

Machine Reading, Question Answering & Dialog

AMMI – Deep NLP

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Facebook AI Research (Paris)

April 13-17, 2020

Who are we?



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Director FAIR Paris

+ Help from **Sebastian Riedel** (Research Scientist FAIR London)



This Class:

- Machine Reading with deep learning
- Open-domain Question answering
- Deep learning for dialogue

Quick schedule (Kigali Time)

- Monday: 10am **Lecture** [Antoine] + 3pm **Q&A** [All] + 4pm **Labs** [Angela/Louis]
- Tuesday: 10am **Lecture** [Antoine] + 3pm **Labs** [Angela/Louis] + 5pm **Q&A** [All]
- Wednesday: 10am **Lecture** [Antoine] + 3pm **Q&A** [All] + 4pm **Labs** [Angela/Louis]
- Thursday: 3pm **Q&A** [All]
- Friday: 3pm **Quizz** [All]

ROBOTS CAN NOW READ BETTER THAN HUMANS, PUTTING MILLIONS OF JOBS AT RISK

BY **ANTHONY CUTHBERTSON** ON 1/15/18 AT 8:00 AM



ROBOTS CAN NOW PATTERN MATCH ON A BENCHMARK DATASET BETTER THAN HUMANS

BY **ANTHONY CUTHBERTSON** ON 1/15/18 AT 8:00 AM



BUT THERE HAS BEEN A LOT OF PROGRESS AND MACHINE READING RESEARCH ACTIVITY HAS SKYROCKETED

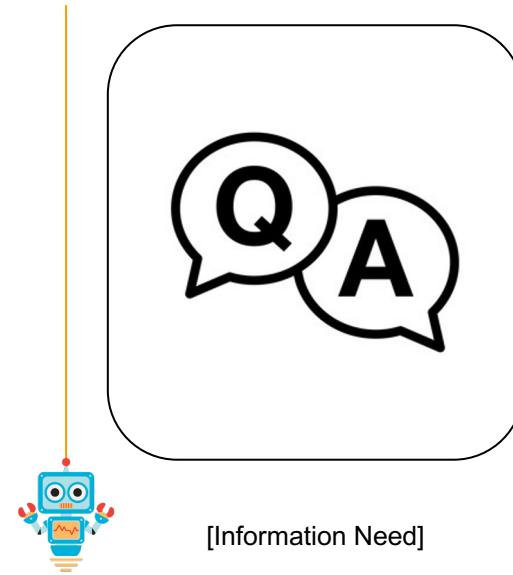
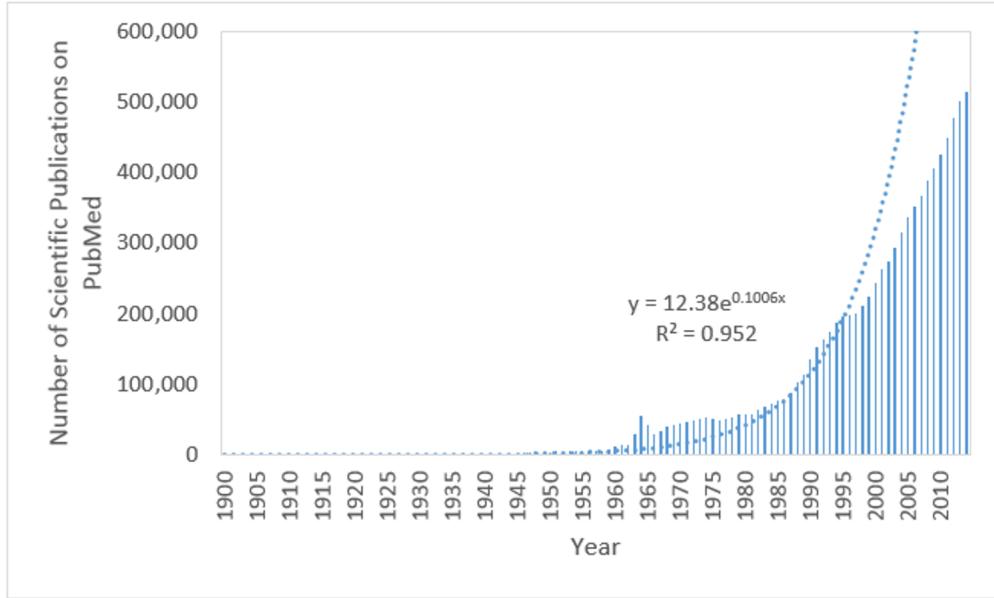
BY **ANTHONY CUTHBERTSON** ON 1/15/18 AT 8:00 AM



Main (big) motivation

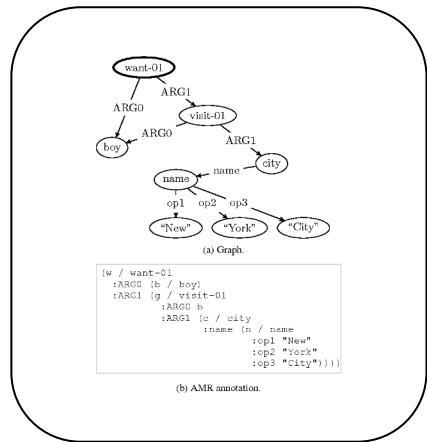
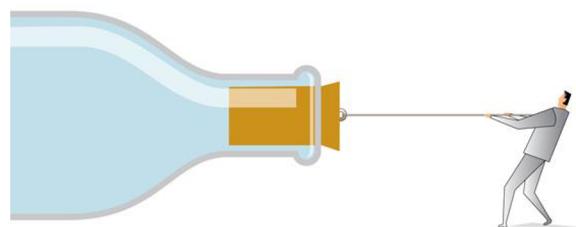
Machines processing **text** to
satisfy an **information need** is
long standing goal of AI

Motivation 1: Information Overload

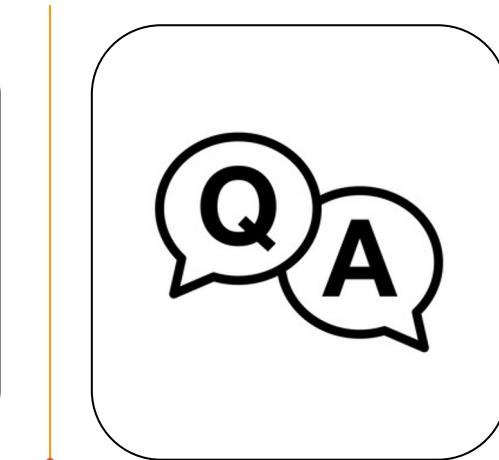


Motivation 2: The Knowledge Acquisition Bottleneck

“The problem of knowledge acquisition is the critical bottleneck problem in artificial intelligence.”
E. A. Feigenbaum 1984



[Meaning]



uses for

Applications: Question Answering

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospić for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

[Text]

?

[Meaning]

What city did Tesla move to in 1880?

Prague

[Information Need]

Applications: Support a Molecular Tumor Board

Poon et al., ACL'17

The deletion mutation on exon-19 of EGFR gene was present in 16 patients, while the L858E point mutation on exon-21 was noted in 10. All patients were treated with gefitinib and showed a partial response.

[Text]

?

[Meaning]



[Information Need]

COVID-19 Open Research Dataset Challenge (CORD-19)

An AI challenge with AI2, CZI, MSR, Georgetown, NIH & The White House



Allen Institute For AI and 8 collaborators • updated 2 days ago (Version 7)

[Data](#)[Tasks \(10\)](#)[Kernels \(741\)](#)[Discussion \(249\)](#)[Activity](#)[Metadata](#)[Download \(7 GB\)](#)[New Notebook](#)

Tasks

What is known about transmission, incubation, and environmental stability?

^ 998

COVID-19 Open Research Dataset Challenge (CORD-19)

Paul Mooney · 84 Submissions

What do we know about COVID-19 risk factors?

^ 318

COVID-19 Open Research Dataset Challenge (CORD-19)

Paul Mooney · 71 Submissions

What do we know about virus genetics, origin, and evolution?

^ 161

COVID-19 Open Research Dataset Challenge (CORD-19)

Paul Mooney · 55 Submissions

What do we know about vaccines and therapeutics?

^ 136

COVID-19 Open Research Dataset Challenge (CORD-19)

Paul Mooney · 53 Submissions

What has been published about medical care?

^ 114

COVID-19 Open Research Dataset Challenge (CORD-19)

Paul Mooney · 42 Submissions

<https://www.kaggle.com/allen-institute-for-ai/CORD-19-research-challenge/tasks>

Applications: Helping Agents to learn Faster

Branavan et al., JMLR'12

The natural resources available where a population settles affects its ability to produce food and goods. Build your city on a plains or grassland square with a river running through it if possible.

[Text]

?

[Meaning]

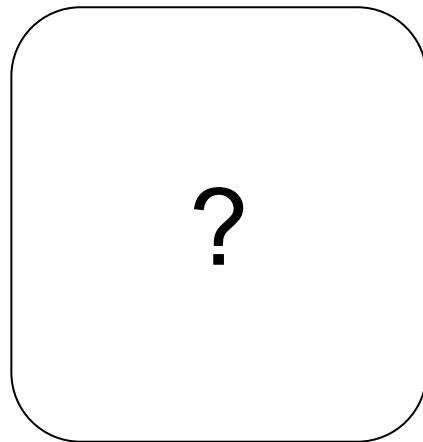


[Information Need]

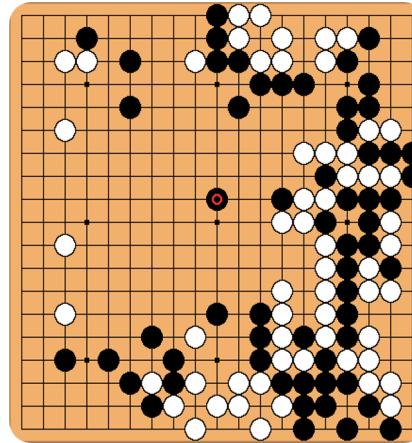
Applications: Helping Agents to learn Faster

A fundamental Go strategy involves keeping stones connected. Connecting a group with one eye to another one-eyed group makes them live together. Connecting individual stones into a single group results in an increase of liberties ...

[Text]



[Meaning]



[Information Need]

Machine Reading

Machines understanding text?

Machine Reading

“A machine comprehends a passage of text if, for any question regarding that text that can be answered correctly by a majority of native speakers, that machine can provide a string which those speakers would agree both answers that question, and does not contain information irrelevant to that question.”

Towards the Machine Comprehension of Text: An Essay

Christopher J.C. Burges
Microsoft Research
One Microsoft Way
Redmond, WA 98052, USA

December 23, 2013

Machine Reading

A **machine** processes a **passage of text** to satisfy an **information need** (usually answer a question on it)

Machine Reading

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospić for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

[Passage of Text]



uses for



[Information Need]

Machine Reading

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospic for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

[Passage of Text]



converts into

?

[Meaning]



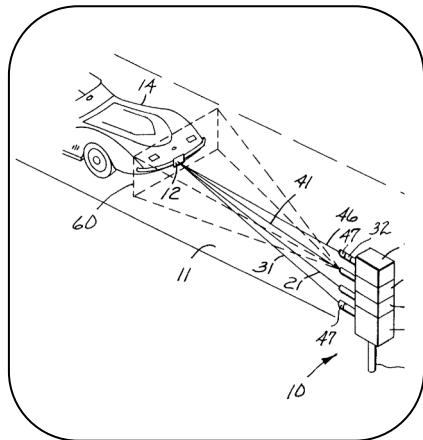
uses for



[Information Need]

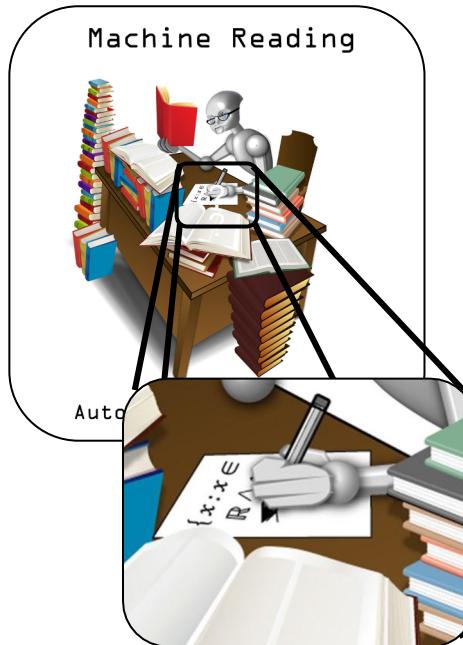
Timeline of Machine Reading

Something else
entirely!

