Cheap Tricks and the Perils of Machine Learning

Percy Liang

Stanford / (Semantic Machines / Microsoft)

NAACL Workshop on New Forms of Generalization — June 5, 2018

[with Pranav Rajpurkar et al; 2016]

Reading Comprehension (SQuAD)

In meteorology, precipitation is any product of the condensation of atmospheric water vapor that falls under **gravity**. The main forms of precipitation include drizzle, rain, sleet, snow, **graupel** and hail... Precipitation forms as smaller droplets coalesce via collision with other rain drops or ice crystals **within a cloud**. Short, intense periods of rain in scattered locations are called "showers".

What causes precipitation to fall?
gravity

What is another main form of precipitation besides drizzle, rain, snow, sleet and hail?
graupel

Where do water droplets collide with ice crystals to form precipitation?
within a cloud

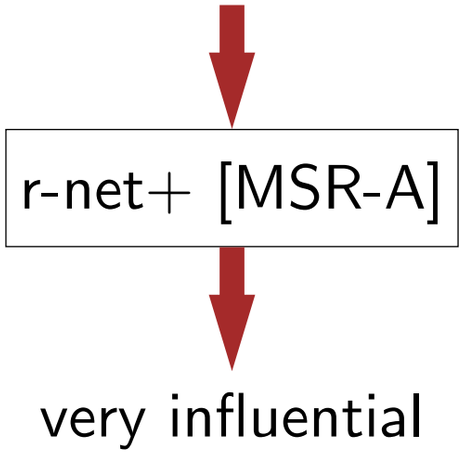
Rank	Model	EM	F1
	Human Performance *Stanford University* (Rajpurkar et al. '16)	82.304	91.221
1 Mar 19, 2018	QANet (ensemble) *Google Brain & CMU*	**83.877**	**89.737**
2 May 10, 2018	MARS (ensemble) *YUANFUDAO research NLP*	83.520	89.612
3 Mar 06, 2018	QANet (ensemble) *Google Brain & CMU*	82.744	89.045
4 May 09, 2018	MARS (single model) *YUANFUDAO research NLP*	82.587	88.880
4 Jan 22, 2018	Hybrid AoA Reader (ensemble) *Joint Laboratory of HIT and iFLYTEK Research*	82.482	89.281
4 Feb 19, 2018	Reinforced Mnemonic Reader + A2D (ensemble model) *Microsoft Research Asia & NUDT*	82.849	88.764
5 Jan 03, 2018	r-net+ (ensemble) *Microsoft Research Asia*	82.650	88.493
5 Feb 02, 2018	Reinforced Mnemonic Reader (ensemble model) *NUDT and Fudan University* https://arxiv.org/abs/1705.02798	82.283	88.533
5 Feb 27, 2018	QANet (single model) *Google Brain & CMU*	82.209	88.608
5 Jan 05, 2018	SLQA+ (ensemble) *Alibaba iDST NLP*	82.440	88.607
6 Dec 17, 2017	r-net (ensemble) *Microsoft Research Asia* http://aka.ms/rnet	82.136	88.126

[with Robin Jia; EMNLP 2017]

Reading comprehension

The way a teacher promotes the course they are teaching, the more the student will get out of the subject matter. The three most important aspects of teacher enthusiasm are enthusiasm about teaching, enthusiasm about the students, and enthusiasm about the subject matter. A teacher must enjoy teaching. If they do not enjoy what they are doing, the students will be able to tell. They also must enjoy being around their students. A teacher who cares for their students is going to help that individual succeed in their life in the future. The teacher also needs to be enthusiastic about the subject matter they are teaching. For example, a teacher talking about chemistry needs to enjoy the art of chemistry and show that to their students. A spark in the teacher may create a spark of excitement in the student as well. An **enthusiastic teacher** has the ability to be very influential in the **young student**'s life.

What can an enthusiastic teacher be to a young student?



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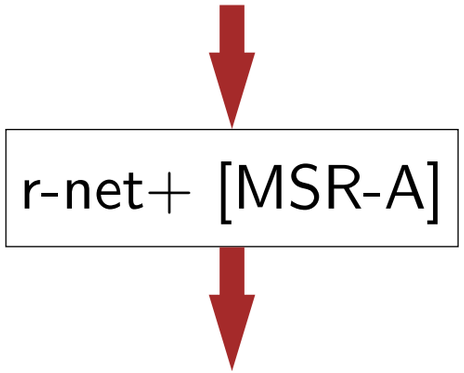

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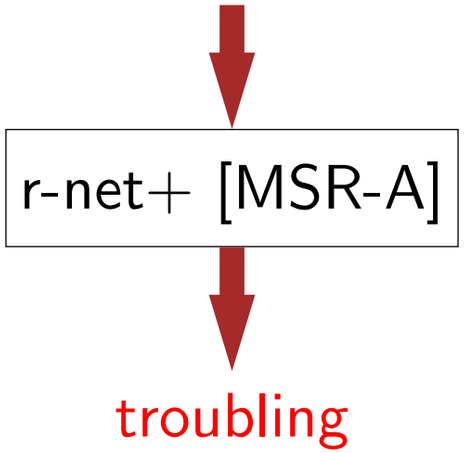
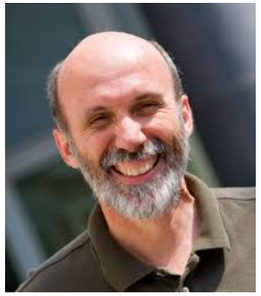


Humans versus machines

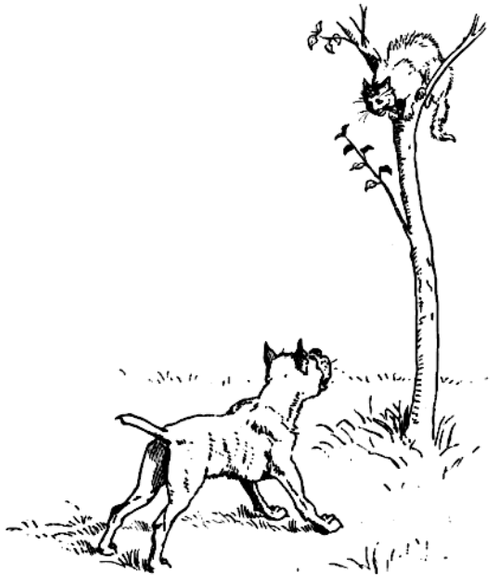
Harder tests?



We want multiple-choice questions that people can answer easily. But we also want to avoid as much as possible questions that can be answered using **cheap tricks** *(aka heuristics).*

— Hector Levesque, 2013

Winograd schema



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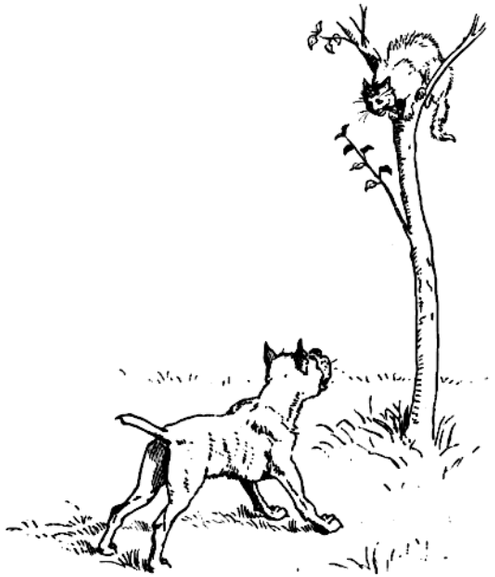

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[hat tip: Fernando Pereira]

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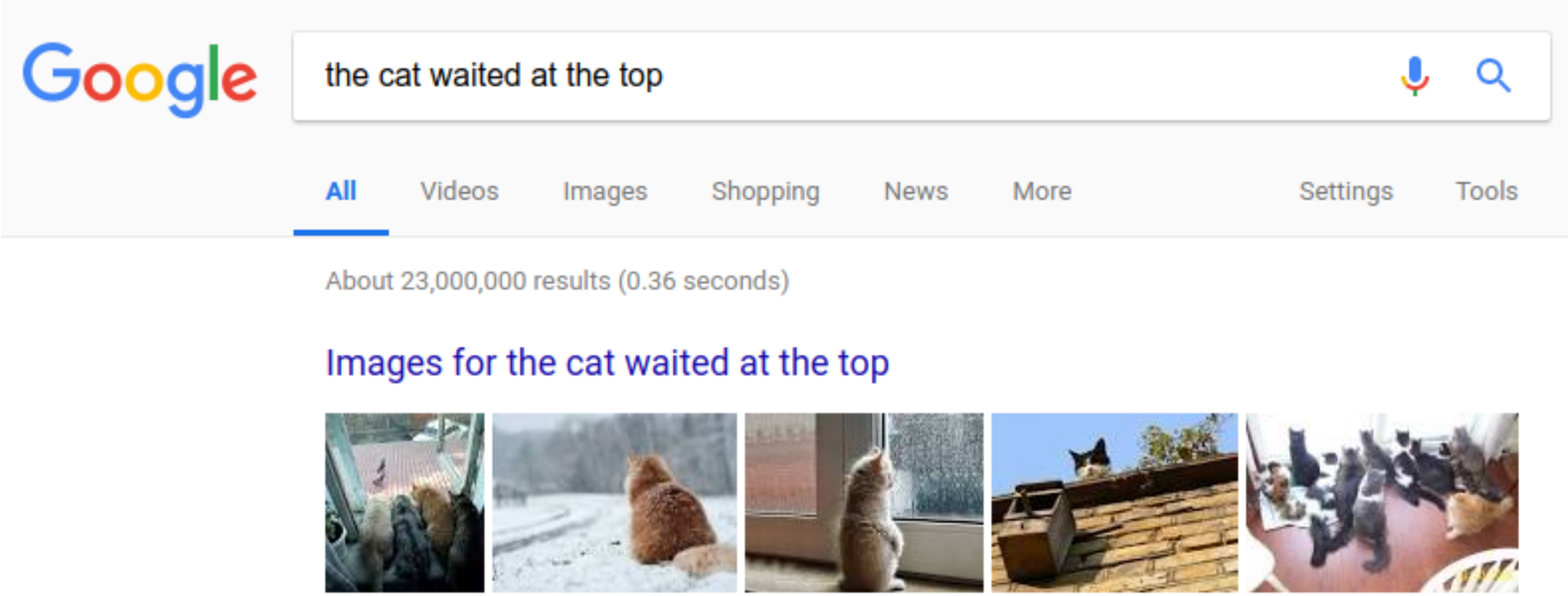

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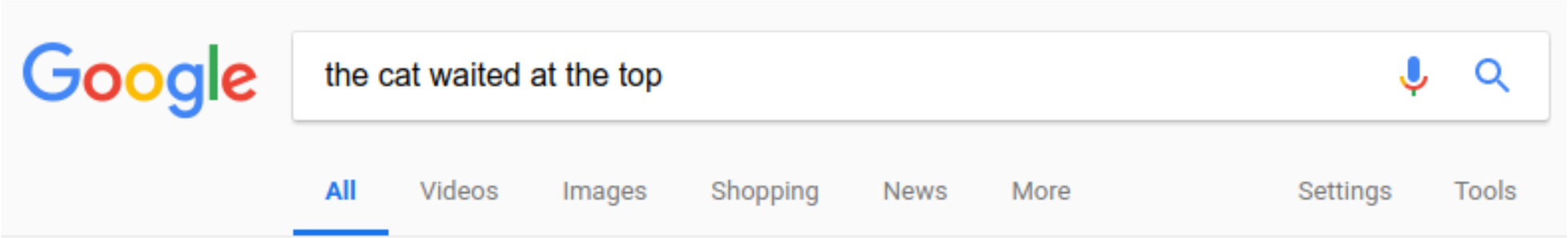

