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

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Presented by: Qihao Shao

Overview

- Introduction
- Model
- Wizard-of-Oz Data Collection
- Empirical Experiments
- Conclusions

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Introduction

- Treat as a POMDP and use RL to train dialogue policies
- Build end-to-end trainable, non-task-oriented conversational systems using seq2seq model
- The authors propose a model by balancing the strengths and the weaknesses of these two

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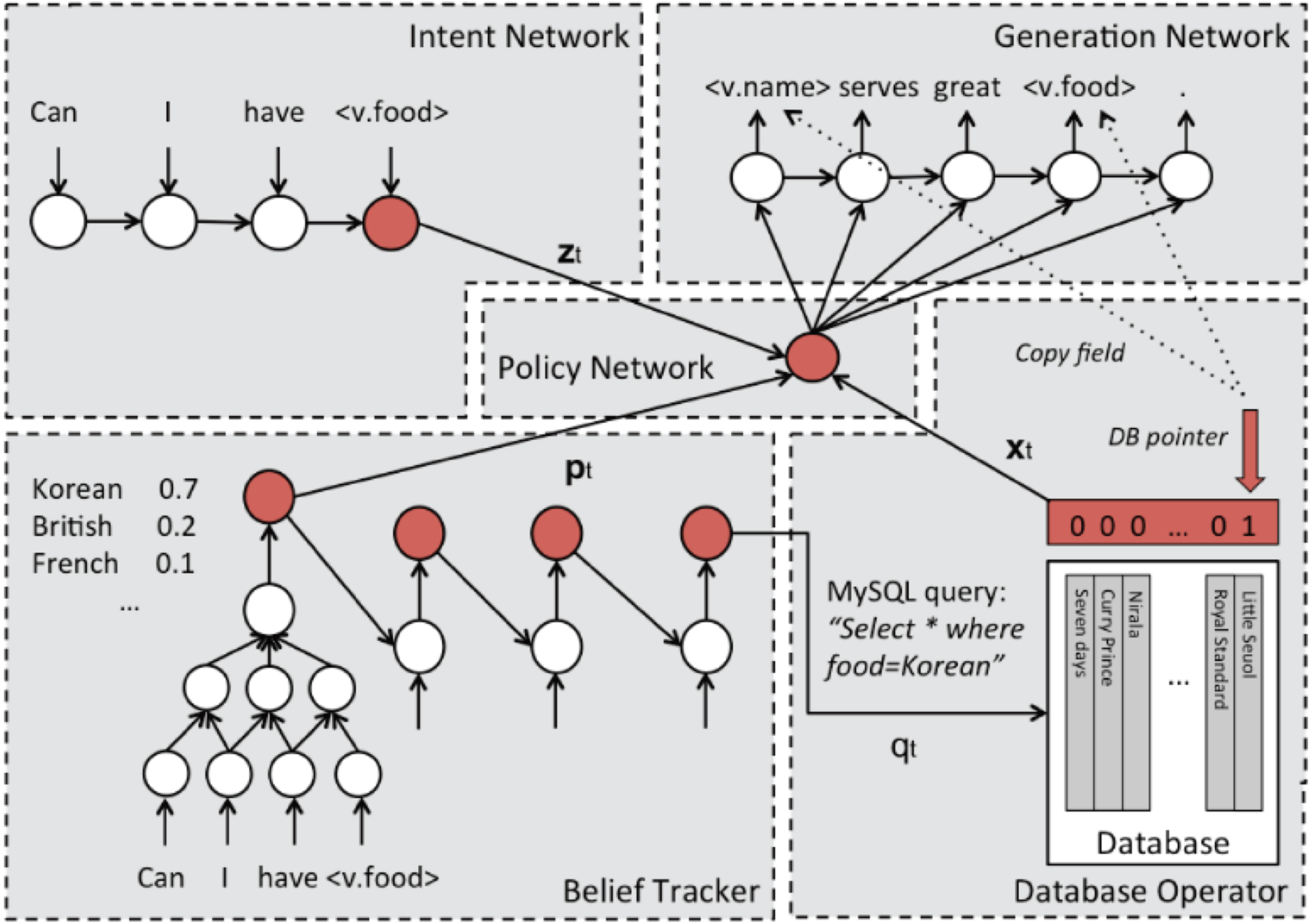
Model

- Intent Network
- Belief Trackers
- Database Operator
- Policy Network
- Generation Network