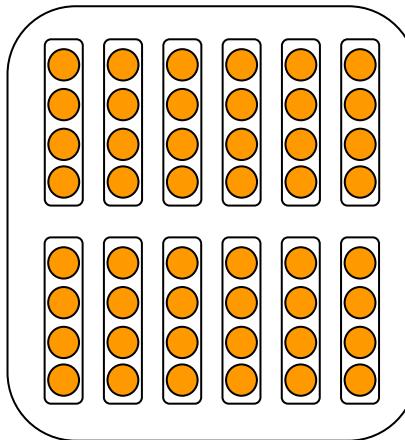


before 2006

Text to Meaning
Representations

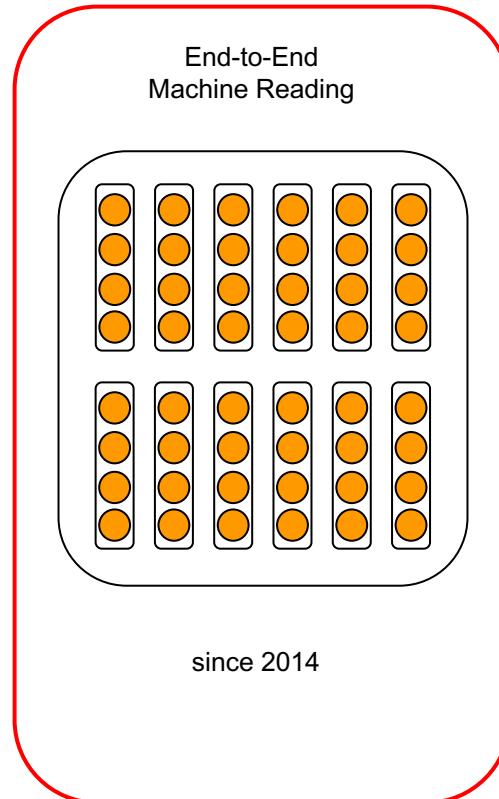


End-to-End
Machine Reading



since 2014

Today we cover:



Machine Reading

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospic for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

[Passage of Text]



converts into

?

[Meaning]



uses for

Q A

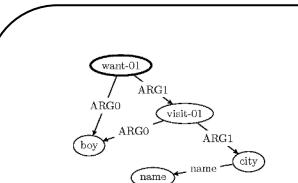
[Information Need]

Symbolic Approaches (until 2014 or so)

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospić for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.



[Passage of Text]



(a) Graph.

```
(w / want-01
:ARG0 (b / boy)
:ARG1 (g / visit-01
:ARG0 b
:ARG1 (c / city
:lname (n / name
:op1 "New"
:op2 "York"
:op3 "City"))))
```

(b) AMR annotation.

converts into



[Meaning]

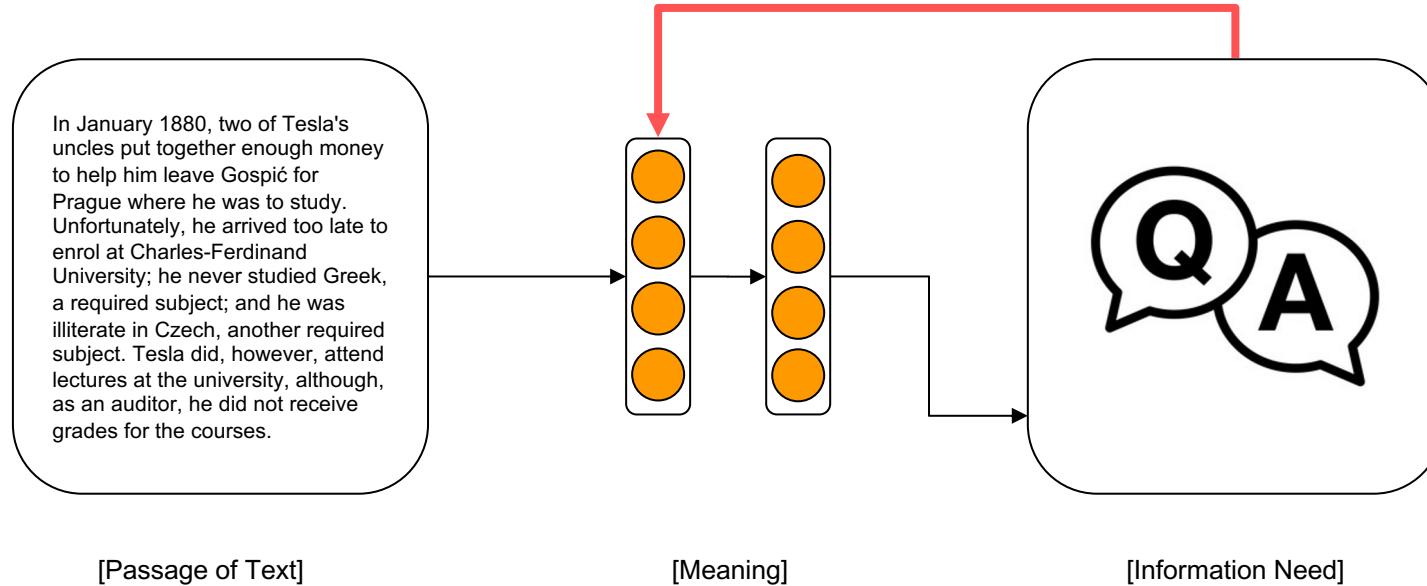


uses for



[Information Need]

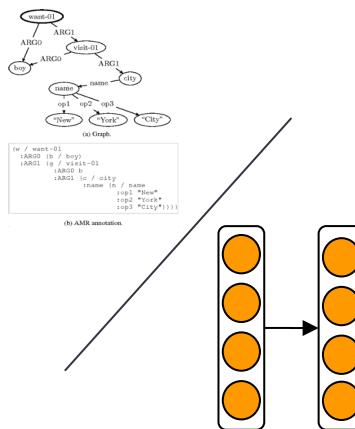
End-to-End Approaches (since 2014 or so)



What do we need from a representation?

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospić for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

[Passage of Text]



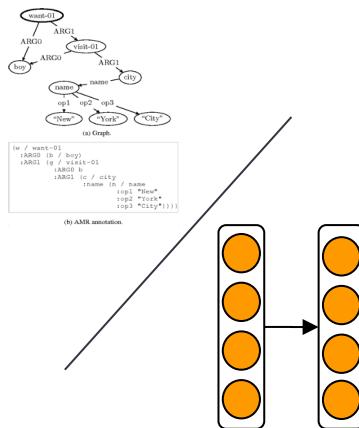
[Meaning]

- Fast Retrieval
 - Generalization
 - Broad Coverage
 - Easy Engineering
 - Support Reasoning
 - Small Memory Footprint

What are the core challenges?

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospić for Prague where he was to study. Unfortunately, he arrived too late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

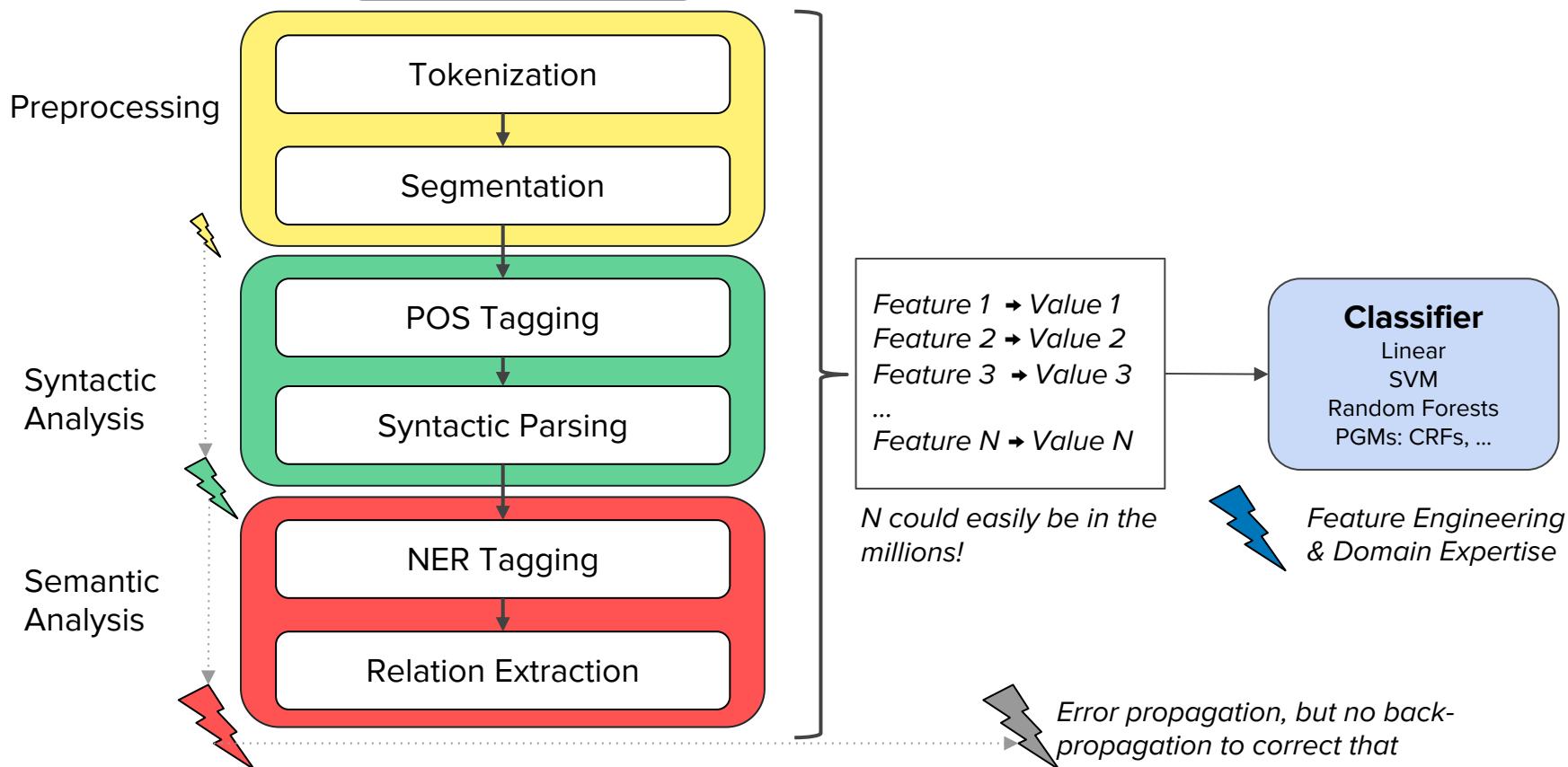
[Passage of Text]



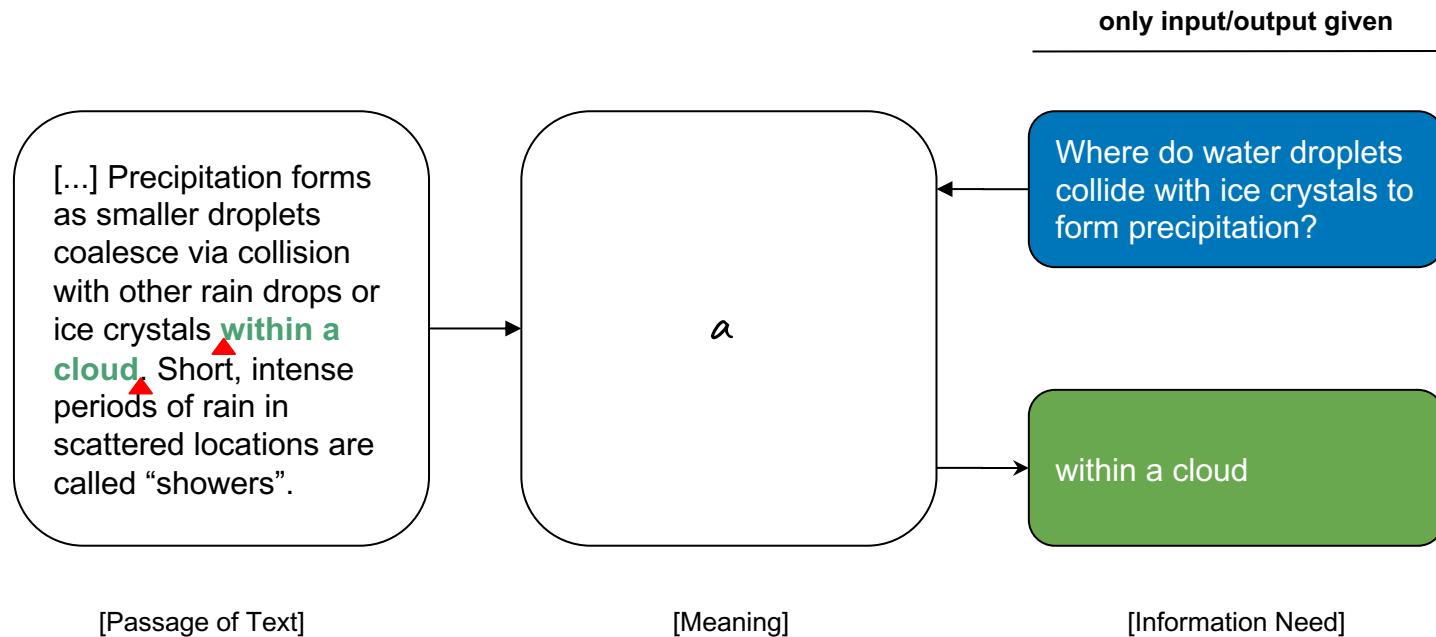
- Ambiguity
- Variation
- Coreference
- Common Sense
- Scale
- ...

