Secure Your Code with AI and NLP

Dr. Eliezer Kanal

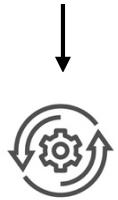
Mr. Ben Cohen

Dr. Nathan VanHoudnos

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

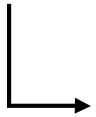
Natural Language Processing

Raw text



Machine-friendly representation

Find patterns, repetition



- Predictions
- Generate natural sequences
- Summarize
- Translate
- Classify

Code + NLP = ?

“Naturalness Hypothesis”

Programming languages, in theory, are complex, flexible and powerful, but the programs that real people actually write are mostly simple and rather repetitive, and thus they have usefully predictable statistical properties that can be captured in statistical language models and leveraged for software engineering tasks.

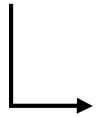
A. Hindle, E. T. Barr, Z. Su, M. Gabel, and P. Devanbu, “On the naturalness of software,” in *2012 34th International Conference on Software Engineering (ICSE)*, 2012, pp. 837–847.

Natural Language Processing

Raw text

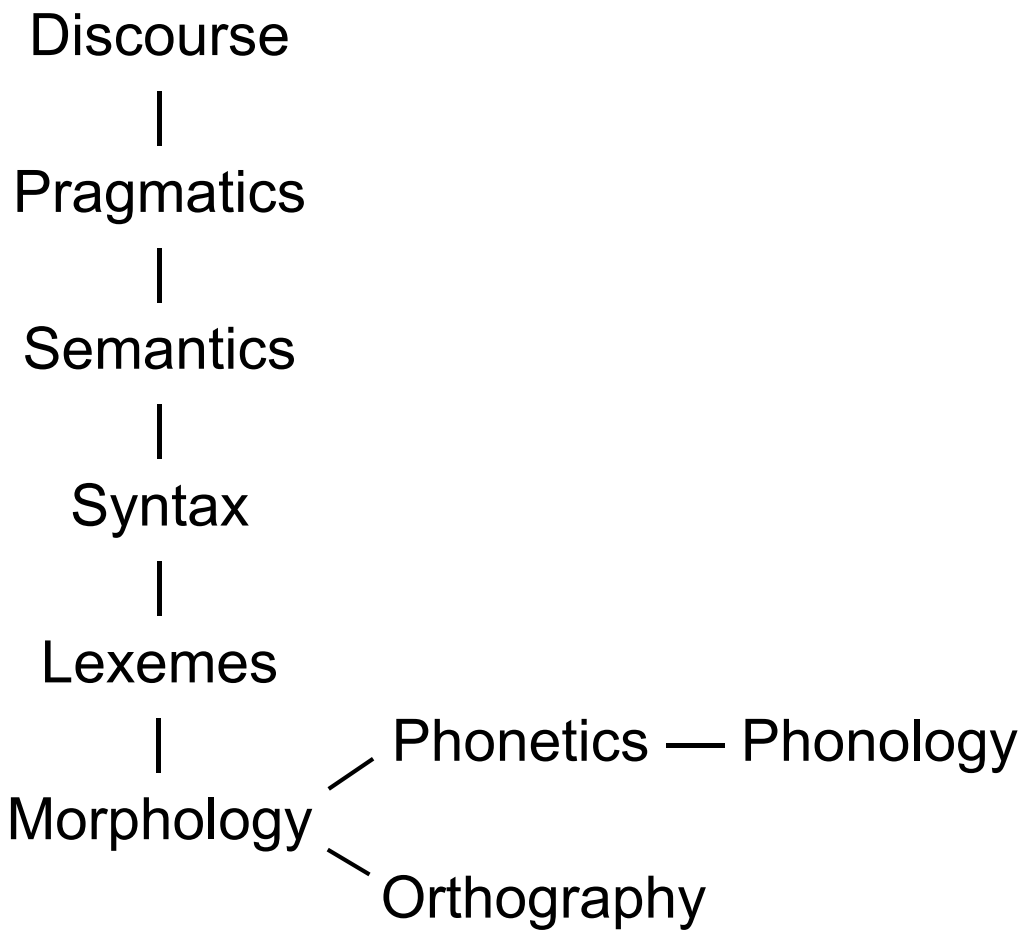
Machine-friendly representation

Find patterns, repetition

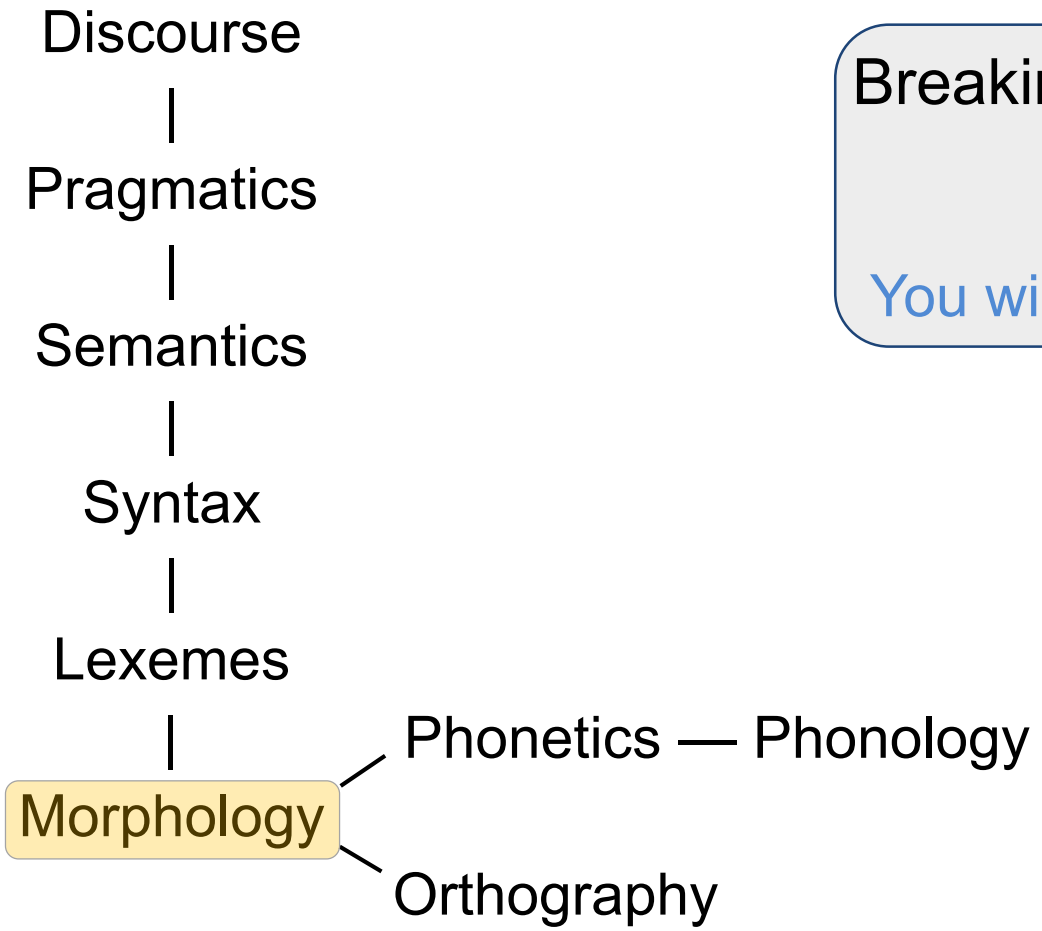


- Predictions
- Generate natural sequences
- Summarize
- Translate
- Classify

What is “representation”?



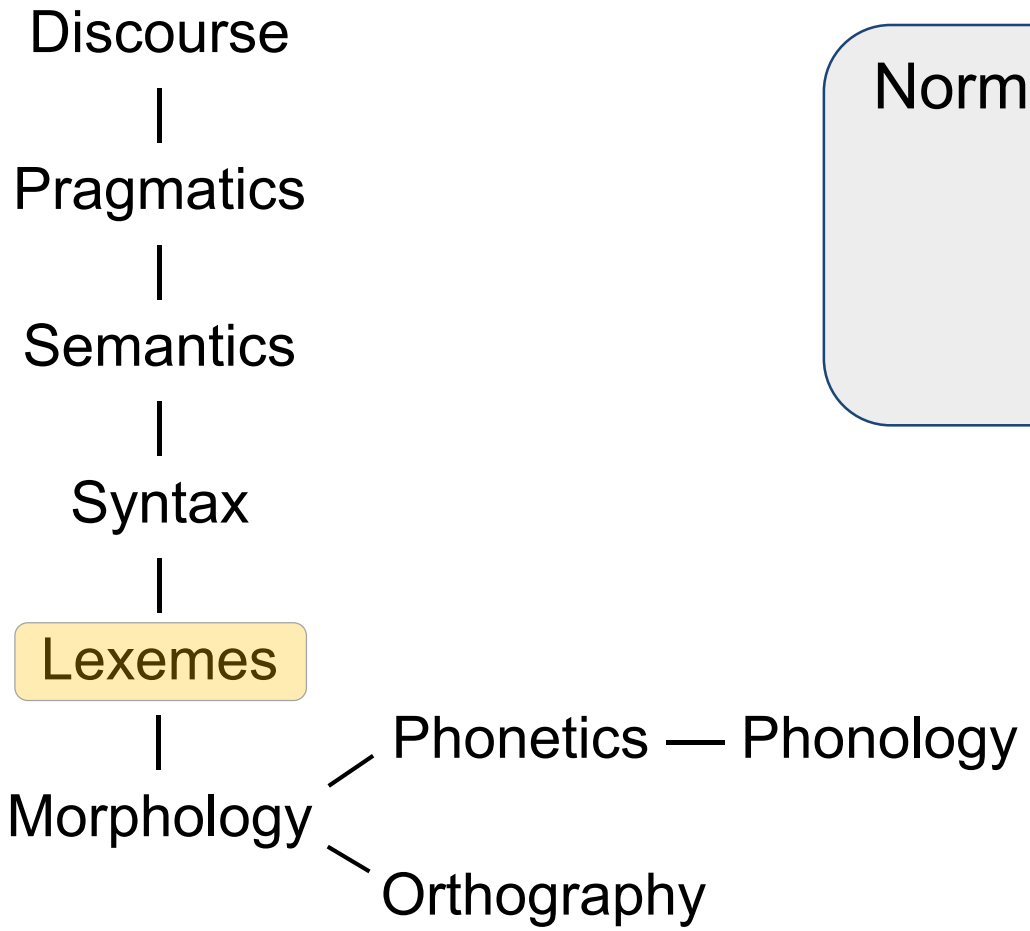
What is “representation”?



