Transaction Bot using LSTM

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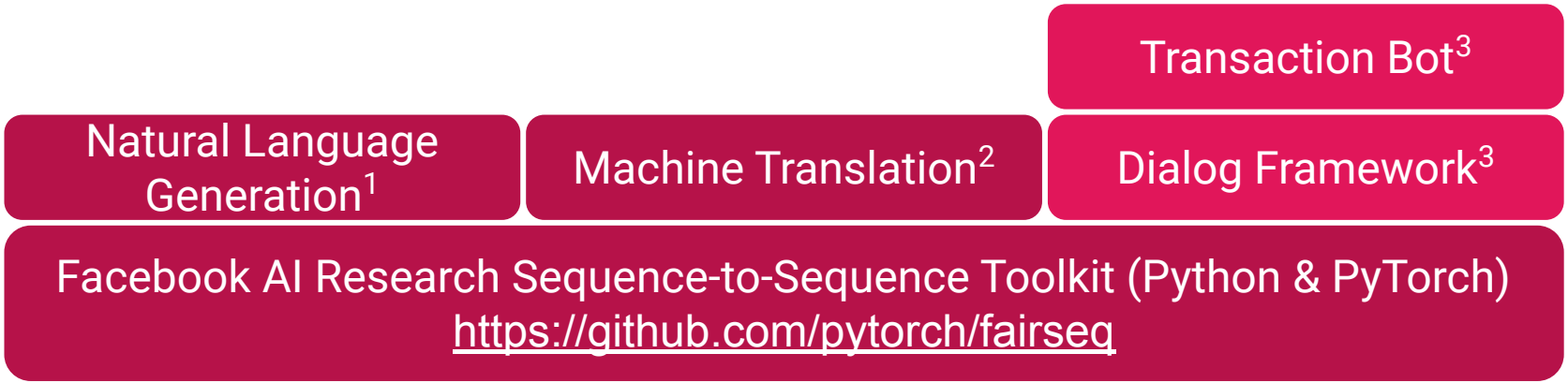
Slides: https://vineetk1.github.io/Transaction-bot-using-LSTM.pdf
Implementation: https://github.com/vineetk1/fairseq/tree/dialog
Datasets: https://fb-public.app.box.com/s/chnq60iivzv5uckpvj2n2vijlyepze6w

Agenda

1. Open Source Implementation
2. Problem
3. A Solution (high-level view)
4. Word Embeddings
5. Encoder
6. Decoder
7. Attention
8. Beam Search
9. Results (Dataset: One dialog that passed; One dialog that failed)
10. Improvements
11. Relevant Publications

Open Source Implementation



Implementation of Transaction Bot: https://github.com/vineetk1/fairseq/tree/dialog

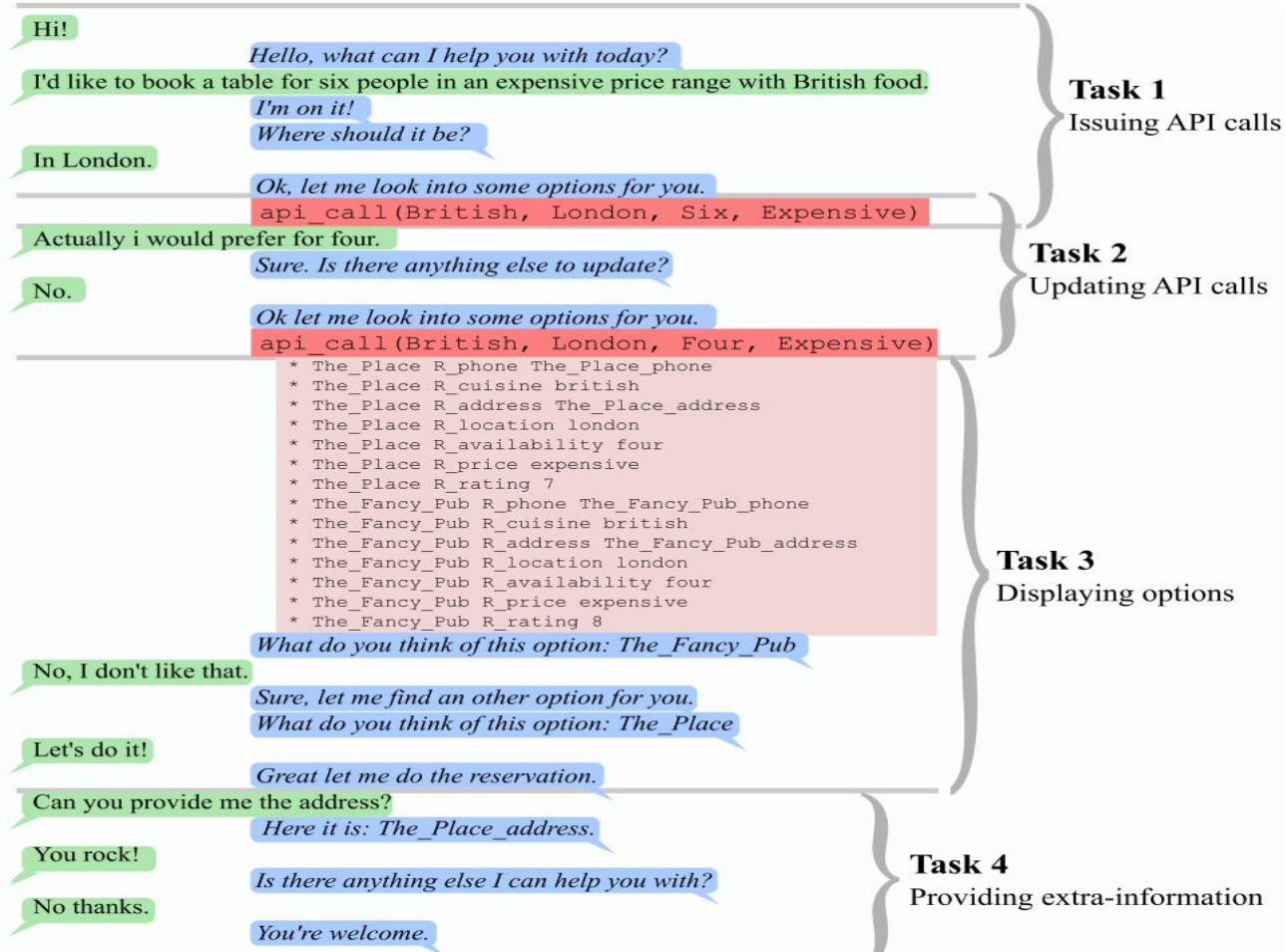
1. Predict the next word in a sequence of words
2. Given a source sequence (e.g. English), predict a target sequence (e.g. French)
3. Given a source sequence plus all previous sequences, predict a target sequence

