

Conversational IR

Mohammad Aliannejadi
University of Amsterdam

Information Retrieval Evolution

- Search on desktop
 - Web search
 - Desktop search
 - Email search, etc.
- Search on smartphones
 - Web search
 - App search: email, facebook, etc.
 - Zero-query retrieval: information cards
- Search through conversation
 - Multi-modal information access
 - Limited-channel

Search on desktop

- Query
- Search result page
- Relevance perception
- User and system interaction:
 - Snippet scanning
 - Result click
 - Page click
 - Verticals
 - Information cards
 - etc.

Google dinosaur

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Top stories

- Police in hysterics as they chase 8ft inflatable 'dinosaur' down street (The Sun - 11 hours ago)
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 Evolution of dinosaurs · Feathered dinosaurs · Dinosaur (disambiguation)
 · Clade

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What type of dinosaur is blue?
When did dinosaurs become extinct?
What was the first dinosaur?
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Searches related to dinosaur

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dinosaurs names	dinosaur extinction
dinosaur history	dinosaurs games
dinosaur lower classifications	dinosaurs video

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Dinosaur

Reptile

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Scientific name: Dinosauria

Higher classification: Dinosauriformes

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Subclass: Diapsid

Lower classifications

Tyrann... rex Bird Veloci... Spino... Diplodoc...

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Tyrannos... rex


Bird

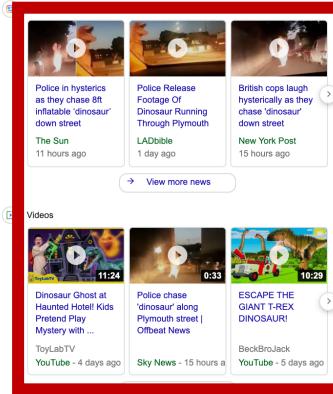

Velociraptor


Spinosaur...


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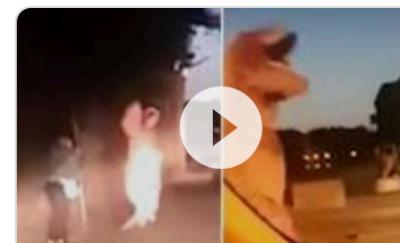
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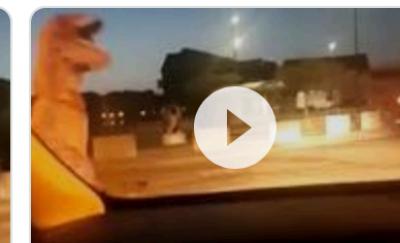
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11 hours ago



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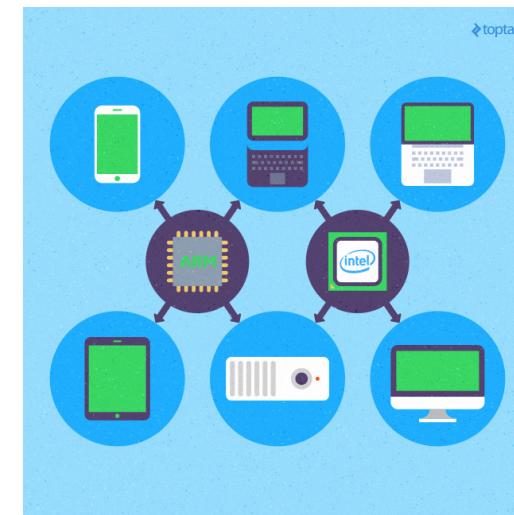
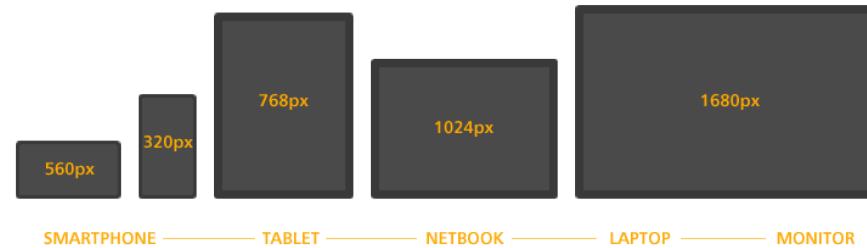
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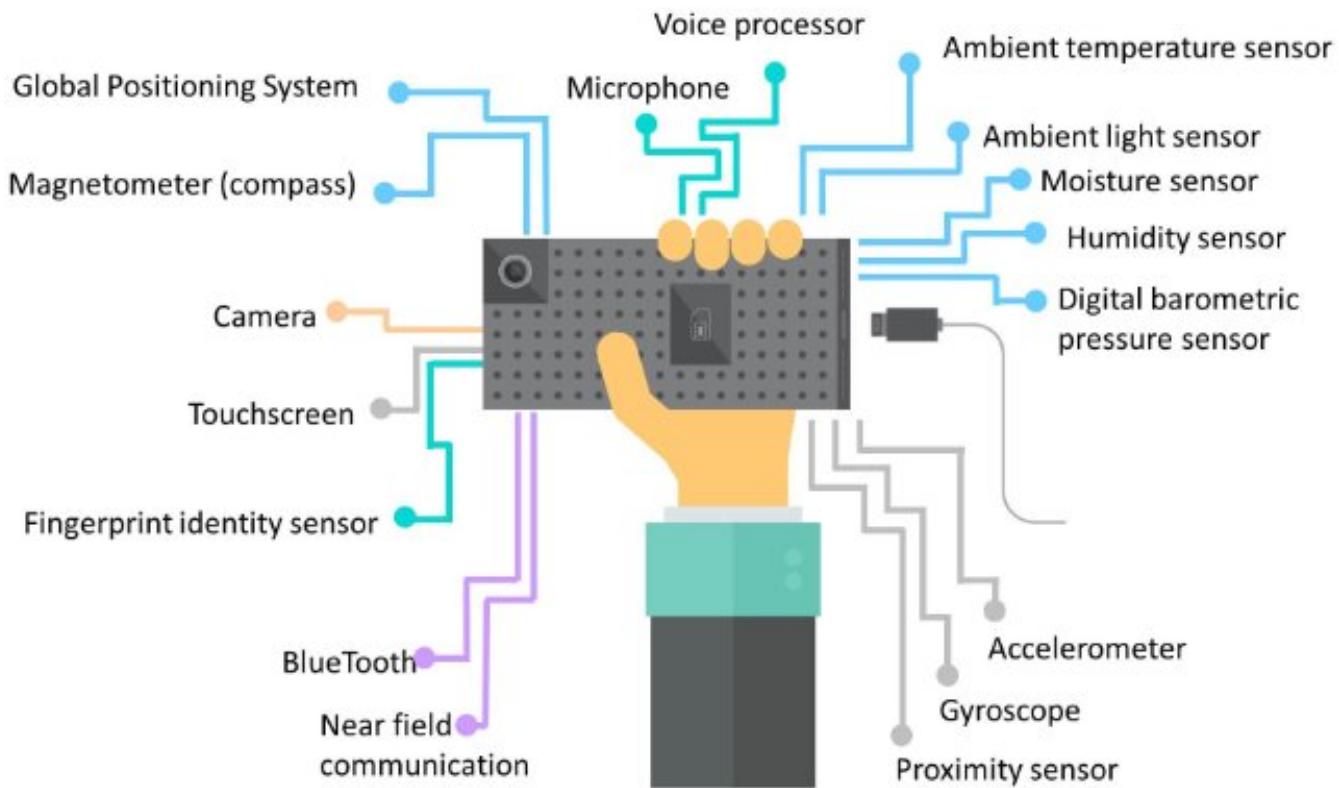
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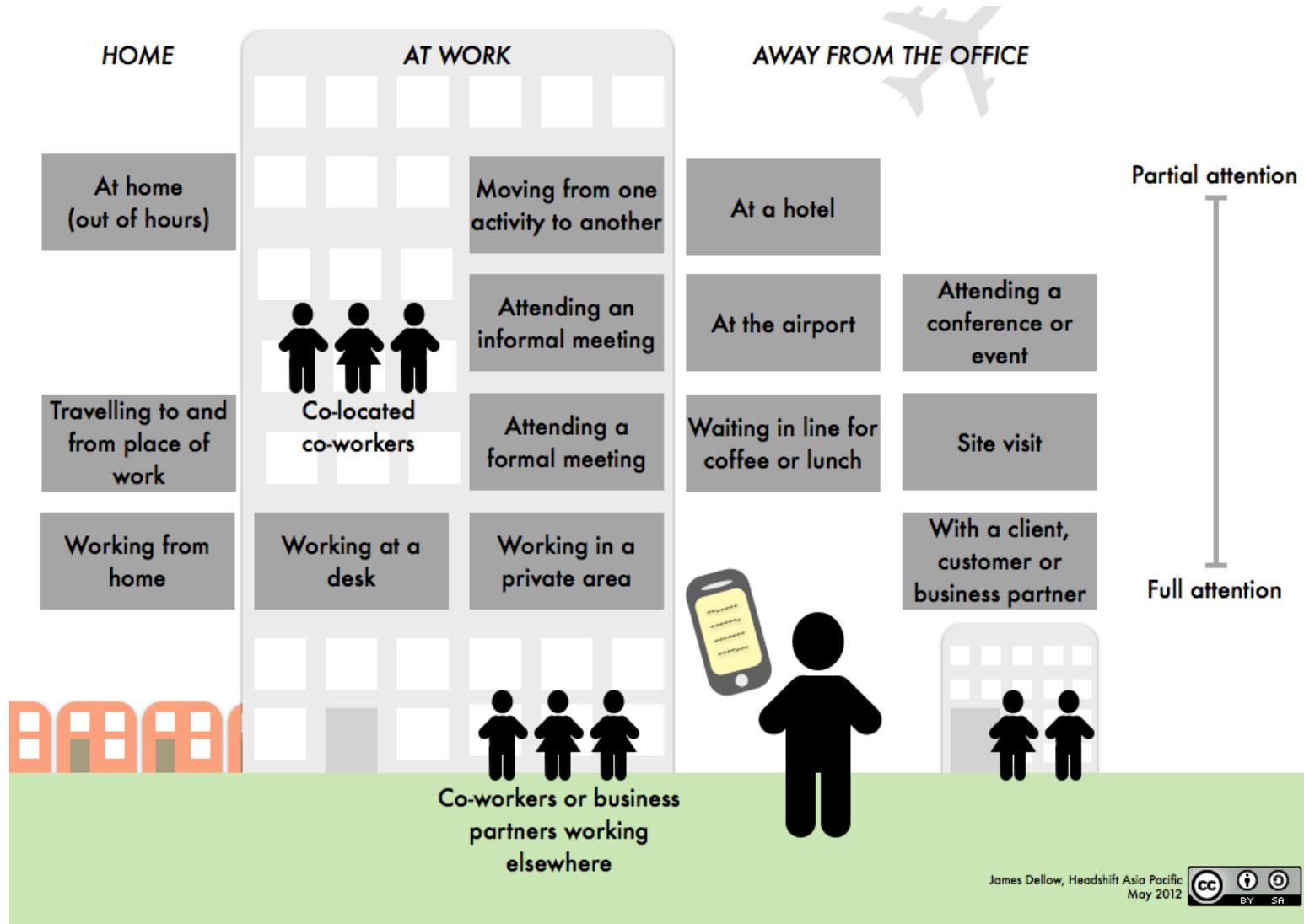
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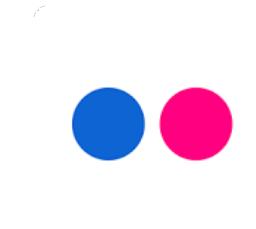


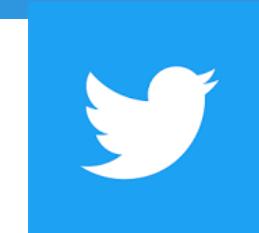
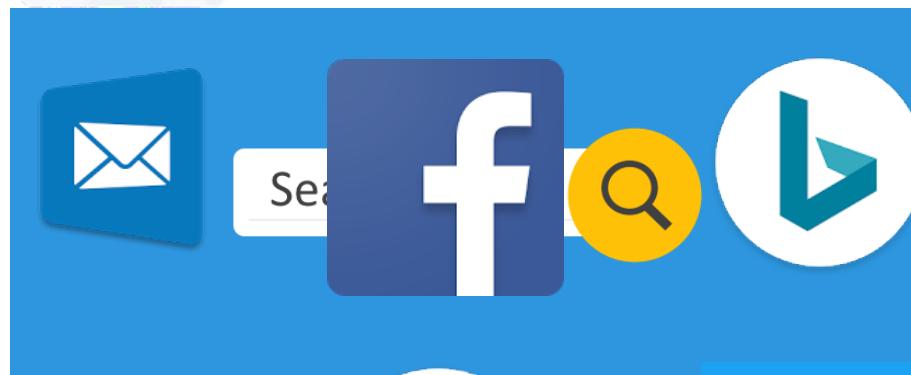
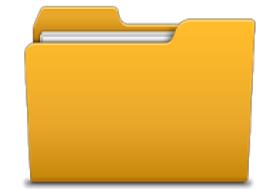
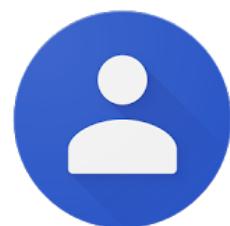
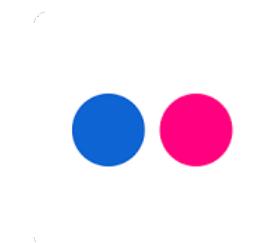
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Index of Different Mobile Searches by Context









Examples?