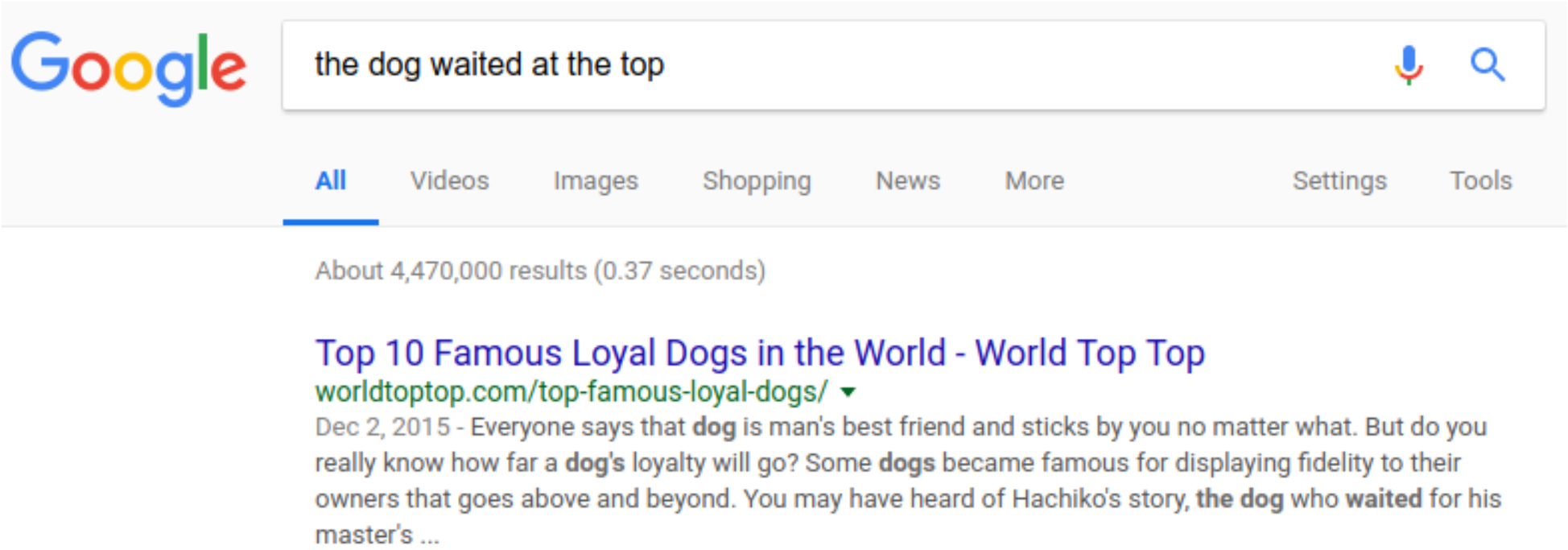

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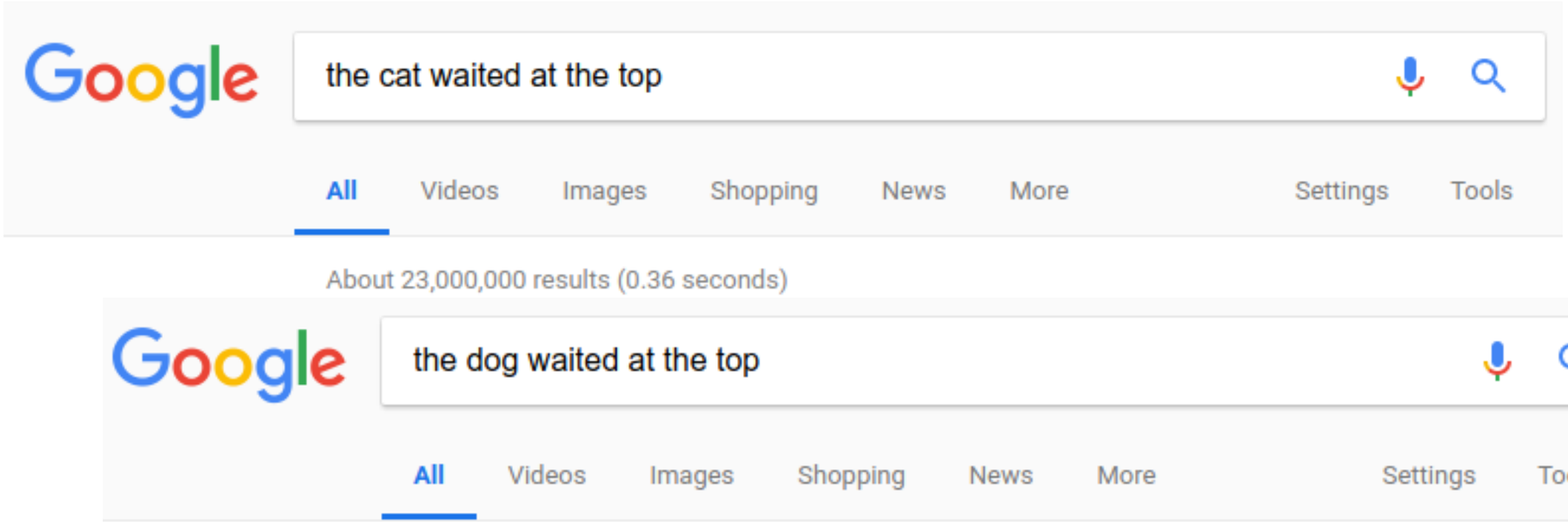

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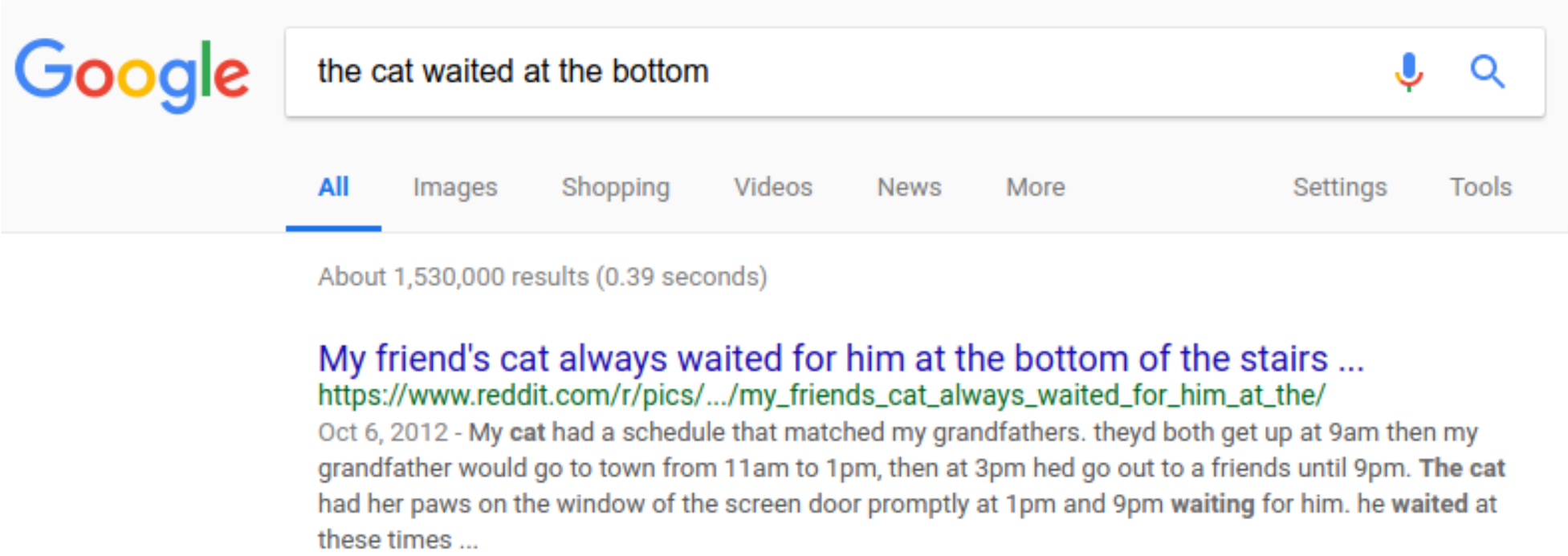

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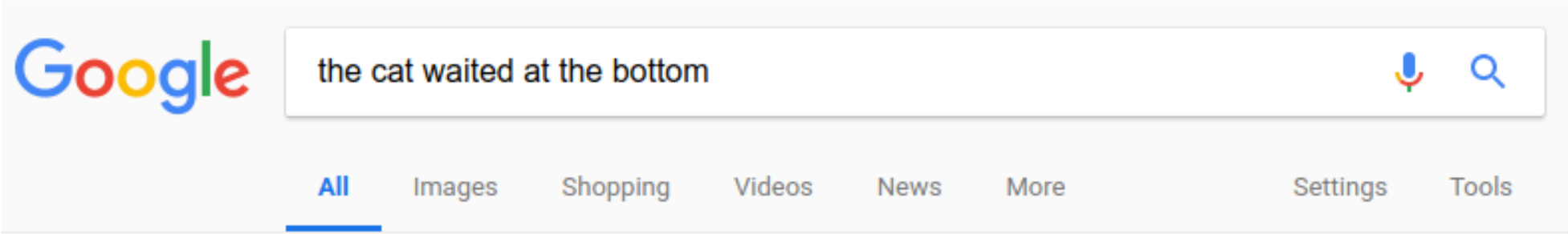

