Carnegie Mellon University
School of Computer Science

Learning to Mine Aligned Code and Natural Language Pairs from Stack Overflow

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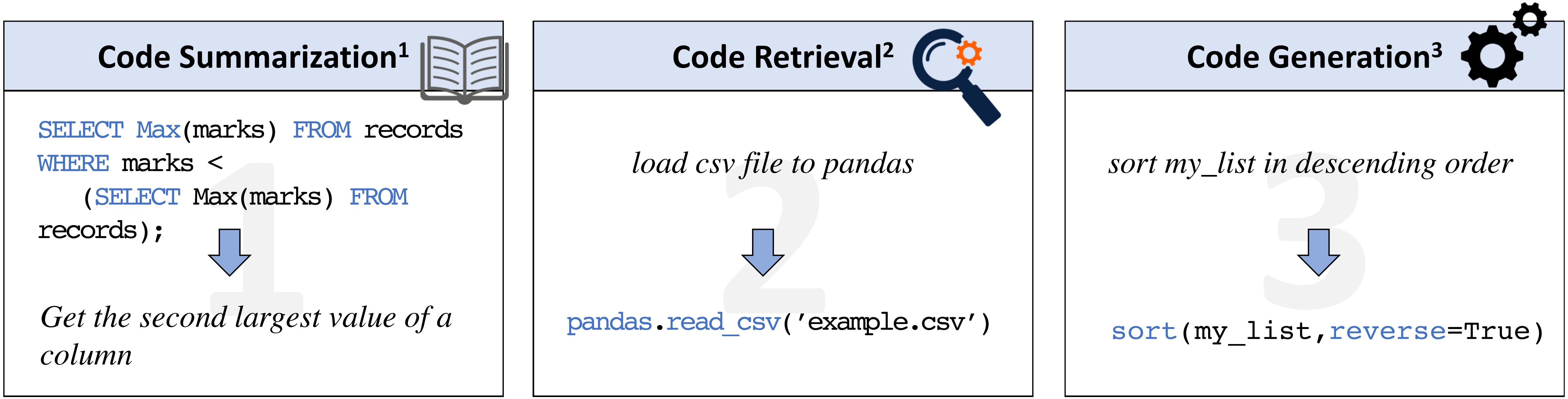
Language Technologies Institute NEULAB isr institute for SOFTWARE RESEARCH STRUDEL SOCIO-TECHNICAL RESEARCH USING DATA EXCAVATION LAB

Background

- When Natural Language Processing (NLP) meets Software Engineering…



Code Summarization[1]

```
SELECT Max(marks) FROM records
WHERE marks <
   (SELECT Max(marks) FROM
records);
```

Get the second largest value of a column

Code Retrieval[2]

load csv file to pandas

```
pandas.read_csv('example.csv')
```

Code Generation[3]

sort my_list in descending order

```
sort(my_list,reverse=True)
```

- These tasks, mostly powered by **data-driven models**, heavily rely on parallel training (and evaluation) corpora of source code and natural language in **high quality** and **large amount**

[1] Iyer et al., ACL '16; Allamanis et al., ICML '16

[2] Zhang et al., FSE '16; Gu et al., ICSE '18

[3] Raghothaman et al., ICSE '16; Yin et al., ACL '17, ACL '18

Collecting Intent/Snippet Pairs from SO

- Such data-driven models require parallel data of natural language **intents** and source code **snippets** and in high volume and high quality
  - **Intent** natural language description of what a programmer would like to do
  - **Snippet** a piece of source code that implements the intent

Intent get the maximum value of a column

Snippet SELECT MAX(marks) from records

Intent read a csv file into pandas

Snippet pandas.read_csv('example.csv')

Intent sort my_list in descending order

Snippet sort(my_list, reverse=True)

