Teaching Machines like we Teach People

Igor Labutov

Joint work with: Bishan Yang, Shashank Srivastava, Amos Azaria, Anusha Prakash, Tom Mitchell

Machine Learning for Machine Teaching
Machine Learning for Machine Teaching
There are six homeworks this semester, each due on ...

In addition to homeworks, there are projects ...

All assignments have a deadline

If a student emails a late homework, deduct 1 point per day ...
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<table>
<thead>
<tr>
<th>Assignment</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW1</td>
<td>May 23</td>
</tr>
</tbody>
</table>

A Personal Ontology

- Project
- Assignment
- HW
- Deadline

- HW1 hasDeadline on May 23
- HW1 isA HW
- Assignment isA Project
- Deadline isA HW
- HW isA Assignment
- Student isA HW
There are six homeworks this semester, each due on ...

In addition to homeworks, there are projects ...

All assignments have a deadline

If a student emails a late homework, deduct 1 point per day ...

<table>
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<tr>
<th>Assignment</th>
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<th>HW2</th>
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<th>HW4</th>
<th>HW5</th>
<th>HW6</th>
</tr>
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<td>Deadline</td>
<td>May 23</td>
<td>May 25</td>
<td>May 27</td>
<td>May 29</td>
<td>May 31</td>
<td>June 2</td>
</tr>
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A Personal Ontology

- Project
- Assignment
- HW
- Deadline
- HW1 hasDeadline May 23
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- HW3 isA HW
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DEMO
for example his affiliation is CMU

Setting university affiliation field of oscar to cmu.

most of my colleagues have a university affiliation

create a field called "university affiliation" for concept colleague, right?
for example his affiliation is CMU
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also make sure that the sender has an email address of a colleague of mine
check that some email address fields of colleagues instances appears in sender field of email that arrived, right?

if there is an important meeting
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check if the subject mentions words like meet or meeting

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for example his affiliation is CMU

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Check if the subject mentions words like meet or meeting

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No

Sorry, did you actually mean I will check that subject field of email that arrived is either "meet", "meeting"?
Knowledge-Base Construction

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Semantic Parsing

no

Sorry, did you actually mean I will check that subject field of email that arrived is either "meet", "meeting"?
Learning To Interpret Language
(Semantic Parsing)

- check if the subject mentions words like meet or meeting
  - I will check that subject field of email that arrived is "like meet or meeting", right?

- no
  - Sorry, did you actually mean I will check that subject field of email that arrived is either "meet", "meeting"?
Learning To Interpret Language
(Semantic Parsing)

Negative Feedback
Learning To Interpret Language (Semantic Parsing)

Bootstrapping Semantic Parsers from Conversations
Yoav Artzi and Luke Zettlemoyer

Integrated Learning of Dialog Strategies and Semantic Parsing
Aishwarya Padmakumar, Jesse Thomason, Raymond J. Mooney
Learning To Interpret Language
(Semantic Parsing)

Negative Feedback

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Learning To Interpret Language
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Implicit Instruction vs Explicit Instruction

Annotated logical forms
 Executions of logical forms (denotations)

no, I meant the word meeting, not like meeting

Ah, got it!

Negative Feedback
Learning To Interpret Language
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Implicit Instruction vs Explicit Instruction

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EMNLP 2018
Learning to Learn Semantic Parsers from Natural Language Supervision
Igor Labutov, Bishan Yang, Tom Mitchell
User Utterance: In [2014] how many jobs did he hold?
System NLG: find number of employments [Bob] had, prior to [2014]?
User Feedback: During 2014, not prior to.
User Utterance: Before [September 10th], how many places was [Brad] employed?

System NLG: find employment [Brad] had, prior to [September 10th]

User Feedback: Yes, but I also want you to count how many placed Brad was employed at.
User Utterance: anytime after [1995], did [Matt] talk to anybody about this at [JP Morgan]?

System NLG: find communications between [Matt] and people employed at [JP Morgan] about anything, that occurred after [1995]

User Feedback: No, I mean about the stock market, not just anything.
User Utterance: Do we know if [John] and [Neal] spoke?

System NLG: find communications between [John] and [Neal] about [the financial reports] at any time.