Breaking words to components

תפגוש את הילד בגן
You will meet the boy in the park

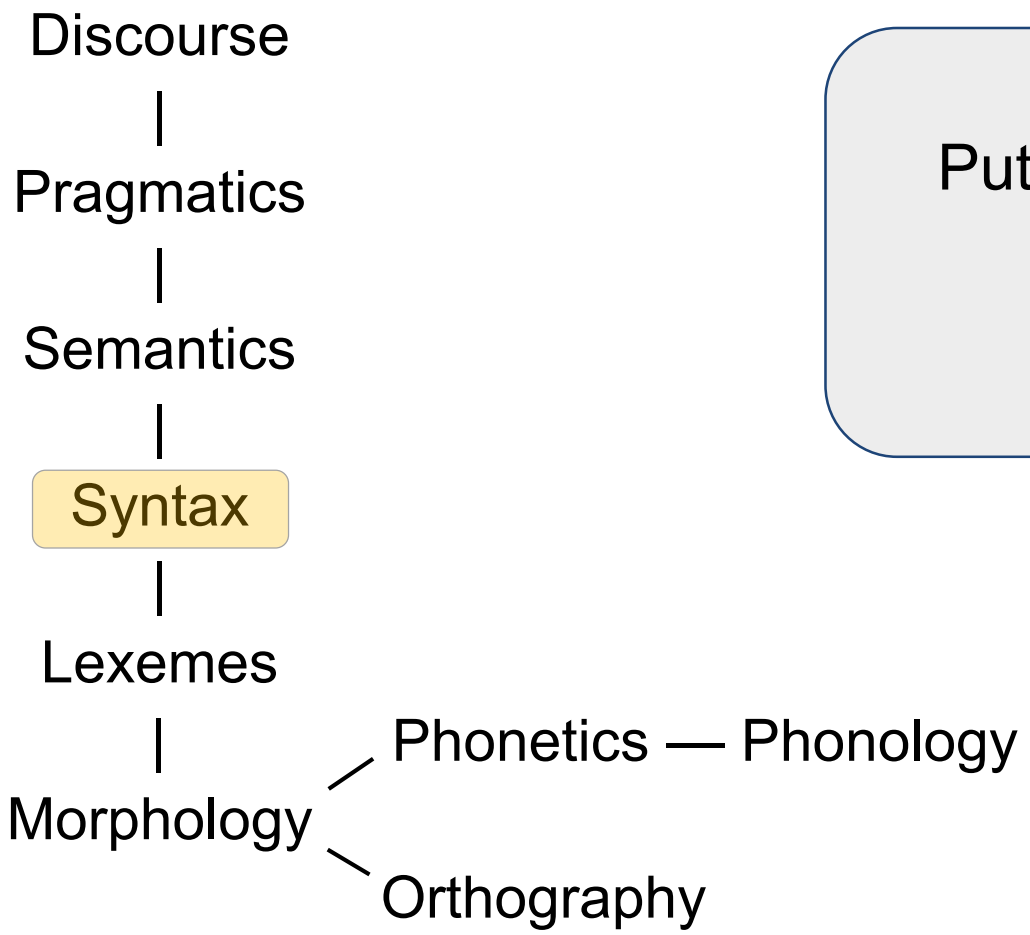
What is “representation”?



Normalize/disambiguate words

Bank (finance)
Bank (river)
Bank (airplane)

What is “representation”?



Put symbols in a hierarchy

see example….

One morning I shot an elephant in my pajamas. How he got into my pajamas I don't know.

Groucho Marx, *Animal Crackers*, 1930

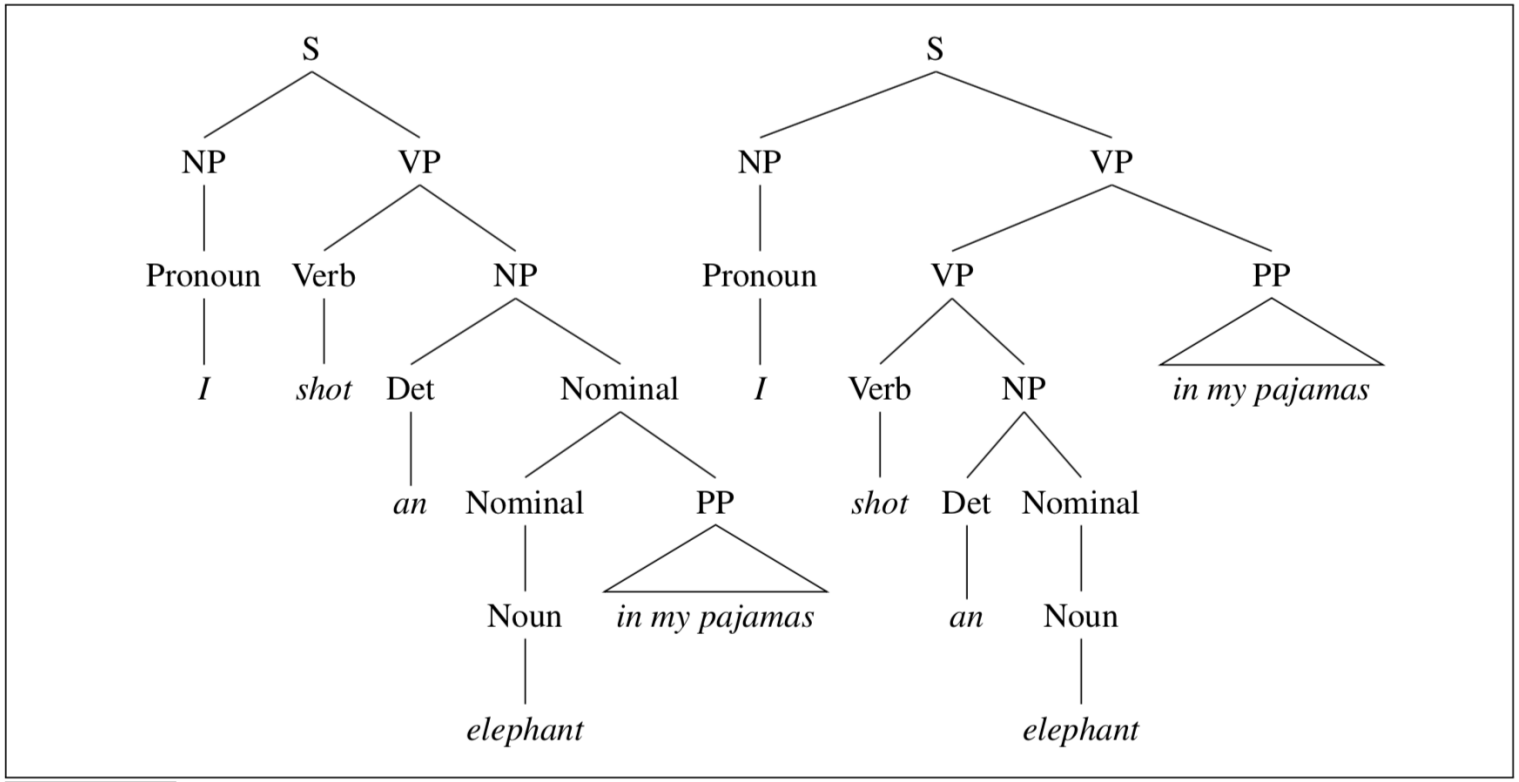
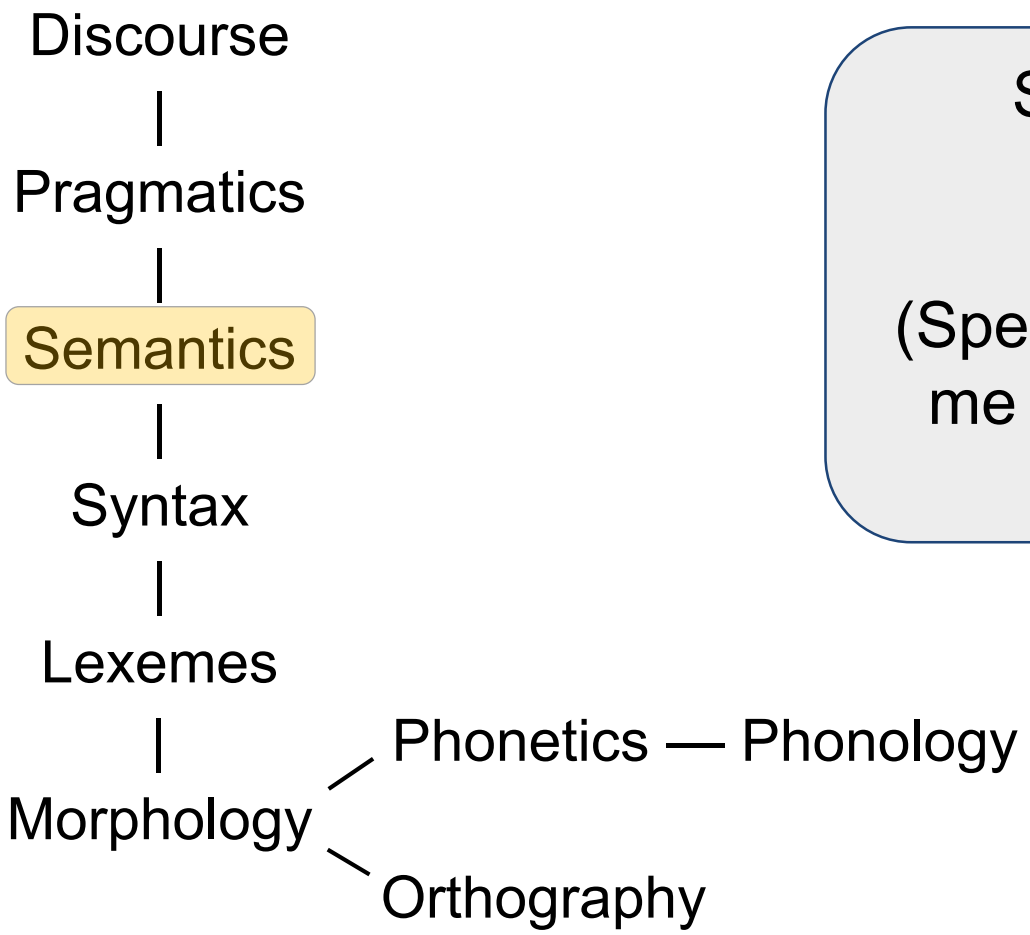


Figure 11.2 Two parse trees for an ambiguous sentence. The parse on the left corresponds to the humorous reading in which the elephant is in the pajamas, the parse on the right corresponds to the reading in which Captain Spaulding did the shooting in his pajamas.