- Smartphones: SIRI, Google Assistant
- Cars
- Robots
- Clinical uses for mental health
- Chatting for fun

Outline

- User Interactions
- Evaluation
- Document Representation
- Learning to Rank

User Interactions

Types of Conversations

- Single initiatives
- Mixed initiatives
- Goal-based dialog agents
- Chatbots
- Question answering
- Information seeking
- Recommendation

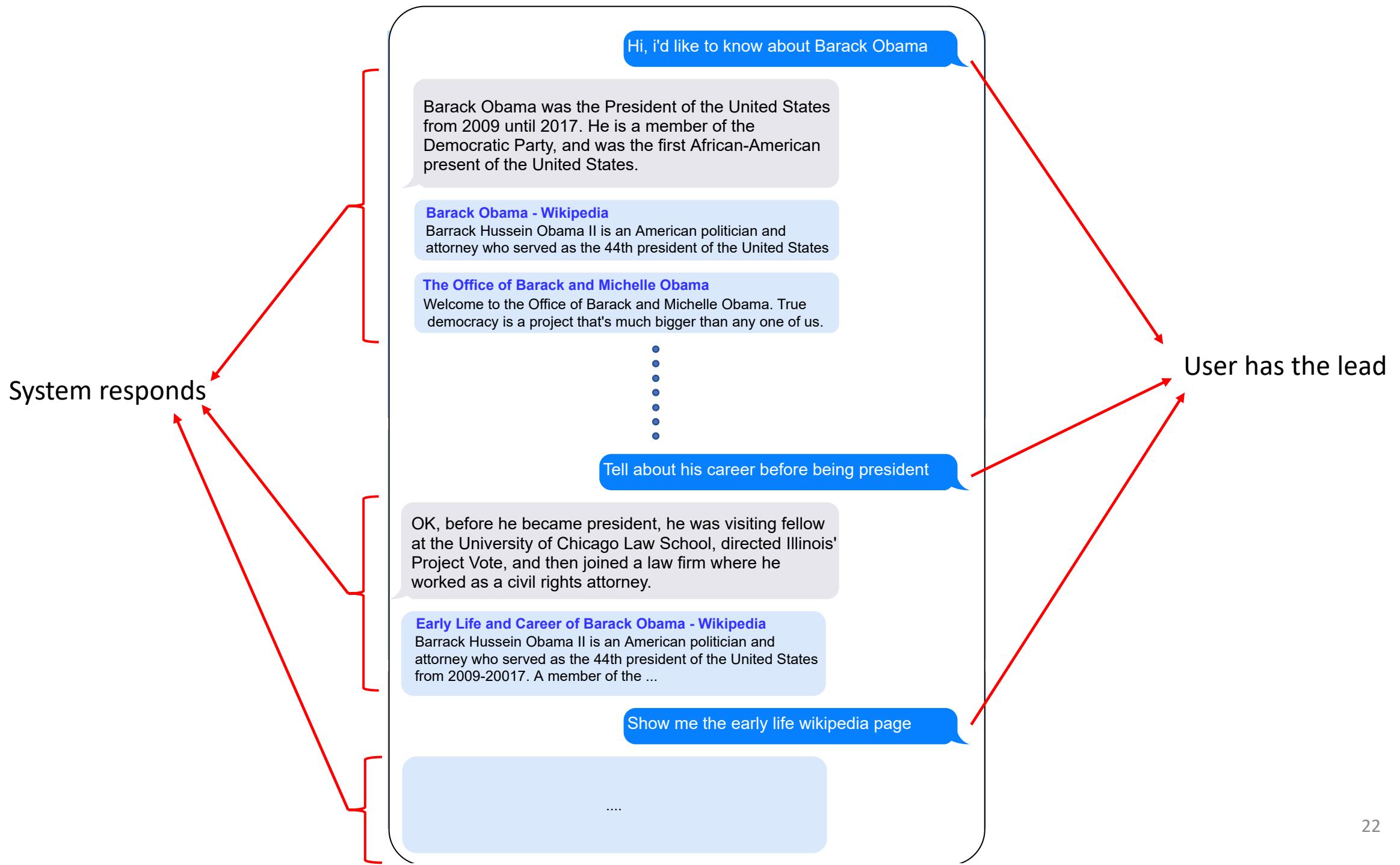
Single vs. Mixed Initiative

Single Initiatives

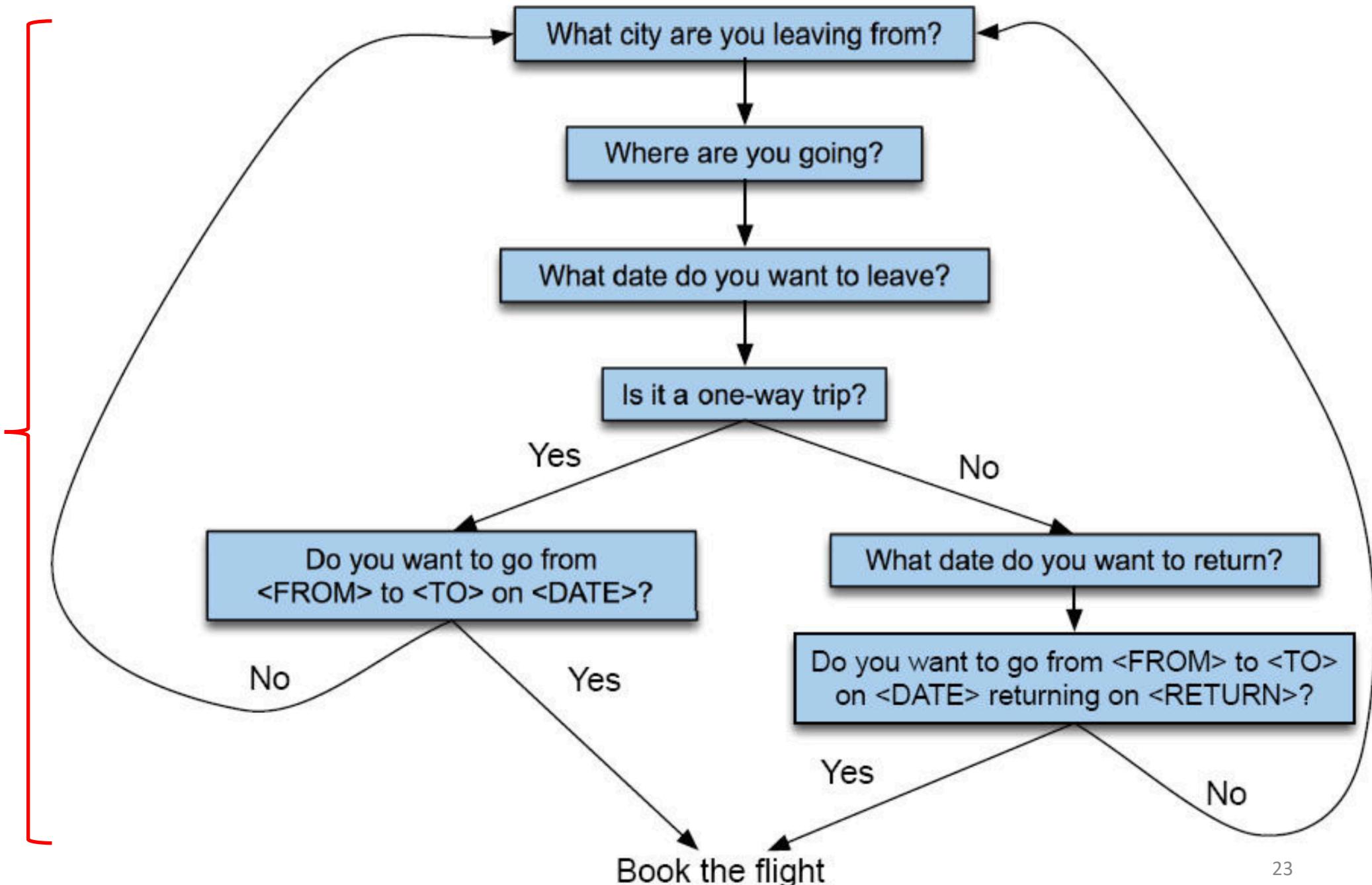
- User has the control
- System is passive
- Only responds to user's requests
- System has the control
- User is passive
- Only responds to system's requests

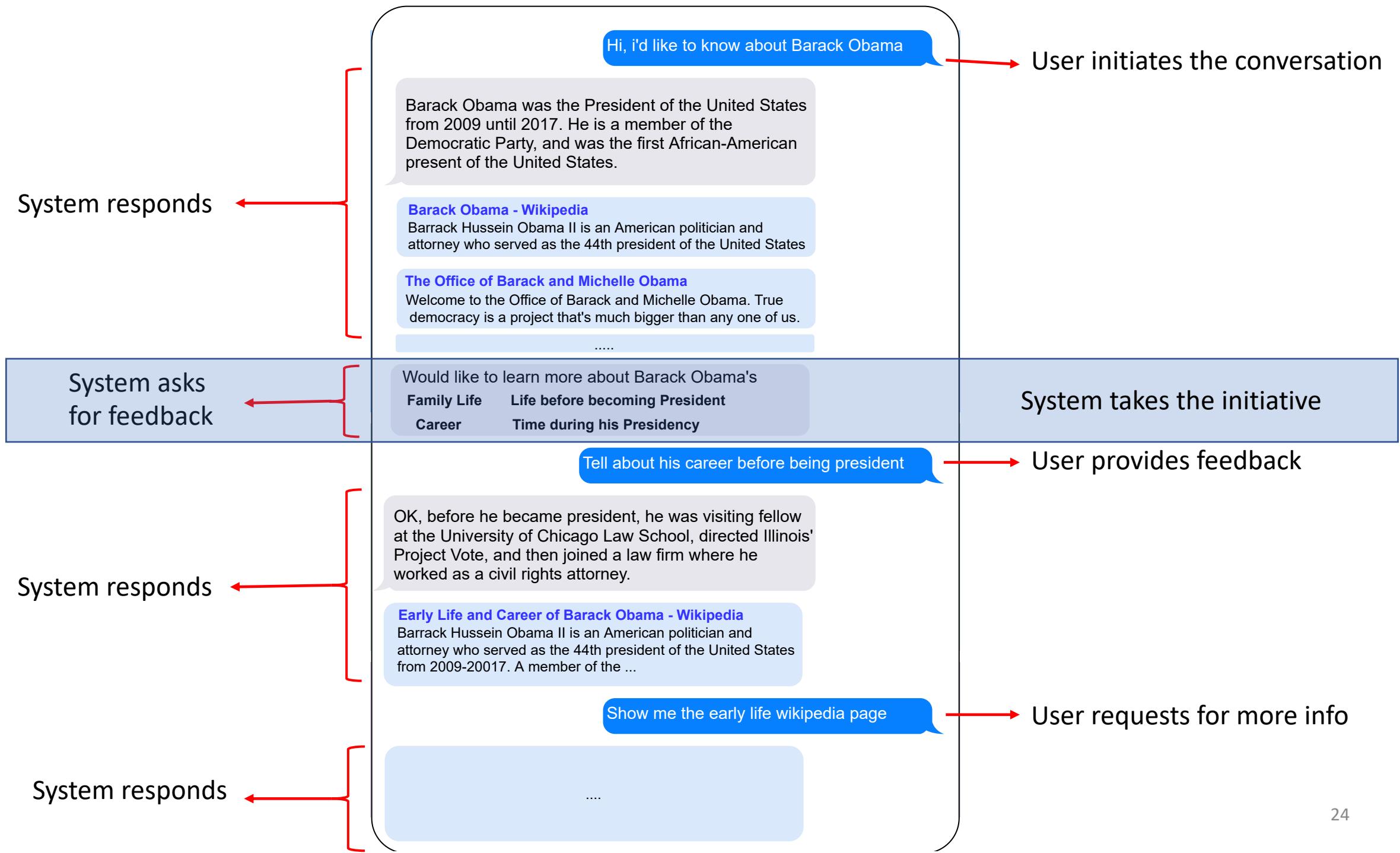
Mixed Initiatives

- User and system have the control
- Both system and user can be active
- Responds to one's requests
- Can also prompt for one's input (e.g., feedback)

