New Resources and Ideas for Semantic Parsing

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Collaborators: Jonas Kuhn (advisor, Stuttgart) and Jonathan Berant (work on "polyglot semantic parsing", Tel Aviv)
Main Topic: Semantic Parsing

- **Task**: mapping text to formal meaning representations (ex., from Herzig and Berant (2017)).

  **Text**: *Find an article with no more than two authors.*

  \[
  \text{LF: } \text{Type.Article} \sqcap R[\lambda x.\text{count}(\text{AuthorOf}.x)] \leq 2
  \]
Main Topic: Semantic Parsing

- **Task**: mapping text to formal meaning representations (ex., from Herzig and Berant (2017)).

  **Text**: *Find an article with no more than two authors.*

  →

  **LF**: \( \text{Type'article} \sqcap R[\lambda x.\text{count}(\text{AuthorOf} x)] \leq 2 \)

  "Machines and programs which attempt to answer English question have existed for only about five years.... Attempts to build machine to test logical consistency date back to at least Roman Lull in the thirteenth century... Only in recent years have attempts been made to translate mechanically from English into logical formalisms..."

Classical Natural Language Understanding

- Conventional **pipeline model**: focus on capturing deep inference and entailment.

    ![Diagram](image)

    **1. Semantic Parsing**
    - List samples that contain every major element

    **2. Knowledge Representation**
    - (FOR EVERY X / MAJORELT : T; (FOR EVERY Y / SAMPLE : (CONTAINS Y X); (PRINTOUT Y)))

    **3. Reasoning**

    ![Database](image)

    \[ [sem] = \{S10019, S10059, \ldots \} \]

Lunar QA system of Woods (1973)
Classical Natural Language Understanding

List samples that contain every major element

\[ \text{sem} = \{\text{S10019, S10059, ...} \} \]

1. Semantic Parsing
   - Translating input to sem, input → sem

2. Knowledge Representation
   - Defining a sufficiently expressive sem language.

3. Reasoning/Execution
   - Going from sem to denotations in the real-word.
Data-driven Semantic Parsing and NLU

1. Semantic Parsing

List samples that contain every major element

2. Knowledge Representation

3. Reasoning

[\textit{sem}] = \{S10019, S10059, \ldots\}

- **Data-driven NLU**: Asks an empirical question: Can we learn NLU models from examples?
1. Semantic Parsing

List samples that contain every major element

\[
\text{database} \quad \{ \text{S10019, S10059, ...} \}
\]

2. Knowledge Representation

\[
\text{(FOR EVERY X / MAJORELT : T; (FOR EVERY Y / SAMPLE : (CONTAINS Y X); (PRINTOUT Y))})
\]

3. Reasoning

**Semantic Parser Induction:** Learn semantic parser (weighted transduction) from parallel text/meaning data, constrained SMT task.

**Resource Problem:** Where does the parallel data come from, what do we learn from? Does not occur 'in the wild'
Talk Overview

<table>
<thead>
<tr>
<th>Sub-problem</th>
<th>Problem Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Semantic Parsing</td>
<td><em>Translating input to sem, input → sem</em></td>
</tr>
<tr>
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</tbody>
</table>

1. **Resource Problem**: Using technical documentation as a parallel corpus (problems 1,4), from Richardson and Kuhn (2017b,a)

2. **Polyglot Modeling**: Building semantic parsers from multiple datasets, ”polyglot decoding” (problems 1,4), from Richardson et al. (2018)

3. **Learning from Entailment**: Integrating entailment into a semantic parsing pipeline (problems 1,2,3), from Richardson and Kuhn (2016).
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New resources and ideas (going beyond standard tasks/evaluation)
<Resource Problem>
What state has the largest population?

\[ z = \operatorname{argmax} (\lambda x. (\text{state } x) \lambda x. (\text{population } x)) \]

- **Learning from LFs**: Pairs of text \( x \) and logical forms \( z \), \( D = \{(x, z)_i\}_i^n \), learn \( \text{sem} : x \to z \)

- **Modularity**: Study the translation independent of other semantic issues.
**Semantic Parsing and Parallel Data**

What state has the largest population?

\[ z = \text{argmax} \ (\lambda x. \ (\text{state} \ x) \ \lambda x. \ (\text{population} \ x)) \]

- **Learning from LFs**: Pairs of text \( x \) and logical forms \( z \), \( D = \{(x, z)_i\}_i^n \), learn \( \text{sem} : x \rightarrow z \)

- **Modularity**: Study the translation independent of other semantic issues.