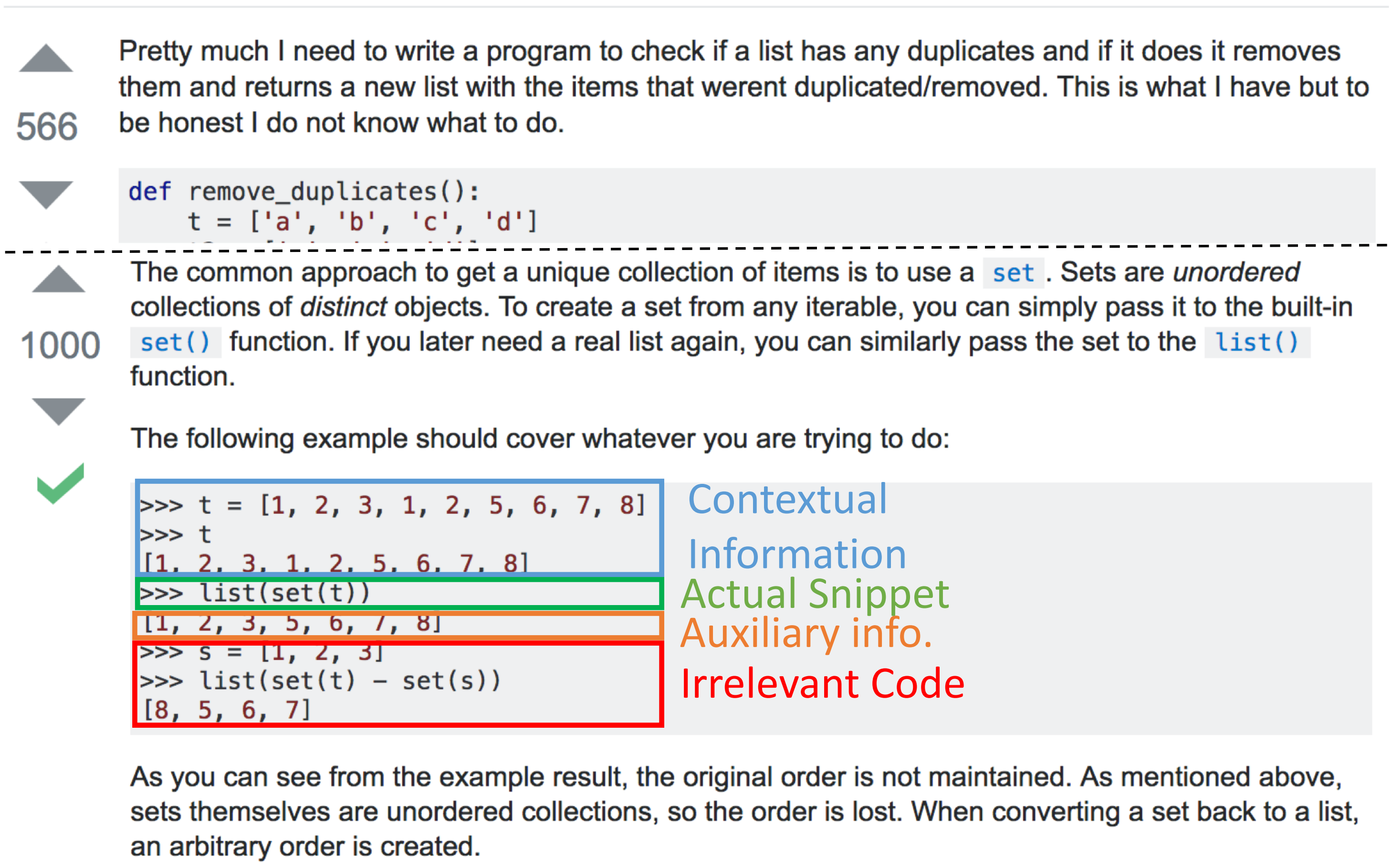
⋮

Can we collect such data from stackoverflow ?

Heuristic approaches [Wong et al., 2013; Iyer et al., 2016]?
- Select **all** code blocks
- Select **all** code blocks in **accepted answers**

Are these Heuristic Approaches Good Enough?

Intent Removing duplicates in lists



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Pretty much I need to write a program to check if a list has any duplicates and if it does it removes them and returns a new list with the items that werent duplicated/removed. This is what I have but to be honest I do not know what to do.

```
def remove_duplicates():
    t = ['a', 'b', 'c', 'd']
```

1000

The common approach to get a unique collection of items is to use a `set`. Sets are *unordered* collections of *distinct* objects. To create a set from any iterable, you can simply pass it to the built-in `set()` function. If you later need a real list again, you can similarly pass the set to the `list()` function.

The following example should cover whatever you are trying to do:

```
>>> t = [1, 2, 3, 1, 2, 5, 6, 7, 8]
>>> t
[1, 2, 3, 1, 2, 5, 6, 7, 8]
>>> list(set(t))
[1, 2, 3, 5, 6, 7, 8]
>>> s = [1, 2, 3]
>>> list(set(t) - set(s))
[8, 5, 6, 7]
```

Contextual Information

Actual Snippet

Auxiliary info.

Irrelevant Code

As you can see from the example result, the original order is not maintained. As mentioned above, sets themselves are unordered collections, so the order is lost. When converting a set back to a list, an arbitrary order is created.

However, acquiring such data from Stack Overflow posts may not be that straight-forward ....

1. Contextual Information package import statements, variable definition
2. Auxiliary information return values, example outputs
3. Irrelevant Code
4. Counter-examples

Heuristic approaches? ☹

- Select **all** code blocks
- Select **all** code blocks in **accepted answers**