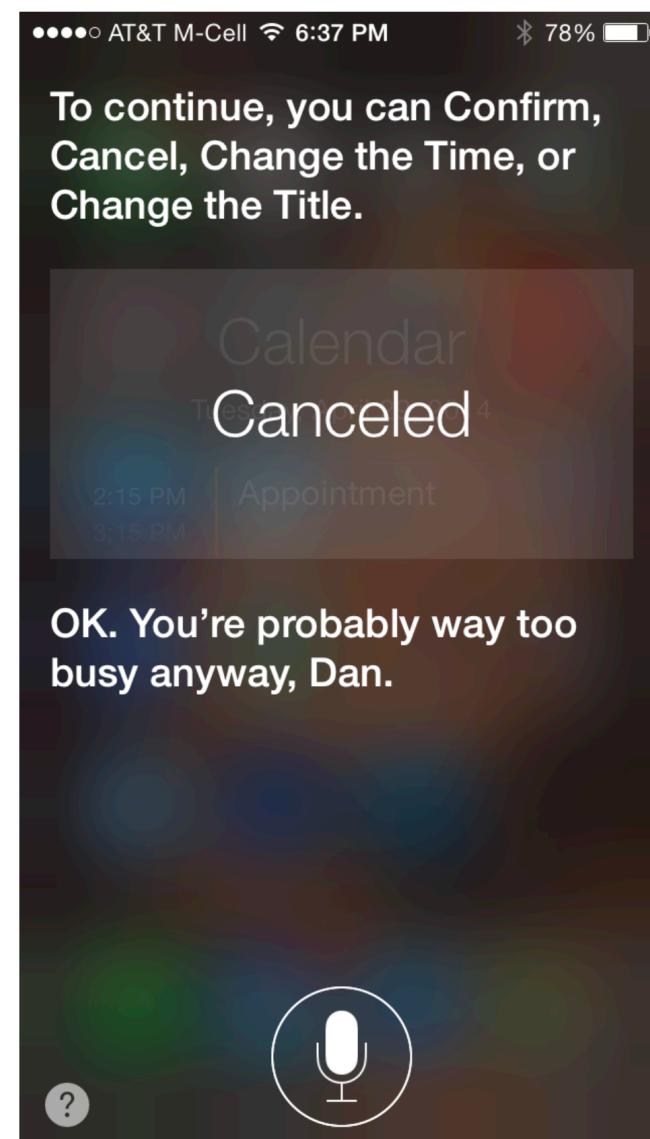
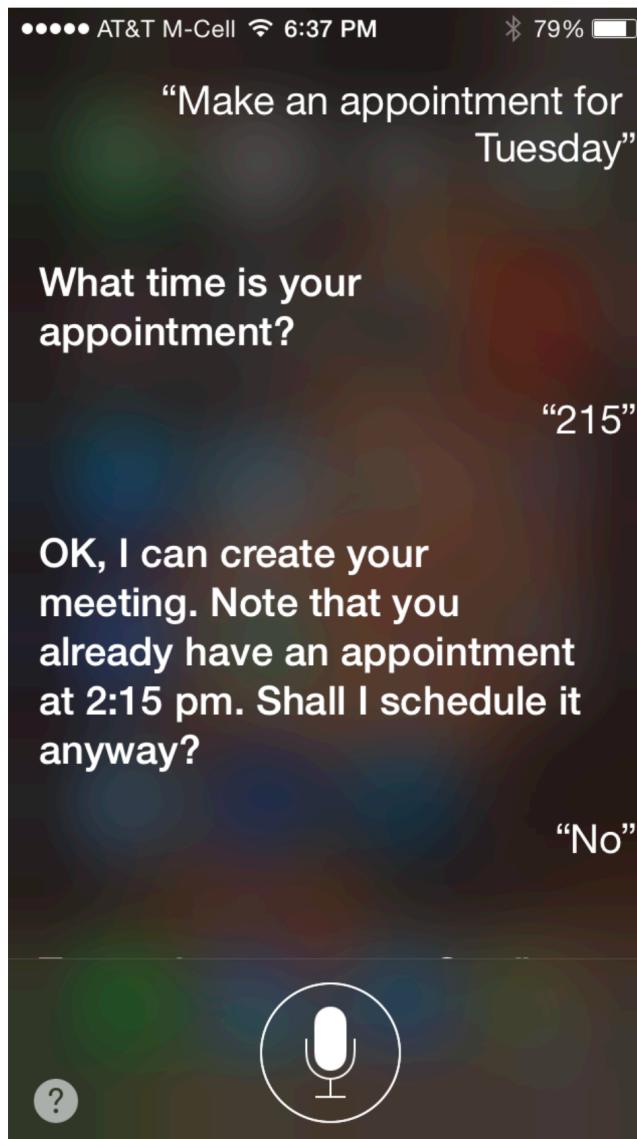


System controls
the conversation





Goal-based dialog agents



••••• AT&T M-Cell 6:18 PM

87%

“Find restaurants near me”
tap to edit

I found fifteen restaurants
fairly close to you:

15 Restaurants

Emmy's Spaghetti Shack 0.2 mi >
18 Virginia Ave
Italian, \$\$\$
★★★★★ 1101 Reviews

ICHI Sushi 0.2 mi >
3369 Mission St
Japanese, Sushi Bars, \$\$\$
★★★★★ 260 Reviews

Avedano's Holly Park M... 0.2 mi >

••••• AT&T M-Cell 6:19 PM

86%

“Tell me more about the
second one”
tap to edit

I'm sorry, Dan, I'm afraid I
can't do that.

"Find restaurants near me"

tap to edit

I found fifteen restaurants
fairly close to you:

15 Restaurants

Emmy's Spaghetti Shack 0.2 mi >

18 Virginia Ave

Italian, \$\$\$

★★★★★ 1101 Reviews

ICHI Sushi

0.2 mi >

3369 Mission St

Japanese, Sushi Bars, \$\$\$

★★★★★ 260 Reviews

Avedano's Holly Park M... 0.2 mi >

"Are any of them Italian"

tap to edit

My web search turned this
up:

Web Search

Are any of them Italian

any - Dizionario inglese-italiano

WordReference

www.wordreference.com

English-Italian Dictionary | any ... of any sort

adj (of an unspecified variety) di qualsiasi

Italian language - Wikipedia, the free
encyclopedia

en.wikipedia.org

Italian or lingua italiana) is a Romance

Question Answering

Section:  Daffy Duck, Origin & History

- STUDENT: **What is the origin of Daffy Duck?**
TEACHER: ↗ first appeared in Porky's Duck Hunt
- STUDENT: **What was he like in that episode?**
TEACHER: ↗ assertive, unrestrained, combative
- STUDENT: **Was he the star?**
TEACHER: ↗ No, barely more than an unnamed
bit player in this short
- STUDENT: **Who was the star?**
TEACHER: ↗ No answer
- STUDENT: **Did he change a lot from that first
episode in future episodes?**
TEACHER: ↗ Yes, the only aspects of the char-
acter that have remained consistent (...) are his
voice characterization by Mel Blanc
- STUDENT: **How has he changed?**
TEACHER: ↗ Daffy was less anthropomorphic
- STUDENT: **In what other ways did he change?**
TEACHER: ↗ Daffy's slobbery, exaggerated lisp
(...) is barely noticeable in the early cartoons.
- STUDENT: **Why did they add the lisp?**
TEACHER: ↗ One often-repeated "official" story
is that it was modeled after producer Leon
Schlesinger's tendency to lisp.
- STUDENT: **Is there an "unofficial" story?**
TEACHER: ↗ Yes, Mel Blanc (...) contradicts
that conventional belief
- ...

Mixed-Initiative Recommendation

Can you find me a **mobile phone** on Amazon?

Sure, what **operating system** do you prefer? 🤖

I want an **Android** one.

OK, and any preference on **screen size**? 🤖

Better larger than **5 inches**.

Do you have requirements on **storage capacity**? 🤖

I want it to be at least **64 Gigabytes**.

And any preference on **phone color**? 🤖

Not particularly.

Sure, then what about the following choices? 🤖

I don't like them very much...

OK, do you have any preference on the **brand**? 🤖

Better be **Samsung or Huawei**.

Any requirement on **price**? 🤖

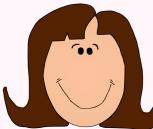
Should be **within 700 dollars**.

OK, then what about these ones? 🤖

Great, I want the first one, can you order it for me?

Sure, I have placed the order for you, enjoy! 🤖

Clarifying Questions

 dinosaur 	 dinosaur 
<p>Information Need (Facet)</p> <p>I'm looking for the Discovery Channel's dinosaur site, which has pictures of dinosaurs and games.</p> <p> Are you looking for dinosaur books?</p> <p> No, just the discovery channel website.</p> <p> Are you looking for meat-eating or plant-eating dinosaurs?</p> <p> I'm not sure.</p> <p> Would you like to see pictures or videos of dinosaurs?</p> <p> I'd like to see pictures of dinosaurs on the discovery channels website.</p>	<p>Information Need (Facet)</p> <p>I'm looking for a list of all (or many of) the different kinds of dinosaurs, with pictures.</p> <p> Are you looking for dinosaur books?</p> <p> Yes, if they contain pictures of all the different kinds of dinosaurs.</p> <p> Which dinosaurs are you interested in?</p> <p> I'm interested in any and all dinosaurs.</p> <p> Do you want a list of dinosaurs names?</p> <p> Yes, I would also like the list to include pictures of the dinosaurs.</p>

Preference Elicitation

ASST Can you tell me what types of movies you enjoy watching?

USER Mostly action adventure drama fantasy, documentary

ASST And what about those kinds of movies do you like?

USER Usually I like movies like that that consist with those genres.

USER I just like the storytelling, how deep some movies can get into, the characters, and pretty much like the creativity.

ASST Alright, whats one of your favorite movies?

USER Mr. Nobody

ASST And what was it about that movie that made it enjoyable?

USER Because it dealt with basically all of life, making choices, and that each choice has a different consequence.

USER So, think before you do.

ASST I see.

ASST OK. Now, tell me about a movie you didnt like.

USER I guess Spaceballs, because it was kind of just annoying in some parts. I mean, it was all right, but most of the time, you know, it just It needed to have a little bit different kind of comedy in it. I didn't like the some of the characters in it, so

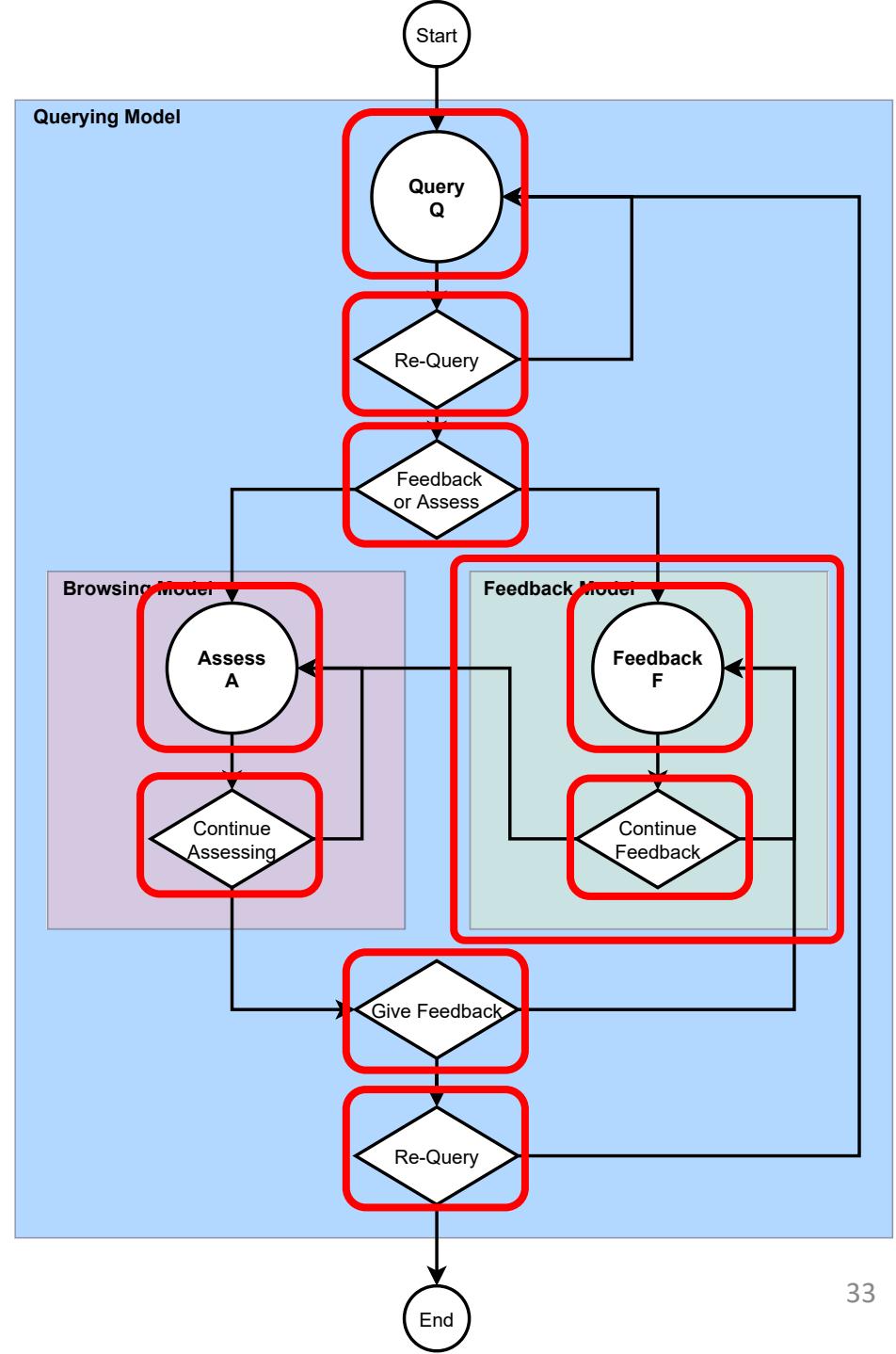
ASST Generally speaking, what did you not like about that particular type of movie?