late to enrol at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

“Traditional” NLP



End-to-end System



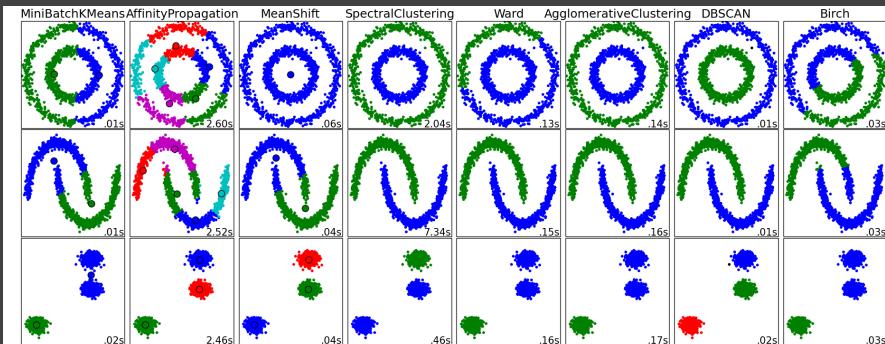
Machine Reading / Data

Limits of Big Model + Big Data

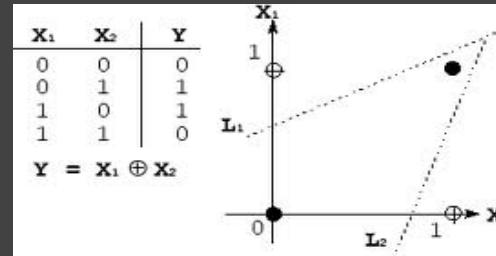
- End-to-end systems need a lot of cleaned data!
- Getting real conditions large-scale data is difficult:
 - Real large-scale data is complex, noisy, **unlabeled...**
 - Interpretation of success or failure is complex
- **Complicates the design of innovative learning systems**
- Some recent process with large amounts of unlabeled data [see Tomorrow]

A long history of artificial problems in ML

Two moons and friends (clustering)



XOR (neural networks)



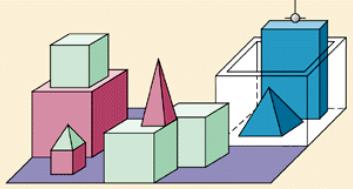
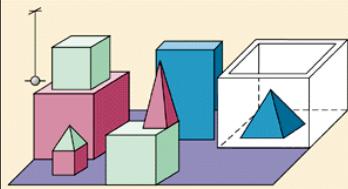
Many in the UCI repository
(regression, classification)

Toy/artificial problems in ML: crucial for demonstrating and assessing the usefulness/efficiency of new algorithms



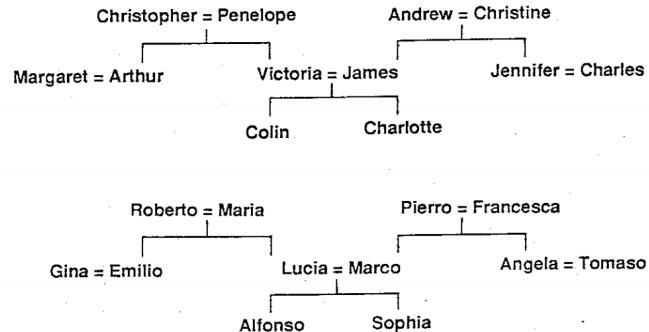
And in early AI too

Block Worlds (Winograd 1971)



```
Person: PICK UP A BIG RED BLOCK.  
Computer: OK. (does it)  
Person: GRASP THE PYRAMID.  
Computer: I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.  
Person: FIND A BLOCK WHICH IS TALLER THAN THE ONE YOU ARE HOLDING AND PUT IT INTO THE BOX.  
Computer: BY "IT", I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.  
Computer: OK. (does it)  
Person: WHAT DOES THE BOX CONTAIN?  
Computer: THE BLUE PYRAMID AND THE BLUE BLOCK.  
Person: WHAT IS THE PYRAMID SUPPORTED BY?  
Computer: THE BOX.  
Person: HOW MANY BLOCKS ARE NOT IN THE BOX?  
Computer: FOUR OF THEM.  
Person: IS AT LEAST ONE OF THEM NARROWER THAN THE ONE WHICH I TOLD YOU TO PICK UP?  
Computer: YES, THE RED CUBE.  
Person: IS IT SUPPORTED?  
Computer: YES, BY THE TABLE.  
Person: CAN THE TABLE PICK UP BLOCKS?  
Computer: NO.  
Person: CAN A PYRAMID BE SUPPORTED BY A BLOCK?  
Computer: YES.  
Person: CAN A PYRAMID SUPPORT A PYRAMID?  
Computer: I DON'T KNOW.  
Person: STACK UP TWO PYRAMIDS.
```

Family trees (Hinton CogSci'86)



bAbI Tasks

Weston et al., ICLR'15

- 20 artificial tasks for machine reading
- Answer has to be picked among a set of candidates
- Each task checks one skill that a reasoning system should have.
- Goal: develop systems able to solve all tasks *with no task specific engineering.*

A postulate is that *performing well on all of them is a pre-requisite for any system aiming at understanding language and able to reason.*

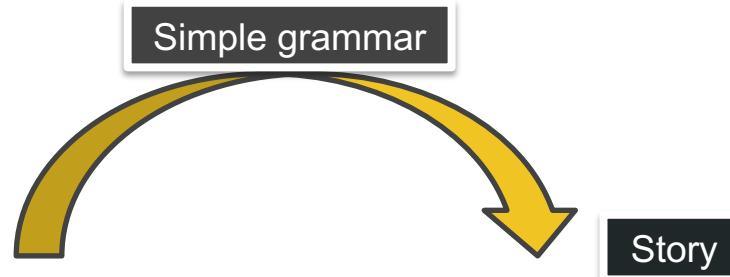
Simulation commands

- go <place>
- get <object>
- get <object1> from <object2>
- put <object1> in/on <object2>
- give <object> to <person>
- drop <object>
- look
- inventory
- examine <object>

+ 2 commands for "gods" (superusers):

- create <object>
- set <obj1> <relation> <obj2>

Example



Command format

jason go kitchen

jason get milk

jason go office

jason drop milk

jason go bathroom

where is milk ? A: office

where is jason? A: bathroom

Jason went to the kitchen.

Jason picked up the milk.

Jason travelled to the office.

Jason left the milk there.

Jason went to the bathroom.

Where is the milk now? **A: office**

Where is Jason? **A: bathroom**

(T1) Single supporting fact “where is actor”

- A single supporting fact, previously given, provides the [answer](#).
 - Simplest case of this: asking for the location of a person.

John is in the playground. 
Bob is in the office.
Where is John? A:playground



(T2) Two supporting facts “where is actor+object”

- Harder task: two supporting statements have to be chained to answer



John is in the playground.

Bob is in the office.

John picked up the football.

Bob went to the kitchen.

Where is the football? A:playground

Where was Bob before the kitchen? A:office

SUPPORTING FACT

SUPPORTING FACT

- To answer the first question *Where is the football?* both John picked up the football and John is in the playground are supporting facts

(T3) Three supporting facts

- Similarly, one can make a task with **three supporting facts**:

John picked up the apple.

John went to the office.

John went to the kitchen.

John dropped the apple.

Where was the apple before the kitchen? **A:office**



- The first three statements are all required to answer this.

(T4) Two argument relations: subj vs. obj.

- To answer questions the ability to differentiate and recognize subjects and objects is crucial
- Extreme case - sentences feature re-ordered words:

The office is north of the bedroom.
The bedroom is north of the bathroom.
What is north of the bedroom? A:office
What is the bedroom north of? A:bathroom



- The two questions above have exactly the same words, but in a different order, and different answers.
- So a bag-of-words will not work.

(T6) Yes/No questions

- This task tests, in the simplest case possible (with a single supporting fact) the ability of a model to answer true/false type questions:



John is in the playground.
Daniel picks up the milk.
Is John in the classroom? A: no
Does Daniel have the milk? A: yes



(T7) Counting

- This task tests the ability of the QA system to perform **simple counting operations**, by asking about the number of objects with a certain property:

Daniel picked up the football.
Daniel dropped the football.
Daniel got the milk.
Daniel took the apple.
How many objects is Daniel holding? A:**two**



(T17) Positional reasoning

- This task tests spatial reasoning:

The triangle is to the right of the blue square.

The red square is on top of the blue square.

The red sphere is to the right of the blue square.

Is the red sphere to the right of the blue square? A:yes

Is the red square to the left of the triangle? A:yes



- Close from **block worlds**, with no vision input.
- The Yes/No task (6) is a prerequisite.

(T18) Reasoning about size

- This task requires [reasoning about relative size](#) of objects :

The football fits in the suitcase.
The suitcase fits in the cupboard.
The box of chocolates is smaller than the football.
Will the box of chocolates fit in the suitcase? **A:yes**



- Inspired by the commonsense reasoning examples of the [Winograd schema challenge](#)
- Tasks 3 (three supporting facts) and 6 (Yes/No) are prerequisites.

Winograd Schemas

Levesque, AAAI'11

Definition: A Winograd schema is a pair of sentences that differ in only one or two words and that contain an ambiguity that is resolved in opposite ways in the two sentences and requires the use of world knowledge and reasoning for its resolution.

The **trophy**
would not fit in
the brown
suitcase
because **it** was
too **big**.

The **trophy**
would not fit in
the brown
suitcase
because **it** was
too **small**.

it = **trophy** or **suitcase** ?

More schemas here: <https://cs.nyu.edu/faculty/davise/papers/WinogradSchemas/WSCollection.html>

(T19) Path finding

- In this task the goal is to **find the path** between locations:

The kitchen is north of the hallway.
The den is east of the hallway.
How do you go from den to kitchen? **A:west,north**



- This task is difficult because it effectively **involves search**.

Training on 1k stories

Dashboard

Weak supervised

Fully supervised

TASK	N-grams	LSTMs	StructSVM + COREF + SRL	Attention model
T1. Single supporting fact	36	50	PASS	PASS
T2. Two supporting facts	2	20	74	PASS
T3. Three supporting facts	7	20	17	PASS

Rank	Method	Accuracy (trained on 10k)	Accuracy (trained on 1k)	Mean Error Rate	Paper Title	Year	Paper	Code
1	QRN	99.7%	90.1%	0.3%	Query-Reduction Networks for Question Answering	2016		
2	EntNet	99.5%	89.1%	9.7%	Tracking the World State with Recurrent Entity Networks	2016		

T11. Basic coreference	Source: https://paperswithcode.com/sota/question-answering-babi			PASS
T12. Conjunction	5	14	PASS	PASS
T13. Compound coreference	26	PASS	PASS	PASS
T14. Time reasoning	19	27	PASS	PASS
T15. Basic deduction	20	21	PASS	PASS
T16. Basic induction	43	23	24	PASS
T17. Positional reasoning	46	51	61	48
T18. Size reasoning	52	52	62	68
T19. Path finding	0	8	49	4
T20. Agent's motivation	76	91	PASS	PASS

Artificial tasks for Machine Reading

- Advantages:
 - Total control on the complexity of the tasks/reasoning
 - Clear interpretation of results
 - Small-ish scale so easy to prototype on them
- Challenges:
 - How do we know that artificial data models the right problem?
 - By creating the tasks that we are solving, aren't we fooling ourselves?
 - How transfer from artificial to real conditions?

Other Machine Reading & QA Datasets

Leaderboards						
TREND	DATASET	BEST METHOD	PAPER TITLE	PAPER	CODE	COMPARE
	SQuAD2.0	Retro-Reader on ALBERT (ensemble)	Retrospective Reader for Machine Reading Comprehension			See all
	SQuAD1.1	XLNet (single model)	XLNet: Generalized Autoregressive Pretraining for Language Understanding			See all
	SQuAD1.1 dev	T5-11B	Exploring the Limits of Transfer Learning with a Unified Text-to-Text Transformer			See all
	WikiQA	TANDA-RoBERTa (ASNQ, WikiQA)	TANDA: Transfer and Adapt Pre-Trained Transformer Models for Answer Sentence Selection			See all
	CNN / Daily Mail	GA+MAGE (32)	Linguistic Knowledge as Memory for Recurrent Neural Networks			See all
<hr/>						
Quora Question Pairs ALBERT ALBERT: A Lite BERT for Self-supervised Learning of Language Representations See all						
SQuAD2.0 dev XLNet+DSC Dice Loss for Data-imbalanced NLP See all						
bAbi STM Self-Attentive Associative Memory See all						
NarrativeQA (NarrativeQA + MS MARCO) Generative Reading Comprehension See all						
Children's Book Test GPT-2 Language Models are Unsupervised Multitask Learners See all						
CoQA BERT Large Augmented (single model) BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding See all						
QASent Attentive LSTM Neural Variational Inference for Text Processing See all						
YahooCQA sMIM (1024) + SentenceMIM: A Latent Variable Language Model See all						

Many more (30+) on: paperswithcode.com/task/question-answering

Stanford Question Answering Dataset (SQuAD)

Rajpurkar et. al., EMNLP'16

- **Dataset size:** 107,702 samples
- Widely used benchmark dataset
- **Task:** Extractive Question Answering
 - System has to predict the start and end position of the answer in the passage of text

Stanford Question Answering Dataset (SQuAD)

Text Passage

[...] Precipitation occurs as smaller drops coalesce via collision with other rain droplets to form larger ice crystals **within the cloud**. Short, intense periods of rain in scattered locations are called “showers.”

