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Deep Learning for Dialogue Systems

Outline

- Introduction & Background
  - Neural Networks
  - Reinforcement Learning
- Modular Dialogue System
  - Spoken/Natural Language Understanding (SLU/NLU)
  - Dialogue Management (DM)
    - Dialogue State Tracking (DST)
    - Dialogue Policy Optimization ← Break
  - Natural Language Generation (NLG)
- Evaluation
- Recent Trends on Learning Dialogues
  - End-to-End Neural Dialogue Systems
  - Dialogue Breadth
  - Dialogue Depth

Introduction & Background

Neural Networks

Reinforcement Learning

Brief History of Dialogue Systems

Keyword Spotting
(e.g., AT&T)
System: "Please say collect, calling card, person, third number, or operator"

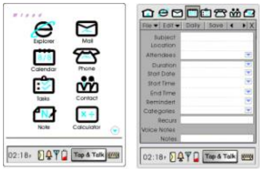
Early 1990s

Task-specific argument extraction
(e.g., Nuance, SpeechWorks)
User: "I want to fly from Boston to New York next week."

Intent Determination
(Nuance's Emily™, AT&T HMIHY)
User: "Uh…we want to move…we want to change our phone line from this house to another house"

Early 2000s

Multi-modal systems
e.g., Microsoft MiPad, Pocket PC



TV Voice Search
e.g., Bing on Xbox

IBM WATSON

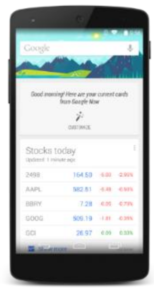
DARPA
CALO Project

2017

Virtual Personal Assistants

Language Empowering Intelligent Assistant

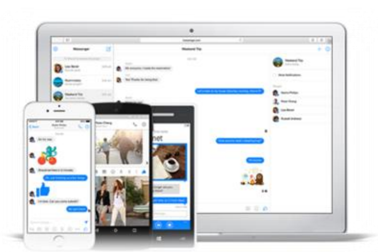
Apple Siri (2011)



Google Now (2012)
Google Assistant (2016)

Microsoft Cortana (2014)

Amazon Alexa/Echo (2014)



Facebook M & Bot (2015)

Google Home (2016)

Apple HomePod (2017)

Challenges

- Variability in natural language
- Robustness
- Recall/Precision Trade-off
- Meaning Representation
- Common Sense, World Knowledge
- Ability to learn
- Transparency

Two Branches of Dialogue Systems

Task-Oriented

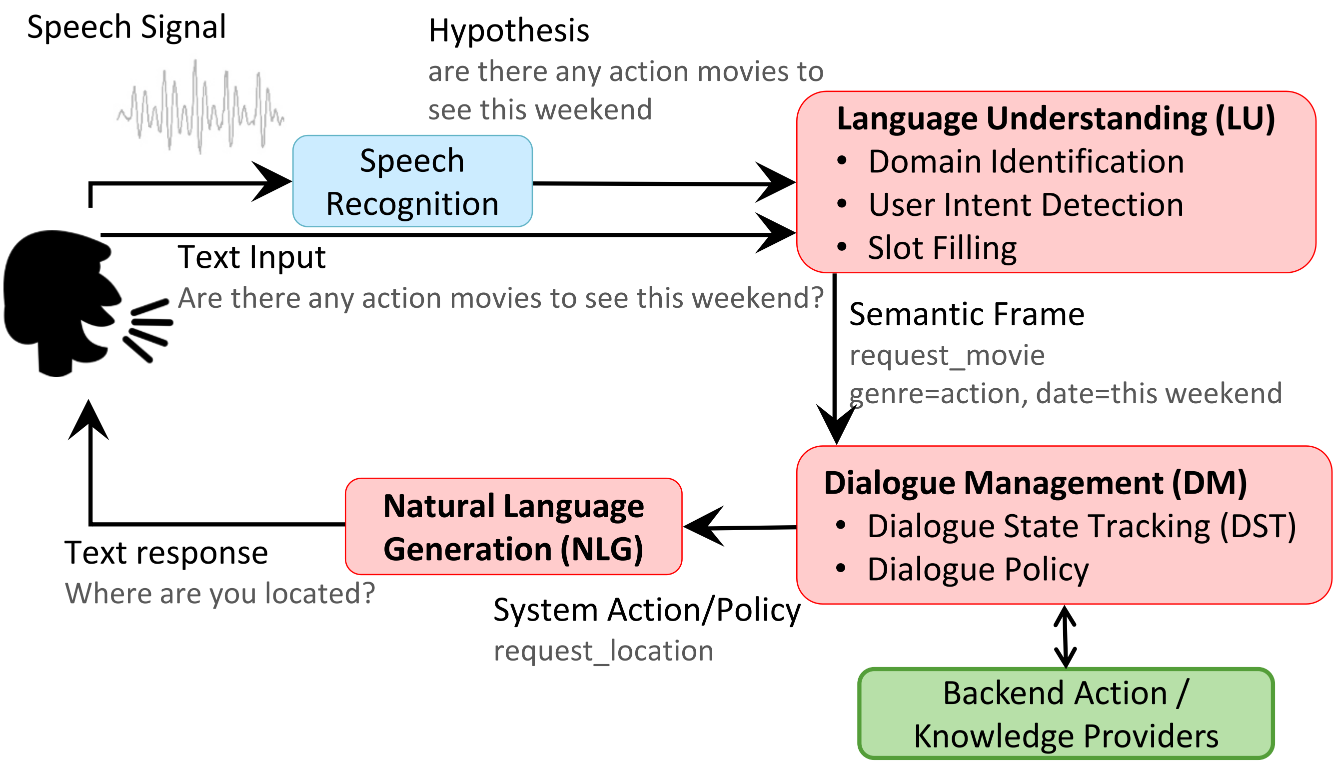
- Personal assistant, helps users achieve a certain task
- Combination of <u>rules</u> and <u>statistical</u> components
  - POMDP for spoken dialog systems (Williams and Young, 2007)
  - End-to-end trainable task-oriented dialogue system (Wen et al., 2016; Li et al., 2017)
  - End-to-end reinforcement learning dialogue system (Zhao and Eskenazi, 2016)

Chit-Chat

- No specific goal, focus on natural responses
- Using variants of seq2seq model
  - A neural conversation model (Vinyals and Le, 2015)
  - Reinforcement learning for dialogue generation (Li et al., 2016)
  - Conversational contextual cues for response ranking (Al-Rfou et al., 2016)

Task-Oriented Dialogue System (Young, 2000)

http://rsta.royalsocietypublishing.org/content/358/1769/1389.short



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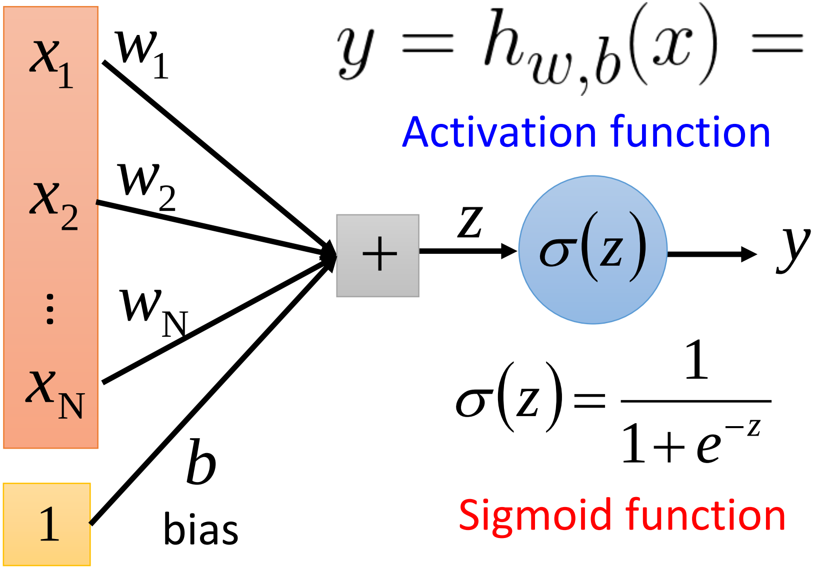
A Single Neuron

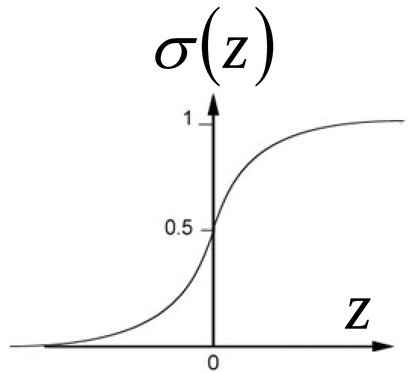
$$y = h_{w,b}(x) = \sigma(w^T x + b)$$

Activation function



$$\sigma(z) = \frac{1}{1+e^{-z}}$$

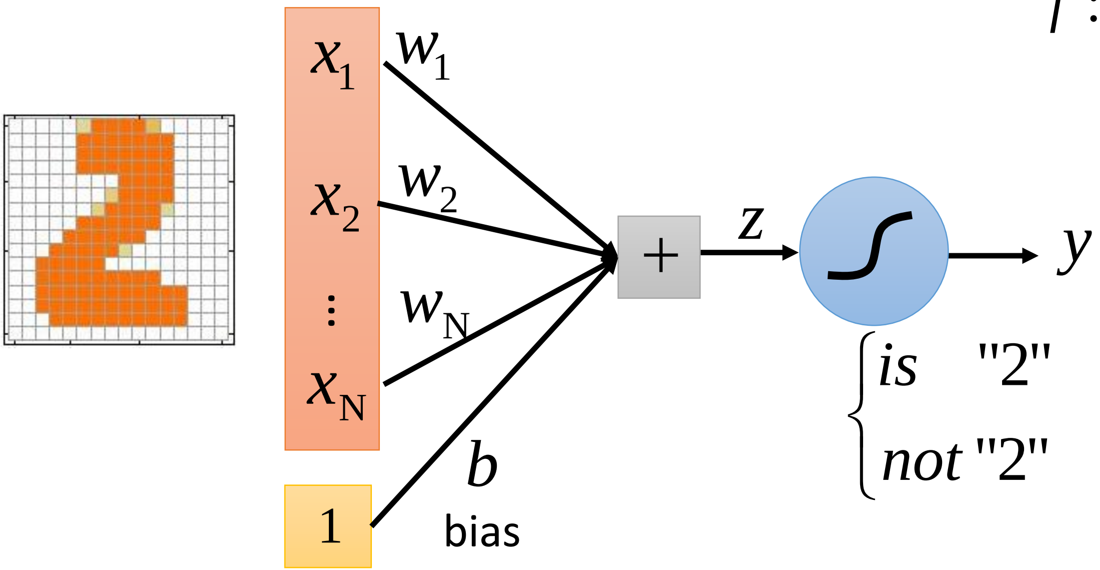
Sigmoid function



w, b are the parameters of this neuron

A Single Neuron

$$f: R^N \rightarrow R^M$$



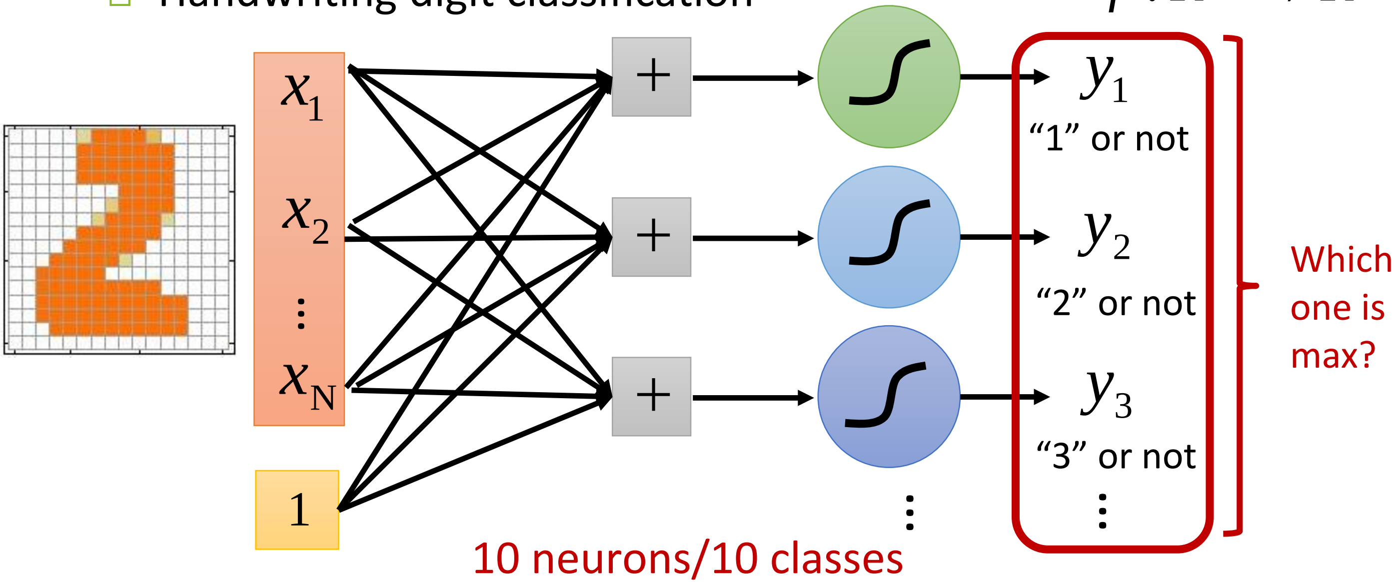
$$\begin{cases} is \quad "2" & y \geq 0.5 \\ not\ "2" & y < 0.5 \end{cases}$$

A single neuron can only handle binary classification

A Layer of Neurons

- Handwriting digit classification

$f : R^N \to R^M$

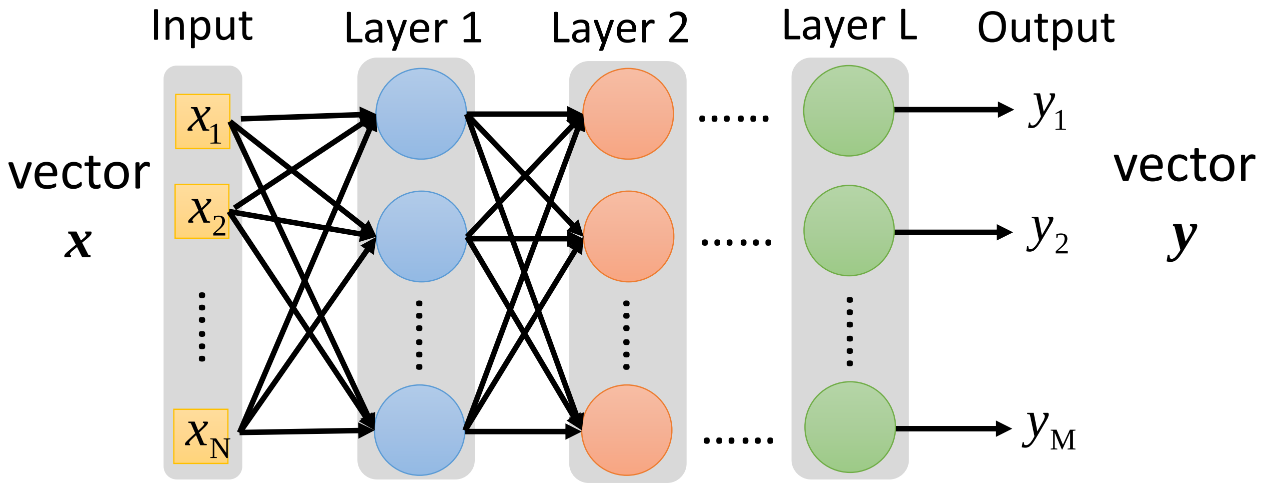


A layer of neurons can handle multiple possible output, and the result depends on the max one

Deep Neural Networks (DNN)

- Fully connected feedforward network

$$f : R^N \rightarrow R^M$$



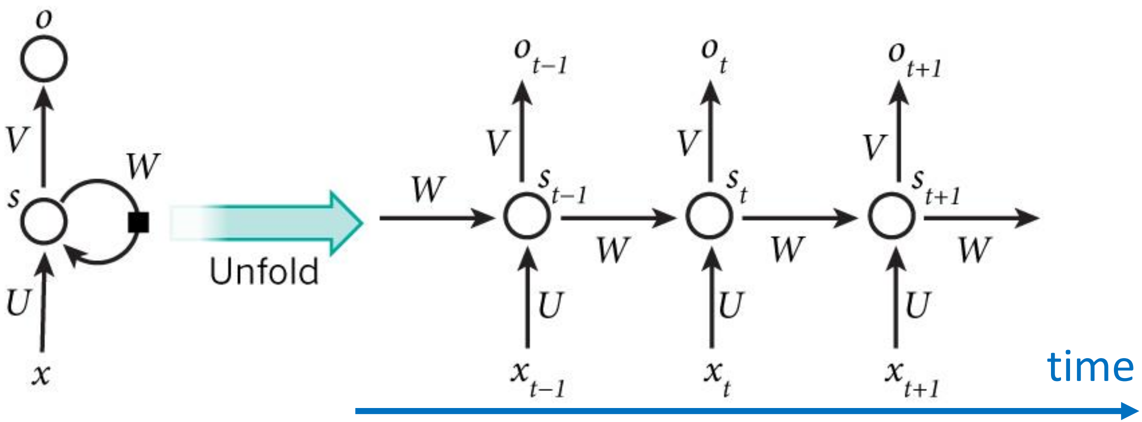
Deep NN: multiple hidden layers

Recurrent Neural Network (RNN)

$$s_t = \sigma(W s_{t-1} + U x_t)$$

$\sigma(\cdot)$: tanh, ReLU

$$o_t = \mathrm{softmax}(V s_t)$$



RNN can learn accumulated sequential information (time-series)

http://www.wildml.com/2015/09/recurrent-neural-networks-tutorial-part-1-introduction-to-rnns/

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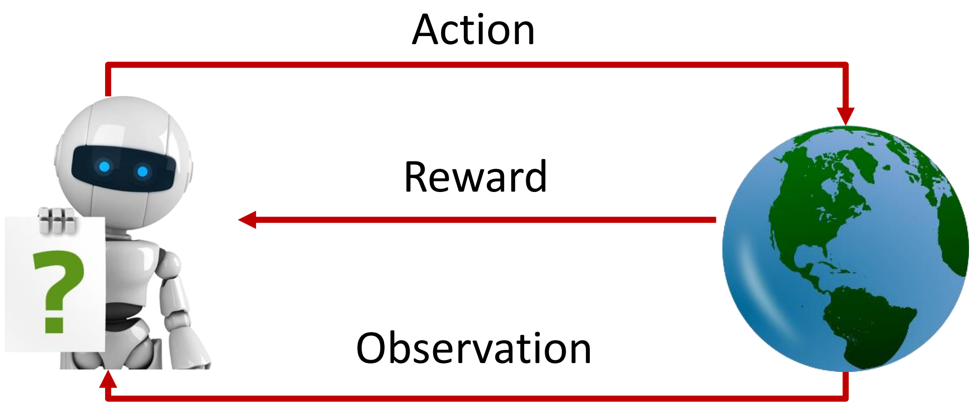
Reinforcement Learning

- RL is a general purpose framework for **decision making**
  - RL is for an *agent* with the capacity to *act*
  - Each *action* influences the agent's future *state*
  - Success is measured by a scalar *reward* signal
  - Goal: *select actions to maximize future reward*



Supervised v.s. Reinforcement

- Supervised

“Hello” Say “Hi”

Learning from teacher

“Bye bye” Say “Good bye”

- Reinforcement

……. …….

……

Hello ☺ ……

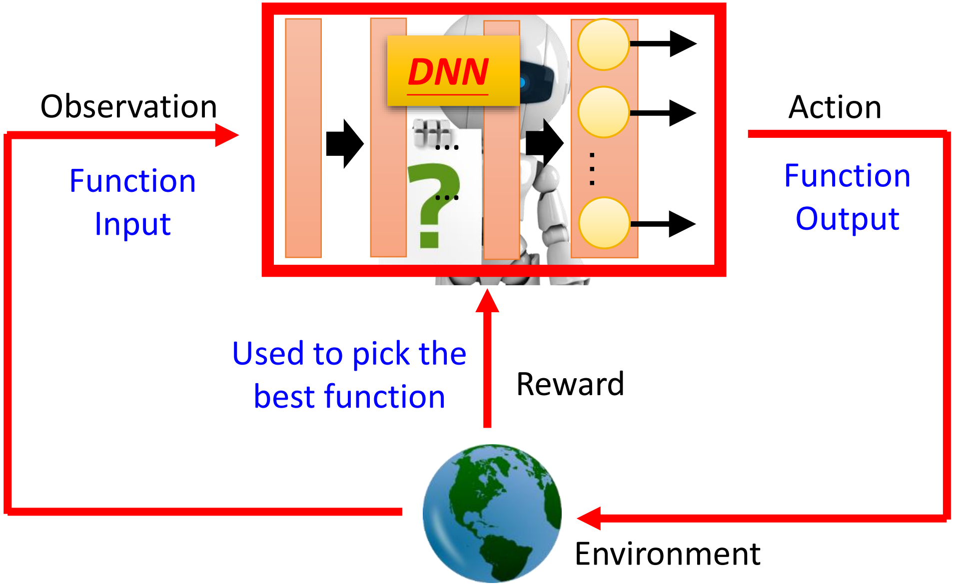
Bad

Learning from critics

Agent Agent

Material: http://deepdialogue.miulab.tw

Deep Reinforcement Learning



Reinforcing Learning

- Start from state s_0
- Choose action a_0
- Transit to $s_1 \sim P(s_0, a_0)$
- Continue…

$$s_0 \xrightarrow{a_0} s_1 \xrightarrow{a_1} s_2 \xrightarrow{a_2} s_3 \xrightarrow{a_3} \ldots$$

- Total reward: $R(s_0) + \gamma R(s_1) + \gamma^2 R(s_2) + \cdots$

Goal: select actions that maximize the expected total reward

$$\mathbb{E}[R(s_0) + \gamma R(s_1) + \gamma^2 R(s_2) + \cdots]$$

Reinforcement Learning Approach

- Policy-based RL
  - Search directly for optimal policy π^*

π^* is the policy achieving maximum future reward

- Value-based RL
  - Estimate the optimal value function $Q^*(s, a)$

$Q^*(s, a)$ is maximum value achievable under any policy

- Model-based RL
  - Build a model of the environment
  - Plan (e.g. by lookahead) using model

Part II

Modular Dialogue System

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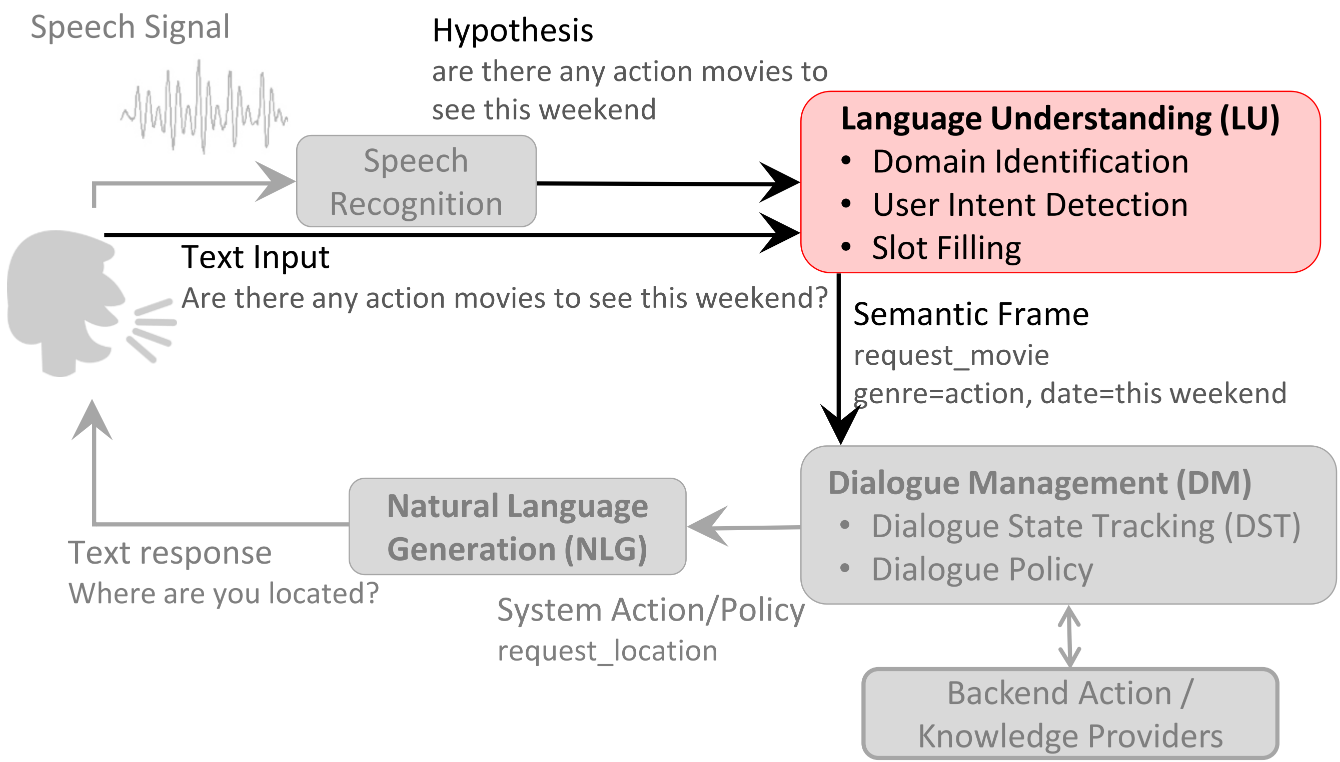
Task-Oriented Dialogue System (Young, 2000)

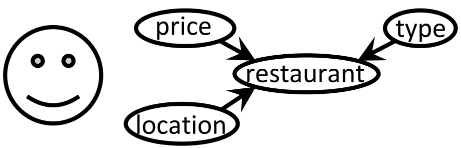


Semantic Frame Representation

- Requires a domain ontology: early connection to backend
- Contains **core content (intent, a set of slots with fillers)**

Restaurant Domain

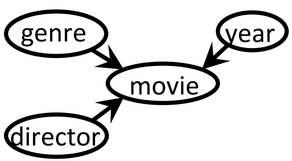
find me a cheap taiwanese restaurant in oakland



find_restaurant (price="cheap", type="taiwanese", location="oakland")

Movie Domain

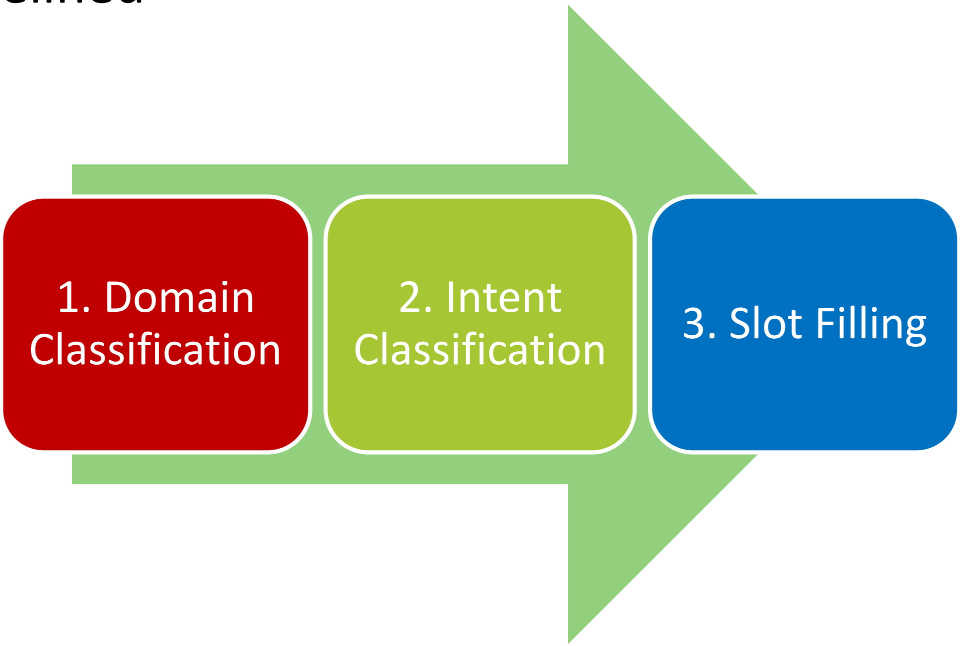
show me action movies directed by james cameron



find_movie (genre="action", director="james cameron")

Language Understanding (LU)

- Pipelined



LU – Domain/Intent Classification

As an utterance classification task

- Given a collection of utterances u_i with labels c_i, $D = \{(u_1,c_1),\ldots,(u_n,c_n)\}$ where $c_i \in C$, train a model to estimate labels for new utterances u_k.