USER The storytelling wasn't really on pace.

USER So the plot could have been better.

Modeling Interactions

- Infinite possibilities
 - Feedback First (FF)
 - Feedback After (FA)
- Mixed-Initiative Approach:
 - Query Suggestion (QS)
 - Query Clarifications (QC)
- Unknown cost of each action



Hi, i'd like to know about Barack Obama

Barack Obama was the President of the United States from 2009 until 2017. He is a member of the Democratic Party, and was the first African-American present of the United States.

Barack Obama - Wikipedia

Barrack Hussein Obama II is an American politician and attorney who served as the 44th president of the United States

The Office of Barack and Michelle Obama

Welcome to the Office of Barack and Michelle Obama. True democracy is a project that's much bigger than any one of us.

....

Would like to learn more about Barack Obama's

Family Life **Life before becoming President**

Career **Time during his Presidency**

Tell about his career before being president

OK, before he became president, he was visiting fellow at the University of Chicago Law School, directed Illinois' Project Vote, and then joined a law firm where he worked as a civil rights attorney.

Early Life and Career of Barack Obama - Wikipedia

Barrack Hussein Obama II is an American politician and attorney who served as the 44th president of the United States from 2009-2017. A member of the ...

Show me the early life wikipedia page

....

Query Turn
User Issues Query
Agent responds

Feedback Turn
User provides Feedback
Agent responds

Assess Turn
User selects a result
Agent responds

Querying Model

Browsing Model

Start

Query Q

Re-Query

Feedback or Assess

Assess A

Continue Assessing

Feedback F

Continue Feedback

Give Feedback

Re-Query

End

Feedback First vs. Feedback After



dinosaur 

Information Need (Facet)

I'm looking for the Discovery Channel's dinosaur site, which has pictures of dinosaurs and games.

 Are you looking for dinosaur books?

 No, just the discovery channel website.

 Are you looking for meat-eating or plant-eating dinosaurs?

 I'm not sure.
 No answer

 Would you like to see pictures or videos of dinosaurs?

 I'd like to see pictures of dinosaurs on the discovery channels website.

Feedback First

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Show me the early life wikipedia page

....

Feedback After

What is the tradeoff?

- How often should the system take the initiative?
- Feedback first or feedback after?
- Which mixed-initiative approach should the system adopt?
- Gain and cost of each action.
 - How to compute cost of each action?
 - How to compute gain of a conversation?

Grounding the Costs

- Time as an estimation of cost.
- Crowdsourcing:

- Feedback

What do you want to know about COVID-19?

Symptoms Vaccine Restrictions

Number of cases Not interested

- Assessment

Current Information about COVID-19

<https://www.rivm.nl/en/novel-coronavirus-covid-19/current-information>

You are looking for current information about the novel coronavirus (COVID-19) in the Netherlands. Weekly updates with an overview of COVID-19 confirmed cases, number of ...

Grounded Costs

# submitted queries	144
# snippet assessments	1,280
# web page assessments	1,000
# provided feedbacks	268
<hr/>	
# workers	81
mean query per worker	2.72
mean snippet assessment per worker	26.67
mean web page assessment per worker	23.81
mean feedback per worker	4.31

	Submit Query	Assess Snippet	Assess Document	Provide Feedback
Mean	29.33	6.26	16.96	8.33
Median	22.59	3.63	10.22	5.77

Summary

- Different interaction strategies:
 - Single vs. mixed initiatives
- Different applications:
 - Goal-oriented & question answering
 - Recommender systems & information seeking
- Mixed-initiative strategies:
 - Feedback first vs. feedback after
- Cost and gain; what is the tradeoff?
 - Time as an estimation of cost
 - Gain? Let's evaluate the systems!

Evaluation

Types of Evaluation

- Automatic evaluation
- Human evaluation
- Single Initiatives
- Mixed Initiatives

Limited bandwidth

- Unlike Web search, not many results can be scanned.
- Small-screen devices.
- Voice-only devices.
- Various contexts, e.g., walking.

- Definition of utility is different.
- Top of the list is even more important.

Defining Utility

- Chitchatting
 - Longer or short conversations are desired?
- How about information-seeking conversations?
 - Would the user prefer to receive quasi-relevant results faster, or wait more for relevant results?
- How about recommendation?

Automatic Evaluation

- Need for an offline strategy to evaluate
- Depends on the application:
 - Goal-oriented dialog systems:
 - Is the goal achieved eventually? How many turns did it take?
 - Question answering:
 - Did the user find the answer to their question?
 - Recommender systems:
 - Are the recommended items useful to the user?
 - Information seeking:
 - Is the provided information useful to the user?

We adapt IR evaluation metrics for automatic evaluation!

TREC CAsT

- Text REtrieval Conference (TREC).
- Common evaluation.
- The TREC Conversational Assistance Track (CAsT).
- Single-initiative conversations.
- Passage retrieval.
- Automatic evaluation.

TREC CAsT (cont.)

Title: Uranus and Neptune

Description: Information about Uranus and Neptune.

Turn Conversation Utterances

- 1 Describe Uranus.
 - 2 What makes it so unusual?
 - 3 Tell me about its orbit.
 - 4 Why is it tilted?
 - 5 How is its rotation different from other planets?
 - 6 What is peculiar about its seasons?
 - 7 Are there any other planets similar to it?
 - 8 Describe the characteristics of Neptune.
 - 9 Why is it important to our solar system?
 - 10 How are these two planets similar to each other?
 - 11 Can life exist on either of them?
-

Conversational Passage Retrieval

- Given a conversation history.
- Retrieve relevant passages.
- Passage Collection: MS MARCO, TREC CAR

<https://msmarco.blob.core.windows.net/msmarcoranking/collection.tar.gz>

<http://trec-car.cs.unh.edu/datasets/v2.0/paragraphCorpus.v2.0.tar.xz>

Evaluation

- Relevance of retrieved documents to the overall topic
- Relevance of retrieved documents to the current question

Title: Uranus and Neptune

Description: Information about Uranus and Neptune.

Turn Conversation Utterances

- | | |
|----|---|
| 1 | Describe Uranus. |
| 2 | What makes it so unusual? |
| 3 | Tell me about its orbit. |
| 4 | Why is it tilted? |
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| 8 | Describe the characteristics of Neptune. |
| 9 | Why is it important to our solar system? |
| 10 | How are these two planets similar to each other? |
| 11 | Can life exist on either of them? |

Top of the list

- Mean reciprocal rank (MRR):
 - what is the ranking of the first ranked item?
- Mean average precision (MAP):
 - what precision do we get for different values of recall?
- Normalized Discounted Cumulative Gain at top 3 (nDCG@3):
 - what is our cumulative gain at the top 3 results?

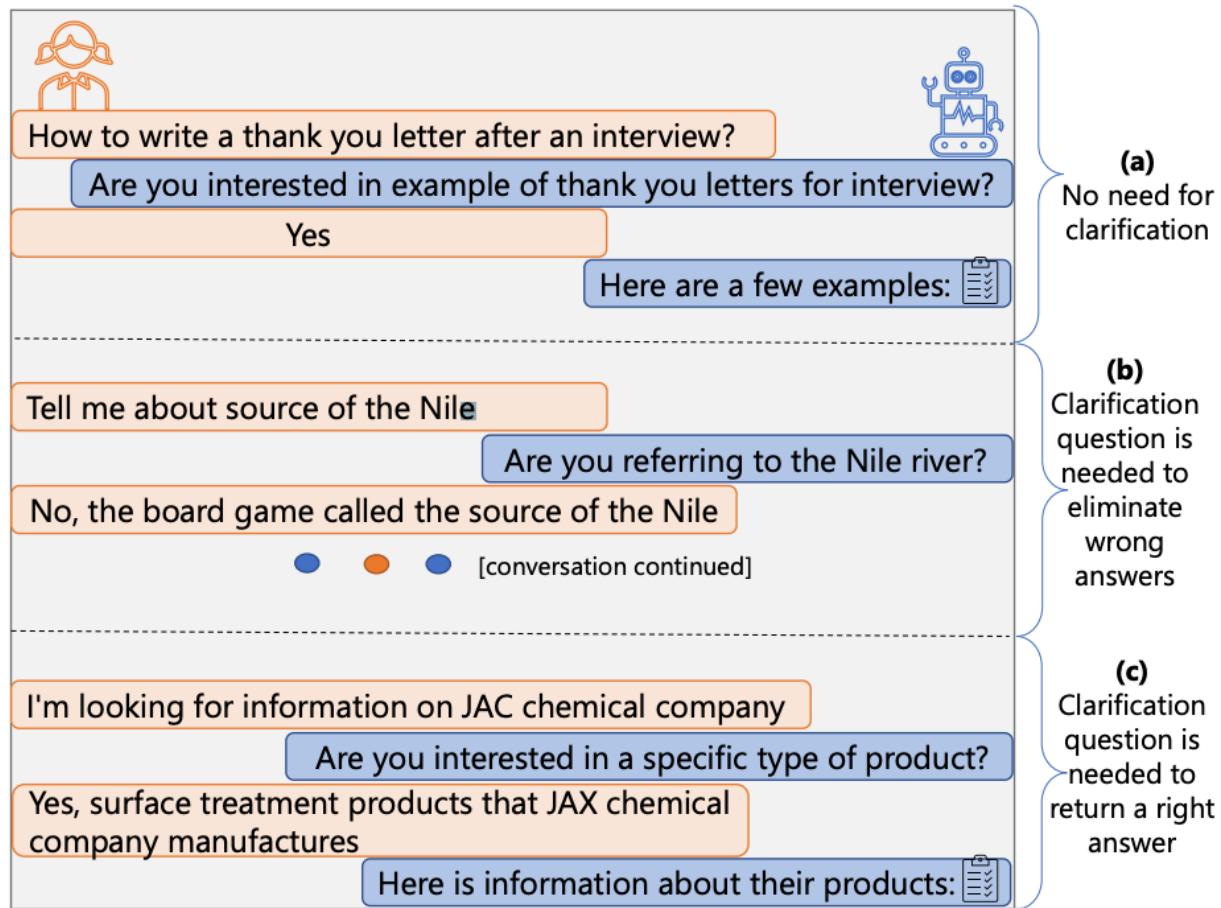
ClariQ

- ConvAI3 Data challenge.
- Common evaluation.
- Data challenge on clarifying questions (ClariQ).
- Mixed-initiative conversations.
- Document retrieval.
- Automatic evaluation.