D. Jurafsky and J. H. Martin, *Speech and Language Processing*, Third edition, Draft. Self-published, 2018.

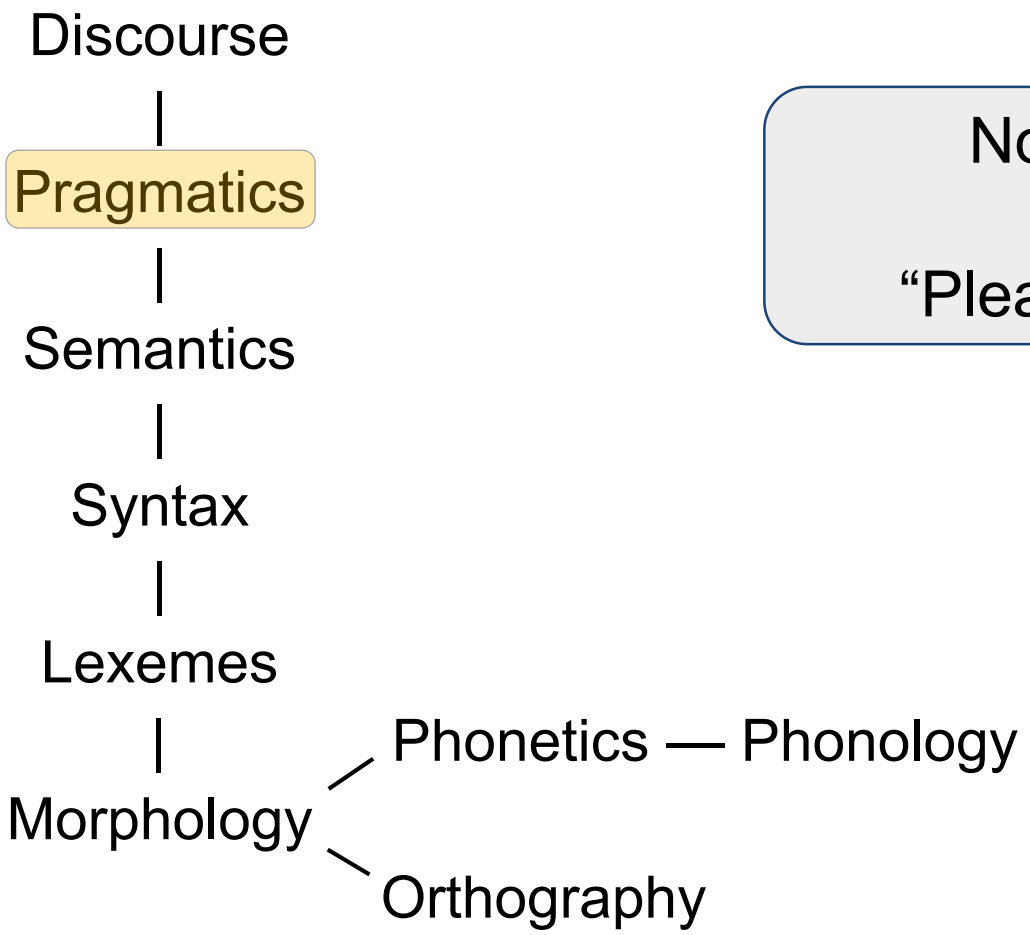
What is “representation”?



Sentences to domain representation

(Speaking to phone) “Remind me to buy groceries when I leave the house”

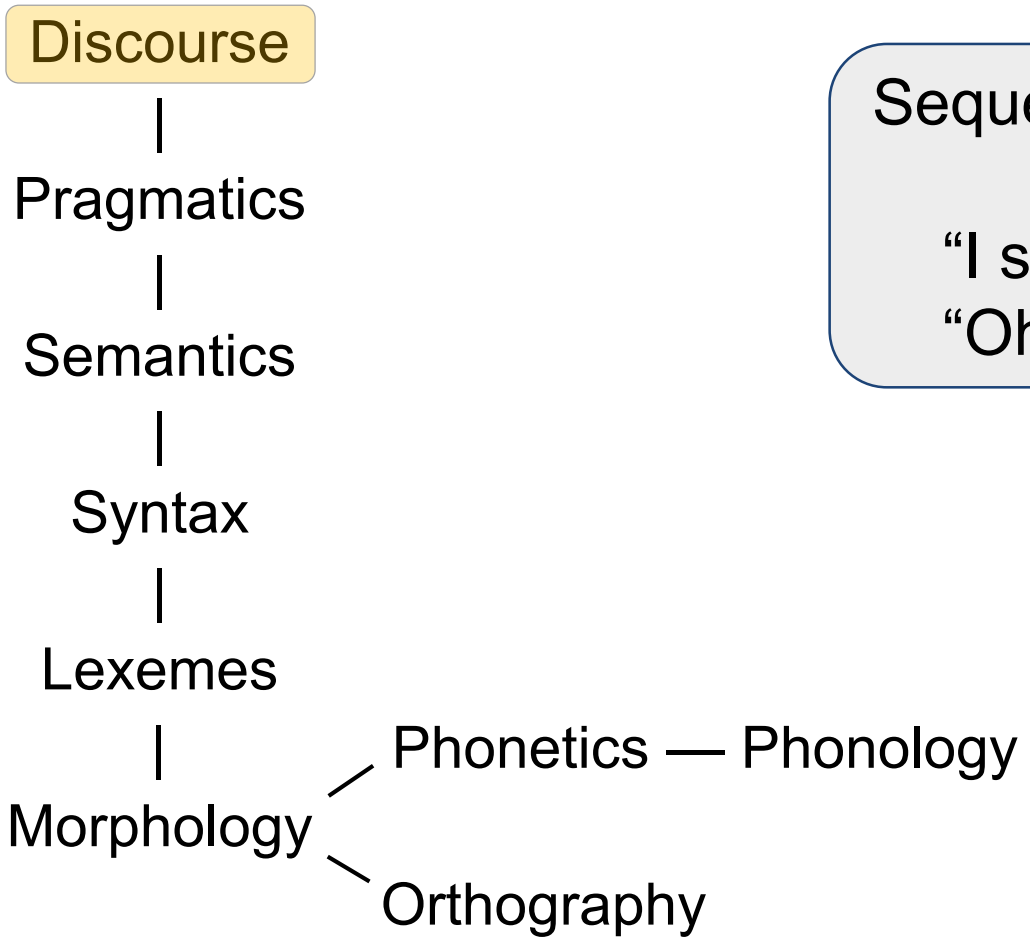
What is “representation”?



Non-local meanings

“Please pass that down.”

What is “representation”?



Sequences, Conversation

“I said the *black* shoes.”
“Oh, *black*.”


```
var exerciseTimer = function (exercises) {
	$("#workouts").hide();

	var time = document.getElementById("time");
	var desc = document.getElementById("desc");

	var i = 0;
	var exercise = exercises.workout[i];
	var tt = setInterval(function () {

		desc.textContent = exercise[0];
		time.textContent = exercise[1];

		document.getElementById("time").textContent = exercise[1].toFixed(0);
		exercise[1] = exercise[1] - 1;

		if (exercise[1] <= 0) {
			i++;
			exercise = exercises.workout[i];
			if (i > exercises.workout.length - 1) {
				setTimeout(function (){
					clearInterval(tt);
					desc.textContent = "You're done!";
					time.textContent = "";
					$("#workouts").show();
				}, 1000);
			}
		}
	}, 1000);
	desc.textContent = exercise[0];
	time.textContent = exercise[1];
};
```

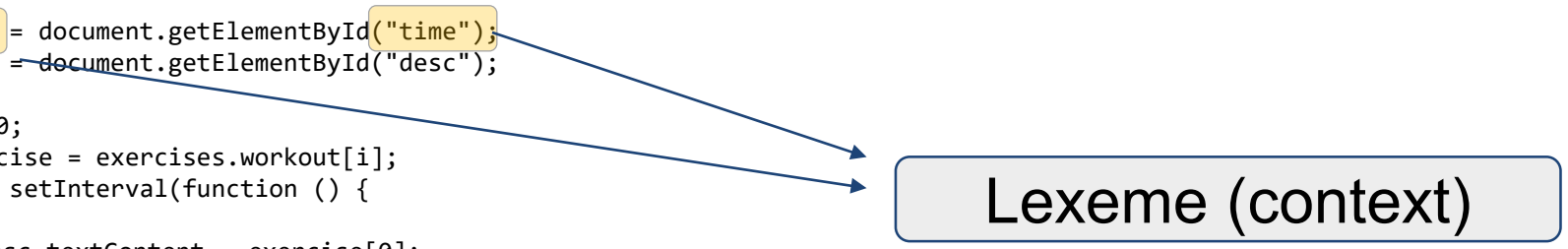
https://github.com/eykanal/exerciseTimer/blob/master/js/timer.js

```
var exerciseTimer = function (exercises) {
	$("#workouts").hide();

	var time = document.getElementById("time");
	var desc = document.getElementById("desc");

	var i = 0;
	var exercise = exercises.workout[i];
	var tt = setInterval(function () {

		desc.textContent = exercise[0];
		time.textContent = exercise[1];

		document.getElementById("time").textContent = exercise[1].toFixed(0);
		exercise[1] = exercise[1] - 1;

		if (exercise[1] <= 0) {
			i++;
			exercise = exercises.workout[i];
			if (i > exercises.workout.length - 1) {
				setTimeout(function (){
					clearInterval(tt);
					desc.textContent = "You're done!";
					time.textContent = "";
					$("#workouts").show();
				}, 1000);
			}
		}
	}, 1000);
	desc.textContent = exercise[0];
	time.textContent = exercise[1];
};
```

Symbols (morphology)

https://github.com/eykanal/exerciseTimer/blob/master/js/timer.js

```
var exerciseTimer = function (exercises) {
	$("#workouts").hide();

	var time = document.getElementById("time");
	var desc = document.getElementById("desc");

	var i = 0;
	var exercise = exercises.workout[i];
	var tt = setInterval(function () {

		desc.textContent = exercise[0];
		time.textContent = exercise[1];

		document.getElementById("time").textContent = exercise[1].toFixed(0);
		exercise[1] = exercise[1] - 1;

		if (exercise[1] <= 0) {
			i++;
			exercise = exercises.workout[i];
			if (i > exercises.workout.length - 1) {
				setTimeout(function (){
					clearInterval(tt);
					desc.textContent = "You're done!";
					time.textContent = "";
					$("#workouts").show();
				}, 1000);
			}
		}
	}, 1000);
	desc.textContent = exercise[0];
	time.textContent = exercise[1];
};
```