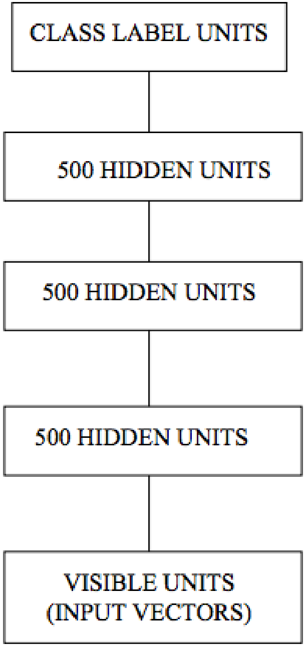
find me a cheap taiwanese restaurant in oakland

Domain	Intent
Movies	find_movie, buy_tickets
Restaurants	find_restaurant, find_price, book_table
Music	find_lyrics, find_singer
Sports	…
…	

Deep Neural Networks for Domain/Intent Classification – I (Sarikaya et al, 2011)

http://ieeexplore.ieee.org/abstract/document/5947649/

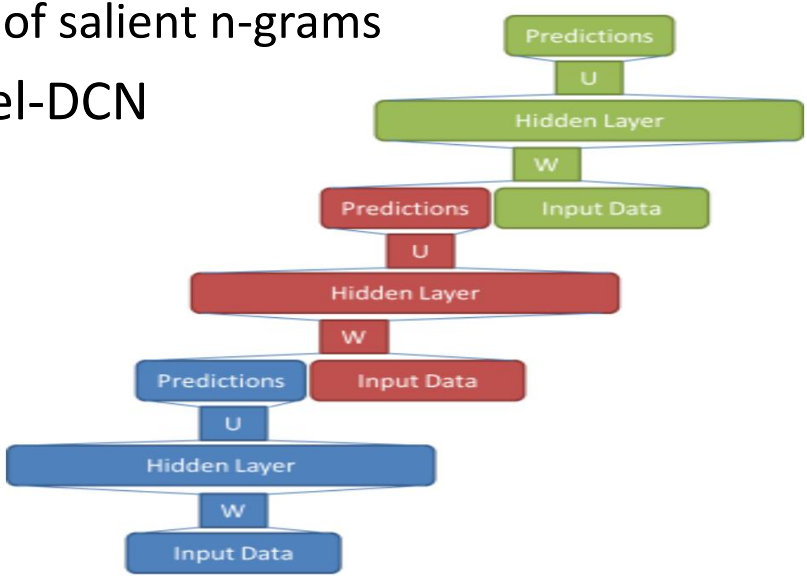
- Deep belief nets (DBN)
  - Unsupervised training of weights
  - Fine-tuning by back-propagation
  - Compared to MaxEnt, SVM, and boosting



Deep Neural Networks for Domain/Intent Classification – II (Tur et al., 2012; Deng et al., 2012)

http://ieeexplore.ieee.org/abstract/document/6289054/; http://ieeexplore.ieee.org/abstract/document/6424224/

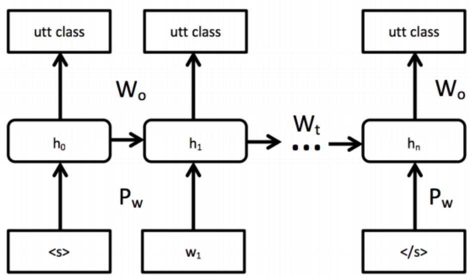
- Deep convex networks (DCN)
  - Simple classifiers are stacked to learn complex functions
  - Feature selection of salient n-grams
- Extension to kernel-DCN

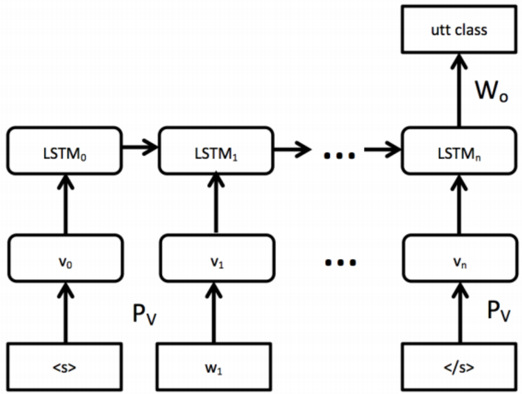


Deep Neural Networks for Domain/Intent Classification – III (Ravuri & Stolcke, 2015)

https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/RNNLM_addressee.pdf

- RNN and LSTMs for utterance classification

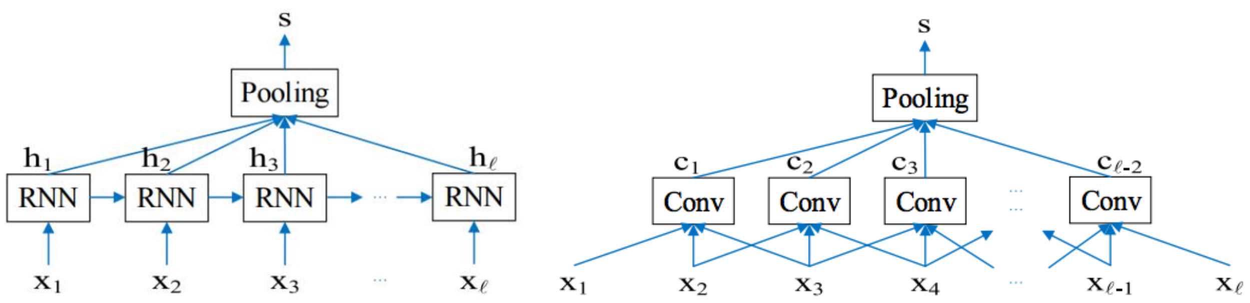




Intent decision after reading all words performs better

Deep Neural Networks for Dialogue Act Classification – IV (Lee & Dernoncourt, 2016)

- RNN and CNNs for dialogue act classification



LU – Slot Filling

As a sequence tagging task

- Given a collection tagged word sequences, $S=\{((w_{1,1},w_{1,2},\ldots, w_{1,n1}), (t_{1,1},t_{1,2},\ldots,t_{1,n1})), ((w_{2,1},w_{2,2},\ldots,w_{2,n2}), (t_{2,1},t_{2,2},\ldots,t_{2,n2})) \ldots\}$ where $t_i \in M$, the goal is to estimate tags for a new word sequence.

flights from Boston to New York today

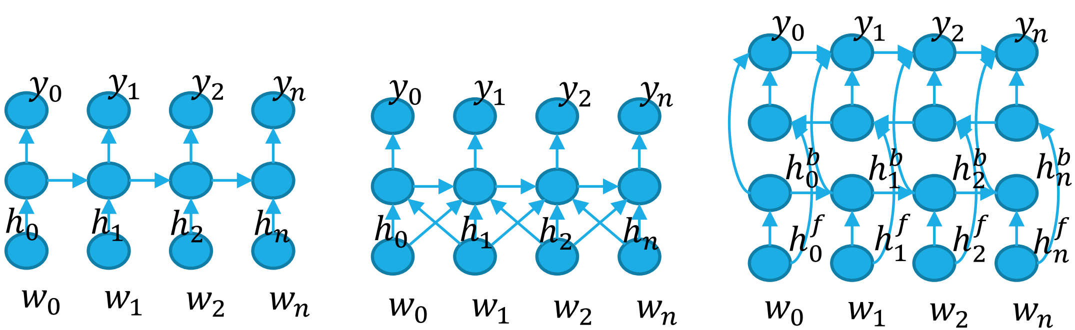
	flights	from	Boston	to	New	York	today
Entity Tag	O	O	B-city	O	B-city	I-city	O
Slot Tag	O	O	B-dept	O	B-arrival	I-arrival	B-date

Recurrent Neural Nets for Slot Tagging – I

(Yao et al, 2013; Mesnil et al, 2015)

http://131.107.65.14/en-us/um/people/gzweig/Pubs/Interspeech2013RNNLU.pdf; http://dl.acm.org/citation.cfm?id=2876380

- Variations:
  a. RNNs with LSTM cells
  b. Input, sliding window of n-grams
  c. Bi-directional LSTMs



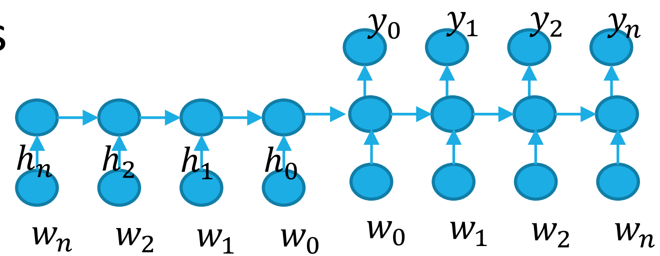
(a) LSTM (b) LSTM-LA (c) bLSTM

Recurrent Neural Nets for Slot Tagging – II

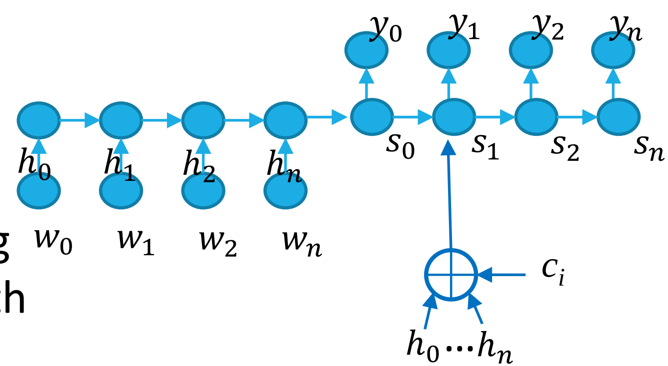
(Kurata et al., 2016; Simonnet et al., 2015)

http://www.aclweb.org/anthology/D16-1223

- Encoder-decoder networks
  - Leverages sentence level information



- Attention-based encoder-decoder
  - Use of attention (as in MT) in the encoder-decoder network
  - Attention is estimated using a feed-forward network with input: h_t and s_t at time t

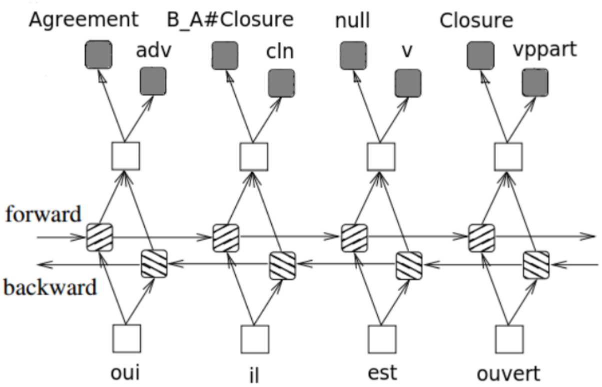


Recurrent Neural Nets for Slot Tagging – III

(Jaech et al., 2016; Tafforeau et al., 2016)

https://arxiv.org/abs/1604.00117; http://www.sensei-conversation.eu/wp-content/uploads/2016/11/favre_is2016b.pdf

- Multi-task learning
  - Goal: exploit data from domains/tasks with a lot of data to improve ones with less data
  - Lower layers are shared across domains/tasks
  - Output layer is specific to task

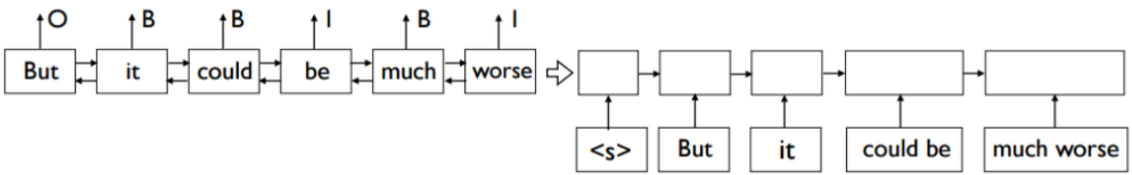


Joint Segmentation and Slot Tagging

(Zhai et al., 2017)

https://arxiv.org/pdf/1701.04027.pdf

- Encoder that segments
- Decoder that tags the segments



Joint Semantic Frame Parsing

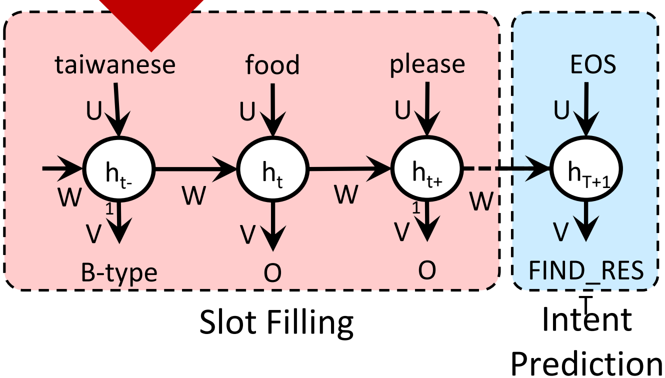
https://www.microsoft.com/en-us/research/wp-content/uploads/2016/06/IS16_MultiJoint.pdf; https://arxiv.org/abs/1609.01454

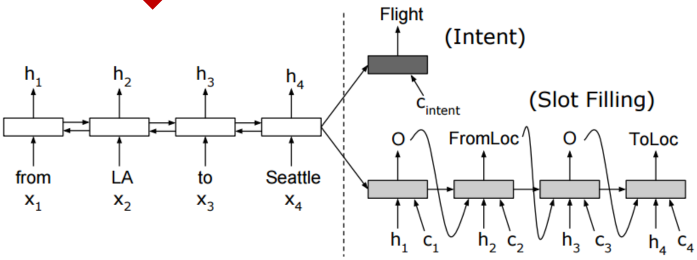
Sequence-based (Hakkani-Tur et al., 2016)

- Slot filling and intent prediction in the same output sequence

Parallel (Liu and Lane, 2016)

- Intent prediction and slot filling are performed in two branches





Material: http://deepdialogue.miulab.tw

Contextual LU

Domain Identification → Intent Prediction → Slot Filling

D communication *I* send_email

Single Turn

U	just	sent	email	to	bob	about	fishing	this	weekend
S	O	O	O	O	B-contact_name	O	B-subject	I-subject	I-subject

→ send_email(contact_name="bob", subject="fishing this weekend")

Multi-Turn

U_1 send email to bob

S_1 B-contact_name

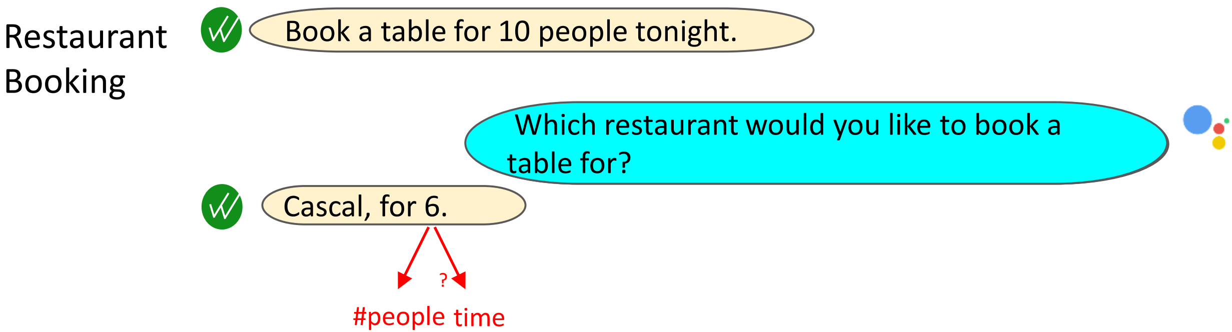
→ send_email(contact_name="bob")

U_2	are	we	going	to	fish	this	weekend
S_2	B-message	I-message	I-message	I-message	I-message	I-message	I-message

→ send_email(message="are we going to fish this weekend")

Contextual LU

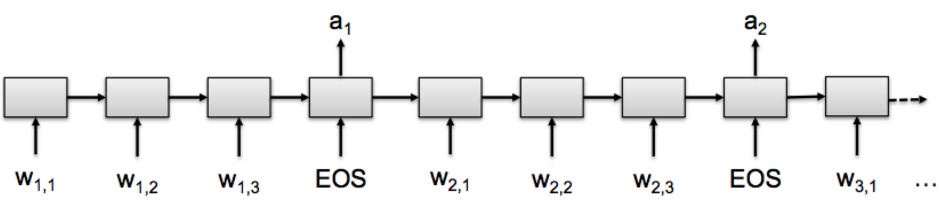
- User utterances are highly ambiguous in isolation



Contextual LU (Bhargava et al., 2013; Hori et al, 2015)

https://www.merl.com/publications/docs/TR2015-134.pdf

- Leveraging contexts
  - Used for individual tasks
- Seq2Seq model
  - Words are input one at a time, tags are output at the end of each utterance



- Extension: LSTM with speaker role dependent layers

End-to-End Memory Networks

(Sukhbaatar et al, 2015)

U: "i d like to purchase tickets to see deepwater horizon"

S: "for which theatre"

U: "angelika"

S: "you want them for angelika theatre?"

U: "yes angelika"

S: "how many tickets would you like ?"

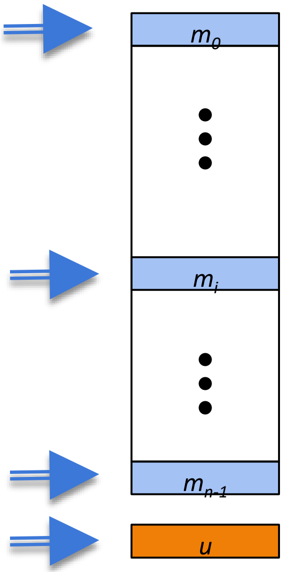
U: "3 tickets for saturday"

S: "What time would you like ?"

U: "Any time on saturday is fine"

S: "okay , there is 4:10 pm , 5:40 pm and 9:20 pm"

U: "Let's do 5:40"



E2E MemNN for Contextual LU (Chen et al., 2016)

https://www.microsoft.com/en-us/research/wp-content/uploads/2016/06/IS16_ContextualSLU.pdf

1. Sentence Encoding

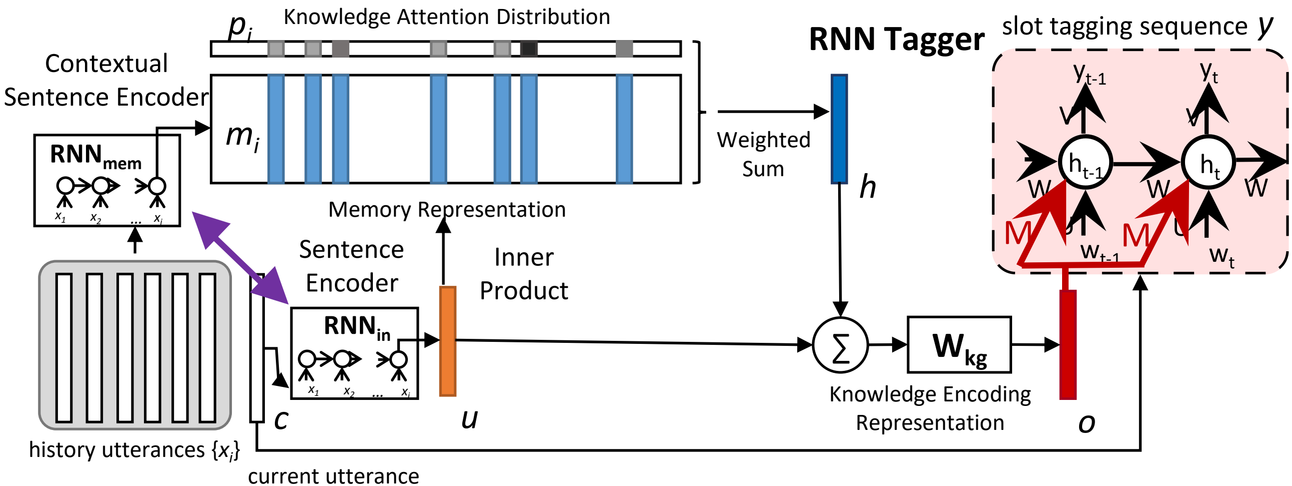
$$m_i = \text{RNN}_{\text{mem}}(x_i)$$
$$u = \text{RNN}_{\text{in}}(c)$$

2. Knowledge Attention

$$p_i = \text{softmax}(u^T m_i)$$

3. Knowledge Encoding

$$h = \sum_i p_i m_i \quad o = W_{\text{kg}}(h + u)$$



Idea: additionally incorporating contextual knowledge during slot tagging

→ track dialogue states in a latent way

Analysis of Attention

U: "i d like to purchase tickets to see deepwater horizon" 0.69

S: "for which theatre"

U: "angelika"

S: "you want them for angelika theatre?"

U: "yes angelika"

S: "how many tickets would you like ?" 0.13

U: "3 tickets for saturday"

S: "What time would you like ?"