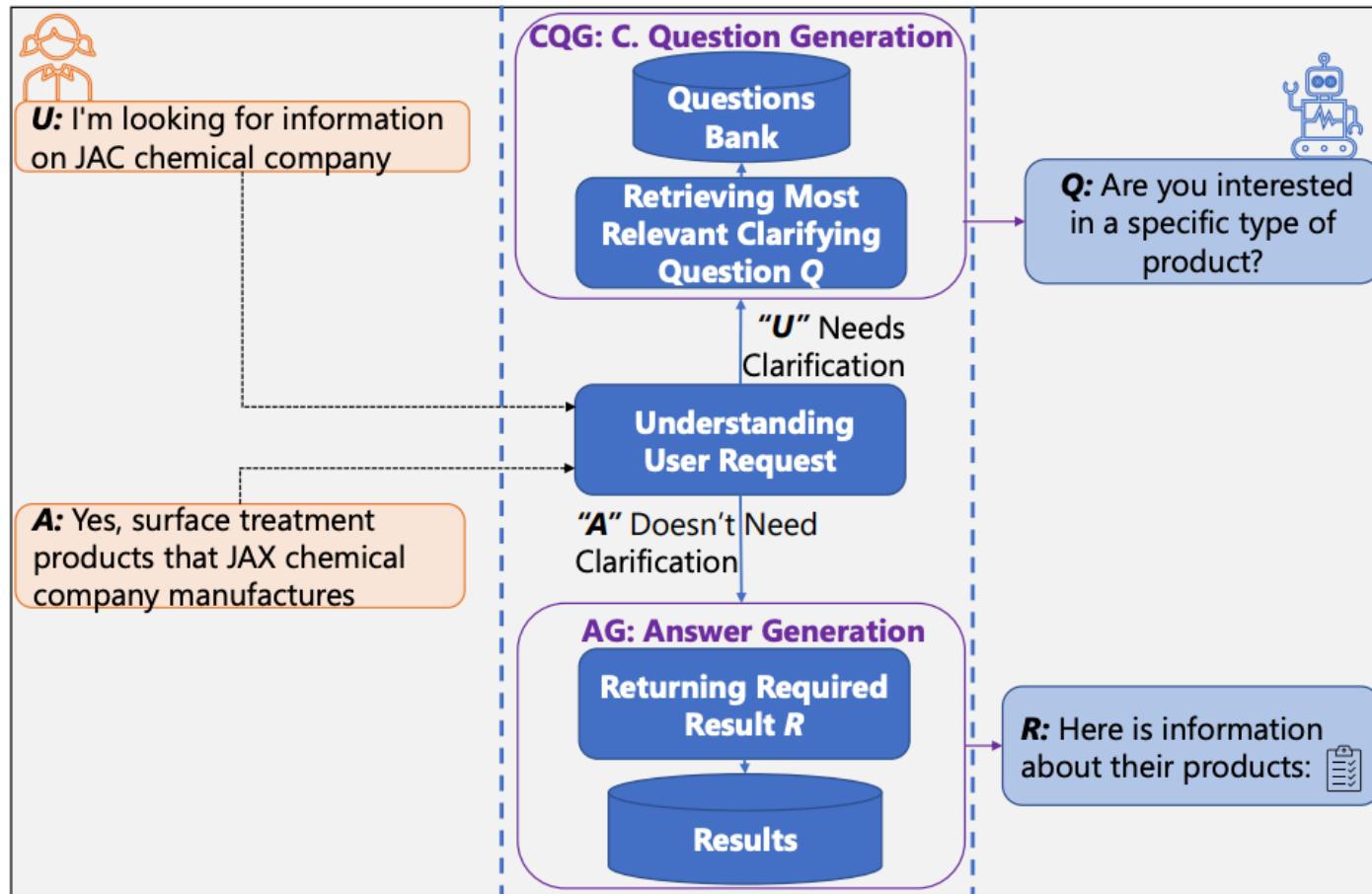
Asking Clarifying Questions

- Original request is incomplete.
- It can be interpreted in various ways.
- Instead of returning bad results, the system asks clarifying questions to understand the intent.

ClariQ (cont.)



Pipeline



ClueWeb Collection

- A part of the Lemur Project
- A common web crawl (English) with 50M documents
- TREC Web Track 2009 – 2014
- Ad-hoc retrieval and **diversification** tasks

dinosaur



TREC facets



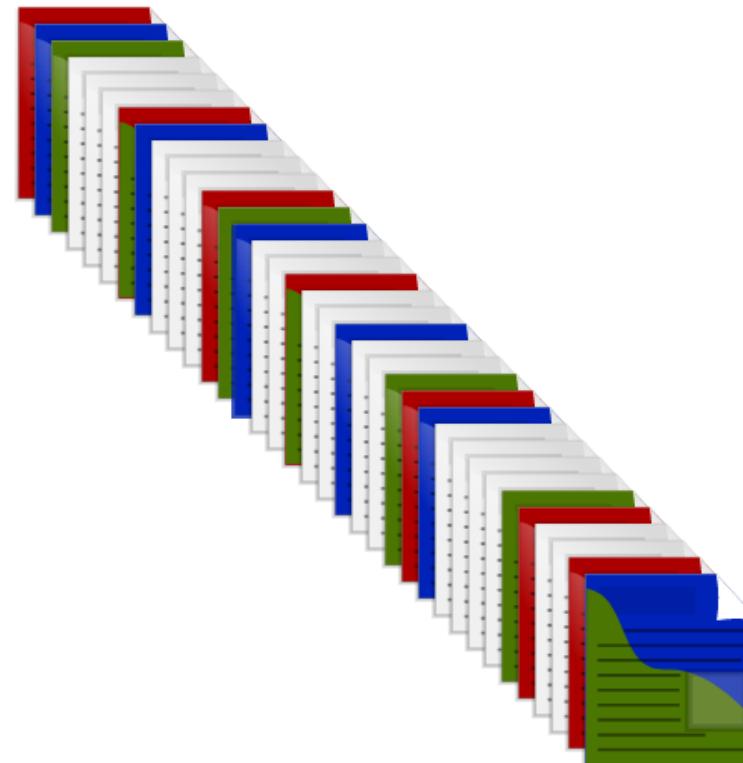
Discovery channel



Dinosaur pictures

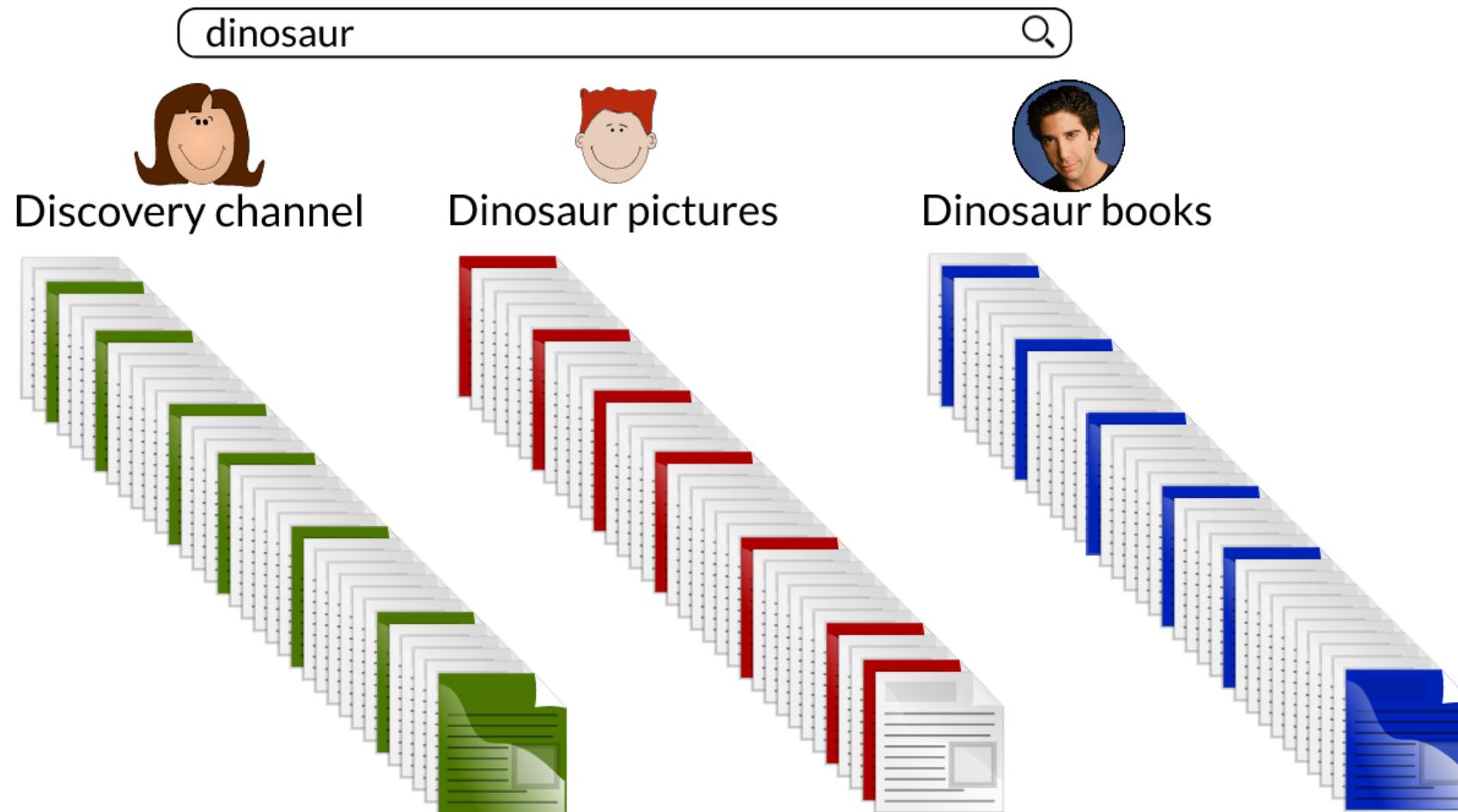


Dinosaur books



An offline evaluation methodology

- We assume that each user is interested in one facet per topic.



An offline evaluation methodology

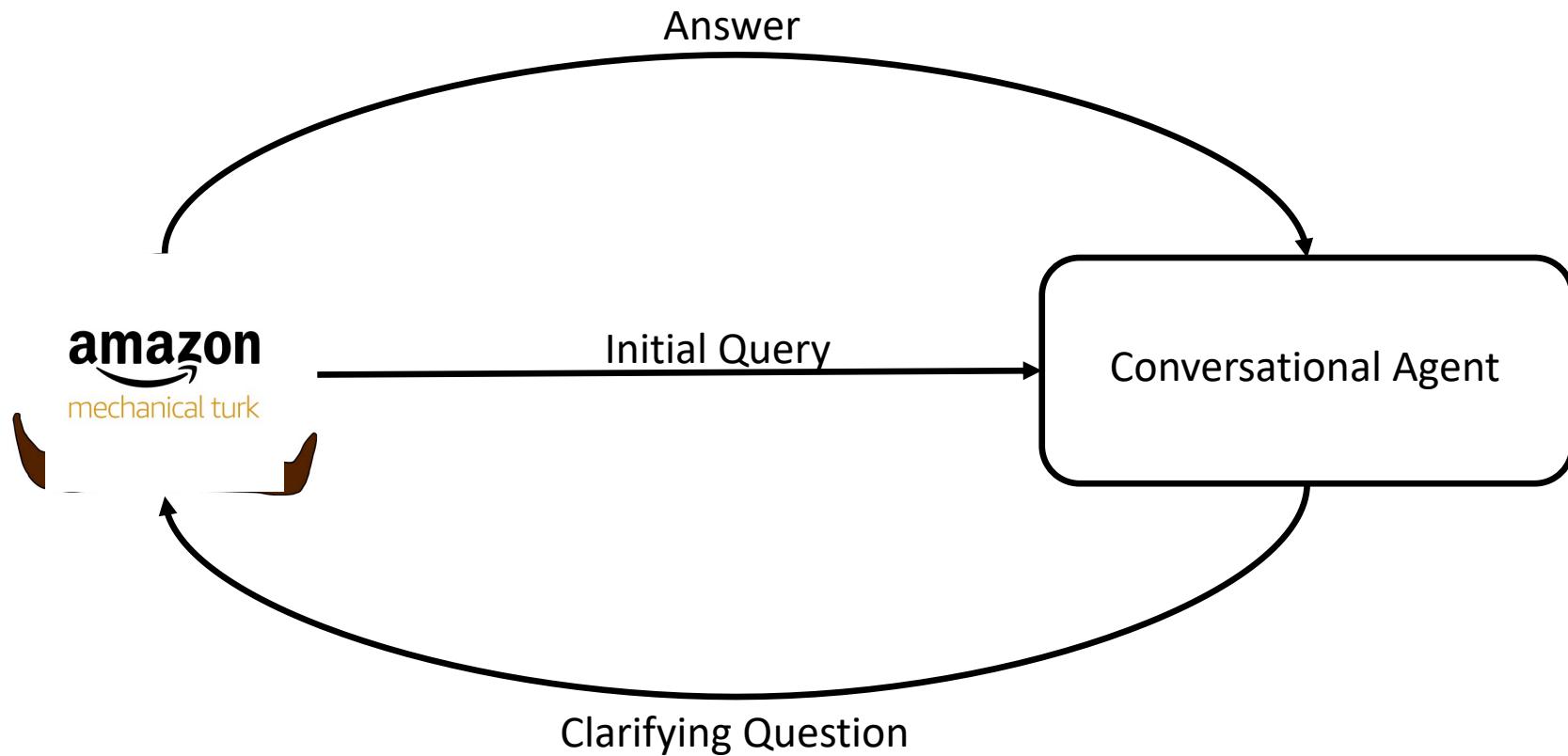
Borrowed from the ClueWeb Collection

- Let $T = \{t_1, t_2, \dots, t_n\}$ be the set of topics (queries).
 - A collection of facet sets: $F = \{\mathbf{f}_1, \mathbf{f}_2, \dots, \mathbf{f}_n\}$
 - $\mathbf{f}_i = \{f_1^i, f_2^i, \dots, f_{m_i}^i\}$ includes all defined facets for topic t_i .
 - A collection of clarifying question sets: $Q = \{\mathbf{q}_1, \mathbf{q}_2, \dots, \mathbf{q}_n\}$
 - With $\mathbf{q}_i = \{q_1^i, q_2^i, \dots, q_{m_i}^i\}$ including all clarifying questions relevant to topic t_i .
-
- An offline evaluation requires defining $A(t, f, q) \rightarrow a$.

