StaQC: A Systematically Mined Question-Code Dataset from Stack Overflow

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The Web Conference 2018, May 25th

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THE OHIO STATE UNIVERSITY

UNIVERSITY of WASHINGTON

FUJITSU

shaping tomorrow with you

Mapping between natural language and programming language

Question

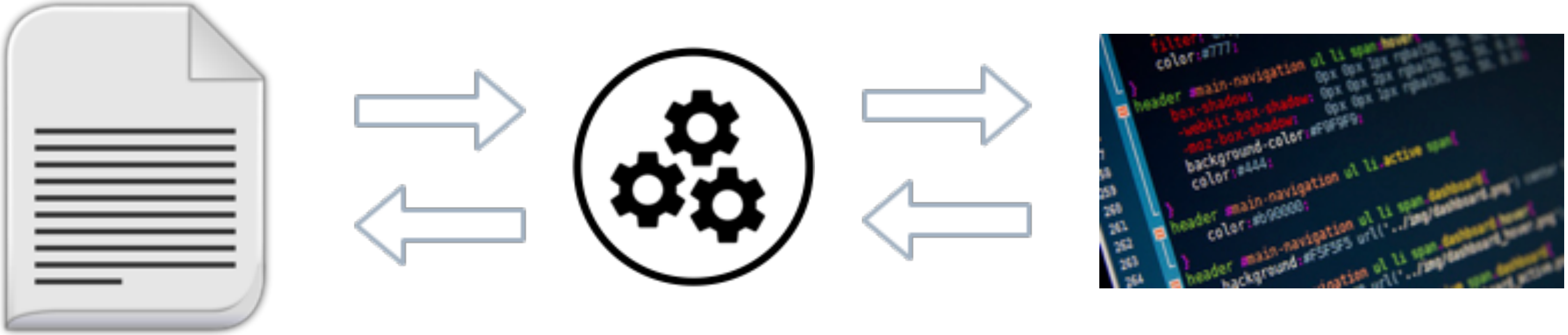
"how to clone or copy a python list?"

↔

Code

```
“new_list =
copy.copy(old_list)”
```

e.g., automated code search/annotation/generation.



Challenges

- Lack of large-scale datasets for model development.
  i.e., pairs of <natural language question, code snippet>

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  i.e., pairs of <natural language question, code snippet>

- And datasets are important:

IMAGENET
SQuAD
The Stanford Question Answering Dataset
Microsoft COCO
Common Objects in Context

This work: StaQC

StaQC: the largest dataset to date of ~148K Python and ~120K SQL “how-to-do-it”* Question-Code pairs!

Example:

Question

“how to clone or copy a python list?”

↔

Code

```
“new_list =
copy.copy(old_list)”
```

“how-to-do-it” questions [Souza et al., 2014; Defim et al., 2016]: *the questioner provides a scenario and asks how to implement it.*

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Continuously growing in *size* and *diversity*

stackoverflow

Diversity of StaQC

- Containing multiple code solutions to the same question.
  - Question “How to limit a number to be within a specified range?”
  - **4** code solutions in StaQC:

```
def clamp(n, minn, maxn):
  return max(min(maxn, n),
minn)
```

(1)

```
clamp = lambda n, minn,
maxn: max(min(maxn, n),
minn)
```

(2)

```
def clamp(n, minn, maxn):
  if n < minn:
    return minn
  elif n > maxn:
    return maxn
  else:
    return n
```

(3)

```
n = minn if n < minn else maxn if n > maxn else n
```

(4)

Diversity of StaQC

- Containing different questions asking for semantically similar code solutions.

Question A: "*How to find a gap in range in SQL*"

```
SELECT id + 1
FROM test mo
WHERE NOT EXISTS
(
  SELECT NULL
  FROM test mi
  WHERE mi.id = mo.id + 1
  ) and mo.id> 100
ORDER BY
        id
LIMIT 1
```

Question B: "*How do I find a “gap” in running counter with SQL?* "

```
SELECT id + 1
FROM mytable mo
WHERE NOT EXISTS
(
  SELECT NULL
  FROM mytable mi
  WHERE mi.id = mo.id + 1
  )
ORDER BY
        id
LIMIT 1
```

Diversity of StaQC

- Containing different questions asking for semantically sim

Critical for Model Robustness:

1. Natural language variation.
2. Different implementations to do the same thing in programming language.

```
   ) and mo.id> 100
ORDER BY
        id
LIMIT 1
```

```
   )
ORDER BY
        id
LIMIT 1
```

This work: StaQC

StaQC: the largest dataset to date of ~148K Python and ~120K SQL "how-to-do-it"* Question-Code pairs!

Continuously growing in *size* and *diversity*

stackoverflow

A better source for constructing models mapping between NL and PL

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Continuously growing in *size* and *diversity*

stackoverflow

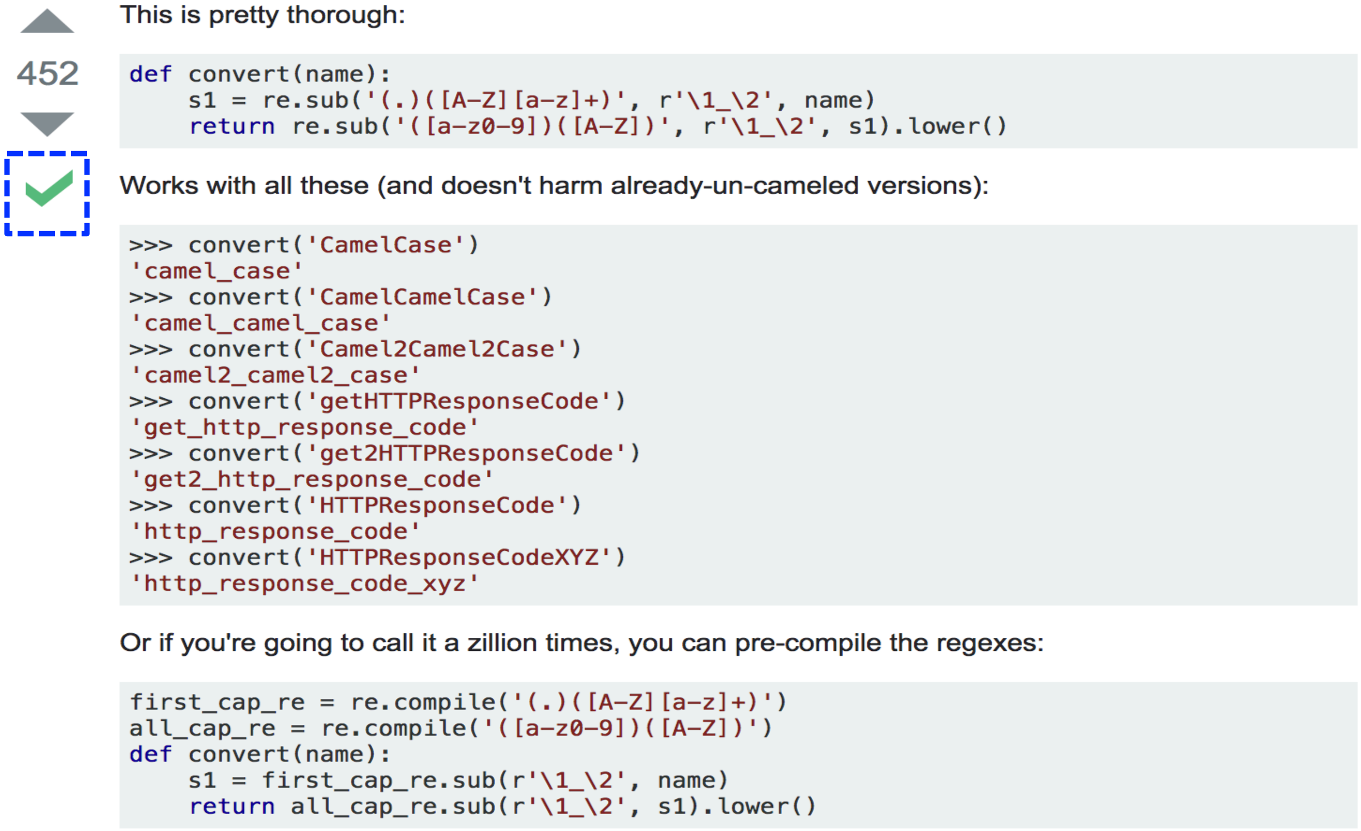
A better source for constructing models mapping between NL and PL

Example

stackoverflow

Question Elegant Python function to convert CamelCase to snake_case?

Accepted answer post



This is pretty thorough:

```
def convert(name):
    s1 = re.sub('(.)([A-Z][a-z]+)', r'\1_\2', name)
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

Works with all these (and doesn't harm already-un-cameled versions):