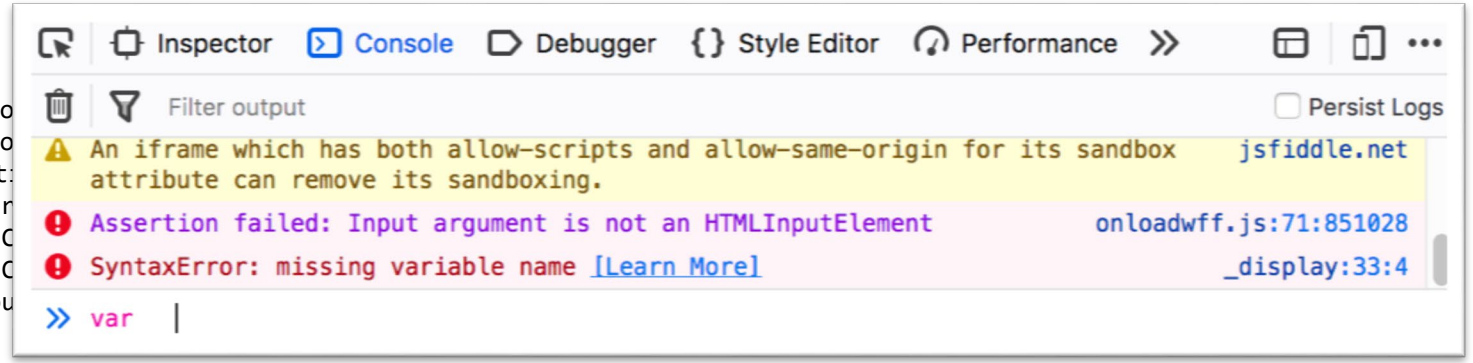


https://github.com/eykanal/exerciseTimer/blob/master/js/timer.js

```
var exerciseTimer = function (exercises) {
      $("#workouts").hide();

      var time = document.getElementById("time");
      var desc = document.getElementById("desc");

      var i = 0;
      var exercise = exercises.workout[i];
      var tt = setInterval(function () {

            desc.textContent = exercise[0];
            time.textContent = exercise[1];

            document.getElementById("time").textContent = exercise[1].toFixed(0);
            exercise[1] = exercise[1] - 1;

            if (exercise[1] <= 0) {
                  i++;
                  exercise = exercises.wo
                  if (i > exercises.worko
                        setTimeout(funct
                              clearInter
                              desc.textC
                              time.textC
                              $("#workou
                        }, 1000);
                  }
            }
      }, 1000);
      desc.textContent = exercise[0];
      time.textContent = exercise[1];
};
```

Syntax

We all know this one



https://github.com/eykanal/exerciseTimer/blob/master/js/timer.js

```
var exerciseTimer = function (exercises) {
      $("#workouts").hide();

      var time = document.getElementById("time");
      var desc = document.getElementById("desc");

      var i = 0;
      var exercise = exercises.workout[i];
      var tt = setInterval(function () {

            desc.textContent = exercise[0];
            time.textContent = exercise[1];

            document.getElementById("time").textContent = exercise[1].toFixed(0);
            exercise[1] = exercise[1] - 1;

            if (exercise[1] <= 0) {
                  i++;
                  exercise = exercises.workout[i];
                  if (i > exercises.workout.length - 1) {
                        setTimeout(function (){
                              clearInterval(tt);
                              desc.textContent = "You're done!";
                              time.textContent = "";
                              $("#workouts").show();
                        }, 1000);
                  }
            }
      }, 1000);
      desc.textContent = exercise[0];
      time.textContent = exercise[1];
};
```

Pragmatics, Discourse

Complex apps
APIs

https://github.com/eykanal/exerciseTimer/blob/master/js/timer.js

NLP for “Big Code”

https://ml4code.github.io/

A Survey of Machine Learning for Big Code and Naturalness

MILTIADIS ALLAMANIS, Microsoft Research
EARL T. BARR, University College London
PREMKUMAR DEVANBU, University of California, Davis
CHARLES SUTTON, University of Edinburgh and The Alan Turing Institute

NLP for “Big Code”:

- Code-generating models
- Representational models
- Pattern mining models

A++++
WOULD READ AGAIN

M. Allamanis, E. T. Barr, P. Devanbu, and C. Sutton, “A Survey of Machine Learning for Big Code and Naturalness,” Sep. 2017.

Code generating models – *n*-grams

"I made a peanut butter and jelly _____."

Bigram: "jelly _____"

$$P\left(w_n|w_1^{n-1}\right) \approx P\left(w_n|w_{n-1}\right)$$

5-gram: "peanut butter and jelly _____"

$$P\left(w_n|w_1^{n-1}\right) \approx P\left(w_n|w_{n-4}^{n-1}\right)$$

General case:

$$P\left(w_n|w_1^{n-1}\right) \approx P\left(w_n|w_{n-N+1}^{n-1}\right)$$

n-grams

```
for i in range(10
```

Bigram: “10”

4-gram: “range(10”

6-gram: “i in range(10”

n-grams – Does it work?

3- or 4-grams optimal for both natural language and code

Code 5x more regular (predictable) than natural language

2nd study (not shown) suggests ~62k LOC needed for code language model

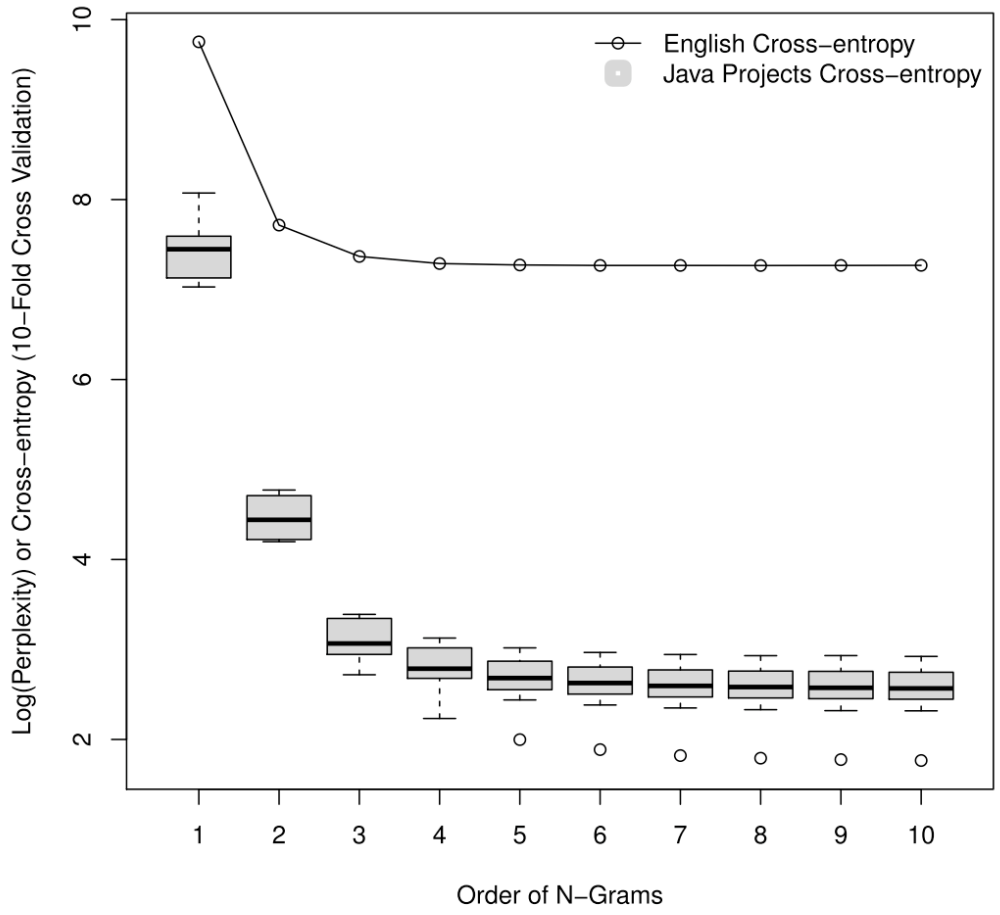
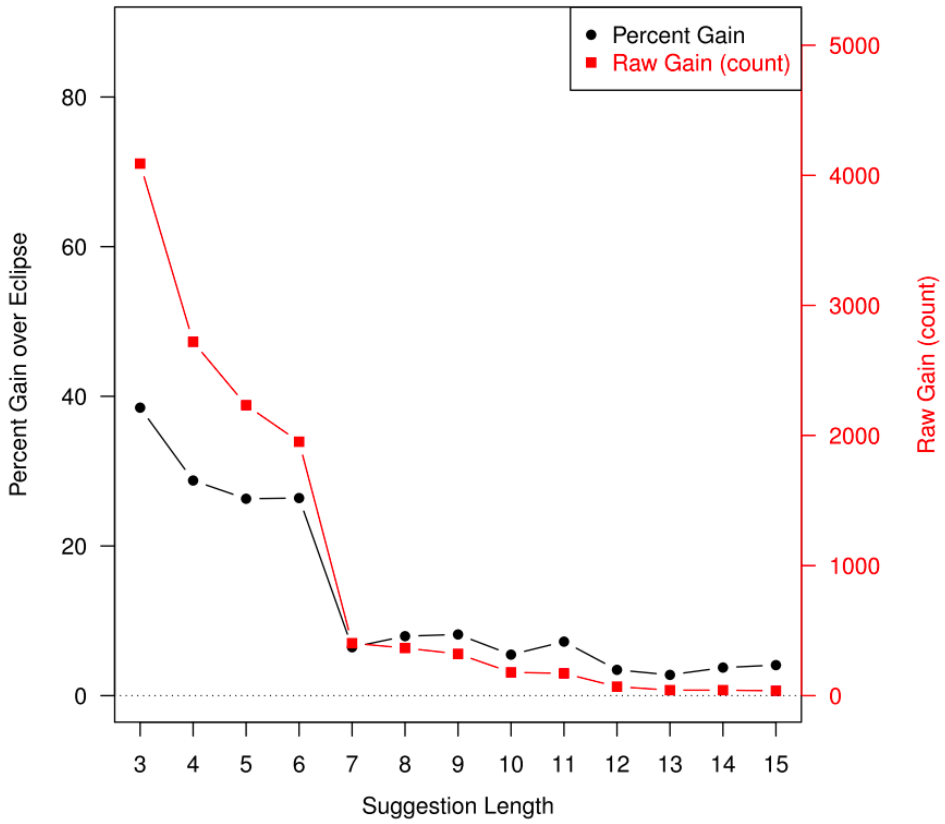


Figure 1. Comparison of English cross-entropy versus the code cross-entropy of 10 Java projects.

