Microsoft

The Adverse Effects of Code Duplicates in Machine Learning Models of Code

Miltos Allamanis

Onward! 2019

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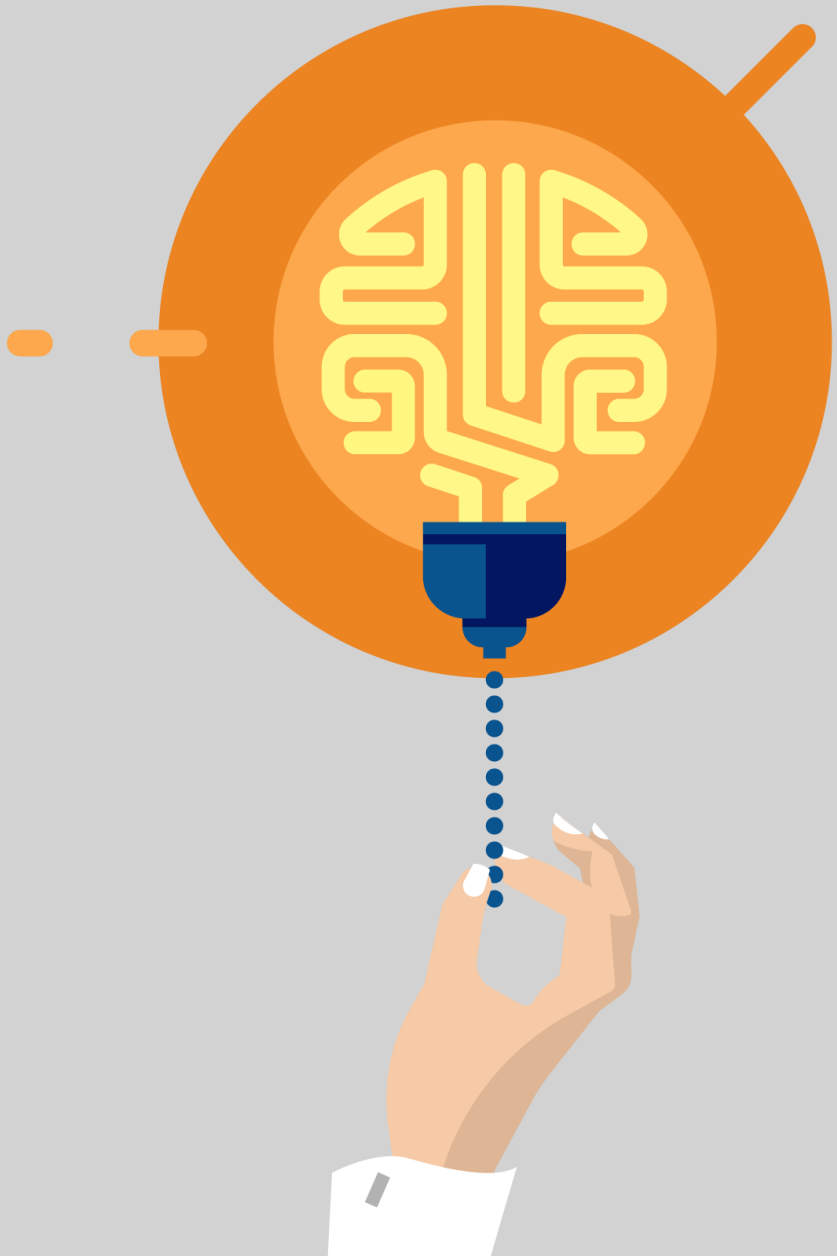
Microsoft Research Cambridge