```
>>> convert('CamelCase')
'camel_case'
>>> convert('CamelCamelCase')
'camel_camel_case'
>>> convert('Camel2Camel2Case')
'camel2_camel2_case'
>>> convert('getHTTPResponseCode')
'get_http_response_code'
>>> convert('get2HTTPResponseCode')
'get2_http_response_code'
>>> convert('HTTPResponseCode')
'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
```

Or if you're going to call it a zillion times, you can pre-compile the regexes:

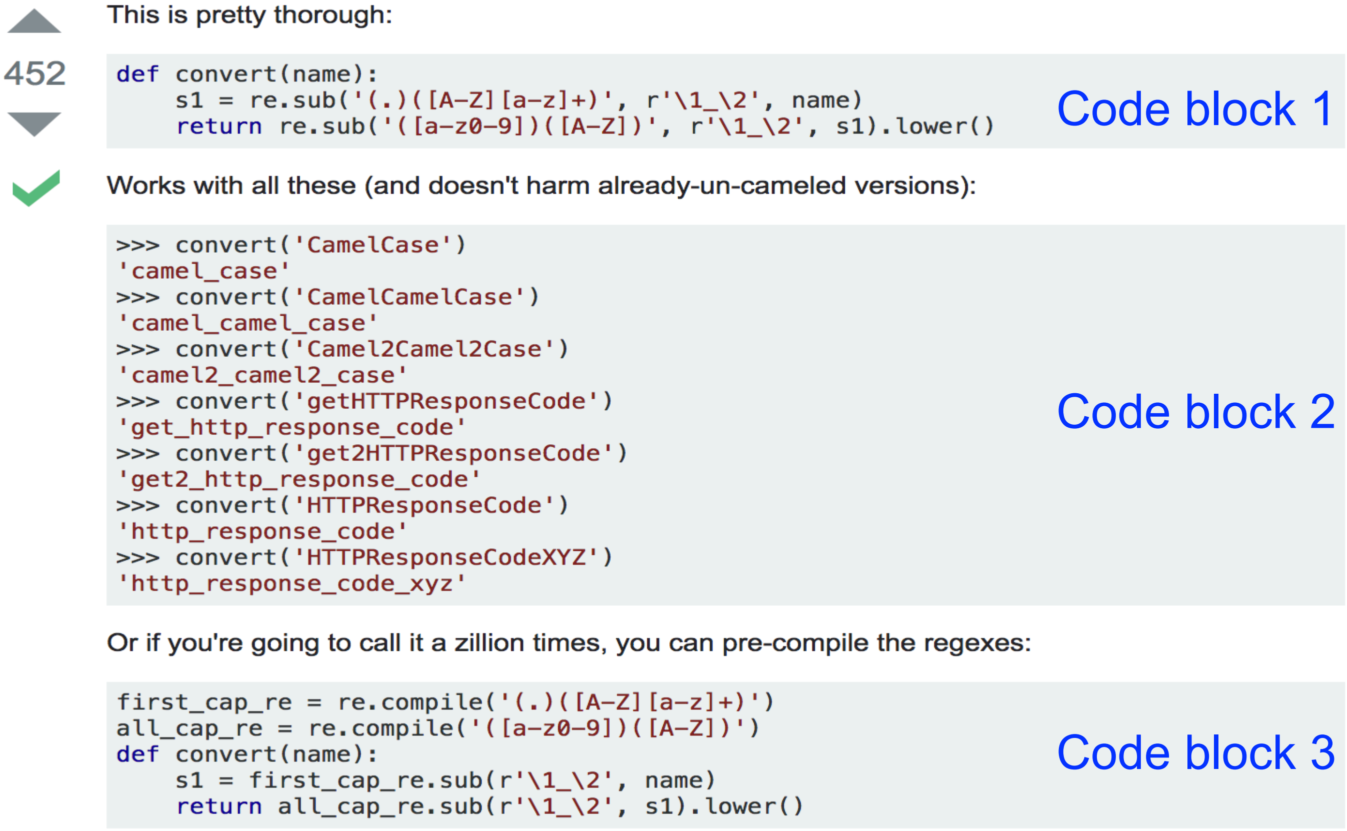
```
first_cap_re = re.compile('(.)([A-Z][a-z]+)')
all_cap_re = re.compile('([a-z0-9])([A-Z])')
def convert(name):
    s1 = first_cap_re.sub(r'\1_\2', name)
    return all_cap_re.sub(r'\1_\2', s1).lower()
```

Example

stackoverflow

Question Elegant Python function to convert CamelCase to snake_case?

Accepted answer post



452

This is pretty thorough:

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def convert(name):
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```

Code block 1

Works with all these (and doesn't harm already-un-cameled versions):

```
>>> convert('CamelCase')
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>>> convert('HTTPResponseCode')
'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
```

Code block 2

Or if you're going to call it a zillion times, you can pre-compile the regexes:

```
first_cap_re = re.compile('(.)([A-Z][a-z]+)')
all_cap_re = re.compile('([a-z0-9])([A-Z])')
def convert(name):
    s1 = first_cap_re.sub(r'\1_\2', name)
    return all_cap_re.sub(r'\1_\2', s1).lower()
```

Code block 3

Example

Question Elegant Python function to convert CamelCase to snake_case?

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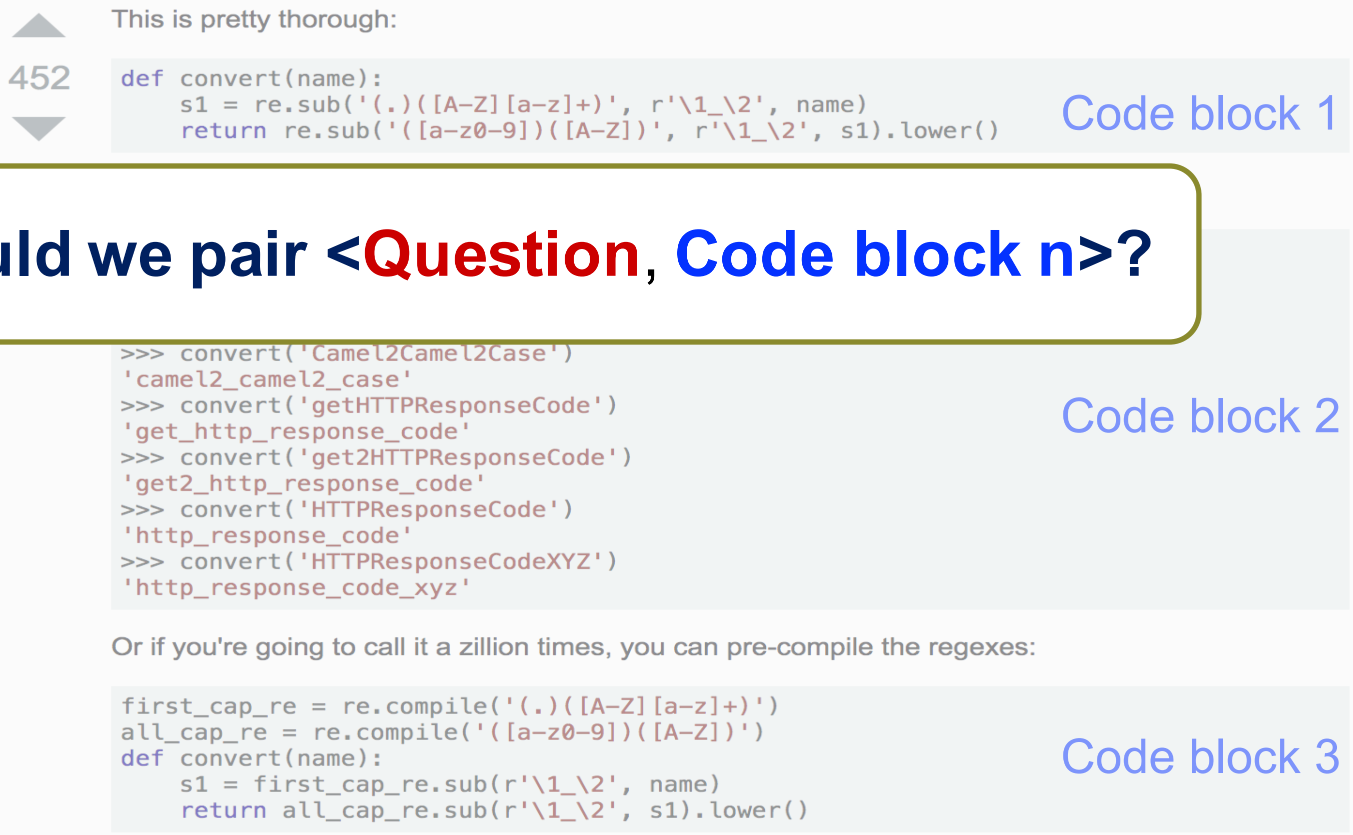

452

This is pretty thorough:

```
def convert(name):
    s1 = re.sub('(.)([A-Z][a-z]+)', r'\1_\2', name)
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

Code block 1

Should we pair <Question, Code block n>?

```
>>> convert('Camel2Camel2Case')
'camel2_camel2_case'
>>> convert('getHTTPResponseCode')
'get_http_response_code'
>>> convert('get2HTTPResponseCode')
'get2_http_response_code'
>>> convert('HTTPResponseCode')
'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
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```

Code block 2

Or if you're going to call it a zillion times, you can pre-compile the regexes:

```
first_cap_re = re.compile('(.)([A-Z][a-z]+)')
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Code block 3

Example

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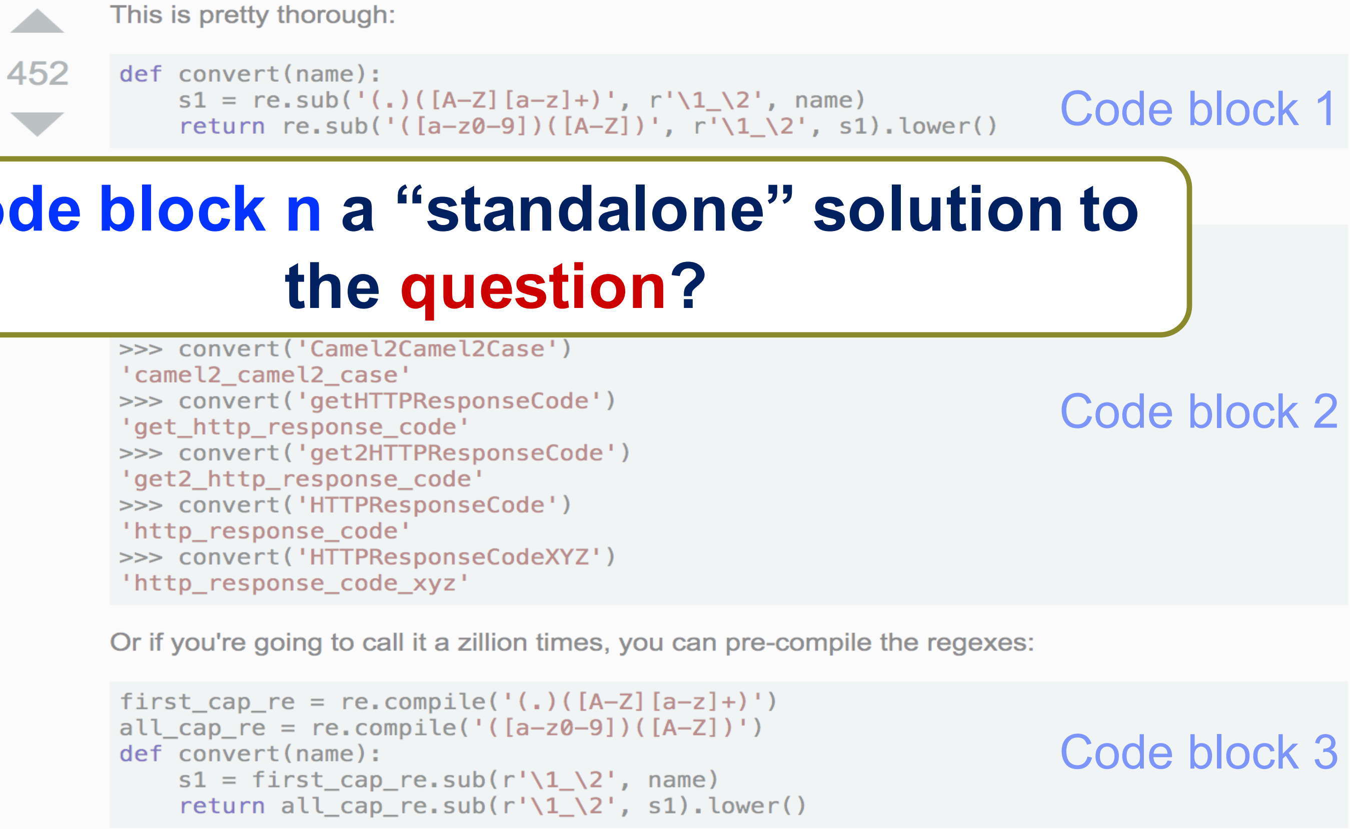