- **Resource issue**: Finding *parallel data*, current lack of resources.
Source Code and API Documentation

```java
public static Long max(long a, long b)
```

- Returns the greater of two long values
- @param a an argument
- @param b another argument
- @return the larger of a and b
- @see java.lang.Long#MAX_VALUE

» Source Code Documentation: High-level descriptions of internal software functionality paired with code.
* Returns the greater of two long values
*
* @param a an argument
* @param b another argument
* @return the larger of a and b
* @see java.lang.Long#MAX_VALUE
*
```java
public static Long max(long a, long b)
```

▶ **Source Code Documentation:** High-level descriptions of internal software functionality paired with code.

▶ **Idea:** Treat as a parallel corpus (Allamanis et al., 2015; Gu et al., 2016; Iyer et al., 2016), or synthetic semantic parsing dataset.
Source Code as a Parallel Corpus

Observation 1: Tight coupling between high-level text and code.

```java
public static Long max(long a, long b)
```

```clojure
(ns ... clojure.core)
(defn random-sample
  "Returns items from coll with random probability of prob (0.0 - 1.0)"
  ([prob] ...)
  ([prob coll] ...))
```
Source Code as a Parallel Corpus

▶ **Observation 1:** Tight coupling between high-level text and code.

* Returns the greater of two long values
* @param a an argument
* @param b another argument
* @return the larger of a and b
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* /

```java
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▶ **Function signatures:** Header-like representations, containing function name, (optionally typed) arguments, (optional) return value, namespace.
Source Code as a Parallel Corpus

- **Observation 1:** Tight coupling between high-level text and code.

```java
public static Long max(long a, long b)
```

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  ([prob coll] ...))
```

- **Function signatures:** Header-like representations, containing function name, (optionally typed) arguments, (optional) return value, namespace.

  *Returns the greater of two long values*  
  *Returns items from coll with random probability of prob (0.0 - 1.0)*
Observation 2: There are many languages, hence many datasets.

* Returns the greater of two long values
* @param a an argument
  * @param b another argument
  * @return the larger of a and b
  * @see java.lang.Long#MAX_VALUE
  */
public static Long max(long a, long b)

(nslong.clojure.core)
(defn random-sample
  "Returns items from coll with random probability of prob (0.0 - 1.0)"
  ([prob] ...)
  ([prob coll] ...))

{-# zipfile.py
  """Read and write ZIP files""
class ZipFile(object):
  """Class to open ... zip files.""
  def write(filename,arcname,....):
    """Put the bytes from filename into the archive under the name..""

--| Mostly functions for reading and showing RealFloat like values
module Numeric

-- | Show non-negative Integral numbers in base 10.
showInt :: Integral a => a -> ShowS
Observation 3: Many NLs, hence many multilingual datasets.

```php
namespace ArrayIterator;
/**
 * Appends values as the last element
 * @param value The value to append
 * @see ArrayIterator::next()
 */
public void append(mixed $value)
```

```php
namespace ArrayIterator;
/**
 * Ajoute une valeur comme dernier élément
 * @param value La valeur à ajouter
 * @see ArrayIterator::next()
 */
public void append(mixed $value)
```

```php
namespace ArrayIterator;
/**
 * Dobavlyaet znachenie value, kak posledni element massiva.
 * @param value znachenie, kotoroe nuzhno dobavit'.
 * @see ArrayIterator::next()
 */
public void append(mixed $value)
```

```php
namespace ArrayIterator;
/**
 * Anade el valor cómo el último elemento.
 * @param value El valor a anadir.
 * @see ArrayIterator::next()
 */
public void append(mixed $value)
```
Observation 4: Code collections contain rich amount of background info.

NAME: dappprof
profile user and lib function usage.

SYNOPSIS
dappprof [-ac..] .. -p PID | command

DESCRIPTION
--a       print all data
--p PID    examine the PID

EXAMPLES
Run and examine the ‘‘df -h’’ command
dappprof command='‘df -h’’

Print elapsed time for PID 1871
dappprof -p PID=1871

SEE ALSO
dapptrace(1M), dtrace(1M), ...