What we know…

DéjàVu: A Map of Code Duplicates on GitHub

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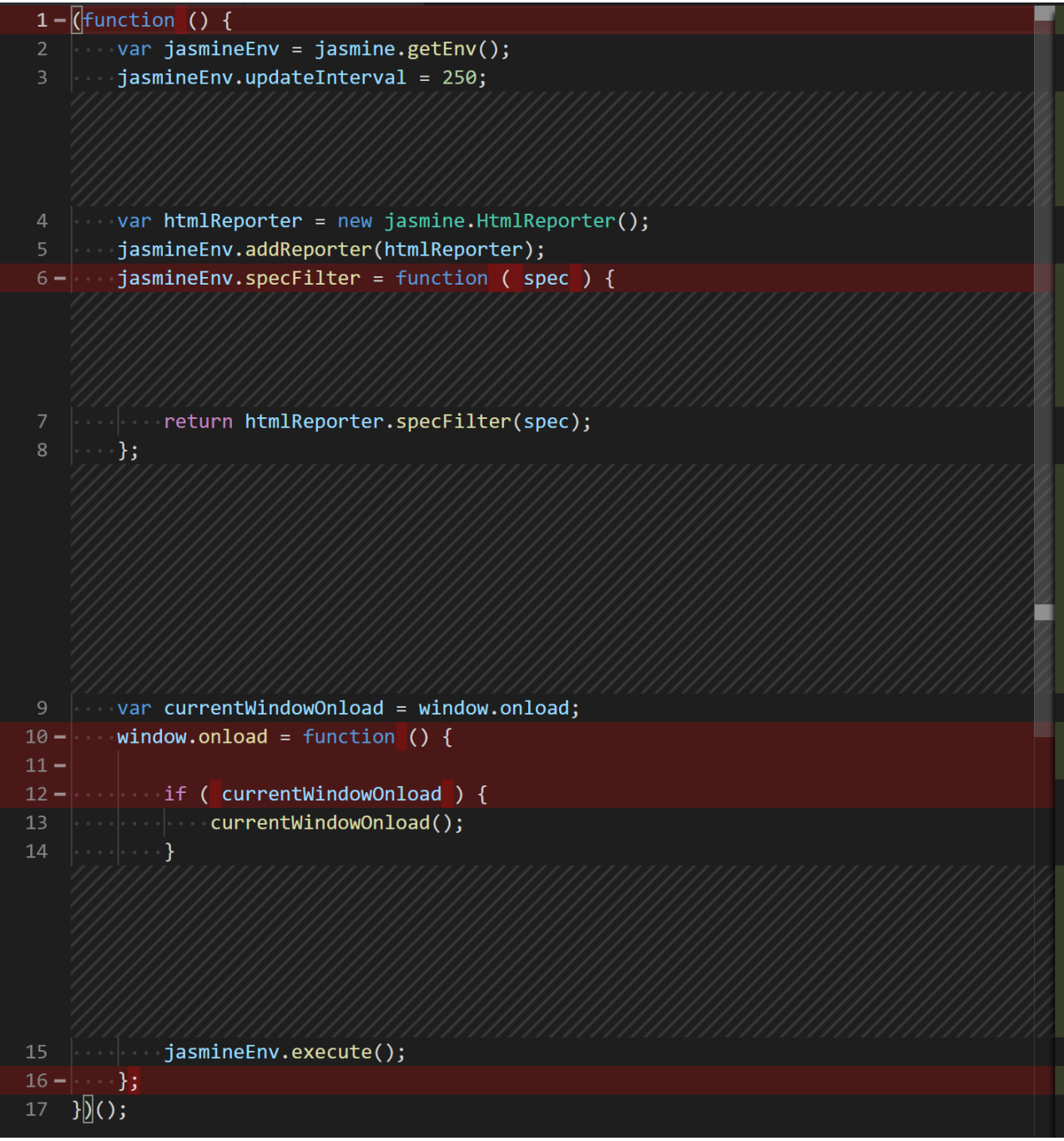
Previous studies have shown that there is a non-trivial amount of duplication in source code. This paper analyzes a corpus of 4.5 million non-fork projects hosted on GitHub representing over 428 million files written in Java, C++, Python, and JavaScript. We found that this corpus has a mere 85 million unique files. In other words, 70% of the code on GitHub consists of clones of previously created files. There is considerable variation between language ecosystems. JavaScript has the highest rate of file duplication, only 6% of the files are distinct. Java, on the other hand, has the least duplication, 60% of files are distinct. Lastly, a project-level analysis shows that between 9% and 31% of the projects contain at least 80% of files that can be found elsewhere. These rates of duplication have implications for systems built on open source software as well as for researchers interested