A. Hindle, E. T. Barr, Z. Su, M. Gabel, and P. Devanbu, "On the naturalness of software," in *2012 34th International Conference on Software Engineering (ICSE)*, 2012, pp. 837–847.

n-grams – Does it work?

Built autocomplete augmenter first 2, 6, or 10 suggestions from ngrams model (10 shown)



(c) Gain using top 10 suggestions.

Figure 4. Suggestion gains from merging n-gram suggestions into those of Eclipse.

A. Hindle, E. T. Barr, Z. Su, M. Gabel, and P. Devanbu, "On the naturalness of software," in *2012 34th International Conference on Software Engineering (ICSE)*, 2012, pp. 837–847.

Embeddings – word2vec

- How do computers represent what a word “means”?
- Ontologies (e.g., WordNet) – list all words & relationships
  - tedious (read: expensive) to build
  - often miss relationships
  - impossible to keep up-to-date
- **Basic problem**: discrete representation of words fails
  - e.g., “hotel” = `[0 0 0 … 0 0 0 1 0 … 0 0]`
    “motel” = `[0 0 0 … 0 1 0 0 0 … 0 0]`
  - Can’t use typical math tools (dot product, cosine similarity)
  - Expensive to maintain secondary mapping vectors

T. Mikolov, K. Chen, G. Corrado, and J. Dean, “Efficient Estimation of Word Representations in Vector Space,” Jan. 2013.

Embeddings – word2vec

"You shall know a word by the company it keeps"
(Firth, J. R. 1957:11)

word2vec: represent meaning by frequency of words appearing in similar context

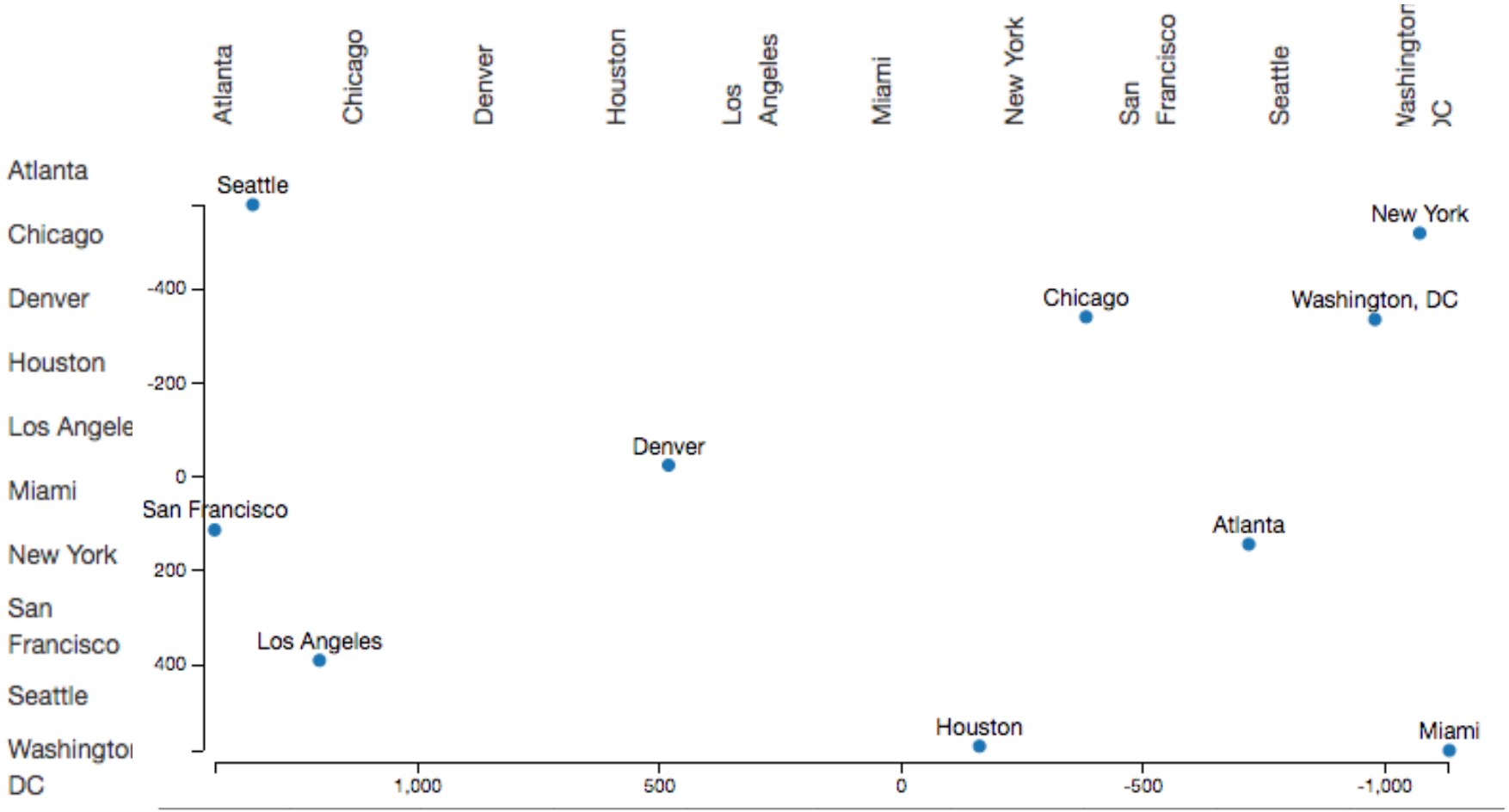
Usually, the large-scale **factory** is portrayed as a product of capitalism…

At the magnetron workshop in the old biscuit **factory**, Fisk sometimes wore a striped…

These words will represent "factory"

Behemoth: A History of the Factory and the Making of the Modern World, by Joshua B. Freeman
The Idea Factory: Bell Labs and the Great Age of American Innovation, by Jon Gertner

Embeddings - Maps



https://www.benfrederickson.com/multidimensional-scaling/

Embeddings – word2vec

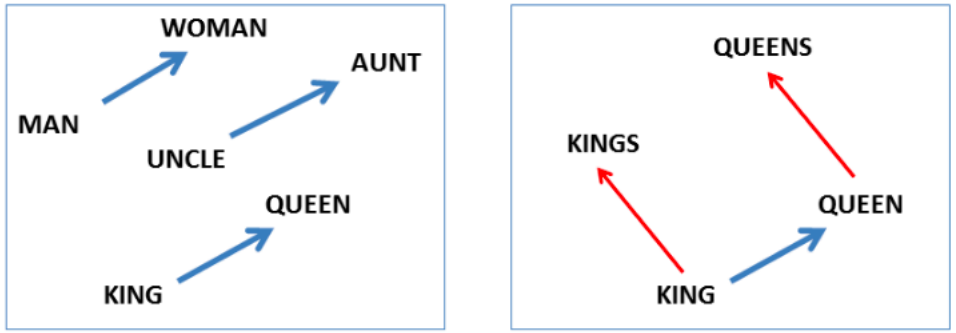


Figure 2: Left panel shows vector offsets for three word pairs illustrating the gender relation. Right panel shows a different projection, and the singular/plural relation for two words. In high-dimensional space, multiple relations can be embedded for a single word.

T. Mikolov, W. Yih, and G. Zweig, "Linguistic Regularities in Continuous Space Word Representations." pp. 746–751, 2013.

Somewhat surprisingly, it was found that similarity of word representations goes beyond simple syntactic regularities. Using a word offset technique where simple algebraic operations are performed on the word vectors, it was shown for example that *vector("King") - vector("Man") + vector("Woman")* results in a vector that is closest to the vector representation of the word *Queen* [20].

T. Mikolov, K. Chen, G. Corrado, and J. Dean, "Efficient Estimation of Word Representations in Vector Space," Jan. 2013.

Embeddings

- How it works: https://jalammar.github.io/illustrated-word2vec/

  …also a million other sites

- Advances: doc2vec, seq2seq, numerous others

code2vec – find code vectors!

U. Alon, M. Zilberstein, O. Levy, and E. Yahav, "code2vec: Learning Distributed Representations of Code," Mar. 2018.

Step back – Language model

"Assign a probability to a sequence of words"

Language:

Roethlisberger is a better QB than Brady

Colorless green ideas sleep furiously

Code:

```
for i in range(10):
    print(i)
```

```
52 var % function
eeeee class ".(
```

Entirely dependent on training data!

Step back – Language model

Model* built from training codebase

- Code symbols
- Other details in the dataset

Possible uses?

- Examine frequency of symbols
- Given some code, what is “similar” code?
- Given non-code input (e.g., comments, requirements), what code best matches input?