Task: Given a text passage, predict the text spans that answer questions.

Rank	Model	EM	F1
	Human Performance Stanford University (Rajpurkar & Jia et al. '18)	86.831	89.452
1 Mar 05, 2019	BERT + N-Gram Masking + Synthetic Self-Training (ensemble) Google AI Language https://github.com/google-research/bert	86.673	89.147
2 Mar 05, 2019	BERT + N-Gram Masking + Synthetic Self-Training (single model) Google AI Language https://github.com/google-research/bert	85.150	87.715
3 Jan 15, 2019	BERT + MMFT + ADA (ensemble) Microsoft Research Asia	85.082	87.615
4 Jan 10, 2019	BERT + Synthetic Self-Training (ensemble)	84.292	86.967
5 Dec 16, 2018	PAML+BERT (ensemble model) PINGAN GammaLab	83.457	86.122
5 Dec 21, 2018		043	

Very popular leaderboard!

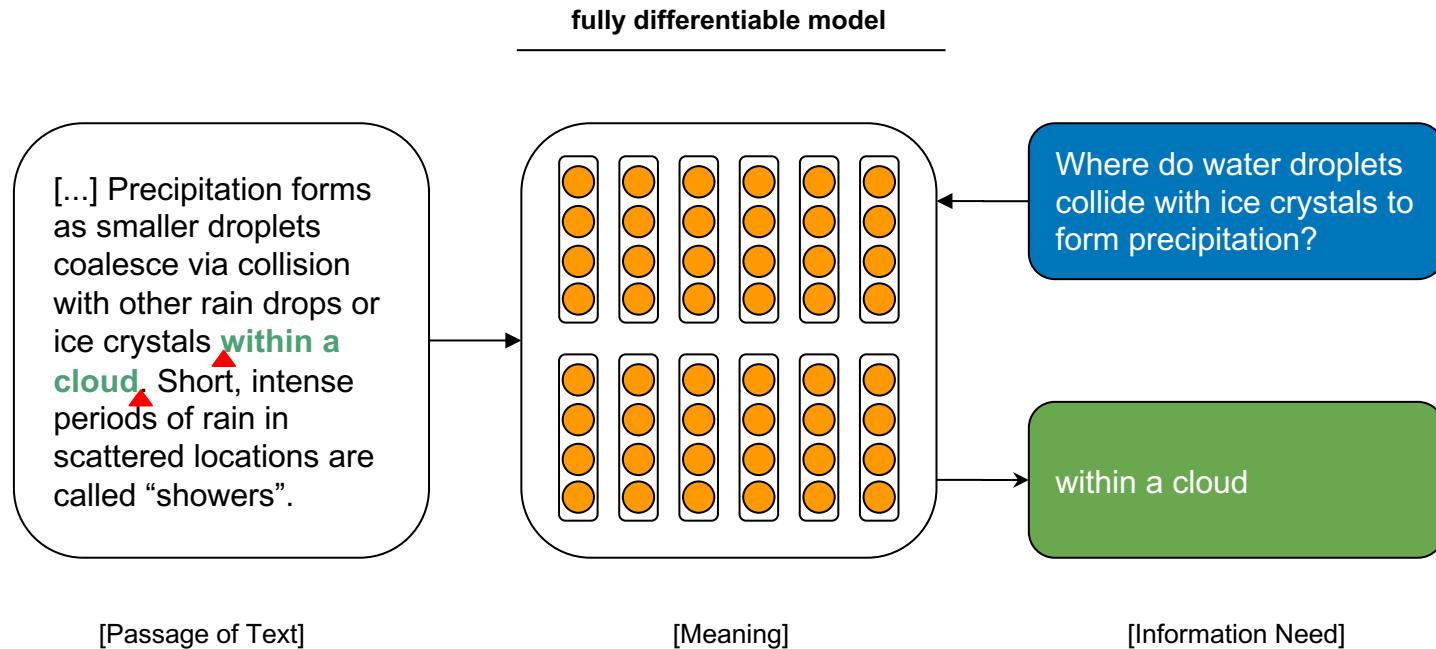
<https://stanford-qa.com>

Answer

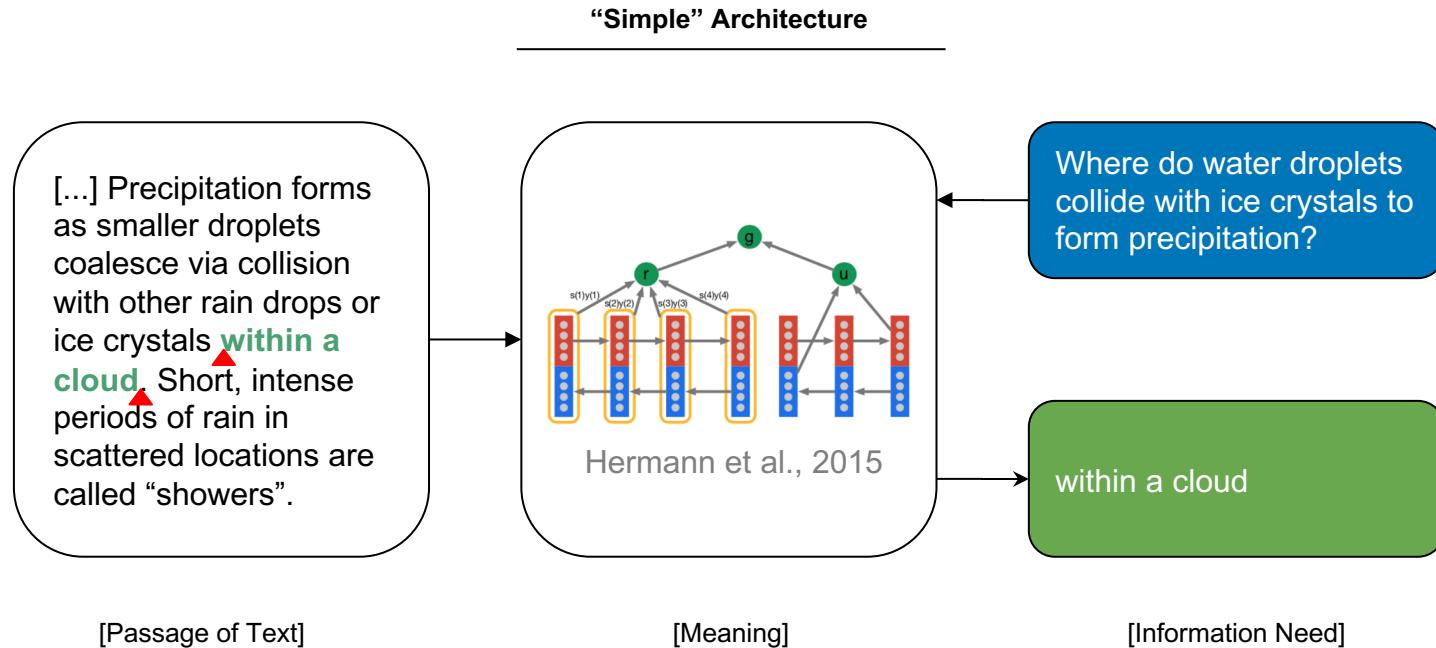
Water droplets freeze into ice crystals to form snowflakes?

Machine Reading / Models

End-to-end Machine Reading for Question Answering



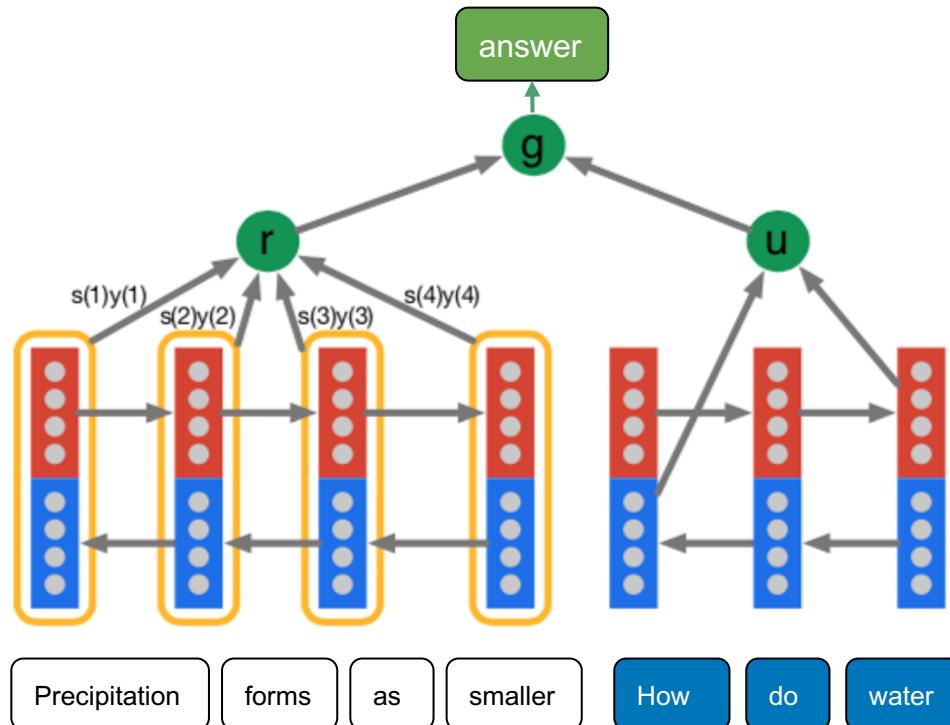
End-to-end Machine Reading for Question Answering



The Attentive Reader Model: Overview

Hermann et al., NIPS'15

- ‘early’ neural model for Machine Reading
- main components reused in many other models