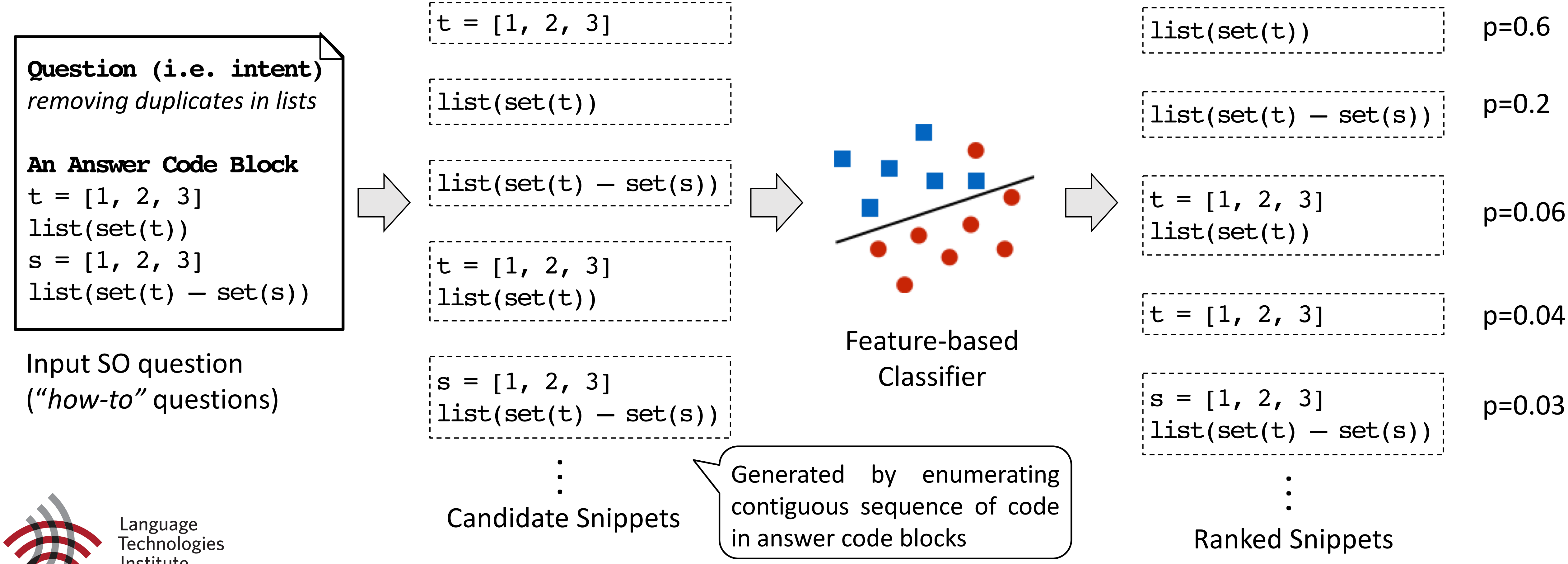
Our Solution

- **CONALA**, a system to collect parallel data of source **co**de snippet and **na**tural **la**nguage intents from Stack Overflow
  - *data-driven:* learn patterns of “good” and “bad” intent/snippet pairs from data (using neural networks)
  - *language-agnostic:* applicable to different programming languages (e.g., Python and Java)
  - *Scalable:* capable of applying to full-scale Stack Overflow data (collected ~600K intent/snippet pairs for Python)

Project Website: *conala-corpus.github.io*

System Architecture

- Enumerate all possible candidate intent/snippet pairs in a Stack Overflow page
- Learn a classifier to rank each candidate intent/snippet pair



Question (i.e. intent)
removing duplicates in lists

An Answer Code Block

```
t = [1, 2, 3]
list(set(t))
s = [1, 2, 3]
list(set(t) — set(s))
```

Input SO question
(“*how-to*” questions)

```
t = [1, 2, 3]
```

```
list(set(t))
```

```
list(set(t) — set(s))
```

```
t = [1, 2, 3]
list(set(t))
```

```
s = [1, 2, 3]
list(set(t) — set(s))
```

⋮

Candidate Snippets

Generated by enumerating contiguous sequence of code in answer code blocks

Feature-based Classifier

```
list(set(t))
```

p=0.6

```
list(set(t) — set(s))
```

p=0.2

```
t = [1, 2, 3]
list(set(t))
```

p=0.06

```
t = [1, 2, 3]
```

p=0.04

```
s = [1, 2, 3]
list(set(t) — set(s))
```

p=0.03

⋮

Ranked Snippets

Features

- **Purpose** measure the probability (plausibility) of each intent/snippet candidate
- **Two types of features** language independent, highly-indicative

$$\mathrm{P}\left\{ \mathit{correct} \,\middle|\, \begin{array}{l} \textbf{Intent} \;\; = \textit{removing duplicates in lists} \\ \textbf{Snippet} = \texttt{list(set(t))} \end{array} \right\}$$

Structural Features

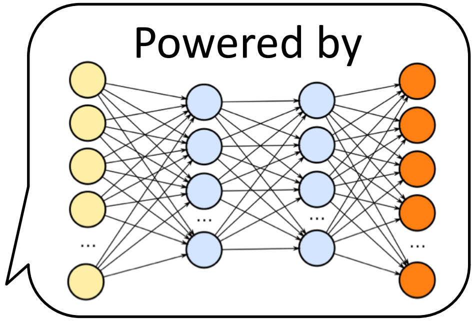
Inspired by heuristic approaches, does **not** use intent information

Code Shape features: FullBlock ContainsImport StartsWithAssignment ...

Answer quality features: IsAcceptedAnswer PostRank ...