Problem

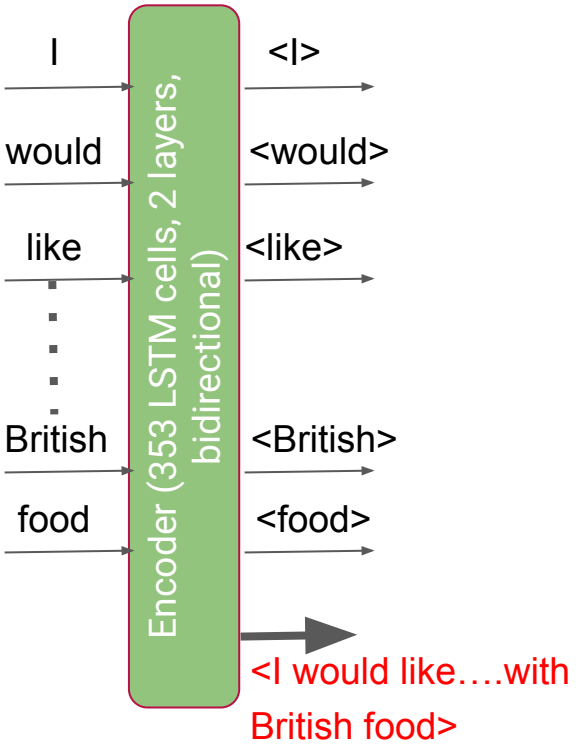
- Build Bot using AI (NOT rule-based, slot-filling, etc.)
  - Makes reservation for table at restaurant
- Modified version of Dialog State Tracking Challenge 2 (DSTC 2)
  - 1000 dialogs for training, 1000 for validation and 1000 for testing
  - Vocabulary: 952 tokens
  - Dialog: Client and Customer Service Agent

Restaurant Reservation System

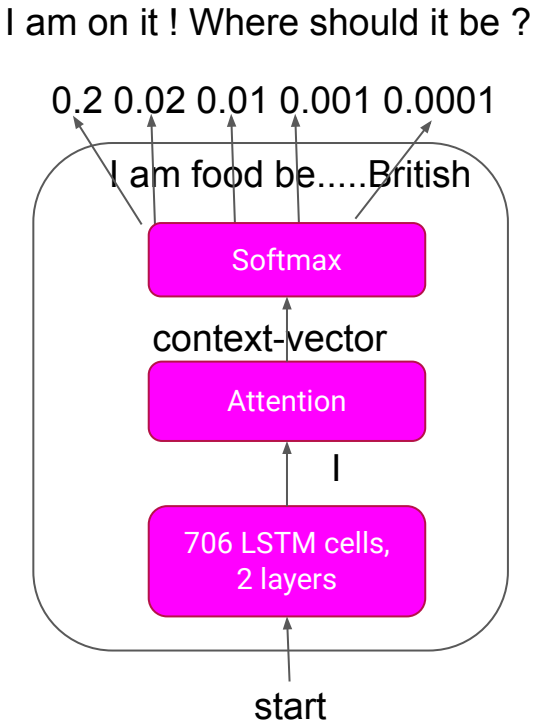
Client | Customer Service Agent



A Solution (high-level view)