The Attentive Reader Model: Overview

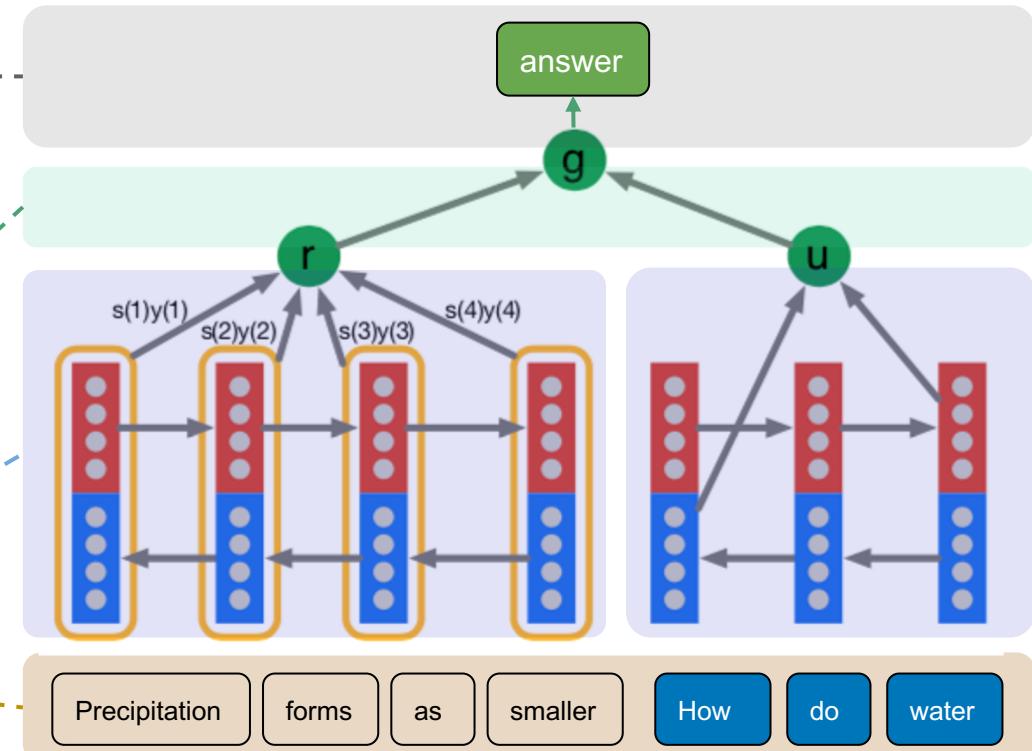
Answer Selection:
answer prediction

answer

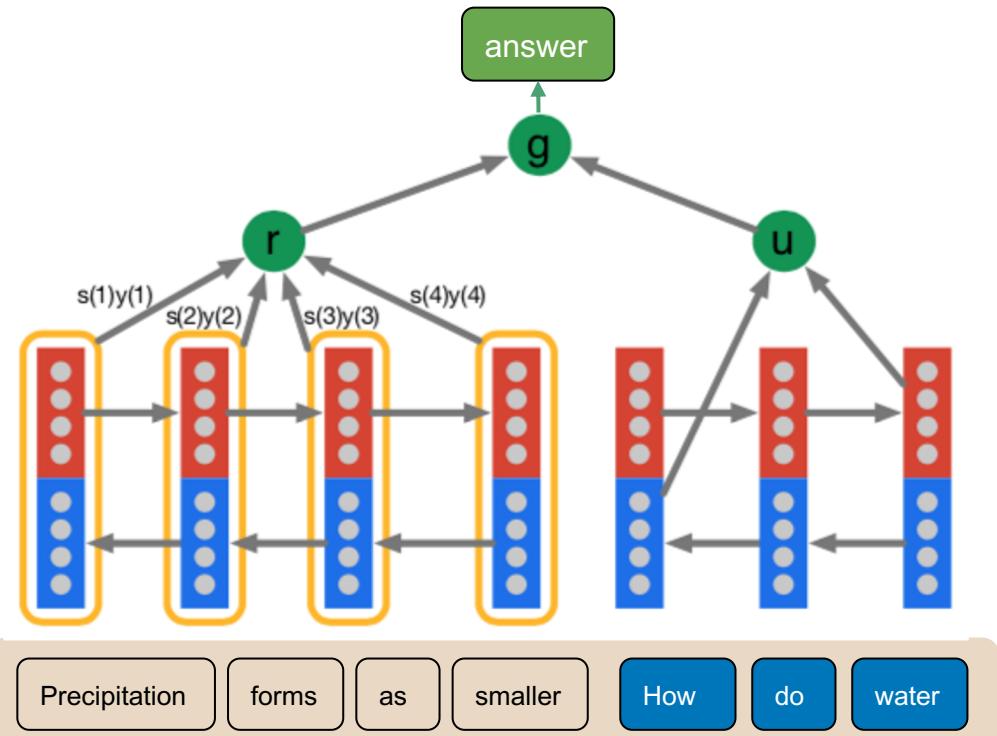
Sequence Interaction:
Matching text with question

Composition: incorporating
context around words

Input: Representing symbols as
vectors

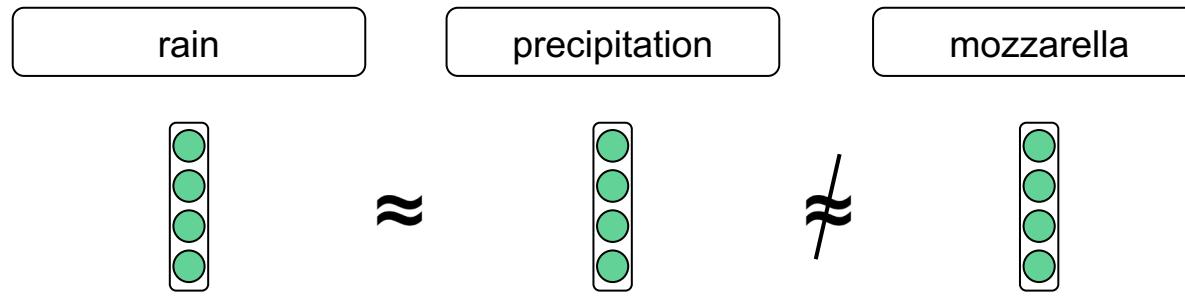


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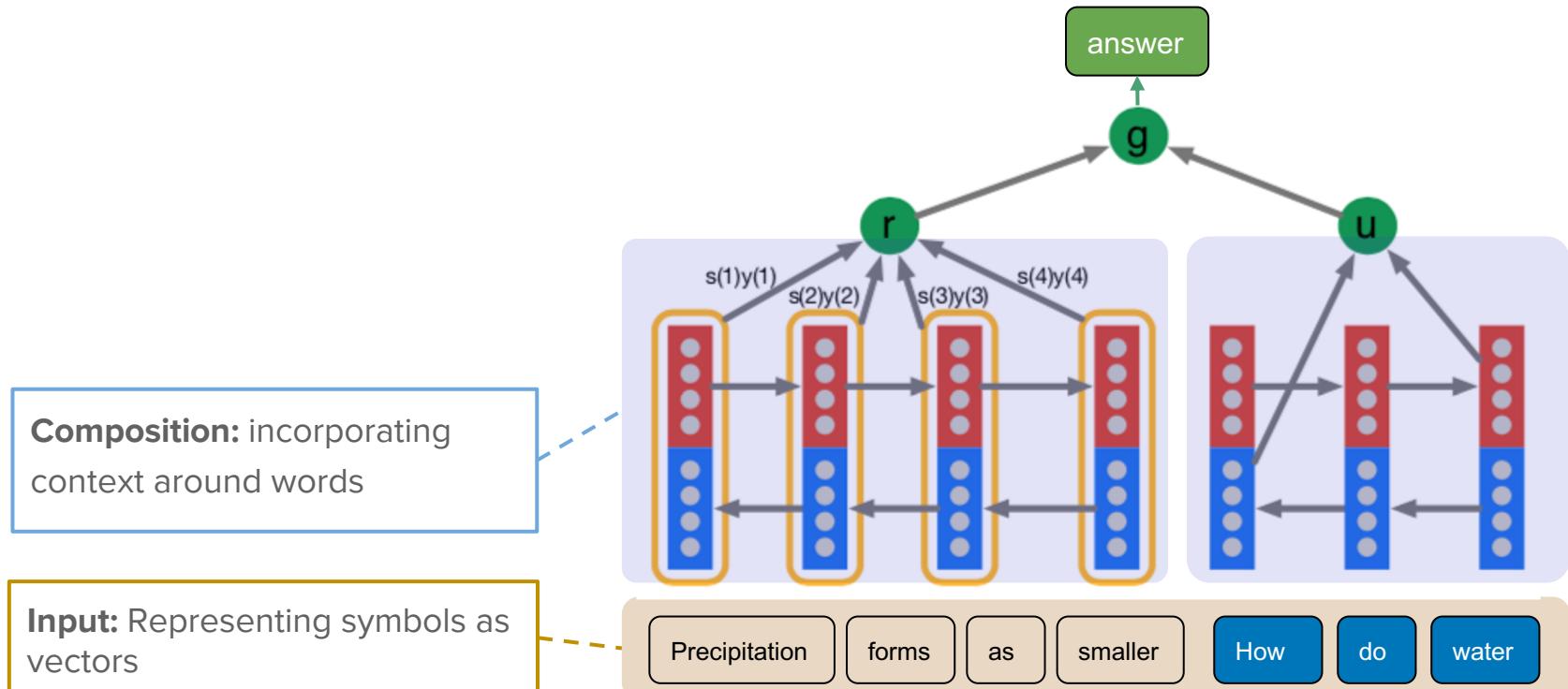
Modified visualization from Hermann et. al. NIPS'15

Representations for words: Embeddings

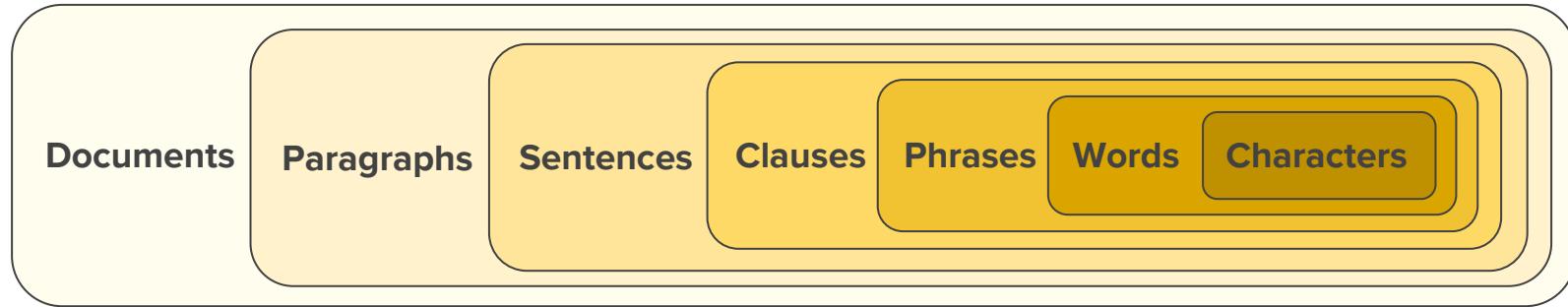


Similar meaning of words → similar vector representations – see previous lectures!

The Attentive Reader Model: Overview



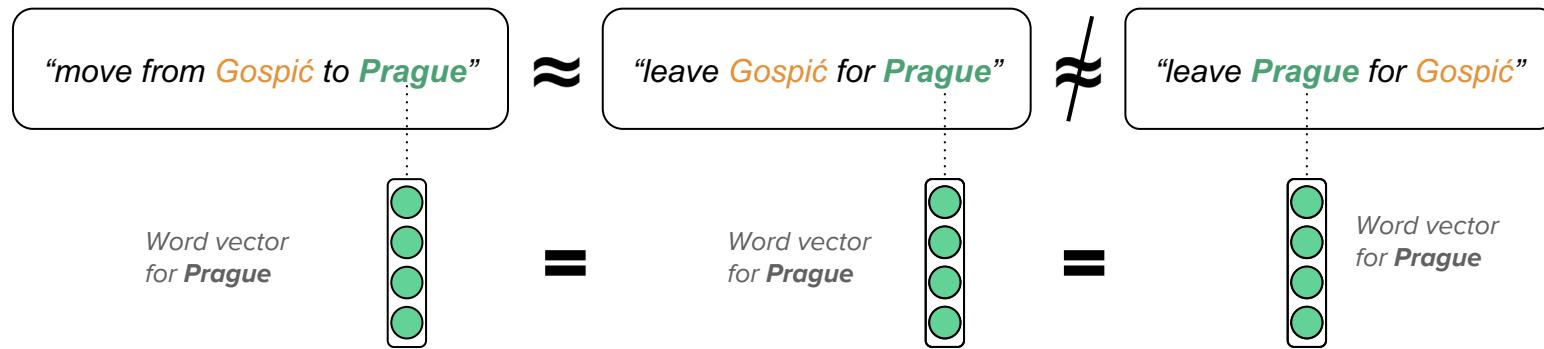
Language is compositional



Challenges

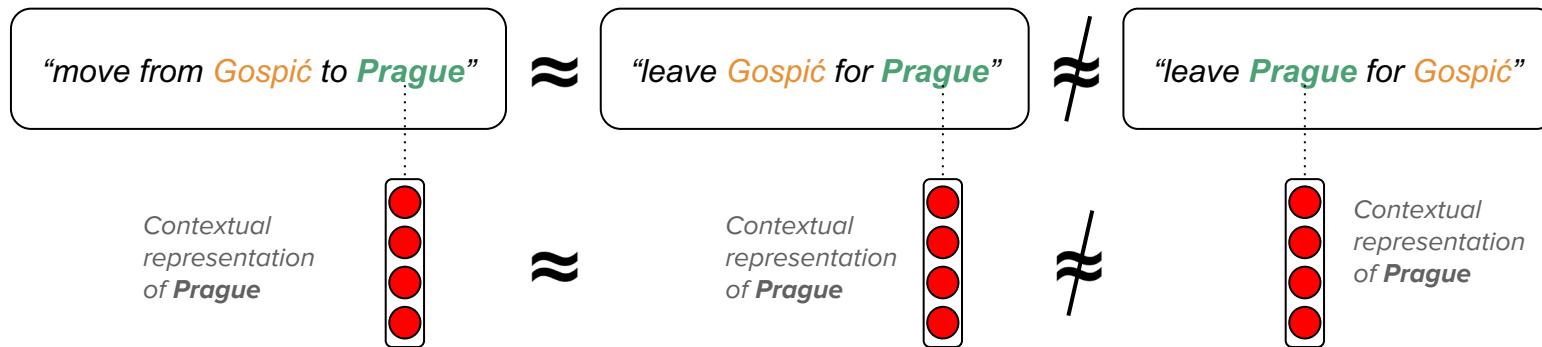
- Inductive bias: which composition function to use?
 - sequence, tree or more general graph structures?
 - varies for different levels
- Capturing long-range dependencies
 - **co-reference** (tracking entities)
 - effective information flow: ease of learning