Descriptions: textual descriptions of parameters, return values, ...
Cluster information: pointers to related functions/utilities, ...
Syntactic information: function/code syntax
## Resource 1: Standard Library Documentation

<table>
<thead>
<tr>
<th>Dataset</th>
<th>#Pairs</th>
<th>#DescrSymbols</th>
<th>#Words</th>
<th>Vocab.</th>
<th>Example Pairs ((x, z)), <strong>Goal</strong>: learn a function (x \rightarrow z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Java</td>
<td>7,183</td>
<td>4,804</td>
<td>4,072</td>
<td>82,696</td>
<td>(x): Compares this Calendar to the specified Object. z: <code>boolean util.Calendar.equals(Object obj)</code></td>
</tr>
<tr>
<td>Ruby</td>
<td>6,885</td>
<td>1,849</td>
<td>3,803</td>
<td>67,274</td>
<td>(x): Computes the arc tangent given (y) and (x). z: <code>Math.atan2(y, x) \rightarrow Float</code></td>
</tr>
<tr>
<td>PHP(_{en})</td>
<td>6,611</td>
<td>13,943</td>
<td>8,308</td>
<td>68,921</td>
<td>(x): Delete an entry in the archive using its name. z: <code>bool ZipArchive::deleteName(string $name)</code></td>
</tr>
<tr>
<td>Python</td>
<td>3,085</td>
<td>429</td>
<td>3,991</td>
<td>27,012</td>
<td>(x): Remove the specific filter from this handler. z: <code>logging.Filterer.removeFilter(filter)</code></td>
</tr>
<tr>
<td>Elisp</td>
<td>2,089</td>
<td>1,365</td>
<td>1,883</td>
<td>30,248</td>
<td>(x): Returns the total height of the window. z: <code>(window-total-height window round)</code></td>
</tr>
<tr>
<td>Haskell</td>
<td>1,633</td>
<td>255</td>
<td>1,604</td>
<td>19,242</td>
<td>(x): Extract the second component of a pair. z: <code>Data.Tuple.snd :: (a, b) \rightarrow b</code></td>
</tr>
<tr>
<td>Clojure</td>
<td>1,739</td>
<td>–</td>
<td>2,569</td>
<td>17,568</td>
<td>(x): Returns a lazy seq of every nth item in coll. z: <code>(core.take-nth n coll)</code></td>
</tr>
<tr>
<td>C</td>
<td>1,436</td>
<td>1,478</td>
<td>1,452</td>
<td>12,811</td>
<td>(x): Returns current file position of the stream. z: <code>long int ftell(FILE *stream)</code></td>
</tr>
<tr>
<td>Scheme</td>
<td>1,301</td>
<td>376</td>
<td>1,343</td>
<td>15,574</td>
<td>(x): Returns a new port and the given state. z: <code>(make-port port-type state)</code></td>
</tr>
<tr>
<td>Geoquery</td>
<td>880</td>
<td>–</td>
<td>167</td>
<td>6,663</td>
<td>(x): What is the tallest mountain in America? z: <code>(highest(mountain(loc_2(countryid usa))))</code></td>
</tr>
</tbody>
</table>

▶ Standard library documentation for 9+ programming languages, 7 natural languages, from Richardson and Kuhn (2017b).
Resource 1: Non-English collection.

<table>
<thead>
<tr>
<th>Dataset</th>
<th># Pairs</th>
<th>#Descr.</th>
<th>Symbols</th>
<th>Words</th>
<th>Vocab.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHP\textsubscript{fr}</td>
<td>6,155</td>
<td>14,058</td>
<td>7,922</td>
<td>70,800</td>
<td>5,904</td>
</tr>
<tr>
<td>PHP\textsubscript{es}</td>
<td>5,823</td>
<td>13,285</td>
<td>7,571</td>
<td>69,882</td>
<td>5,790</td>
</tr>
<tr>
<td>PHP\textsubscript{ja}</td>
<td>4,903</td>
<td>11,251</td>
<td>6,399</td>
<td>65,565</td>
<td>3,743</td>
</tr>
<tr>
<td>PHP\textsubscript{ru}</td>
<td>2,549</td>
<td>6,030</td>
<td>3,340</td>
<td>23,105</td>
<td>4,599</td>
</tr>
<tr>
<td>PHP\textsubscript{tr}</td>
<td>1,822</td>
<td>4,414</td>
<td>2,725</td>
<td>16,033</td>
<td>3,553</td>
</tr>
<tr>
<td>PHP\textsubscript{de}</td>
<td>1,538</td>
<td>3,733</td>
<td>2,417</td>
<td>17,460</td>
<td>3,209</td>
</tr>
</tbody>
</table>

- **Non-English:** PHP documentation collection, French (fr), Spanish (es), Japanese (ja), Russian (ru), Turkish (tr), German (de)
Resource 2: Open source Python projects