Model



Intent Network
Can
I
have
<v.food>
z_t
Generation Network
<v.name> serves great <v.food> .
Policy Network
Copy field
DB pointer
x_t
p_t
Korean 0.7
British 0.2
French 0.1
...
0 0 0 ... 0 1
MySQL query:
"Select * where food=Korean"
q_t
Seven days
Curry Prince
Nirala
...
Royal Standard
Little Seuol
Database
Can I have <v.food>
Belief Tracker
Database Operator

Intent Network

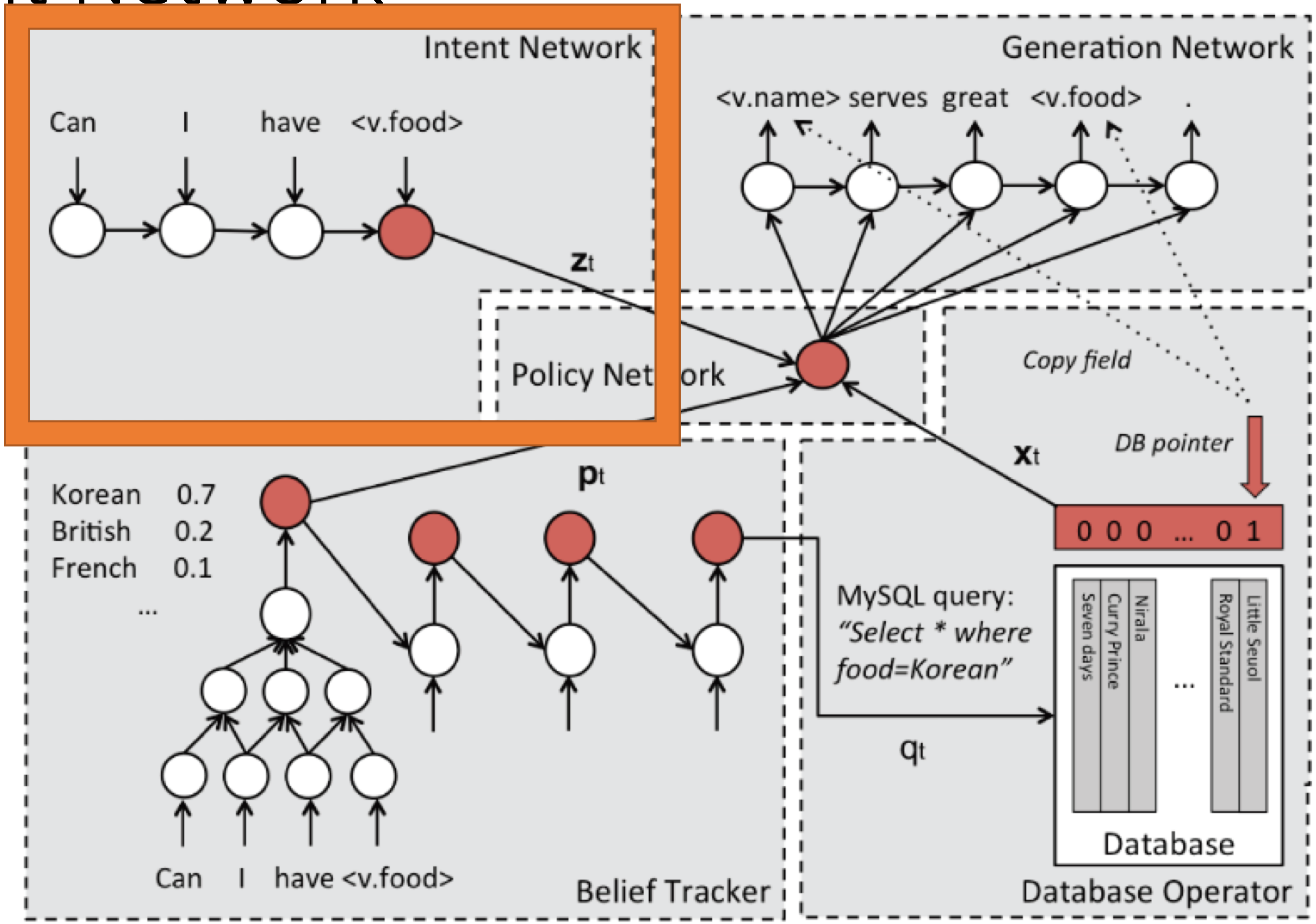
- Encoder in the sequence-to-sequence framework
- Typically, an LSTM network is used

$$\mathbf{z}_t = \mathbf{z}_t^N = \mathrm{LSTM}(w_0^t, w_1^t, ...w_N^t)$$

- Alternatively, a CNN can be used

$$\mathbf{z}_t = \mathrm{CNN}(w_0^t, w_1^t, ...w_N^t)$$

Intent Network



Belief Trackers

- Core component of the model
- Every slot has its belief tracker
- Each tracker is a Jordan type RNN with a CNN feature extractor