Representing Words in Context



- Word representations should vary depending on context

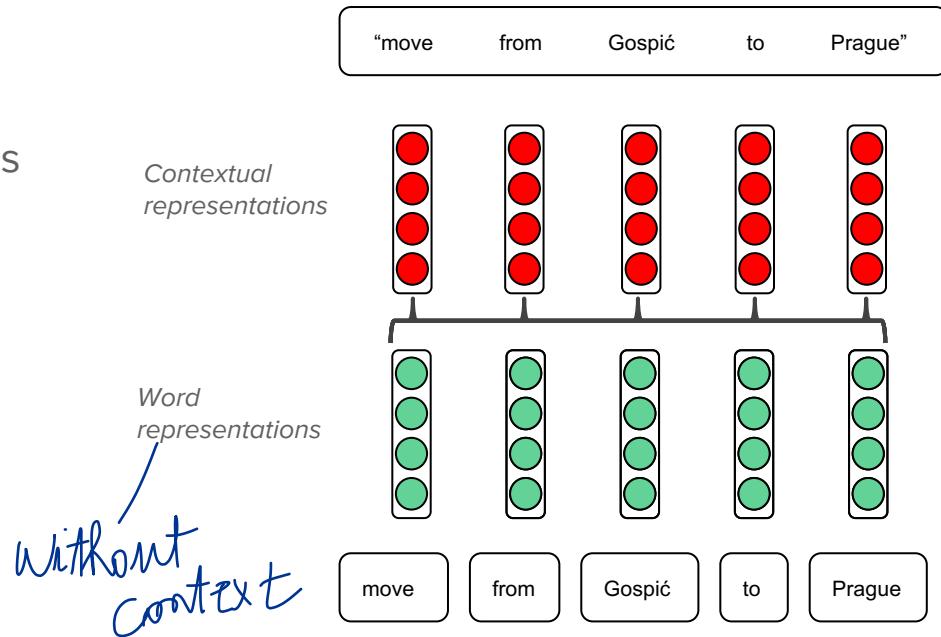
Representing Words in Context



- Word representations should vary depending on context
- **Contextual word representation:**
 - a word representation, computed conditionally on the given context

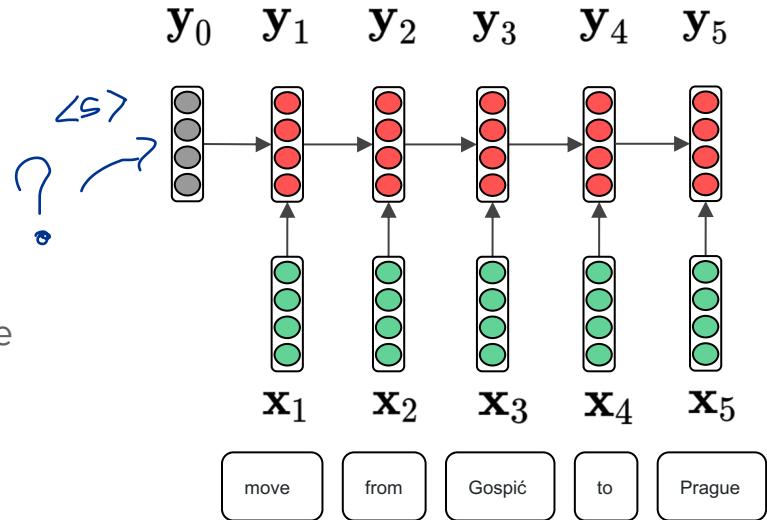
Representing Words in Context

- composition of word vectors into contextualized word representations
- use vector composition function



Recurrent Neural Network Layers

- **Idea:** text as sequence
- Prominent types: *LSTM, GRU*
- **Inductive bias:** Recency
 - more recent symbols have bigger impact on hidden state
- **Advantages**
 - everything is connected
 - easy to train and robust in practice
- **Disadvantages**
 - Slow → computation time linear in length of text
 - not good for (very) long range dependencies
- *Good for:* sentences, small paragraphs



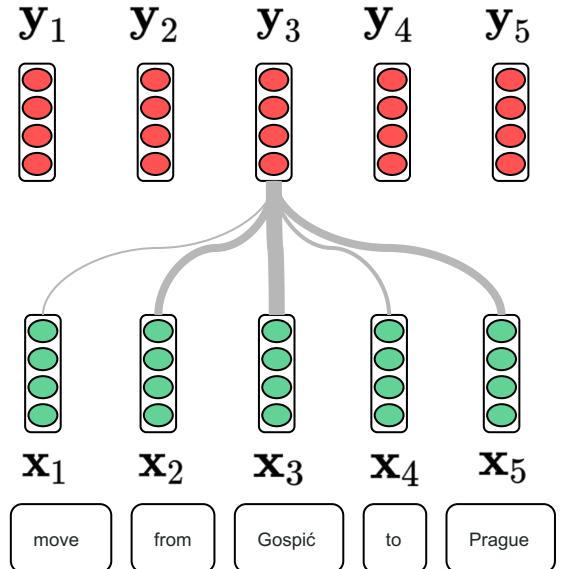
$$\mathbf{y}_t = f(\mathbf{x}_t, \mathbf{y}_{t-1})$$

Tree-variants:

- TreeLSTM (Tai et al., SCL'15)
- RNN Grammars (Dyer et al. NAACL'16)
- Bias towards syntactic hierarchy

Self-Attention Layer

- **Idea:** latent graph on text
- **Inductive bias:**
 - relationships between word pairs
- compute K separate weighted word representation(s) of the context for each word t
- **Advantages**
 - can capture long-range dependencies
 - Parallelizable and fast
- **Disadvantages**
 - careful setup of hyper-parameters
 - potentially memory intensive computation of attention weights for large contexts, $O(T * T * K)$
- *Good for:* phrases, sentences, paragraphs

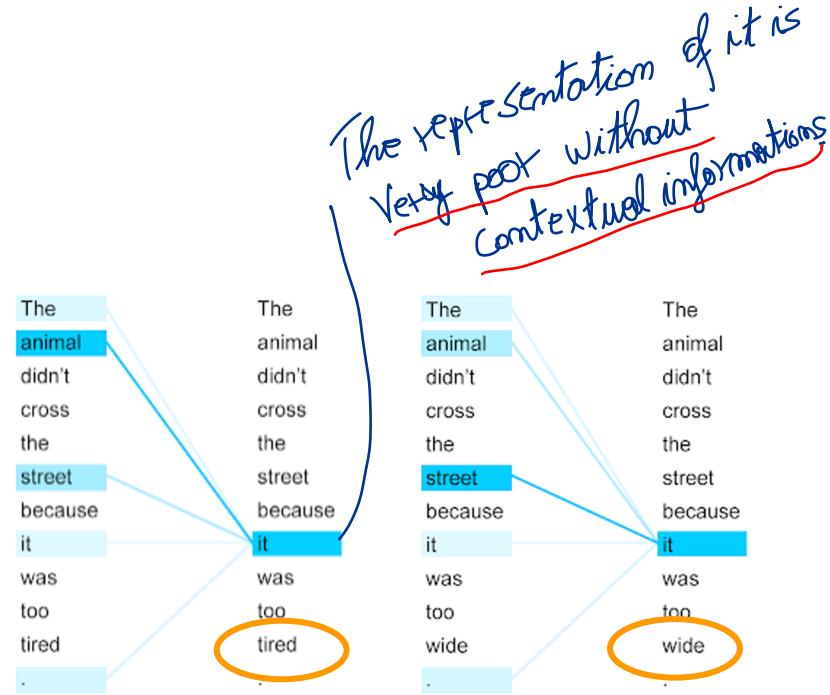


$$\begin{aligned}\mathbf{y}_t &= f(\mathbf{x}_1, \dots, \mathbf{x}_T) \\ \tilde{\mathbf{x}}_t^k &= \sum_{j=1}^T \alpha_{j,t}^k \mathbf{x}_j \quad k = 1, \dots, K \\ f(\mathbf{x}_1, \dots, \mathbf{x}_T) &= \text{nonlinear}(\tilde{\mathbf{x}}_t^1, \dots, \tilde{\mathbf{x}}_t^K)\end{aligned}$$

$\alpha_t^k : k^{th}$ self-attention weights for token

Self-Attention Layer

- Graph with weighted edges of K types
- Can capture:
 - coreference chains
 - syntactic dependency structure in text



Transformer Self-Attention Coreference Visualization

<https://ai.googleblog.com/2017/08/transformer-novel-neural-network.html>

Transformer

Vaswani et al., NIPS'17

- Residual connections before and after multi-head attention
- Decoder uses both self attention and encoder attention

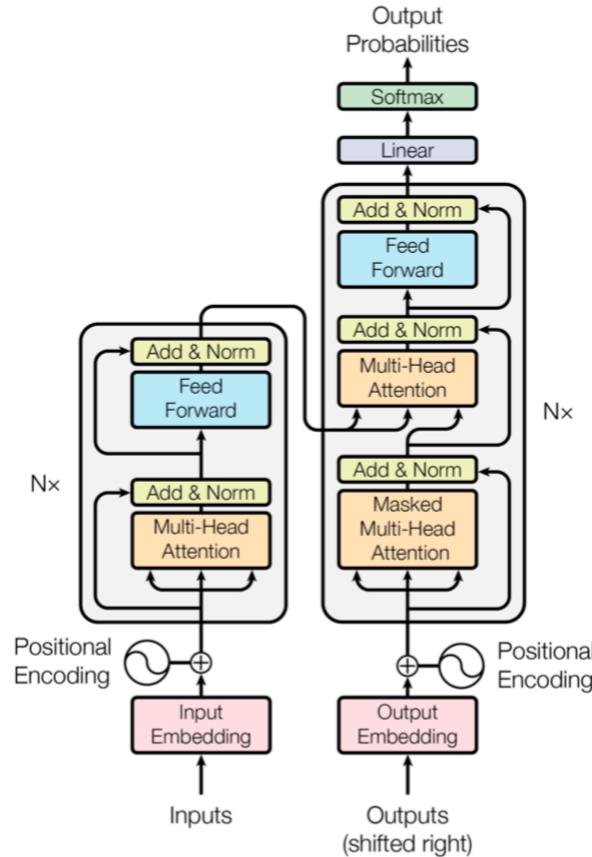
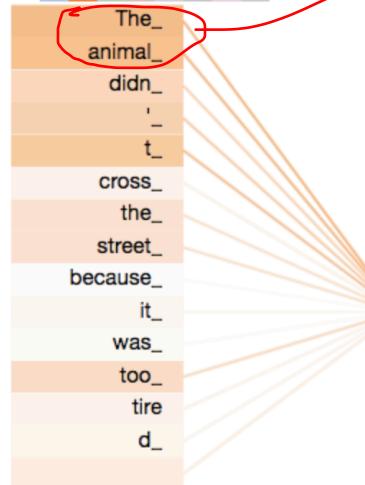


Figure from Vaswani et al., NIPS'17

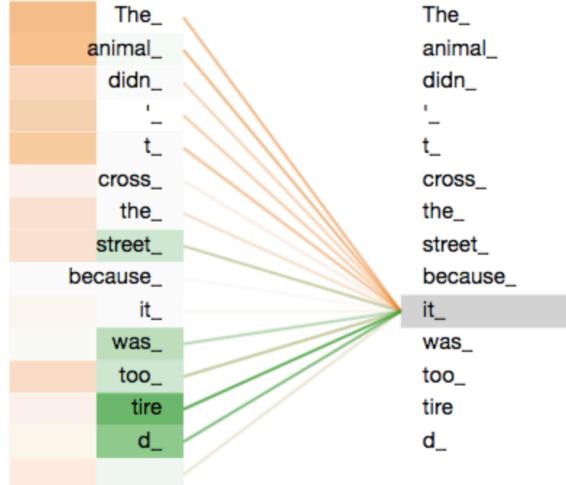
Multi-head attention

What about
the animal

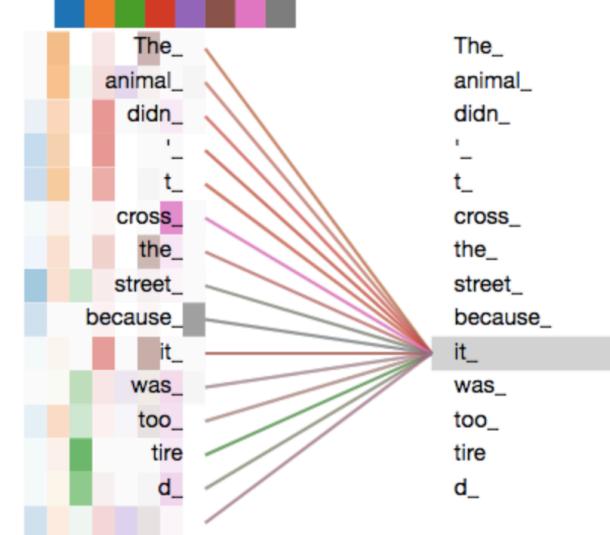
Layer: 5 Attention: Input - Input



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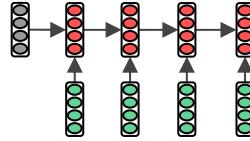
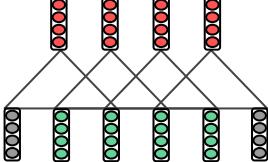
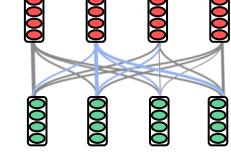