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def convert(name):
    s1 = re.sub('(.)([A-Z][a-z]+)', r'\1_\2', name)
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

Code block 1

Is Code block n a “standalone” solution to the question?

```
>>> convert('Camel2Camel2Case')
'camel2_camel2_case'
>>> convert('getHTTPResponseCode')
'get_http_response_code'
>>> convert('get2HTTPResponseCode')
'get2_http_response_code'
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'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
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```

Code block 2

Or if you're going to call it a zillion times, you can pre-compile the regexes:

```
first_cap_re = re.compile('(.)([A-Z][a-z]+)')
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def convert(name):
    s1 = first_cap_re.sub(r'\1_\2', name)
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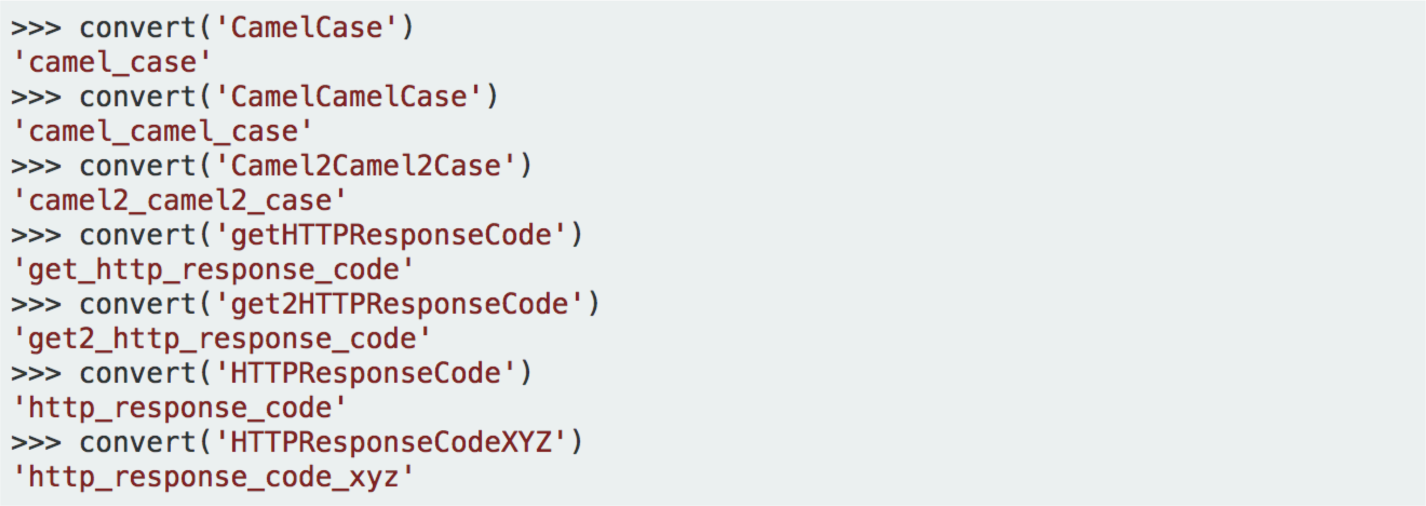
```

Code block 3

“Standalone” code solution

By looking at Code block n,



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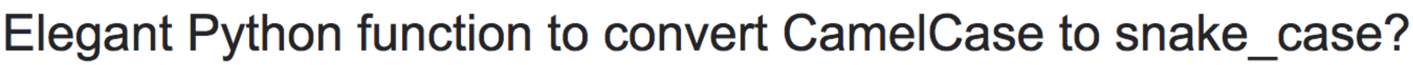
```

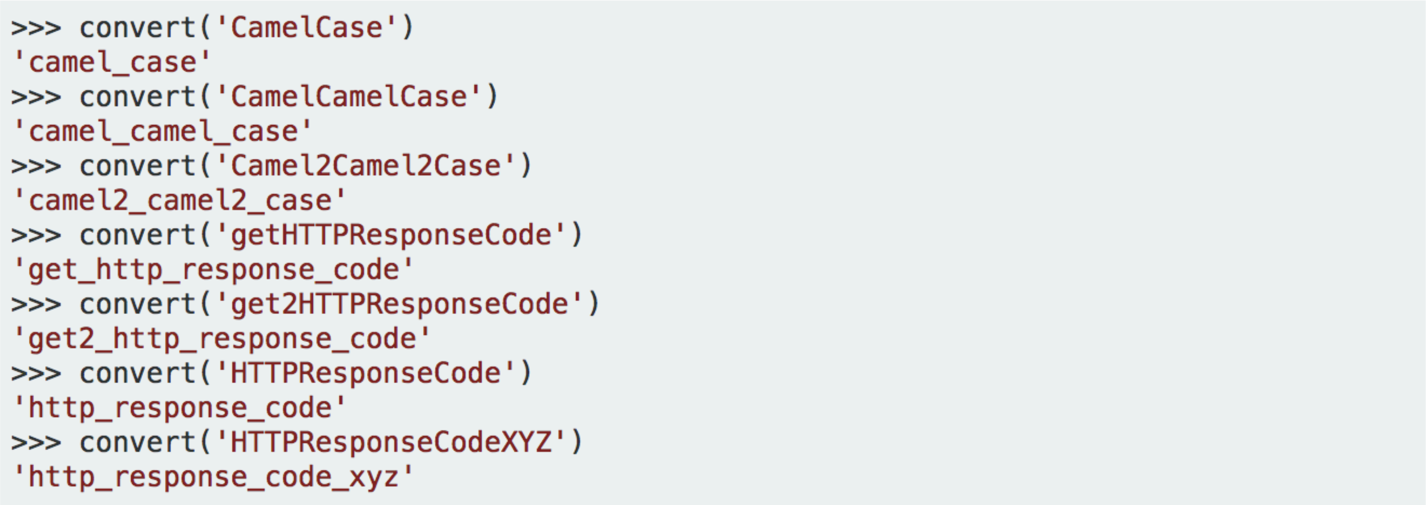
can you solve the problem:



Elegant Python function to convert CamelCase to snake_case?

“Standalone” code solution

By looking at Code block n,



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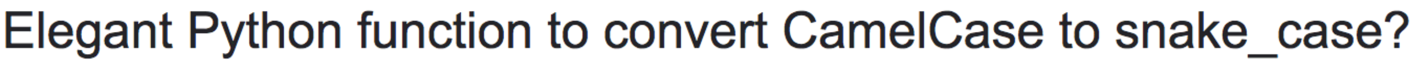


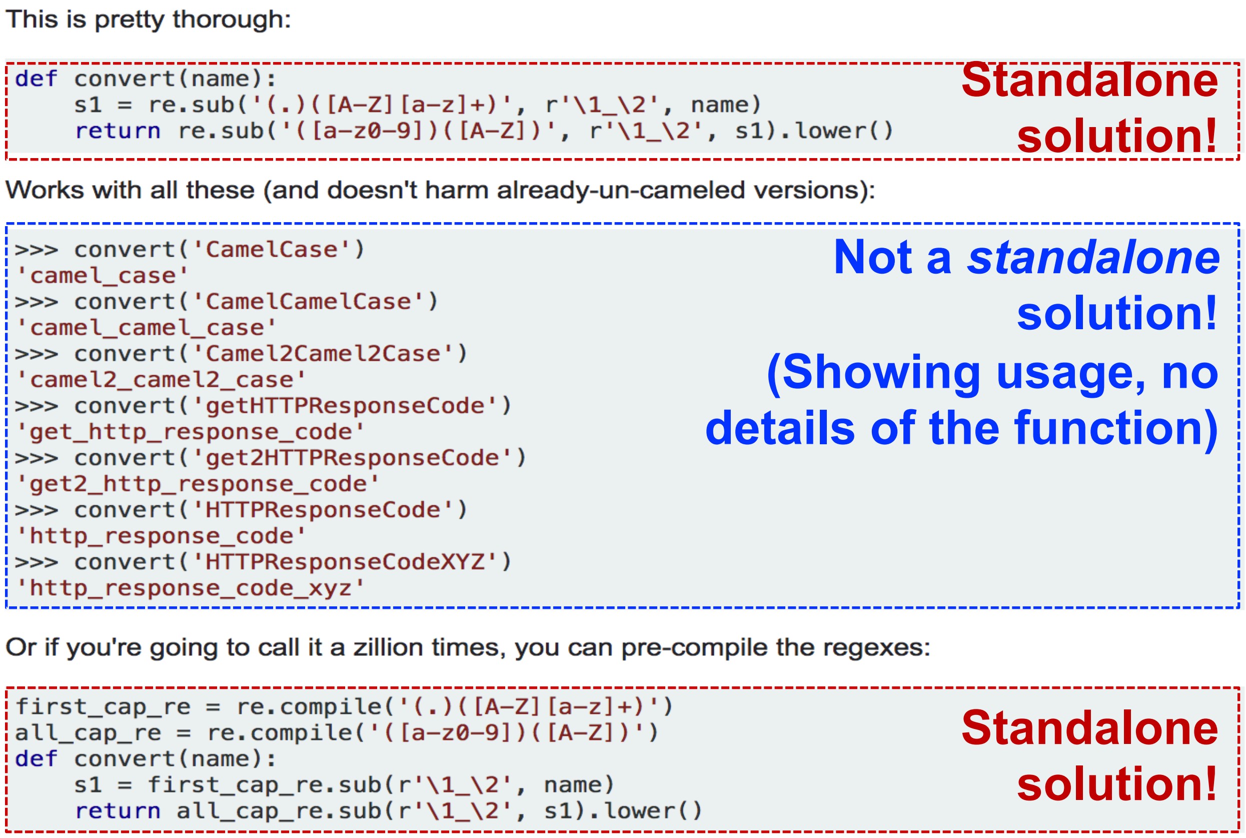
Elegant Python function to convert CamelCase to snake_case?