Belief Trackers

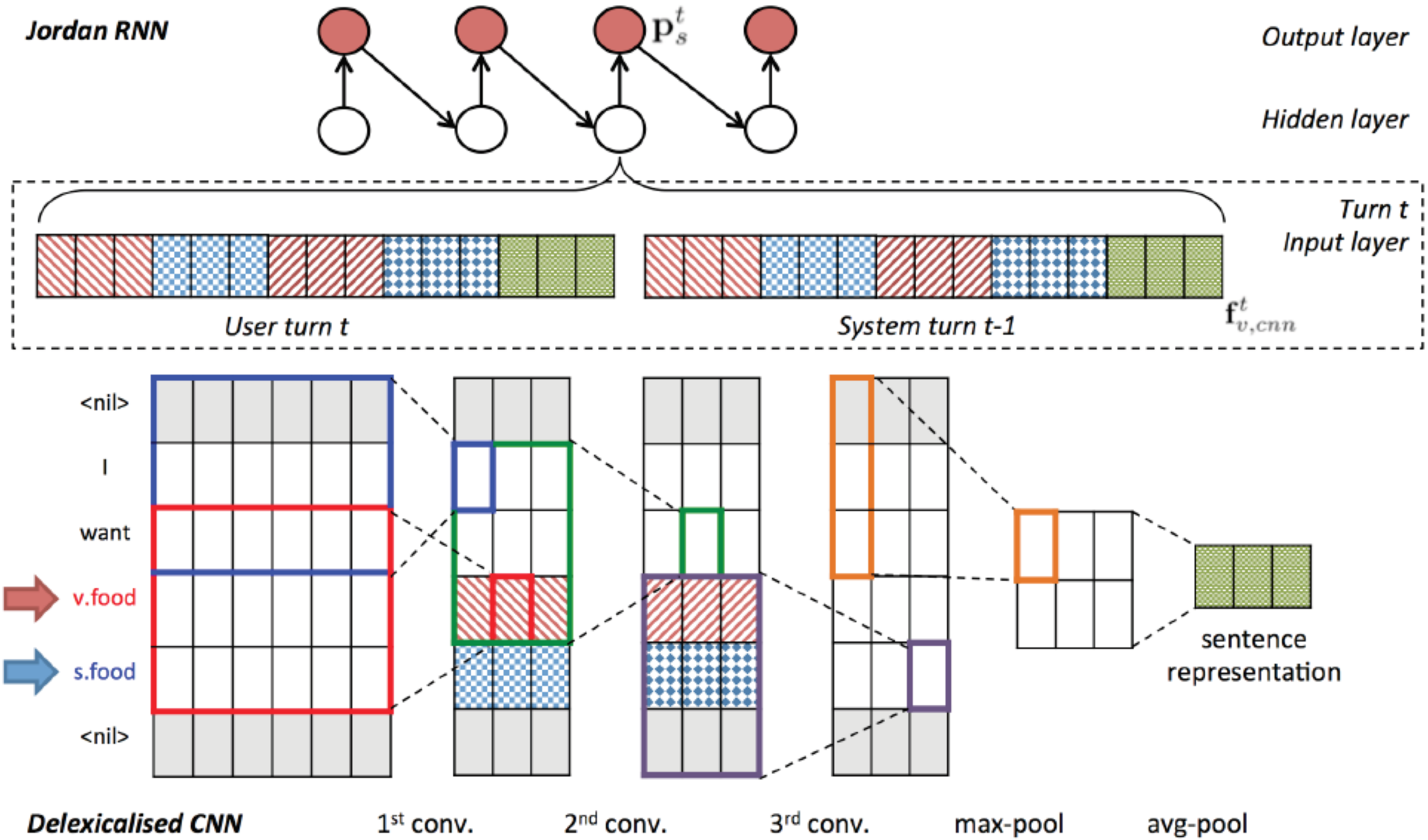
$$\mathbf{f}_{v,cnn}^{t} = \mathrm{CNN}_{s,v}^{(u)}(u_t) \oplus \mathrm{CNN}_{s,v}^{(m)}(m_{t-1})$$

$$\mathbf{f}_{v}^{t} = \mathbf{f}_{v,cnn}^{t} \oplus p_v^{t-1} \oplus p_{\emptyset}^{t-1}$$