ClariQ Dataset

# search topics	298
# faceted & ambiguous topics	250
# single topics	48
# facets	1070
# questions	3,304
Average terms per question	9.74 ± 2.62
Average terms per answer	8.48 ± 4.40
# synthetic conversations (all)	1,596,757
# synthetic conversations (2 turns)	203,050
# synthetic conversations (3 turns)	1,393,707
# human-machine dialogues (1 turn)	15,226
# human-machine dialogues (3 turns)	499

Let the human in the loop



Let the human in the loop (cont.)

# search topics	298
# faceted & ambiguous topics	250
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Average terms per question	9.74 ± 2.62
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# human-machine dialogues (1 turn)	15,226
# human-machine dialogues (3 turns)	499

I would like to know more about raspberry pi.

Do you want to know where raspberry pi is made?

No.

Do you want to know about its OS?

Yes, tell me more.

Do you want to know its minimum requirements?

You are looking for general information about raspberry pi and its operating system.

Answer the latest question, assuming that you have had the whole conversation to this point:

Please enter here...

NEXT

Automatic Evaluation

- **Question relevance:** how many relevant questions are retrieved from the question bank?
 - Recall@k
- **Document relevance:** how much does the selected question help improve the retrieval performance?
 - MRR, Precision@k, NDCG@k

Human Evaluation

- Human annotators to judge how good a conversation is.
- Pairwise comparison: two competing systems get evaluated.
- Single- and mixed-initiative conversations.
- Correlation with automatic evaluation.
- Multiple aspects:
 - Engagement
 - Knowledgeable
 - Interesting
 - Human-like
 - Clarifying questions

I'm looking for
dinosaurs.

Are you looking for
dinosaur photos?

No. I want to find some
videos.

What kind of dinosaurs
are you interested in?

It doesn't matter. Just
show me some videos.

Are you looking for
dinosaur books?

Show me videos please.

I'm looking for
dinosaurs.

What type of information
are you looking for?

Videos would be great.

Are you looking for
documentaries or
animations?

Documentaries.

What kind of dinosaurs
are you interested in?

Doesn't matter. Just
show me some videos.

Which one asks better (or more reasonable) clarifying questions?

- I would prefer to talk to Speaker 1 I would prefer to talk to Speaker 2

**Please provide a brief justification for your choice (a few words or a
sentence)**

Please enter here...

NEXT

What to ask human annotators?

Question	Choice 1	Agrm.
Engagingness (PersonaChat)		
Which speaker is more engaging to talk to?	Speaker 1 is more engaging	82.5%
Who would you prefer to talk to for a long conversation?	I would prefer to talk to Speaker 1	*87.5%
Which speaker do you think is more captivating?	Speaker 1 is more captivating than Speaker 2	84.2%
Interestingness (PersonaChat)		
If you had to say one of these speakers is interesting and one is boring, who would you say is more interesting?	Speaker 1 is more interesting	*86.7%
Which speaker is more interesting to talk to?	Speaker 1 is more interesting	*81.5%
Which speaker is more boring to talk to?	Speaker 1 is more boring	69.6%
Who would you rather talk to for fun?	Speaker 1 is more fun	70.8%
Humanness (PersonaChat)		
Which speaker sounds more human?	Speaker 1 sounds more human	*76.9%
If you had to guess that one speaker is human and one is a bot, which do you think is human?	Speaker 1 sounds human	71.4%
Which speaker sounds more like a real person?	Speaker 1 sounds more like a real person	76.9%
Knowledgeable (Wizard of Wikipedia)		
Which speaker is more knowledgeable?	Speaker 1 is more knowledgeable	*88.9%
If you had to say that one speaker is more knowledgeable and one is more ignorant, who is more knowledgeable?	Speaker 1 is more knowledgeable	*100%
Which speaker is more well-informed?	Speaker 1 is more well-informed	*85.0%

Summary

- Top of the list is important.
- Automatic evaluation is vital.
- Single-initiative:
 - TREC CAsT: conversational passage retrieval.
- Mixed-initiative:
 - ClariQ: asking clarifying questions for document retrieval
- Human in the loop for multi-turn conversations.
- Pairwise human evaluation.

Document Representation

Tasks

- Response retrieval
- Information-seeking conversations
- Asking Clarifying Questions
- Single Initiatives
- Mixed Initiatives

Conversational Answer Retrieval

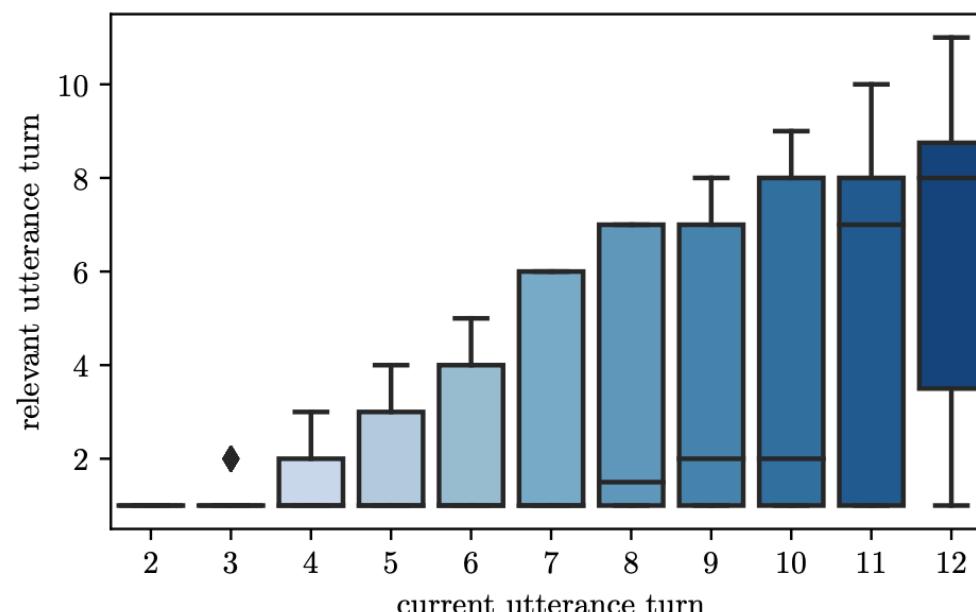
- Open-domain, natural language text questions
- Answers extracted from the corpus (or corpora) being searched, and may be at different levels of granularity, depending on the question
 - Focus on passage-level answers
- Dialog is about questions and answers, including history, with the aim of refining the understanding of questions and improving the quality of answers
- Evaluated as an open-domain IR task, in contrast to conversational chat or template-based conversation

TREC CAsT

- Query resolution:
 - Relevant utterance in context.
 - “When was he born?” → How is he?
- Query rewriting:
 - Generative models to rewrite the query.
 - “When was he born?” -> “When was Barrack Obama born?”
- Passage ranking:
 - Neural and non-neural ranking based on the final query.

Relevant Context

- Capturing the context of conversation
- Studying how a conversation evolves
- Predicting the relevance of conversation turns



Number:	37
Title:	prison psychology studies
Description:	The Stanford Experiment and its ramifications in human testing, particularly on prisoners and its ethics.
1	What was the Stanford Experiment?
2	What did it show?
3	Tell me about the author of the experiment.
4	Was it ethical?
5	What are other similar experiments?
6	What happened in the Milgram experiment?
7	Why was it important?
8	What were the similarities and differences between the studies?
...	...

Annotations on the right side of the table:

- A green arrow labeled "Relevant Utterance" points to the first four rows (1-4).
- A green arrow labeled "Relevant Utterance" points to the next three rows (6-8).
- A blue arrow labeled "Current Utterance" points to the last two rows (9-10).

Predicting Relevant Utterance

- Binary classification task.
- Bidirectional Encoder Representations from Transformers (BERT)
- Fine-tune for this task:

$$p(R = 1|u_i, u_j; i, j) = \psi(\phi_U(u_i), \phi_C(u_j), \eta_U(i), \eta_C(j))$$

- Predict relevance label, given two utterances and their positions in a conversation.
- BERT + classification layer.

Classification Performance

	Prec.	Recall	F1
FirstUtterance	0.60	0.65	0.62
PrevUtterance	0.29	0.31	0.30
FirstPrevUtterance	0.42	0.85	0.56
AllPrevUtterances	0.20	1.00	0.33
Random	0.20	0.50	0.29
k-NN	0.64	0.49	0.55
MLP	0.63	0.48	0.54
SVM	0.64	0.43	0.52
k-NN-AWE	0.64	0.49	0.55
MLP-AWE	0.64	0.53	0.58
SVM-AWE	0.66	0.49	0.57
BERT-CUR BASE	0.66	0.69	0.67
BERT-CUR LARGE	0.65	0.67	0.66

Evaluated Retrieval Models

Name	Description
Orig.	The original unmodified utterance.
FU	The current utterance reformulated using the first utterance of the conversation.
PU	The current utterance reformulated using the immediate previous utterance of the conversation.
FPU	The current utterance reformulated using the first and immediate previous utterance of the conversation.
AU	The current utterance reformulated using all the previous utterances of the conversation until that point.
PrU	The current utterance reformulated using the relevant utterance predicted by BERT-CUR.
Oracle	The current utterance reformulated using the true relevance labels.

Model	MAP	MRR	nDCG@5	nDCG@10	nDCG@20	P@5	P@10	P@20
DFR	Orig.	0.1079	0.1497	0.0988	0.1086	0.1319	0.0950	0.0800
	FU	0.1682 ⁵	0.2480	0.1687 ⁵	0.1840 ⁵	0.2189 ⁵	0.1450 ⁴⁵	0.1108 ⁴⁵
	PU	0.1438	0.2072	0.1399	0.1505	0.1793	0.1233	0.0983
	FPU	0.1487	0.2312	0.1387	0.1654	0.1963	0.1050	0.0942
	AU	0.1226	0.1923	0.1201	0.1299	0.1573	0.1017	0.0842
	PrU	0.1919 ¹³⁴⁵	0.2754 ¹³⁵	0.1906 ¹³⁴⁵	0.2058 ¹³⁵	0.2418 ¹³⁵	0.1650 ¹³⁴⁵	0.1317 ¹³⁴⁵
	Oracle	0.2009 ¹²³⁴⁵	0.3004 ¹²³⁴⁵	0.2004 ¹³⁴⁵	0.2154 ¹³⁴⁵	0.2551 ¹²³⁴⁵	0.1717 ¹³⁴⁵	0.1308 ¹²³⁴⁵
BM25	Orig.	0.0887	0.1420	0.0841	0.0948	0.1131	0.0817	0.0733
	FU	0.1359 ⁵	0.2287 ⁵	0.1432 ⁵	0.1668 ⁵	0.1907 ⁵	0.1250 ⁴⁵	0.1092 ⁴⁵
	PU	0.1263	0.1962	0.1268	0.1364	0.1679	0.1083	0.0908
	FPU	0.1272	0.2108	0.1301	0.1472	0.1754	0.0967	0.0883
	AU	0.1014	0.1654	0.1013	0.1135	0.1374	0.0883	0.0783
	PrU	0.1546 ⁵	0.2465 ⁵	0.1548 ⁵	0.1805 ¹³⁵	0.2097 ⁵	0.1400 ⁴⁵	0.1258 ¹³⁴⁵
	Oracle	0.1633 ¹³⁴⁵	0.2658 ³⁴⁵	0.1671 ¹³⁴⁵	0.1925 ¹³⁴⁵	0.2225 ¹³⁴⁵	0.1450 ¹³⁴⁵	0.1267 ¹³⁴⁵
QL	Orig.	0.1290	0.1603	0.1115	0.1302	0.1681	0.1100	0.0933
	FU	0.2026 ⁵	0.2788	0.1726 ⁵	0.2111 ⁵	0.2602 ⁵	0.1500 ⁵	0.1408 ⁵
	PU	0.1745	0.2486	0.1522	0.1799	0.2164	0.1433	0.1300
	FPU	0.1884 ⁵	0.2735 ⁵	0.1602 ⁵	0.1968 ⁵	0.2368 ⁵	0.1250	0.1275 ⁵
	AU	0.1429	0.2220	0.1211	0.1519	0.1848	0.1083	0.1083
	PrU	0.2362 ¹³⁴⁵	0.3009 ⁵	0.2082 ¹³⁴⁵	0.2470 ¹³⁴⁵	0.2984 ¹³⁴⁵	0.1883 ¹²³⁴⁵	0.1658 ¹²³⁴⁵
	Oracle	0.2435 ¹²³⁴⁵	0.3243 ¹²³⁴⁵	0.2059 ¹³⁴⁵	0.2493 ¹²³⁴⁵	0.3103 ¹²³⁴⁵	0.1817 ¹²³⁴⁵	0.1692 ¹²³⁴⁵

Query Rewriting

Description:

The Bronze Age collapse and the transition into a dark age.