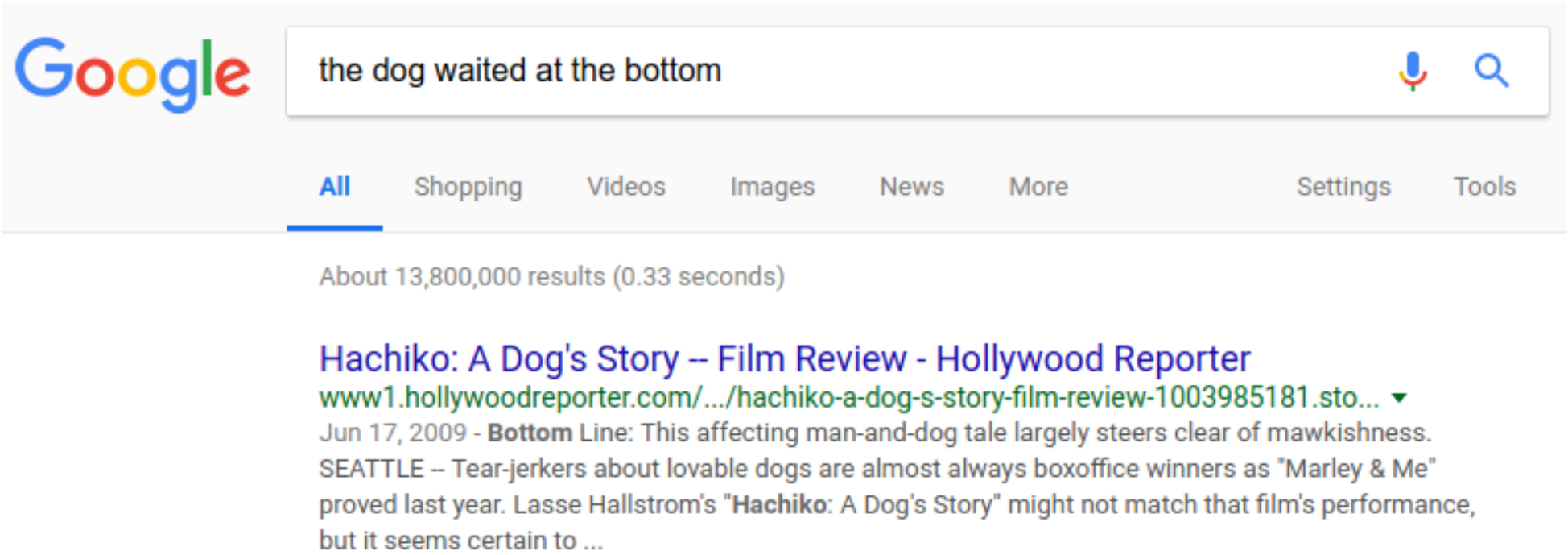

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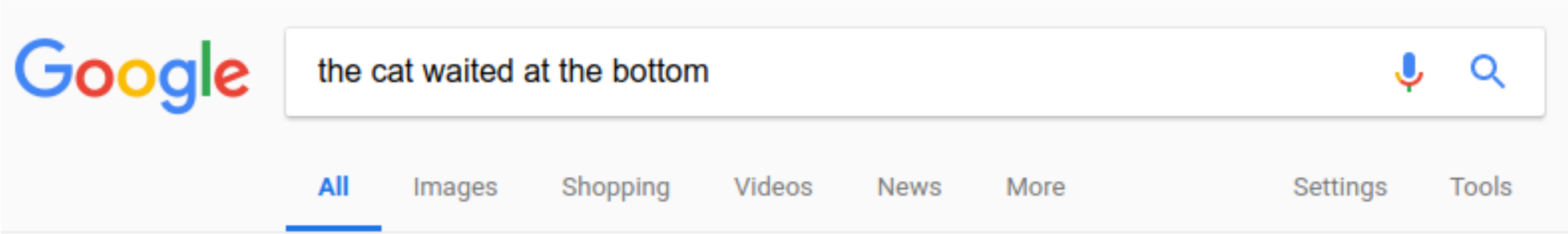

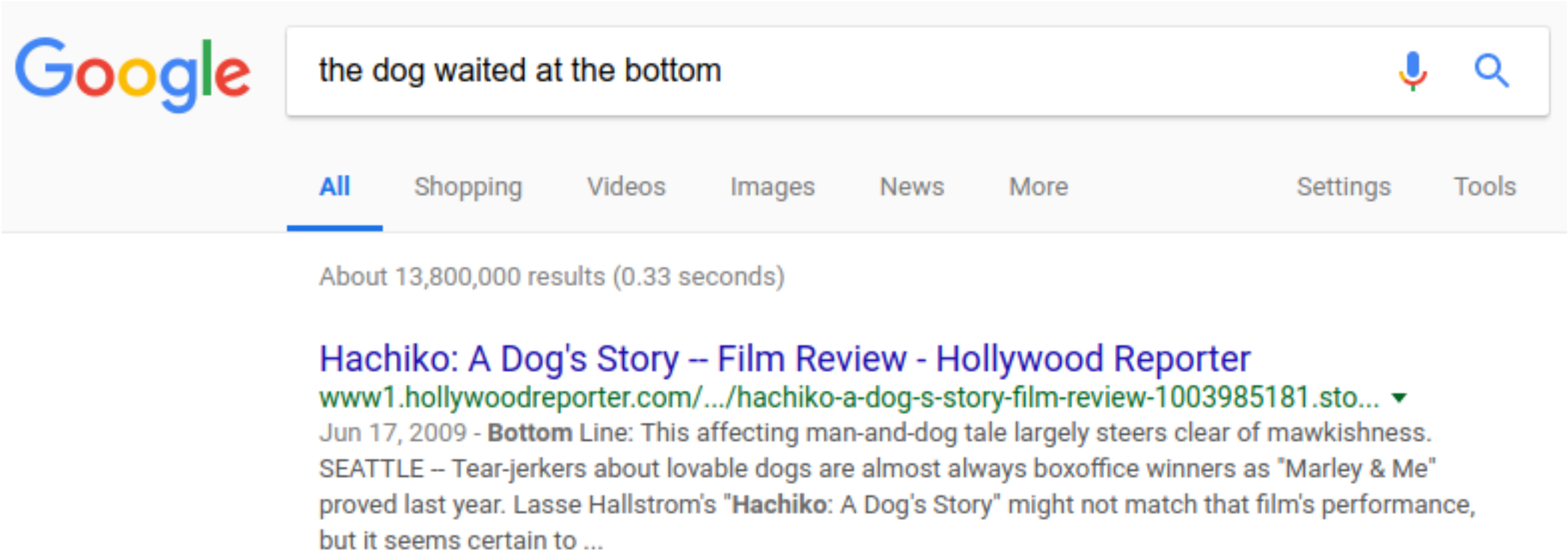

But what about...

Commonsense knowledge

Logical reasoning

Linguistic phenomena

Intuitive physics

...

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Logical reasoning

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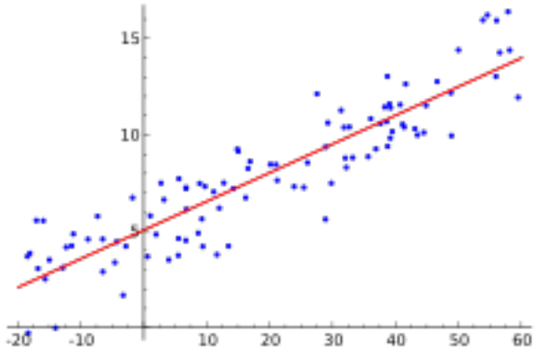
...

MACHINE LEARNING DOESN'T CARE

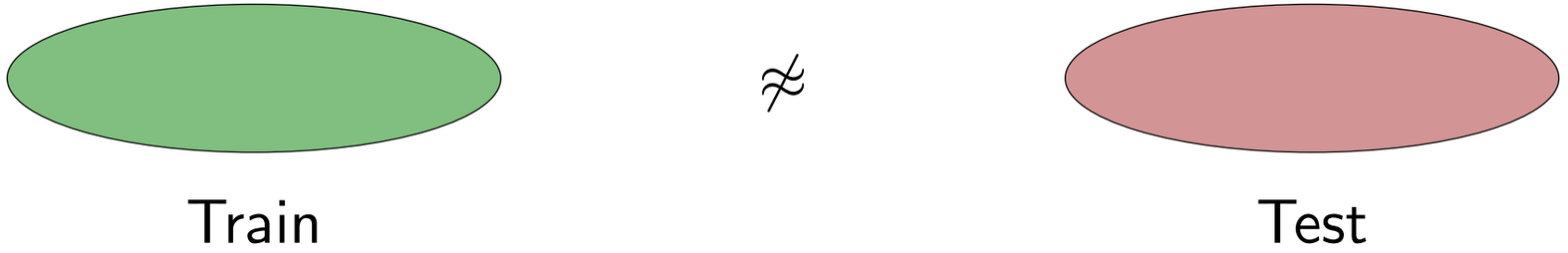
Interpolation is insufficient

Interpolation is insufficient



Any expressive model with enough data will do the job

Extrapolation is harder



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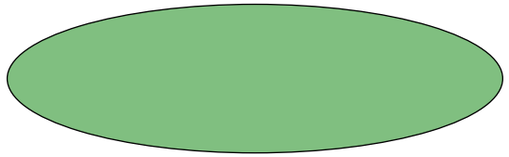
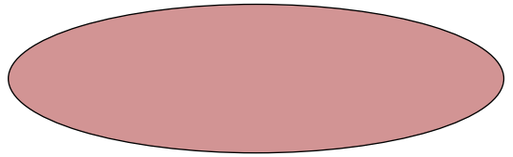
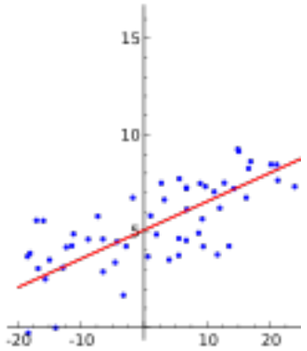


$\not\approx$



Train

Test



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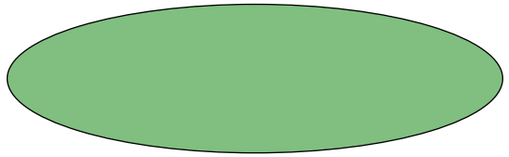

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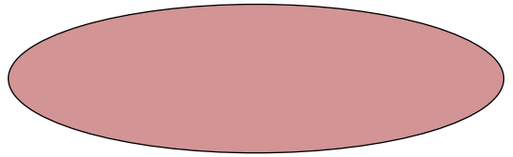

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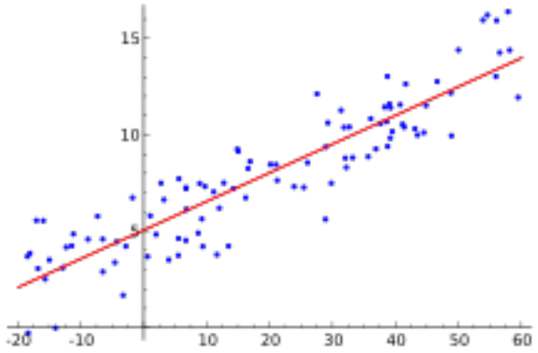
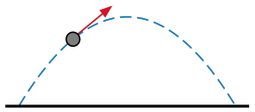


To extrapolate (and be robust), must get a more "correct" model

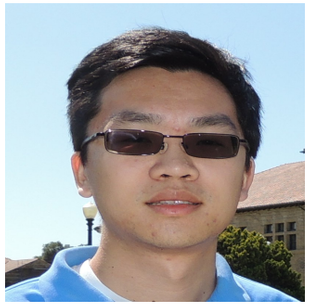
Outline

Harder data



Stronger models

Adversarial evaluation of reading comprehension (EMNLP 2017)



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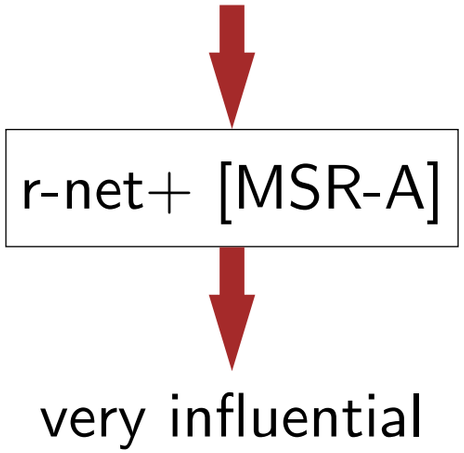

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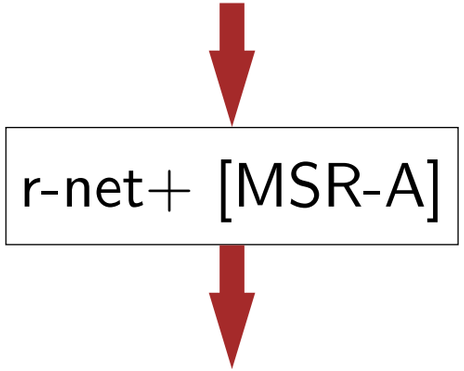

