Lecture 1: Course Introduction

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Weakly-Supervised Semantic Processing

- **Semantic Processing:** Formal and computational modeling of natural language meaning.
- **Weakly Supervised:** Machine learning methods and problems that involve partially annotated data.
Weakly-Supervised Semantic Processing

- **Semantic Processing**: Formal and computational modeling of natural language meaning.
- **Weakly Supervised**: Machine learning methods and problems that involve partially annotated data.
Formal Modeling of Natural Language Meaning

“I reject the contention that an important theoretical difference exists between formal and natural languages.” Montague (1970)

- **object-language** A student in the room is also an instructor.
- **meta-language** $\exists x. \text{Students}(x) \land \text{Instructors}(x)$

![Diagram](image)
Formal Modeling of Natural Language Meaning

“I reject the contention that an important theoretical difference exists between formal and natural languages.” Montague (1970)

- **object-language** All instructors in the room are students.
- **meta-language** $\forall x. \text{Instructors}(x) \rightarrow \text{Students}(x)$

![Venn diagram showing the relationship between students and instructors with three students and one instructor labeled: s1, s2, s3, and kyle.]}
Formal Modeling of Natural Language Meaning

“I reject the contention that an important theoretical difference exists between formal and natural languages.” Montague (1970)

- **object-language** Student instructors of this class.
- **meta-language** \( \lambda x. \text{Instructors}(x) \land \text{Students}(x) \)

\[
U
\]

\[
\begin{array}{c}
\text{Students} \\
\text{Instructors}
\end{array}
\]

\[
\begin{array}{c}
s_2 \\
s_1 \\
s_3 \\
\text{kyle}
\end{array}
\]
Formal Modeling of Natural Language Meaning

Allows us to rigorously define the truth conditions of statements.

- **object-language** Student instructors of this class.
- **meta-language**  \( \lambda x. \text{Instructors}(x) \land \text{Students}(x) \)

\[(\lambda x. \text{Instructors}(x) \land \text{Students}(x))(\text{Kyle}) \rightarrow \text{True} \]
\[(\lambda x. \text{Instructors}(x) \land \text{Students}(x))(\text{Prof. Kuhn}) \rightarrow \text{False} \]
\[(\lambda x. \text{Instructors}(x) \land \text{Students}(x))(\text{Anna}) \rightarrow \text{False} \]
(setf Students '(kyle mary anna john)) ;; Students
(setf Instructors '(kyle))) ;; Instructors

((lambda (x)
    (and
      (member x Students)
      (member x Instructors)))
  'kyle)
;; => True
;; => True
Students = set(['Kyle', 'Mary', 'Anna', 'John'])
Instructors = set(['Kyle'])

Student_Instructors = lambda x :
    (x in Students) and (x in Instructors)

Student_Instructors('Kyle')
## => True
Student_Instructors('Mary')
## => False
Logic and Inference

Logic can be used for drawing new conclusions or reasoning with background knowledge.

- **object-language** All instructors in the room are students.
- **meta-language** \( \forall x. \text{Instructor}(x) \rightarrow \text{Students}(x) \)

\[ \Rightarrow \text{All tall instructors in the room are students.} \]
\[ \Rightarrow \text{No instructors here are professors.} \]
\[ \Rightarrow \text{Our instructor is a student.} \]
\[ \neg \text{Our instructor is a professor.} \]
\[ \neg \text{Our instructor is a famous professor.} \]
\[ ? \text{Our instructor is a brilliant student.} \]
Automated Reasoning: Cyc

Query: Who or what had a motive for the assassination of Hariri?
Answer: Syria
Because:
Detailed Justification:
- Syria had a motive for the assassination of Hariri.
  - If
    - some intelligent agent opposes some policy,
    - and some other intelligent agent VICTIM is an advocate of that policy,
    - and some other intelligent agent ADOPTER is responsible for according with the policy,
    - and it is adopted by ADOPTER in some ADOPT-TYPE,
    - and some ACT prevents VICTIM from playing the role "key participants" in ADOPT-TYPE,

then that intelligent agent has a motive for ACT.
- Since 2000, Lebanon has been responsible for according with Lebanese economic reform ¹
- Syria has opposed Lebanese economic reform since 2000. ¹
- Syria is an intelligent agent.
- The assassination of Hariri prevents Rafik Hariri from playing the role "key participants" in any adoption of economic reforms by Lebanon.
  - If something dies in some event, then that event prevents that thing from being a deliberate actor in any other event from that point on.
  - The assassination of Hariri occurred on February 14, 2005. ²
  - Rafik Hariri was killed during the assassination of Hariri. ²
  - Adoption of economic reforms by Lebanon is a type of event.
  - Rafik Hariri is an advocate of Lebanese economic reform.