Turn Conversational Queries

Q_1 Tell me about the Bronze Age collapse.

Q_2 What is the evidence for it?

Q_3 What are some of the possible causes?

Manual Query Rewrites

Q_2^* What is the evidence for **the Bronze Age collapse**?

Q_3^* ... the possible causes **of the Bronze Age collapse**?

Task Formulation

- The conversational query rewriting task is to rewrite a context dependent query Q_k to a fully de-contextualized query Q'_k , with the help of previous queries $Q_{<k}$:

$$Q'_k = \text{QueryRewriter}(Q_k; Q_{<k})$$

- Generative Pre-trained Transformer 2 (GPT-2) to generate query terms $\{w'_1, \dots, w'_M\}$ in Q'_k :

$$w'_i = f(w'_{<i}; Q_k, Q_{<k})$$

- Input format:

$$Q_1 \circ [SEP] \circ \dots \circ [SEP] \circ Q_k \circ [BOS] \circ [w'_1, \dots, w'_{i-1}]$$

Weak Supervision

- Gold labels are expensive.
- Weak labels for learn the task.
- Consecutive queries in the same session:
 - Self-contained queries; can be used as gold rewrites: $\tilde{S}^* = \{\tilde{Q}_1^*, \dots, \tilde{Q}_i^*, \dots, \tilde{Q}_N^*\}$
 - Convert to conversational session queries: $\tilde{S} = \{\tilde{Q}_1, \dots, \tilde{Q}_i, \dots, \tilde{Q}_N\}$
- Rule-based:
 - Omission and coreference.
- Self-supervised:
 - GPT-2 to simplify queries.

Method	BLEU-2	NDCG@3	QA-ROUGE
TREC CAsT Auto Runs			
clacBase*	—	0.360	—
pgbert*	—	0.413	—
CFDA_CLIP_RUN7*	—	0.436	—
CAsT Queries			
Original	0.659	0.304	0.231
AllenNLP Coref w/o sw	—	0.314	—
AllenNLP Coref w/ sw	0.750	0.437	0.278
Oracle	1.000	0.544	0.314
Zero-Shot Rewriter			
GPT-2 Raw	0.112	0.124	0.196
MARCO Raw	0.380	0.172	0.183
Rule-Based	0.755	0.437	0.266
Few-Shot Rewriter			
Rule-Based + CV w/o PLM	0.178	0.065	0.151
Self-Learn	0.750	0.435	0.263
CV	0.793	0.467	0.280
Rule-Based + CV	0.809	0.492	0.291
Self-Learn + CV	0.804	0.491	0.291

Asking Clarifying Questions

- Document Retrieval
- Question Retrieval
- Question Selection

Document Retrieval

- Task: given a query, question and answer retrieve documents relevant to the conversation.
- Objective: high precision.
- Linear interpolation of query likelihood models.
- Dirichlet smoothing.
- Query probability: $p(w|t, \mathbf{h}, q, a) = \alpha \times p(w|\theta_t) + (1 - \alpha) \times p(w|\theta_{\mathbf{h}, q, a})$
- Document probability: $p(d|t, \mathbf{h}, q, a) = \sum_{w_k \in \tau} p(w_k|t, \mathbf{h}, q, a) \log(p(w_k|d))$

Question Retrieval

- Task: Given a topic and a context (question-answer history), retrieve clarifying questions.
- Desired objective: high recall
- Approaches:
 - Term matching retrieval models: language models, BM25, RM3 (query expansion)
 - Learning to rank: LambdaMART, RankNet, neural ranking models (e.g., BERT)

Question Retrieval

Method	MAP	Recall@10	Recall@20	Recall@30
QL	0.6714	0.5917	0.6946	0.7076
BM25	0.6715	0.5938	0.6848	0.7076
RM3	0.6858	0.5970	0.7091	0.7244
LambdaMART	0.7218	0.6220	0.7234	0.7336
RankNet	0.7304	0.6233	0.7314	0.7500
BERT-LeaQuR	0.8349*	0.6775*	0.8310*	0.8630*

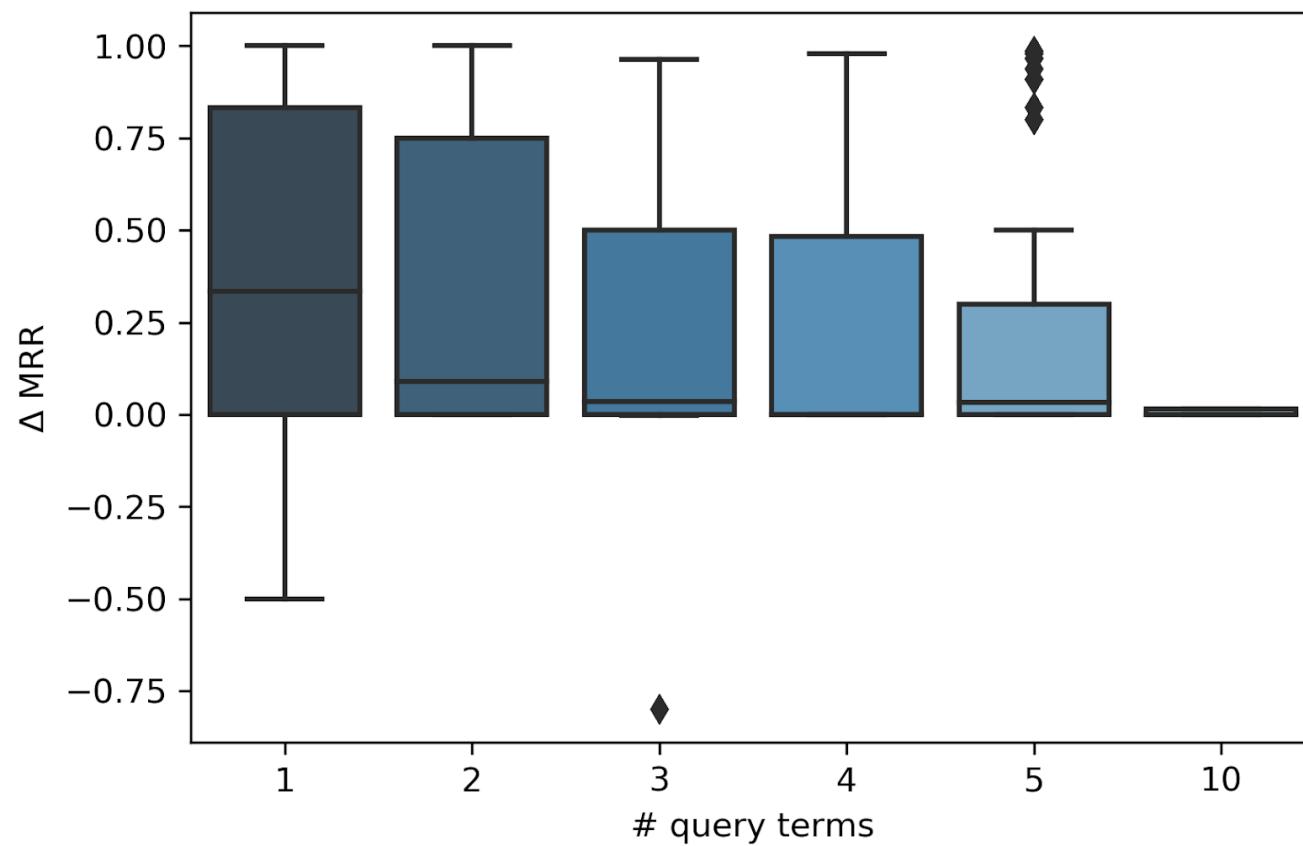
Question Selection

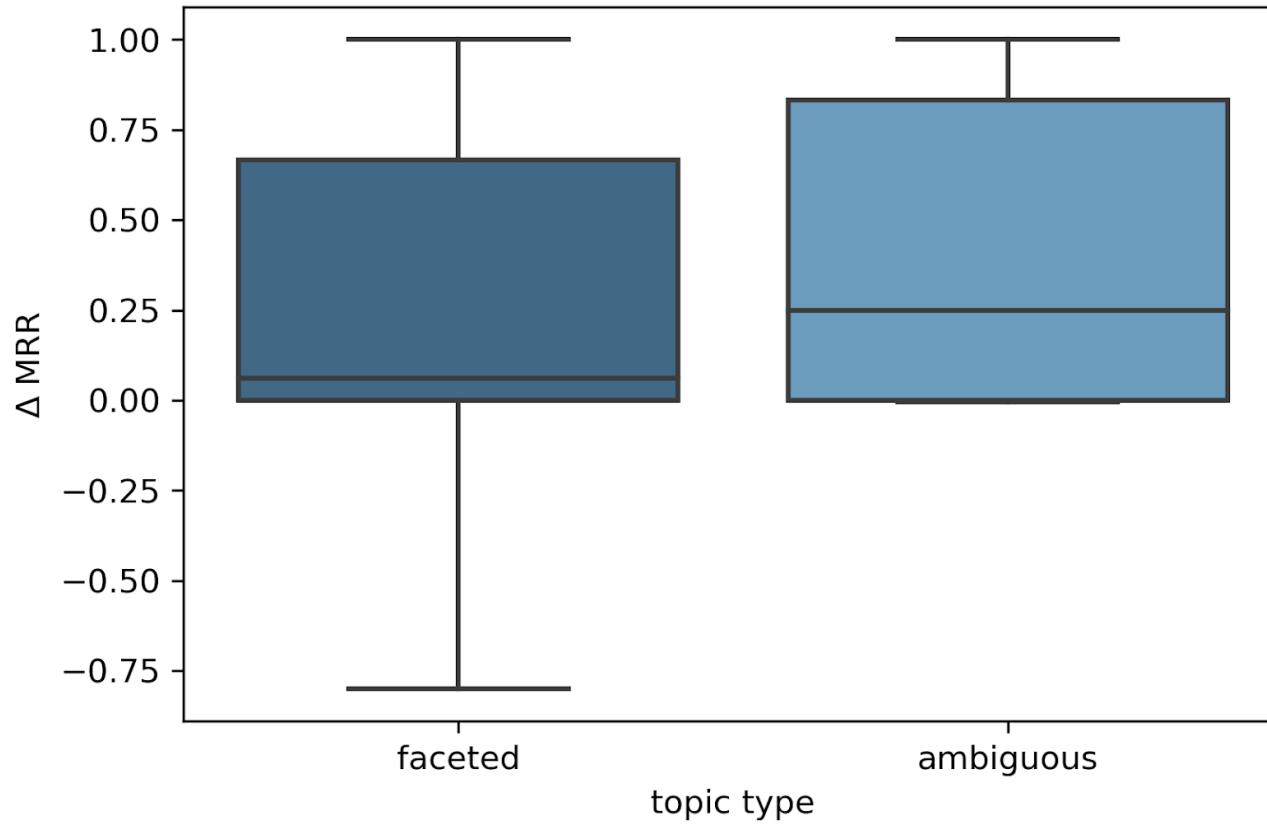
- Task: selecting a clarifying question that leads to retrieval improvement
- Objective: high precision (in retrieval)
- Approaches:
 - Query performance prediction (QPP): predicting the retrieval performance after asking each question (without answer) and selecting the one with the highest QPP.
 - Learning to rank: defining a set of features for ranking questions. The features include QPP, similarity to the topic, similarity to the context, etc.
 - Neural ranking models: learning to rank with representation learning (e.g., BERT)