<table>
<thead>
<tr>
<th>Project</th>
<th># Pairs</th>
<th># Symbols</th>
<th># Words</th>
<th>Vocab.</th>
</tr>
</thead>
<tbody>
<tr>
<td>scapy</td>
<td>757</td>
<td>1,029</td>
<td>7,839</td>
<td>1,576</td>
</tr>
<tr>
<td>zipline</td>
<td>753</td>
<td>1,122</td>
<td>8,184</td>
<td>1,517</td>
</tr>
<tr>
<td>biopython</td>
<td>2,496</td>
<td>2,224</td>
<td>20,532</td>
<td>2,586</td>
</tr>
<tr>
<td>renpy</td>
<td>912</td>
<td>889</td>
<td>10,183</td>
<td>1,540</td>
</tr>
<tr>
<td>pyglet</td>
<td>1,400</td>
<td>1,354</td>
<td>12,218</td>
<td>2,181</td>
</tr>
<tr>
<td>kivy</td>
<td>820</td>
<td>861</td>
<td>7,621</td>
<td>1,456</td>
</tr>
<tr>
<td>pip</td>
<td>1,292</td>
<td>1,359</td>
<td>13,011</td>
<td>2,201</td>
</tr>
<tr>
<td>twisted</td>
<td>5,137</td>
<td>3,129</td>
<td>49,457</td>
<td>4,830</td>
</tr>
<tr>
<td>vispy</td>
<td>1,094</td>
<td>1,026</td>
<td>9,744</td>
<td>1,740</td>
</tr>
<tr>
<td>orange</td>
<td>1,392</td>
<td>1,125</td>
<td>11,596</td>
<td>1,761</td>
</tr>
<tr>
<td>tensorflow</td>
<td>5,724</td>
<td>4,321</td>
<td>45,006</td>
<td>4,672</td>
</tr>
<tr>
<td>pandas</td>
<td>1,969</td>
<td>1,517</td>
<td>17,816</td>
<td>2,371</td>
</tr>
<tr>
<td>sqlalchmy</td>
<td>1,737</td>
<td>1,374</td>
<td>15,606</td>
<td>2,039</td>
</tr>
<tr>
<td>pyspark</td>
<td>1,851</td>
<td>1,276</td>
<td>18,775</td>
<td>2,200</td>
</tr>
<tr>
<td>nupic</td>
<td>1,663</td>
<td>1,533</td>
<td>16,750</td>
<td>2,135</td>
</tr>
<tr>
<td>astropy</td>
<td>2,325</td>
<td>2,054</td>
<td>24,567</td>
<td>3,007</td>
</tr>
<tr>
<td>sympy</td>
<td>5,523</td>
<td>3,201</td>
<td>52,236</td>
<td>4,777</td>
</tr>
<tr>
<td>ipython</td>
<td>1,034</td>
<td>1,115</td>
<td>9,114</td>
<td>1,771</td>
</tr>
<tr>
<td>orator</td>
<td>817</td>
<td>499</td>
<td>6,511</td>
<td>670</td>
</tr>
<tr>
<td>obspy</td>
<td>1,577</td>
<td>1,861</td>
<td>14,847</td>
<td>2,169</td>
</tr>
<tr>
<td>rdkit</td>
<td>1,006</td>
<td>1,380</td>
<td>9,758</td>
<td>1,739</td>
</tr>
<tr>
<td>django</td>
<td>2,790</td>
<td>2,026</td>
<td>31,531</td>
<td>3,484</td>
</tr>
<tr>
<td>ansible</td>
<td>2,124</td>
<td>1,884</td>
<td>20,677</td>
<td>2,593</td>
</tr>
<tr>
<td>statsmodels</td>
<td>2,357</td>
<td>2,352</td>
<td>21,716</td>
<td>2,733</td>
</tr>
<tr>
<td>theano</td>
<td>1,223</td>
<td>1,364</td>
<td>12,018</td>
<td>2,152</td>
</tr>
<tr>
<td>ntk</td>
<td>2,383</td>
<td>2,324</td>
<td>25,823</td>
<td>3,151</td>
</tr>
<tr>
<td>sklearn</td>
<td>1,532</td>
<td>1,519</td>
<td>13,897</td>
<td>2,115</td>
</tr>
</tbody>
</table>

- 27 Python projects from Github, from Richardson and Kuhn (2017a), similar to Barone and Sennrich (2017)
Summary of Current Resources

▶ **API Datasets**: Stdlib collection and Py27, consists of 45 APIs across 11 programming languages, 8 natural languages.

▶ **Other Resources**: Function Assistant, tool for extracting parallel datasets from Python projects

▶ **forthcoming**: around 500 additional Python/Java API datasets for data-to-text generation (Richardson et al., 2017).

https://github.com/yakazimir/Code-Datasets
Text to Signature Translation: How hard it is?

- **Task**: For each API dataset of text/signature pairs (each within a finite signature space), learn a sp: text → signature.