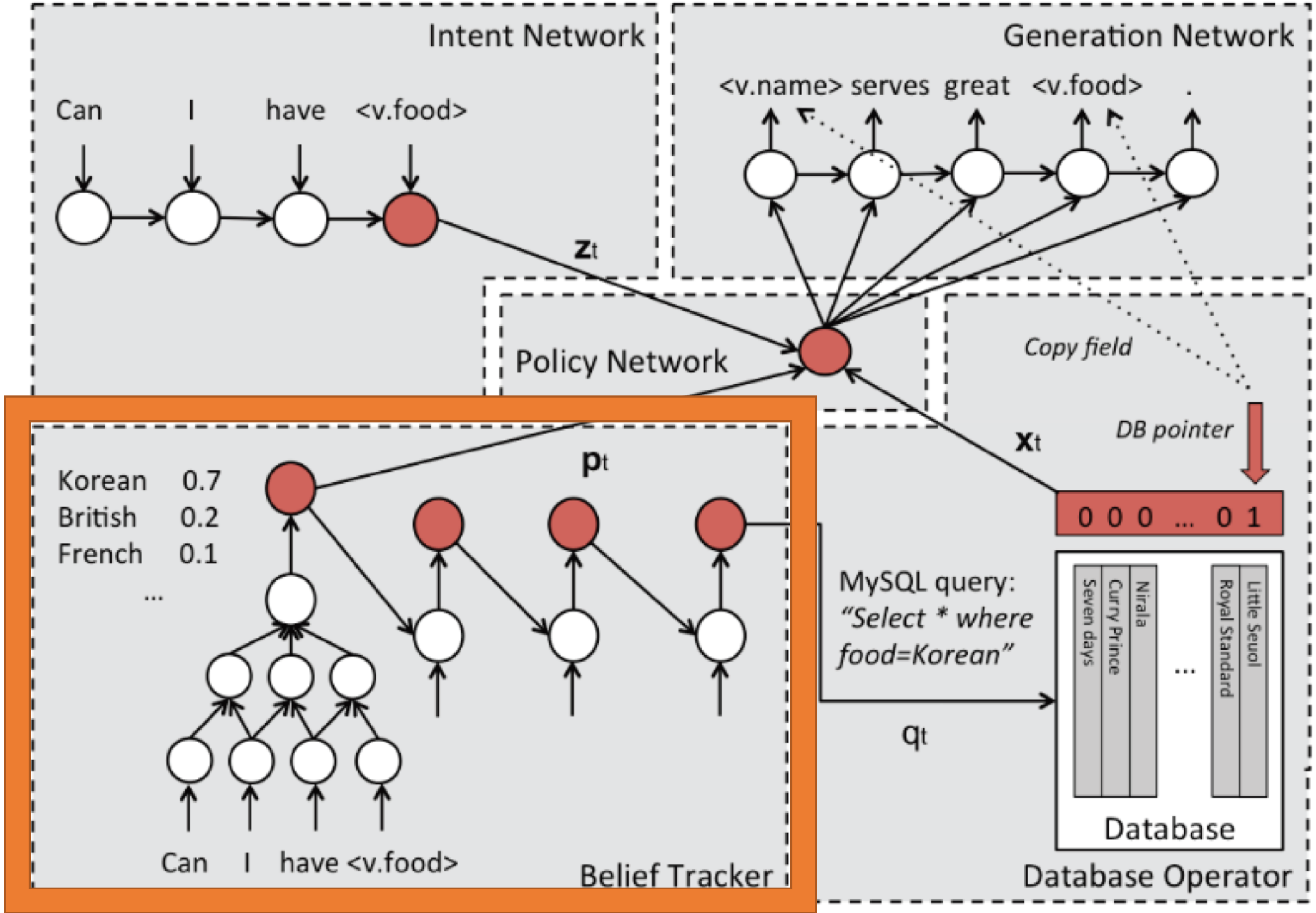
$$g_v^t = \mathbf{w}_s \cdot \mathrm{sigmoid}(\mathbf{W}_s \mathbf{f}_v^t + \mathbf{b}_s) + b'_s$$

$$p_v^t = \frac{\exp(g_v^t)}{\exp(g_{\emptyset,s}) + \sum_{v' \in V_s} \exp(g_{v'}^t)}$$