No! (it shows the usage, but with no details of the function)

Example: Question-Code pairs

Question Elegant Python function to convert CamelCase to snake_case?

Accepted answer post



This is pretty thorough:

☑

```
def convert(name):
    s1 = re.sub('(.)([A-Z][a-z]+)', r'\1_\2', name)
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

Standalone solution!

Works with all these (and doesn't harm already-un-cameled versions):

✖

```
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>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
```

Not a *standalone* solution!

(Showing usage, no details of the function)

Or if you're going to call it a zillion times, you can pre-compile the regexes:

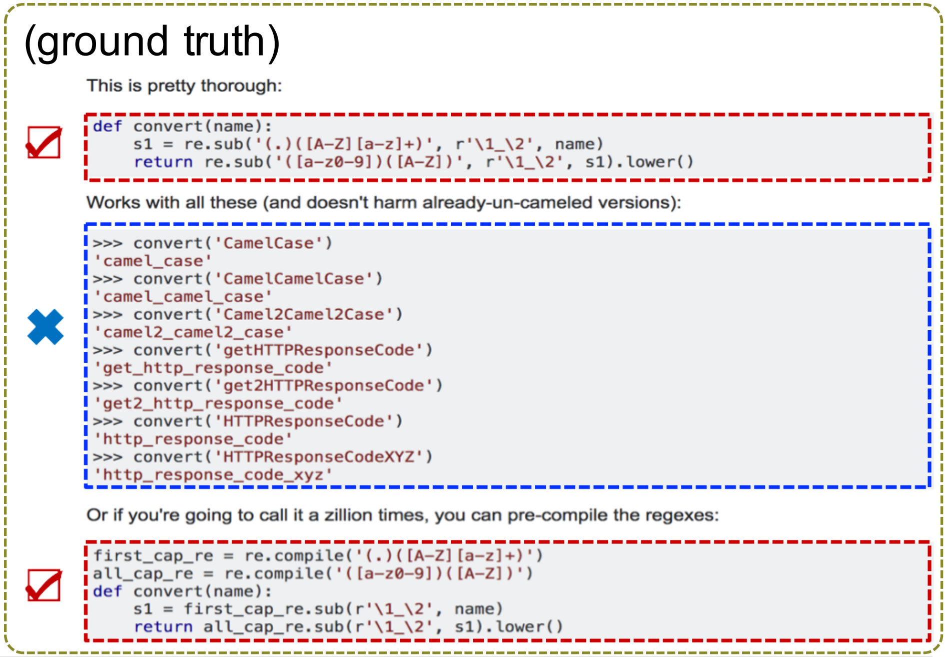
☑

```
first_cap_re = re.compile('(.)([A-Z][a-z]+)')
all_cap_re = re.compile('([a-z0-9])([A-Z])')
def convert(name):
    s1 = first_cap_re.sub(r'\1_\2', name)
    return all_cap_re.sub(r'\1_\2', s1).lower()
```

Standalone solution!

Previous methods: heuristics based

- “**Select All**”: Taking *all* code snippets in the answer post as code solutions. [Allamanis et al., 2015][Zilberstein and Yahav, 2016]
  - Low precision



(ground truth)

This is pretty thorough:

☑

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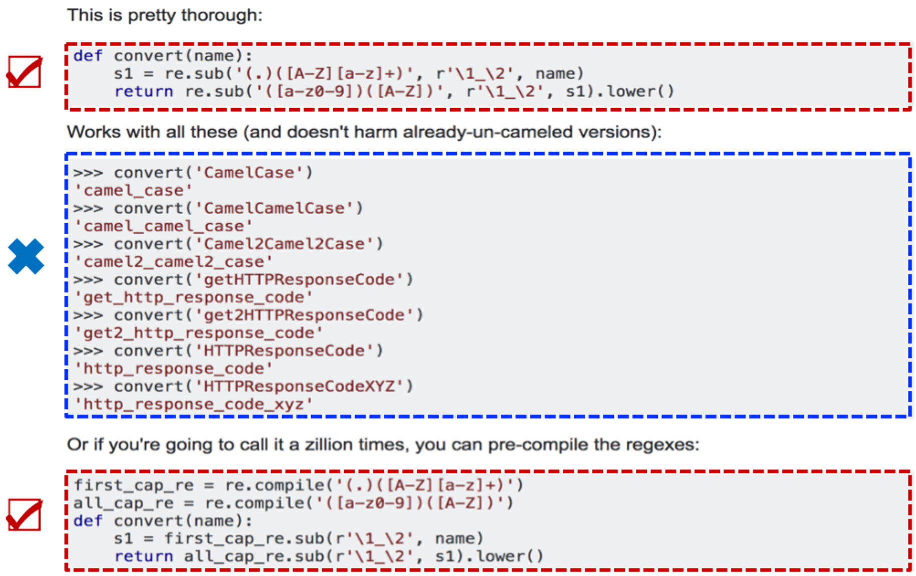
```

Previous methods: heuristics based

- “**Select First**”: Taking only the *<u>first</u>* code snippet in the answer post as a code solution, or considering only answer posts containing exactly one code snippet.
  [Iyer et al., 2016]
  - Low recall

(ground truth)



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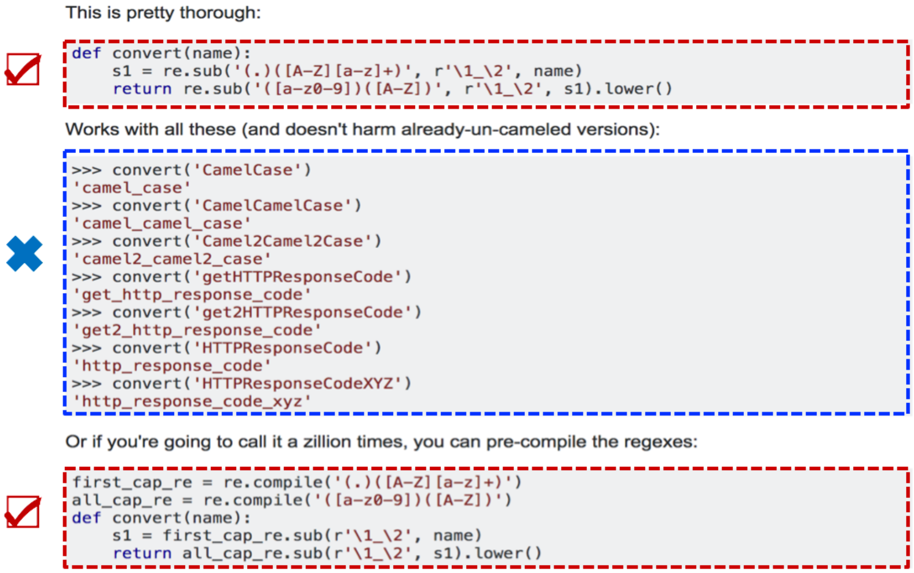
    return all_cap_re.sub(r'\1_\2', s1).lower()
```

Our solution: A systematic framework

- Binary classification formulation:

  Input: A question on Stack Overflow and its accepted answer post with multiple code snippets

  Output: A binary label for each code snippet on whether it is a standalone solution to the question



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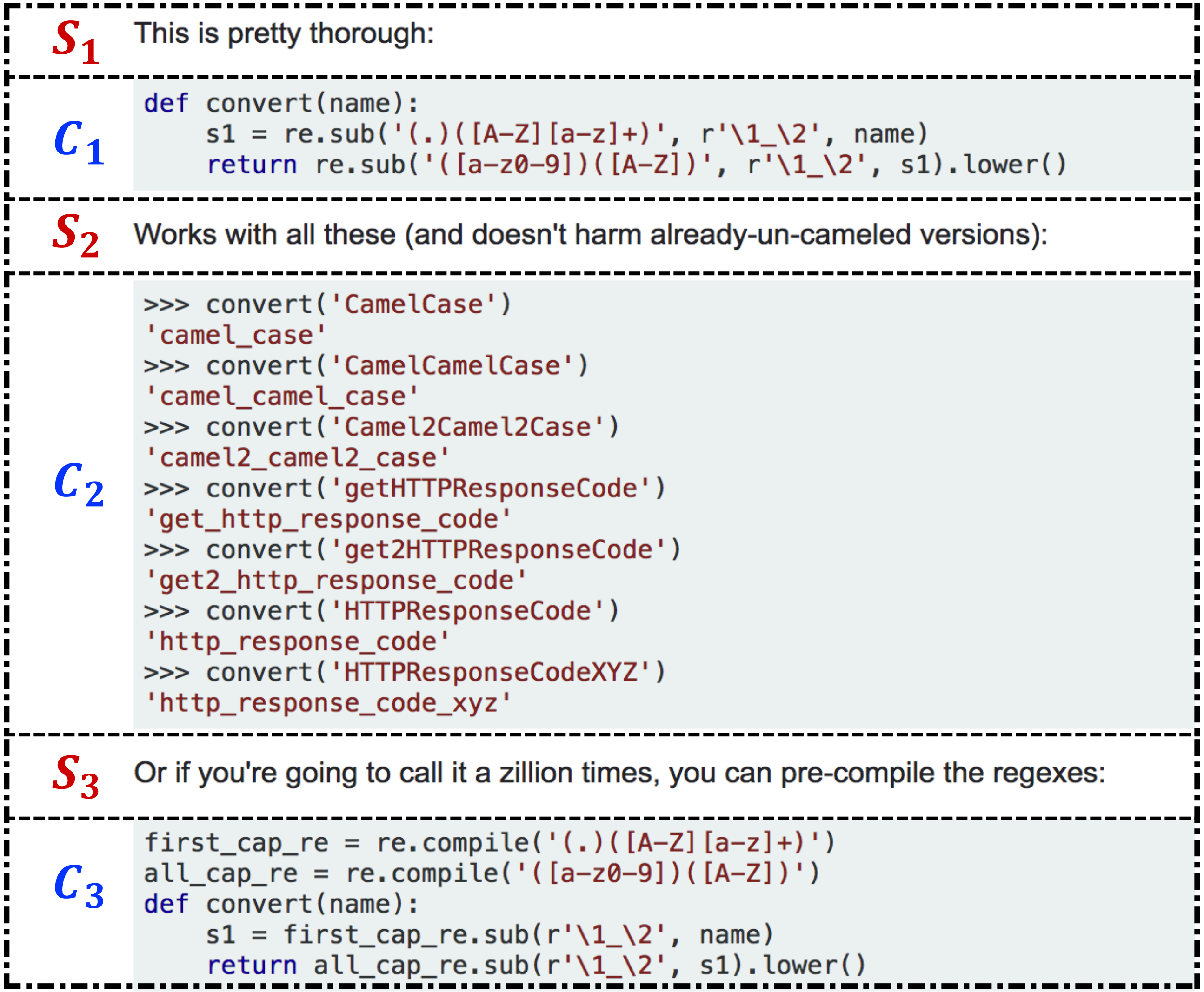
```