- **Question** Can background info. from API help?
Text to Signature Translation: How hard it is?

- **Task**: For each API dataset of text/signature pairs (each within a finite signature space), learn a sp: text $\rightarrow$ signature.
- **Question**: Can background info. from API help?

- **Baseline Model**: (Deng and Chrupała, 2014), sequence prediction model.

$k$-best signature translation list

- **SMT Model**
- **Task specific decoder**
- **Evaluation**
- **Accuracy @i?**

- **Discriminative Model**

$\times$ string APCIterator::key(void)
$\times$ int APCIterator::getTotalHits(void)
$\times$ int APCIterator::getSize(void)
int APCIterator::getTotalSize(void)
$\times$ int Memcached::append(string $key$
...

$\times$ string APCIterator::key(void)
$\times$ int APCIterator::getTotalHits(void)
$\times$ int APCIterator::getSize(void)
int APCIterator::getTotalSize(void)
$\times$ int Memcached::append(string $key$
...

Background API Information

- **Reranker Model**: See-also annotations, abstract syntax info., parameter descriptions,...

\[ \phi(x,z) = \begin{cases} 
\text{Model score}: \text{is it in top 5..10?} \\
\text{Alignments}: (\text{hyperbolic, cosh}), (\text{cosine, cosh}), ... \\
\text{Phrases}: (\text{hyperbolic cosine, cosh}), (\text{of arg, float $arg$}), ... \\
\text{See also classes}: (\text{hyperbolic, \{cos,acosh,sinh,..\}}), ... \\
\text{In descriptions}: (\text{arg, $arg$}) \\
\text{Matches/Tree position}: ... \\
\end{cases} \]
**Text to Signature Translation: How hard it is?**

```
gets the total cache size

× string APCIterator::key(void)
× int APCIterator::getTotalHits(void)
× int APCIterator::getSize(void)
int APCIterator::getTotalSize(void)
× int Memcached::append(string $key)
...
```

**SMT Model**

**Task specific decoder**

**Evaluation**

**Discriminative Model**

**k-best signature translation list**

<table>
<thead>
<tr>
<th>Dataset (Avg.)</th>
<th>Term Matching</th>
<th>SMT</th>
<th>SMT + Reanker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Library Docs.</td>
<td>12.7 32.0 19.2</td>
<td>28.9 67.7 41.9</td>
<td>31.1 71.1 44.5</td>
</tr>
<tr>
<td>Py27</td>
<td>22.9 50.6 32.4</td>
<td>29.3 67.4 42.5</td>
<td>32.4 73.5 46.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>accuracy @1</th>
<th>accuracy @10</th>
<th>MRR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dataset (Avg.)**

**Term Matching**

**SMT**

**SMT + Reanker**

**accuracy @1**

**accuracy @10**

**MRR**
How hard is it?: Certainly not trivial, simple SMT models do alright, but lots of room for improvement

New Challenges: Highly sparse vocabulary, very hard to apply existing semantic parsing and MT methods (more about this next).

Many other uses of this data! (polyglot modeling, modeling textual entailment, data-to-text translation, natural language programming,....)
</Resource Issue>
Traditional approaches to semantic parsing train individual models for each available parallel dataset.

Resource Problem: Datasets tend to be small, hard and unlikely to get certain types of parallel data, e.g., (de, Haskell).
Polyglot Models: Training on Multiple Datasets

- Idea: concatenate all datasets into one, build a single-model with shared parameters, capture redundancy (Herzig and Berant, 2017).
- Polyglot Translator: translates from any input language to any output (programming) language.
Polyglot Models: Training on Multiple Datasets

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- **Polyglot Translator**: translates from any input language to any output (programming) language.

1. **Multiple Datasets**: Does this help learn better translators?

2. **Zero-Short Translation** (Johnson et al., 2016): Can we translate between different APIs and unobserved language pairs?
Polyglot Models: Training on Multiple Datasets

- **Challenge**: Building a polyglot decoder, or translation mechanism that facilitates crossing between (potentially unobserved) language pairs.
Polyglot Models: Training on Multiple Datasets

- **Challenge**: Building a polyglot decoder, or translation mechanism that facilitates crossing between (potentially unobserved) language pairs.
  - **Constraint 1**: Must ensure well-formed code (or LF) output (not guaranteed in ordinary MT, cf. Cheng et al. (2017))
  - **Constraint 2**: Must be able to translate to target APIs/programming languages on demand.
**Idea**: Exploit finite-ness of target translation space, represent full search space as directed acyclic graph (DAG).
Graph Based Approach

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- **Trick**: Prepend to each signature an artificial token that identifiers the API project or programming language (Johnson et al., 2016).
Graph Based Approach

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- **Trick**: Prepend to each signature an artificial token that identifiers the API project or programming language (Johnson et al., 2016).