Belief Trackers



Belief Trackers



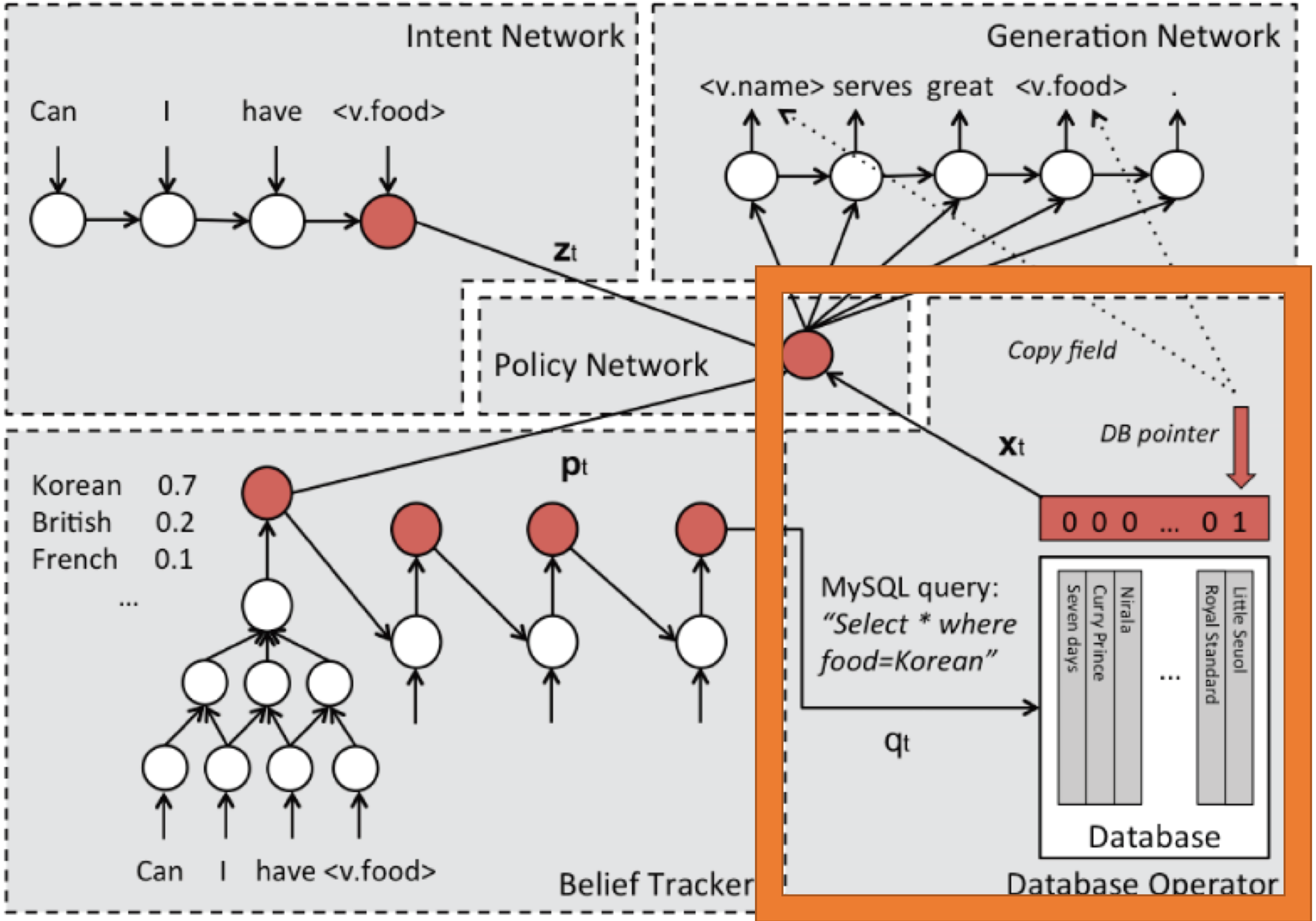
Database Operator

- The DB query qt is formed by

$$q_t = \bigcup_{s' \in S_I} \{\operatorname*{argmax}_v \mathbf{p}_{s'}^t\}$$

- Then query is applied to the DB to create a binary truth value vector xt over DB entities
- The entity referenced by the entity pointer is used to form the final system response