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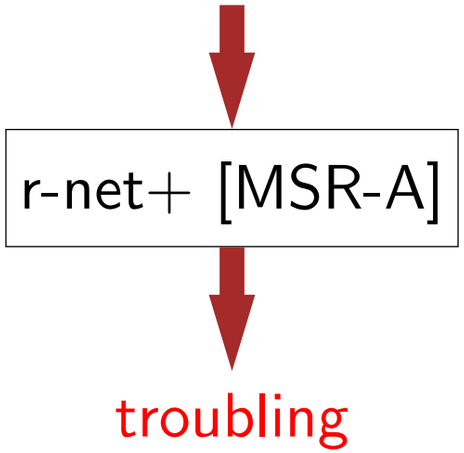

worksheets.codalab.org

submit model to evaluate on hidden test set

Results on SQuAD models

Model	**Original F1**	**Adversarial F1**
SLQA+	88.6	64.2
r-net+	88.5	63.4
ReasoNet-E	81.1	49.8
SEDT-E	80.1	46.5
BiDAF-E	80.0	46.9
Mnemonic-E	79.1	55.3
Ruminating	78.8	47.7
jNet	78.6	47.0
Mnemonic-S	78.5	56.0
ReasoNet-S	78.2	50.3
MPCM-S	77.0	50.0

Results on SQuAD models

Model	**Original F1**	**Adversarial F1**
Humans	92.6	89.2
SLQA+	88.6	64.2
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Mnemonic-E	79.1	55.3
Ruminating	78.8	47.7
jNet	78.6	47.0
Mnemonic-S	78.5	56.0
ReasoNet-S	78.2	50.3
MPCM-S	77.0	50.0

Training versus testing

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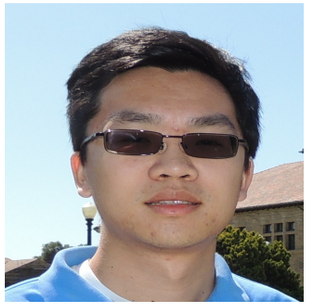
- If retrain model on adversarial examples (appended), 74.3 F1 $\Rightarrow$ 70.0 F1
- If test this model on prepended sentences, 70.0 F1 $\Rightarrow$ 36.9 F1

Cannot patch these issues automatically!

Question: can we supply stronger information with the help of humans?

Know What You Don't Know: Unanswerable Questions for SQuAD (ACL 2018)

Pranav Rajpurkar



Robin Jia

Cheap tricks

Who was ...?

... Jefferson ...

When was ...?

... In 1812, ...

Cheap tricks

Who was ...?

... Jefferson ...

When was ...?

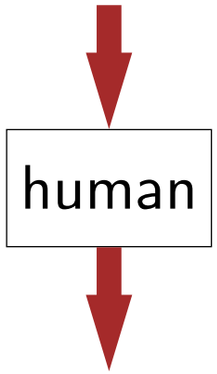
... In 1812, ...

Can find plausible answers by just detecting entities

Unanswerable questions

As of August 2010, Victoria had 1,548 public schools, 489 Catholic schools and 214 independent schools. Just under 540,800 students were enrolled in public schools, and just over 311,800 in private schools. Over 61 per cent of private students attend Catholic schools. More than 462,000 students were enrolled in primary schools and more than 390,000 in secondary schools. Retention rates for the final two years of secondary school were 77 per cent for public school students and 90 per cent for private school students. **Victoria** has about 63,519 **full-time** teachers.

How many full time janitors does Victoria have?

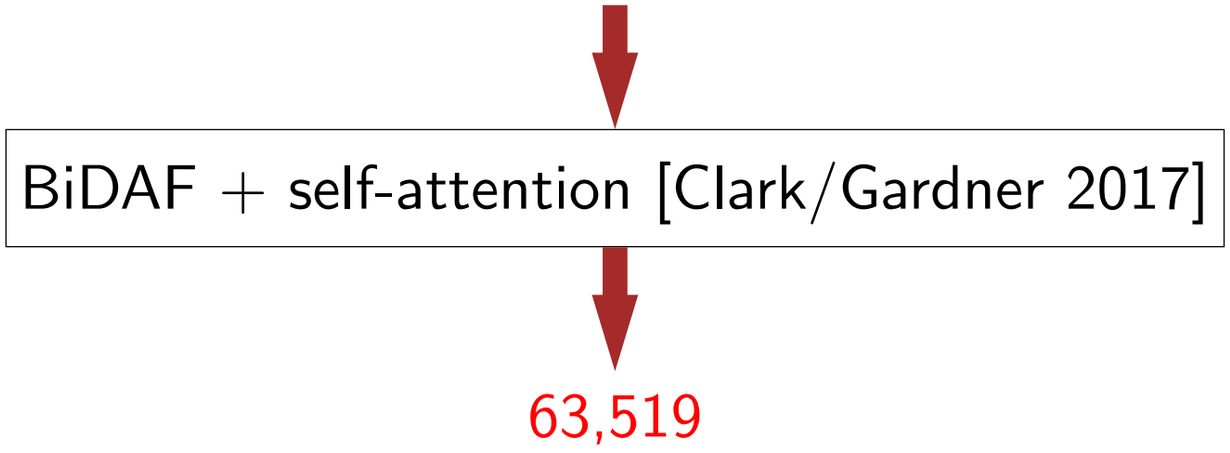


no answer

Unanswerable questions

As of August 2010, Victoria had 1,548 public schools, 489 Catholic schools and 214 independent schools. Just under 540,800 students were enrolled in public schools, and just over 311,800 in private schools. Over 61 per cent of private students attend Catholic schools. More than 462,000 students were enrolled in primary schools and more than 390,000 in secondary schools. Retention rates for the final two years of secondary school were 77 per cent for public school students and 90 per cent for private school students. **Victoria** has about 63,519 **full-time** teachers.

How many full time janitors does Victoria have?



Unanswerable questions

- Took the same 536 documents from SQuAD
- 100K original SQuAD + 50K unanswerable questions

DocQA+ELMo:	66.3
Humans:	89.5

Unanswerable questions

- Took the same 536 documents from SQuAD
- 100K original SQuAD + 50K unanswerable questions

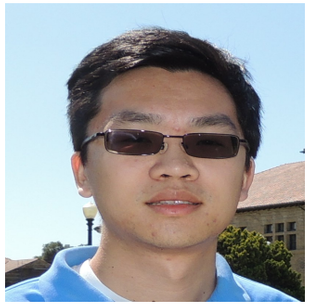
DocQA+ELMo:	66.3
Humans:	89.5

- Automatically generated questions are too easy

TF-IDF questions	Rule-based questions	Crowdsourced
83.0	89.6	62.6

Need humans to give us information!