User Feedback: I mean about anything, not about the financial reports.
User Utterance  what was his last day at [Samsung]?
System NLG  find when employment of [Andy] at [Samsung] started
User Feedback  No, when it ended.
User-Agent Dialog

User's task utterance

System's confirmation

User's feedback
User-Agent Dialog

User's task utterance

U

NLG - Did you mean...

F - No, what I meant was

User's feedback

Original parse (possibly incorrect)

= Old parse
User-Agent Dialog

True parse

Logical Form parse of \( u \)

User's task utterance

\( U \)

User's feedback

\( NLG - \) Did you mean...

\( F – \) No, what I meant was

Old parse (possibly incorrect)
User-Agent Dialog

Hidden

Logical Form parse of $u$

True parse

User's task utterance

User's feedback

Original parse (possibly incorrect)

$U$

NLG - Did you mean...

$f - No, what I meant was$
Task Parser: $P(y \mid u; \theta_t)$
Feedback Parser: $P(y \mid u, f, \hat{y}; \theta_f)$
Task Parser: $P(y | u; \theta_t)$
Feedback Parser: $P(y | u, f, \hat{y}; \theta_f)$
Task Parser: $P(y | \hat{u}; \theta_t)$

Feedback Parser: $P(y | u, f, \hat{y}; \theta_f)$
Task Parser: $P(y \mid u; \theta_t)$

Feedback Parser: $P(y \mid u, f, \hat{y}; \theta_f)$

Joint Model

$$P(y \mid u, f, \hat{y}; \theta_t, \theta_f) = \frac{1}{Z} P(y \mid u; \theta_t) P(y \mid u, f, \hat{y}; \theta_f)$$

- **Logical Form**
- **Task utterance**
- **Original logical form**
- **Task utterance**
- **Feedback utterance**
- **Feedback utterance**
Parsing Accuracy on held-out data

![Graph showing parsing accuracy with different methods and the number of unlabeled questions.](image-url)
Inferring correct logical form from feedback of different “complexity”

The graph shows the average number of predicates in logical form plotted against the number of corrections expressed in feedback utterance. The x-axis represents the number of corrections, ranging from 1 to 3, and the y-axis represents the unlabeled accuracy. The graph includes four lines, each representing different models:

- **MH (full model)**
- **MH (no feedback + reject \( \hat{y} \))**
- **MH (no feedback)**
- **Self-training**

The models are compared for their accuracy and the average number of predicates in logical form.

The shaded area under the graph indicates the range of accuracy for each model. The lines show a decreasing trend with an increase in the number of corrections, indicating a decrease in unlabeled accuracy and an increase in the average number of predicates.
Knowledge-Base Construction

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for example his affiliation is CMU
Setting university affiliation field of oscar to cmu.

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Concept Learning
Grounding Concepts

Joint concept learning and semantic parsing from natural language explanations
Shashank Srivastava, Igor Labutov, Tom Mitchell
Teaching fuzzy concepts

“Important Email”
“Meeting Request”
“Job opportunity”
Teaching fuzzy concepts

“These emails usually closes with a name or title”

“Emails from a public domain are most likely not office requests”

“Talk announcements will usually be from a colleague”
Learning a classifier from Natural Language Descriptions

- “These emails usually close with a name or title”
- “Emails from a public domain are most likely not office requests”
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\[ y \in \{0, 1\} \]

\[ f(x) \]
Learning a classifier from Natural Language Descriptions

"These emails usually closes with a name or title"
"Emails from a public domain are most likely not office requests"
"Talk announcements will usually be from a colleague"

Small number of training examples

Learning Algorithm

\( f(x) \)

\( y \in \{0, 1\} \)
Learning a classifier from Natural Language Descriptions (under the hood)

1. Parse NL concept descriptions to feature functions

"Emails from my boss are usually important" → equals(email.sender, getContactEmail("boss"))
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“Emails from my boss are usually important”

equals( email.sender, getContactEmail(“boss”) )

2. Learn weights over those features

\[ y \]

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findWord(‘deadline’, body)

findSemanticCategory( cat:DATE_TIME, body)
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\[
\begin{align*}
\mathbf{y} & \leftarrow \begin{array}{c}
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& \quad \begin{array}{c}
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   \[ y \]

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Learning from Natural Language Descriptions

Macro Avg F1 over all concepts

Number of labeled examples

Traditional Bag of Words Classification
Results: Semantic Parsing

- Baseline (red): traditional supervised model trained on statements paired with logical forms

Predicted logical forms are often highly correlated

getPhraseMention( email, stringVal('meeting'))
getPhraseMention( body, stringVal('meeting'))
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This is probably my new favorite Google Home feature.