U: "Any time on saturday is fine"

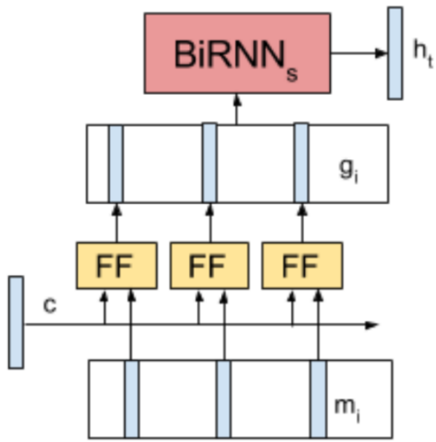
S: "okay , there is 4:10 pm , 5:40 pm and 9:20 pm" 0.16

U: "Let's do 5:40"

Sequential Dialogue Encoder Network
(Bapna et al., 2017)

 Bapna et.al., SIGDIAL 2017

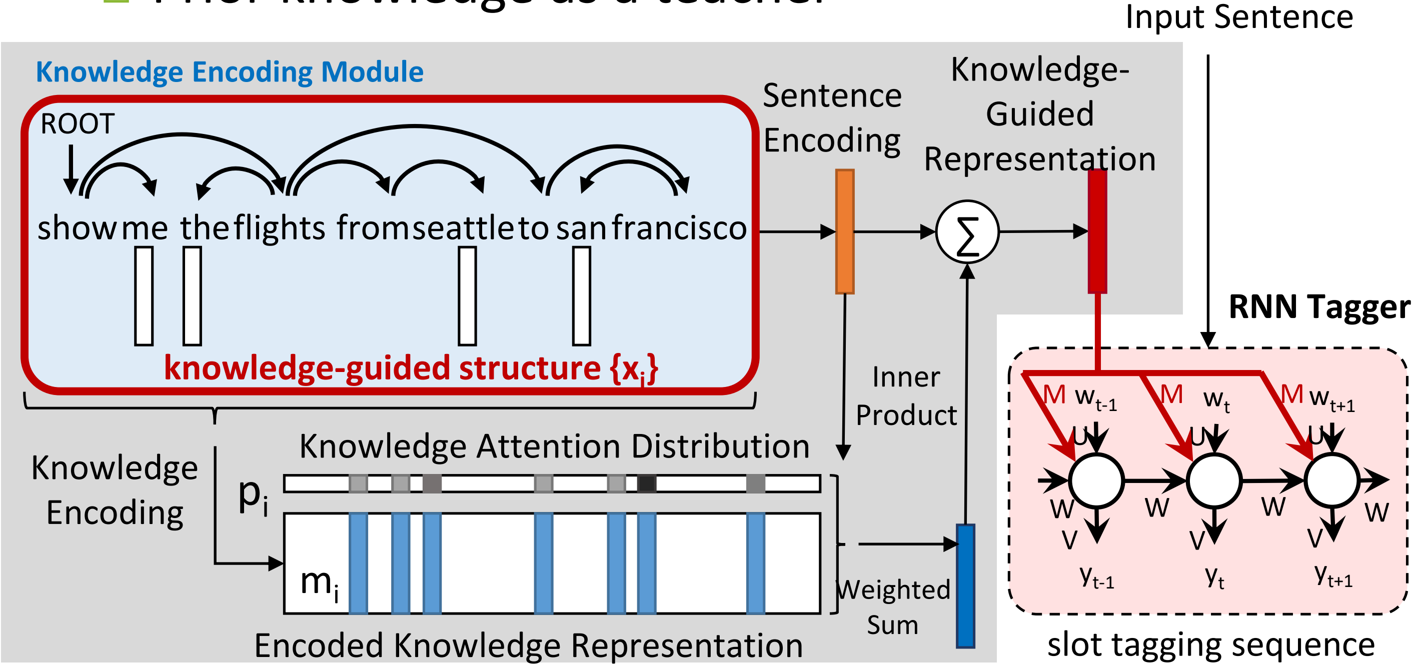
- Past and current turn encodings input to a feed forward network



Structural LU (Chen et al., 2016)

http://arxiv.org/abs/1609.03286

- Prior knowledge as a teacher



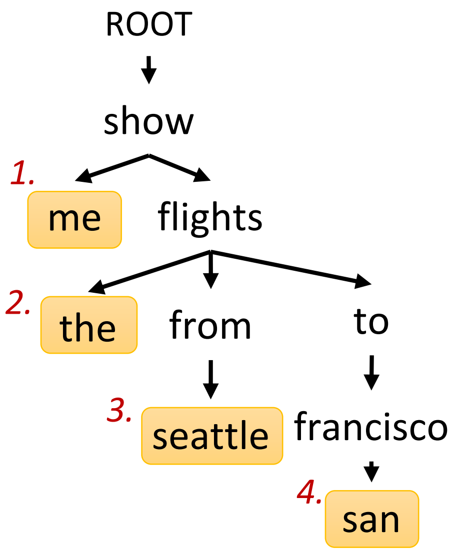
Structural LU (Chen et al., 2016)

http://arxiv.org/abs/1609.03286

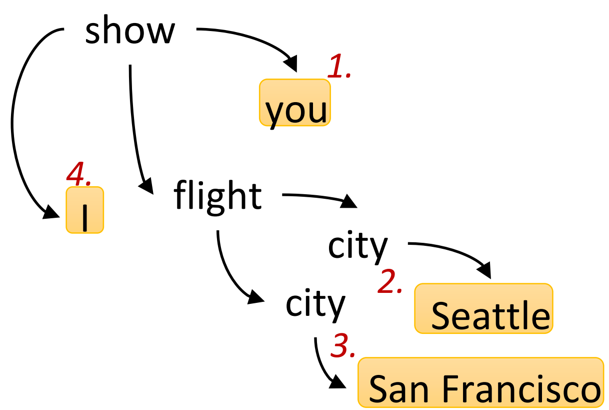
- Sentence structural knowledge stored as memory

Sentence s show me the flights from seattle to san francisco

Syntax (Dependency Tree)



Semantics (AMR Graph)



Structural LU (Chen et al., 2016)

http://arxiv.org/abs/1609.03286

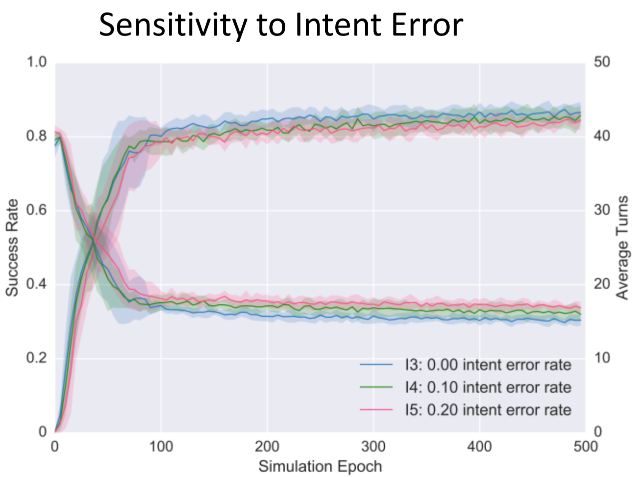
- Sentence structural knowledge stored as memory

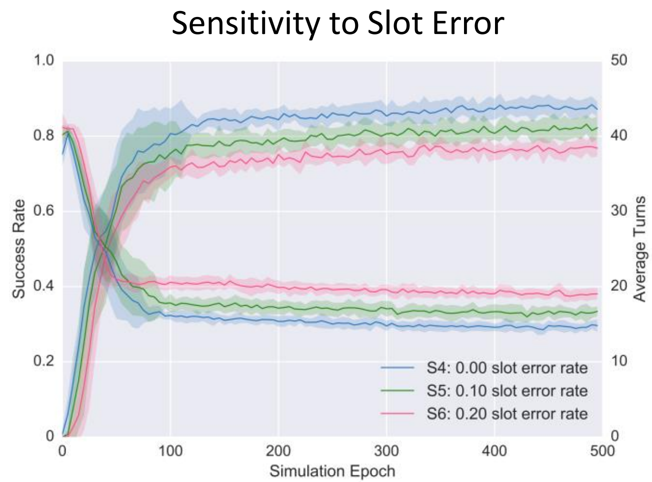
Using *less training data* with K-SAN allows the model pay the similar attention to the *salient substructures* that are important for tagging.

LU Importance (Li et al., 2017)

http://arxiv.org/abs/1703.07055

- Compare different types of LU errors





Slot filling errors have more impact on policy learning than intent detection errors.

LU Evaluation

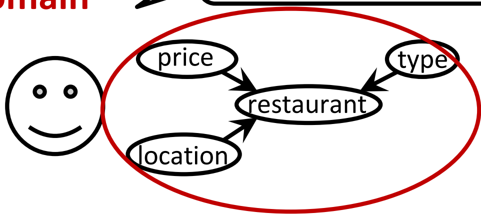
- Metrics
  - Sub-sentence-level: intent accuracy, intent F1, slot F1
  - Sentence-level: whole frame accuracy

Semantic Frame Representation

- Requires a domain ontology: early connection to backend
- Contains **core content (intent, a set of slots with fillers)**

Restaurant Domain

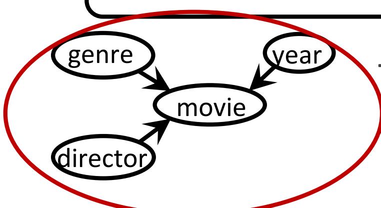
find me a cheap taiwanese restaurant in oakland



find_restaurant (price="cheap", type="taiwanese", location="oakland")

Movie Domain

show me action movies directed by james cameron



find_movie (genre="action", director="james cameron")

LU – Learning Semantic Ontology

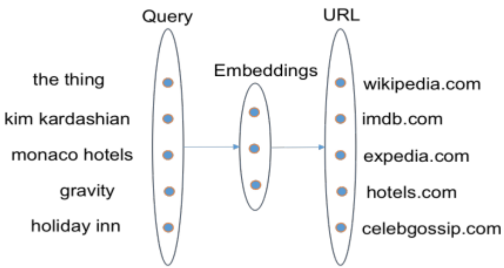
http://www.cs.cmu.edu/~ananlada/ConceptIdentificationICSLP02.pdf, http://ieeexplore.ieee.org/abstract/document/6707716/

- Learning key domain concepts from goal-oriented human-human conversations
  - Clustering with mutual information and KL divergence (Chotimongkol & Rudnicky, 2002)
  - Spectral clustering based slot ranking model (Chen et al., 2013)
    - Use a state-of-the-art frame-semantic parser trained for FrameNet
    - Adapt the generic output of the parser to the target semantic space

LU – Zero-Shot Learning (Daupin et al., 2016)

https://arxiv.org/abs/1401.0509

- Semantic utterance classification
  - Use query click logs to define a task that makes the networks learn the meaning or intent behind the queries



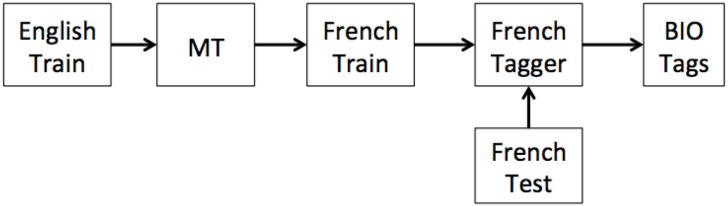
Depiction of the deep network from queries to URLs.

$$\mathcal{L}(X,Y) = -\log P(Y|X) + \lambda H(P(C|X)).$$

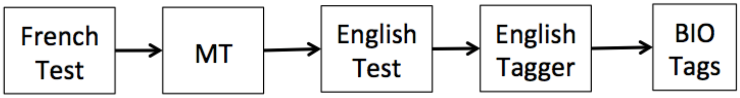
  - The semantic features are the last hidden layer of the DNN
  - Use Zero-Shot Discriminative embedding model combines *H* with the minimization of entropy of a zero-shot classifier

LU – Language Extension

- Train on target (Lefevre et al, 2010)
  http://mi.eng.cam.ac.uk/~sjy/papers/lemy10.pdf



- Test on source (Jabaian et al, 2011)
  lia.univ-avignon.fr/fileadmin/documents/Users/Intranet/fich_art/jabaian.pdf



- Combination (He et al, 2013)
  www.microsoft.com/en-us/research/wp-content/uploads/2016/02/ICASSP13-MultiLingual.pdf

(slide from Shyam Upadhyay)

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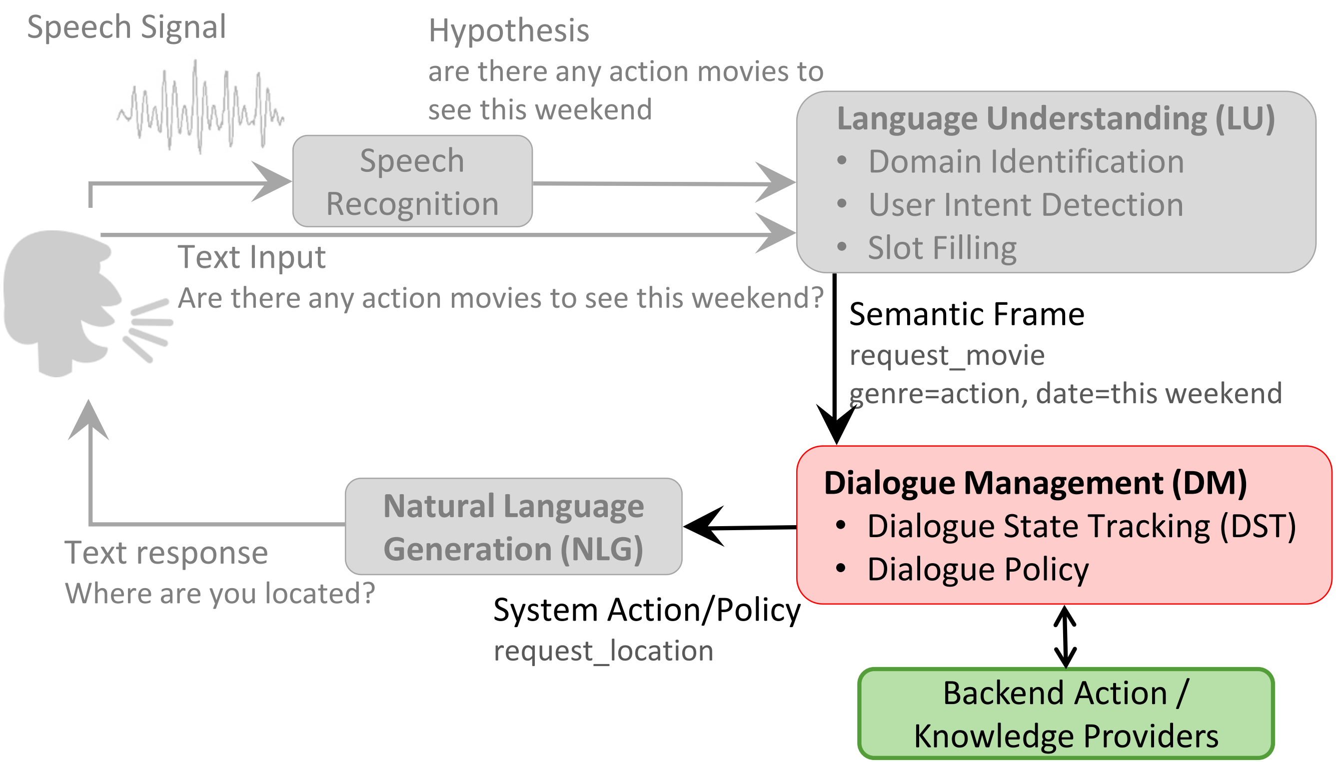
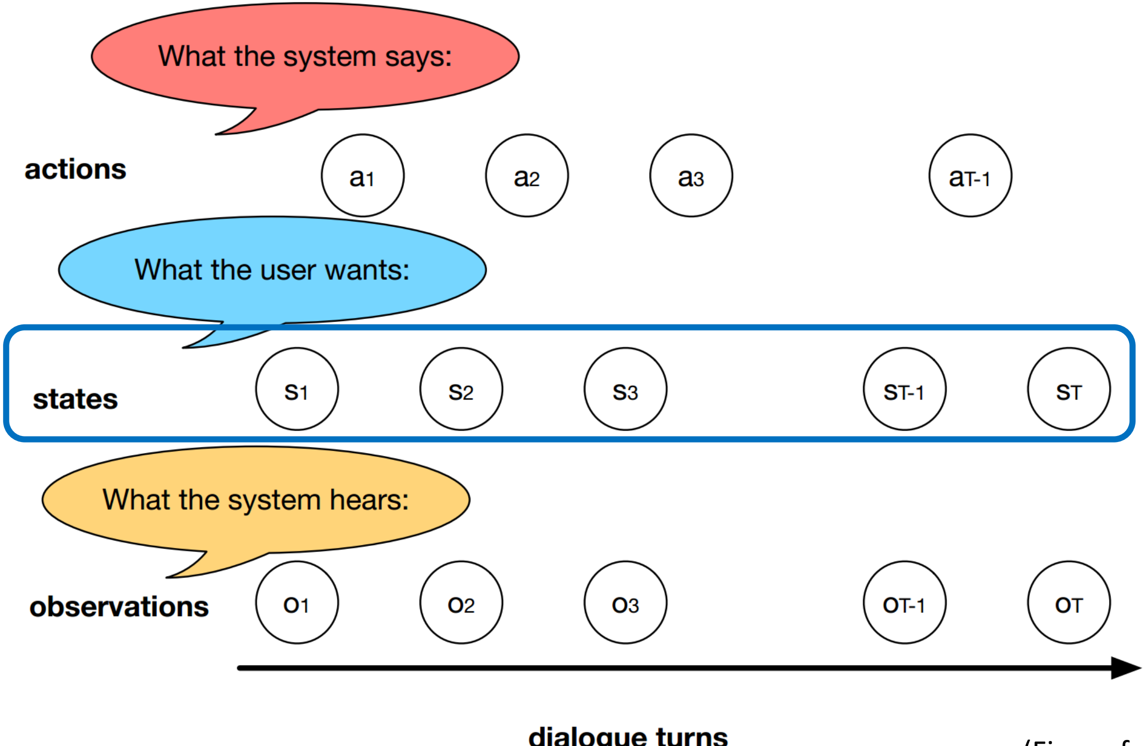
  - Dialogue Breadth
  - Dialogue Depth

Task-Oriented Dialogue System (Young, 2000)



Elements of Dialogue Management



(Figure from Gašić)

Dialogue State Tracking (DST)

- Dialogue state: *a representation of the system's belief of the user's goal(s) at any time during the dialogue*
- Inputs
  - Current user utterance
  - Preceding system response
  - Results from previous turns
- For
  - Looking up knowledge or making API call(s)
  - Generating the next system action/response

Dialogue State Tracking (DST)

- Maintain a probabilistic distribution instead of a 1-best prediction for <u>better robustness to recognition errors</u>

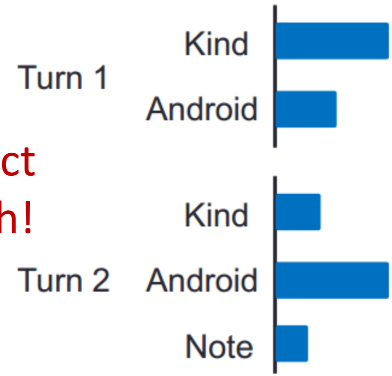
Turn 1
Kind
Android

Turn 2
Note
Android

Turn 1	
Kind	0.5
Android	0.3

Turn 2	
Note	0.4
Android	0.3

Incorrect for both!

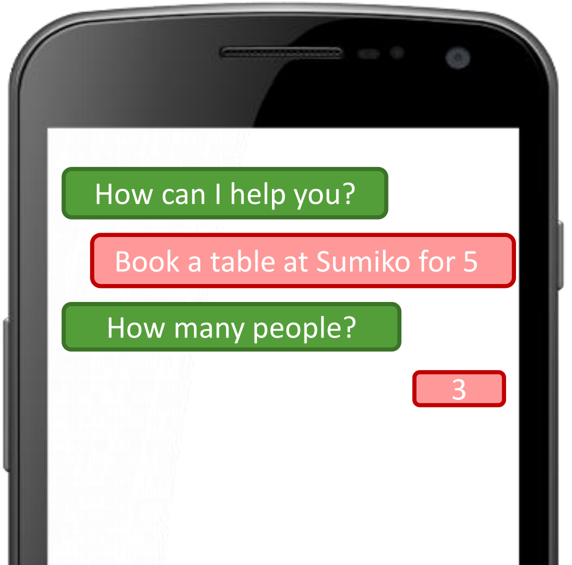


Dialogue State Tracking (DST)

- Maintain a probabilistic distribution instead of a 1-best prediction for better robustness to SLU errors or ambiguous input

Slot	Value
# people	5 (0.5)
time	5 (0.5)

Slot	Value
# people	3 (0.8)
time	5 (0.8)



Multi-Domain Dialogue State Tracking

- A full representation of the system's belief of the user's goal at any point during the dialogue
- Used for making API calls

Movies

11/15/16			
6 pm	7 pm	8 pm	9 pm
2	3		
Inferno	Trolls		
Century 16			

Restaurants

Date	11/15/16		
Time	6:30 pm	7 pm	7:30 pm
Cuisine	Mexican		
Restaurant	Vive Sol		

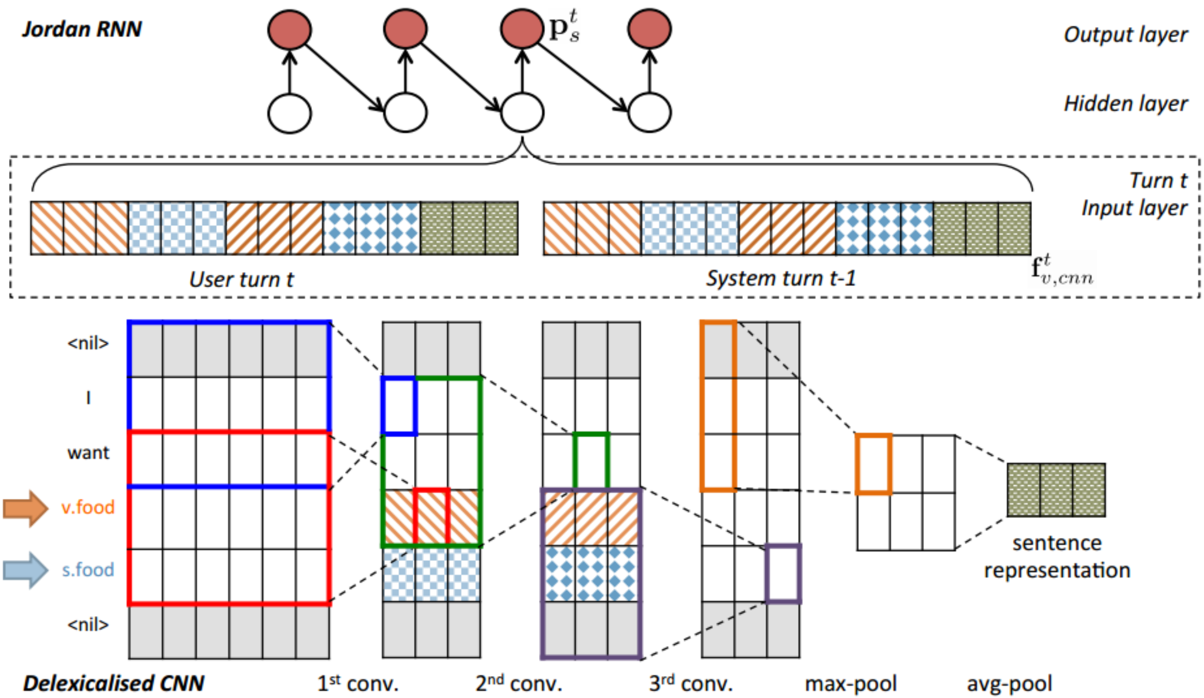
Dialog State Tracking Challenge (DSTC)

(Williams et al. 2013, Henderson et al. 2014, Henderson et al. 2014, Kim et al. 2016, Kim et al. 2016)

Challenge	Type	Domain	Data Provider	Main Theme
DSTC1	Human-Machine	Bus Route	CMU	Evaluation Metrics
DSTC2	Human-Machine	Restaurant	U. Cambridge	User Goal Changes
DSTC3	Human-Machine	Tourist Information	U. Cambridge	Domain Adaptation
DSTC4	Human-Human	Tourist Information	I2R	Human Conversation
DSTC5	Human-Human	Tourist Information	I2R	Language Adaptation

NN-Based DST (Henderson et al., 2013; Henderson et al., 2014; Mrkšić et al., 2015)

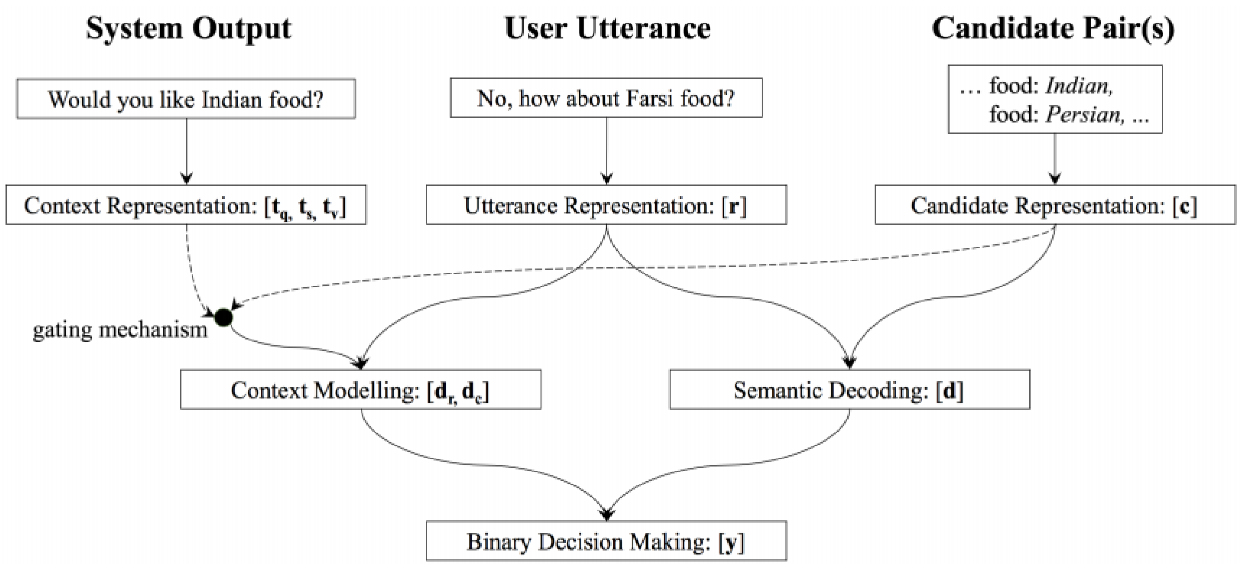
http://www.anthology.aclweb.org/W/W13/W13-4073.pdf; https://arxiv.org/abs/1506.07190



(Figure from Wen et al, 2016)

Neural Belief Tracker (Mrkšić et al., 2016)

https://arxiv.org/abs/1606.03777



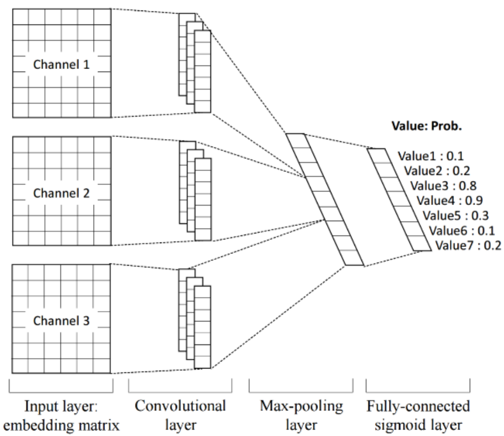
DST Evaluation

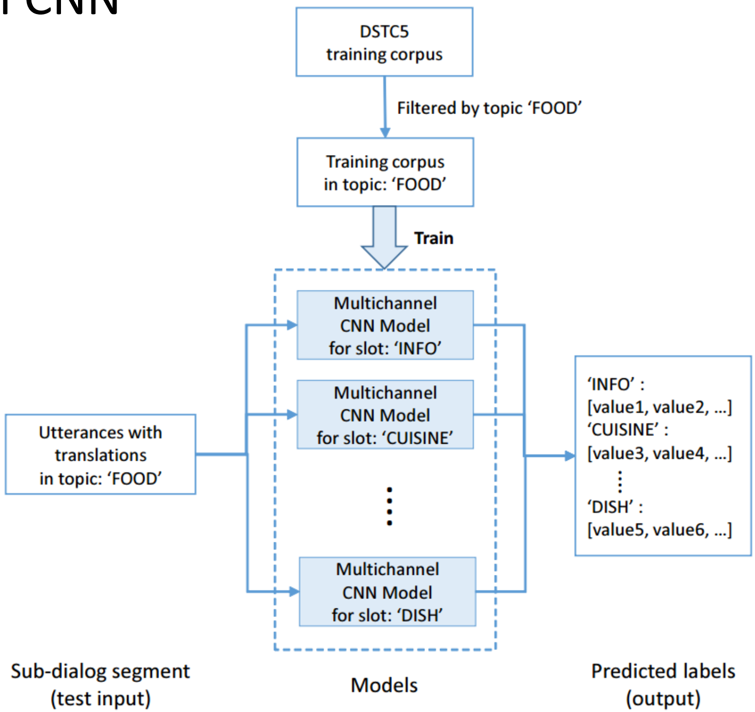
- Dialogue State Tracking Challenges
  - DSTC2-3, human-machine
  - DSTC4-5, human-human
- Metric
  - Tracked state accuracy with respect to user goal
  - Recall/Precision/F-measure individual slots