Evaluating Reading Comprehension Models based on Reductions



Robin Jia

Reductions

slotfilling

semantic parsing → question answering

relation extraction

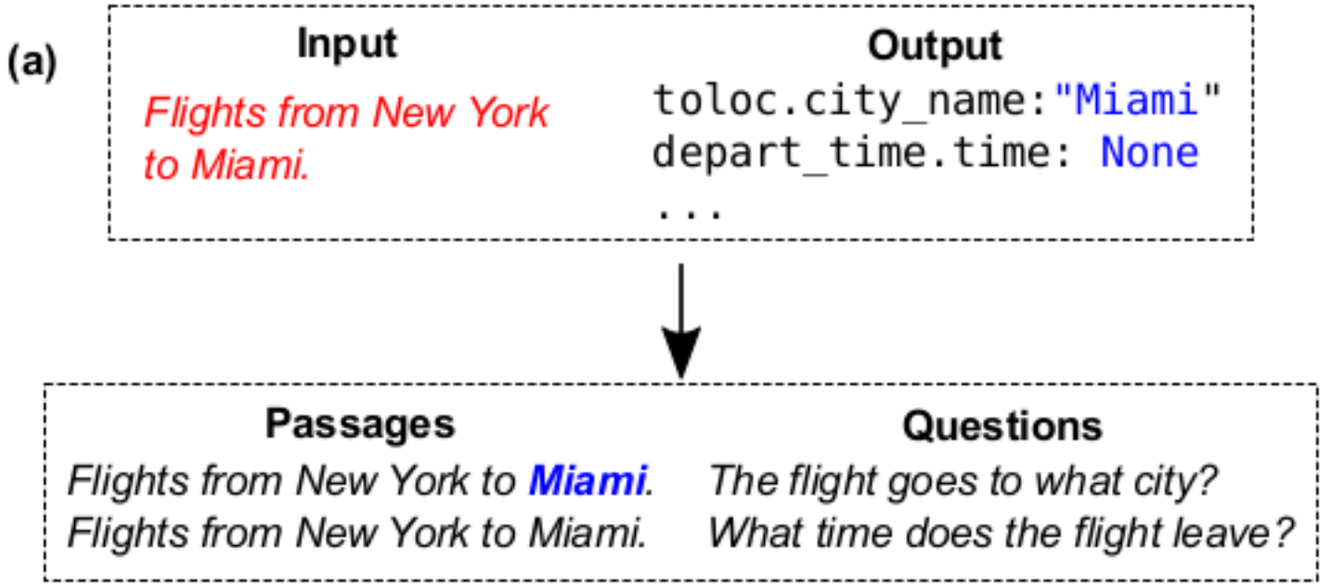
Reductions

slotfilling
semantic parsing → question answering
relation extraction

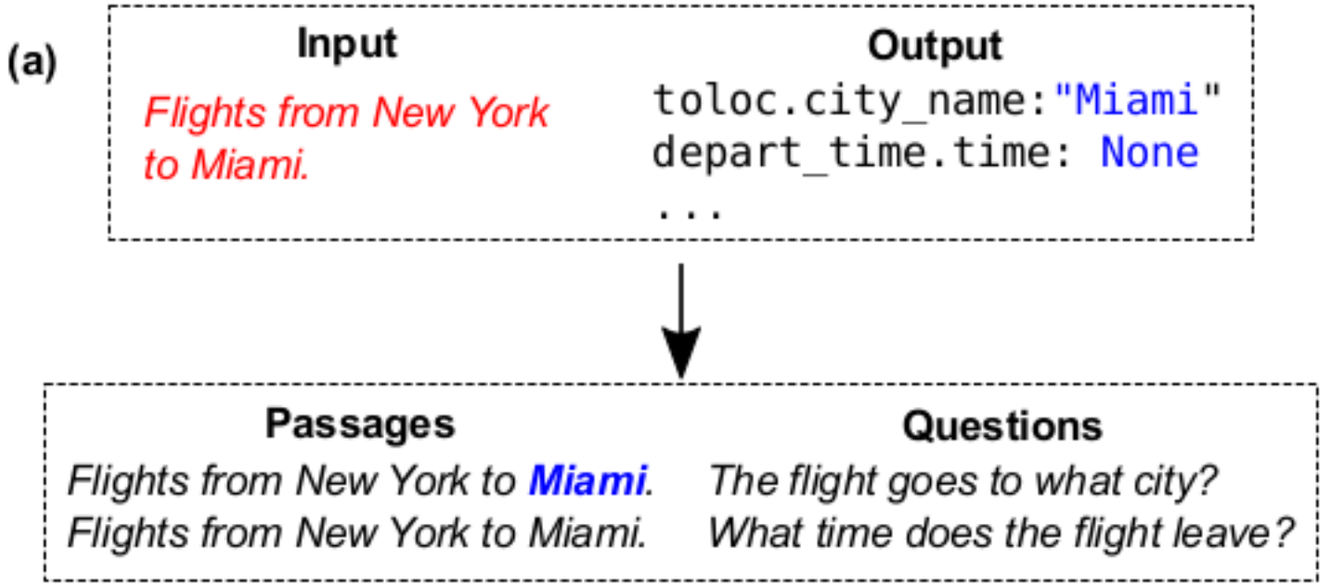
If it works: solve many other NLP tasks

If it doesn't work: evaluation benchmark for question answering

Slotfilling to question answering



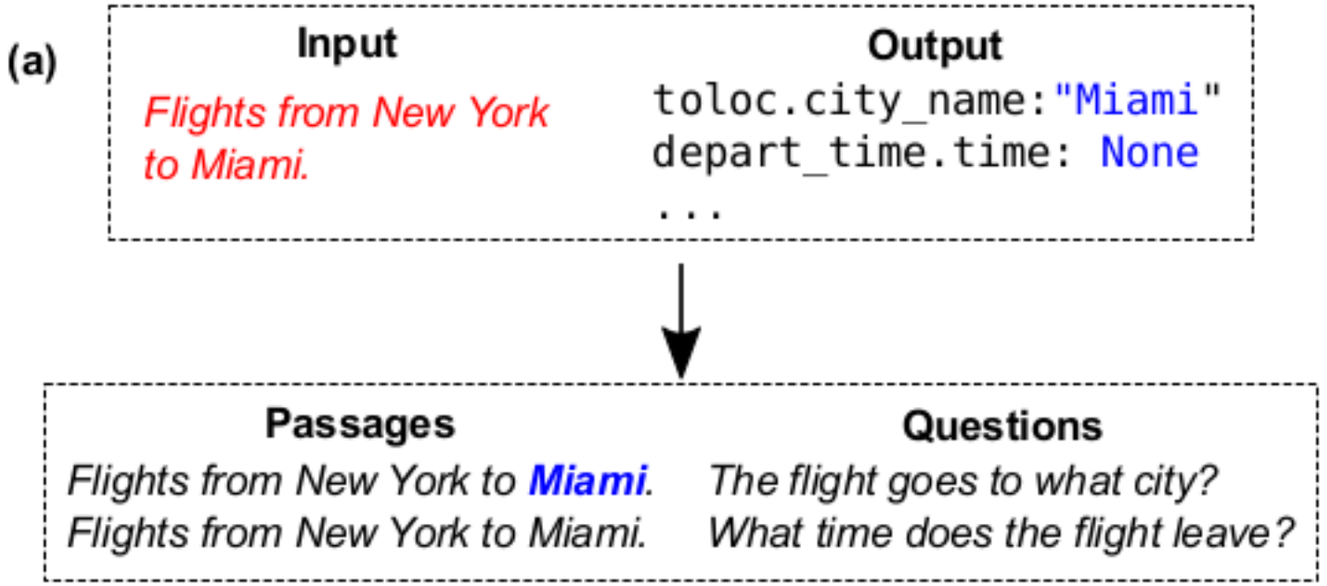
Slotfilling to question answering



Results:

Baseline	49.1
Reduction to QA	75.4

Slotfilling to question answering



Results:

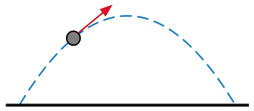
Baseline	49.1
Reduction to QA	75.4 :(
Baseline + 4 rules	83.2
Zhai et al. (2017)	95.9

Summary

- **Adversarial examples** for question answering expose problems quickly
- Need **humans** to cover the space, but space is still too big
- **Reductions** as a way of evaluating systems in a useful way

Outline

Harder data



Stronger models

Example 1: laws of physics

Train: small objects, the past

Test: large objects, the future

Extrapolate to novel configurations

Example 2: compositional semantics

Train:

the blue block

right of the blue block

Example 2: compositional semantics

Train:

the blue block

right of the blue block

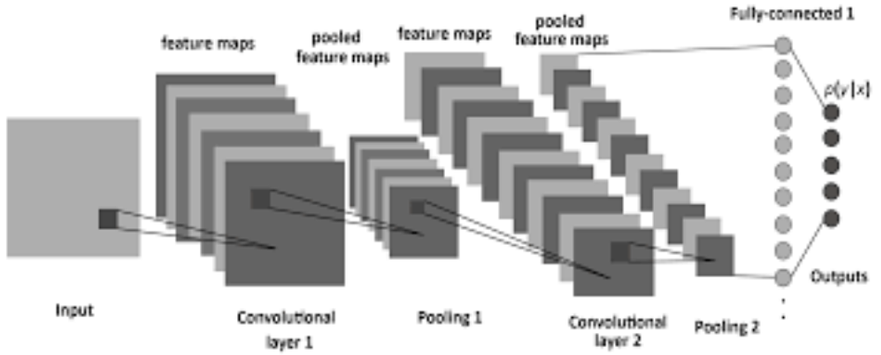
Test:

right of the blue block and left of the green block

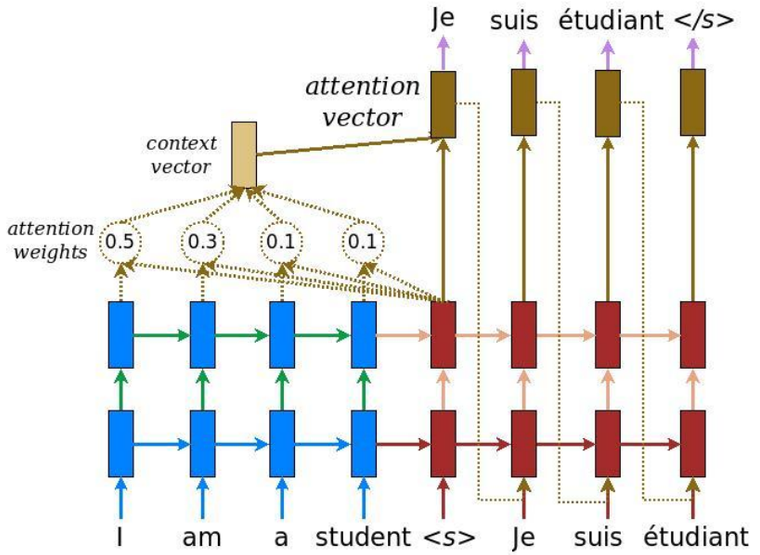
Extrapolate to longer sentences

Inductive bias in neural networks

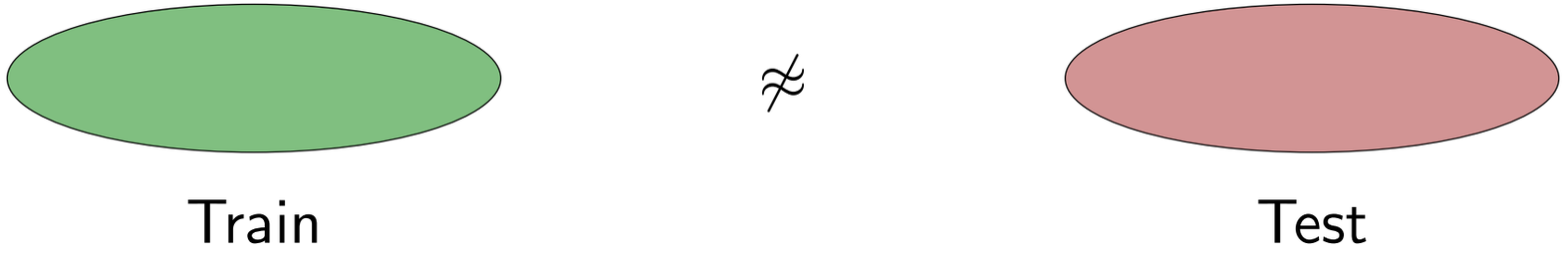
Convolutional neural networks:



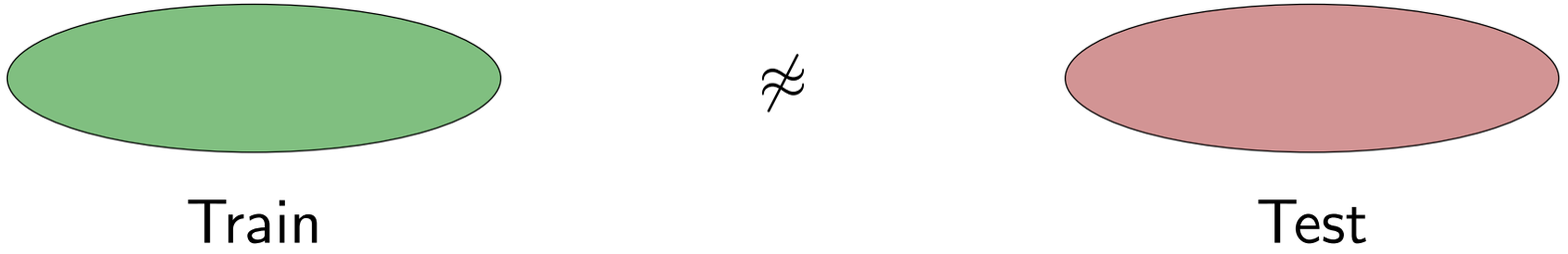
Attention-based mechanisms:



Extrapolation



Extrapolation

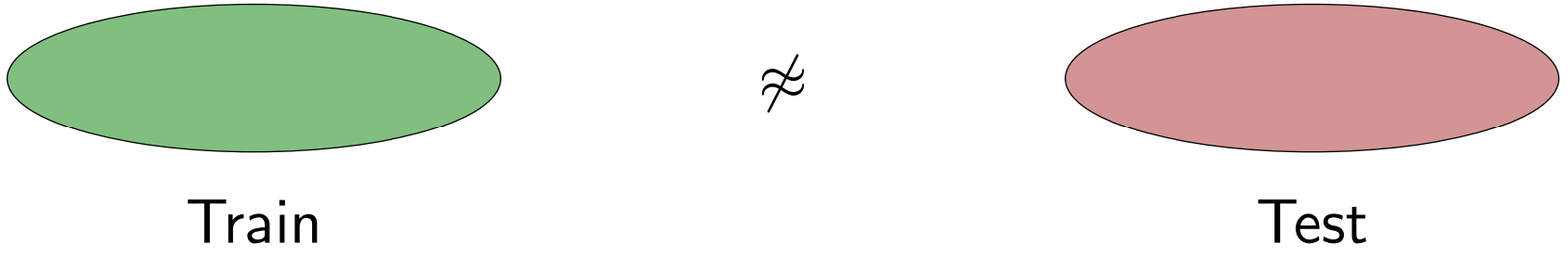


Domain adaptation (unseen distribution):

Train: input → output

Test: input' → output'

Extrapolation



Domain adaptation (unseen distribution):

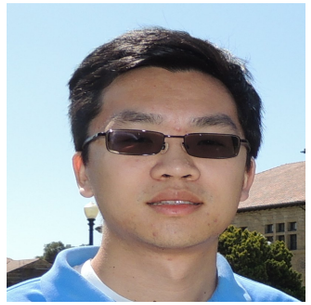
Train: input → output Test: input' → output'

Unsupervised learning (unseen task):

Train: input → side information Test: input → output

Style / attribute transfer in natural language (NAACL 2018)

Juncen Li



Robin Jia

He He

Task setup

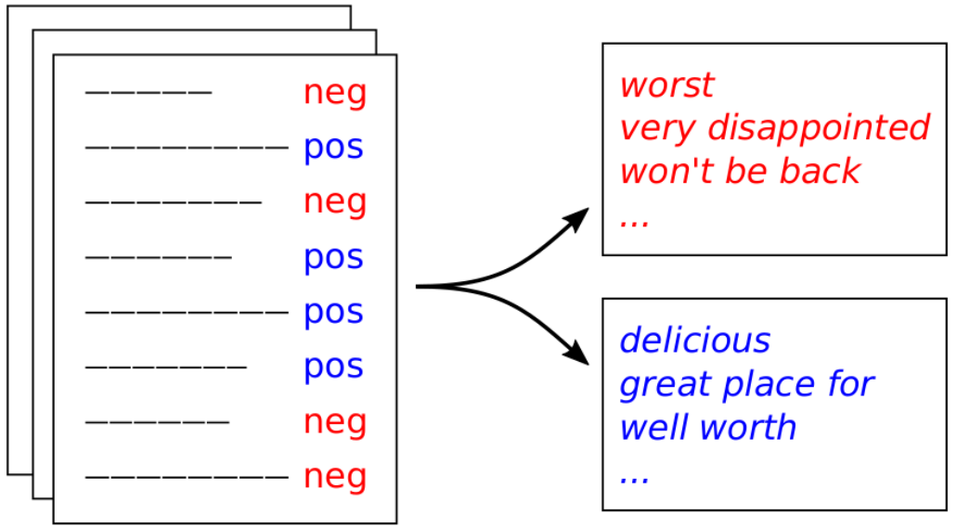
Train (review $\Rightarrow$ sentiment):

very tasty burritos, and cheap too!	$\Rightarrow$ positive
found hair in my soup, would never go back again	$\Rightarrow$ negative
...	...