5:05 PM - Jan 25, 2017

68 people like this
32 people are talking about this
"OK Google, remember that I put my passport in the bottom drawer of my filing cabinet."

"OK Google, remember that my spare key to the truck is hidden outside."

"OK Google, remember that Alex has my wallet."

"OK Google, remember that my password is money."

"OK Google, where is my passport?"

"OK Google, what did I tell you about my wallet?"

"OK Google, what is my password?"
Software Engineering World

1. There is a new important mobile project
2. That project is in the implementation stage
3. Hiram is a tester on mobile project
4. Mobile project has moved to the deployment stage
5. Andrew created a new issue for mobile project: fails with apache stack
6. Andrew is no longer assigned to that project
7. That developer resolved the changelog needs to be added issue

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...
She and Amy are both TAs for this course.

John is now the department head.

Which PhD students are advised by the department head?
Simulated Worlds

Academic Faculty World
Software Project World
Student World
Shopping World
Meeting Scheduling World
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Are there any developers assigned to projects in the evaluation stage?
[Tawnya, Charlott, Hiram]

Who is the null pointer exception during parsing issue assigned to?
Hiram

Are there any issues that are resolved for experimental projects?
[saving data throws exception,
  wrong pos tag on consecutive words]
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[saving data throws exception, wrong pos tag on consecutive words]
Types of Questions

Set John’s email address to john.adams@gmail.com

Questions

What is John’s email?
Types of Questions

John and Mike just enrolled in my ML class

Andy just dropped this course

Questions

Who is taking the ML class?
Who is taking the ML class?

\[ \lambda x. \text{TakingClass}(x, \text{ML}) \]
Which students are enrolled in one of the classes I am teaching?

\[ \lambda x. \exists y. \text{TakingClass}(x, y) \land \text{CourseTaughtByMe}(y) \]
Which undergrads are enrolled in one of the classes I am teaching?

\[ \lambda x. \exists y. \text{TakingClass}(x, y) \wedge \text{CourseTaughtByMe}(y) \wedge \text{Undergraduate}(x) \]
\( \lambda x.\text{EmailAddress}(\text{John}, x) \)  
Single Entity / Single Relation

\( \lambda x.\text{TakingClass}(x, \text{ML}) \)  
Multi-Entity / Single Relation

\( \lambda x.\exists y.\text{TakingClass}(x, y) \wedge \text{CourseTaughtByMe}(y) \)  
Multi-Entity / Two Relations

\( \lambda x.\exists y.\text{TakingClass}(x, y) \wedge \text{CourseTaughtByMe}(y) \wedge \text{Undergraduate}(x) \)  
Multi-Entity / Three Relations
1. There is an associate professor named Andy
2. He returned from a sabbatical
3. This professor currently has funding
4. There is a masters level course called G301
5. That course is taught by him
6. That class is part of the mechanical engineering department
7. Roslyn is a student in this course
8. U203 is an undergraduate level course
9. Peggy and that student are TAs for this course

Question

“Who are the undergrads enrolled in one of the classes I am teaching?”
Supervised Learning
Supervised Learning
Supervised Learning

Learning from Labeled Examples

Supervised Learning
Supervised Learning

Learning from Labeled Examples

Active Learning
Supervised Learning

Learning from Labeled Examples

Labeling Features

Active Learning

Supervised Learning
Supervised Learning

Learning from Labeled Examples

Active Learning

Labeling Features

Active learning with features

Learning with constraints
Supervised Learning

Learning from Labeled Examples

Active Learning

Active learning with features

Learning with constraints

Labeling Features

Problem structure
Supervised Learning

- Learning from Labeled Examples
- Active Learning
- Active learning with features
- Learning with constraints
- Labeling Features

Language as interface

Problem structure
LÆR.AI

/ˈlær/ (imperative)
1. To Teach
2. To Learn
Conversational assistant for the workplace that can:

- Answer questions
- Solve problems
- Learn new things
Conversational assistant for the workplace that can:

- Answer questions
- Solve problems
- Learn new things

Join us in building the future of search - jobs@laer.ai

Igor.labutov@laer.ai
Bishan.yang@laer.ai