DST Language Extension – Multichannel Tracker (Shi et al., 2016)

https://arxiv.org/abs/1701.06247

- Training a multichannel CNN for each slot
  - Chinese character CNN
  - Chinese word CNN
  - English word CNN





DST – Task Lineages (Lee & Stent, 2016)

https://www.aclweb.org/anthology/W/W16/W16-36.pdf#page=29

- Slot values shared across tasks
- Utterances with complex constraints on user goals
- Interleaved multiple task discussions

Task Frame:

Connection to Manhattan and find me a Thai restaurant, not Italian

$$\begin{bmatrix} \begin{bmatrix} \textbf{Task} & \text{Transit} \\ \textbf{DAIs} & (0.8, \text{inform}(\text{dest}=\text{MH})^{0.1}_{0.7}) \end{bmatrix} \\ \begin{bmatrix} \textbf{Task} & \text{Restaurant} \\ \textbf{DAIs} & (0.7, \text{inform}(\text{food}=\text{thai})^{0.9}_{1.2}) \\ & (0.6, \text{deny}(\text{food}=\text{italian})^{1.4}_{1.7}) \end{bmatrix} \end{bmatrix}$$

(confidence, dialog act item$^{\text{Start_time}}_{\text{End_time}}$)

Task State:

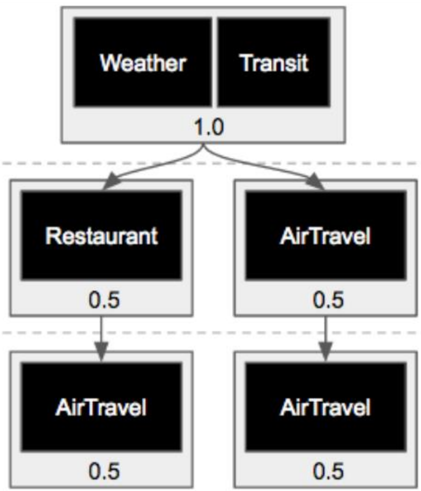
Thai restaurant, not Italian

$$\begin{bmatrix} \textbf{Task} & \text{Restaurant} \\ \textbf{Constraints} & (0.7, \text{food} = \text{thai}) \\ & (0.6, \text{food} \neq \text{italian}) \\ \textbf{DB} & [\text{“Thai To Go”}, \text{“Pa de Thai”}] \\ \textbf{Timestamps} & 01/01/2016 : 12\text{-}00\text{-}00 \\ \ldots & \ldots \end{bmatrix}$$

DST – Task Lineages (Lee & Stent, 2016)

https://www.aclweb.org/anthology/W/W16/W16-36.pdf#page=29

Turn	User Input	Task Lineages
0	Weather in New York. Connection to Manhattan	
1	Want to go to Thai	
2	I want to travel to Thai	



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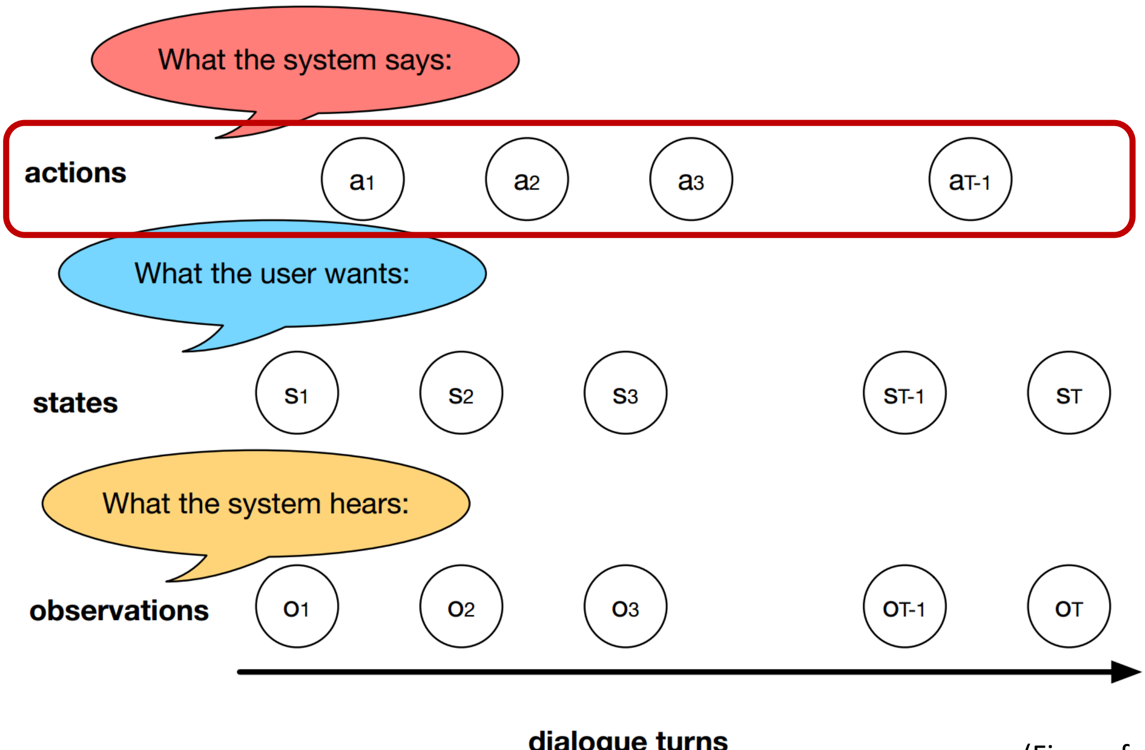
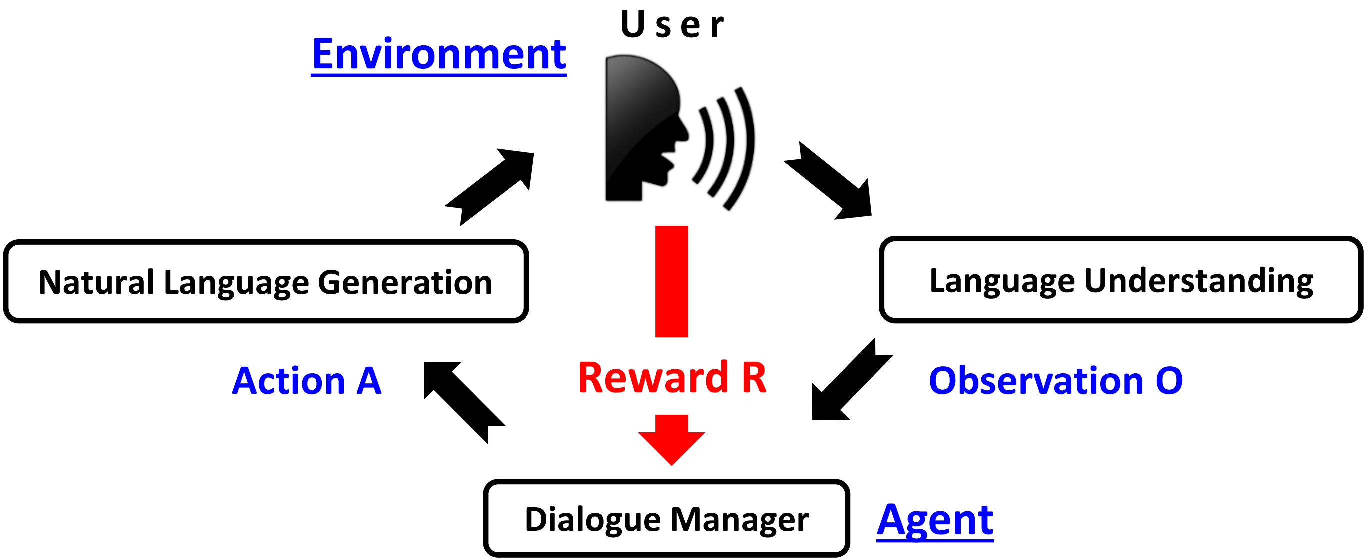
Elements of Dialogue Management



(Figure from Gašić)

Dialogue Policy Optimization

- Dialogue management in a RL framework



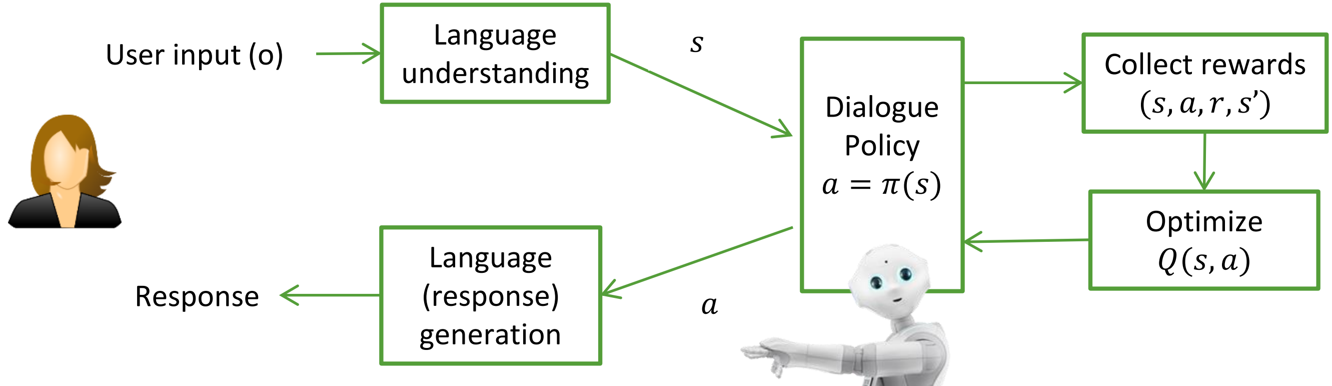
The optimized dialogue policy selects the best action that maximizes the future reward.
Correct rewards are a crucial factor in dialogue policy training

Reward for RL ≅ Evaluation for System

- Dialogue is a special RL task
  - Human involves in **interaction** and **rating (evaluation)** of a dialogue
  - Fully human-in-the-loop framework
- Rating: correctness, appropriateness, and adequacy

- Expert rating	high quality, high cost
- User rating	unreliable quality, medium cost
- Objective rating	Check desired aspects, low cost

Reinforcement Learning for Dialogue Policy Optimization



Type of Bots	State	Action	Reward
Social ChatBots	Chat history	System Response	# of turns maximized; Intrinsically motivated reward
InfoBots (interactive Q/A)	User current question + Context	Answers to current question	Relevance of answer; # of turns minimized
Task-Completion Bots	User current input + Context	System dialogue act w/ slot value (or API calls)	Task success rate; # of turns minimized

Goal: develop a generic deep RL algorithm to learn dialogue policy for all bot categories

Dialogue Reinforcement Learning Signal

Typical reward function

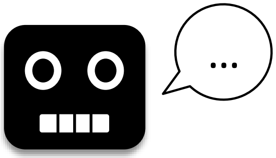
- -1 for per turn penalty
- Large reward at completion if successful

Typically requires domain knowledge

✓ Simulated user

✓ Paid users (Amazon Mechanical Turk)

✗ Real users

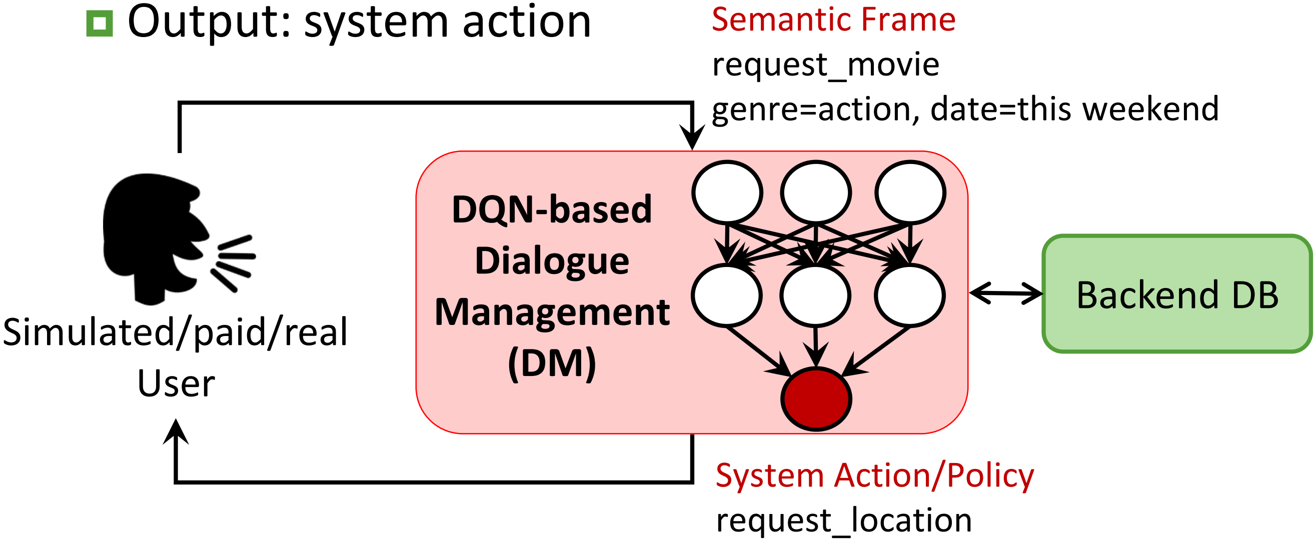


The **user simulator** is usually required for dialogue system training before deployment

Neural Dialogue Manager (Li et al., 2017)

https://arxiv.org/abs/1703.01008

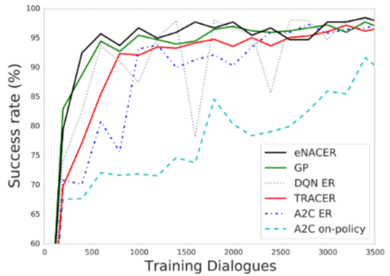
- Deep RL for training DM
  - Input: current semantic frame observation, database returned results
  - Output: system action

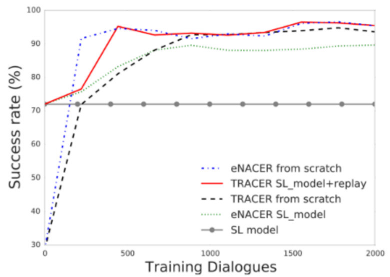


SL + RL for Sample Efficiency (Su et al., 2017)

Su et.al., SIGDIAL 2017

- Issue about RL for DM
  - slow learning speed
  - cold start
- Solutions
  - Sample-efficient actor-critic
    - Off-policy learning with experience replay
    - Better gradient update
  - Utilizing supervised data
    - Pretrain the model with SL and then fine-tune with RL
    - Mix SL and RL data during RL learning
    - Combine both

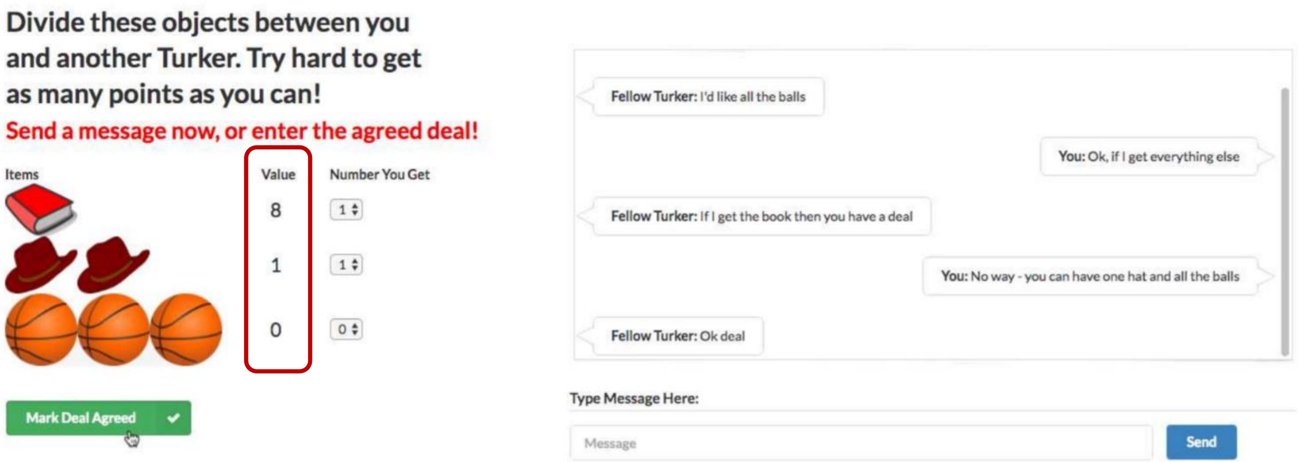




Learning to Negotiate (Lewis et al., 2017)

https://arxiv.org/pdf/1706.05125.pdf

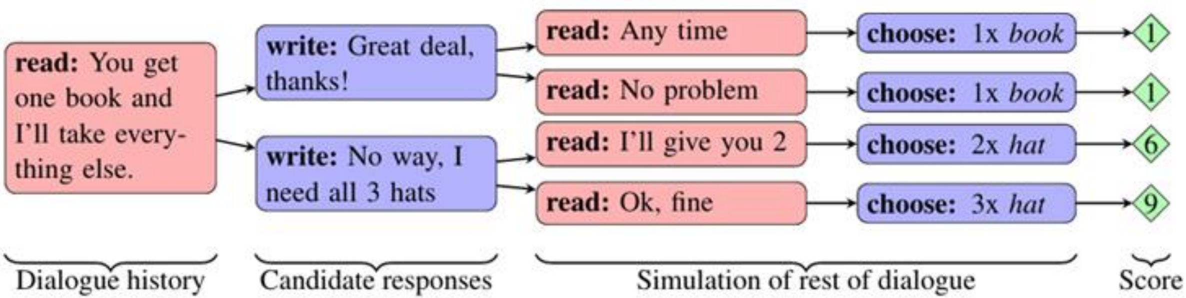
- Task: multi-issue bargaining
  - Each agent has its own value function



Learning to Negotiate (Lewis et al., 2017)

https://arxiv.org/pdf/1706.05125.pdf

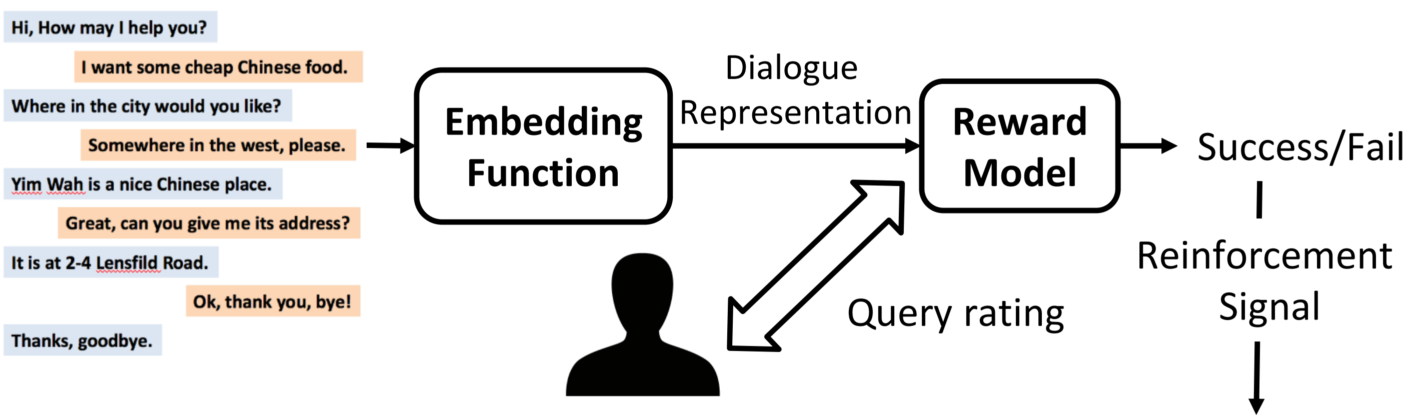
- Dialogue rollouts to simulate a future conversation
- SL + RL
  - SL aims to imitate human users' actions
  - RL tries to make agents focus on the goal



Online Training (Su et al., 2015; Su et al., 2016)

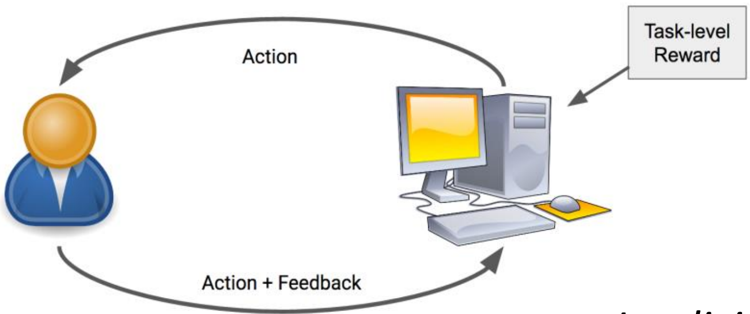
http://www.anthology.aclweb.org/W/W15/W15-46.pdf#page=437; https://www.aclweb.org/anthology/P/P16/P16-1230.pdf

- Policy learning from real users
  - Infer reward directly from dialogues (Su et al., 2015)
  - User rating (Su et al., 2016)
- Reward modeling on user binary success rating



Interactive RL for DM (Shah et al., 2016)

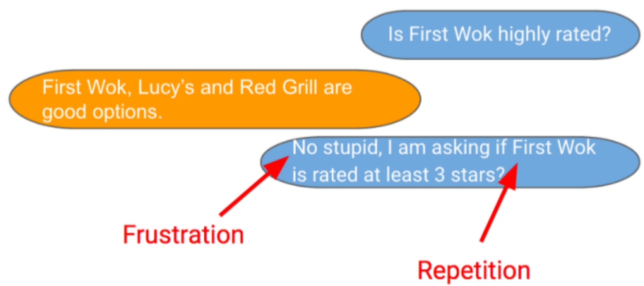
https://research.google.com/pubs/pub45734.html



Immediate Feedback

Explicit

Implicit

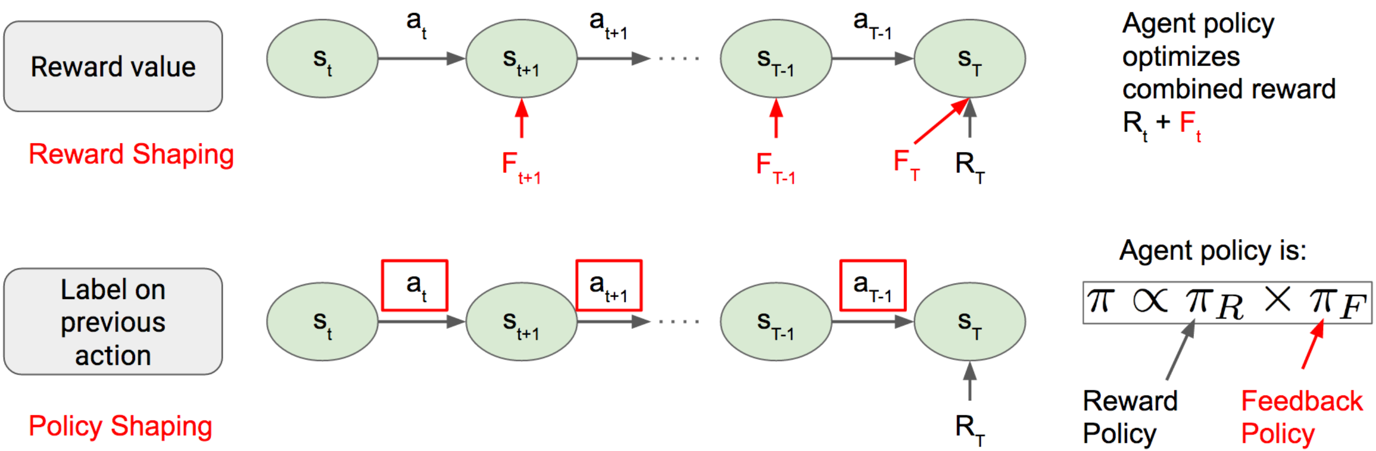


Use a third agent for providing interactive feedback to the DM

Interpreting Interactive Feedback

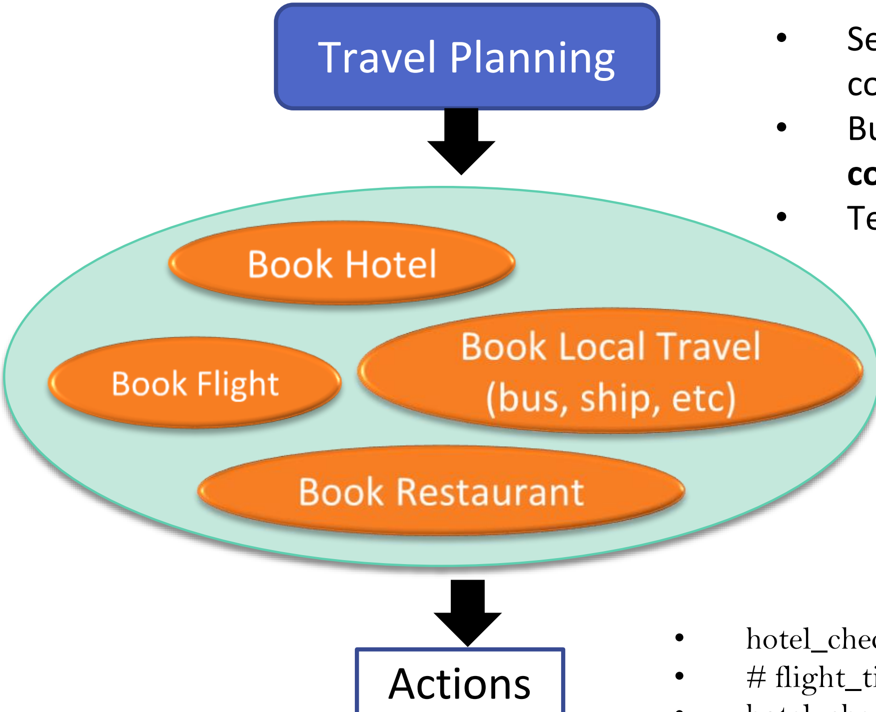
(Shah et al., 2016)

https://research.google.com/pubs/pub45734.html



Multi-Domain Policy – Hierarchical RL for Composite Tasks (Peng et al., 2017)