* Assign a probability to a sequence of words

Embeddings – code2vec

code2vec: Learning Distributed Representations of Code

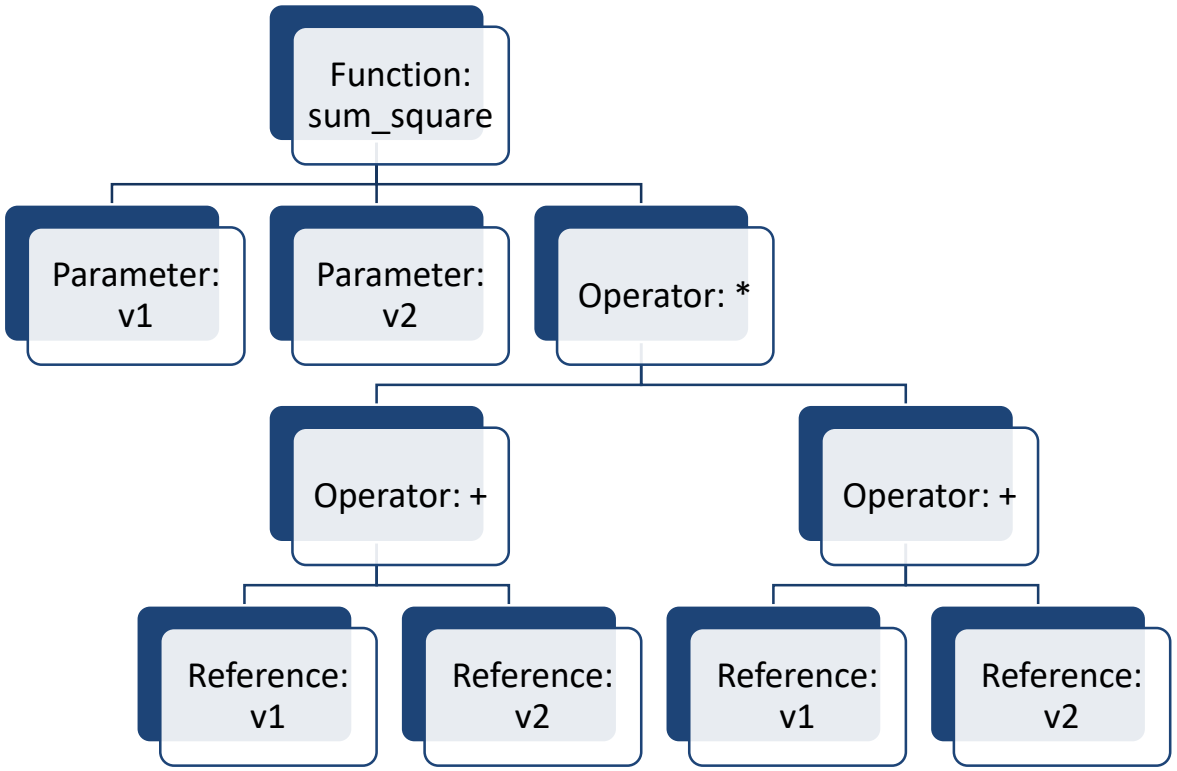
URI ALON, Technion
MEITAL ZILBERSTEIN, Technion
OMER LEVY, Facebook AI Research
ERAN YAHAV, Technion

Grabbed a ton of code from Github (>10k Java code repos)

Motivating question: Can we predict a method name simply by looking at the method's code?

Uses tokenized representation of AST (Abstract Syntax Trees) to describe code

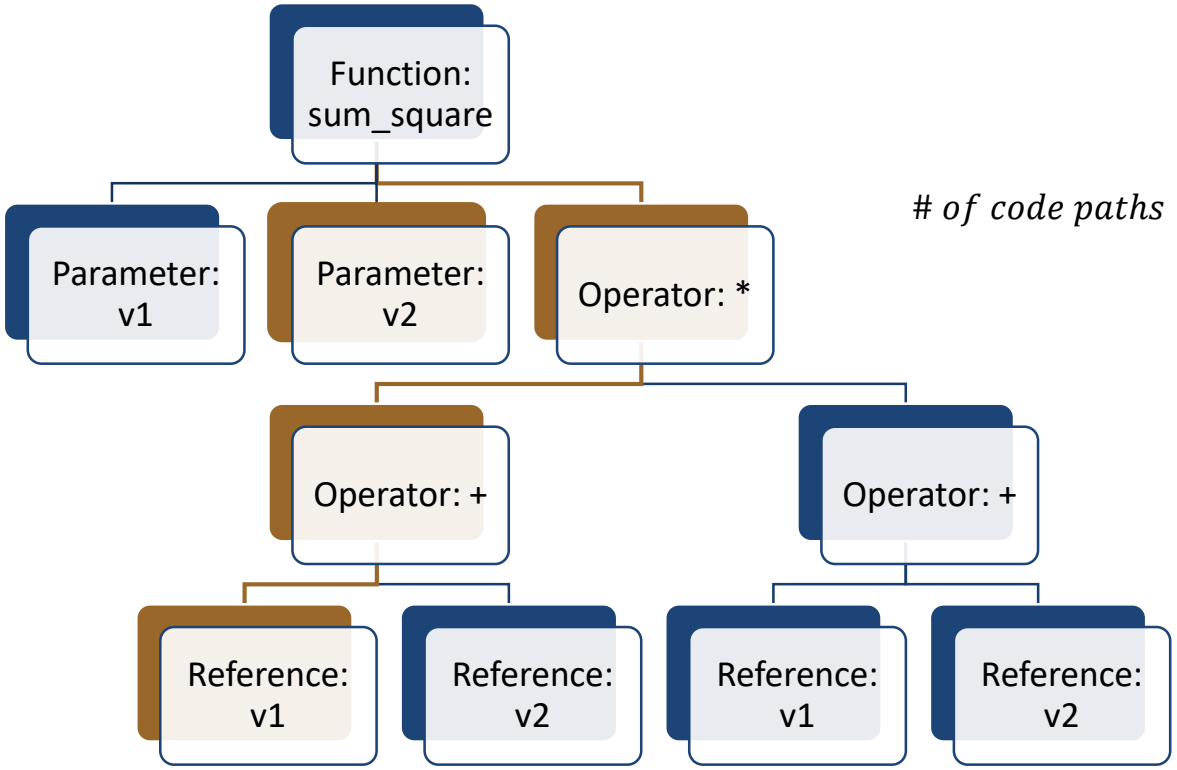
Step back (again) – Abstract Syntax Trees




```
int sum_square(int v1, int v2)
{
      return (v1+v2)*(v1+v2);
}
```

Step back (again) – Abstract Syntax Trees

```
v1, [(Ref)v1 ^ (Op)+ ^ (Op)* ^ (Func) _ (Par)v2], v2
```



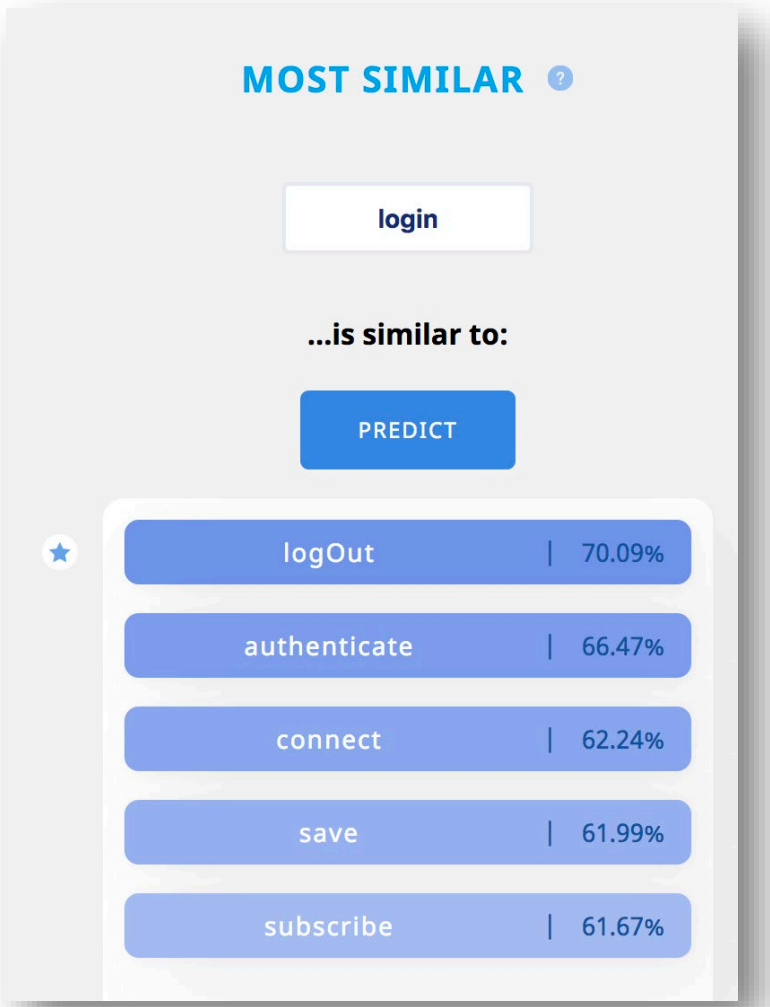
$$\#\ of\ code\ paths\ \approx\ \#\ of\ Leaves^2$$

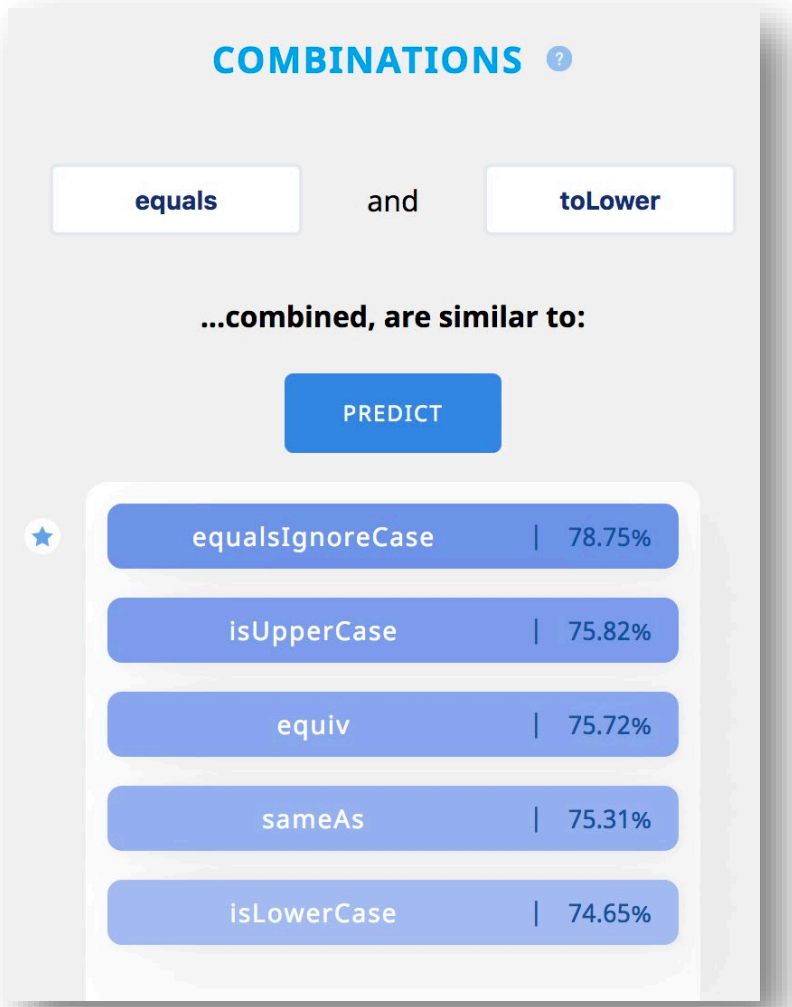
Step back (again) – Abstract Syntax Trees

```
sum|square v1,(PARM_DECL)^(FUNCTION_DECL)_(PARM_DECL),v2
v1,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v1,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v1,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v1,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v2,(PARM_DECL)^(FUNCTION_DECL)_(PARM_DECL),v1
v2,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v2,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v2,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v2,(PARM_DECL)^(FUNCTION_DECL)_(COMPOUND_STMT)_(RETURN_STMT)_(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v1
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v2
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v1
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v2
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v1
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v2
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v1,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v1
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)^(RETURN_STMT)^(COMPOUND_STMT)^(FUNCTION_DECL)_(PARM_DECL),v2
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)^(PAREN_EXPR)^(BINARY_OPERATOR:*)_(PAREN_EXPR)_(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v2
v2,(DECL_REF_EXPR)^(UNEXPOSED_EXPR)^(BINARY_OPERATOR:+)_(UNEXPOSED_EXPR)_(DECL_REF_EXPR),v1
```