A bi-view formulation

Interleaving text and code blocks



S_1 This is pretty thorough:

C_1

```
def convert(name):
    s1 = re.sub('(.)([A-Z][a-z]+)', r'\1_\2', name)
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

S_2 Works with all these (and doesn't harm already-un-cameled versions):

C_2

```
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>>> convert('CamelCamelCase')
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'camel2_camel2_case'
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>>> convert('get2HTTPResponseCode')
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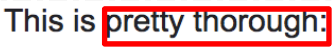
>>> convert('HTTPResponseCode')
'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
```

S_3 Or if you're going to call it a zillion times, you can pre-compile the regexes:

C_3

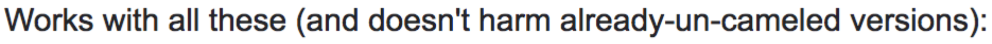
```
first_cap_re = re.compile('(.)([A-Z][a-z]+)')
all_cap_re = re.compile('([a-z0-9])([A-Z])')
def convert(name):
    s1 = first_cap_re.sub(r'\1_\2', name)
    return all_cap_re.sub(r'\1_\2', s1).lower()
```

Text-based view: contextual hints

S_1 

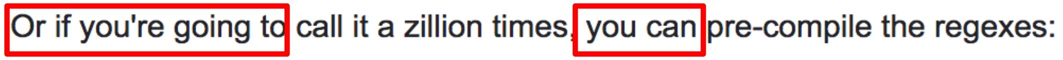
This is pretty thorough:

C_1 → more likely to be a code solution

S_2 

Works with all these (and doesn't harm already-un-cameled versions):

C_2

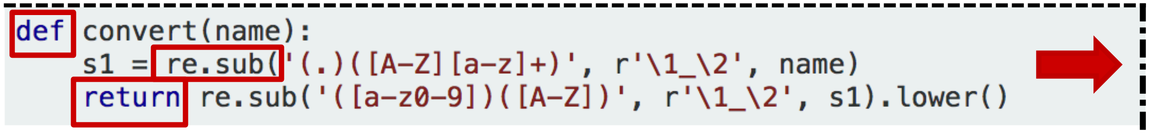
S_3 

Or if you're going to call it a zillion times, you can pre-compile the regexes:

C_3 → more likely to be a code solution

Code-based view: semantics of code content

C_1



```
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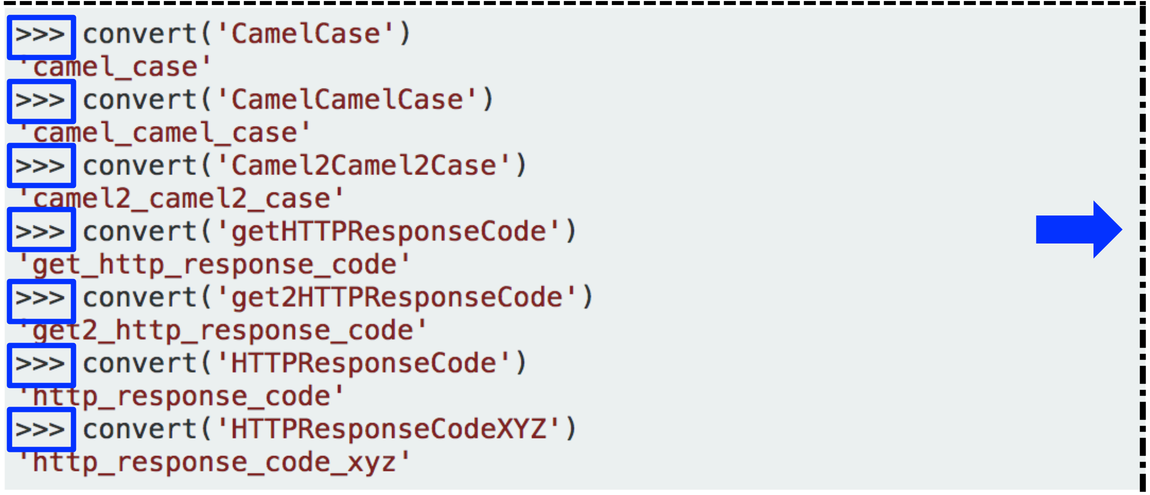
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

more likely to be a solution

C_2



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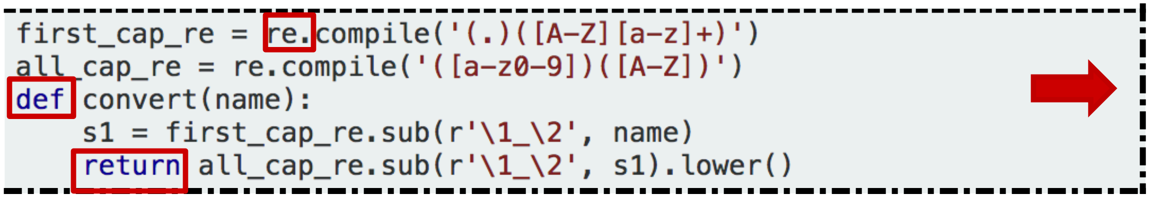
'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
```

possibly a usage demo

C_3



```
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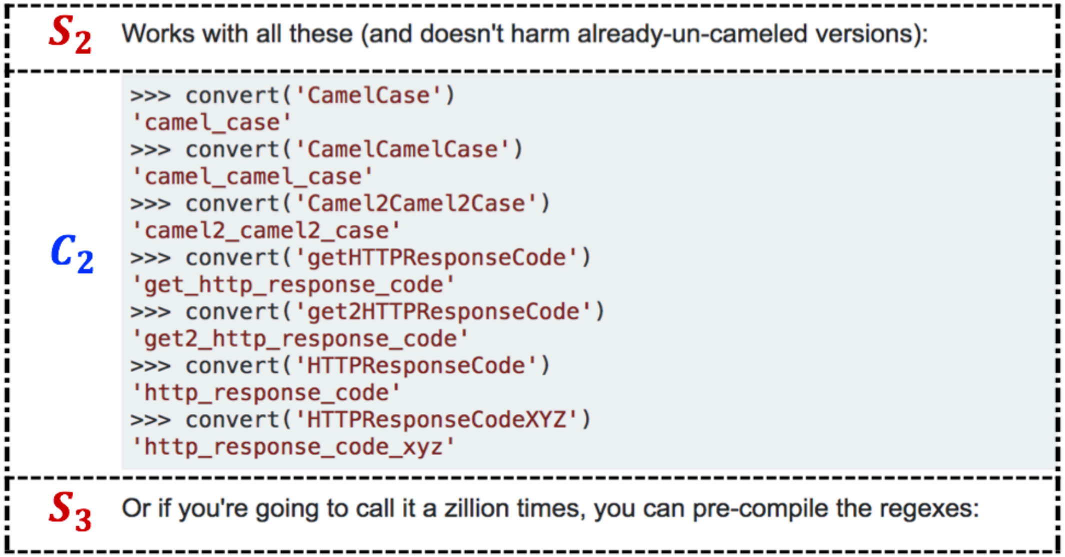
def convert(name):
    s1 = first_cap_re.sub(r'\1_\2', name)
    return all_cap_re.sub(r'\1_\2', s1).lower()
```

more likely to be a solution

Formulation for each code snippet

Predict a “solution or not” label for a code snippet (here C_2) based on:

1. **Textual context** (text view): $\boldsymbol{S_2, S_3}$.
2. **Code content** (code view): $\boldsymbol{C_2}$.



$\boldsymbol{S_2}$ Works with all these (and doesn't harm already-un-cameled versions):

$\boldsymbol{C_2}$