Encoder



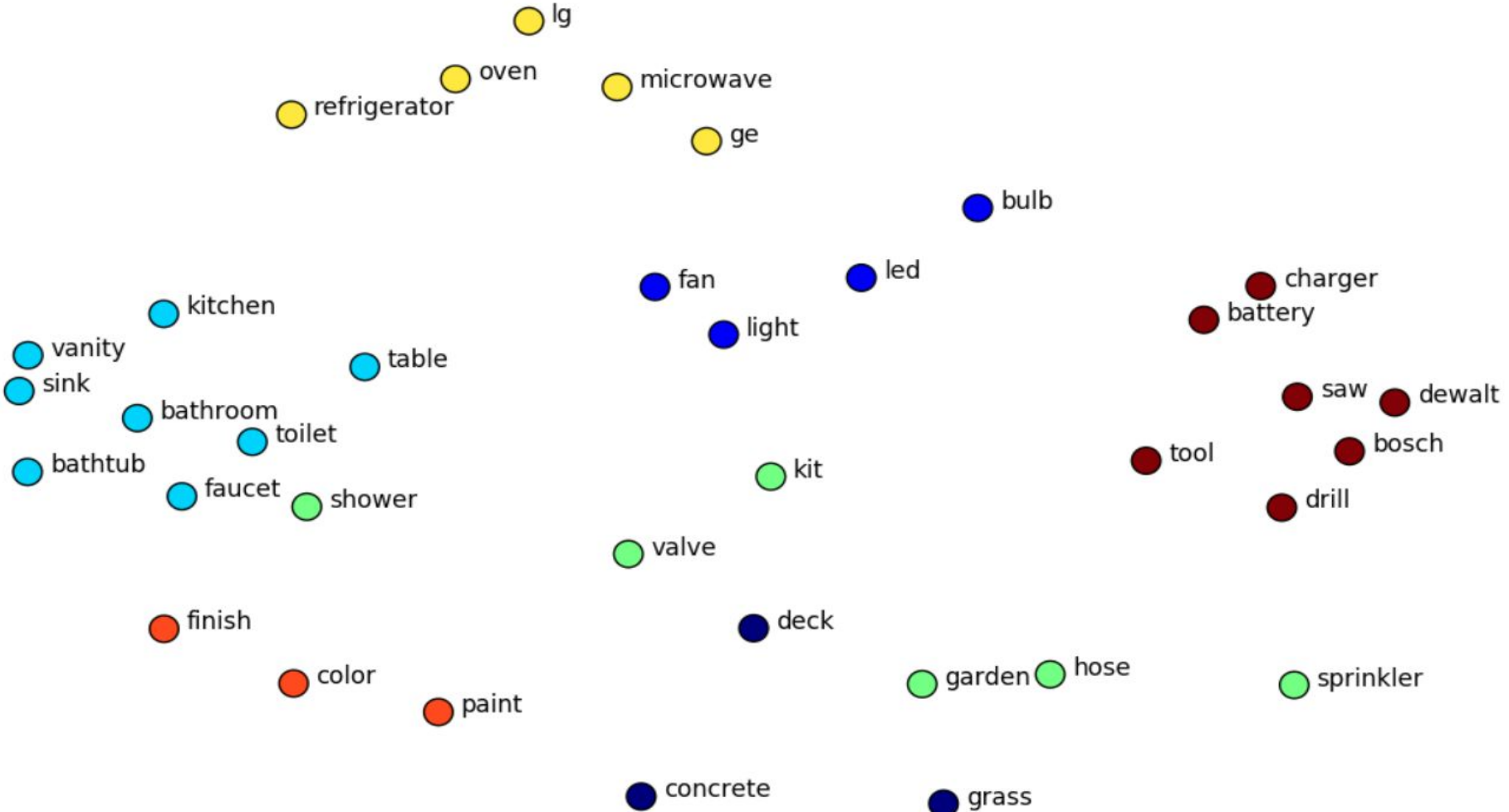
Decoder with Attention

1. Forward propagation
2. Calculate Loss (e.g. using “label smoothed cross entropy” function)
3. Backward propagation for gradients
4. Update parameters using Optimizer (e.g. nag)

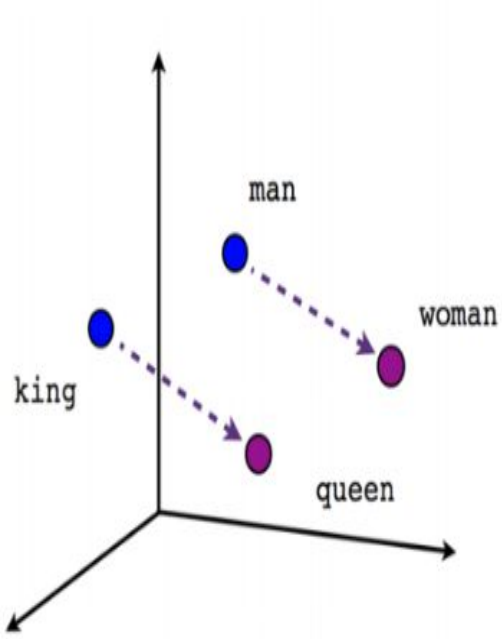
Word Embeddings; word->vector

- Convert words to vectors
- Vectors: 50-d to 1000-d and more
- Download pre-trained vectors; use as look-up table
- Algorithms to generate vectors: word2vec, glove
  - Unsupervised learning
  - Distributional Similarity

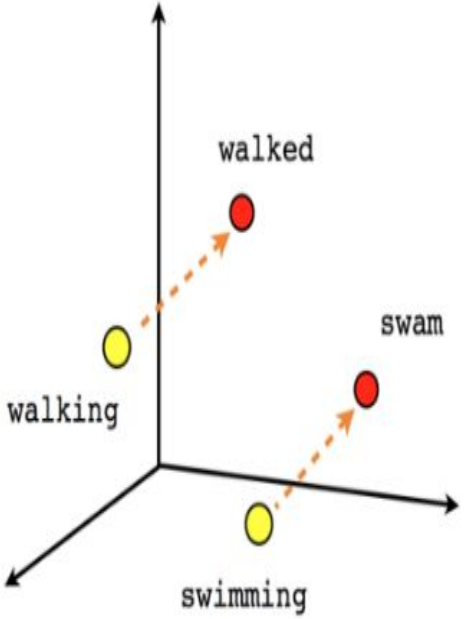
Distributional Similarity -- words that frequently occur together in text are similar