Test (negative review $\Rightarrow$ positive review):

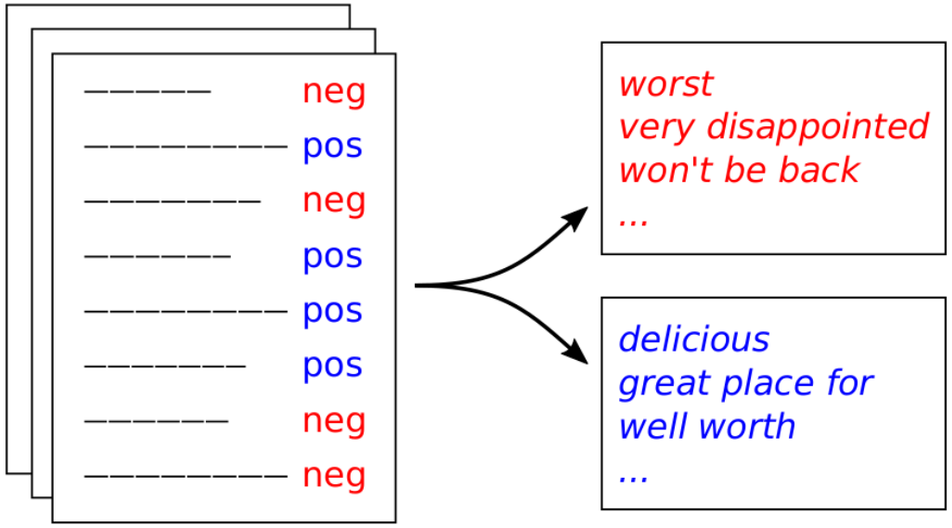
great food but very rude workers $\Rightarrow$ *great food and very friendly staff*

Deletion-based model

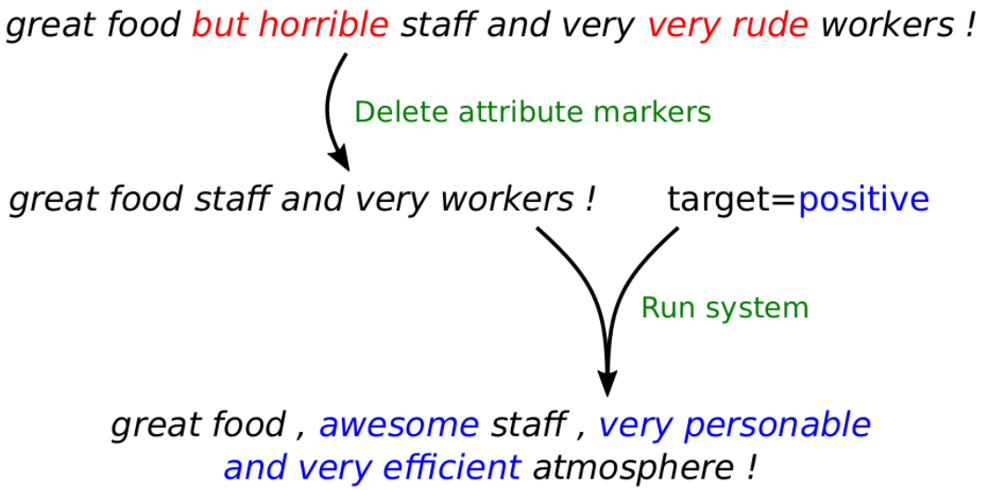


Step 1: extract attributes

Deletion-based model

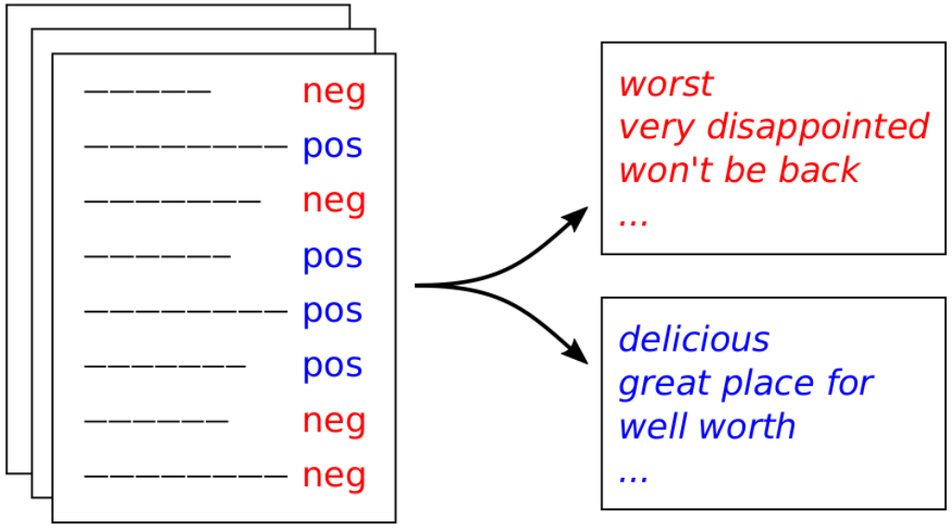


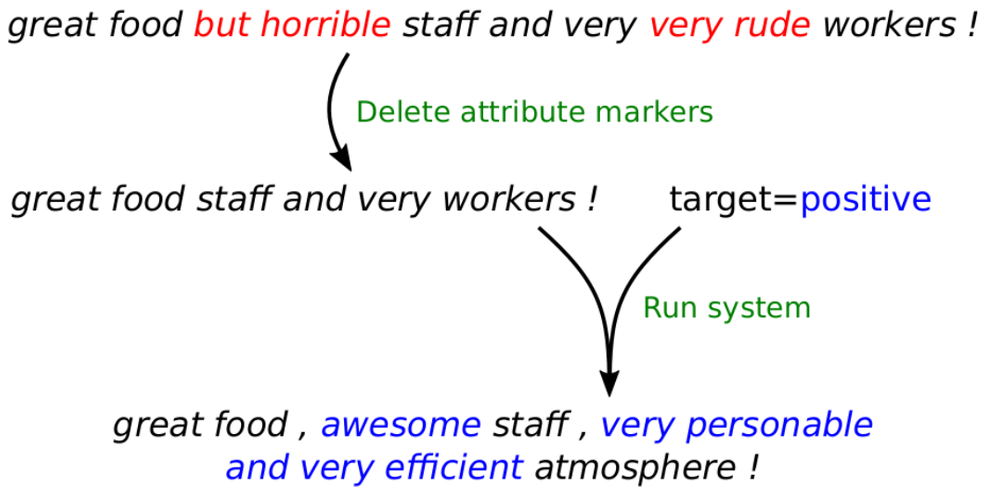
Step 1: extract attributes



Step 2: delete + predict

Deletion-based model





Step 1: extract attributes

Step 2: delete + predict

Inductive bias: attribute/style is localized in the text

Datasets

Dataset	Attributes	Train	Dev	Test
YELP	Positive	270K	2000	500
	Negative	180K	2000	500
CAPTIONS	Romantic	6000	500	0
	Humorous	6000	500	0
	Factual	0	0	500
AMAZON	Positive	277K	985	500
	Negative	278K	1015	500

[Shen+ 2017; Fu+ 2018; Gan+ 2017]

Results

Human evaluation: grammatical, preserve content, has target attribute

	Yelp				Amazon				Captions			
	Gra	Con	Att	Suc	Gra	Con	Att	Suc	Gra	Con	Att	Suc
CrossAligned	2.8	2.9	3.5	14%	3.2	2.5	2.9	7%	3.9	2.0	3.2	16%
StyleEmbedding	3.5	3.7	2.1	9%	3.2	2.9	2.8	11%	3.3	2.9	3.0	17%
MultiDecoder	2.8	3.1	3.0	8%	3.0	2.6	2.8	7%	3.4	2.8	3.2	18%
RetrieveOnly	**4.2**	2.7	**4.2**	25%	3.8	2.8	3.1	17%	**4.2**	2.6	3.8	27%
TemplateBased	3.0	**3.9**	3.9	21%	3.4	3.6	3.1	19%	3.3	**4.1**	3.5	33%
DeleteOnly	3.0	3.7	3.9	24%	3.7	**3.8**	3.2	24%	3.6	3.5	3.5	32%
DeleteAndRetrieve	3.3	3.7	4.0	**29%**	**3.9**	3.7	**3.4**	**29%**	3.8	3.5	**3.9**	**43%**
Human	4.6	4.5	4.5	75%	4.2	4.0	3.7	44%	4.3	3.9	4.0	56%

[Shen+ 2017; Fu+ 2018]

Results

Source: we sit down and we got some really slow and lazy service .

Results

Source:	we sit down and we got some really slow and lazy service .
CrossAligned:	we *went* down and we *were a good , friendly food* .
StyleEmbedding:	we sit down and we got some really *slow* and *prices suck* .
MultiDecoder:	we sit down and we got some really and *fast food* .

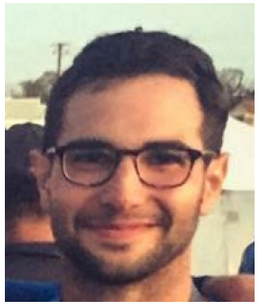
Results

Source:	we sit down and we got some really slow and lazy service .
CrossAligned:	we *went* down and we *were a good , friendly food* .
StyleEmbedding:	we sit down and we got some really *slow* and *prices suck* .
MultiDecoder:	we sit down and we got some really and *fast food* .
Delete:	we sit down and we got some *great* and *quick* service .
Delete+Retrieve:	we got *very nice place to* sit down and we got some service .

Locality inductive bias helps!