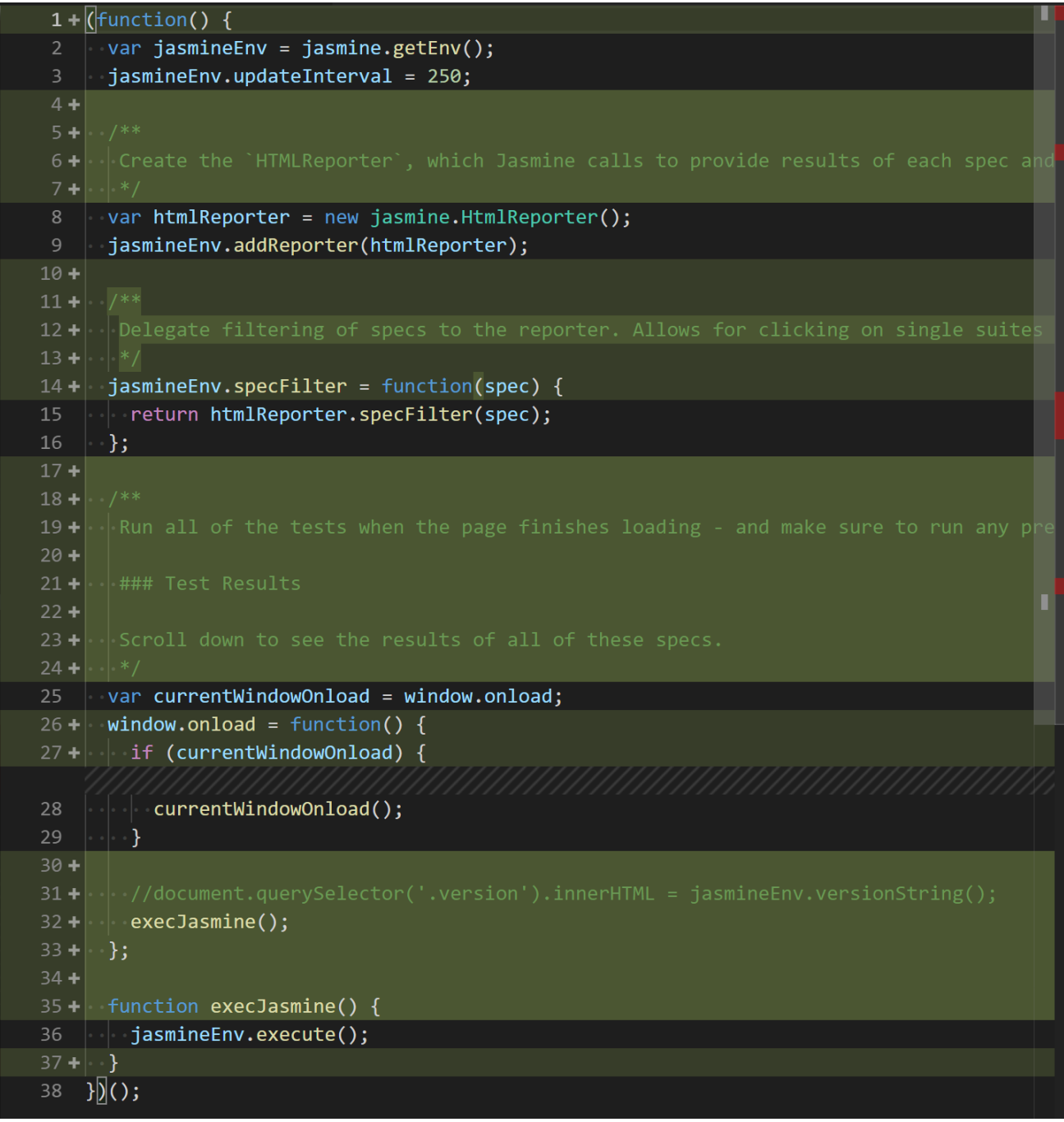
My Definition for Code Duplicates

- **File-Level (smaller chunks are ok)**
- Highly-Similar
- Not all clones are duplicates

```
[
  "0xsky/xblog/xblogroot/admin/tinymce/plugins/codemirror/CodeMirror/lib/codemirror.js",
  "benatkin/codemirror/codemirror.js",
  "cdnjs/cdnjs/ajax/libs/codemirror/3.16.0/codemirror.js",
  "cdnjs/cdnjs/ajax/libs/codemirror/3.21.0/codemirror.js",
  "cdnjs/cdnjs/ajax/libs/codemirror/3.22.0/codemirror.js",
  "cdnjs/cdnjs/ajax/libs/codemirror/3.23.0/codemirror.js",
  "disnet/contracts.js/js/codemirror.js",
  "ericbarnes/wardrobe/app/assets/vendor/plugins/editor/editor.js",
  "Paxa/postbird/lib/codemirror/codemirror.js",
  "renz45/cs_console/demo_app/cs_console.js",
  "tantaman/Strut/app/components/codemirror/codemirror.js",
  "TheMightyFingers/MightyEngine/editor/client/js/plugins/sourceEditor/cm/lib/codemirror.js",
  "yoavram/markx/static/js/codemirror.js"
]
```



```
(function () {
    var jasmineEnv = jasmine.getEnv();
    jasmineEnv.updateInterval = 250;

    var htmlReporter = new jasmine.HtmlReporter();
    jasmineEnv.addReporter(htmlReporter);
    jasmineEnv.specFilter = function ( spec ) {
        return htmlReporter.specFilter(spec);
    };

    var currentWindowOnload = window.onload;
    window.onload = function () {

        if ( currentWindowOnload ) {
            currentWindowOnload();
        }

        jasmineEnv.execute();
    };
})();
```



```
(function() {
  var jasmineEnv = jasmine.getEnv();
  jasmineEnv.updateInterval = 250;

  /**
   Create the `HTMLReporter`, which Jasmine calls to provide results of each spec and
   */
  var htmlReporter = new jasmine.HtmlReporter();
  jasmineEnv.addReporter(htmlReporter);

  /**
   Delegate filtering of specs to the reporter. Allows for clicking on single suites
   */
  jasmineEnv.specFilter = function(spec) {
    return htmlReporter.specFilter(spec);
  };

  /**
   Run all of the tests when the page finishes loading - and make sure to run any pre