```
>>> convert('CamelCase')
'camel_case'
>>> convert('CamelCamelCase')
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'camel2_camel2_case'
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'get_http_response_code'
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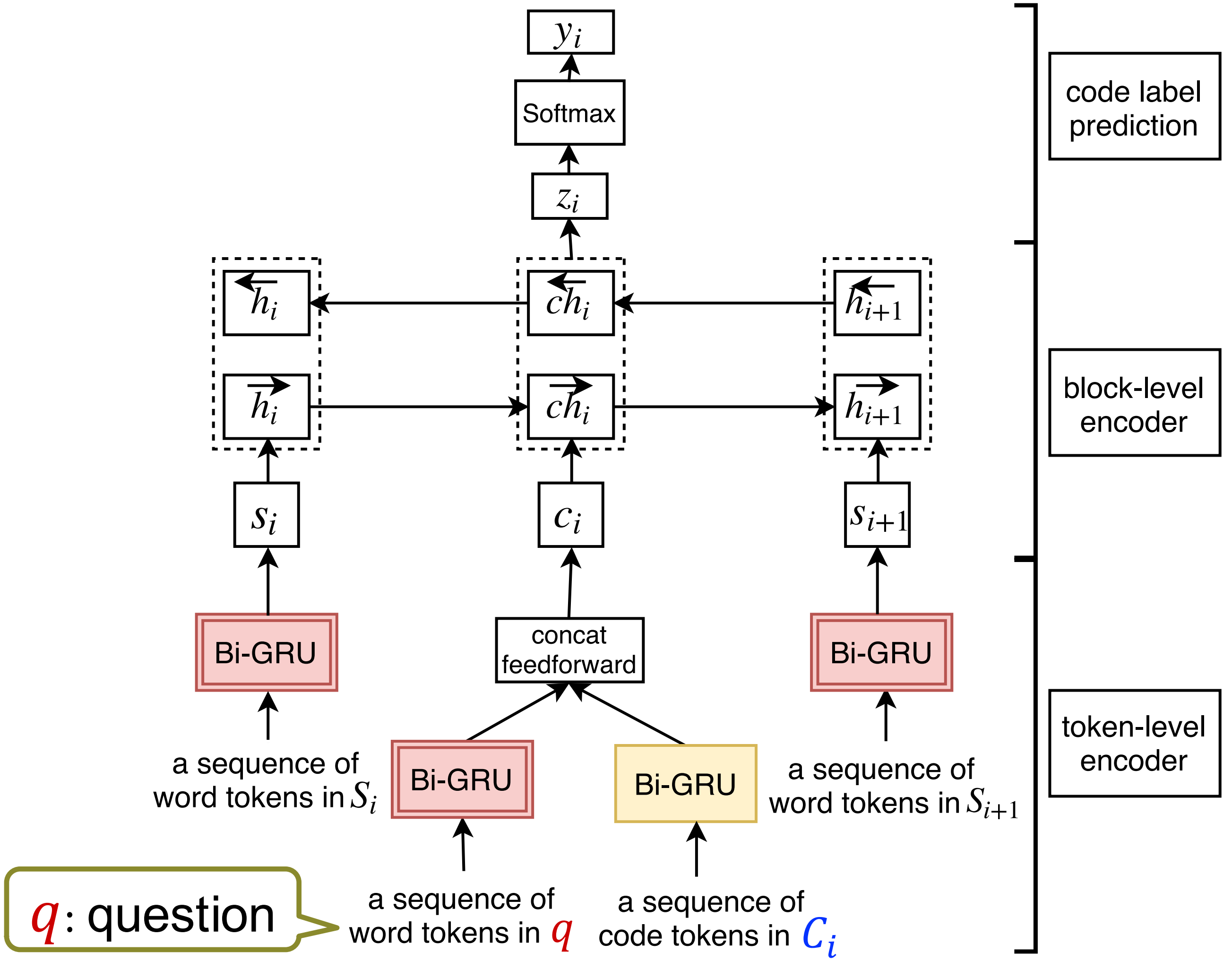
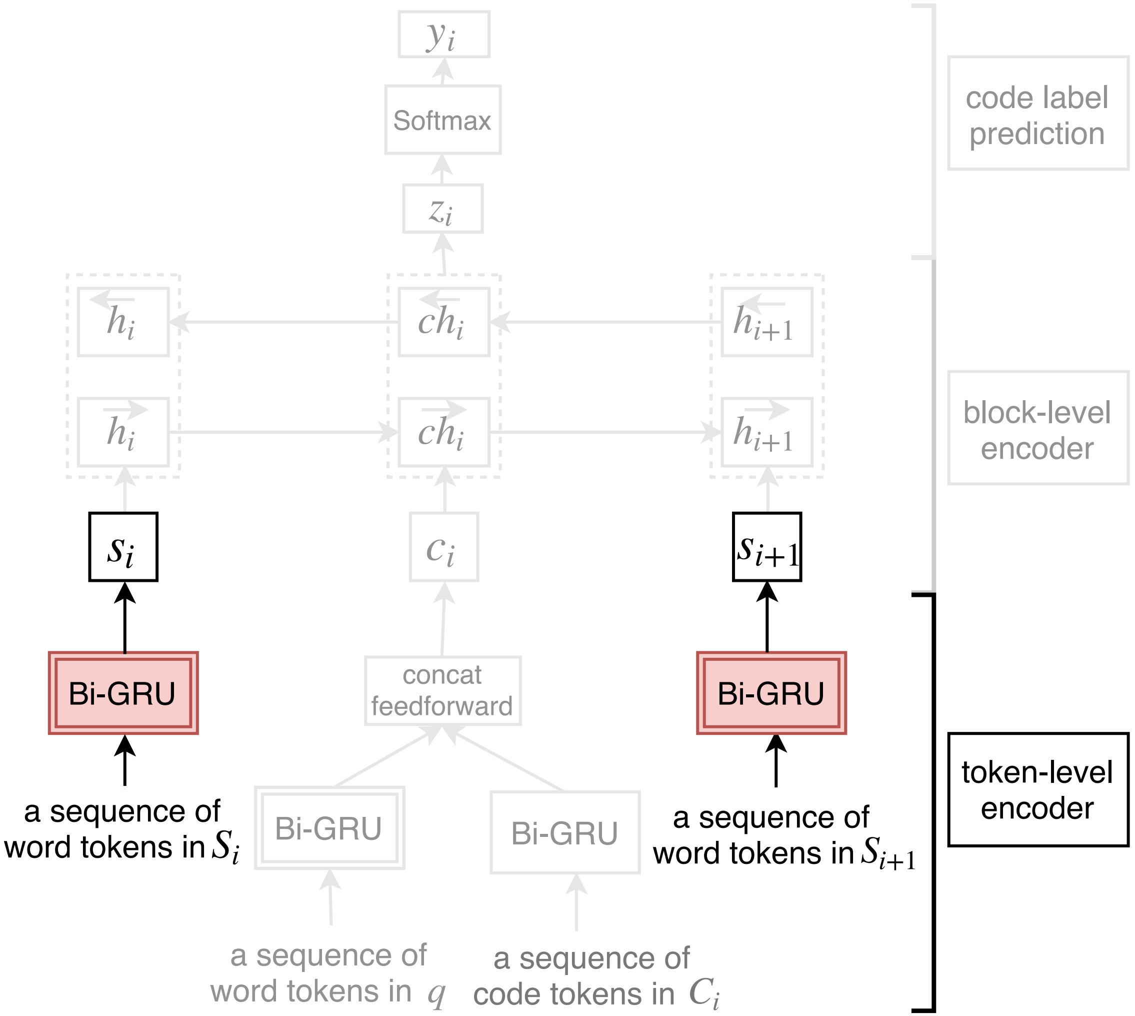
>>> convert('HTTPResponseCode')
'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
```

$\boldsymbol{S_3}$ Or if you're going to call it a zillion times, you can pre-compile the regexes:

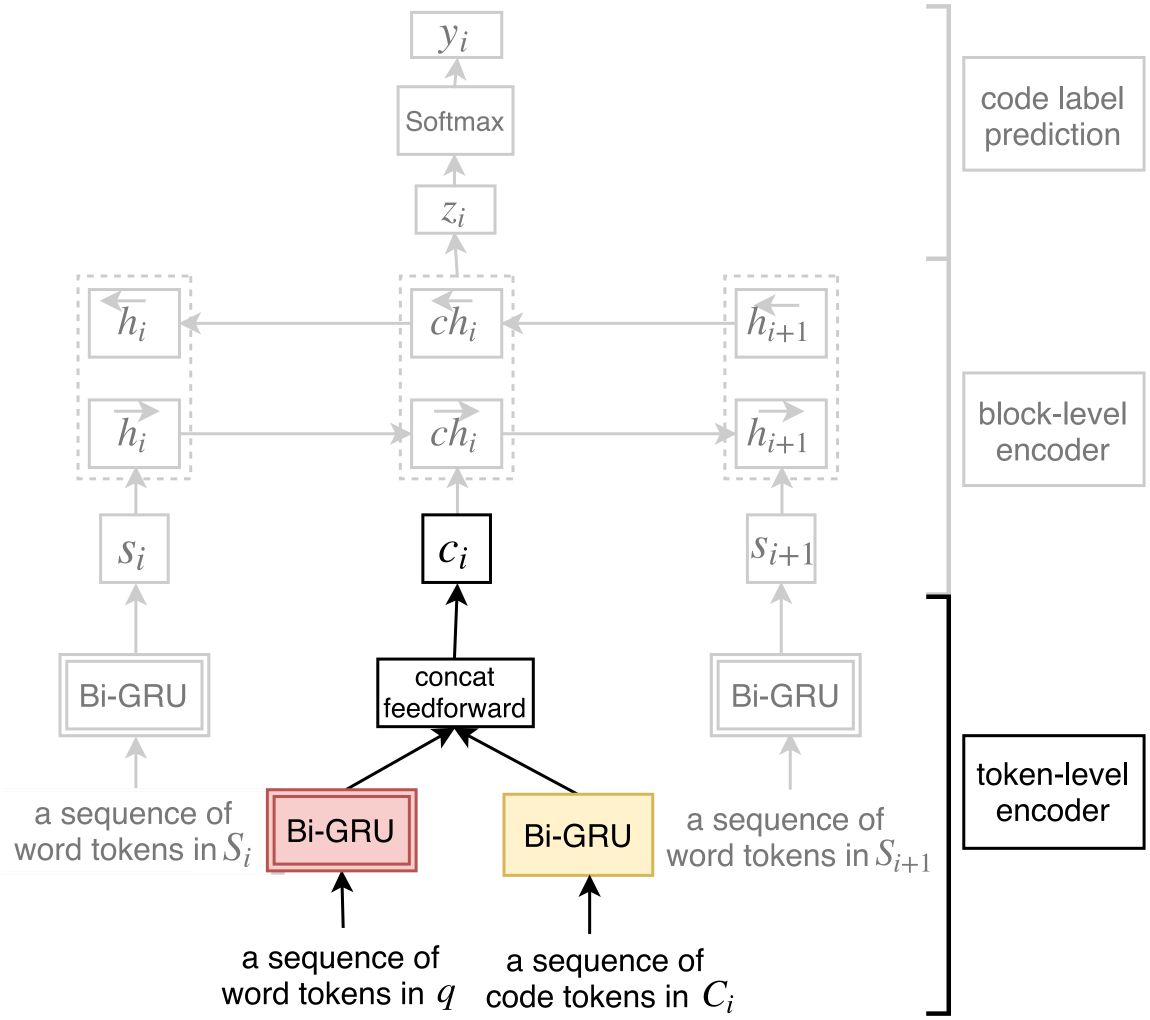
Bi-View Hierarchical Neural Network (BiV-HNN)



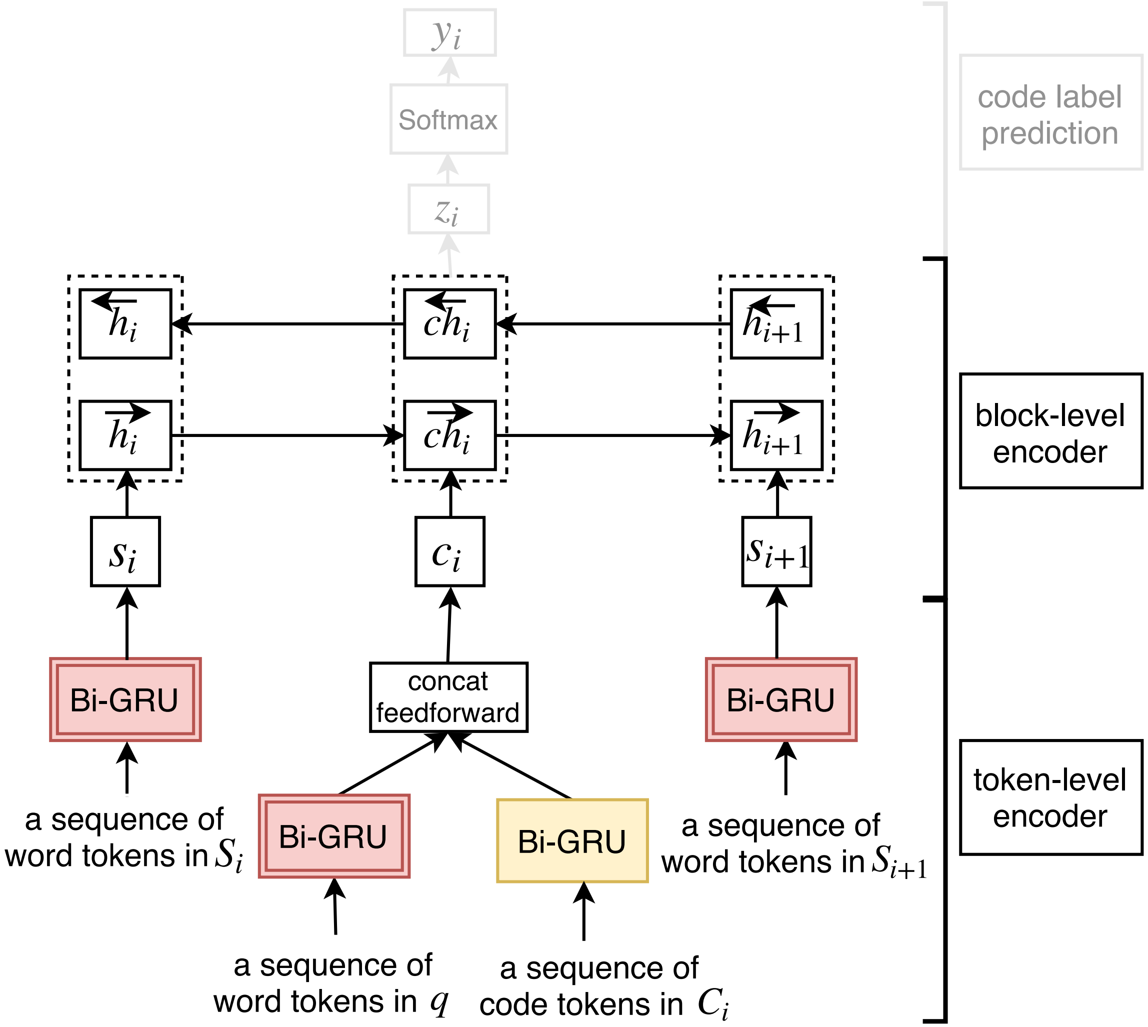
Token-level encoder for text blocks



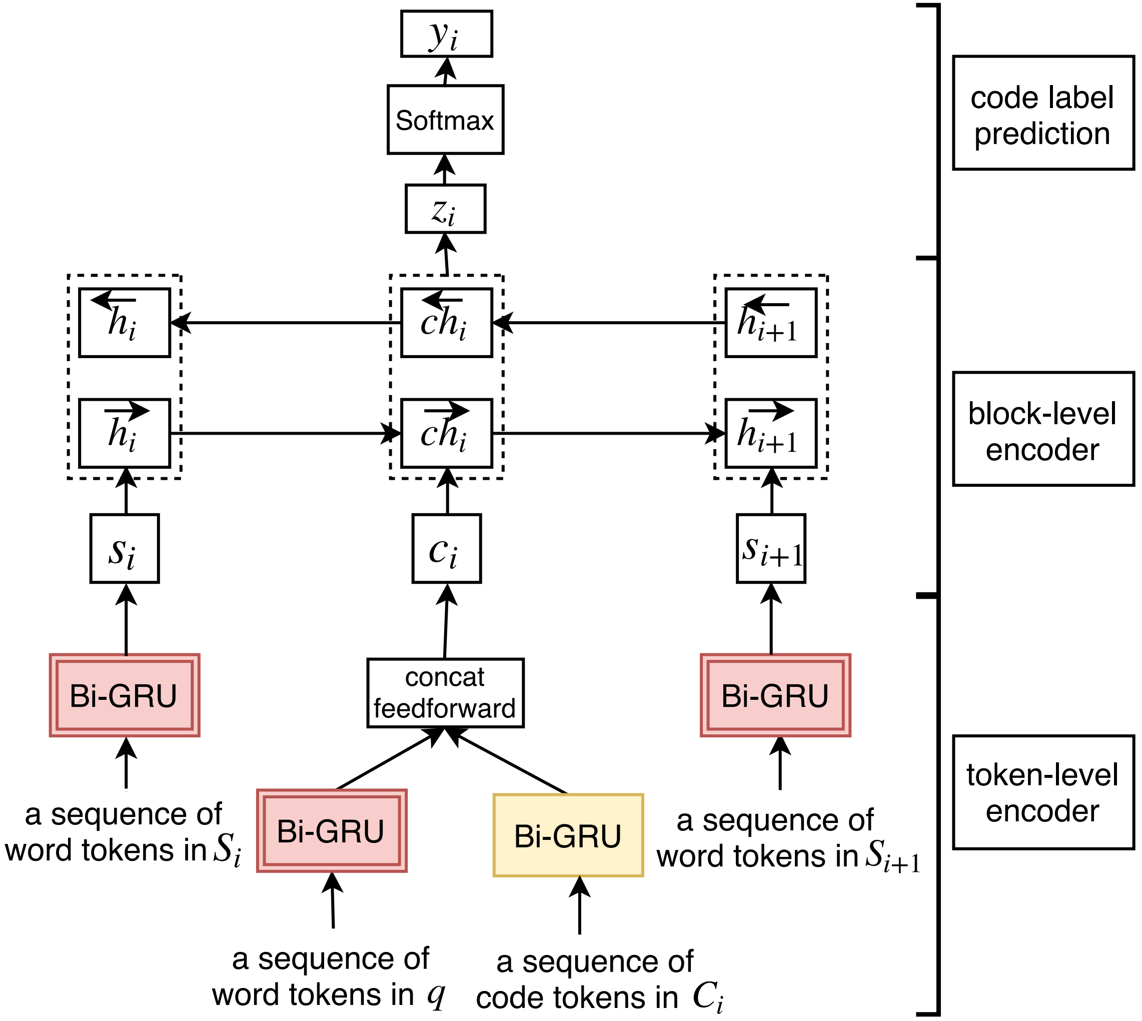
Token-level encoder for code blocks



Block-level encoder



Code label prediction



Experimental Setup

- Manually annotating “solution or not” label on code snippets in one answer post.
  - Python and SQL domain.
  - Four undergraduates with substantial Cohen’s kappa agreement.
- Training/validation/test split: 60% - 20% -20%.

	Python	SQL
# of Question-Code pairs	4,884	3,637
% of positive Question-Code pairs	44%	57%

Main Results

- Heuristic methods: Select-First, Select-All.
- Feature engineering based methods:
  - Logistic Regression (LR), Support Vector Machine (SVM).
  - Features: text-based (uni-/bi-grams, the connectives, etc) and code-based (code tokens, etc).

	Python	SQL
Select-First	0.607	0.613
Select-All	0.642	0.737
LR	0.766	0.846
SVM	0.753	0.850
BiV-HNN	**0.841**	**0.888**

(comparison on F1)

Research questions for understanding BiV-HNN

Q1: text view, code view, or bi-view?

Q2: hierarchical structure or flat structure?

Q3: block-level encoder: sequential or feedforward?

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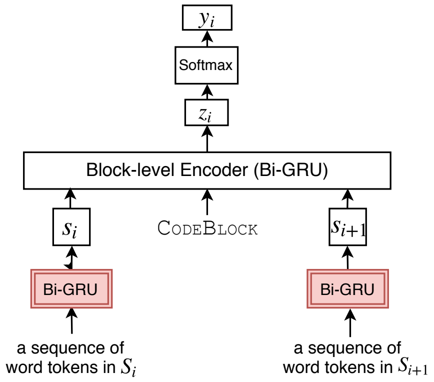
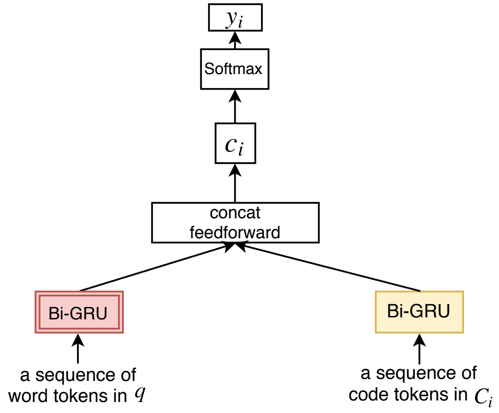
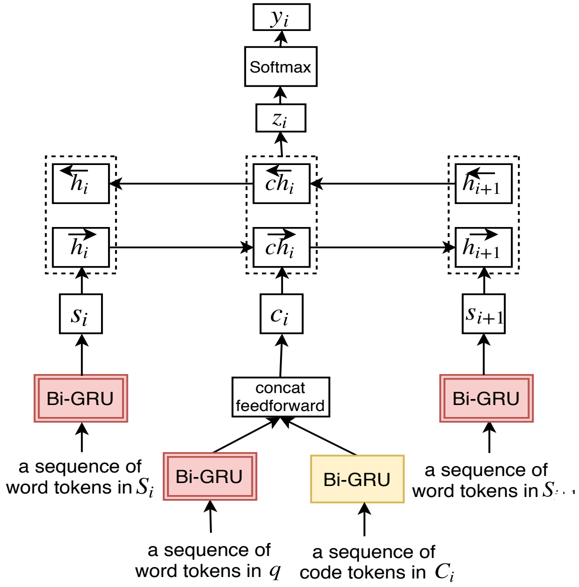

y_i
Softmax
z_i
Block-level Encoder (Bi-GRU)
s_i
CodeBlock
s_{i+1}
Bi-GRU
Bi-GRU
a sequence of word tokens in S_i
a sequence of word tokens in S_{i+1}

Text-HNN
(text view)


y_i
Softmax
c_i
concat feedforward
Bi-GRU
Bi-GRU
a sequence of word tokens in q
a sequence of code tokens in C_i

Code-HNN
(code view)


y_i
Softmax
z_i
$\overleftarrow{h_i}$
$\overleftarrow{ch_i}$
$\overleftarrow{h_{i+1}}$
$\overrightarrow{h_i}$
$\overrightarrow{ch_i}$
$\overrightarrow{h_{i+1}}$
s_i
c_i
s_{i+1}
Bi-GRU
concat feedforward
Bi-GRU
a sequence of word tokens in S_i
Bi-GRU
Bi-GRU
a sequence of word tokens in S_{i+1}
a sequence of word tokens in q
a sequence of code tokens in C_i

BiV-HNN
(bi-view)

	Python	SQL
Text-HNN	0.771	0.840
Code-HNN	0.812	0.851
BiV-HNN	**0.841**	**0.888**

(comparison on F1)

Model combination

- `Text-HNN`, `Code-HNN` and `BiV-HNN` are observed complementary to each other.
  - On Python validation set, 60%~70% of mistakes made by one model can be corrected by the other two models.

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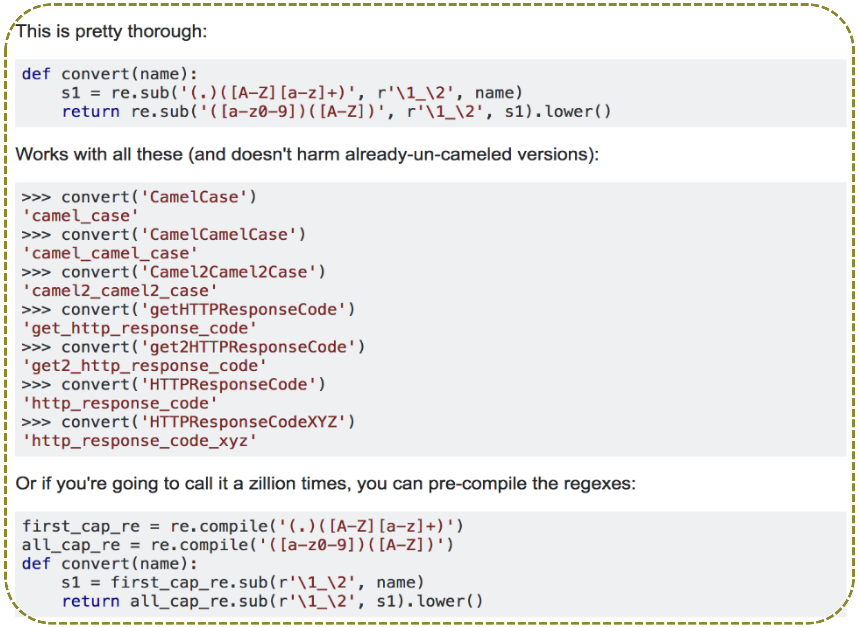
- **Model combination**: the label of a code snippet is predicted only when the three models agree on it.

- Model combination on testing set:
  - Python: ~70% of code snippets are labeled with **0.92** F1.
  - SQL: ~80% of code snippets are labeled with **0.94** F1.

Systematically mined StaQC



This is pretty thorough:

