Machine Reading and Reasoning with Neural Program Interpreters

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"Should we separate meaning from language? [Maybe not?]

The "Classic" NLP Paradigm

Chris Manning
@AKBC 2013

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.

What city did Tesla move to in 1880?

Prague

[Language]

+reusable cache
+interpretable
+supports reasoning

[Meaning]

-misses details
-error prone
-engineering heavy

[Information Need]

“Should we separate meaning from language?” **[Maybe not?]**

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[Language] [Meaning] [Information Need]

End-to-End Reading and Comprehension

(Hermann et. al 2015, Seo et al., 2016, Rajpurkar et al., 2016, Weissenborn 2016…)

[Language] [Information Need]

Machine Reading & Comprehension

Would it be appropriate for me to accept court side seating tickets to an NBA event?

Invitations to expensive or exclusive sporting or cultural events should not be accepted

Rules: Entertainment

Offers of entertainment may be accepted or made where they are necessary to develop and maintain outside contacts relevant to work responsibilities… disproportionately lavish. Invitations to expensive or exclusive sporting or cultural events should not be accepted.

3. Invitations from institutions supervised by the Bank or the FCA, or from professional advisers, should not be accepted without prior agreement of an Executive Director or Governor ….

Machine Reading & Comprehension

Which function do I call for storing items in cape?

cape.client.CapeClient.archive_inbox()

...

Archiving Inbox Items

Once an inbox item has been archived it will no longer appear in the list of inbox items returned by cape.client.CapeClient.get_inbox(). To archive an item call cape.client.CapeClient.archive_inbox() with the ID of the inbox item to archive:

```
from cape.client import CapeClient

cc = CapeClient()
cc.login('username', 'password')
cc.archive_inbox('4123')
```

Newsweek

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

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

Newsweek

ROBOTS CAN NOW MATCH ANSWER TYPES (AND A BIT OF CONTEXT) BETTER THAN HUMANS

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

Machine Reading & Comprehension

What is the name of the quarterback who was 38 in Super Bowl XXXIII?

Jeff Dean

Peyton Manning became the first quarterback ever to lead two different teams to multiple Super Bowls. He is also the oldest quarterback ever to play in a Super Bowl at age 39. The past record was held by John Elway, who led the Broncos to victory in Super Bowl XXXIII at age 38 and is currently Denver's Executive Vice President of Football Operations and General Manager. Quarterback Jeff Dean had jersey number 37 in Champ Bowl XXXIV.

Robin Jia, Percy Liang, 2017

Newsweek

ROBOTS STILL CANNOT REASON WITH THE INFORMATION THEY READ!

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

How to read and **reason end-to-end**?

Learning to Read and Aggregate

Part 1

Which medical specialty deals with pituitary ACTH hypersecretion?

Endocrinology

Pituitary ACTH hypersecretion ... is a form of hyperpituitarism characterized by an abnormally high level of ACTH produced by the **anterior pituitary** …

A major organ of the **endocrine system**, the **anterior pituitary** is the glandular, anterior lobe that ...

The endocrine system is ... ... The field of study dealing with the **endocrine system** and its disorders is **endocrinology**, a branch of internal medicine.

NIPS 2017, TACL 2018

Learning to Read and Calculate

Part 2

How many pictures were in each of the albums?

2

Isabel uploaded **2 pictures from her phone** and **4 from her camera** to facebook. She sorted the pics into **3 different albums** with the same amount of pics in each album.

ICML 2017

Learning to Interpret Rules

Part 3

I am working for an employer in Canada since December 2017. Do I need to carry on paying UK national insurance?

Yes

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EMNLP 2018

And Ask Clarification Questions

Part 3

I am working for an employer in Canada . Do I need to carry on paying UK national insurance?

Have you been working abroad 52 weeks or less?

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EMNLP 2018

Pontus Stenetorp

Johannes Welbl

Tim Rocktäschel

Part 1: Learning to Aggregate

Neural Theorem Provers

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Agent

Program Interpreter

Code

[translates questions]

Question

Reader

Rocktäschel and Riedel **NIPS 2017**

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[translates questions]

Question

What is ACTH hypersecretion created by?

Reader

Rocktäschel and Riedel **NIPS 2017**

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Agent

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Code

[translates questions]

Question

What is the pituitary a part of?

Reader

Rocktäschel and Riedel **NIPS 2017**

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[translates questions]

Question

What topic covers the endocrine system?

Reader

Rocktäschel and Riedel **NIPS 2017**

Vectors Correspond to Interpretable Rules

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Agent

Program Interpreter

Code

```
X deals with Y if
  Y produced by Z
  Z is a part of U
  X deals with U
```

Question

What topic covers the endocrine system?