- **Decoding**: Reduces to finding a path given an input $x$:

  $$x : \text{The ceiling of a number}$$

Can be solved using variant of single-source shortest path (SSSP) problem (Cormen et al., 2009), extendible to $k$-SSSP paths.
Graph Decoder: Shortest Path Decoding

- **Standard SSSP:** assumes a DAG $G = (V, E)$, a weight function: $w : E \rightarrow \mathbb{R}$, (initialized) vector $d \in \mathbb{R}^{|V|}$, unique source node $b$

0: $d[b] \leftarrow 0.0$

1: **for** vertex $u \in V$ in top sorted order

2: **do** $d(v) = \min_{(u,v,z) \in E} \{ d(u) + w(u, v, z) \}$

3: **return** $\min_{v \in V} \{ d(v) \}$
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▶ **Standard SSSP:** assumes a DAG $G = (V, E)$, a weight function: $w : E \rightarrow \mathbb{R}$, (initialized) vector $d \in \infty^{|V|}$, unique source node $b$

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▶ **Variant:** replace $w(\cdot)$ with translation model, dynamically generates weights correspond. to translation scores for $x$ and labels in SSSP search.
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- **Translation models:** Any model can be used, we experiment with lexical translation models (see paper) and attentive encoder-decoder models.
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► **Translation models:** Any model can be used, we experiment with lexical translation models (see paper) and attentive encoder-decoder models.

► **Neural Variant:** assumes input $x$, $G$, neural decoder parameters $\Theta$ (trained normally), $d$, and $s$ (state map):

0: $d[b] \leftarrow 0.0$
1: for each vertex $u \in V$ in top sorted order
2: \[ d(v) = \min_{(u,v,z) \in E} \left\{ -\log p_\Theta(z | z_{<i}, x) + d(u) \right\} \]
3: $s[v] \leftarrow \text{RNN state for min edge}$
4: return $\min_{v \in V} \{ d(v) \}$
Polyglot vs. Monolingual Decoding

- The difference is the input data, and starting point (i.e., source node) in graph.
- **Any Language Decoding**: Letting the decoder decide.
Polyglot vs. Monolingual Decoding

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- **Any Language Decoding**: Letting the decoder decide.

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<th>Source API (stdlib): (es, PHP)</th>
<th>Input: Devuelve el mensaje asociado al objeto lanzado.</th>
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<td></td>
<td>Language: <strong>PHP</strong></td>
<td>Translation: public string Throwable::getMessage ( void )</td>
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<td>Translation: public String lang.getMessage( void )</td>
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<td>Language: <strong>Clojure</strong></td>
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<td><strong>Output</strong></td>
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<td>1</td>
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<td><strong>Input</strong>: конвертирует строку из формата UTF-32 в формат UTF-16.</td>
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<td>Translation: string PDF_utf32.to_utf16 ( ... )</td>
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<td>Translation: String#toutf16 =&gt; string</td>
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<td>Language: <strong>Haskell</strong></td>
<td>Translation: Encoding.encodeUtf16LE :: Text -&gt; ByteString</td>
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<td><strong>Output</strong></td>
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<td>2</td>
<td>Source API (py): (en, stats)</td>
<td><strong>Input</strong>: Compute the Moore-Penrose pseudo-inverse of a matrix.</td>
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<td>Project: <strong>sympy</strong></td>
<td>Translation: matrices.matrix.base.pinv_solve( B, ... )</td>
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<td>Translation: utils.pinvh( a, cond=None,rcond=None,... )</td>
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Our Focus: Does training on multiple datasets (i.e., *polyglot models*) improve monolingual decoding?
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Polyglot vs. Monolingual Decoding: Tech Doc Task

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- **Findings**: Polyglot models can improve performance using SMT models, do not work for Seq2Seq models.
Polyglot Modeling on Benchmark SP Tasks

- **Our Focus**: Does this help on benchmark semantic parsing tasks?
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Multilingual Geoquery: monolingual/polyglot models on Geoquery in en, de, gr, th, polyglot setting improves accuracy, neural Seq2Seq models perform best (consistent with recent findings, (Dong and Lapata, 2016)).
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▶ Recall that these same Seq2Seq models do not work in the technical documentation tasks.
Introduced a new mixed language GeoQuery test set, each sentence contains NPs from two or more languages.