These are the “words” for code2vec

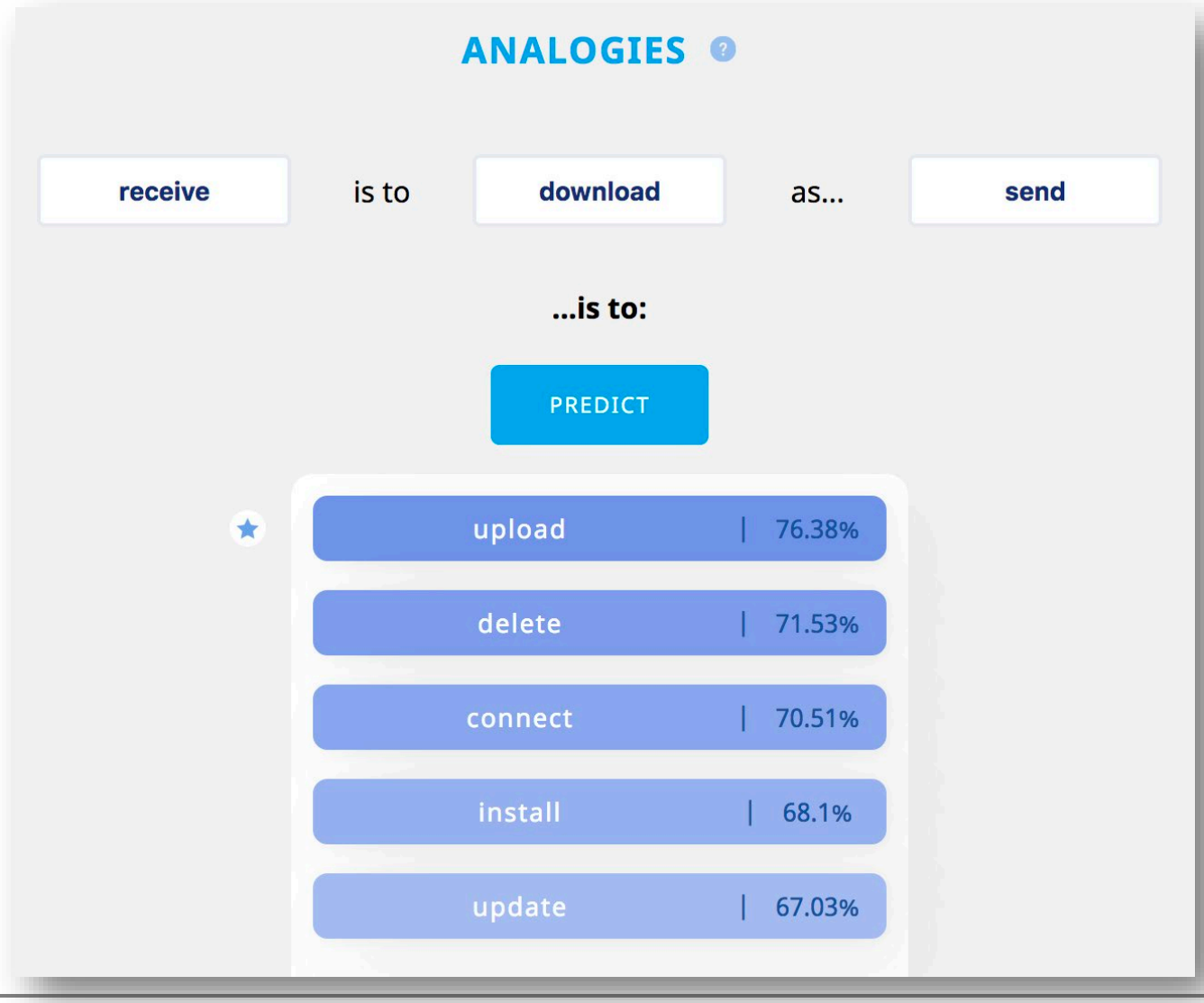
Embeddings – code2vec





https://code2vec.org/

Embeddings – code2vec



https://code2vec.org/

ML for clean code

Coding conventions are critical for medium-to-large teams

- Prevent bugs
- Make code easier to read, navigate, & maintain

Learning Natural Coding Conventions

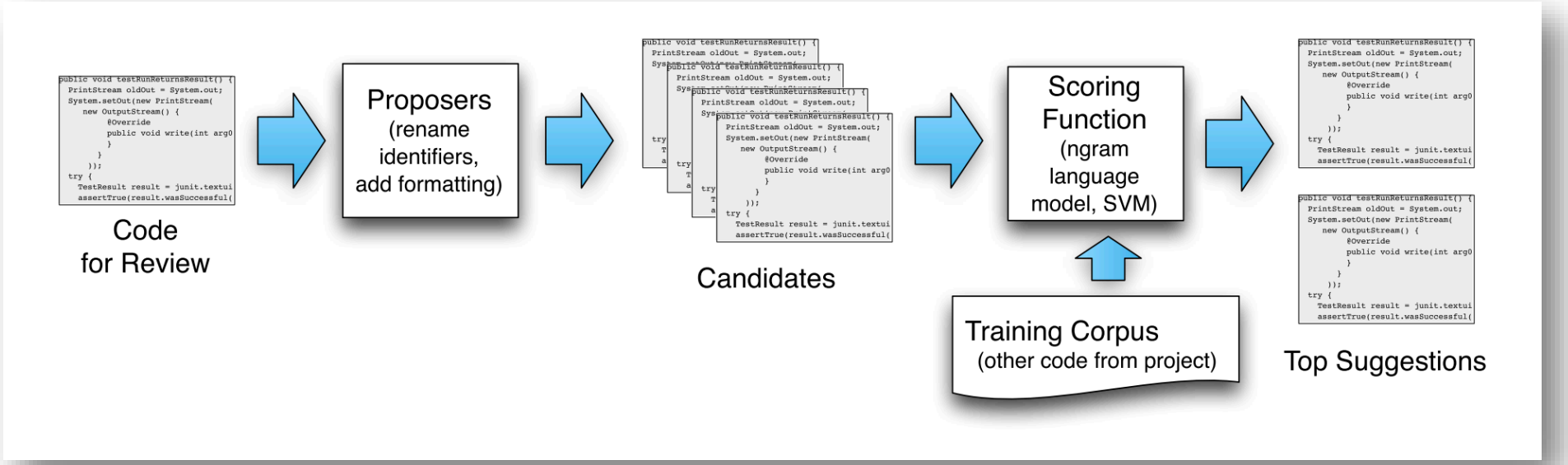
Miltiadis Allamanis[†] Earl T. Barr[‡] Christian Bird[⋆] Charles Sutton[†]

[†]School of Informatics
University of Edinburgh
Edinburgh, EH8 9AB, UK
{m.allamanis, csutton}@ed.ac.uk

[‡]Dept. of Computer Science
University College London
London, UK
e.barr@ucl.ac.uk

[⋆]Microsoft Research
Microsoft
Redmond, WA, USA
christian.bird@microsoft.com

ML for clean code



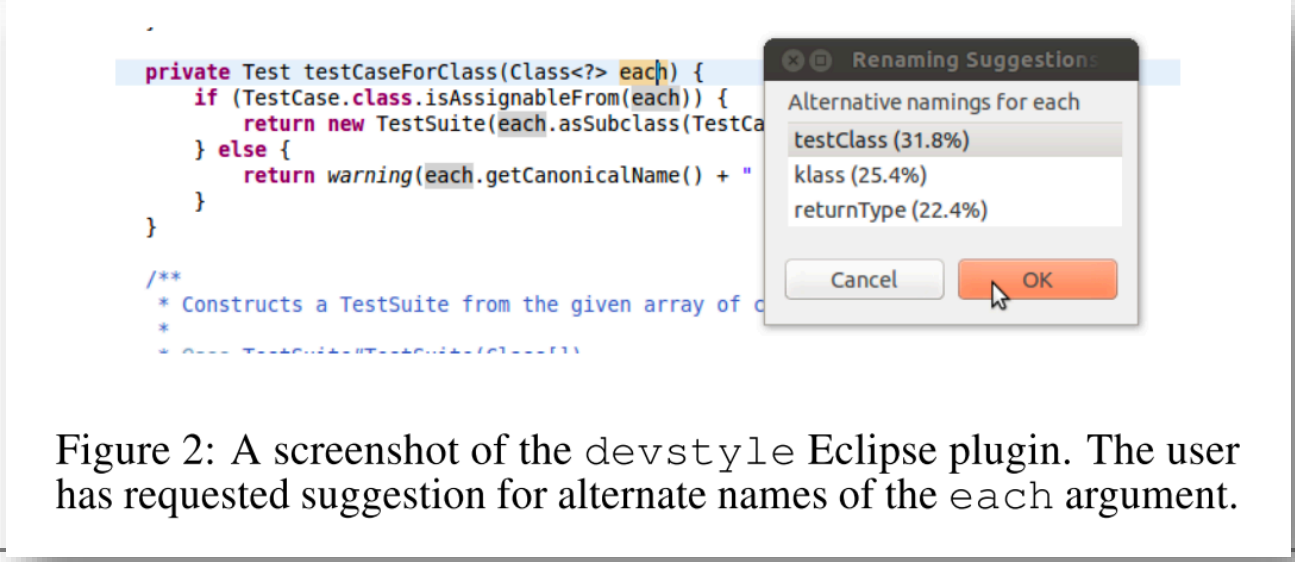


Figure 2: A screenshot of the `devstyle` Eclipse plugin. The user has requested suggestion for alternate names of the `each` argument.