   ### Test Results

   Scroll down to see the results of all of these specs.
   */
  var currentWindowOnload = window.onload;
  window.onload = function() {
    if (currentWindowOnload) {
      currentWindowOnload();
    }

    //document.querySelector('.version').innerHTML = jasmineEnv.versionString();
    execJasmine();
  };

  function execJasmine() {
    jasmineEnv.execute();
  }
})();
```

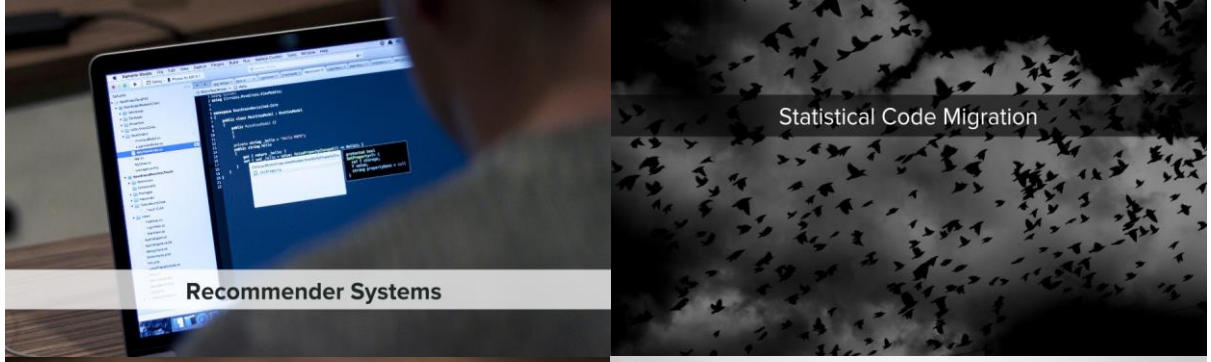
```
1280    return originOrUrl || null;
1281  };
1282
1283
1284  /**
1285   * Set `allowScriptAccess` based on `trustedDomains` and `window.location.host` vs.
1286   *
1287   * @returns The appropriate script access level.
1288   * @private
1289   */
1290  var _determineScriptAccess = (function() {
1291    var _extractAllDomains = function(origins) {
1292      var i, len, tmp,
1293          resultsArray = [];
1294      if (typeof origins === "string") {
1295        origins = [origins];
1296      }
1297      if (!(typeof origins === "object" && origins && typeof origins.length === "numbe
1298        return resultsArray;
1299      }
1300      for (i = 0, len = origins.length; i < len; i++) {
1301        if (_hasOwn.call(origins, i) && (tmp = _extractDomain(origins[i]))) {
1302          if (tmp === "*") {
1303            resultsArray.length = 0;
1304            resultsArray.push("*");
1305            break;
1306          }
1307          if (resultsArray.indexOf(tmp) === -1) {
1308            resultsArray.push(tmp);
1309          }
1310        }
1311      }
1312      return resultsArray;
1313    };
1314
1315    return function(currentDomain, configOptions) {
1316      // Get SWF domain
1317      var swfDomain = _extractDomain(configOptions.swfPath);
1318      if (swfDomain === null) {
1319        swfDomain = currentDomain;
1320      }
1321      // Get all trusted domains
1322      var trustedDomains = _extractAllDomains(configOptions.trustedDomains);
1323
1324      var len = trustedDomains.length;
```