Reader

Rocktäschel and Riedel **NIPS 2017**

Simplify: Working with Relational Data

dealsWith(hypersecretion, X)

Agent

Program Interpreter

Code

```
X deals with Y if
  Y produced by Z
  Z is a part of U
  X deals with U
```

Question

covers(endocrine system, X)

Reader

createdBy(hypersecretion, anterior pituitary)

partOf(endocrine system, anterior pituitary)

dealsWith(endocrine system, endocrinology)

Rocktäschel and Riedel **NIPS 2017**

Why Program Interpreter/Theorem Prover?

dealsWith(**hypersecretion**, X)

Agent

*Amounts the **Backward Chaining** algorithm used in Prolog Interpreters*

createdBy(**hypersecretion, anterior pituitary**)

partOf(**endocrine system**, **anterior pituitary**)

dealsWith(**endocrine system**, **endocrinology**)

Rocktäschel and Riedel **NIPS 2017**

Why Neural? Supports Soft Unification

dealsWith(**hypersecretion**, X)

createdBy(**hypersecretion, anterior pituitary**)

partOf(**endocrine system**, **anterior pituitary**)

(**endocrine system**, **endocrinology**)

Agent

Program Interpreter

Code

```
X deals with Y if
  Y produced by Z
  Z is a part of U
  X covers U
```

Question

(**endocrine system**, **X**)

Reader

Rocktäschel and Riedel **NIPS 2017**

Learn Rules by Learning Symbol Representations

dealsWith(**hypersecretion**, X)

Agent

Program Interpreter

Code

```
X rel32 Y if
  Y rel42 Z
  Z rel51 U
  X rel62 U
```

Question

rel62(**endocrine system**, **X**)

Reader

createdBy(**hypersecretion, anterior pituitary**)

partOf(**endocrine system**, **anterior pituitary**)

dealsWith(**endocrine system**, **endocrinology**)

Rocktäschel and Riedel **NIPS 2017**

Before Learning

X *rel32* Y if
Y *rel42* Z
Z *rel51* U
X *rel62* U

X *deals with* Y if
Y *produced by* Z
Z *is a part of* U
X *deals with* U

After Learning

X *rel32* Y if
Y *rel42* Z
Z *rel51* U
X *rel62* U

X *deals with* Y if
Y *produced by* Z
Z *is a part of* U
X *deals with* U

Results on Benchmark (Rank of Correct Answer)

Comparable or Better than Baselines, and ***interpretable***

Rocktäschel and Riedel **NIPS 2017**

Limitations

- Scalability
  - Currently only works for KBs with < 10k facts (solved!)
  - Small proof depth (getting there)
- **Still requires relational representation (ongoing)**

Pontus Stenetorp **Johannes Welbl**

How to create Datasets for Multihop Reading and Reasoning?

Dataset Construction Method

Unlabelled Text

Knowledge Base

Dataset Construction Method →

Multihop Dataset

Dataset Construction Method

KB Triple

Jamie Burnett, citizenship, Scotland

Entities

Documents

Instance

What is the nationality of Jamie Burnett?

Scotland

China

Dataset Construction Method

[Conditionally Accepted to TACL]

Dataset Construction Method

Dataset Construction Method

Reduction to Traditional Machine Comprehension

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Do Neural Reading Models Aggregate?

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Removing Relevant Documents, Keep Answer Documents

TACL 2018
QAngaroo
Reading Comprehension with Multiple Hops
Paper
Dataset Download
Dataset Distribution under CC BY-SA 3.0

Matko Bosnjak

Tim Rocktäschel

Jason Naradowsky

Part 2: Learning to Read and Calculate

Machine Reading and Reasoning: Math

How many pictures were in each of the albums?

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Isabel uploaded **2 pictures from her phone** and **4 from her camera** to facebook. She sorted the pics into **3 different albums** with the same amount of pics in each album.

Differentiable Program Interpreters

How many pictures were in each of the albums?

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Bosnjak et al. **ICML 2017**

Differentiable Program Interpreters

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Training

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Bosnjak et al. **ICML 2017**

Results on Math Problems (Accuracy)

Seq2Seq solves simpler problem

How many pictures were in each of the albums?

(2 + 4) / 3

Bosnjak et al. **ICML 2017**

Limitations

- Continuous relaxations difficult to train
  - Hard to learn long programs
  - Hard to learn with recursive function calls
- Need better understanding of SGD for networks with discrete/stochastic activations
- Insight: differentiable interpreter (poorly) calculates marginal probabilities of output states (making many independence assumptions)
  - Can we improve this by being more clever about probabilistic inference?

Tim Rocktäschel

Guillaume Bouchard

Marzieh Saeidi

Max Bartolo

Part 3: Learning to Interpret Rules and Ask Clarification Questions

Learning to Interpret Rules

I am working for an employer in Canada since December 2017. Do I need to carry on paying UK national insurance?

Yes

If you're self-employed
You might be able to carry on paying National Insurance if you're:
- usually self-employed in the UK
- working abroad temporarily

If you do, you won't have to pay social security contributions in the country where you're working. You can check this by completing form CA9107.

Working in any other country
You'll carry on paying National Insurance for the first 52 weeks you're abroad if you're working for an employer outside the EEA.

And Ask Clarification Questions

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Generating a Corpus

Do I need to carry on paying UK national insurance?

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Created ~40k instances this way

Seq2Seq?

I am working for an employer in Canada . Do I need to carry on paying UK national insurance?

Were you laid before earning at least the lower earnings limit?

Seq2Seq with attention
(to your needs)

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Conclusion

- Great Progress in End-to-End Reading Comprehension
- **Reasoning** (aggregation, calculation etc.) and **conversation** end-to-end is still very challenging
- Our Approaches
  - cast reasoning as **program learning** and **execution**
  - are **end-to-end differentiable** (can be trained on downstream loss)
  - are inspired and tied to **traditional symbolic formalisms** (Forth, Prolog/Datalog)
  - are learnt models are **interpretable**
  - allow injection of **prior knowledge**
  - **create datasets**