Database Operator

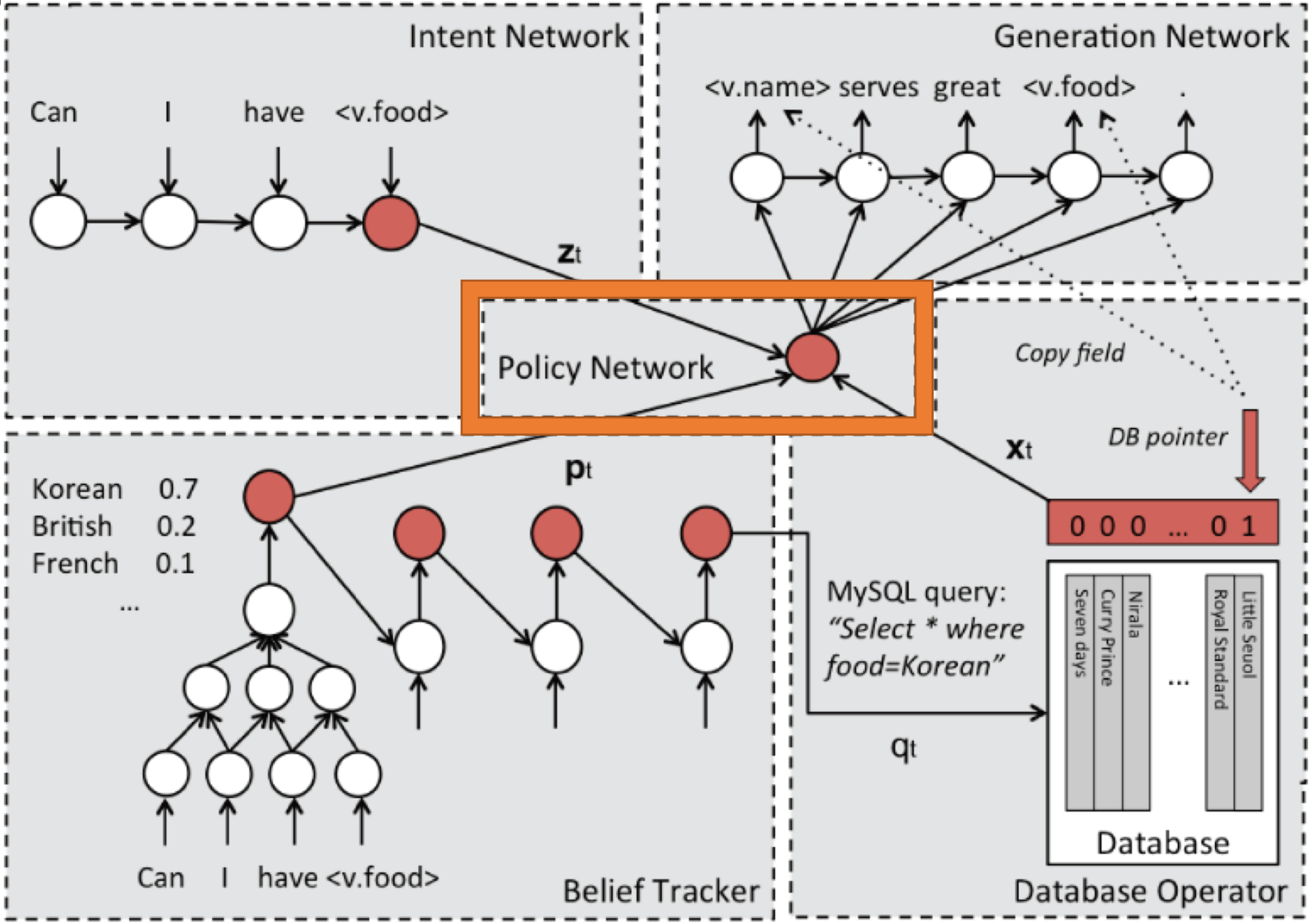


Policy Network

- Can be viewed as the glue binding other modules together

$$\mathbf{o}_t = \tanh(\mathbf{W}_{zo}\mathbf{z}_t + \mathbf{W}_{po}\hat{\mathbf{p}}_t + \mathbf{W}_{xo}\hat{\mathbf{x}}_t)$$

Policy Network



Generation Network

$$P(w_{j+1}^t | w_j^t, \mathbf{h}_{j-1}^t, \mathbf{o}_t) = \mathrm{\mathbf{LSTM}}_j(w_j^t, \mathbf{h}_{j-1}^t, \mathbf{o}_t)$$