Peng et.al., EMNLP 2017 https://arxiv.org/abs/1704.03084



- Set of tasks that need to be fulfilled collectively!
- Build a DM for **cross-subtask constraints (slot constraints)**
- Temporally constructed goals

- hotel_check_in_time > departure_flight_time
- # flight_tickets = #people checking in the hotel
- hotel_check_out_time< return_flight_time,

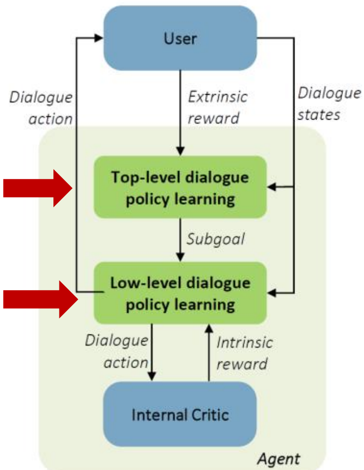
Multi-Domain Policy – Hierarchical RL for Composite Tasks (Peng et al., 2017)

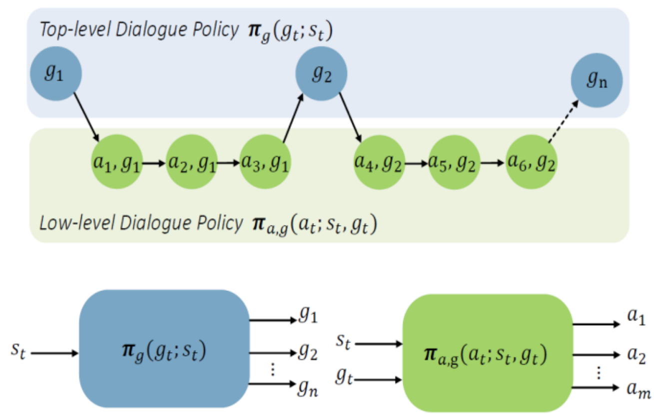
Peng et.al., EMNLP 2017 https://arxiv.org/abs/1704.03084

- Model makes decisions over two levels: *meta-controller & controller*
- The *agent* learns these policies simultaneously
  - the policy of optimal sequence of goals to follow $\pi_g(g_t, s_t; \theta_1)$
  - Policy $\pi_{a,g}(a_t, g_t, s_t; \theta_2)$ for each sub-goal g_t

Meta-Controller

Controller





(mitigate reward sparsity issues)

Dialogue Management Evaluation

- Metrics
  - Turn-level evaluation: system action accuracy
  - Dialogue-level evaluation: task success rate, reward

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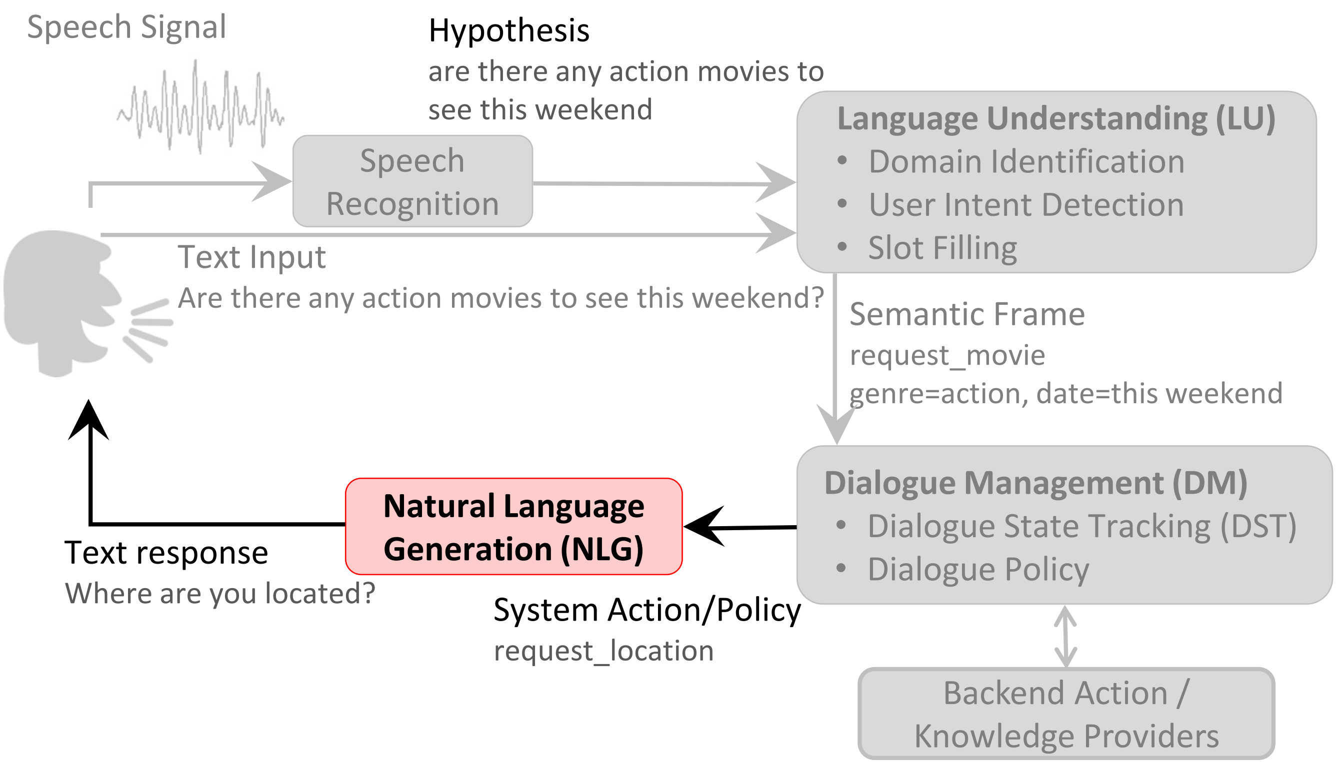


Natural Language Generation (NLG)

- Mapping dialogue acts into natural language

inform(name=Seven_Days, foodtype=Chinese)

Seven Days is a nice Chinese restaurant

Template-Based NLG

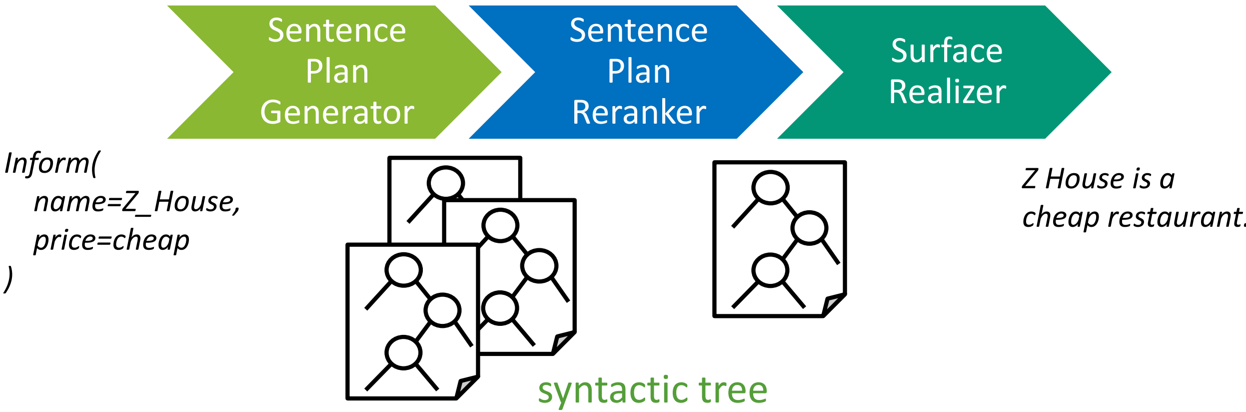
- Define a set of rules to map frames to NL

Semantic Frame	Natural Language
confirm()	"Please tell me more about the product your are looking for."
confirm(area=$V)	"Do you want somewhere in the $V?"
confirm(food=$V)	"Do you want a $V restaurant?"
confirm(food=$V,area=$W)	"Do you want a $V restaurant in the $W."

Pros: simple, error-free, easy to control
Cons: time-consuming, rigid, poor scalability

Plan-Based NLG (Walker et al., 2002)

- Divide the problem into pipeline



  - Statistical sentence plan generator (Stent et al., 2009)
  - Statistical surface realizer (Dethlefs et al., 2013; Cuayáhuitl et al., 2014; …)

Pros: can model complex linguistic structures
Cons: heavily engineered, require domain knowledge

Class-Based LM NLG (Oh and Rudnicky, 2000)

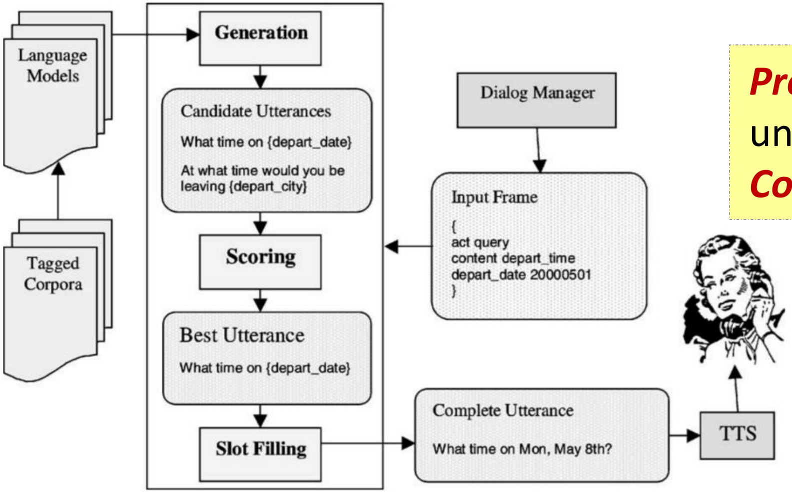
http://dl.acm.org/citation.cfm?id=1117568

- Class-based language modeling

$$P(X \mid c) = \sum_t \log p(x_t \mid x_0, x_1, \cdots, x_{t-1}, c)$$

- NLG by decoding $X^* = \arg\max_X P(X \mid c)$

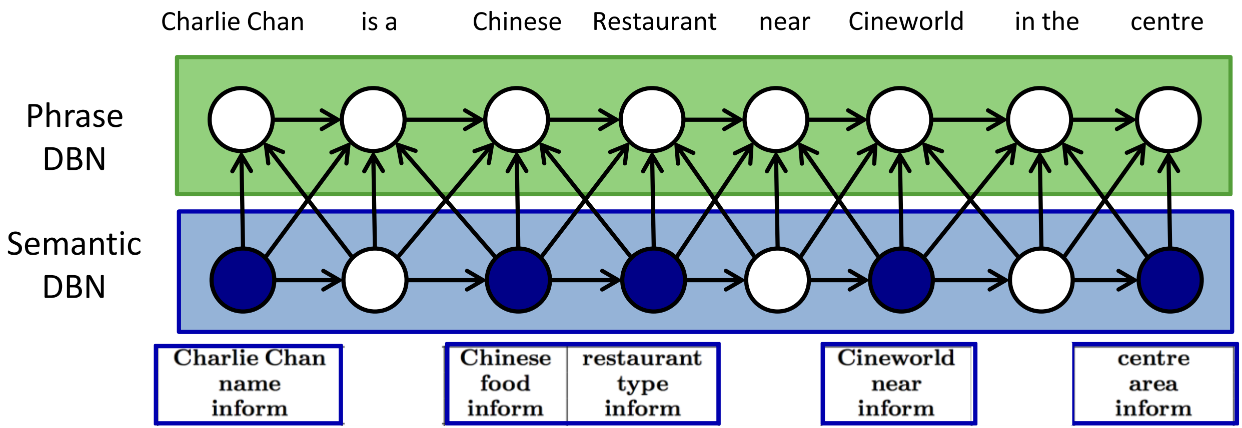
Classes:
inform_area
inform_address
…
request_area
request_postcode



Pros: easy to implement/ understand, simple rules
Cons: computationally inefficient

Phrase-Based NLG (Mairesse et al, 2010)

http://dl.acm.org/citation.cfm?id=1858838



Inform(name=Charlie Chan, food=Chinese, type= restaurant, near=Cineworld, area=centre)

realization phrase semantic stack

r_t	s_t	h_t	l_t
<s>	START	START	START
The Rice Boat	inform(name(X))	X	inform(name)
is a	inform	inform	EMPTY
restaurant	inform(type(restaurant))	restaurant	inform(type)
in the	inform(area)	area	inform
riverside	inform(area(riverside))	riverside	inform(area)
area	inform(area)	area	inform
that	inform	inform	EMPTY
serves	inform(food)	food	inform
French	inform(food(French))	French	inform(food)
food	inform(food)	food	inform
</s>	END	END	END

Pros: efficient, good performance
Cons: require semantic alignments

RNN-Based LM NLG (Wen et al., 2015)

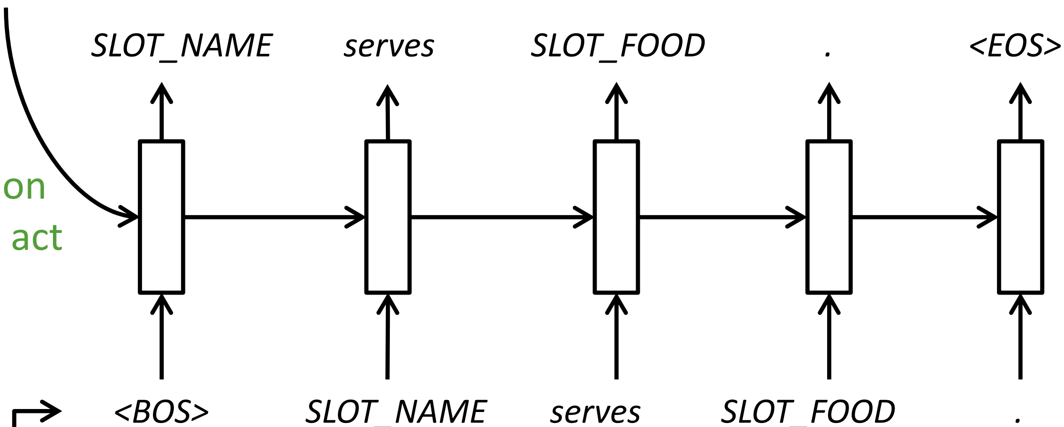
http://www.anthology.aclweb.org/W/W15/W15-46.pdf#page=295

Input *Inform(name=Din Tai Fung, food=Taiwanese)*

dialogue act 1-hot representation

[0, 0, 1, 0, 0, …, 1, 0, 0, …, 1, 0, 0, 0, 0, 0…]

conditioned on the dialogue act



Output *<BOS> Din Tai Fung serves Taiwanese .*

delexicalisation

Slot weight tying

Handling Semantic Repetition

- Issue: semantic repetition
  - Din Tai Fung is a great Taiwanese restaurant that serves Taiwanese.
  - Din Tai Fung is a child friendly restaurant, and also allows kids.
- Deficiency in either model or decoding (or both)
- Mitigation
  - Post-processing rules (Oh & Rudnicky, 2000)
  - Gating mechanism (Wen et al., 2015)
  - Attention (Mei et al., 2016; Wen et al., 2015)

Semantic Conditioned LSTM (Wen et al., 2015)

http://www.aclweb.org/anthology/D/D15/D15-1199.pdf

- Original LSTM cell

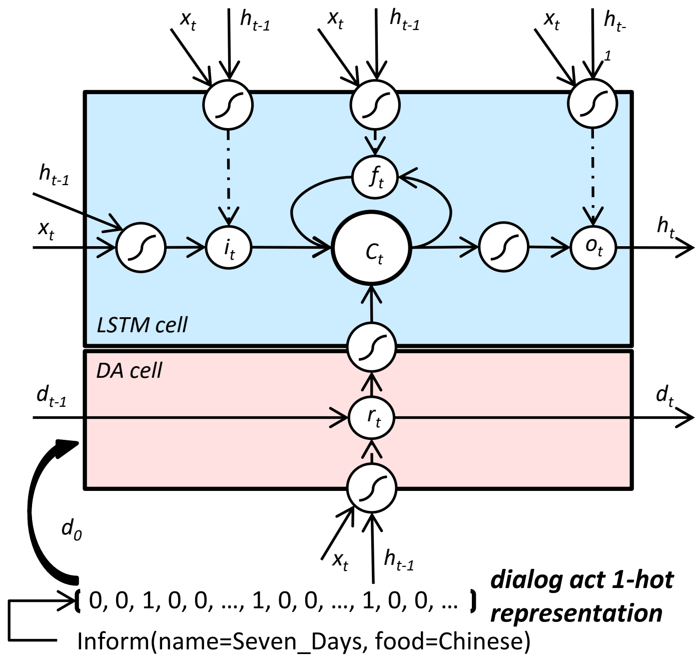
$$\mathbf{i}_t = \sigma(\mathbf{W}_{wi}\mathbf{x}_t + \mathbf{W}_{hi}\mathbf{h}_{t-1})$$
$$\mathbf{f}_t = \sigma(\mathbf{W}_{wf}\mathbf{x}_t + \mathbf{W}_{hf}\mathbf{h}_{t-1})$$
$$\mathbf{o}_t = \sigma(\mathbf{W}_{wo}\mathbf{x}_t + \mathbf{W}_{ho}\mathbf{h}_{t-1})$$
$$\hat{\mathbf{c}}_t = \tanh(\mathbf{W}_{wc}\mathbf{x}_t + \mathbf{W}_{hc}\mathbf{h}_{t-1})$$
$$\mathbf{c}_t = \mathbf{f}_t \odot \mathbf{c}_{t-1} + \mathbf{i}_t \odot \hat{\mathbf{c}}_t$$
$$\mathbf{h}_t = \mathbf{o}_t \odot \tanh(\mathbf{c}_t)$$

- Dialogue act (DA) cell

$$\mathbf{r}_t = \sigma(\mathbf{W}_{wr}\mathbf{x}_t + \mathbf{W}_{hr}\mathbf{h}_{t-1})$$
$$\mathbf{d}_t = \mathbf{r}_t \odot \mathbf{d}_{t-1}$$

- Modify Ct

$$\mathbf{c}_t = \mathbf{f}_t \odot \mathbf{c}_{t-1} + \mathbf{i}_t \odot \hat{\mathbf{c}}_t + \tanh(\mathbf{W}_{dc}\mathbf{d}_t)$$



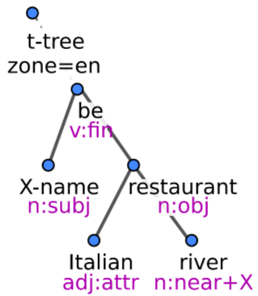
Idea: using gate mechanism to control the generated semantics (dialogue act/slots)

Structural NLG (Dušek and Jurčíček, 2016)

https://www.aclweb.org/anthology/P/P16/P16-2.pdf#page=79

- Goal: NLG based on the syntax tree
  - Encode trees as sequences
  - Seq2Seq model for generation

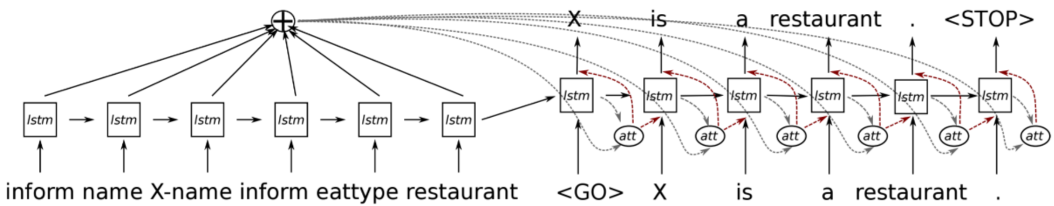
inform(name=X-name,type=placetoeat,eattype=restaurant, area=riverside,food=Italian)



(<root> <root> ((X-name n:subj) be v:fin ((Italian adj:attr) restaurant n:obj (river n:near+X))))

X-name n:subj be v:fin Italian adj:attr restaurant n:obj river n:near+X

X is an Italian restaurant near the river.



Structural NLG (Sharma et al., 2017; Nayak et al., 2017)

Nayak et al., Interspeech 2017 https://arxiv.org/pdf/1606.03632.pdf

- Delexicalized slots do not consider the word level information

Generated output:	There are no restaurants around which serve INFORM-FOOD food.			
Delexicalized slot input:	INFORM-FOOD	✓	INFORM-FOOD	✗
Lexicalized value input:	chinese		pizza	

- Slot value-informed sequence to sequence models

Mention rep.	Input sequence					
SEQ	x_i	x_{i+1}	x_{i+2}	x_{i+3}	x_{i+4}	...
	decor	*decent*	service	good	cuisine	...
JOINT	x_i		x_{i+1}		x_{i+2}	
	⟨ decor, decent ⟩		⟨ service, good ⟩		⟨ cuisine, null ⟩	
CONCAT	$x_{i,1}$	$x_{i,2}$	$x_{i+1,1}$	$x_{i+1,2}$	$x_{i+2,1}$	$x_{i+2,2}$
	decor	decent	service	good	cuisine	null

Structural NLG (Nayak et al., 2017)

Nayak et al., Interspeech 2017

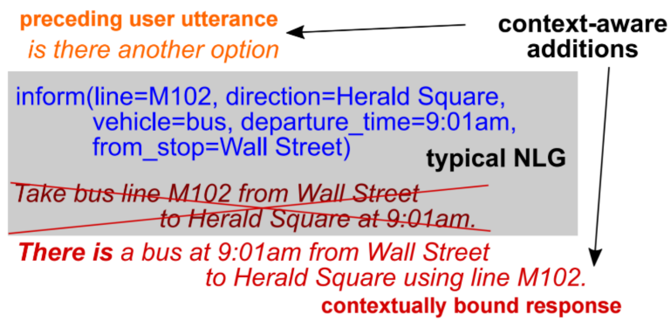
- Sentence plans as part of the input sequence

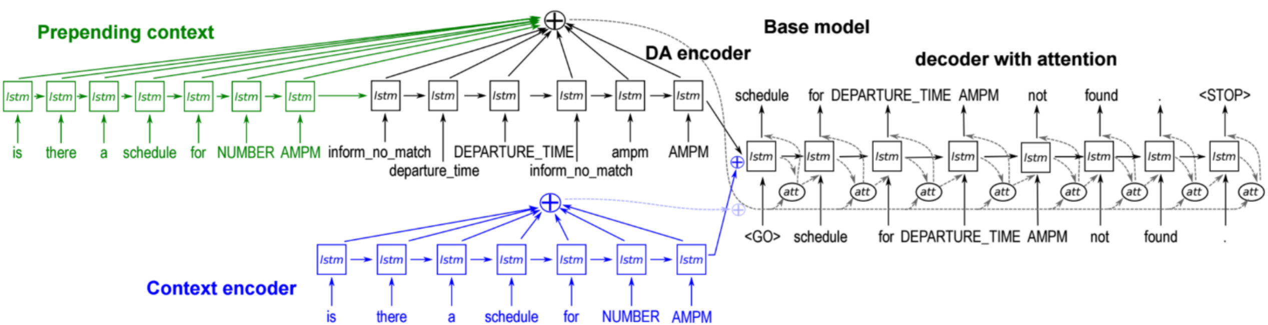
Plan sup.	Input tokens					
NONE	decor	decent	service	decent	quality	good
FLAT	decor	decent	service	decent		
	quality	good				
POSITIONAL	<B>	decor	decent	service	decent	
	<I>	quality	good			

Contextual NLG (Dušek and Jurčíček, 2016)

https://www.aclweb.org/anthology/W/W16/W16-36.pdf#page=203

- Goal: adapting users' way of speaking, providing context-aware responses
  - Context encoder
  - Seq2Seq model

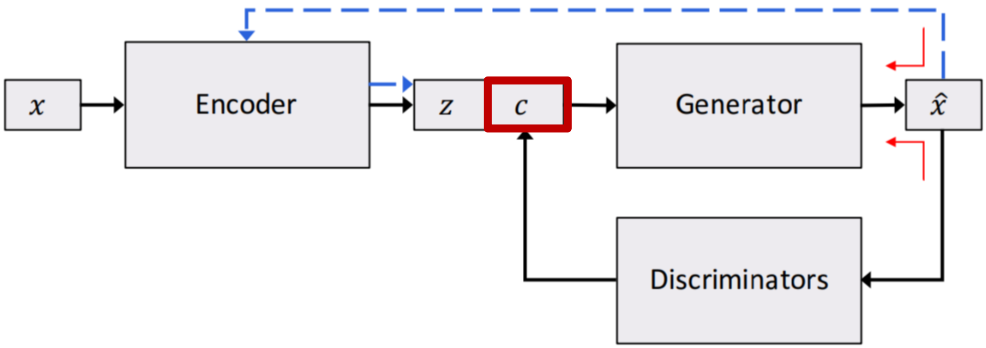




Controlled Text Generation (Hu et al., 2017)

https://arxiv.org/pdf/1703.00955.pdf

- Idea: NLG based on generative adversarial network (GAN) framework
  - c: targeted sentence attributes



NLG Evaluation

- Metrics
  - Subjective: human judgement (Stent et al., 2005)
    - Adequacy: correct meaning
    - Fluency: linguistic fluency
    - Readability: fluency in the dialogue context
    - Variation: multiple realizations for the same concept
  - Objective: automatic metrics
    - Word overlap: BLEU (Papineni et al, 2002), METEOR, ROUGE
    - Word embedding based: vector extrema, greedy matching, embedding average