<table>
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<tr>
<th>Mixed Lang.</th>
<th>Input: Wie hoch liegt der höchstgelegene punkt in Αλαμπάμα?</th>
<th>LF: answer(elevation_1(highest(place(loc_2(stateid('alabama'))))))</th>
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<td>Mixed</td>
<td>Best Monolingual Seq2Seq 4.2 18.2</td>
<td>Polyglot Seq2Seq 75.2 90.0</td>
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Learning from multiple datasets: Summary

- **Take Away**: polyglot modeling can be a useful technique for improving semantic parsing and transfer learning.

- **New Ideas**: Translating between datasets and languages, mixed language parsing.

- **Technical Docs**: has features of a low-resource translation task, difficult especially for neural modeling.
<Learning from Entailment>

(high level overview)
Entailment: One of the *basic aims* of semantics. (Montague (1970))

Representations should be *grounded* in judgements about entailment.

\[
\text{database} \quad \begin{cases} \text{input} & \text{Semantic Parsing} \rightarrow \text{sem} \\
\text{All samples that contain a major element} & \rightarrow \text{Reasoning} \\
\text{Some sample that contains a major element} & \end{cases}
\]

\[
\begin{align*}
\lbrack \text{sem} \rbrack &= \{S10019, S10059, \ldots \} \\
&\supseteq \{S10019\}
\end{align*}
\]
Semantic Parsing and Entailment

- **Minimal requirement**: A semantic parser should be able to recognize certain types of entailments.

- **RTE**: Would a human reading t infer h? Dagan et al. (2005)

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Inference: \( t \rightarrow h \) Uncertain (human)
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Sportscaster corpus (Chen and Mooney (2008))
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How to improve this?

- **General Problem:** Semantic representations are underspecified, fail to capture entailments, background knowledge missing.

- **Goal:** Capture the missing knowledge and inferential properties of text, 
  *incorporate entailment information into learning.*
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- **Goal:** Capture the missing knowledge and inferential properties of text, **incorporate entailment information into learning.**

- **Solution:** Use entailment information (EI) as weak signal to train parser and logical reasoning, in Richardson and Kuhn (2016).

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<td>$\text{input} \xrightarrow{\text{Trans.}} \text{LF}$</td>
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<td>${(input_t, input'_h, EI_i)}_i^N$</td>
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Learning from Entailment: Illustration

- Entailments are used to reason about target symbols and find holes in the analyses.

Data: \( D = \{(t, h)_i, z_i\}_{i=1}^{N} \), generic logical calculus. **Task:** learn (latent) proof \( y \)
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Grammar Approach: Sentences to Logical Form

- Use a semantic CFG, rules constructed from target representations using small set of templates (Börschinger et al. (2011))

\[(x: \text{purple 10 quickly kicks}, z: \{\text{kick(purple10), block(purple7),...}\})\]

\[\downarrow\ (\text{rule extraction})\]
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\[\begin{array}{cccc}
\checkmark & \checkmark & \times & \times \\
\text{kick(purple10)} & \text{kick(purple10)} & \text{block(purple7)} & \text{block(purple9)}
\end{array}\]
Rules used to define a PCFG $G_\theta$, learn correct derivations.

**Learning:** EM bootstrapping approach (Angeli et al. (2012))

Purple 7 kicks to Purple 4

$Z = \{\text{pass(purple7,purple4)}\}$
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Learning Entailment Rules

- Rules define an inference PCFG $G'_\theta$, learn correct proofs, uses natural logic calculus from MacCartney and Manning (2009).
- **Learning:** Grammatical inference problem as before, EM bootstrapping.

**Input**

- $t$: pink 1 kicks
- $h$: pink 1 quickly passes to pink 2

**Beam Parser $\theta^t$**

- Interpretation
- $z = \text{Uncertain}$

**k-best list**

- $\theta^{t+1}$
Reasoning about Entailment

- Improving the internal representations (before, a, after, b).

a.

```
Sem_{sv}
  └── player_{arg1}
        └── play-transitive
              └── purple_{9c}
                  └── purple 9
```

```c
  pass_r
  └── pass_c
      └── purple_{9c}
          └── purple 9
```

```c
  └── passes to
      └── purple
```

```c
  └── 6 under pressure
```

b.

```
Sem_{sv}
  └── player_{arg1}
        └── play-transitive
              └── purple_{9c}
                  └── purple 9
```

```c
  pass_r
  └── pass_c
      └── purple_{9c}
          └── purple 9
```

```c
  └── passes to
      └── purple
```

```c
  └── under pressure
```
Reasoning about Entailment

- Learned modifiers from example proofs trees.