- Once the output token sequence has been generated, the generic tokens are replaced by their actual values

Generation Network

- Attentive Generation Network

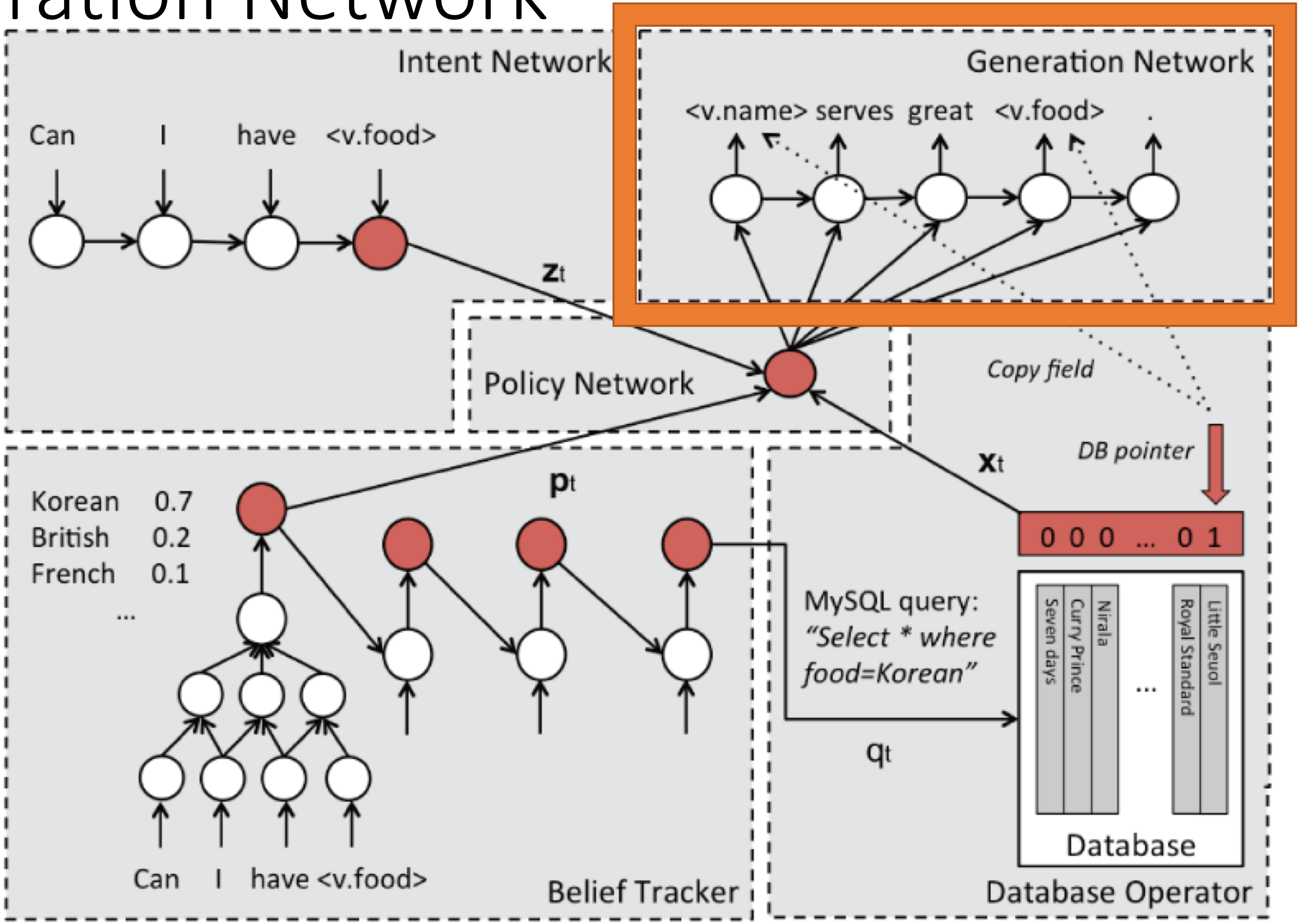
$$\mathbf{o}_t^{(j)} = \tanh(\mathbf{W}_{zo}\mathbf{z}_t + \hat{\mathbf{p}}_t^{(j)} + \mathbf{W}_{xo}\hat{\mathbf{x}}_t)$$

$$\hat{\mathbf{p}}_t^{(j)} = \sum \alpha_s^{(j)} \tanh(\mathbf{W}_{po}^s \cdot \hat{\mathbf{p}}_s^t)$$

$$\alpha_s^{(j)} = \text{softmax}\left(\mathbf{r}^\mathsf{T} \tanh(\mathbf{W}_r \cdot \mathbf{u}_t)\right)$$

$$\mathbf{u}_t = \mathbf{z}_t \oplus \hat{\mathbf{x}}_t \oplus \hat{\mathbf{p}}_s^t \oplus \mathbf{w}_j^t \oplus \mathbf{h}_{j-1}^t$$