Correspondence Features

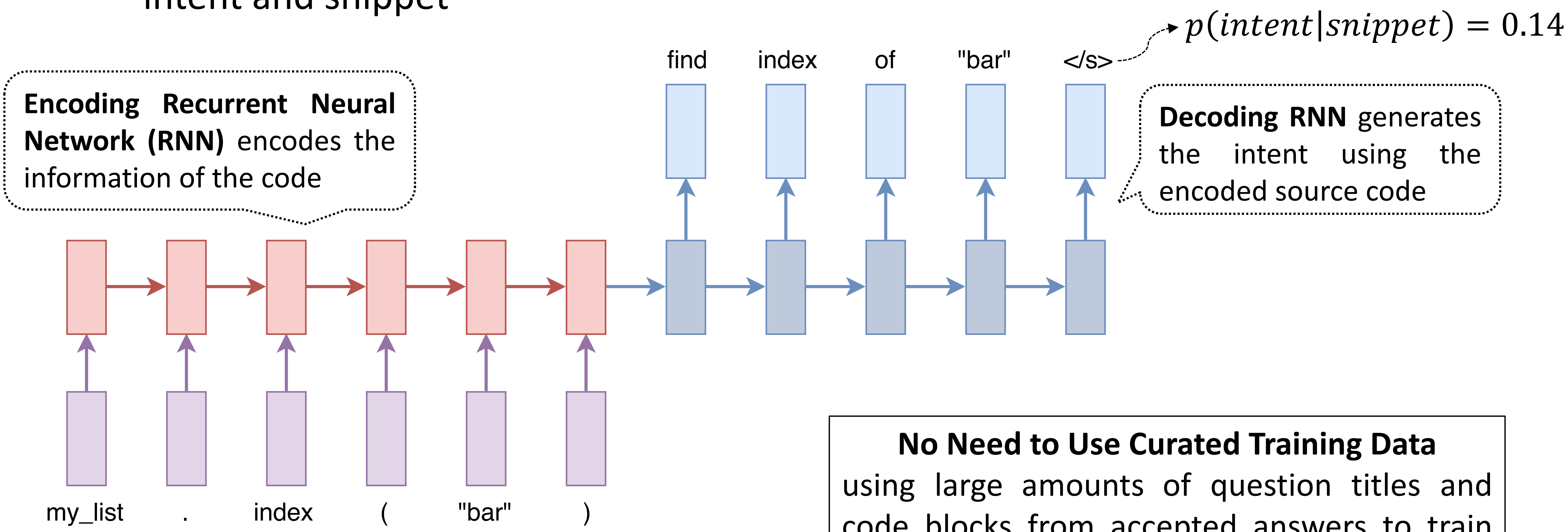
★ Use state-of-the-art **neural networks** to estimate the (semantic) correspondence between and intent and snippet



$$\mathrm{Score}\{\, \textit{removing duplicates in lists} \Leftrightarrow \texttt{list(set(t))} \}$$

Neural Correspondence Model between Code and Intent

- **Neural sequence-to-sequence networks** for translation probability between intent and snippet



Encoding Recurrent Neural Network (RNN) encodes the information of the code

Decoding RNN generates the intent using the encoded source code

Neural Net for Snippet ⟼ Intent

No Need to Use Curated Training Data using large amounts of question titles and code blocks from accepted answers to train the model 😀

What Left to be Learned?

- **Structural Features** shown by existing works as indicative
- **Correspondence Features** already pre-trained on massive, readily available data on Stack Overflow (questions and code blocks)!
- We just need **small amount** of manually annotated intent/snippet pairs to tune the ~20 weights in the classifier 😀