There is a gap between human perception and automatic metrics

System Evaluation

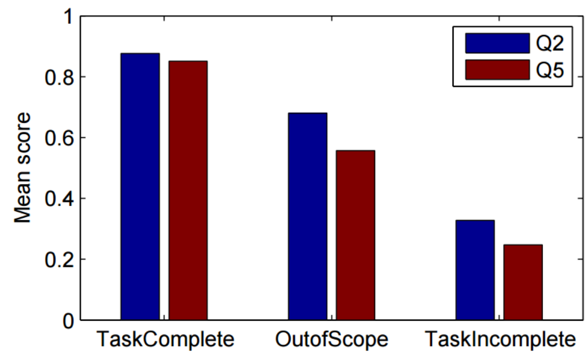
Dialogue System Evaluation

- Dialogue model evaluation
  - Crowd sourcing
  - User simulator
- Response generator evaluation
  - Word overlap metrics
  - Embedding based metrics

Crowd Sourcing for Dialogue System Evaluation (Yang et.al. 2012)

http://www-scf.usc.edu/~zhaojuny/docs/SDSchapter_final.pdf

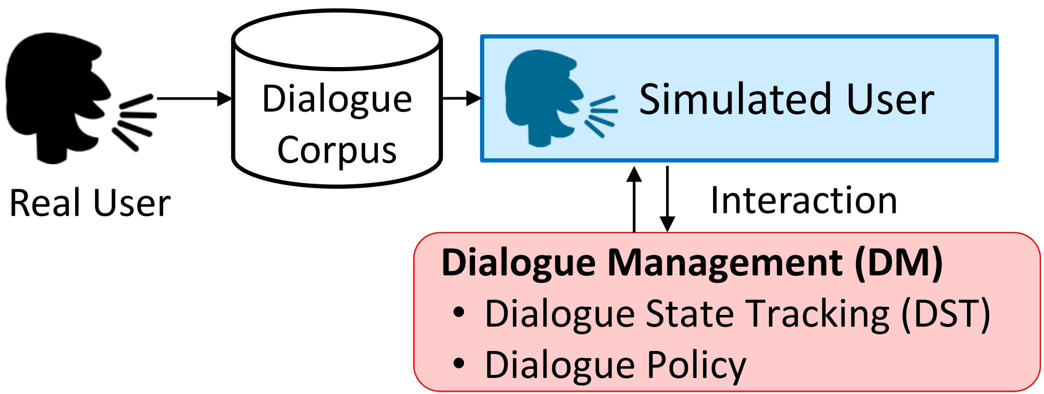
Q1	**Do you think you understand from the dialog what the user wanted?**
Opt	1) No clue 2) A little bit 3) Somewhat 4) Mostly 5) Entirely
Aim	*elicit the Worker's confidence in his/her ratings.*
Q2	**Do you think the system is successful in providing the information that the user wanted?**
Opt	1) Entirely unsuccessful 2) Mostly unsuccessful 3) Half successful/unsuccessful 4) Mostly successful 5) Entirely successful
Aim	*elicit the Worker's perception of whether the dialog has fulfilled the informational goal of the user.*
Q3	**Does the system work the way you expect it?**
Opt	1) Not at all 2) Barely 3) Somewhat 4) Almost 5) Completely
Aim	*elicit the Worker's impression of whether the dialog flow suits general expectations.*
Q4	**Overall, do you think that this is a good system?**
Opt	1) Very poor 2) Poor 3) Fair 4) Good 5) Very good
Aim	*elicit the Worker's overall impression of the SDS.*
Q5	**What category do you think the dialog belongs to?**
Opt	1) Task is incomplete 2) Out of scope 3) Task is complete
Aim	*elicit the Worker's impression of whether the dialog reflects task completion.*



The normalized mean scores of Q2 and Q5 for approved ratings in each category. A higher score maps to a higher level of task success

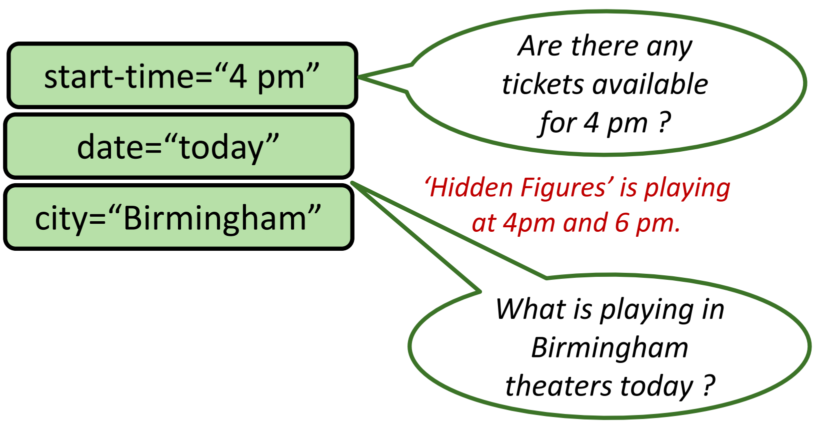
User Simulation

- Goal: Generate natural and reasonable conversations to enable reinforcement learning for exploring the policy space
- Conventional corpora cannot be used to train RL agents.
- Simulator is replaced by crowd users to replicate real environment.



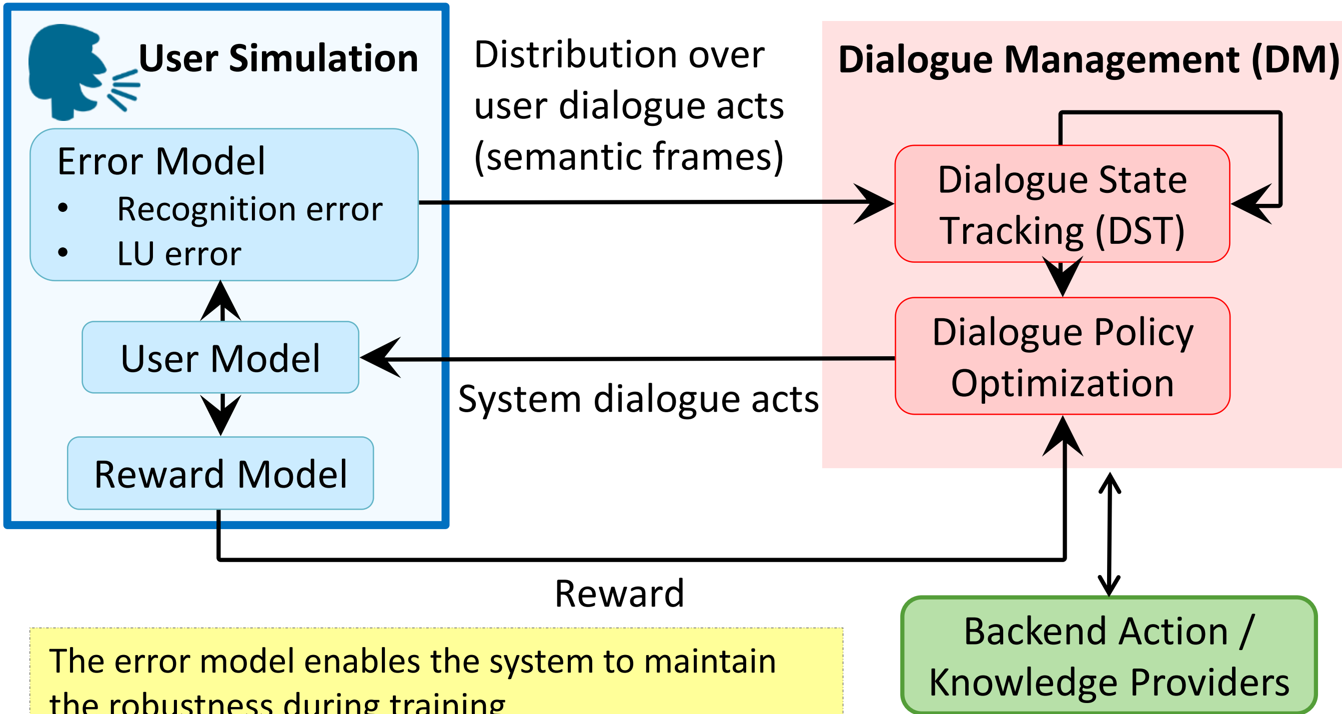
User Simulation

- First, generate a user goal.
- The user goal contains:
  - Dialog act
  - Inform slots
  - Request slots




```
{
  "request_slots": {
    "ticket": "UNK",
    "theater": "UNK"
  },
  "diaact": "request",
  "inform_slots": {
    "city": "birmingham",
    "numberofpeople": "2",
    "state": "al",
    "starttime": "4 pm",
    "date": "today",
    "moviename": "deadpool"
  }
}
```

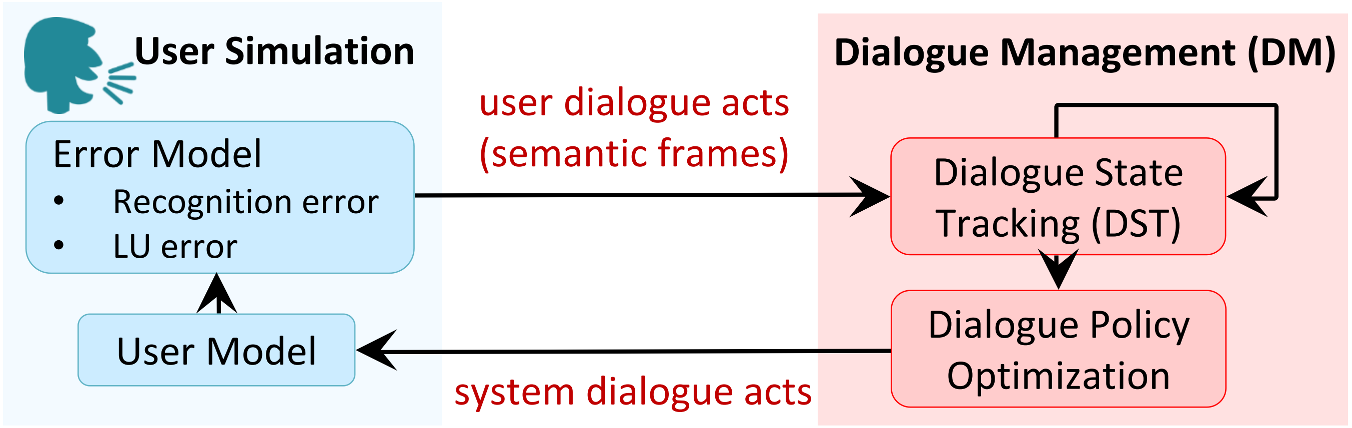
Elements of User Simulation



The error model enables the system to maintain the robustness during training

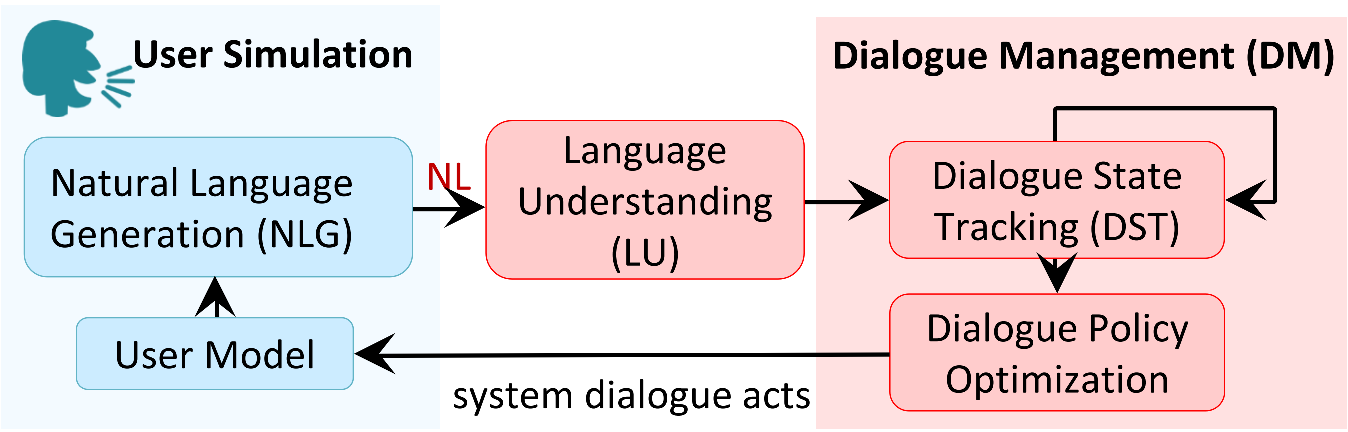
Frame-Level Interaction

- DM receives frame-level information
  - No error model: perfect recognizer and LU
  - Error model: simulate the possible errors



Natural Language Level Interaction

- User simulator sends natural language
  - No recognition error
  - Errors from NLG or LU



Rule-Based Simulator for RL Based System
(Li et.al., 2016)

http://arxiv.org/abs/1612.05688

- rule-based simulator + collected data
- starts with sets of goals, actions, KB, slot types
- publicly available simulation framework
- movie-booking domain: ticket booking and movie seeking
- provide procedures to add and test own agent

```
class AgentDQN(Agent):
    def run_policy(self, representation):
        """ epsilon-greedy policy """

        if random.random() < self.epsilon:
            return random.randint(0, self.num_actions - 1)
        else:
            if self.warm_start == 1:
                if len(self.experience_replay_pool) > self.experience_replay_pool_size:
                    self.warm_start = 2
                return self.rule_policy()
            else:
                return self.dqn.predict(representation, {}, predict_model=True)

    def train(self, batch_size=1, num_batches=100):
        """ Train DQN with experience replay """

        for iter_batch in range(num_batches):
            self.cur_bellman_err = 0
            for iter in range(len(self.experience_replay_pool)/(batch_size)):
                batch = [random.choice(self.experience_replay_pool) for i in xrange(batch_size)]
                batch_struct = self.dqn.singleBatch(batch, {'gamma': self.gamma}, self.clone_dqn)
```

Model-Based User Simulators

- Bi-gram models (Levin et.al. 2000)
- Graph-based models (Scheffler and Young, 2000)
- Data Driven Simulator (Jung et.al., 2009)
- Neural Models (deep encoder-decoder)

Data-Driven Simulator for Automated Evaluation (Jung et.al., 2009)

- Three step process
  1) User intention simulator

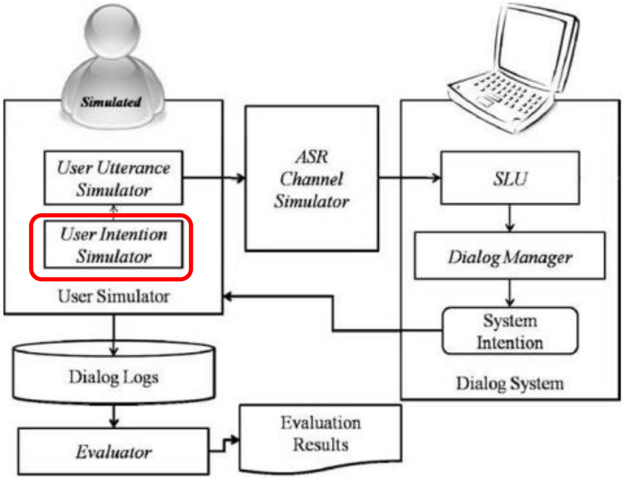
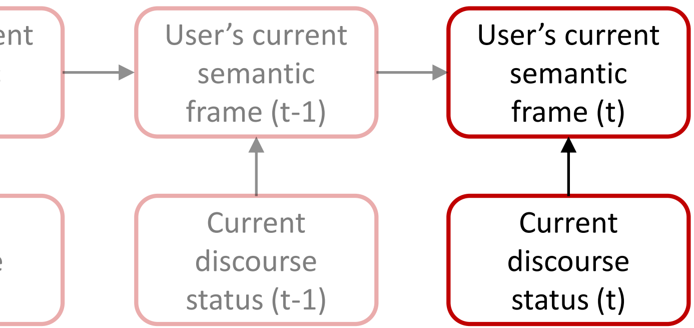


Fig. 1. Overall architecture of dialog simulation.

request+search_loc



features (DD+DI)

(*) compute all possible semantic frame given previous turn info
(*) randomly select one possible semantic frame

Data-Driven Simulator for Automated Evaluation (Jung et.al., 2009)

- Three step process
  1) User intention simulator
  2) User utterance simulator

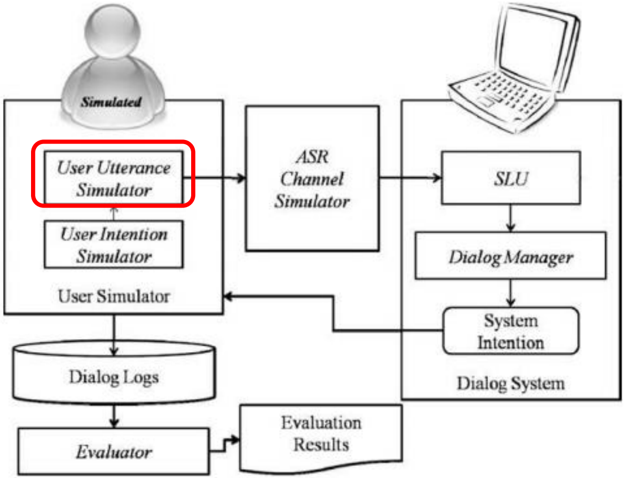


Fig. 1. Overall architecture of dialog simulation.

request+search_loc

I **want** to **go** to the **city hall**

PRP VB TO VB TO [loc_name]

Given a list of POS tags associated with the semantic frame, using LM+Rules they generate the user utterance.

Data-Driven Simulator for Automated Evaluation (Jung et.al., 2009)

- Three step process:
  1) User intention simulator
  2) User utterance simulator
  3) ASR channel simulator
- Evaluate the generated sentences using BLUE-like measures against the reference utterances collected from humans (with the same goal)

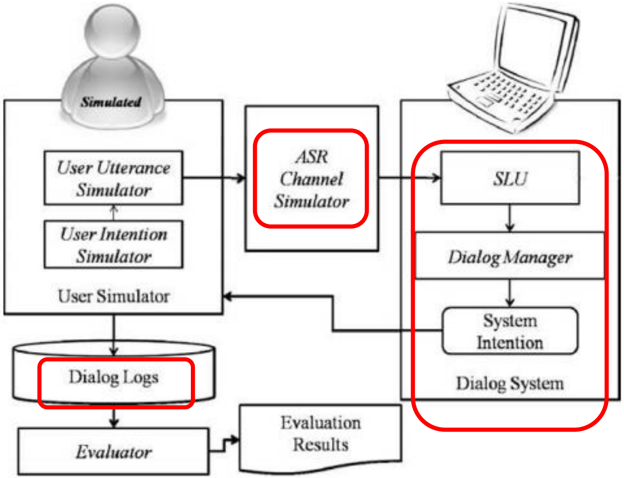
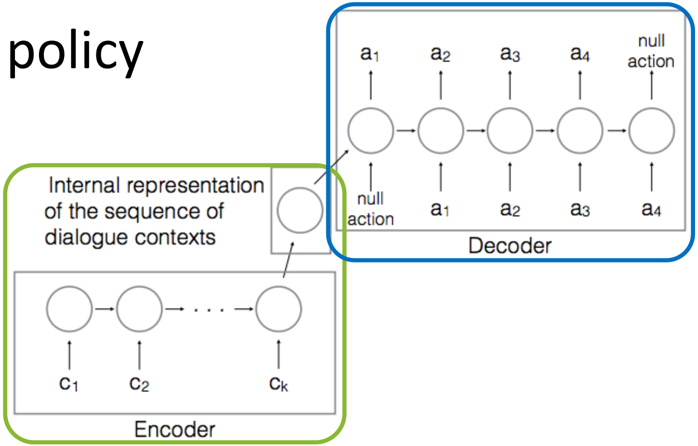


Fig. 1. Overall architecture of dialog simulation.

Seq2Seq User Simulation (El Asri et al., 2016)

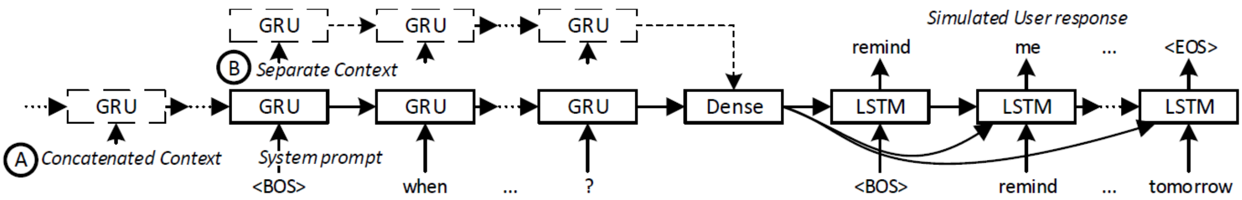
https://arxiv.org/abs/1607.00070

- Seq2Seq trained from dialogue data
  - Input: c_i encodes contextual features, such as the previous system action, consistency between user goal and machine provided values
  - Output: a dialogue act sequence form the user
- Extrinsic evaluation for policy



Seq2Seq User Simulation (Crook and Marin, 2017)

- Seq2Seq trained from dialogue data
  - No labeled data
  - Trained on just human to machine conversations



User Simulator for Dialogue Evaluation Measures

Understanding Ability

- whether **constrained values** specified by users can be understood by the system
- agreement percentage of system/user understandings over the entire dialog (averaging all turns)

Efficiency

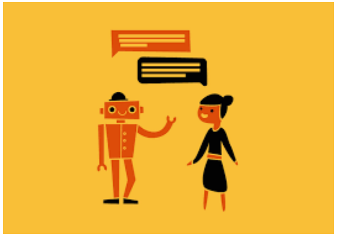
- Number of dialogue turns
- Dissimilarity between the dialogue turns (larger is better)

Action Appropriateness

- an explicit **confirmation** for an uncertain user utterance is an appropriate system action
- providing information based on misunderstood user requirements

How NOT to Evaluate Dialogue System
(Liu et.al., 2017)

https://arxiv.org/pdf/1603.08023.pdf



- How to evaluate the quality of the generated response ?
  - Specifically investigated for chat-bots
  - Crucial for task-oriented tasks as well
- Metrics:
  - Word overlap metrics, e.g., BLEU, METEOR, ROUGE, etc.
  - Embeddings based metrics, e.g., contextual/meaning representation between target and candidate

Dialogue Response Evaluation (Lowe et al., 2017)

- Problems of existing automatic evaluation
  - can be biased
  - correlate poorly with human judgements of response quality
  - using word overlap may be misleading
- Solution
  - collect a dataset of accurate human scores for variety of dialogue responses (e.g., coherent/un-coherent, relevant/irrelevant, etc.)
  - use this dataset to train an automatic dialogue evaluation model – learn to compare the reference to candidate responses!
  - Use RNN to predict scores by comparing against human scores!