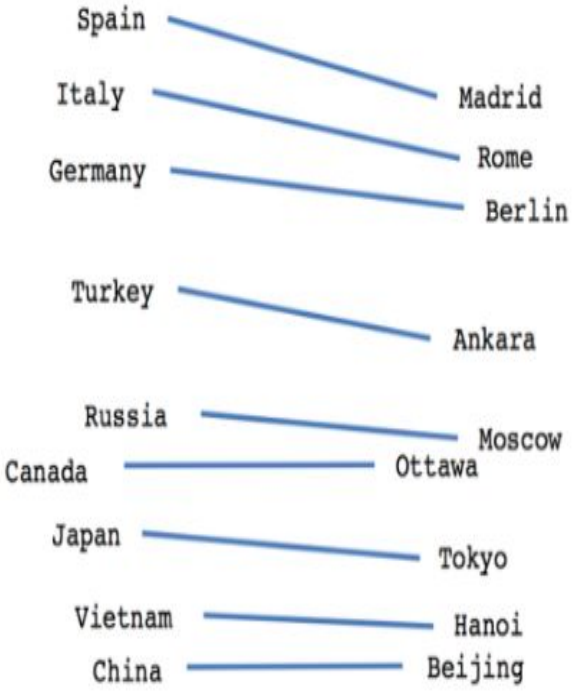
Some features/properties of vectors



Male-Female

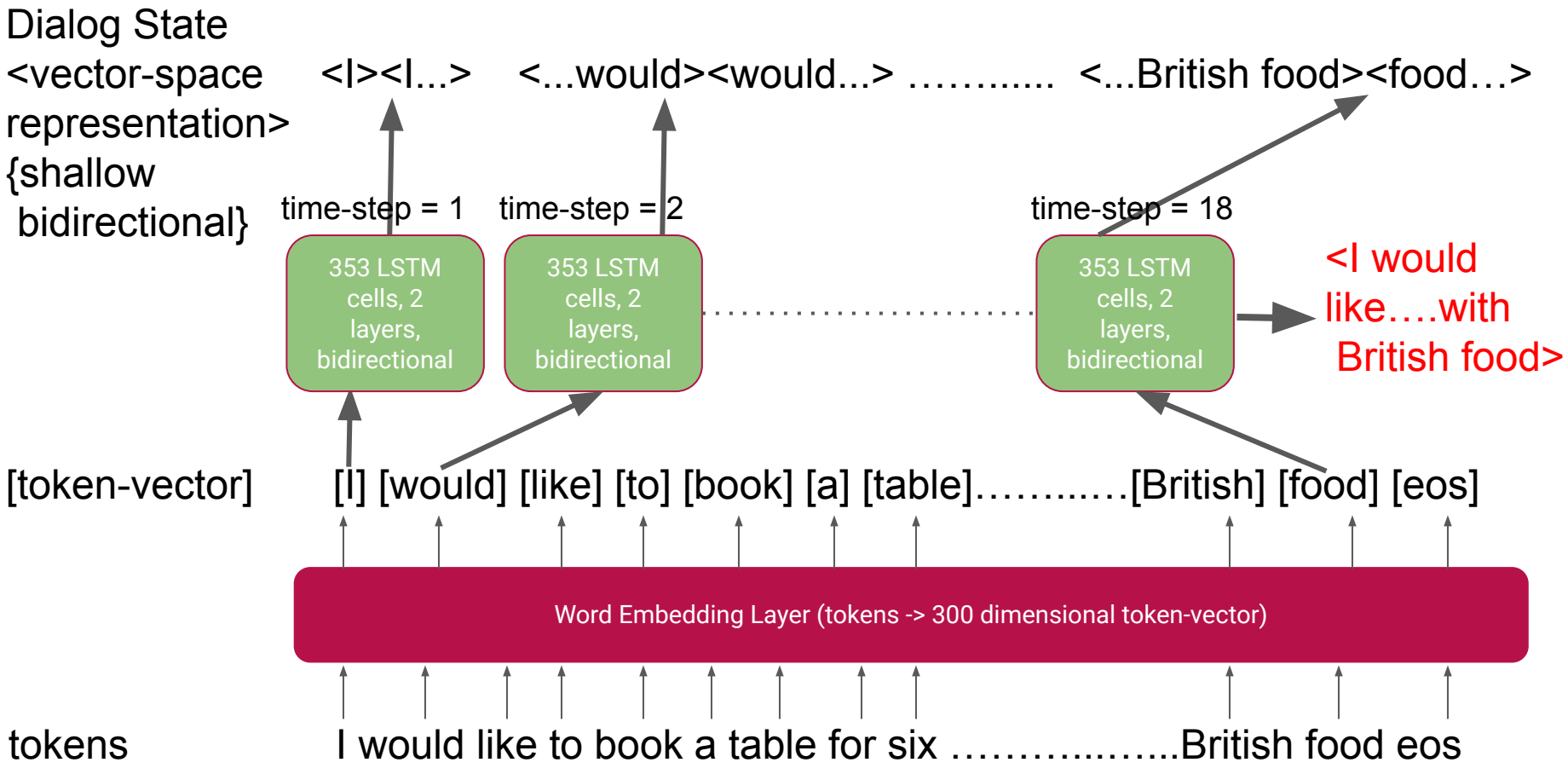


Verb tense

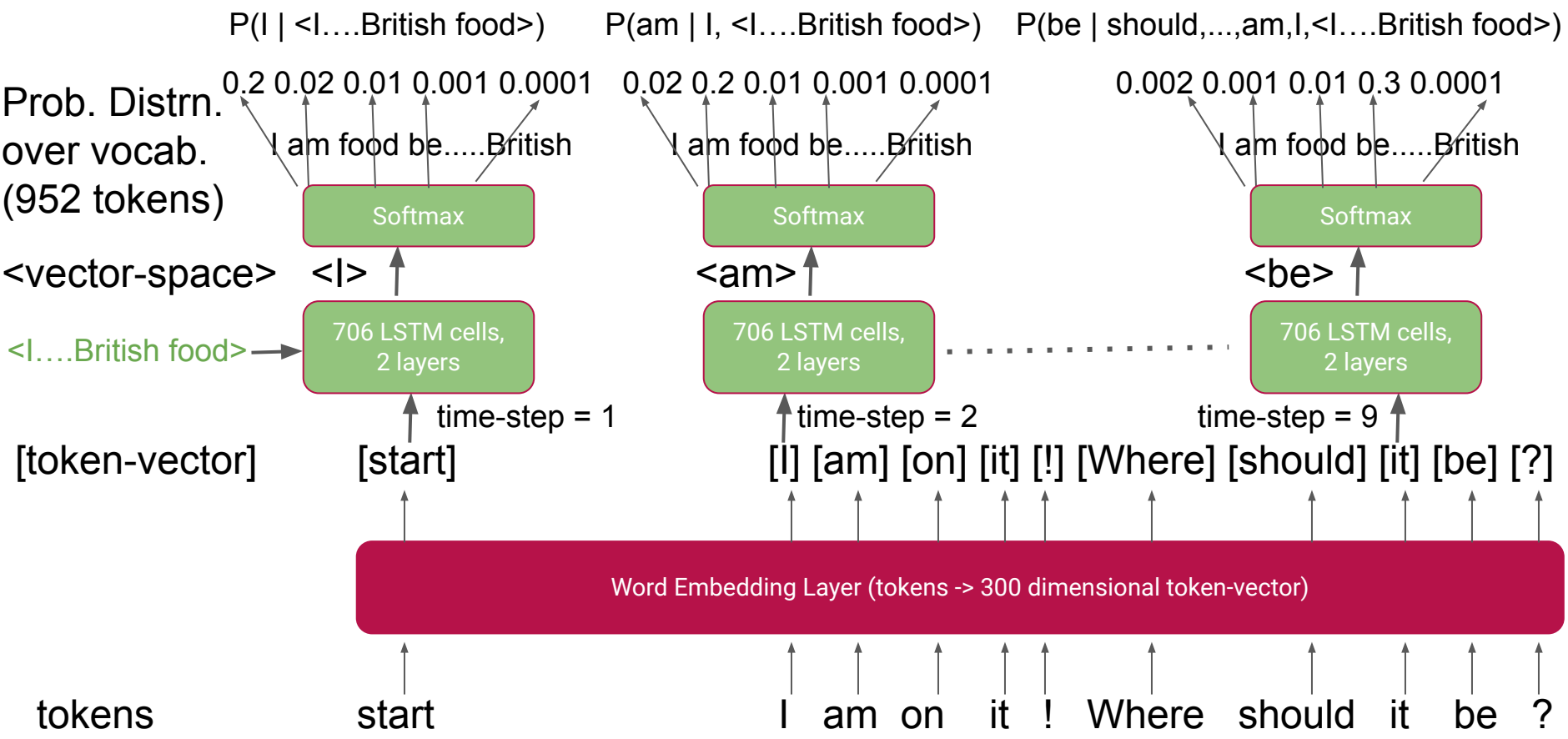


Country-Capital

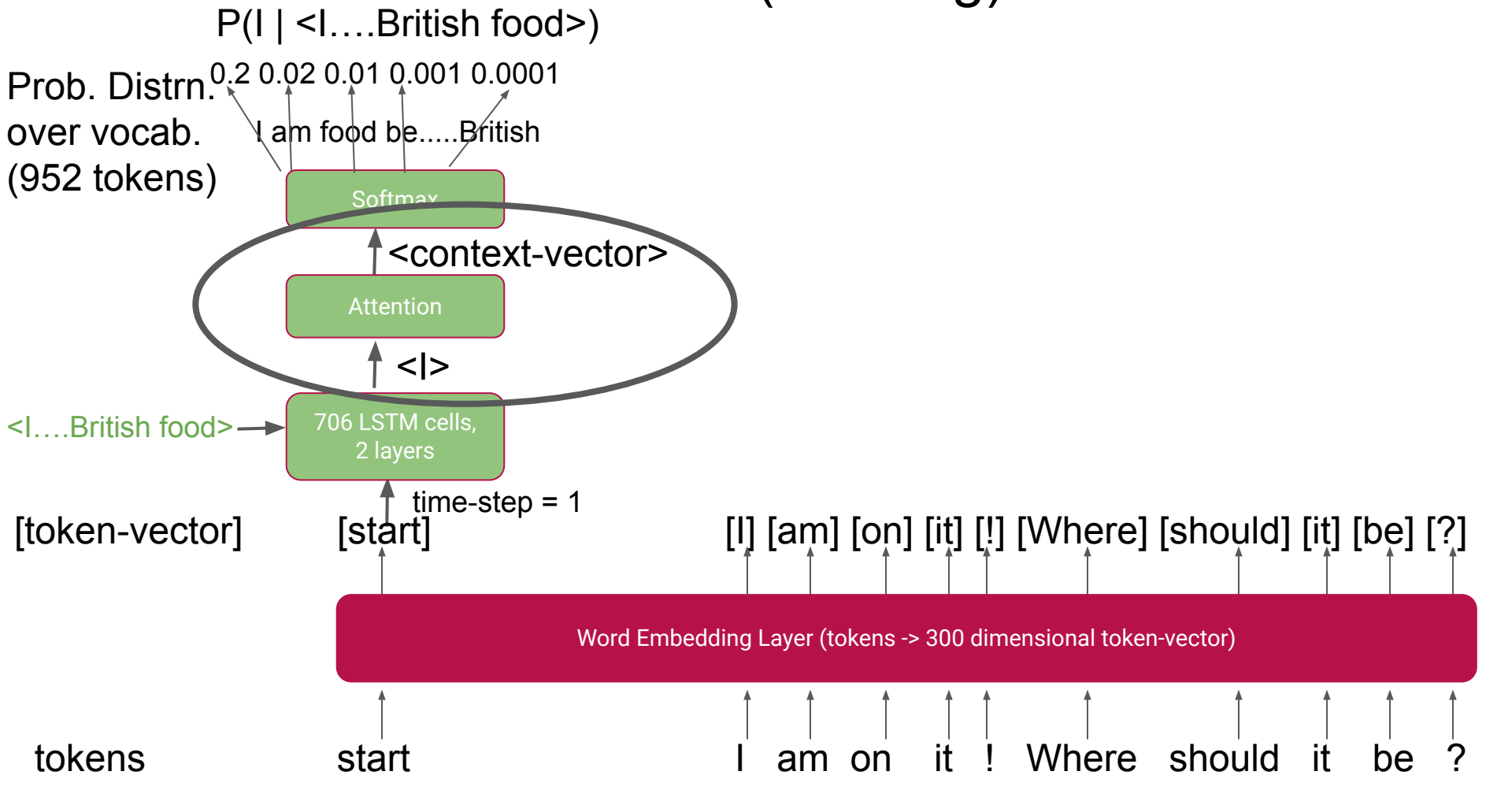
Encoder (Training)



Decoder (Training)



Attention (Training)



Luong's Attention (Training)

Context Vector	tanh(W(<attention vector><I>))			
Attn. Vector	……. 0.5(<I><I...>) + 0.2(<...would><would...>) +...+ 0.04(<..British..>)			