Gold Annotations

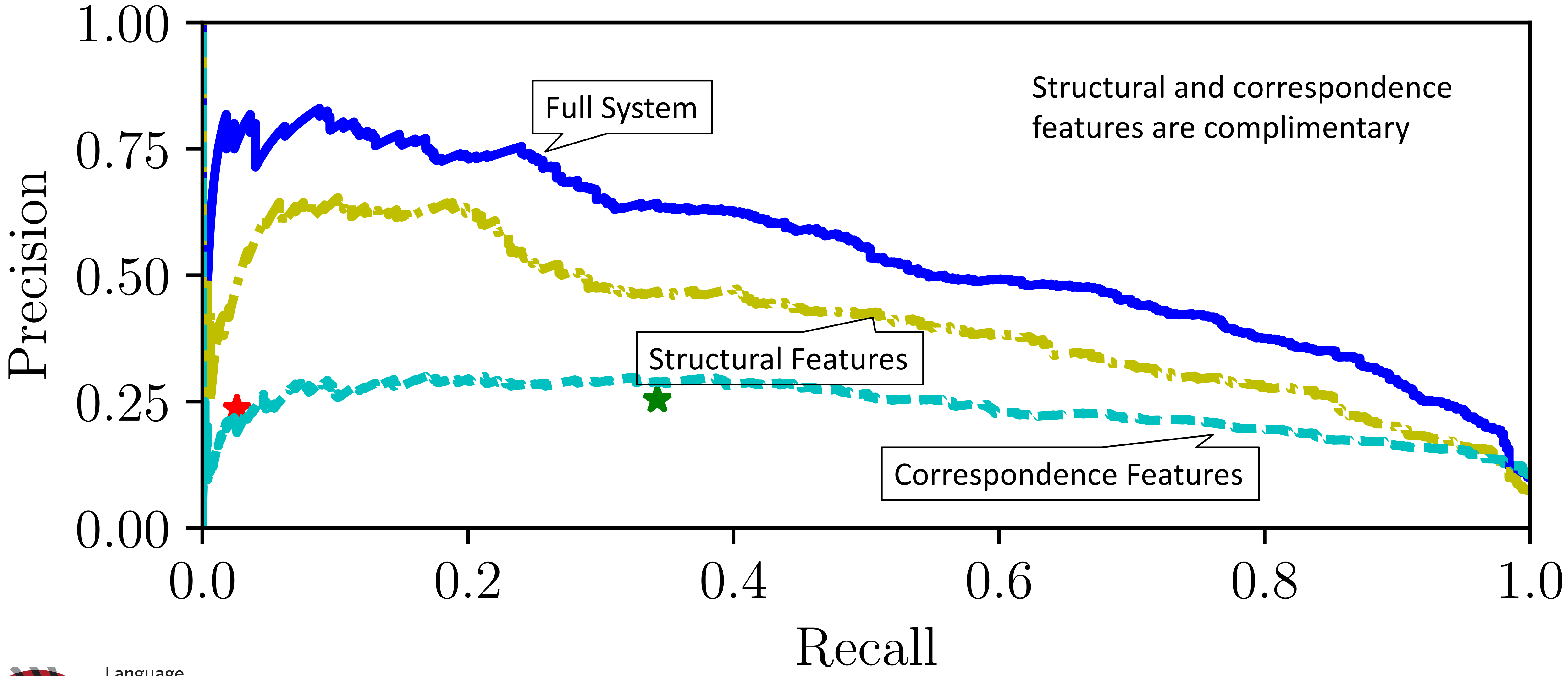
python

527 examples
142 questions

Java

330 examples
100 questions

Cross-Validation Results



Full System

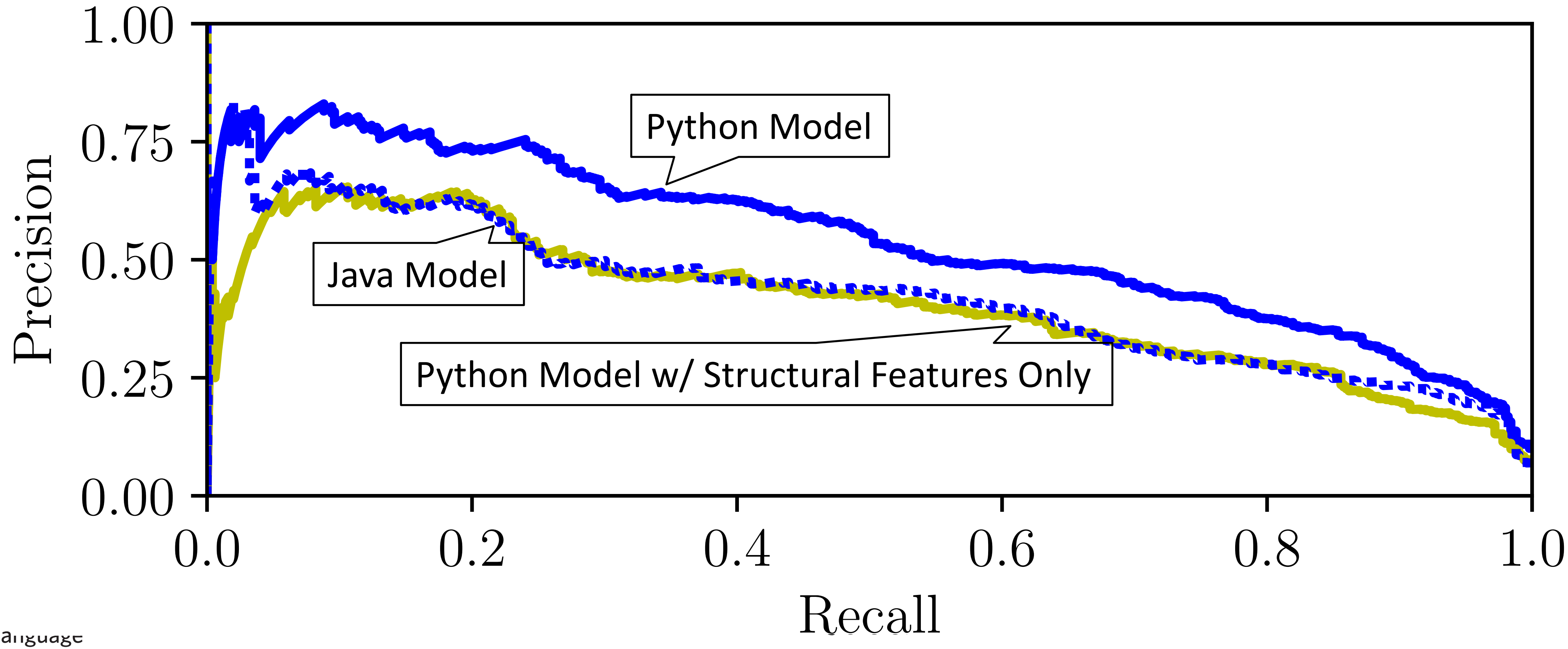
Structural Features

Correspondence Features

Structural and correspondence features are complimentary

Must we Annotate each Language?