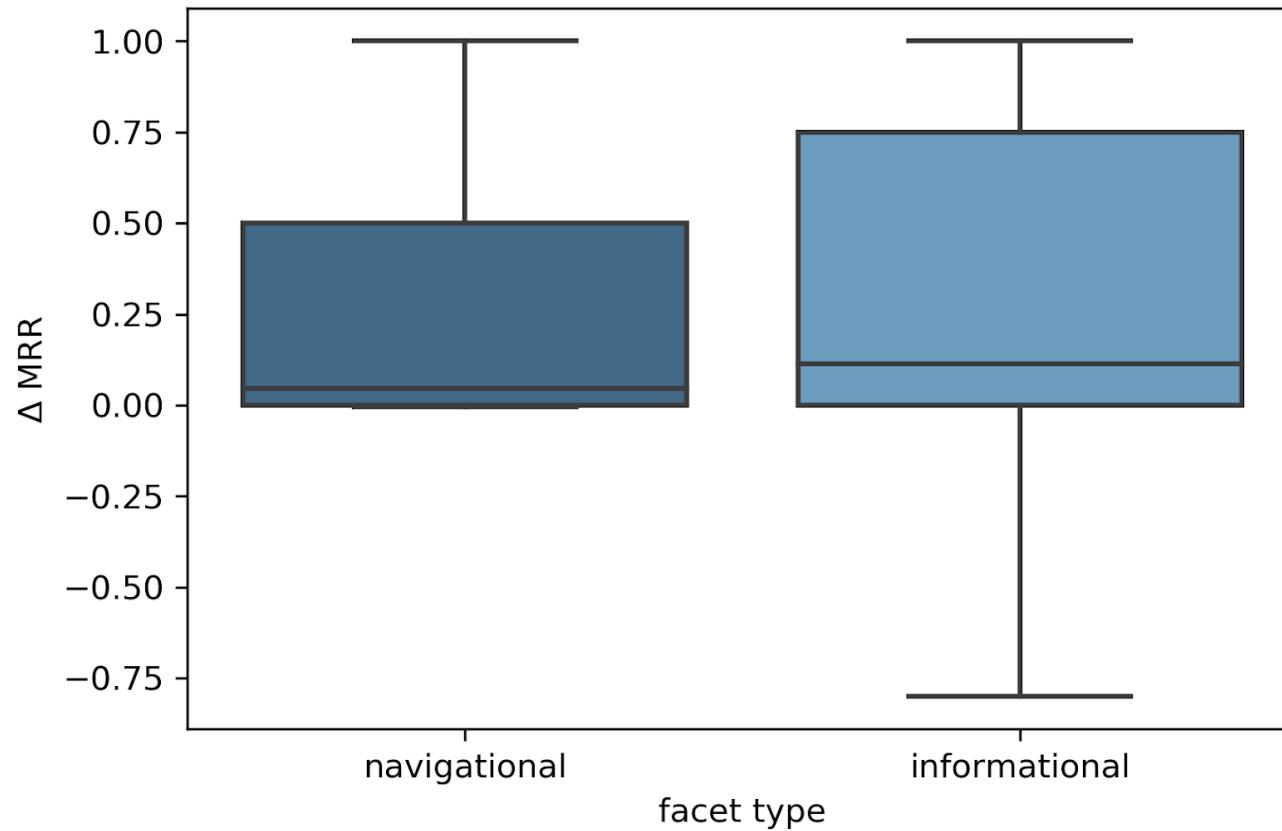
Question Selection

Method	Qulac-T Dataset					Qulac-F Dataset				
	MRR	P@1	nDCG@1	nDCG@5	nDCG@20	MRR	P@1	nDCG@1	nDCG@5	nDCG@20
OriginalQuery	0.2715	0.1842	0.1381	0.1451	0.1470	0.2715	0.1842	0.1381	0.1451	0.1470
σ -QPP	0.3570	0.2548	0.1960	0.1938	0.1812	0.3570	0.2548	0.1960	0.1938	0.1812
LambdaMART	0.3558	0.2537	0.1945	0.1940	0.1796	0.3501	0.2478	0.1911	0.1896	0.1773
RankNet	0.3573	0.2562	0.1979	0.1943	0.1804	0.3568	0.2559	0.1986	0.1944	0.1809
NeuQS	0.3625*	0.2664*	0.2064*	0.2013*	0.1862*	0.3641*	0.2682*	0.2110*	0.2018*	0.1867*
WorstQuestion	0.2479	0.1451	0.1075	0.1402	0.1483	0.2479	0.1451	0.1075	0.1402	0.1483
BestQuestion	0.4673	0.3815	0.3031	0.2410	0.2077	0.4673	0.3815	0.3031	0.2410	0.2077

Asking only one good question improves the performance by over 100%.



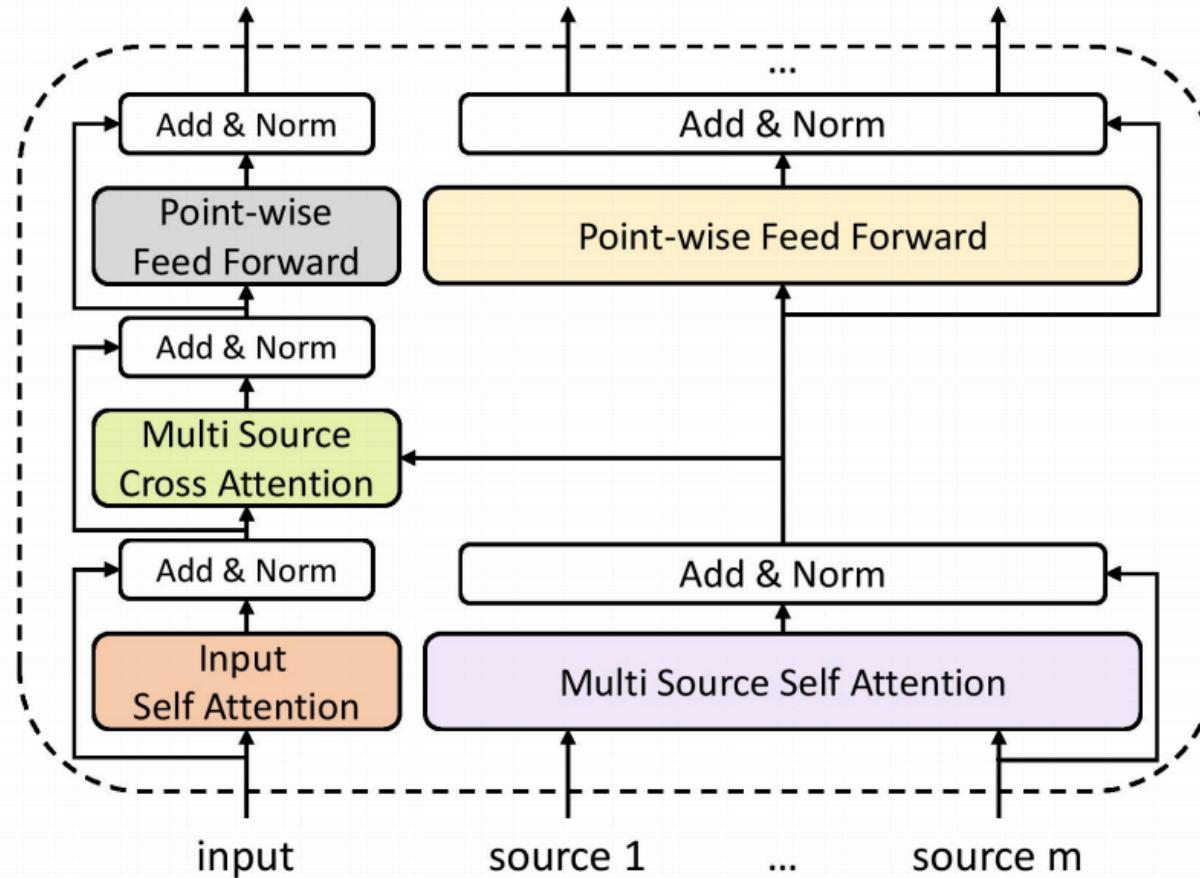




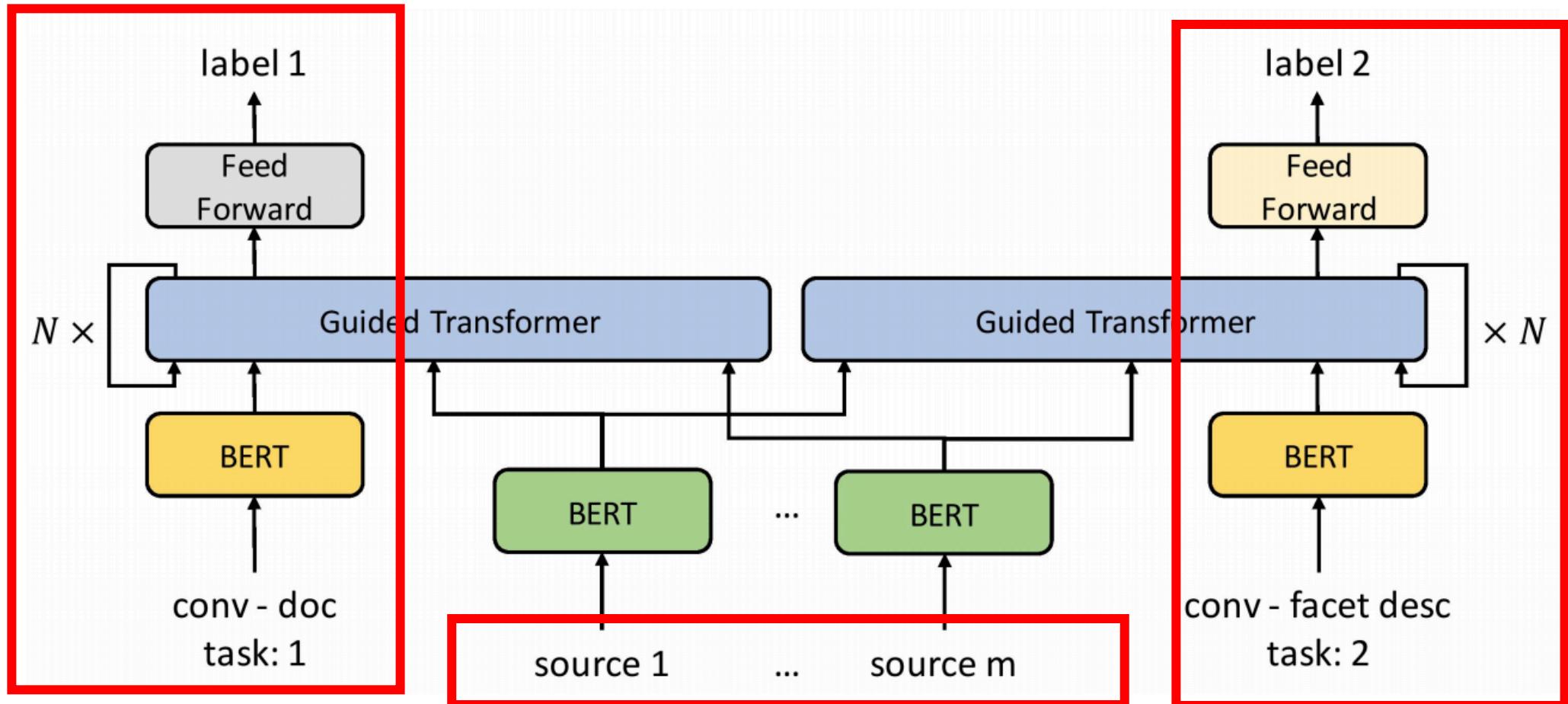
User of External Signals

- Use of Transformers to learn question and document representations.
- Use of external knowledge to learn attention of words:
 - Top retrieved documents.
 - Different clarifying questions for the query.

Guided Transformers



External Signals



	Method	MRR	nDCG@1	nDCG@5	nDCG@20
Baselines	QL	0.3187	0.2127	0.2120	0.1866
	RM3	0.3196	0.2189	0.2149	0.2176
	ERM	0.3291	0.2222	0.2191	0.2208
	SDM	0.3235	0.2267	0.2185	0.2182
	BERT	0.3527	0.2360	0.2267	0.2249
GT Network	Source	Loss			
	Docs	STL	0.3710 [‡]	0.2388	0.2309 [†]
		MTL	0.3826 ^{‡*}	0.2407 ^{†*}	0.2376 ^{‡*}
	CQs	STL	0.4028 [‡]	0.2638 [‡]	0.2521 [‡]
		MTL	0.4259 ^{‡*}	0.2742 ^{‡*}	0.2626 ^{‡*}
	Docs	STL	0.4338 [‡]	0.2792 [‡]	0.2714 [‡]
	+CQs	MTL	0.4554^{‡*}	0.2939^{‡*}	0.2803^{‡*}
					0.2697^{‡*}

Summary

- Single-initiative answer retrieval:
 - Model the conversation history.
 - Rewrite the query.
 - Passage Retrieval.
- Mixed-initiative; clarifying questions:
 - Multiple tasks, e.g., document ranking, question retrieval and selection.
 - Term matching
 - Guided transformers

Learning to Rank

Learning to rank and Conversations

- Not much explored.
- Used for ranking clarifying questions.

Task

- Clarifying question selection.
- Given a clarifying question, ranked list, and history,
- Should the question be presented to the user?

Features

- BERT representation of:
 - Query;
 - Current question;
 - Previous questions and answers.
- Ranked list scores:
 - Predicted relevance scores at top 200;
 - The variance of scores at top 200.

Question Selection

Method	Qulac-T Dataset					Qulac-F Dataset				
	MRR	P@1	nDCG@1	nDCG@5	nDCG@20	MRR	P@1	nDCG@1	nDCG@5	nDCG@20
OriginalQuery	0.2715	0.1842	0.1381	0.1451	0.1470	0.2715	0.1842	0.1381	0.1451	0.1470
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WorstQuestion	0.2479	0.1451	0.1075	0.1402	0.1483	0.2479	0.1451	0.1075	0.1402	0.1483
BestQuestion	0.4673	0.3815	0.3031	0.2410	0.2077	0.4673	0.3815	0.3031	0.2410	0.2077

Summary

- Learning to rank is not explored in conversational IR.
- Perhaps because of the dominance of BERT and other Transformer-based models.
- Lots of room for exploration.