\[(t, h)\]:

- **Beautiful pass to, passes to**
  \[
  \subseteq_c \Rightarrow \text{play-tran} = \subseteq_c \text{play-tran}
  \]
  \[
  \subseteq_c / \lambda \quad \text{pass/pass}
  \]
  `"beautiful"/λ "pass to"/"passes to"

- **Gets a free kick, freekick from the**
  \[
  \subseteq_c \Rightarrow \text{game-play} = \subseteq_c \text{game-play}
  \]
  \[
  \subseteq_c / \lambda \quad \text{freekick/freekick}
  \]
  `"gets a"/λ "free kick" / "freekick from the"

**Analysis:**
- generalization:
  \[
  \text{beautiful}(X) \subseteq X
  \]
  \[
  \text{get}(X) \equiv X
  \]

\[(t, h)\]:

- **Yet again passes to, kicks to**
  \[
  \subseteq_c \Rightarrow \text{play-tran} = \subseteq_c \text{play-tran}
  \]
  \[
  \subseteq_c / \lambda \quad \text{pass/pass}
  \]
  `"yet again"/λ "passes to"/"kicks to"

- **Purple 10, purple 10 who is out front**
  \[
  \equiv_{\text{player}_2} \Rightarrow \exists_c = \equiv_{\text{player}_2}
  \]
  \[
  \equiv_{\text{player}_2} / \lambda \quad \text{purple10/purple10}
  \]
  `"purple 10"/"purple 10" λ/"who is out front"

**Analysis:**
- generalization:
  \[
  \text{yet-again}(X) \subseteq X
  \]
  \[
  X \subseteq \text{out_front}(X)
  \]
Reasoning about Entailment

- Learned lexical relations from example proof trees

\[(t, h): \quad \text{(pink team is offsides, purple 9 passes) \quad \text{(bad pass..., loses the ball to)}}\]

\[
\begin{align*}
\text{team}_{arg1} \\
\text{substitute} \\
pink \text{ team/purple9} \\
\text{“pink team”/“purple 9”} \\
\end{align*}
\begin{align*}
\subseteq \text{play-tran} \\
\text{substitute} \\
\text{bad pass/turnover} \\
\text{“bad pass .. picked off by”/“loses the ball to”} \\
\end{align*}
\]

\[
\begin{align*}
\text{analysis:} \\
\text{relation:}
\end{align*}
\begin{align*}
pink \text{ team} | \text{ purple9} \\
\text{bad pass} \subseteq \text{ turnover} \\
\end{align*}
\]

\[
\begin{align*}
(t, h): \quad \text{(free kick for, steals the ball from) \quad (purple 6 kicks to, purple 6 kicks)}\]
\end{align*}
\begin{align*}
\text{game-play} \\
\text{substitute} \\
\text{free kick/steal} \\
\text{“free kick for”/“steals the ball from”} \\
\end{align*}
\begin{align*}
\subseteq \text{play-tran.} \\
\text{substitute} \\
\text{pass/kick} \\
\text{“kicks to”/“kicks’} \\
\end{align*}
\]

\[
\begin{align*}
\text{analysis:} \\
\text{relation:}
\end{align*}
\begin{align*}
\text{free kick} | \text{ steal} \\
\text{pass} \subseteq \text{ kick} \\
\end{align*}
\]
Reasoning about Entailment: Summary

- **New Ideas**: Evaluating semantic parsers on RTE.
Reasoning about Entailment: Summary

▶ **New Ideas**: Evaluating semantic parsers on RTE.

<table>
<thead>
<tr>
<th>Inference Prediction</th>
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</tr>
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<tbody>
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</tr>
<tr>
<td>Logical Form Matching</td>
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<tr>
<td><strong>Learning from Entailment</strong></td>
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Reasoning about Entailment: Summary

- **New Ideas**: Evaluating semantic parsers on RTE.

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- **Take Away**: Using entailment as a weak signal can help improve representations being learned, help theory construction.
Reasoning about Entailment: Summary

- **New Ideas**: Evaluating semantic parsers on RTE.

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- **Take Away**: Using entailment as a weak signal can help improve representations being learned, help theory construction.

- **Conceptually**: Training our semantic parsers to be more like a semanticist, work backwards from entailments to representations.
</Learning from Entailment>
Conclusions

- **Natural language understanding:** pursue a data-driven approach, centering around semantic parser induction.

- Explore many areas of the problem, developed new resources and techniques, looking at the problem holistically.
  - Easy to get stuck on the translation problem!

- **Hope:** Ideas and approach will facilitate the deep NLU.
Thank You
References I


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References II