- The classifier requires small set of gold-standard annotations to train on
- When apply our system to a new language, can we use the existing model trained on another (old) language?



Apply the model trained on Java data to mine Python intent/snippet data

Dataset Collection

- Apply the system to Python questions on Stack Overflow, collecting ~600K pairs
- ~2500 (and counting) high-quality annotated intent/code snippet pairs
- **Rewritten Intents** manually annotated, revised intents to reflect the full meaning of the code
  - Add free variable names, arguments to the intent
  - Useful for fine-grained language to code tasks like code generation

Crowdsourced

Intent	copying one file's contents to another
Rewritten Intent	copy the content of file 'file.txt' to file 'file2.txt'
Code Snippet	`shutil.copy('file.txt','file2.txt')`

An example from the annotation dataset

Examples

- Examples covers a wide variety of use cases
  - Built-in data type operation
  - I/O and string operation
  - Third-party library usage
- Examples are highly expressive and compositional!
  - Pose challenges to existing code/NL models

Intent dict how to create key or append an element to key

Rewritten Intent Create a key \`key\` if it does not exist in dict \`dic\` and append element \`value\` to value

Code Snippet `dic.setdefault(key, []).append(value)`

Intent How do I check if all elements in a list are the same

Rewritten Intent check if all elements in list \`mylist\` are the same

Code Snippet `len(set(mylist)) == 1`

Intent Iterate through words of a file in Python

Rewritten Intent check if all elements in list \`mylist\` are the same

Code Snippet `words = open('myfile').read().split()`

Intent Delete Column in Pandas based on Condition

Rewritten Intent delete all columns in DataFrame \`df\` that do not hold a non-zero value in its records

Code Snippet `df.loc[:, ((df != 0).any(axis=0))]`

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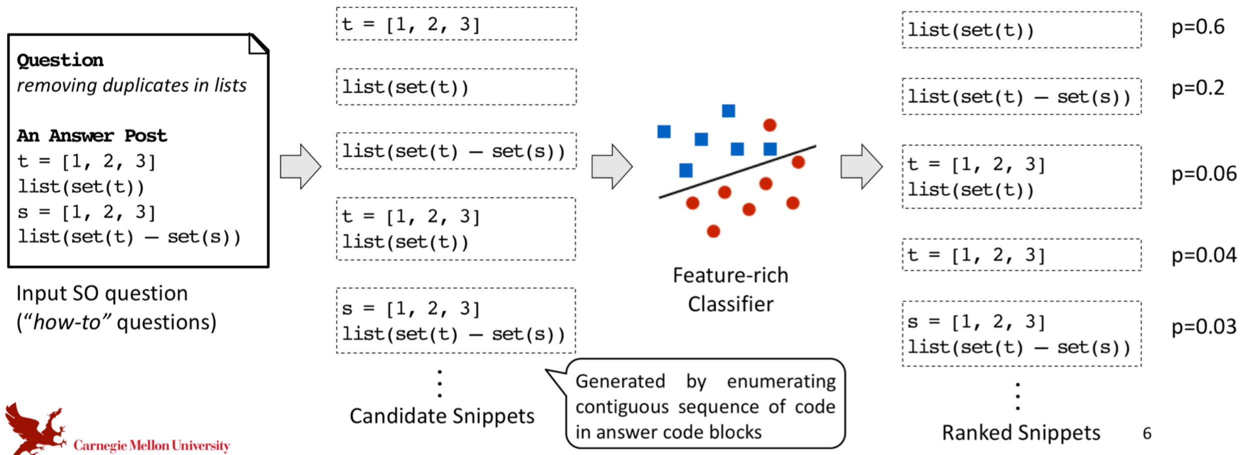

Question
removing duplicates in lists

An Answer Post

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t = [1, 2, 3]
list(set(t))
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```

Input SO question
(*"how-to"* questions)