Normalized Attn. Score	0.5	0.2	…….....	0.04
Attn. Score	500	212	…….....	30
Dot Product	…..(<I><I...>).<I>	(<...would><would...>).<I>	…….....	(<..British..>).<I>
Dialog State	….. <I><I...>	<...would><would...>	…….....	<...British food><food…>

Vinyal's Attention (Training)

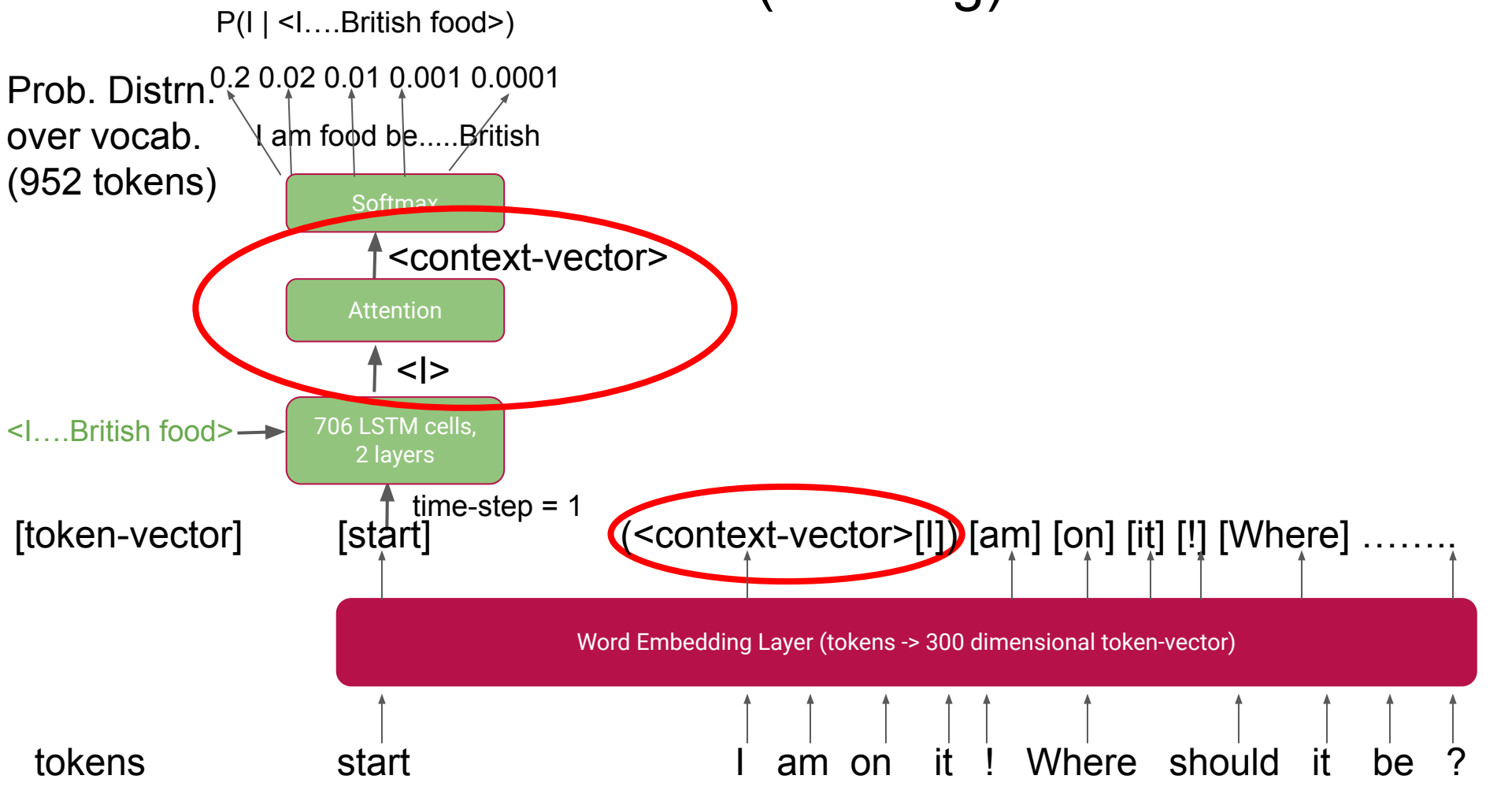
Context Vector	tanh(W(<attention vector><I>))			
Attn. Vector	0.5(<I would>.<I>) + 0.2(<I would like..>.<I>) +...+ 0.04(<..British food>.<I>)			
Normalized Attn. Score	0.5	0.2	…….....	0.04