Layer: 5 Attention: Input - Input

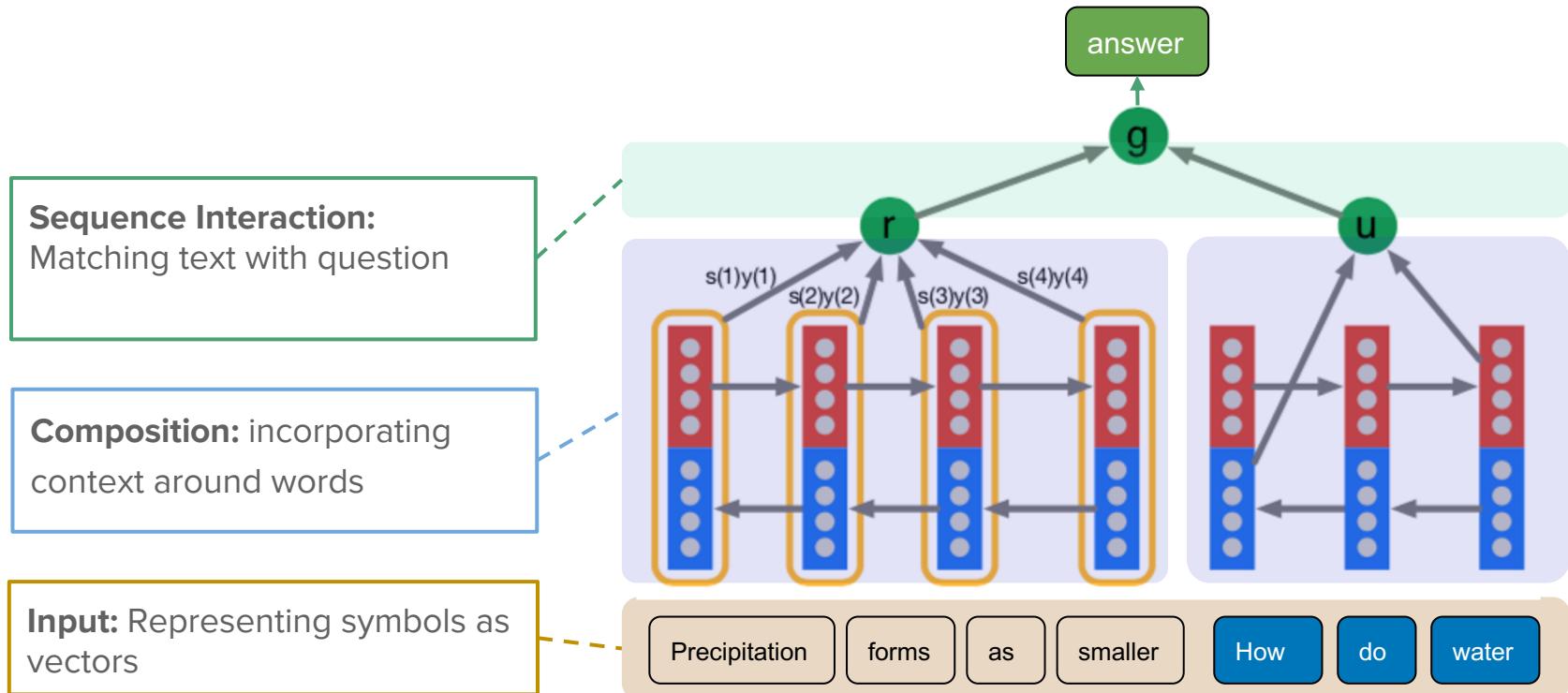


Compositional Sequence Encoders - Overview

- Language is compositional!
 - Characters → Words → Phrases → Clauses → Sentences → Paragraphs → Documents

Architecture	RNN (LSTM, GRU)	CNN	Self-Attention
Illustration			
Function $\mathbf{y}_t =$	$f(\mathbf{x}_t, \mathbf{y}_{t-1})$	$f(\mathbf{x}_{t-k}, \dots, \mathbf{x}_{t+k})$	$f(\mathbf{x}_1, \dots, \mathbf{x}_T)$
Advantages	- unlimited context - recency bias	- parallelizable → fast - local n-gram patterns	- parallelizable → fast - long-range dep
Disadvantages	- slower - strong recency bias - long-range dep	- limited context - strong locality bias - long-range dep	- harder to train - careful setup of hyper-parameters

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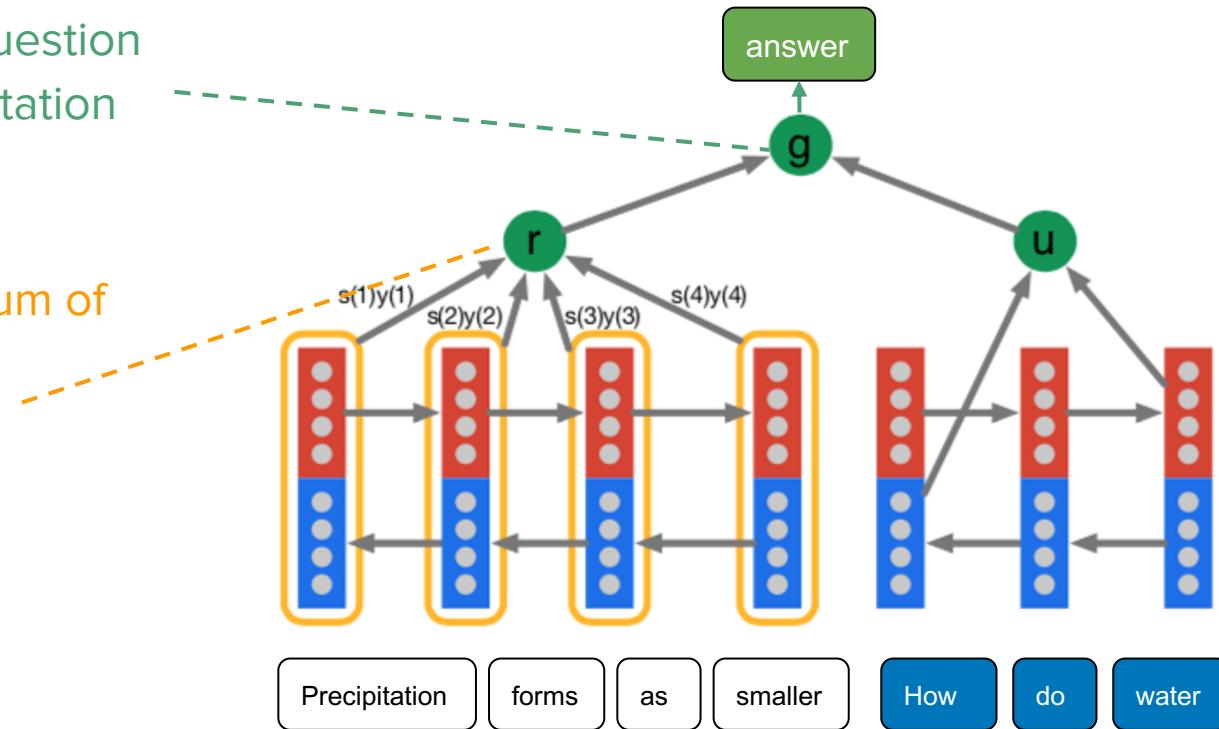
Modelling sequence interactions

- **Why?** QA requires matching between question and text.
 - condition text representation on question (and vice versa)
- “**Naive approach**”: concatenation
 - append question after text, use RNN with longer sequence
- **Problem with naive approach:**
 - Long range dependencies: Many recurrent steps between answer and question → dilution of signal

Modelling sequence interactions

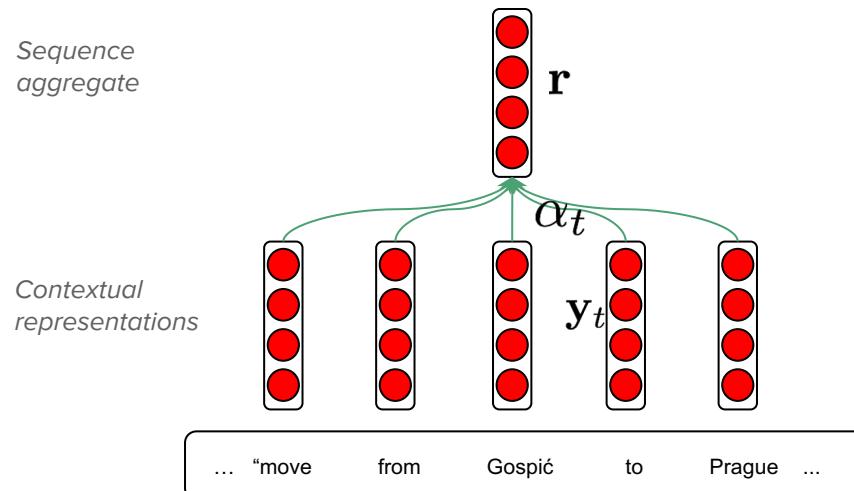
Combination of question
and text representation

attention-weighted sum of
contextualised word
representations



Modelling sequence interactions: Attention

- **Attention:** relevance-weighted pooling of vectors across sequence
 - Attention mask computed can be conditional on question and text
 - Determines relevance of tokens for answering the question

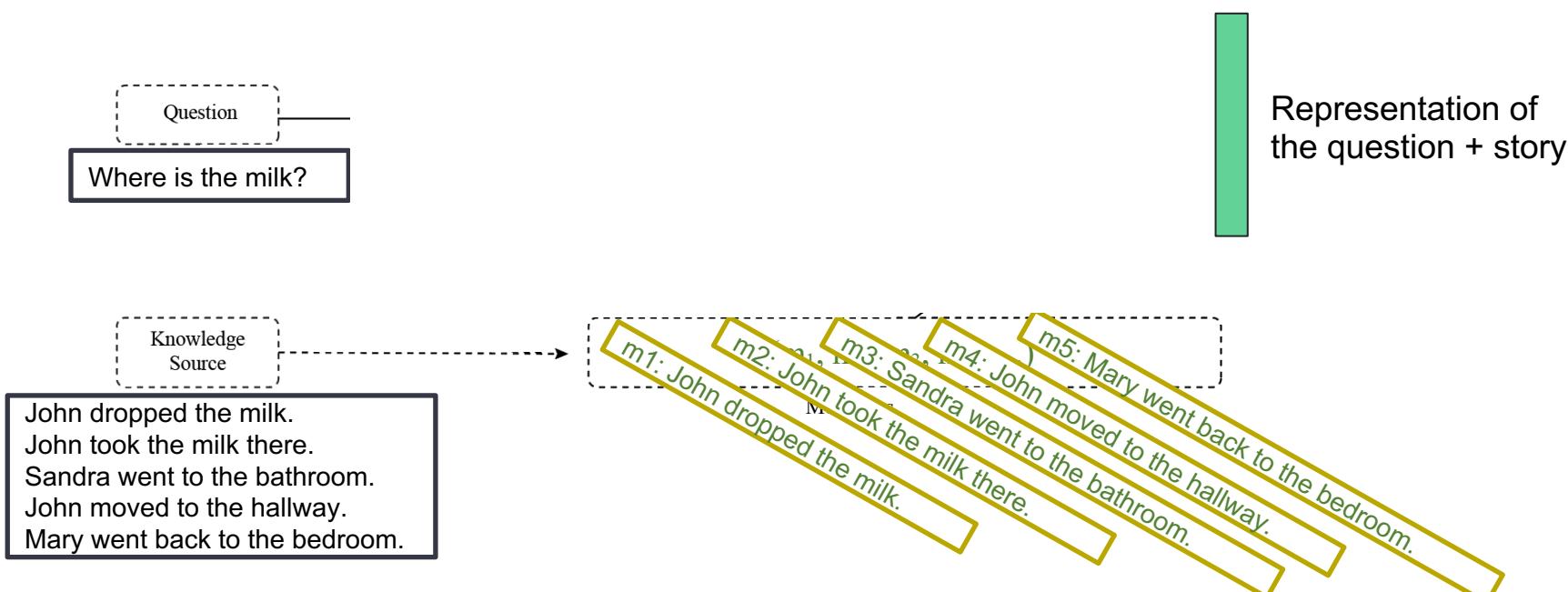


$$\mathbf{r} = \sum_{t=1}^T \alpha_t \mathbf{y}_t$$

$$\sum_{t=1}^T \alpha_t = 1; \quad \alpha_t \in [0, 1]$$

Modelling sequence interactions: Memory Networks

Sukhbaatar et al., NIPS'15 / Miller et al., EMNLP'16



Example: Learned attention patterns

Story (1: 1 supporting fact)	Support	Hop 1	Hop 2	Hop 3
Daniel went to the bathroom.		0.00	0.00	0.03
Mary travelled to the hallway.		0.00	0.00	0.00
John went to the bedroom.		0.37	0.02	0.00
John travelled to the bathroom.	yes	0.60	0.98	0.96
Mary went to the office.		0.01	0.00	0.00
Where is John? Answer: bathroom Prediction: bathroom				