Context of Conversation **Speaker A:** *Hey, what do you want to do tonight?* **Speaker B:** *Why don't we go see a movie?*
Model Response *Nah, let's do something active.*
Reference Response *Yeah, the film about Turing looks great!*

Recent Trends and Challenges

End-to-End Learning for Dialogues

Dialogue Breadth

Dialogue Depth

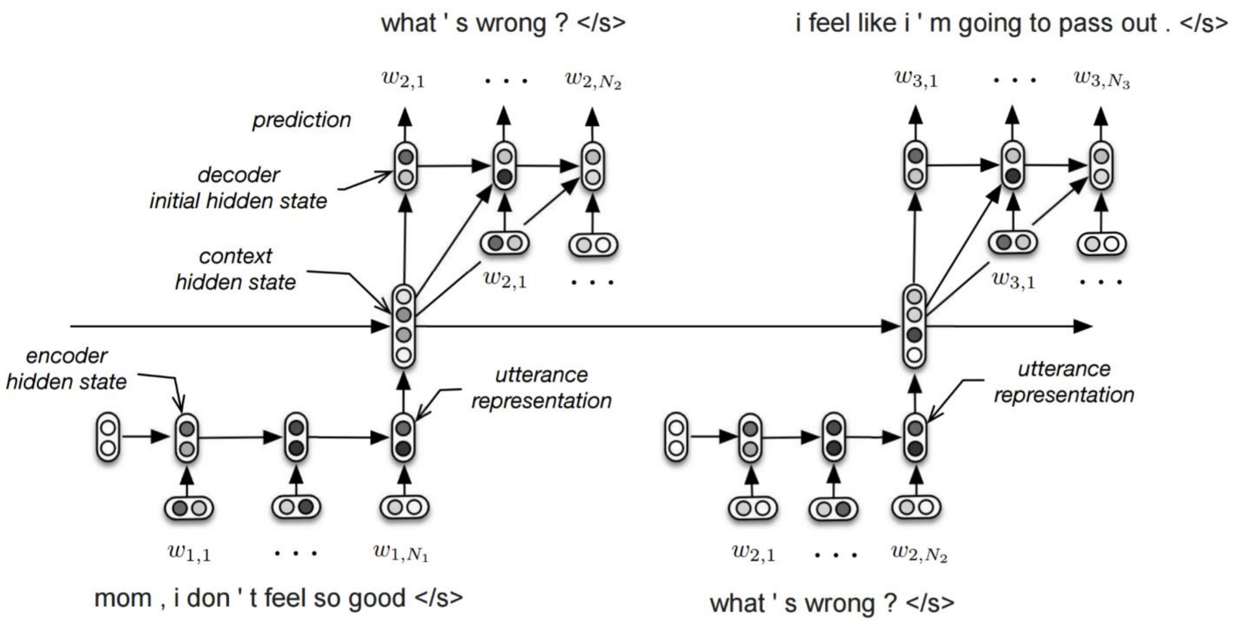
Outline

ChitChat Hierarchical Seq2Seq

(Serban et.al., 2016)

http://www.aaai.org/ocs/index.php/AAAI/AAAI16/paper/view/11957

- A hierarchical seq2seq model for generating dialogues

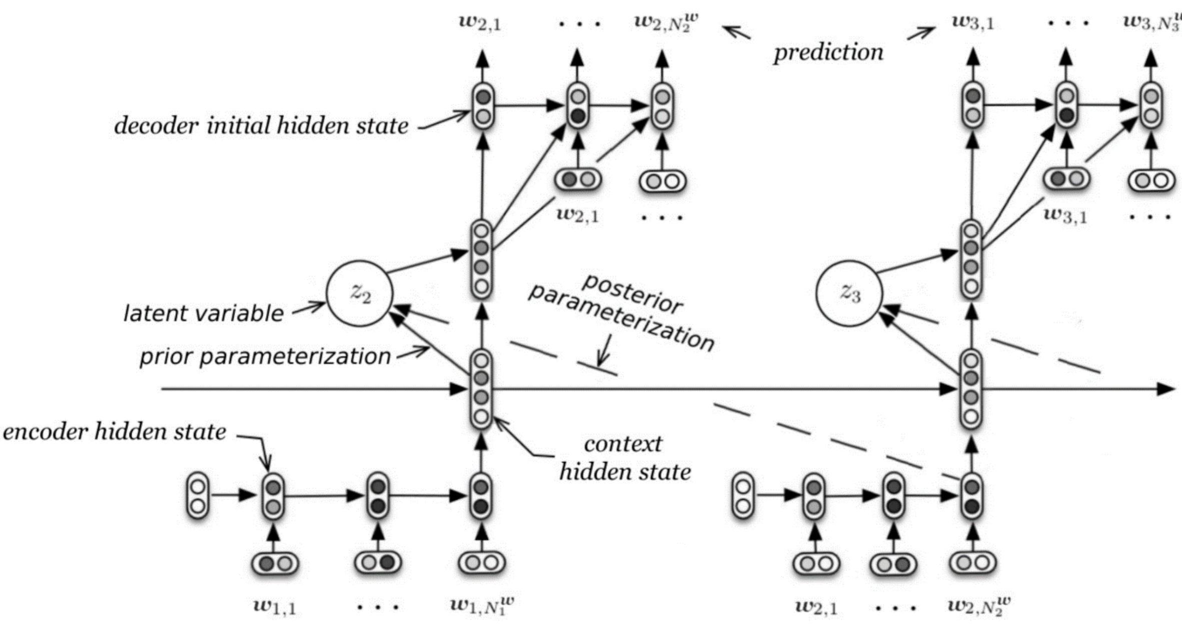


ChitChat Hierarchical Seq2Seq

(Serban et.al., 2017)

https://arxiv.org/abs/1605.06069

- A hierarchical seq2seq model with Gaussian latent variable for generating dialogues

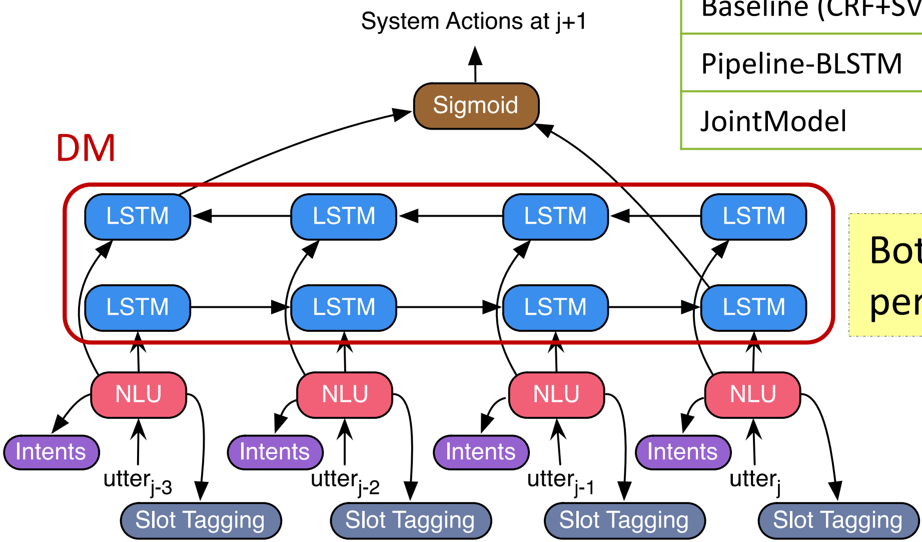


E2E Joint NLU and DM (Yang et al., 2017)

https://arxiv.org/abs/1612.00913

- Idea: errors from DM can be propagated to NLU for better robustness

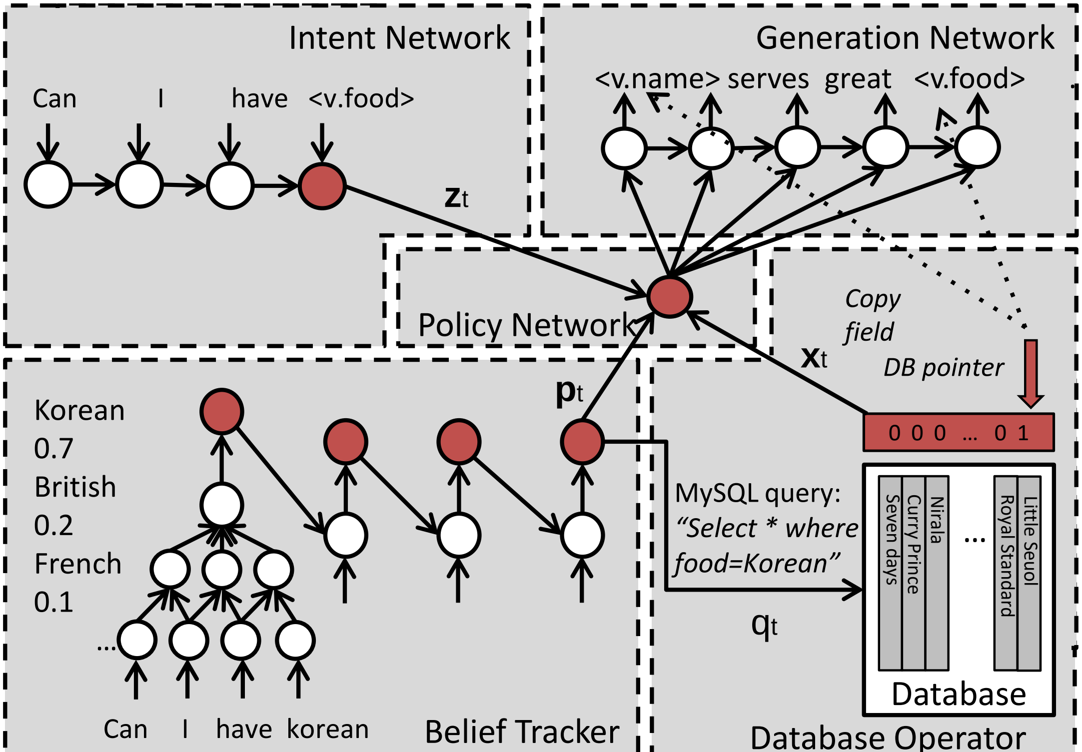
Model	DM	NLU
Baseline (CRF+SVMs)	7.7	33.1
Pipeline-BLSTM	12.0	36.4
JointModel	**22.8**	**37.4**



Both DM and NLU performance is improved

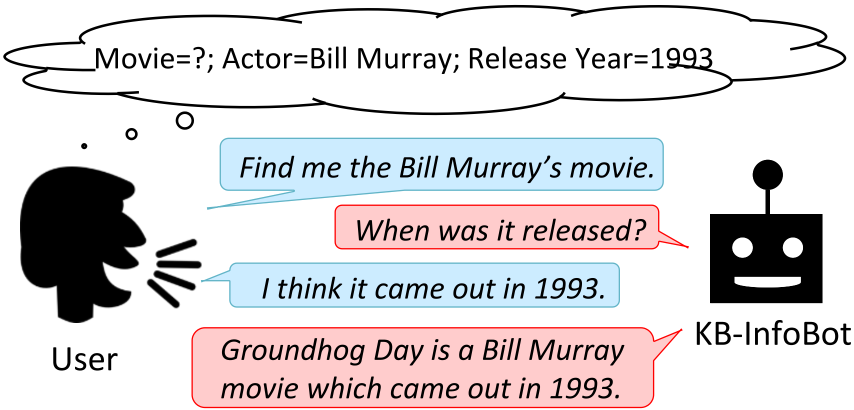
E2E Supervised Dialogue System (Wen et al., 2016)

https://arxiv.org/abs/1604.04562



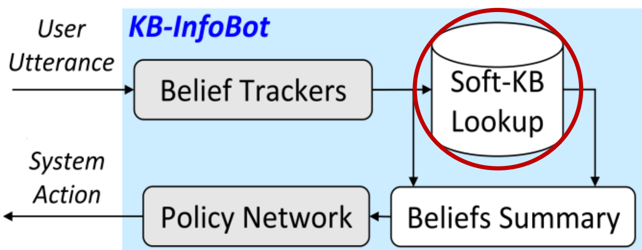
E2E RL-Based Info-Bot (Dhingra et al., 2016)

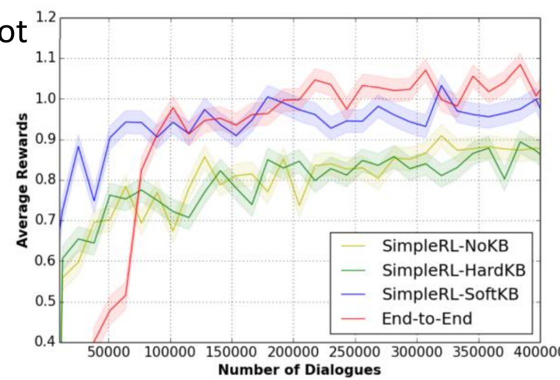
http://www.aclweb.org/anthology/P/P17/P17-1045.pdf



Entity-Centric Knowledge Base

Movie	Actor	Year
Groundhog Day	Bill Murray	1993
Australia	Nicole Kidman	X
Mad Max: Fury Road	X	2015

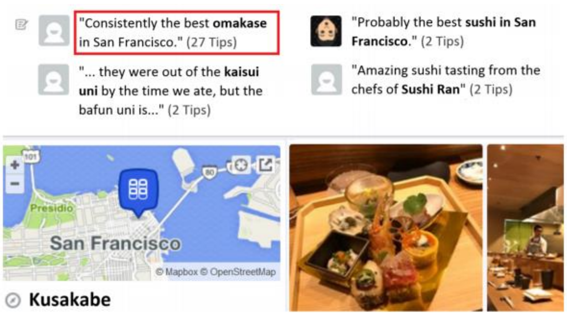




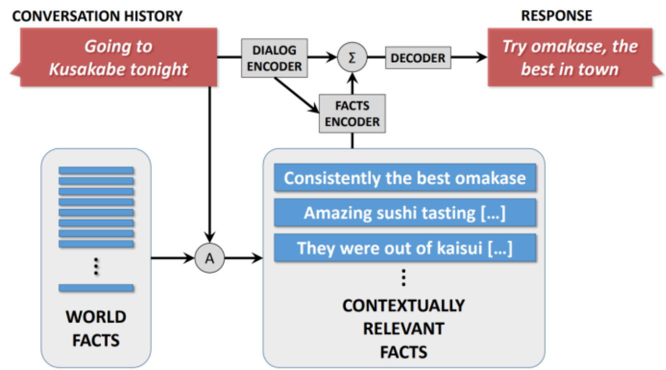
Idea: differentiable database for propagating the gradients

Knowledge Grounded Neural Conv. Model

(Ghazvininejad et al., 2017)



User input: *Going to Kusakabe tonight.*
Neural model: Have a great time!
Human: You'll love it! Try omasake, the best in town.



A: **Looking forward to trying** *@pizzalibretto* **tonight! my expectations are high.**
B: **Get** *the rocco salad.* **Can you eat** *calamari*?

A: **Anyone in** *Chi* **have a** *dentist office* **they recommend? I'm never going back to** *[...]* **and would love a reco!**
B: **Really looved** *Ora* **in** *Wicker Park.*

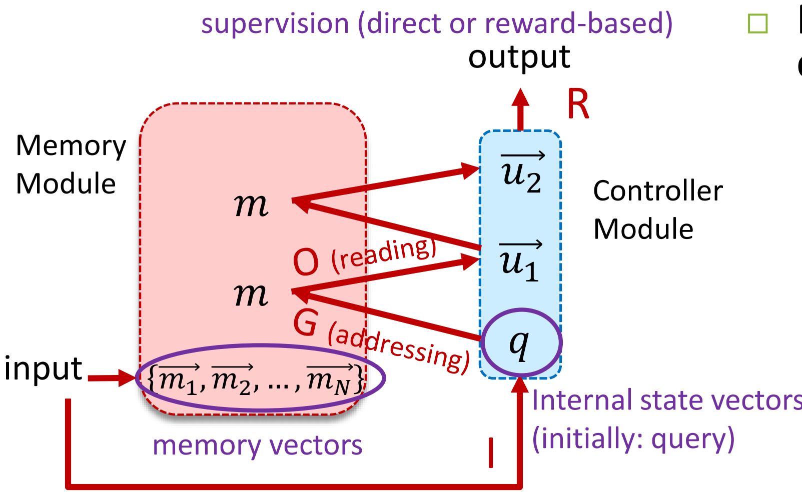
A: **I'm at** *California Academy of Sciences*
B: **Make sure you catch** *the show* **at** *the Planetarium.* **Tickets are usually limited.**

A: **I'm at** *New Wave Cafe.*
B: **Try to get to** *Dmitri's* **for dinner. Their** *pan fried scallops* **and** *shrimp scampi* **are to die for.**

A: **I just bought:** *[...] 4.3-inch portable GPS navigator* **for my wife, shh, don't tell her.**
B: **I heard this brand** *loses battery power.*

Memory Networks (Weston et al., 2014)

 https://arxiv.org/abs/1410.3916



Story (16: basic induction)	Support	Hop 1	Hop 2	Hop 3
Brian is a frog.	yes	0.00	0.98	0.00
Lily is gray.		0.07	0.00	0.00
Brian is yellow.	yes	0.07	0.00	1.00
Julius is green.		0.06	0.00	0.00
Greg is a frog.	yes	0.76	0.02	0.00
What color is Greg? Answer: yellow	Prediction: yellow			

- Memory networks have 4 components:
  - **I:** (input feature map) convert incoming data to the internal feature representation
  - **G:** (generalization) update memories given new input
  - **O:** produce new output (in feature representation space) given the memories
  - **R:** (response) convert output O into a response seen by the outside world

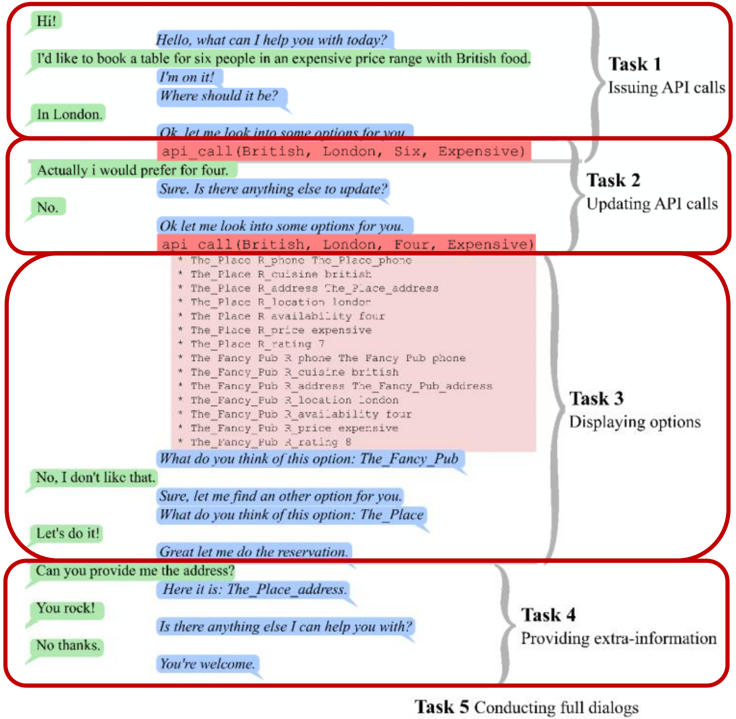
Memory module stores the history to make the model find the supporting facts

E2E MemNN for Dialogues (Bordes et al., 2016)

https://arxiv.org/abs/1605.07683

- Split dialogue system actions into subtasks
  - API issuing
  - API updating
  - Option displaying
  - Information informing

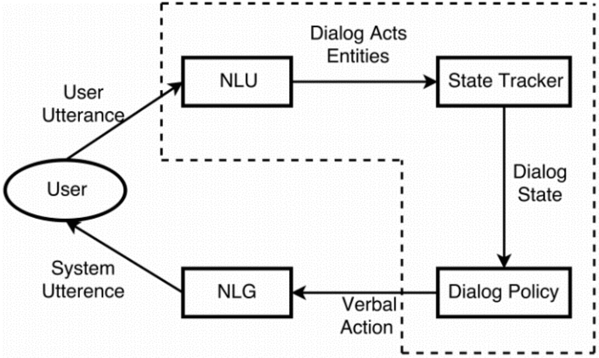
Task	Memory Networks no match type		Memory Networks + match type	
T1: Issuing API calls	**99.9**	(99.6)	**100**	(100)
T2: Updating API calls	**100**	(100)	98.3	(83.9)
T3: Displaying options	**74.9**	(2.0)	**74.9**	(0)
T4: Providing information	59.5	(3.0)	**100**	(100)
T5: Full dialogs	**96.1**	(49.4)	93.4	(19.7)
T1(OOV): Issuing API calls	72.3	(0)	**96.5**	(82.7)
T2(OOV): Updating API calls	78.9	(0)	**94.5**	(48.4)
T3(OOV): Displaying options	74.4	(0)	**75.2**	(0)
T4(OOV): Providing inform.	57.6	(0)	**100**	(100)
T5(OOV): Full dialogs	65.5	(0)	**77.7**	(0)
T6: Dialog state tracking 2	**41.1**	(0)	**41.0**	(0)

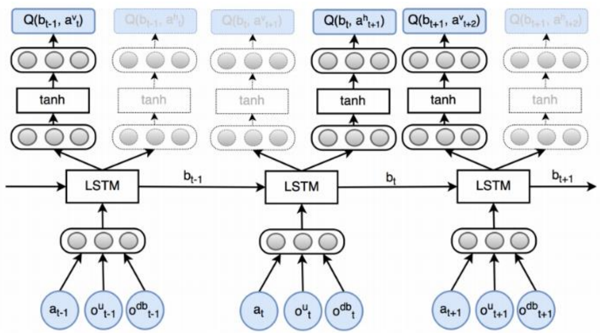


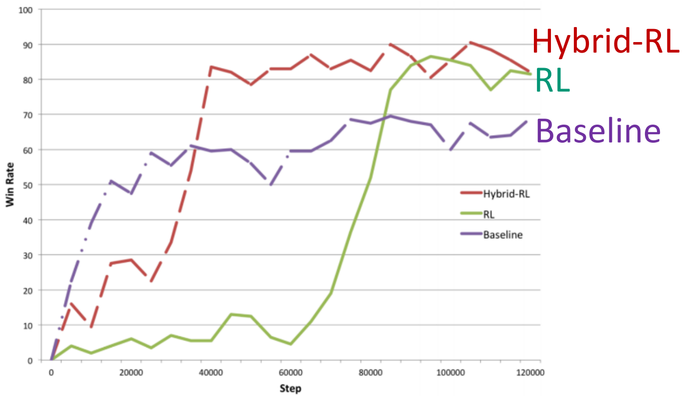
E2E RL-Based System (Zhao and Eskenazi, 2016)

http://www.aclweb.org/anthology/W/W16/W16-36.pdf#page=19

- Joint learning
  - NLU, DST, Dialogue Policy
- Deep RL for training
  - Deep Q-network
  - Deep recurrent network





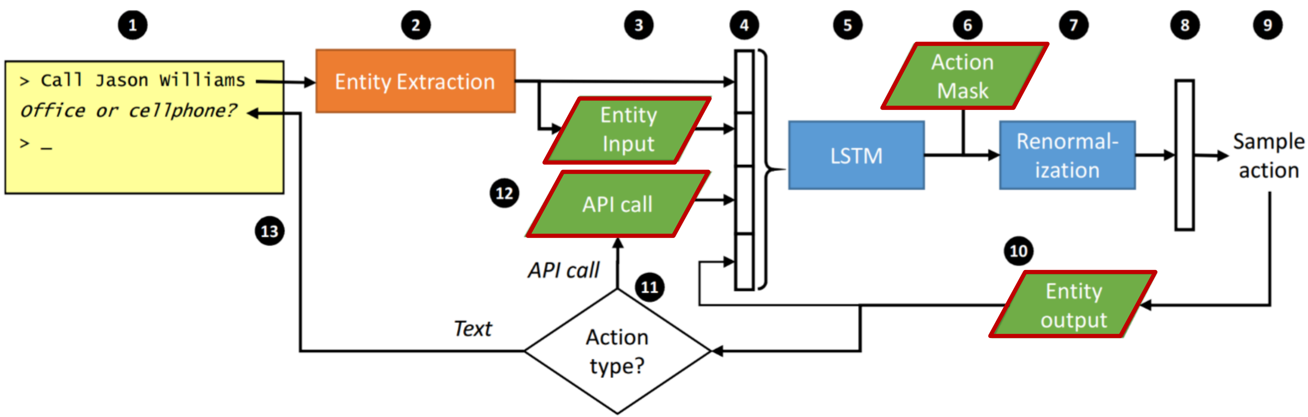


E2E LSTM-Based Dialogue Control

(Williams and Zweig, 2016)

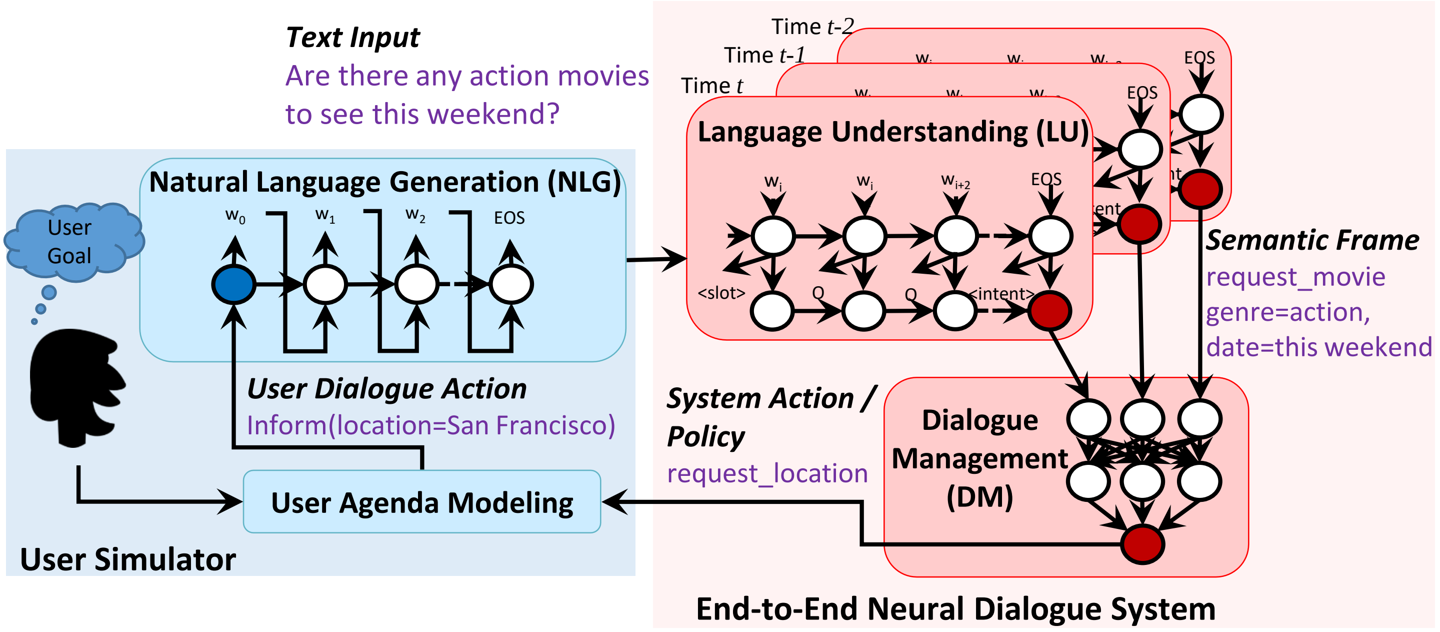
https://arxiv.org/abs/1606.01269

- Idea: an LSTM maps from raw dialogue history directly to a distribution over system actions
  - Developers can provide software including business rules & programmatic APIs
    → LSTM can take actions in the real world on behalf of the user
  - The LSTM can be optimized using SL or RL



E2E Task-Completion Bot (TC-Bot) (Li et al., 2017)

https://arxiv.org/abs/1703.01008



Idea: supervised learning for each component and reinforcement learning for end-to-end training the neural dialogue system

E2E Task-Completion Bot (TC-Bot) (Li et al., 2017)

https://arxiv.org/abs/1703.01008

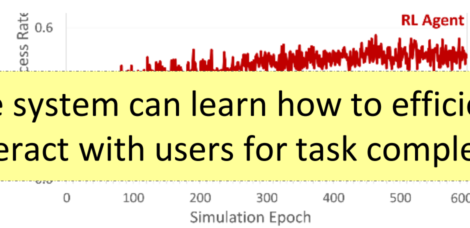
- User goal: ***Two tickets for "the witch" tomorrow 9:30 PM at regal meridian 16, Seattle.***

RULE BASED SYSTEM

User: Can I get 2 tickets for the witch?
Agent: Which theater do you want?
User: Regal meridian 16
Agent: What time would you like to see it?
User: 9:30 pm
Agent: What date would you like to see it?
User: Tomorrow!
Agent: How many people are you?
User: Just two adults.
Agent: What is your location?
User: Seattle!
Agent: What kind of video format do you like?
User: Oh, any kind is okay.
Agent: Do you have any price constraint?
User: No, I don't care.
Agent: Great - I was able to purchase 2 tickets for you to see the witch tomorrow at regal meridian 16 theater in Seattle at 9:30 pm.
User: Thank you.
Agent: Thank you!

REINFORCEMENT LEARNING SYSTEM

User: Can I get 2 tickets for the witch?
Agent: What date would you like to see it?
User: Tomorrow
Agent: Which theater do you prefer?
User: Regal meridian 16
Agent: What is your location?
User: Seattle
Agent: What time would you like to see it?
User: 9:30 pm.
Agent: Great - I was able to purchase 2 tickets for you to see the witch tomorrow at regal meridian 16 theater in Seattle at 9:30 pm.
User: Thanks.
Agent: Thanks!