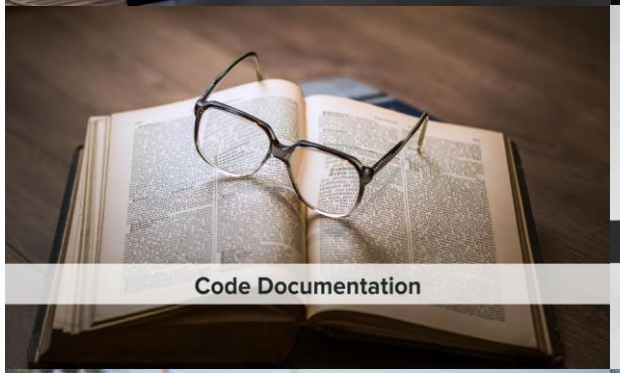
```
1200    return originOrUrl || null;
1201  };
1202
1203  /**
1204   * Set `allowScriptAccess` based on `trustedDomains` and `window.location.host` vs.
1205   *
1206   * @returns The appropriate script access level.
1207   * @private
1208   */
1209  var _determineScriptAccess = function() {
1210    var _extractAllDomains = function(origins, resultsArray) {
1211      var i, len, tmp;
1212      if (origins == null || resultsArray[0] === "*") {
1213        return;
1214      }
1215      if (typeof origins === "string") {
1216        origins = [ origins ];
1217      }
1218      if (!(typeof origins === "object" && typeof origins.length === "number")) {
1219        return;
1220      }
1221      for (i = 0, len = origins.length; i < len; i++) {
1222        if (_hasOwn.call(origins, i) && (tmp = _extractDomain(origins[i]))) {
1223          if (tmp === "*") {
1224            resultsArray.length = 0;
1225            resultsArray.push("*");
1226            break;
1227          }
1228          if (_inArray(tmp, resultsArray) === -1) {
1229            resultsArray.push(tmp);
1230          }
1231        }
1232      }
1233    };
1234
1235    return function(currentDomain, configOptions) {
1236      var swfDomain = _extractDomain(configOptions.swfPath);
1237      if (swfDomain === null) {
1238        swfDomain = currentDomain;
1239      }
1240      var trustedDomains = [];
1241      _extractAllDomains(configOptions.trustedOrigins, trustedDomains);
1242      _extractAllDomains(configOptions.trustedDomains, trustedDomains);
1243      var len = trustedDomains.length;
```

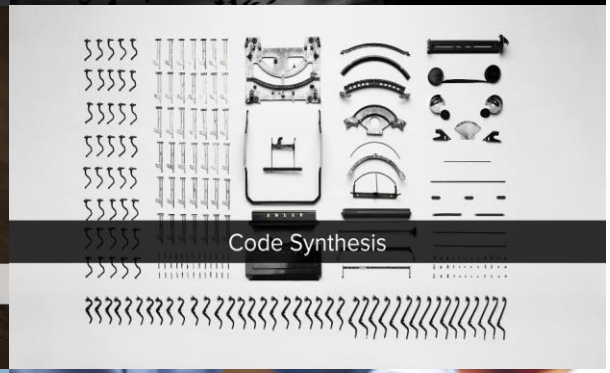
Big Code

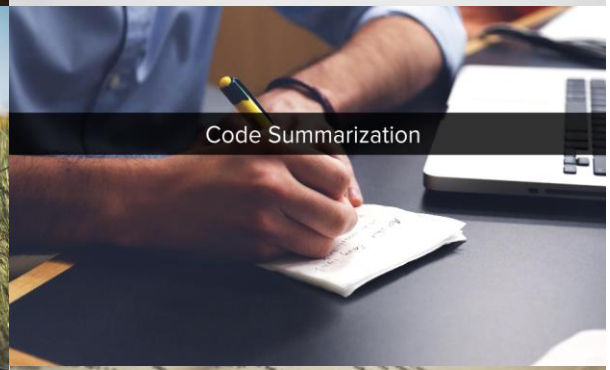
Most often: use trained models to provide recommendations and insights on *new and unseen code* when the software engineer is creating or maintaining it.