Story (2: 2 supporting facts)	Support	Hop 1	Hop 2	Hop 3
John dropped the milk.		0.06	0.00	0.00
John took the milk there.	yes	0.88	1.00	0.00
Sandra went back to the bathroom.		0.00	0.00	0.00
John moved to the hallway.	yes	0.00	0.00	1.00
Mary went back to the bedroom.		0.00	0.00	0.00
Where is the milk? Answer: hallway Prediction: hallway				

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				

Story (18: size reasoning)	Support	Hop 1	Hop 2	Hop 3
The suitcase is bigger than the chest.	yes	0.00	0.88	0.00
The box is bigger than the chocolate.		0.04	0.05	0.10
The chest is bigger than the chocolate.	yes	0.17	0.07	0.90
The chest fits inside the container.		0.00	0.00	0.00
The chest fits inside the box.		0.00	0.00	0.00
Does the suitcase fit in the chocolate? Answer: no Prediction: no				

End-to-end Memory Networks on bAbI tasks

Example: Learned attention patterns

by ent423 ,ent261 correspondent updated 9:49 pm et ,thu march 19 ,2015 (ent261) a ent114 was killed in a parachute accident in ent45 ,ent85 ,near ent312 ,a ent119 official told ent261 on wednesday .he was identified thursday as special warfare operator 3rd class ent23 ,29 ,of ent187 ,ent265 .`` ent23 distinguished himself consistently throughout his career .he was the epitome of the quiet professional in all facets of his life ,and he leaves an inspiring legacy of natural tenacity and focused

...

ent119 identifies deceased sailor as X ,who leaves behind a wife

by ent270 ,ent223 updated 9:35 am et ,mon march 2 ,2015 (ent223) ent63 went familial for fall at its fashion show in ent231 on sunday ,dedicating its collection to `` mamma '' with nary a pair of `` mom jeans "in sight .ent164 and ent21 ,who are behind the ent196 brand ,sent models down the runway in decidedly feminine dresses and skirts adorned with roses ,lace and even embroidered doodles by the designers ' own nieces and nephews .many of the looks featured saccharine needlework phrases like `` i love you ,

...

X dedicated their fall fashion show to moms

Attentive Reader on QACNN/DailyMail dataset

Using self-attention

- Self-attention models like Transformers can also be adapted to model sequence interactions.

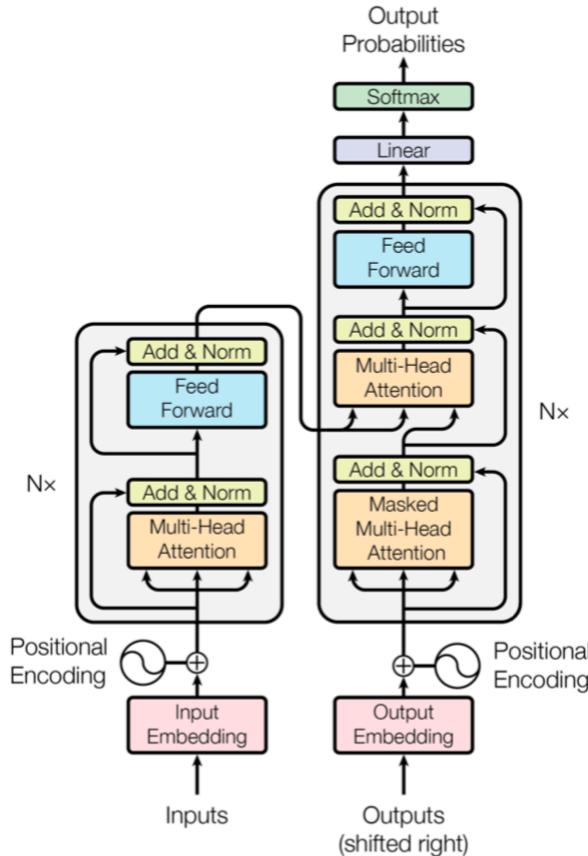


Figure from Vaswani et al., NIPS'17

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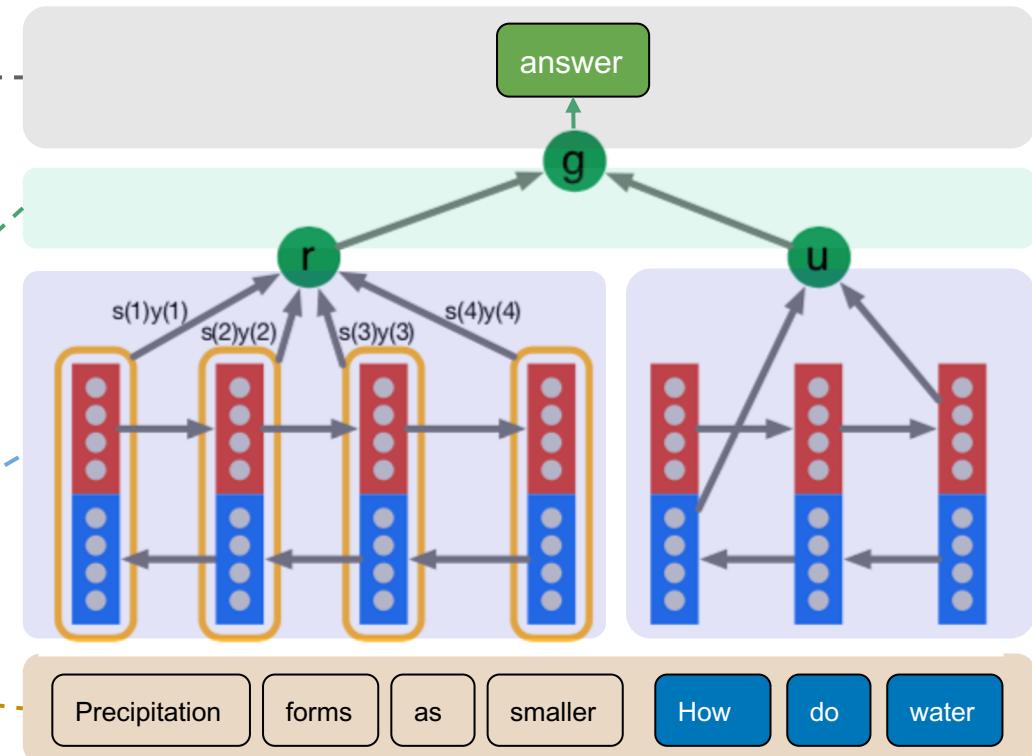
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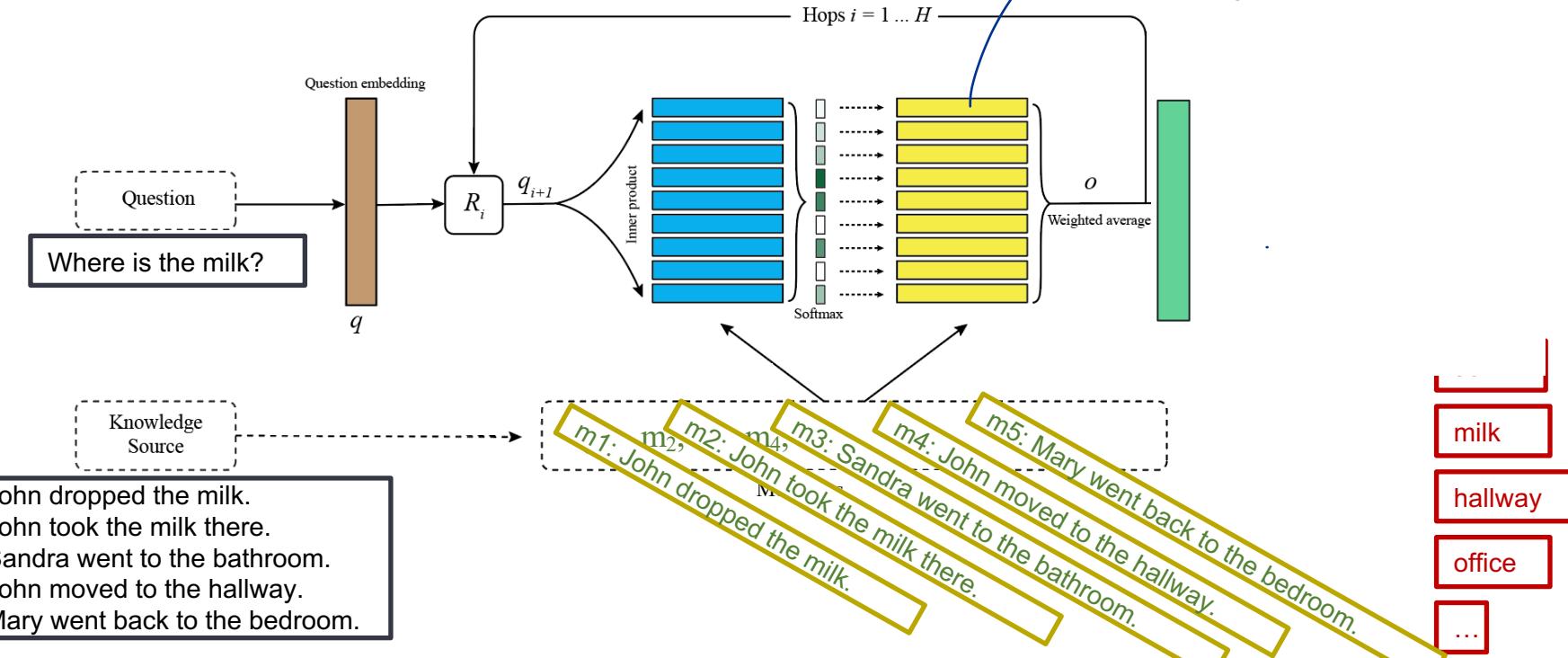
Answer prediction

- Usually linear projection
- **Probability distribution over different answer options**
 - Multiple choices: candidates (as in bAbI)
 - Spans in text -- distribution over positions for beginning and end (as in SQuAD)
- **Training:**
 - Cross-entropy loss
 - Ranking loss

Answer selection: Ranking (Memory Networks)

Sukhbaatar et al., NIPS'15 / Miller et al., EMNLP'16

use the question representation to weigh the input representation



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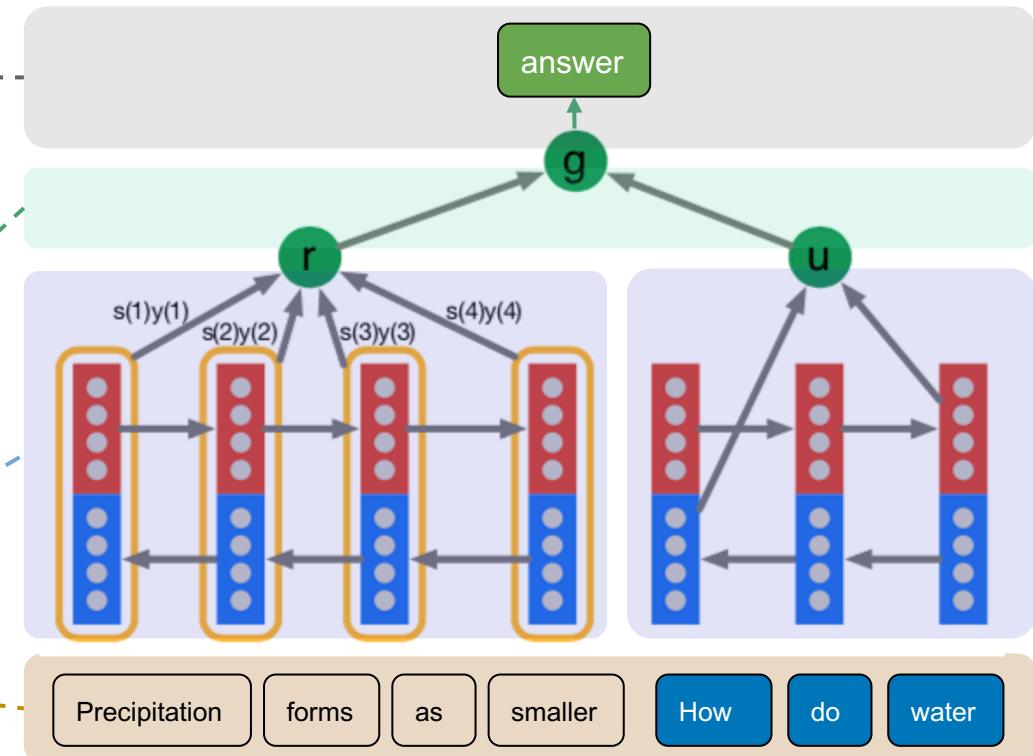
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Conclusion

- We gathered all ingredients to build state-of-the-art supervised Machine Reading systems!
- architectures work well in practice
... as long as we stay in-domain and questions are simple
- We covered only extractive and multiple choice questions settings but there is also generative machine reading
- Practice in Labs on bAbI!

Machine Reading / Current Trend