Vinyal's Attn. Score $v^T(\tanh(W(<I><I...>)<I>))$ where vector v is trainable parameter

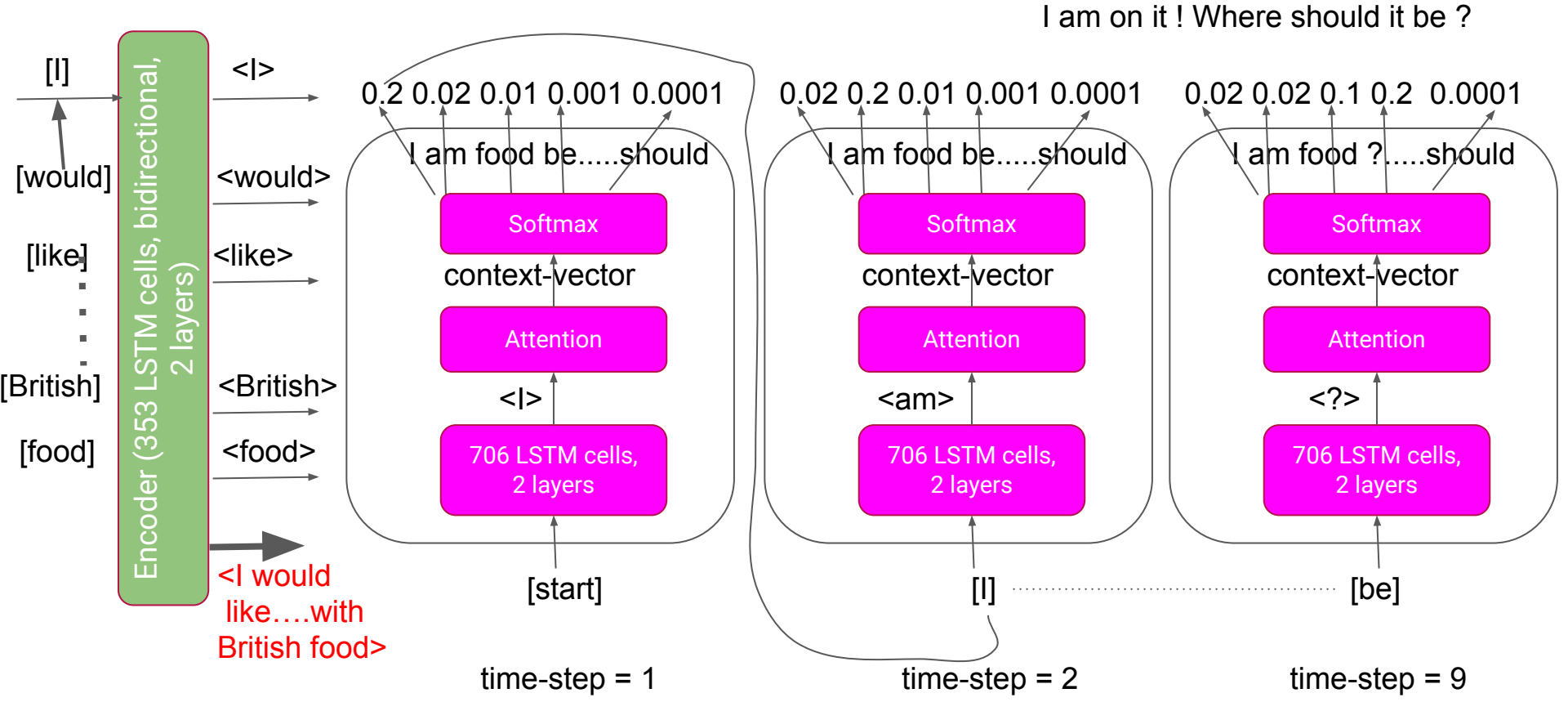
~~Luong's Attn. Score~~	~~500~~	~~212~~	~~……..~~	~~30~~
~~Dot Product~~	~~…..(<I><I...>).<I>~~	~~(<...would><would...>).<I>~~	~~…….....~~	~~(<..British..>).<I>~~