SAT solving with neural networks


Daniel Selsam


Matt Lamm


Benedikt Bunz


Leonardo de Moura


David Dill

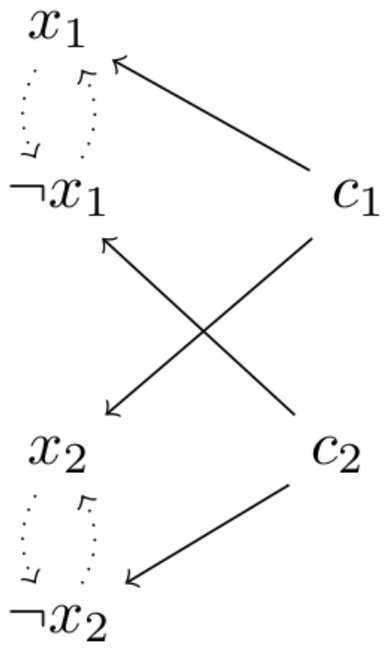
SAT solving

$$(x_1 \vee x_2) \wedge (\neg x_1 \vee x_3) \quad \Rightarrow \quad x_1 = 0, x_2 = 1, x_3 = 1$$

$$x_1 \wedge \neg x_1 \quad \Rightarrow \quad \text{unsat}$$

Can neural networks do logical reasoning?

Model



- Embedding for each literal, clause and time step
- Literals and clauses exchange messages
- At the end, predict vote for each literal, and average

Captures inductive bias of survey propagation

Predicting satisfiability

Train: random instances of sat/unsat minimal pairs

$$\underbrace{(x_1 \vee x_2) \cdots}_{\text{sat}} \Rightarrow 1 \qquad \underbrace{(\neg x_1 \vee x_2) \cdots}_{\text{unsat}} \Rightarrow 0$$

Test: random instances (same distribution)

Predicting satisfiability

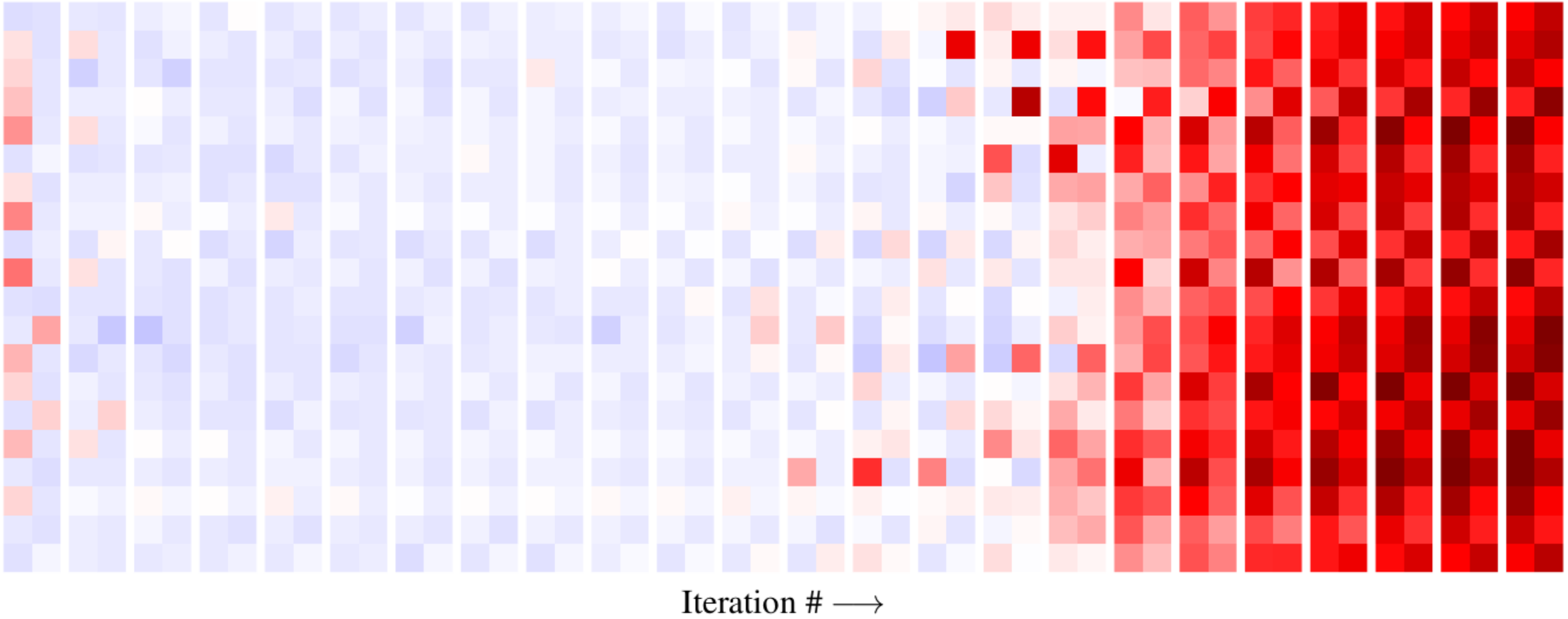
Train: random instances of sat/unsat minimal pairs

$$\underbrace{(x_1 \vee x_2) \cdots}_{\text{sat}} \Rightarrow 1 \qquad \underbrace{(\neg x_1 \vee x_2) \cdots}_{\text{unsat}} \Rightarrow 0$$

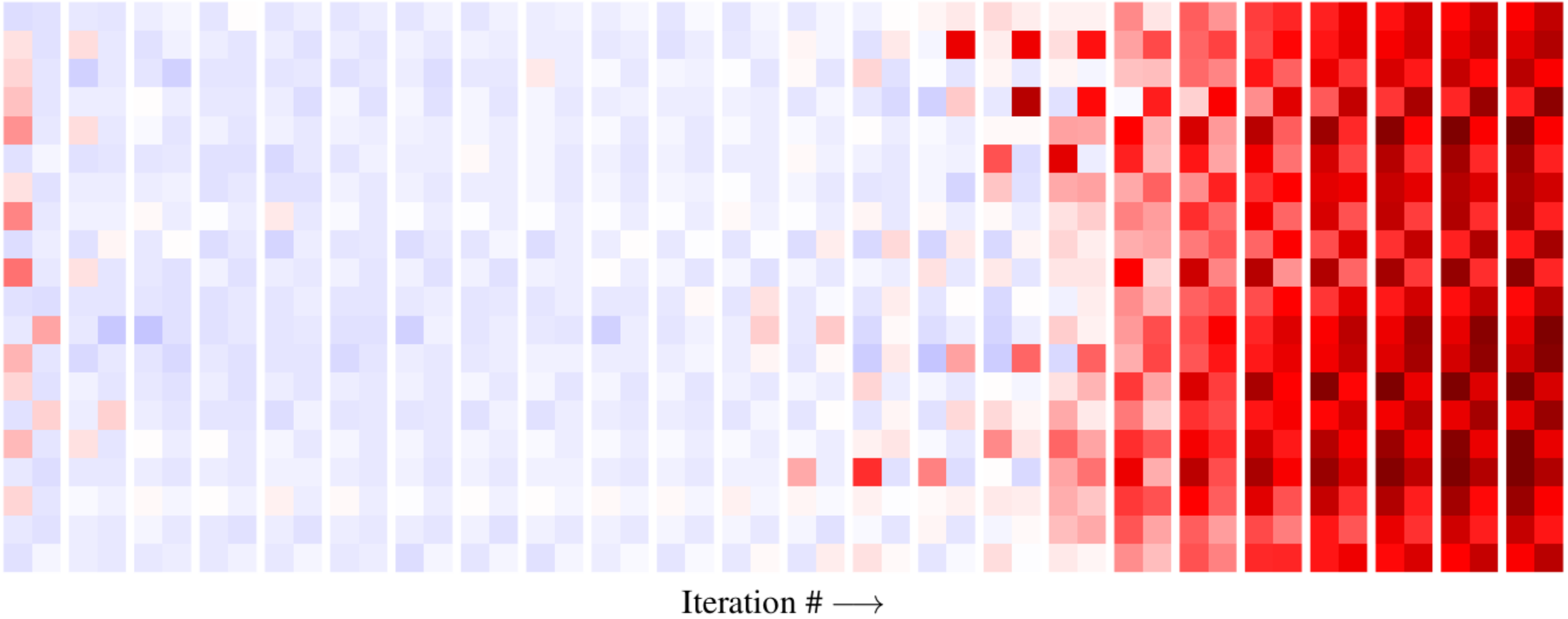
Test: random instances (same distribution)

Test accuracy: 88%

Decoding satisfying assignments

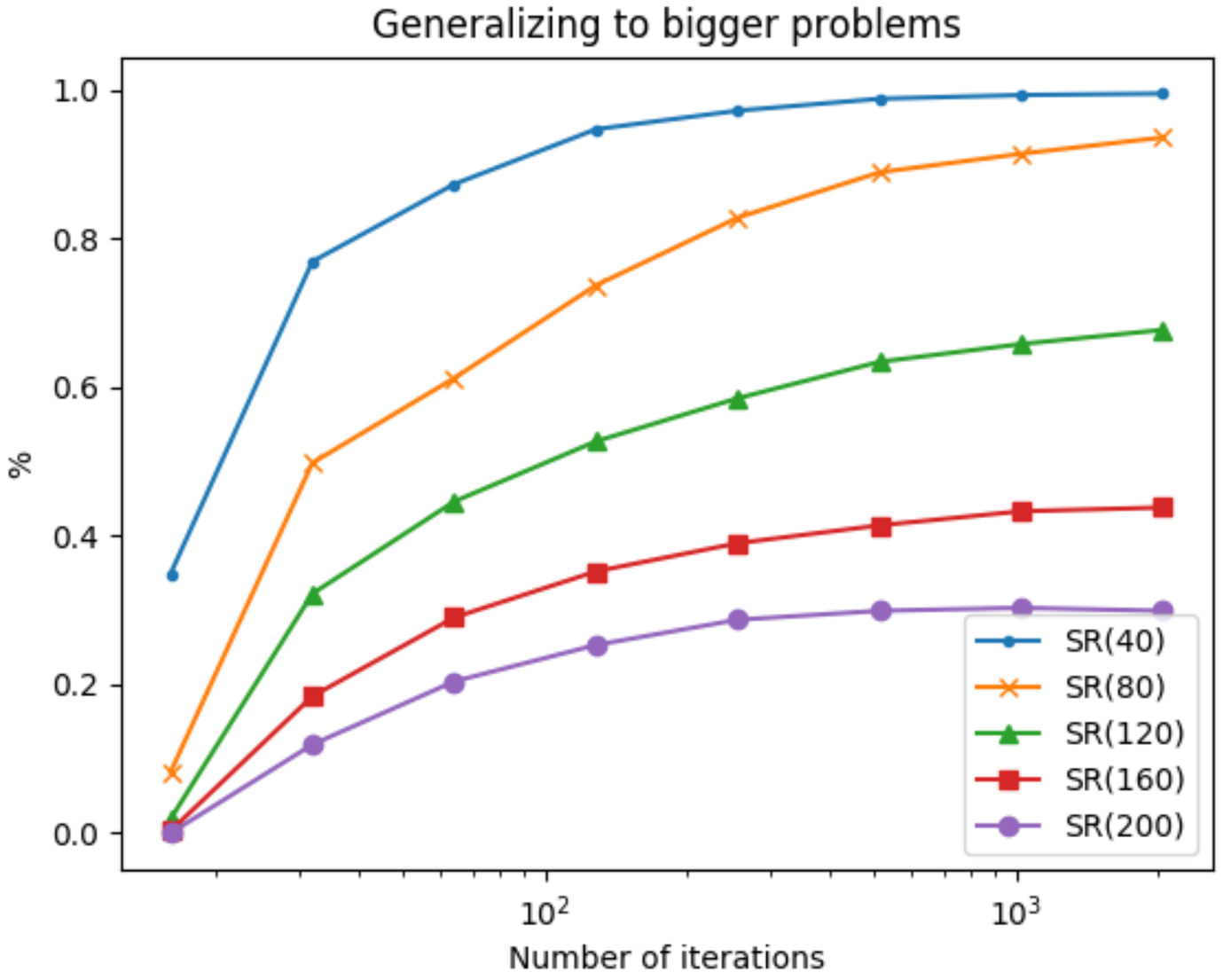


Decoding satisfying assignments



Can decode 90% of instances where model predicts sat — extrapolation!