```
def convert(name):
    s1 = re.sub('(.)([A-Z][a-z]+)', r'\1_\2', name)
    return re.sub('([a-z0-9])([A-Z])', r'\1_\2', s1).lower()
```

Works with all these (and doesn't harm already-un-cameled versions):

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>>> convert('CamelCase')
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>>> convert('CamelCamelCase')
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'http_response_code'
>>> convert('HTTPResponseCodeXYZ')
'http_response_code_xyz'
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Or if you're going to call it a zillion times, you can pre-compile the regexes:

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all_cap_re = re.compile('([a-z0-9])([A-Z])')
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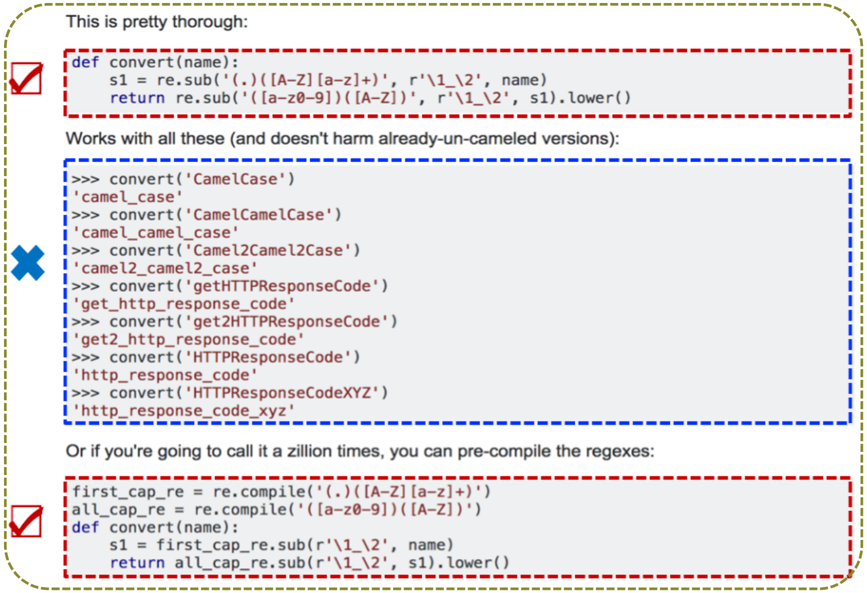
```