Dialog State ….. <I><I...> <...would><would...> ……..... <...British food><food…>

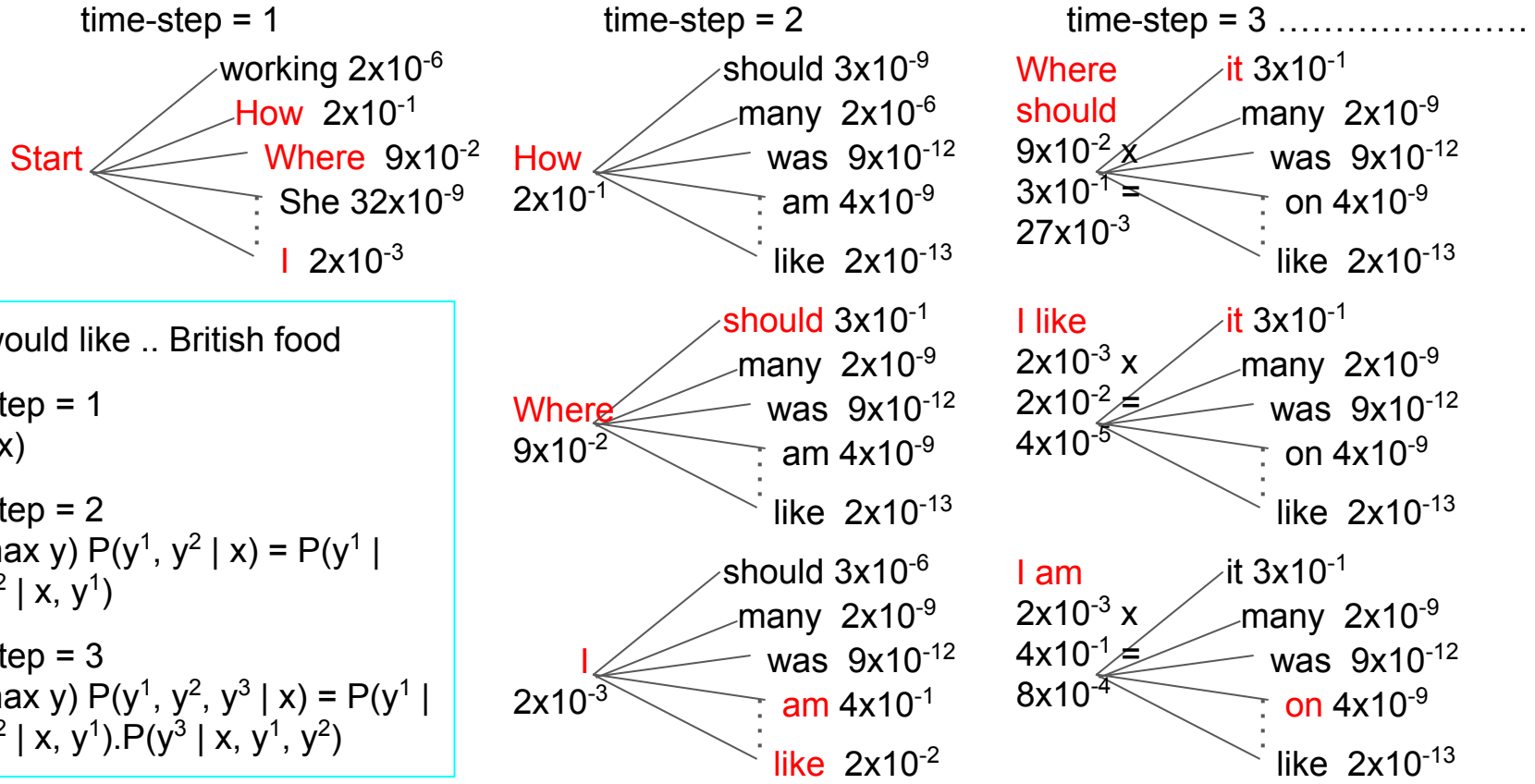
Attention (Training)



Inference


I am on it ! Where should it be ?
[I]
[would]
[like]
[British]
[food]
Encoder (353 LSTM cells, bidirectional, 2 layers)
<I>
<would>
<like>
<British>
<food>
<I would like….with British food>
0.2 0.02 0.01 0.001 0.0001
0.02 0.2 0.01 0.001 0.0001
0.02 0.02 0.1 0.2 0.0001
I am food be.....should
I am food be.....should
I am food ?.....should
Softmax
Softmax
Softmax
context-vector
context-vector
context-vector
Attention
Attention
Attention
<I>
<am>
<?>
706 LSTM cells, 2 layers
706 LSTM cells, 2 layers
706 LSTM cells, 2 layers
[start]
[I]
[be]
time-step = 1
time-step = 2
time-step = 9
Encoder
Decoder with Attention

Beam Search (Inference); beam-width = 3



x = I would like .. British food

time-step = 1
$P(y^1 \mid x)$

time-step = 2
(arg max y) $P(y^1, y^2 \mid x) = P(y^1 \mid x).P(y^2 \mid x, y^1)$

time-step = 3
(arg max y) $P(y^1, y^2, y^3 \mid x) = P(y^1 \mid x).P(y^2 \mid x, y^1).P(y^3 \mid x, y^1, y^2)$

Vocabulary of 952 tokens; if each sequence is 10 words long then 952^{10} combination of sequences:

How many people are in your party?
Where should it be?
I am on it! Where should it be?
I like it! Where should it be?

Dataset

- Real human-machine dialogs vs. Synthetic
  - Bots do very well on Synthetic datasets
  - Real datasets are a challenge
- Dialog State Tracking Challenge 2 (DSTC 2) https://fb-public.app.box.com/s/chnq60iivzv5uckpvj2n2vijlyepze6w
- Noisy because of speech -> text
- Accuracy metric is unnecessarily stringent
  - F1 metric is better but not used

Result

** Translated 1117 dialogs with 11237 turns and 782520 tokens using beam=3 in 195.9s (5.70 dialogs/s, 57.36 turns/s, 3994.54 tokens/s)
** % number of dialogs that passed = (18/1117 x 100) = 1.61%
** (# of turns in dialog: # of occurrences) = (5: 7), (6: 8), (7: 3)
** % number of turns that passed = (4249/11237 x 100) = 37.81%
** % number of dialogs that failed = (1099/1117 x 100) = 98.39%
** (# of consecutive turns that passed, counting from beginning of dialog / # of turns in dialog: # of occurrences) = (2/4: 1), (1/5: 10), (3/5: 1), (1/6: 63), (2/6: 2), (3/6: 3), (1/7: 142), (2/7: 8), (3/7: 3), (4/7: 1), (5/7: 1), (1/8: 160), (2/8: 16), (3/8: 2), (1/9: 149), (2/9: 14), (1/10: 118), (2/10: 11), (3/10: 1), (1/11: 89), (2/11: 13), (3/11: 3), (5/11: 1), (1/12: 77), (2/12: 11), (1/13: 44), (2/13: 5), (3/13: 1), (1/14: 37), (2/14: 4), (3/14: 1), (1/15: 23), (2/15: 5), (3/15: 2), (1/16: 13), (2/16: 3), (3/16: 1), (1/17: 9), (2/17: 1), (1/18: 9), (2/18: 2), (1/19: 11), (1/20: 6), (2/20: 1), (3/20: 1), (1/21: 6), (1/22: 2), (2/22: 1), (1/23: 3), (1/24: 2), (1/25: 1), (1/26: 1), (1/27: 2), (1/28: 1), (1/29: 1)
** Generate test with beam=3: BLEU4 = 23.11, 25.5/22.9/22.1/22.1 (BP=1.000, ratio=2.070, syslen=283321, reflen=136863)