Generation Network



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Wizard-of-Oz Data Collection

- This paper proposed a novel crowdsourcing version of the Wizard-of-Oz paradigm
- Designed two webpages on Amazon Mechanical Turk, one for wizards and the other for users

Wizard-of-Oz Data Collection

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 ?

Next turn!

Customer : (**Your response**)

I dont care about the price range, just give me the address please.

Submit the HIT

Wizard-of-Oz Data Collection

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 ?
Customer : i dont care

Next turn!

Please **modify** the following answers based on the latest customer response:

- What does user want?

What is the **food type** the user wants? gastropub
What is the **area** the user wants? not mentioned
What is the **price range** the user wants? dont care

- What does user ask?

Is the user asking for **food type** of an offered venue? No
Is the user asking for **price range** of an offered venue? No
Is the user asking for **area** of an offered venue? No
Is the user asking for **postcode** of an offered venue? No
Is the user asking for **phone number** of an offered venue? No
Is the user asking for **address** of an offered venue? No
Is the user mentioning any **restaurant names**? No

finish

Info Desk : (**Your response**)

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

Name	Food	Area	Price Range	Phone	Address	Postcode
backstreet bistro	gastropub	centre	expensive	01223 306306	2 Sturton Street City Centre	C.B 1, 2 Q.A
royal standard	gastropub	east	expensive	01223 247877	290 Mill Road City Centre	C.B 1, 3 N.L
the cow pizza kitchen and bar	gastropub	centre	moderate	01223 308871	Corn Exchange Street	C.B 2, 3 Q.F
the slug and lettuce	gastropub	centre	expensive	–	34 - 35 Green Street	C.B 2, 3 J.U
nil	gastropub	nil	nil	nil	nil	nil

Showing 1 to 4 of 4 entries (filtered from 110 total entries)

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Wizard-of-Oz Data Collection

- 99 restaurants in the DB
- 3000 HITs (Human Intelligence Tasks) in total
- 680 dialogues after data cleaning
- Cost ~ 400 USD

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Empirical Experiments

Tracker type	Informable			Requestable		
	Prec.	Recall	F-1	Prec.	Recall	F-1
cnn	99.77%	96.09%	97.89%	98.66%	93.79%	96.16%
ngram	99.34%	94.42%	96.82%	98.56%	90.14%	94.16%

Empirical Experiments

Encoder	Tracker	Decoder	Match(%)	Success(%)	T5-BLEU	T1-BLEU
Baseline						
lstm	-	lstm	-	-	0.1650	0.1718
lstm	turn recurrence	lstm	-	-	0.1813	0.1861
Variant						
lstm	rnn-cnn, w/o req.	lstm	89.70	30.60	0.1769	0.1799
cnn	rnn-cnn	lstm	88.82	58.52	0.2354	0.2429
Full model w/ different decoding strategy						
lstm	rnn-cnn	lstm	86.34	75.16	0.2184	0.2313
lstm	rnn-cnn	+ weighted	86.04	78.40	0.2222	0.2280
lstm	rnn-cnn	+ att.	90.88	80.02	0.2286	0.2388
lstm	rnn-cnn	+ att. + weighted	90.88	83.82	0.2304	0.2369

Empirical Experiments

Metric	NN
Success	98%
Comprehension	4.11
Naturalness	4.05
# of dialogues:	245

Metric	NN	HDC	Tie
Subj. Success	96.95%	95.12%	-
Avg. # of Turn	3.95	4.54	-
Comparisons(%)			
Naturalness	46.95*	25.61	27.44
Comprehension	45.12*	21.95	32.93
Preference	50.00*	24.39	25.61
Performance	43.90*	25.61	30.49

* $p < 0.005$, # of comparisons: 164

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Conclusions

- Combines modularly connected model and end-to-end trainable model
- First end-to-end NN-based model that can conduct meaningful dialogues in a task-oriented application

Thank you