New or unannotated post

Model combination



This is pretty thorough:

✓

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✗

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StaQC: Systematically mined Question-Code pairs

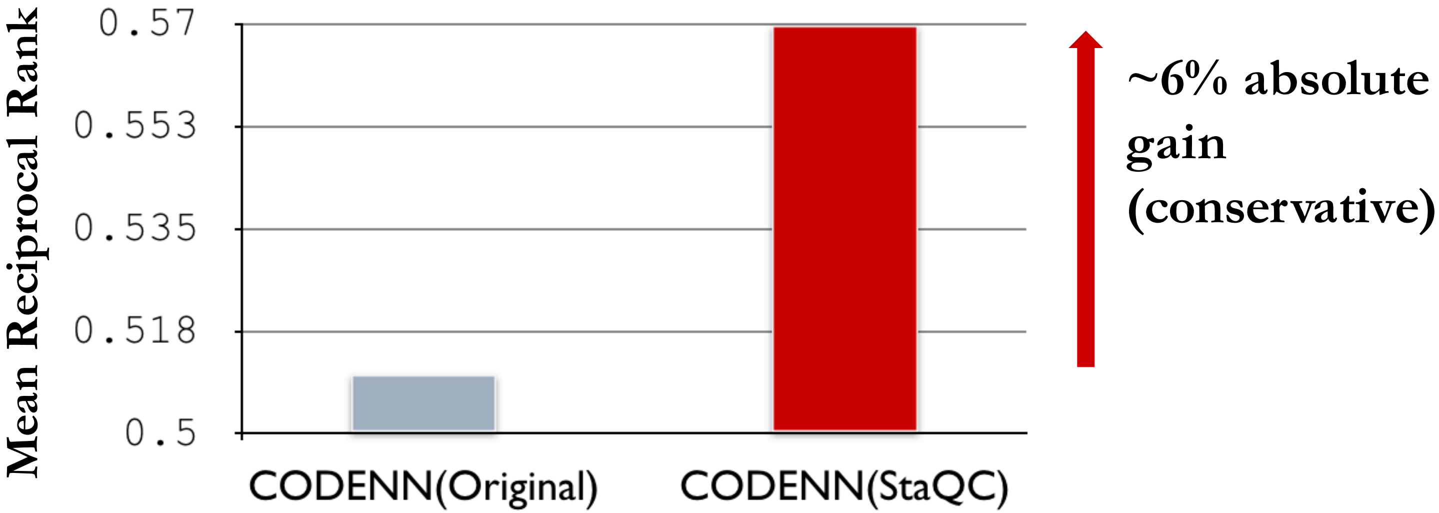
StaQC: the largest dataset to date of ~148K Python and ~120K SQL “how-to-do-it”* Question-Code pairs!

Continuously growing in *size* and *diversity*

A better source for constructing models mapping between natural language and programming language

StaQC: A better source for downstream tasks

- Code Retrieval as an exemplar downstream task (SQL domain).
- Neural Network model CODENN. [Iyer et al., 2016]
  - CODENN(Original): trained on ~26K heuristically collected QC pairs.
  - CODENN(StaQC): trained on ~120K systematically mined QC pairs.



~6% absolute gain (conservative)

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stackoverflow

A better source for constructing models mapping between natural language and programming language

Data and code are available at:
https://github.com/LittleYUYU/StackOverflow-Question-Code-Dataset

Thank you! Questions?