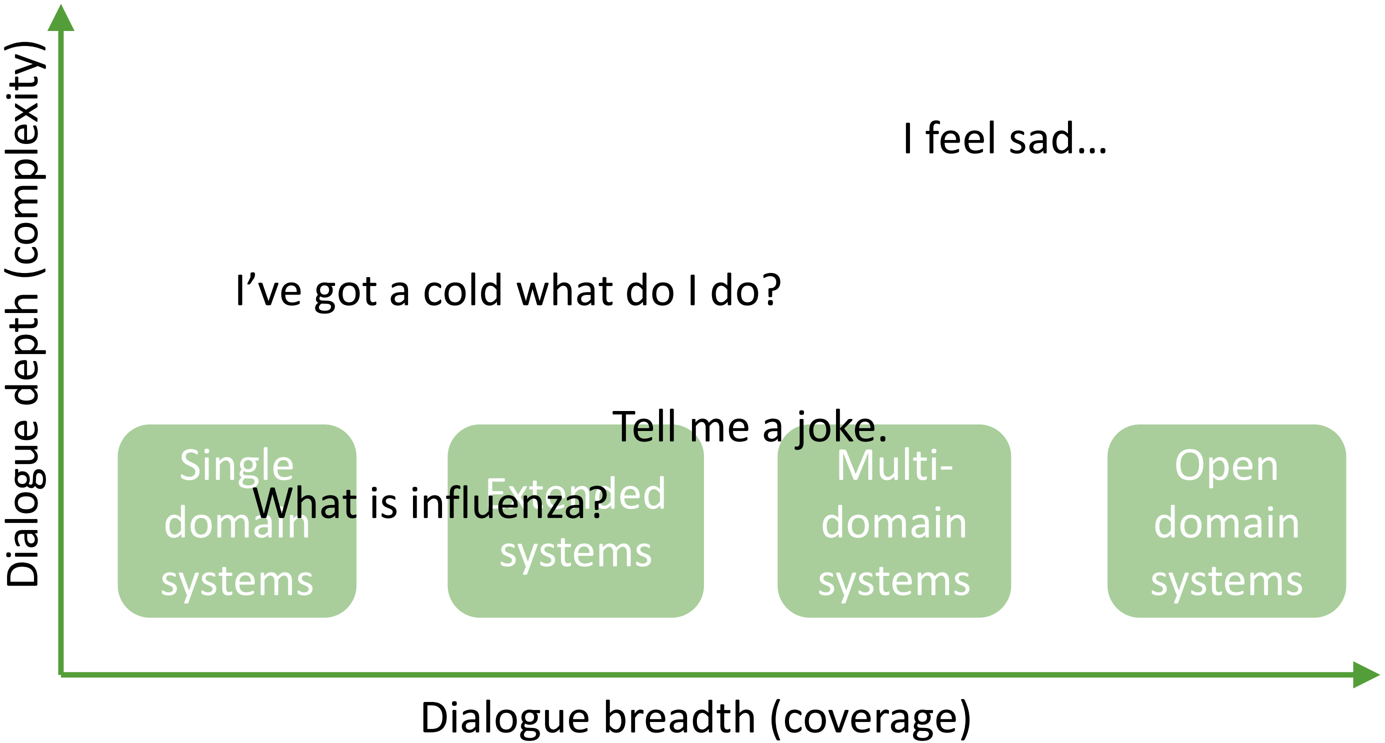


The system can learn how to efficiently interact with users for task completion

Outline

- Introduction & Background
  - Neural Networks
  - Reinforcement Learning
- Modular Dialogue System
  - Spoken/Natural Language Understanding (SLU/NLU)
  - Dialogue Management (DM)
    - Dialogue State Tracking (DST)
    - Dialogue Policy Optimization
  - Natural Language Generation (NLG)
- System Evaluation
- Recent Trends on Learning Dialogues
  - End-to-End Neural Dialogue Systems
  - **Dialogue Breadth**
  - Dialogue Depth

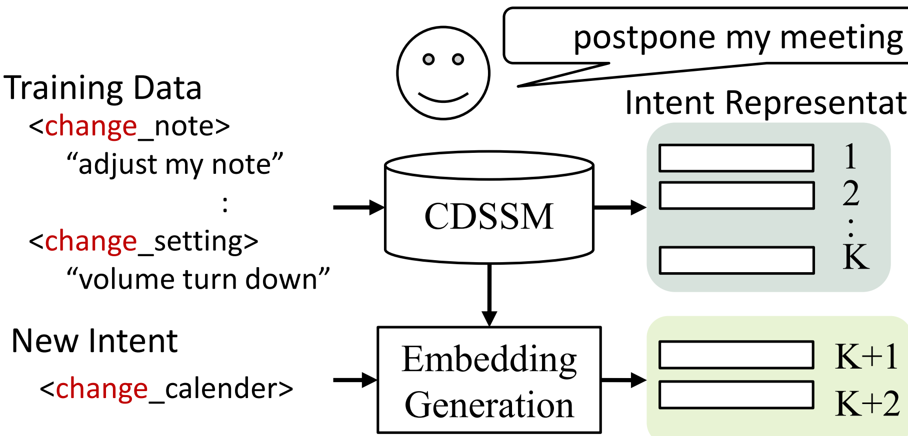
Evolution Roadmap

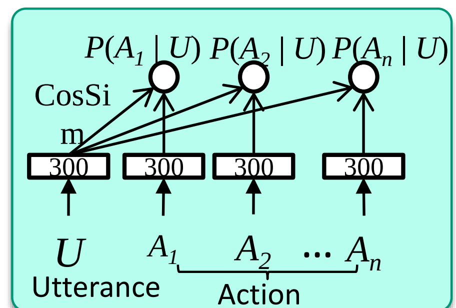


Intent Expansion (Chen et al., 2016)

http://ieeexplore.ieee.org/abstract/document/7472838/

- Transfer dialogue acts across domains
  - Dialogue acts are similar for multiple domains
  - Learning new intents by information from other domains



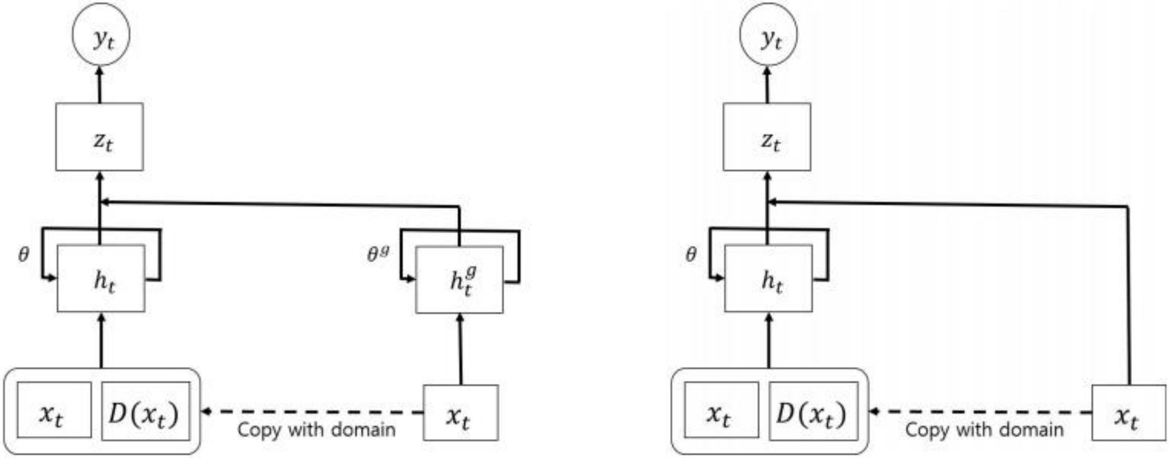


The dialogue act representations can be automatically learned for other domains

Domain Adaptation for SLU (Kim et al., 2016)

http://www.aclweb.org/anthology/C/C16/C16-1038.pdf

- Frustratingly easy domain adaptation
- Novel neural approaches to domain adaptation
- Improve slot tagging on several domains



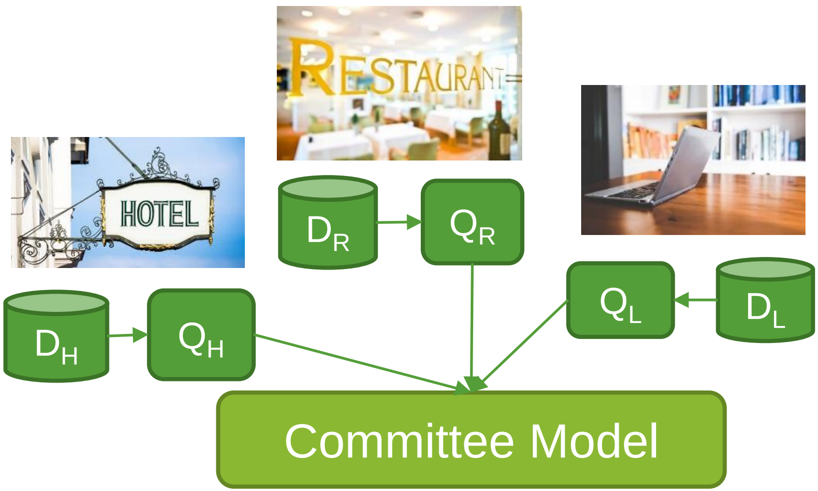
(a) 1 domain specific LSTM + generic LSTM

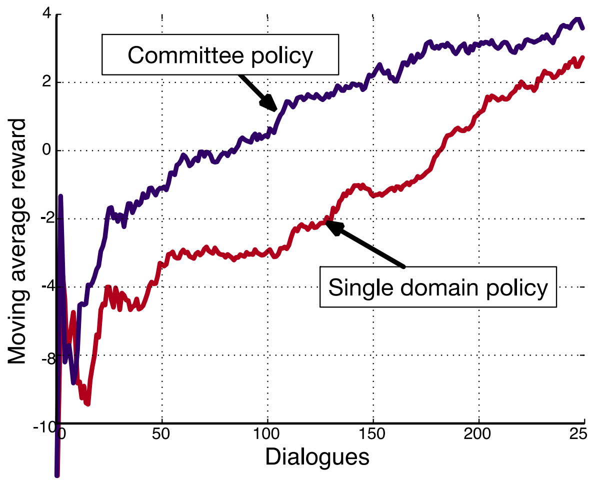
(b) 1 domain specific LSTM + generic embedding

Policy for Domain Adaptation (Gašić et al., 2015)

http://ieeexplore.ieee.org/abstract/document/7404871/

- Bayesian committee machine (BCM) enables estimated Q-function to share knowledge across domains





The policy from a new domain can be boosted by the committee policy

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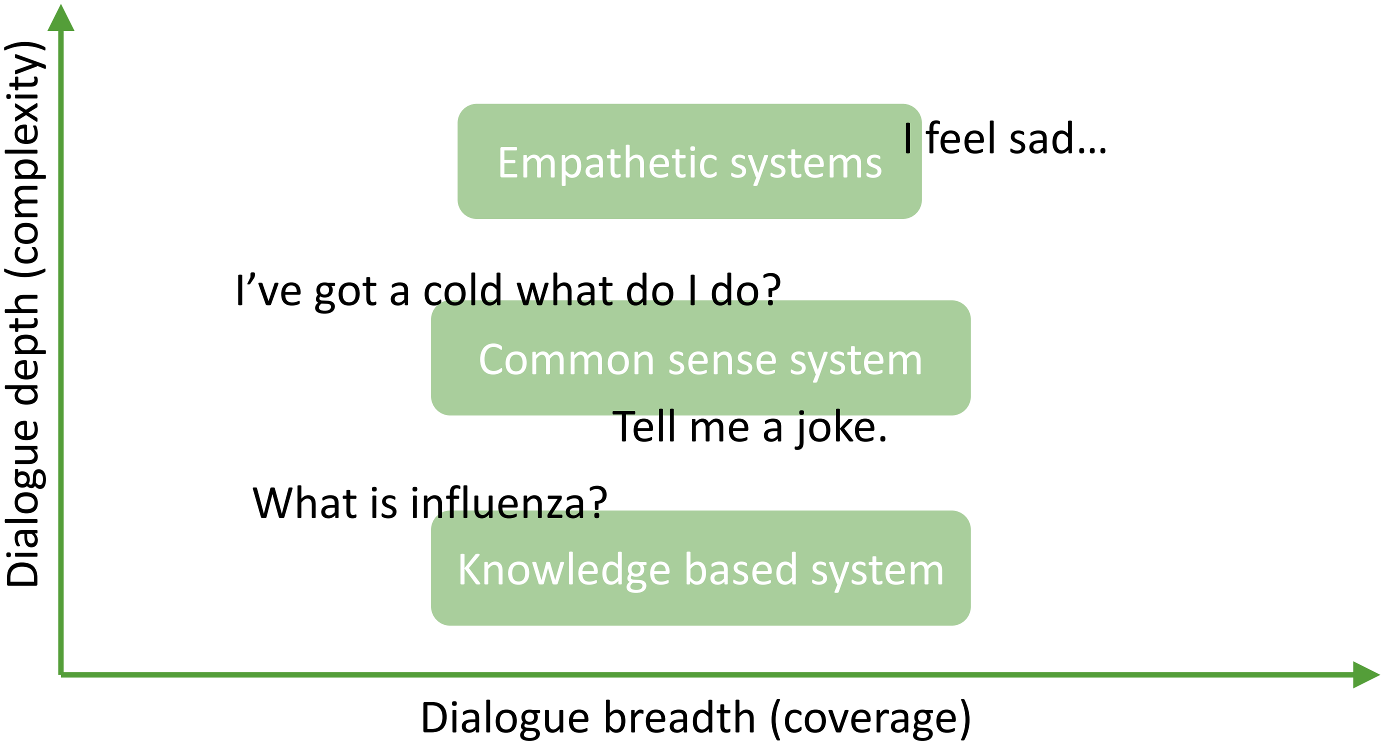
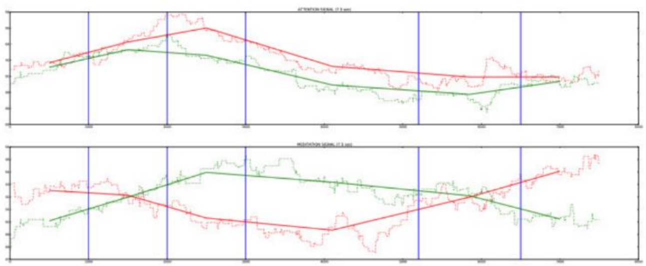
Evolution Roadmap



Brain Signal for Understanding

http://dl.acm.org/citation.cfm?id=2388695

- Misunderstanding detection by brain signal
  - Green: listen to the correct answer
  - Red: listen to the wrong answer



Detecting misunderstanding via brain signal in order to correct the understanding results

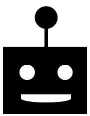
Video for Intent Understanding

I want to see a movie on TV!

Intent: turn_on_tv

Proactive (from camera)

May I turn on the TV for you?

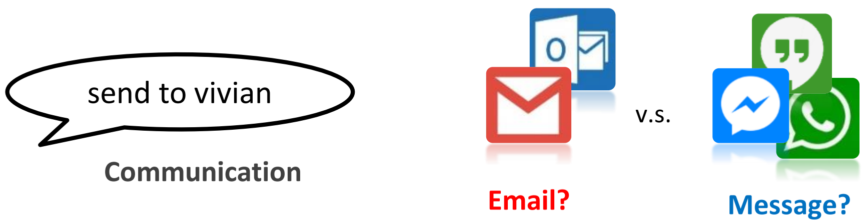


Proactively understanding user intent to initiate the dialogues.

App Behavior for Understanding

http://dl.acm.org/citation.cfm?id=2820781

- Task: user intent prediction
- Challenge: language ambiguity



① **User preference**
- ✓ Some people prefer "Message" to "Email"
- ✓ Some people prefer "Ping" to "Text"

② **App-level contexts**
- ✓ "Message" is more likely to follow "Camera"
- ✓ "Email" is more likely to follow "Excel"

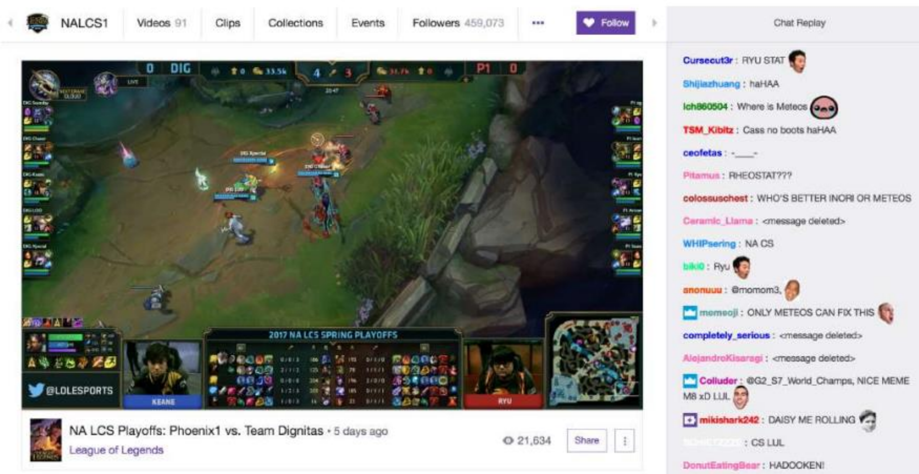
Considering behavioral patterns in history to model understanding for intent prediction.

Material: http://deepdialogue.miulab.tw

Video Highlight Prediction Using Audience Chat Reactions

Fu et.al., EMNLP 2017

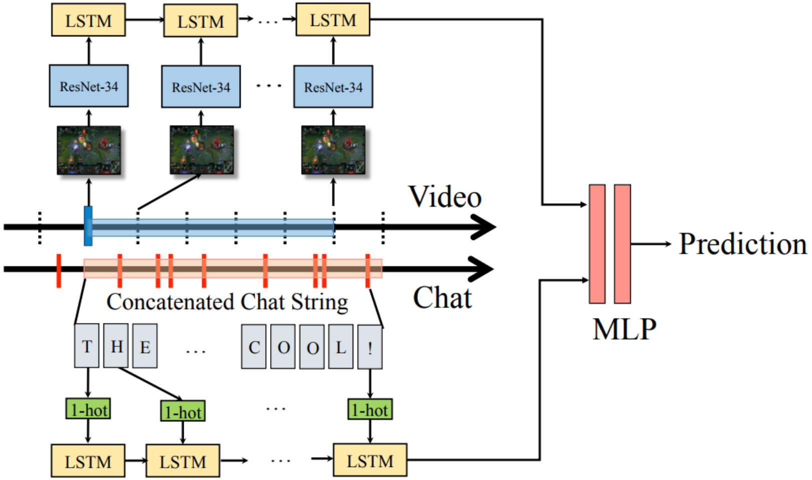
https://arxiv.org/pdf/1707.08559.pdf



Video Highlight Prediction Using Audience Chat Reactions

Fu et.al., EMNLP 2017 https://arxiv.org/pdf/1707.08559.pdf

- Goal: predict highlight from the video
- Input : multi-modal and multi-lingual (real time text commentary from fans)
- Output: tag if a frame part of a highlight or not

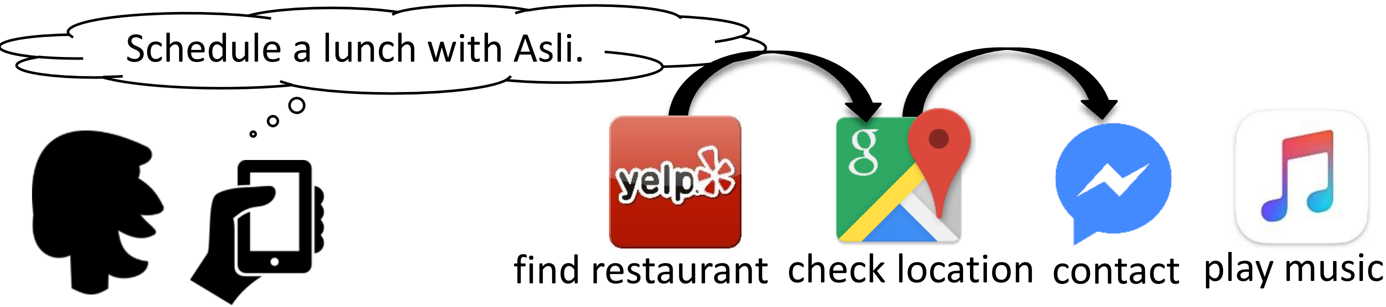


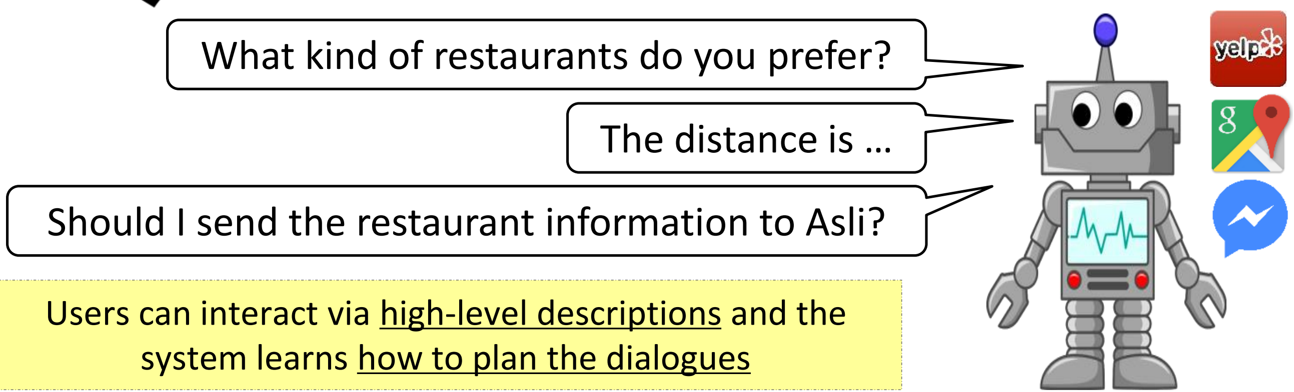
High-Level Intention for Dialogue Planning

(Sun et al., 2016; Sun et al., 2016)

http://dl.acm.org/citation.cfm?id=2856818; http://www.lrec-conf.org/proceedings/lrec2016/pdf/75_Paper.pdf

- High-level intention may span several domains



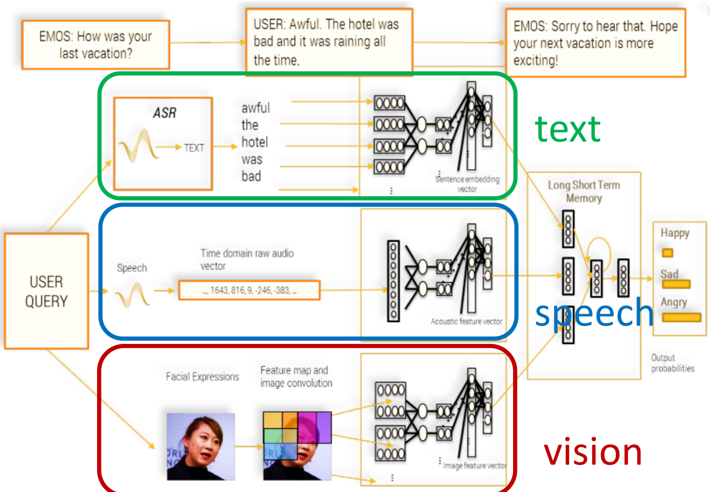


Users can interact via <u>high-level descriptions</u> and the system learns <u>how to plan the dialogues</u>

Empathy in Dialogue System (Fung et al., 2016)

https://arxiv.org/abs/1605.04072

- Embed an empathy module
  - Recognize emotion using multimodality
  - Generate emotion-aware responses



Emotion Recognizer

Zara - The Empathetic Supergirl

Face recognition output

(index):1728

(index):1729


```
{
  "recognition": "Race: Asian Confidence: 65.42750000000001 Smiling: 3.95896 Gender: Female Confidence: 88.9369",
  "race": "Asian",
  "race_confidence": "65.42750000000001",
  "smiling": "3.95896",
  "gender": "Female",
  "gender_confidence": "88.9369"
}
```

Visual Object Discovery through Dialogues
(Vries et al., 2017)

https://arxiv.org/pdf/1611.08481.pdf

- Recognize objects using "Guess What?" game
- Includes "spatial", "visual", "object taxonomy" and "interaction"

Is it a person?	*No*
Is it an item being worn or held?	*Yes*
Is it a snowboard?	*Yes*
Is it the red one?	*No*
Is it the one being held by the person in blue?	*Yes*

Is it a cow?	*Yes*
Is it the big cow in the middle?	*No*
Is the cow on the left?	*No*
On the right ?	*Yes*
First cow near us?	*Yes*

Conclusion

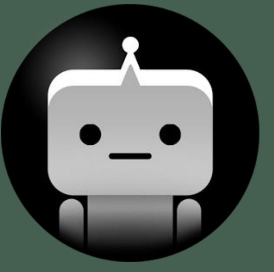
Challenge Summary

- Human-machine interfaces is a hot topic but several components must be integrated!
- Most state-of-the-art technologies are based on DNN
  - Requires huge amounts of labeled data
  - Several frameworks/models are available
- Fast domain adaptation with scarse data + re-use of rules/knowledge
- Handling reasoning
- Data collection and analysis from un-structured data
- Complex-cascade systems requires high accuracy for working good as a whole

Brief Conclusions

- Introduce recent deep learning methods used in dialogue models
- Highlight main components of dialogue systems and new deep learning architectures used for these components
- Talk about challenges and new avenues for current state-of-the-art research
- Provide all materials online!

http://deepdialogue.miulab.tw



Thanks to Tsung-Hsien Wen, Pei-Hao Su, Li Deng, Jianfeng Gao, Sungjin Lee, Milica Gašić, Lihong Li, Xiujin Li, Abhinav Rastogi, Ankur Bapna, Pararth Shah, Shyam Udaphyay and Gokhan Tur for sharing their slides.

THANKS FOR YOUR ATTENTION!

Q & A