Dialog Passed

Tr1-S: <SILENCE>
Tr1-T: Hello , welcome to the Cambridge restaurant system . You can ask for restaurants by area , price range or food type . How may I help you ?
Tr1-H0-P: Hello , welcome to the Cambridge restaurant system . You can ask for restaurants by area , price range or food type . How may I help you ?
Tr2-S: cheap restaurant on the east part of town {Price, Location}
Tr2-T: api_call R_cuisine east cheap
Tr2-H0-P: api_call R_cuisine east cheap
Tr3-S: <SILENCE>
Tr3-T: the_missing_sock is a nice place in the east of town and the prices are cheap
Tr3-H0-P: the_missing_sock is a nice place in the east of town and the prices are cheap
Tr4-S: what is the address
Tr4-T: Sure , the_missing_sock is on the_missing_sock_address
Tr4-H0-P: Sure , the_missing_sock is on the_missing_sock_address
Tr5-S: phone number
Tr5-T: The phone number of the_missing_sock is the_missing_sock_phone
Tr5-H0-P: The phone number of the_missing_sock is the_missing_sock_phone
Tr6-S: what type of food {cuisine}
Tr6-T: the_missing_sock serves international food
Tr6-H0-P: the_missing_sock serves international food
Tr7-S: thank you good bye
Tr7-T: you are welcome
Tr7-H0-P: you are welcome

Entity Types (required):
Cuisine, Location, Price
Entity Types (other):
Post-code, Phone, Address

Dialog Failed

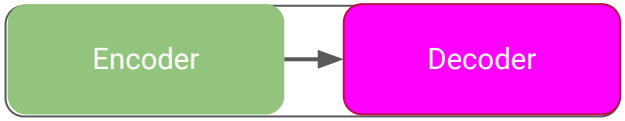
Tr1-S: <SILENCE>
Tr1-T: Hello , welcome to the Cambridge restaurant system . You can ask for restaurants by area , price range or food type . How may I help you ?
Tr1-H0-P: Hello , welcome to the Cambridge restaurant system . You can ask for restaurants by area , price range or food type . How may I help you ?
Tr2-S: expensive australian restaurant {Price, Cuisine}
Tr2-T: You are looking for a australian restaurant right?
Tr2-H0-F: What part of town do you have in mind? {Location?}
Tr3-S: yes
Tr3-T: I'm sorry but there is no restaurant serving australian food
Tr3-H0-F: What kind of food would you like?
Tr4-S: expensive french restaurant {Price, Cuisine}
Tr4-T: You are looking for a australian restaurant right?
Tr4-H0-F: api_call french R_location expensive
Tr5-S: french
Tr5-T: There are restaurants serving french in the expensive price range . What area would you like?
Tr5-H0-F: api_call french R_location expensive
Tr6-S: any
Tr6-T: api_call french R_location expensive
Tr6-H0-F: Would you like something in the cheap , moderate , or expensive price range?

Entity Types (required):
Cuisine, Location, Price
Entity Types (other):
Post-code, Phone, Address

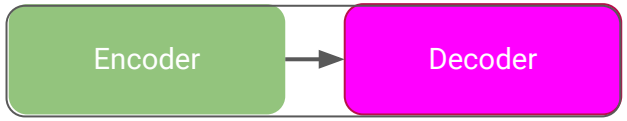
Improvements

- Entity-type (e.g. Cuisine, Location, Place) in input
- Attention-based copy mechanism
  - Pick output token from Dialog State or Decoder output
- Pre-training & Fine-tuning (e.g. BART)
- Modifications to architecture

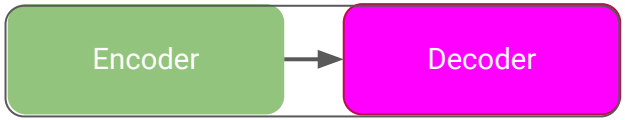
Pre-train & Fine-tune



Initialize Parameters with random weights and bias



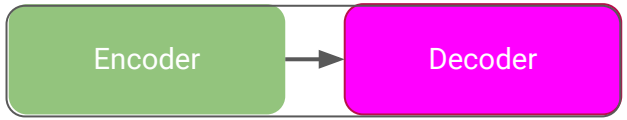
Train with Dialog dataset



Pre-train with relevant (e.g. Natural Language Generation) datasets

Pre-trained model: BART

Transfer the learning



Fine-tune with Dialog dataset

Publications

1. Bordes, A., Boureau, Y. L., & Weston, J. (2016). Learning end-to-end goal-oriented dialog. *arXiv preprint arXiv:1605.07683.* https://arxiv.org/pdf/1605.07683.pdf
2. Eric, M., & Manning, C. D. (2017). A copy-augmented sequence-to-sequence architecture gives good performance on task-oriented dialogue. arXiv preprint arXiv:1701.04024. https://arxiv.org/pdf/1701.04024.pdf
3. Vinyals, O., Kaiser, Ł., Koo, T., Petrov, S., Sutskever, I., & Hinton, G. (2015). Grammar as a foreign language. In Advances in neural information processing systems (pp. 2773-2781). https://papers.nips.cc/paper/5635-grammar-as-a-foreign-language.pdf
4. Luong, M. T., Pham, H., & Manning, C. D. (2015). Effective approaches to attention-based neural machine translation. *arXiv preprint arXiv:1508.04025*. https://arxiv.org/pdf/1508.04025.pdf
5. Bahdanau, D., & Cho, K. (2014). Neural machine translation by jointly learning to align and translate. arXiv preprint arXiv: 1409.0473. https://arxiv.org/pdf/1409.0473.pdf
6. Jia, R., & Liang, P. (2016). Data recombination for neural semantic parsing. *arXiv preprint arXiv:1606.03622*. https://www.aclweb.org/anthology/P16-1002.pdf
7. Lewis, M., Liu, Y., Goyal, N., Ghazvininejad, M., Mohamed, A., Levy, O., ... & Zettlemoyer, L. (2019). Bart: Denoising sequence-to-sequence pre-training for natural language generation, translation, and comprehension. *arXiv preprint arXiv:1910.13461*. https://arxiv.org/pdf/1910.13461.pdf