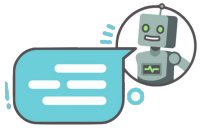
Context-dependent user question → Dialog act type

Dialog act management



Context-dependent user question → SQL query

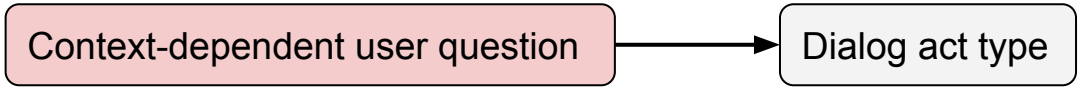
Dialog SQL state tracking



SQL query & execution result → System response (NL description)

System response generation

Task 1: User Dialogue Act Prediction



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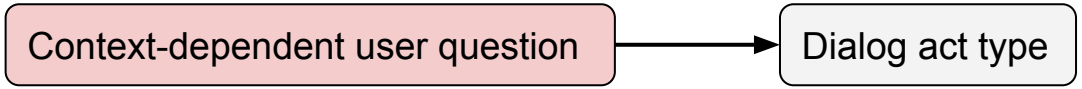

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- Majority -- always predict "INFORM_SQL"
- TBCNN [Mouet al., 2016]

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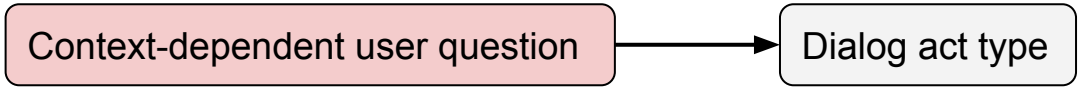

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Model	Dev	Test
Majority	63.3	62.8
TBCNN-pair	84.2	83.9

Accuracy (%)

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Majority	63.3	62.8
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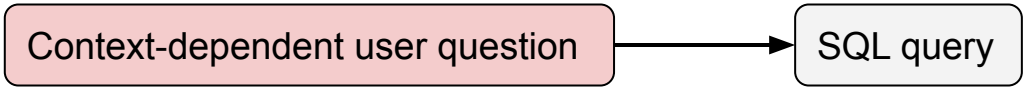
Accuracy (%)

✓ common types ("inform_sql", "thank_you", "greetings")

✘ other types ("ambiguous", "cannot_answer", etc.)

Task 2: SQL state tracking (context-dependent NL2SQL)



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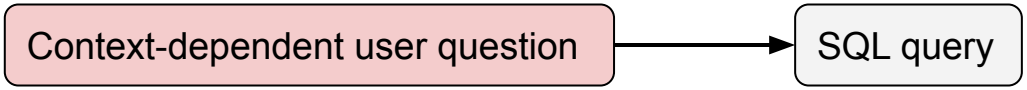

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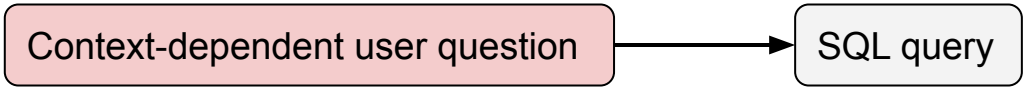

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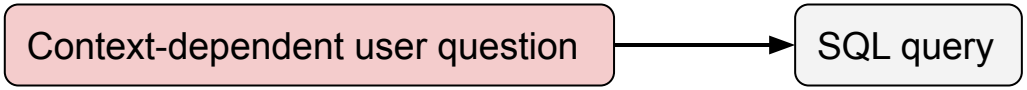

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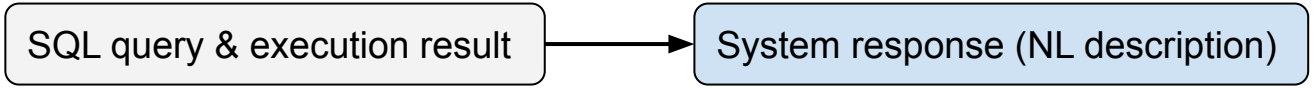
On Spider (single turn):

21%

Task 3: System Response Generation



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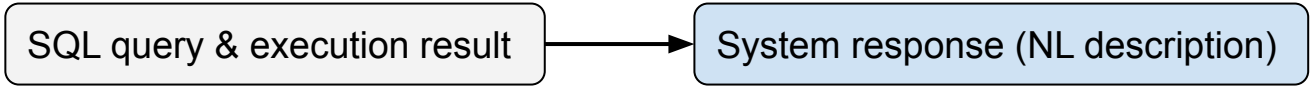

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- Template -- prepared from (SQL, response) pairs in training data
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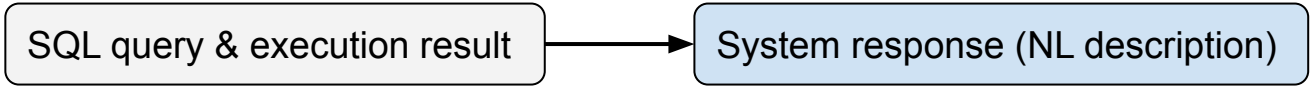

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Model	BLEU		LCR (%)	Grammar
	Dev	Test	Test	Test
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Task 3: System Response Generation

SQL query & execution result → System response (NL description)

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Semantic correctness

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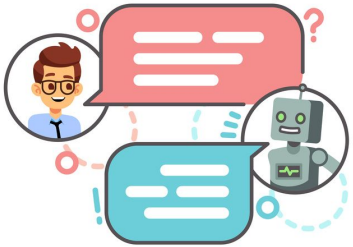
Human evaluation

Summary

- CoSQL, first truly **conversational** NL2SQL corpus
  - Include ambiguous/unanswerable questions real users ask
  - Include system response to improve interpretability & user experience



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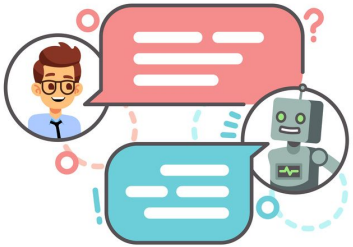

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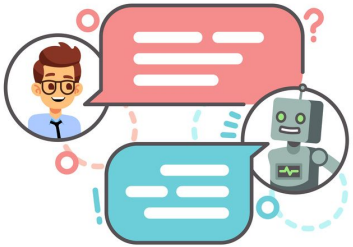

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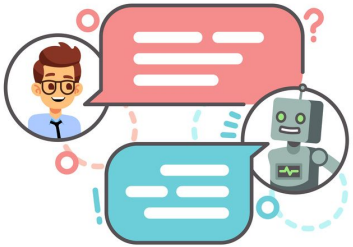
- CoSQL project page: https://yale-lily.github.io/cosql



Thank you!

Michihiro Yasunaga