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⋮

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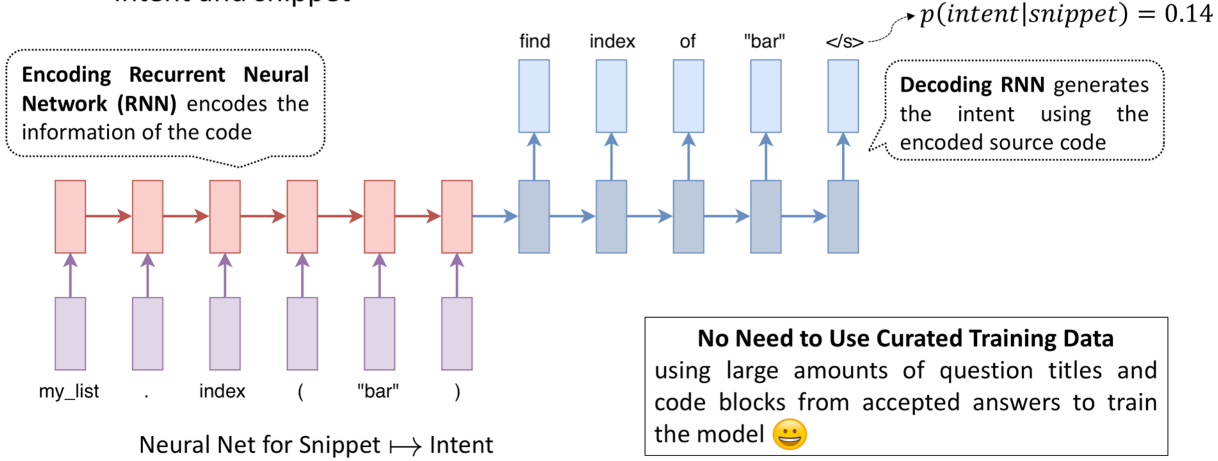

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Check our Dataset at

conala-corpus.github.io

Annotate Gold-standard Dataset

- Our system needs a *small* set of gold-standard intent/snippet data to learn the parameters of the classifier powered by high-level features
- Annotate top-ranked *how-to* questions on Stack Overflow for each language

Gold Annotations

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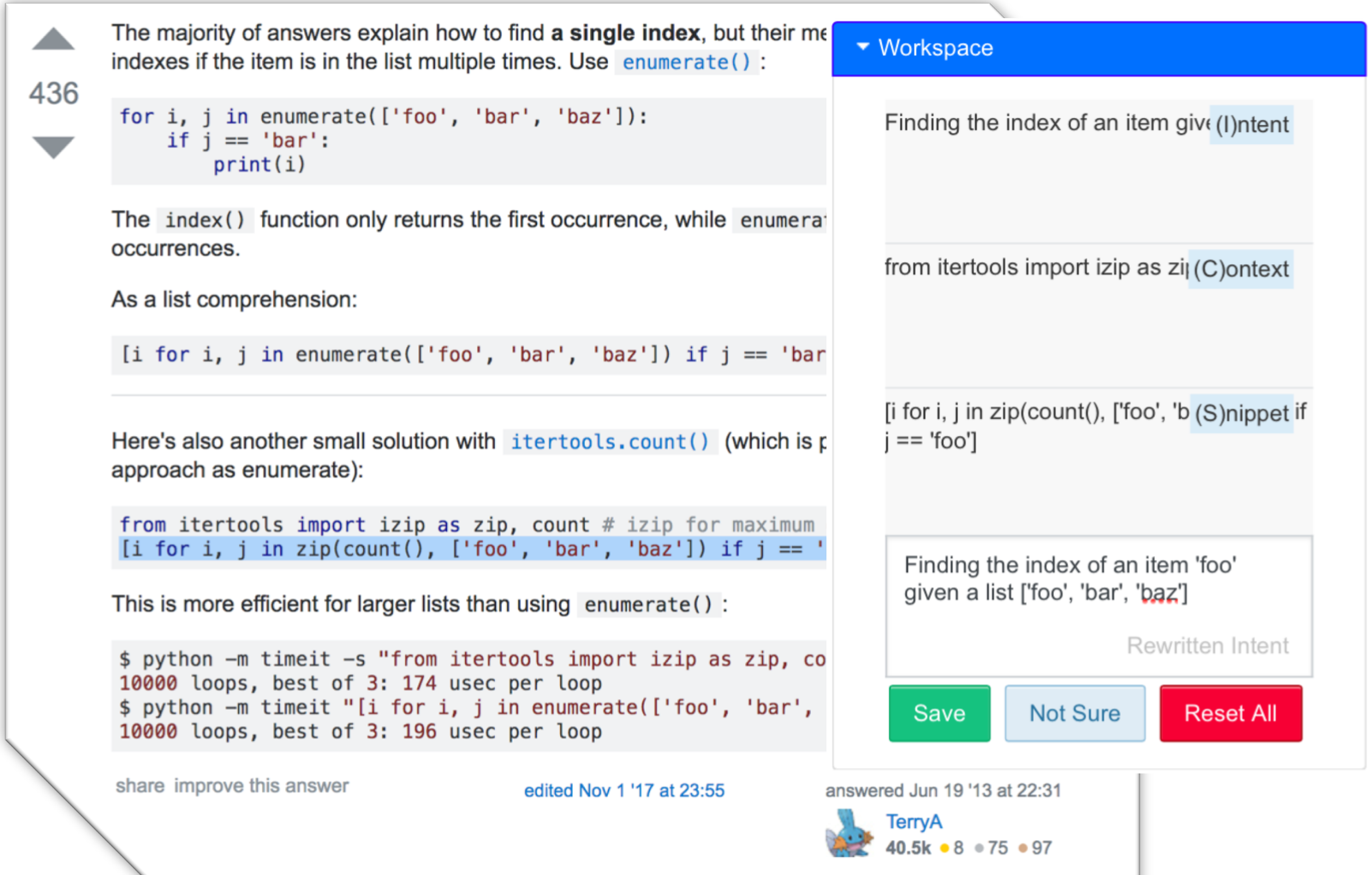
Java	330 examples 100 questions



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The majority of answers explain how to find **a single index**, but their me indexes if the item is in the list multiple times. Use `enumerate()` :

```
for i, j in enumerate(['foo', 'bar', 'baz']):
    if j == 'bar':
        print(i)
```

The `index()` function only returns the first occurrence, while `enumera` occurrences.