Cyc thinks this might be true but can't prove it.

External Sources:
Computational Modeling: The full picture

- Standard processing pipeline

```
List samples that contain every major element

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

Lunar QA system (Woods (1973))
Computational Modeling: The full picture

- Standard processing pipeline

**Diagram:**

Input → Semantic Parsing → sem

List samples that contain every major element

Semantic Parsing

(FOR EVERY X /
  MAJORELT : T;
  (FOR EVERY Y /
    SAMPLE : (CONTAINS Y X);
    (PRINTOUT Y)))

Knowledge Representation

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

Lunar QA system (Woods (1973))
Semantic Parsing: Generating formal representations

- **Data-driven**: Given data, learn a function that can map any given input (x) to a meaning representation (z).
- What kind of data do we learn from?

\[
\text{What state has the largest population?}
\]

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

Geoquery Corpus (Zelle and Mooney (1996))
Semantic Parsing: Generating formal representations

- **Data-driven:** Given data, **learn** a function that can map any given input \((x)\) to a meaning representation \((z)\).
- **What kind of data do we learn from?**

\[
\text{Input} \quad x \quad \text{What state has the largest population?}
\]

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

\[
\text{World} \quad [z] \quad \text{California}
\]

**Supervision:** Dataset \(D\)

- **Logical Forms:** \(D = \{(x_i, z_i)\}_{i=1}^N\)
- **Task:** learn (latent) \(y\), translation
- Zettlemoyer and Collins (2009)
- Kwiatkowski et al. (2010)

- **Denotations:** \(D = \{(x_j, [z_j])\}_{j=1}^N\)
- **Task:** learn \(z, y\), program synthesis
- Liang et al. (2013)
- Berant et al. (2013)

Geoquery Corpus (Zelle and Mooney (1996))
Learning with Weak Supervision

- **Weak-Supervision**: Not all linguistic structure is annotated, learning is autonomous, learning cues are underspecified.

- **Techniques**: Statistical Machine Translation, Parsing, Structured Classification, Program Induction.
Applications
Applications: Facebook graph search

The parse tree, semantic and entity ID used in the above example are for illustration only; they do not represent real information used in Graph Search Beta.
Applications: Smart Homes (KITT.ai)
Applications: Open-domain Question-Answering (KITT.ai)

<table>
<thead>
<tr>
<th>Web Search Intelligence</th>
<th>Knowledge Base Intelligence</th>
<th>Intent-aware Intelligence</th>
</tr>
</thead>
<tbody>
<tr>
<td>what to see and do in Malta?</td>
<td>/travel/travel_destination/tourist_attractions (0.57)</td>
<td>Answer</td>
</tr>
<tr>
<td>Gozo 360° Multivision Show</td>
<td>Casa Rocca Piccola</td>
<td></td>
</tr>
<tr>
<td>Megalithic Temples of Malta</td>
<td>Manoel Theatre</td>
<td></td>
</tr>
<tr>
<td>The Armoury and the Maritime Museum</td>
<td>Fort Rinella</td>
<td></td>
</tr>
<tr>
<td>St. Paul's Catacombs</td>
<td>National Museum of Fine Arts, Malta</td>
<td></td>
</tr>
<tr>
<td>Dingli Cliffs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Organizational Matters
Goals

What this course is not:

▶ Not a semantics course.
▶ Not a pure machine learning or mathematics course.
▶ Not a programming course.

But:

▶ Will involve knowledge of linguistic semantics.
▶ Assumes machine learning and math knowledge.
▶ Requires basic programming and algorithmic knowledge.
▶ An ability to tie together all these different components.
Formal Requirements

▶ Weakly required and supplementary readings.
▶ Writing summaries for a subset of required readings.
▶ Give a presentation on a research paper.
▶ An in-depth term paper about a specific topic.