Extrapolation to larger instances, more iterations



Transferring to different problems

Task	μ_{vars}	μ_{clauses}	#sat	%solved
3-color	30	89	350	64%
4-color	40	135	557	69%
5-color	50	191	590	54%
3-clique	30	389	586	88%
4-clique	40	686	241	96%
5-clique	50	1067	43	28%
2-domset	30	264	278	99%
3-domset	40	454	574	95%
4-domset	50	689	600	100%
4-cover	50	696	128	100%
5-cover	60	976	357	100%
6-cover	70	1301	584	96%
all	45	532	4888	85%

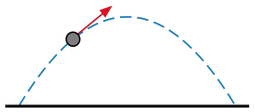
Summary

- Unsupervised learning: evaluate on structurally **unseen task**

- Strong **inductive bias** permits this unsupervised learning

Outline

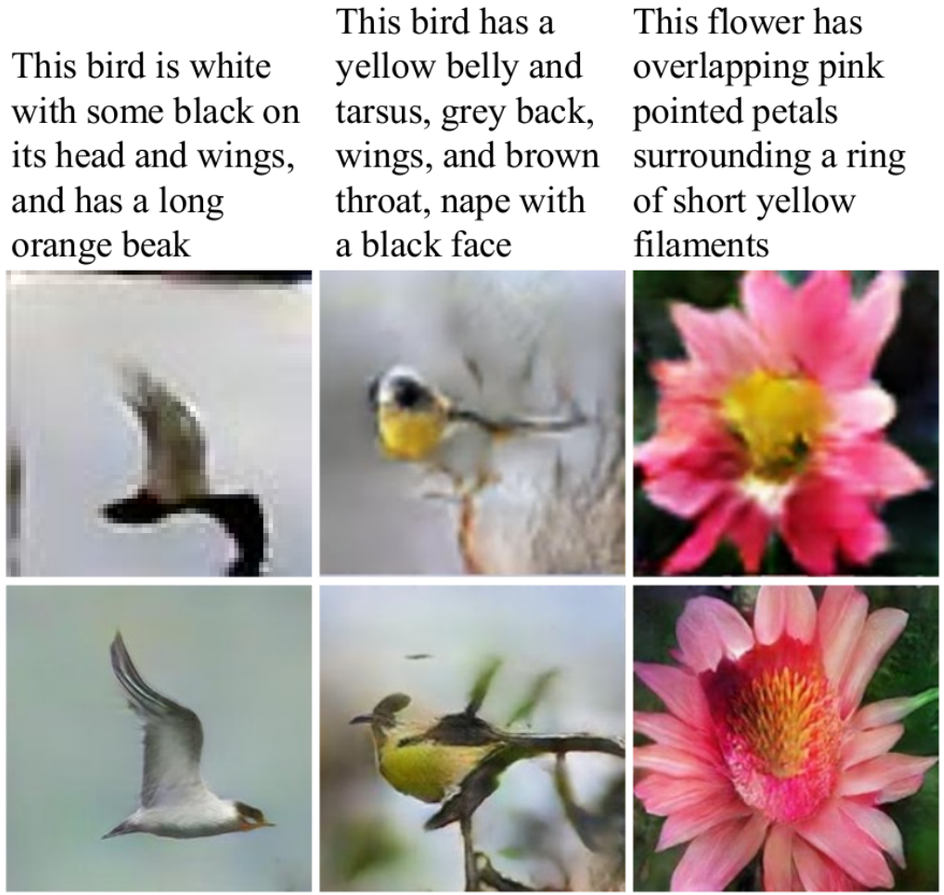
Harder data



Stronger models

Tasks that require understanding?

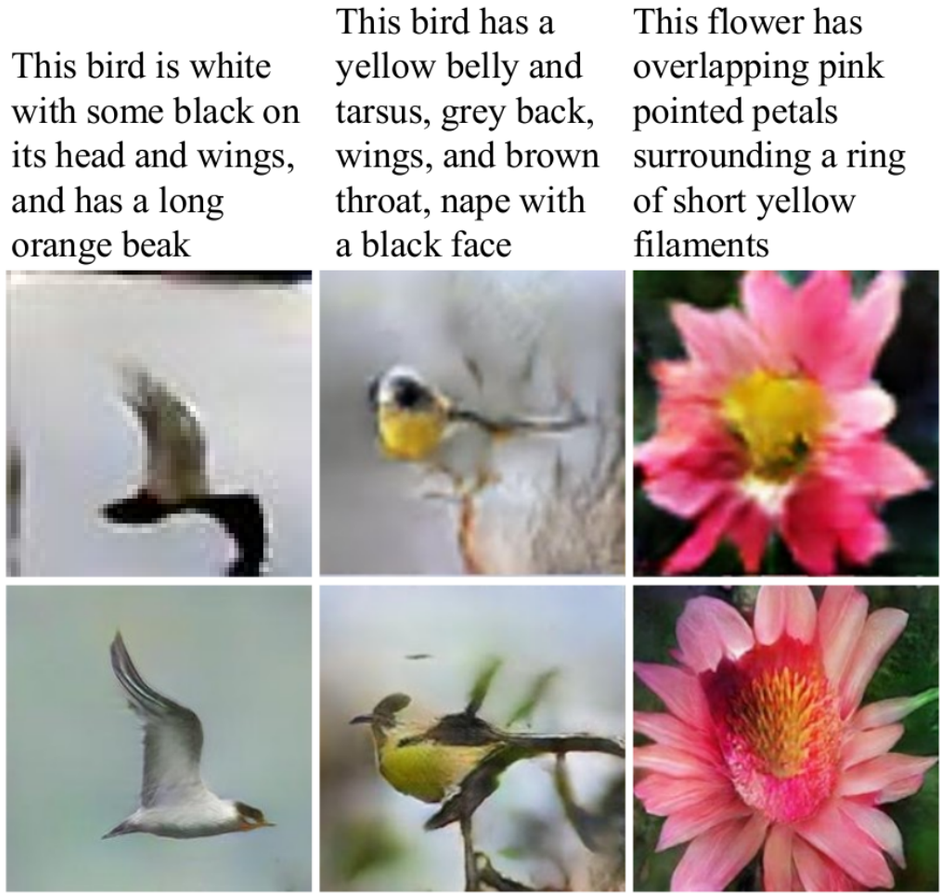
man in black shirt is playing guitar



[Karpathy+ 2014; Zhang+ 2016]

Tasks that require understanding?

man in black shirt is playing guitar



[Karpathy+ 2014; Zhang+ 2016]

If want to evaluate ML, need to think statistically...

Challenge to the community

Today:

Challenge to the community

Today:

Tomorrow (hopefully):

Every paper should evaluate on a **novel distribution or novel task**.

Final message

Need to think like **machine learning** when using machine learning


Public Home
My Home
My Dashboard
Help
pliang
CodaLab
A collaborative platform for reproducible research.
My Home
My Dashboard
Running 100 experiments in parallel on different versions of your code/data? Don't remember how you got that result from 6 months ago? CodaLab allows you to run your jobs on a cluster, document and share your experiments, all while keeping track of full provenance, so you can be a more efficient researcher.

```
> run rnn.py:0xf421264a206142fa97f7bebdac7bb09e "python rnn.py --task sum --num-iters 1000000 --n-input 20 --step-size 0.0001"
```

Recurrent Neural Networks

name: pliang-rnn

uuid: 0x6bad41bbd9a64f71ba0ef7776582fdba

owner: pliang

permissions: you(all) public(read)

Keyboard Shortcuts

Mode: View | Edit source

2015-12-05

Just playing around with RNNs on some toy data...

uuid	task	model	n_hidden	n_input	n_time	step_size	iter	num_iters	error	time	state	description
0xf42126											ready	my program
0xfaee92	sum	rnn	5	2	10	0.001	29000	30000	2.6634	1m10s	ready	baseline
0x8e8f03	sum	rnn	5	2	10	0.001	29000	30000	2.2810	1m43s	ready	
0xd3302b	sum	rnn	5	4	10	0.005	99000	100000	0.1187	2m27s	ready	
0x60aab5	sum	rnn	5	4	10	0.005	334000	1000000	4.4134	3m37s	running	increase #iters
0xae4ff2	sum	rnn	5	20	10	0.005	311000	1000000	11.0963	4m16s	running	
0x062bab	sum	rnn	5	20	10	0.001	264000	1000000	12.5704	2m57s	running	decrease step size
0xae4472	sum	rnn	5	20	10	0.0001		1000000		43.0s	running	decrease step size

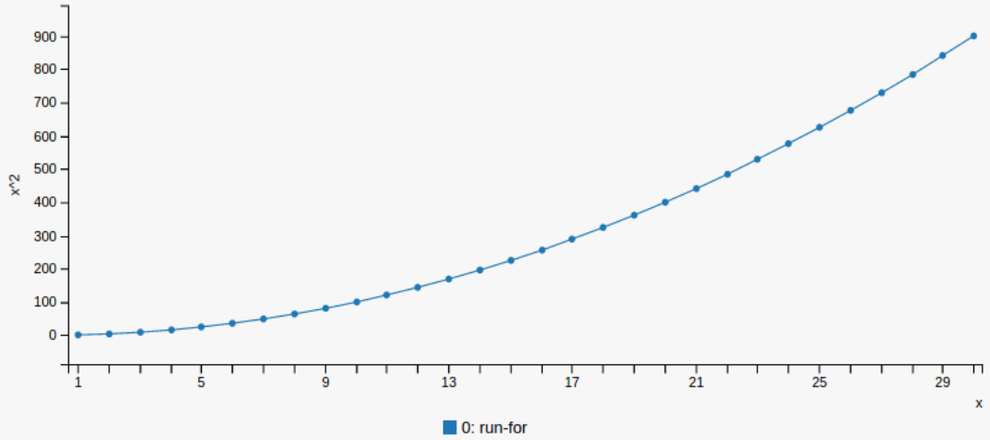
Heading

You can type in **any** markdown with any $\LaTeX$.

uuid	name	summary	state	desc.
0xc19b66	nanc-1m.txt	[uploaded]	ready	1 million sentences from the NANC corpus

```
Two New Orleans riverboat casinos declared bankruptcy in early June after just two months
One of the boats was owned by Harrah 's Jazz partner Christopher Hemmeter .
```

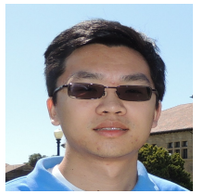
query	count
Montreal	415
Toronto	872



uuid	name	summary	data_size
0x96e9dc	stanford-corenlp-full-2015-01-30	[uploaded]	307m

CodaLab Worksheets

`worksheets.codalab.org`

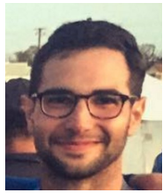

Robin Jia


Pranav Rajpurkar


Juncen Li


He He


Daniel Selsam


Matt Lamm


Benedikt Bunz


Leonardo de Moura


David Dill

Future of Life OpenPhil NSF Facebook Microsoft Tencent

Thank you!