As a list comprehension:

```
[i for i, j in enumerate(['foo', 'bar', 'baz']) if j == 'bar
```

Here's also another small solution with `itertools.count()` (which is p approach as enumerate):

```
from itertools import izip as zip, count # izip for maximum
[i for i, j in zip(count(), ['foo', 'bar', 'baz']) if j == '
```

This is more efficient for larger lists than using `enumerate()` :

```
$ python -m timeit -s "from itertools import izip as zip, co
10000 loops, best of 3: 174 usec per loop
$ python -m timeit "[i for i, j in enumerate(['foo', 'bar',
10000 loops, best of 3: 196 usec per loop
```

share improve this answer

edited Nov 1 '17 at 23:55

answered Jun 19 '13 at 22:31

TerryA

40.5k ●8 ●75 ●97

Workspace

(I)ntent: Finding the index of an item give

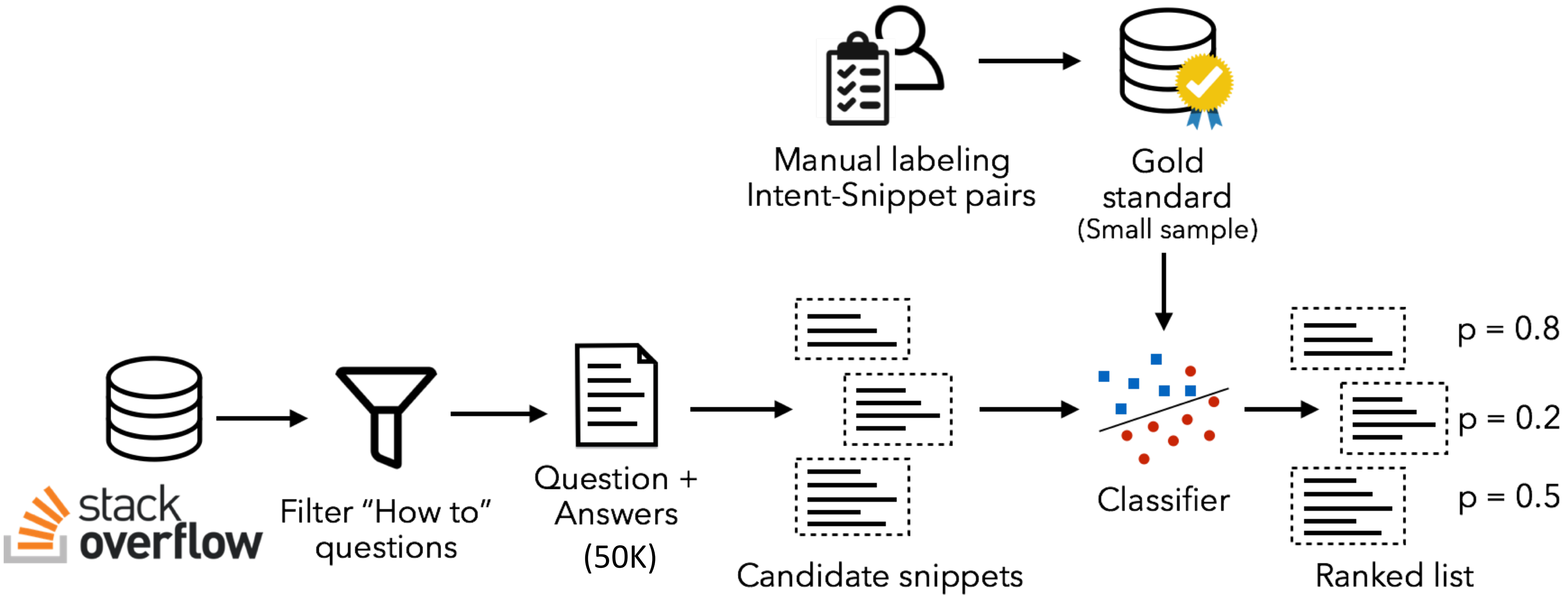
(C)ontext: from itertools import izip as zi

(S)nippet: [i for i, j in zip(count(), ['foo', 'b if j == 'foo']

Rewritten Intent: Finding the index of an item 'foo' given a list ['foo', 'bar', 'baz']

System Deployment

- We deploy our system on the top-50K Python-tagged questions on Stack Overflow, and collected ~600K ranked intent/code-snippet pairs


Manual labeling
Intent-Snippet pairs
Gold
standard
(Small sample)
stack
overflow
Filter "How to"
questions
Question +
Answers
(50K)
Candidate snippets
Classifier
p = 0.8
p = 0.2
p = 0.5
Ranked list