ML for code security

Find bugs themselves

- Most of your code is (probably) correct
- Buggy code is rare
- If you see rare code similar to common code, it's probably buggy

Find bugs themselves

Bugram: Bug Detection with N-gram Language Models

Song Wang*, Devin Chollak*, Dana Movshovitz-Attias†, Lin Tan*
*Electrical and Computer Engineering, University of Waterloo, Canada
†Computer Science Department, Carnegie Mellon University, USA
*{song.wang, dchollak, lintan}@uwaterloo.ca, †dma@cs.cmu.edu

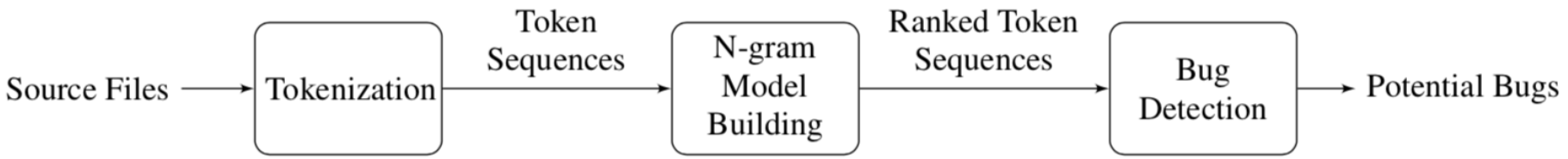


Figure 3: **Overview of Bugram**

S. Wang, D. Chollak, D. Movshovitz-Attias, and L. Tan, "Bugram: bug detection with n-gram language models," 2016.

(a) **Method call sequence from a buggy code snippet (appears once):** `[isDebugEnabled(), debug(), indent(), stringify()]`

```
1 if (LOG.isDebugEnabled()) {
2     LOG.debug(indent(depth)+"converting from
3         Pig " + pigType + " " + value +
4         " using " + stringify(schema));
5 }
```

(b) **A similar but correct method call sequence (appears three times):** `[isDebugEnabled(), debug(), indent(), toString())]`

```
1 if (LOG.isDebugEnabled()) {
2     LOG.debug(indent(depth)+"converting from
3         Pig " + pigType + " " +
              toString(value) +
4         " using " + stringify(schema));
5 }
```

Figure 2: **A motivating example from the latest version 0.15.0 of the project Pig. Bugram automatically detected a real bug in (a), which has been *confirmed and fixed* by Pig developers after we reported it.**

Find bugs themselves

Java

Similar to previous work (same authors), Deep Belief Networks instead of *n*-grams

Motivating example: case where bag-of-words would fail

```
1 int i = 9;
2 if (i == 9) {
3   foo();
4   for (i = 0; i < 10;
        i++) {
5     bar();
6   }
7 }
```

```
1 int i = 9;
2 foo();
3 for (i = 0; i < 10; i
      ++) {
4   if (i == 9) {
5     bar();
6   }
7 }
```

Think back… which techniques would work? Which wouldn't?

S. Wang, T. Liu, and L. Tan, "Automatically learning semantic features for defect prediction," in *Proceedings of the 38th International Conference on Software Engineering - ICSE '16*, 2016, pp. 297–308.

Find bugs themselves

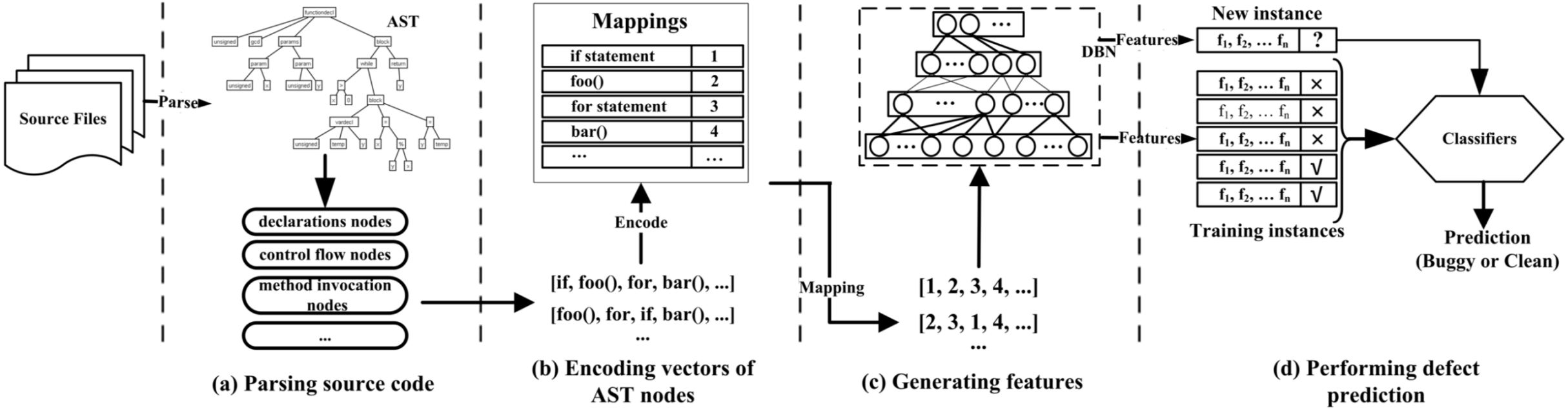


Figure 4: Overview of our proposed DBN-based feature generation and defect prediction

Code-to-Text – Automated documentation

Learning to Generate Pseudo-code from Source Code using Statistical Machine Translation

Yusuke Oda, Hiroyuki Fudaba, Graham Neubig, Hideaki Hata,
Sakriani Sakti, Tomoki Toda, and Satoshi Nakamura
Graduate School of Information Science, Nara Institute of Science and Technology
8916-5 Takayama, Ikoma, Nara 630-0192, Japan
{oda.yusuke.on9, fudaba.hiroyuki.ev6, neubig, hata, ssakti, tomoki, s-nakamura}@is.naist.jp

Four requirements listed:

- Accuracy
- Speed
- Automated
- On-demand

Y. Oda *et al.*, "Learning to Generate Pseudo-Code from Source Code Using Statistical Machine Translation," in *2015 30th IEEE/ACM International Conference on Automated Software Engineering (ASE)*, 2015, pp. 574–584.

Code-to-Text

"SMT" – Statistical Machine Translation

- Find relationships between tokens in different language models
- Propose many sentences, use statistical models to identify "best"

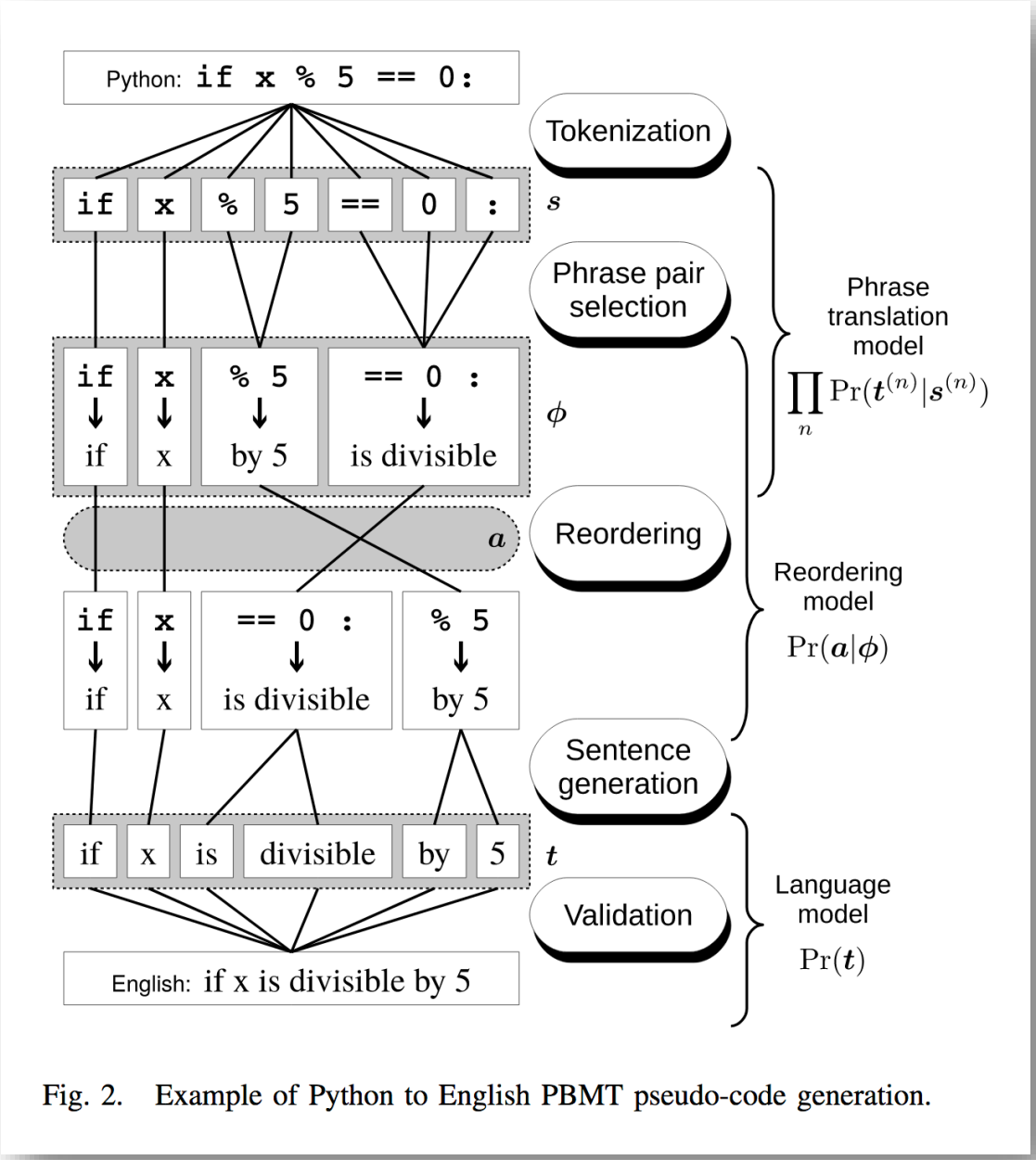


Fig. 2. Example of Python to English PBMT pseudo-code generation.

Code-to-Text

- Very impressive application of NLP to software domain
- Limitations: text is very pedantic, misses “big picture”
- More work described in Allamanis survey paper

Summary

NLP concepts can apply to code (“naturalness hypothesis”)

Techniques we discussed:

- *n*-grams, Annotated n-grams
- Embeddings (word2vec, code2vec)

Applications:

- Bug identification
- Code completion
- Documentation generation

Contact Us

Carnegie Mellon University

Software Engineering Institute

4500 Fifth Avenue

Pittsburgh, PA 15213-2612

412-268-5800

888-201-4479

info@sei.cmu.edu

www.sei.cmu.edu

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

DM19-0416