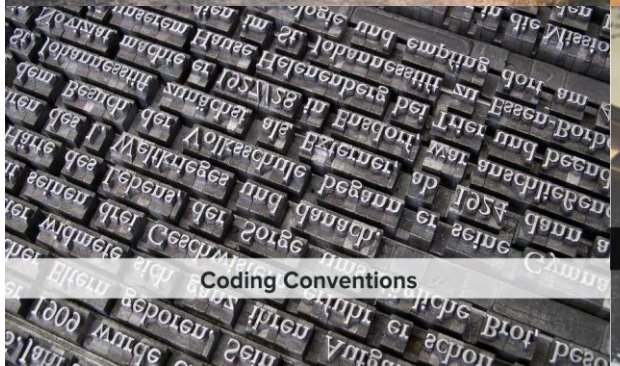
"Would the tool operate in code that contains duplicates?"

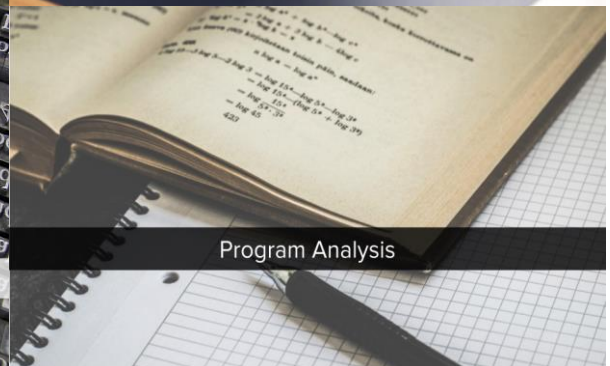










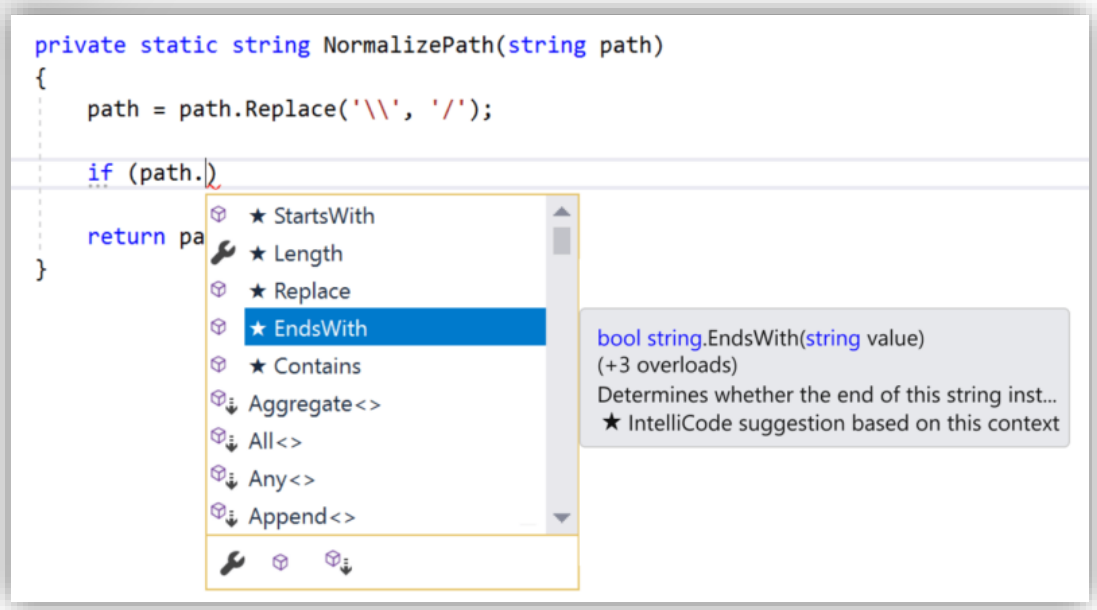


Code Autocompletion

```
Text text = new Text(parent, SWT.NONE);
text.
```

setLayoutData(Object layoutData) : void - Control - 86%
setText(String string) : void - Text - 51%
addModifyListener(ModifyListener listener) : void - Text - 31%
getText() : String - Text - 12%
setEnabled(boolean enabled) : void - Control - 11%
setFont(Font font) : void - Control - 8%
Press '^Space' to show Adaptive Template Proposals (Code Recommenders)

http://www.eclipse.org/recommenders/



https://visualstudio.microsoft.com/services/intellicode/

Variable Misuse

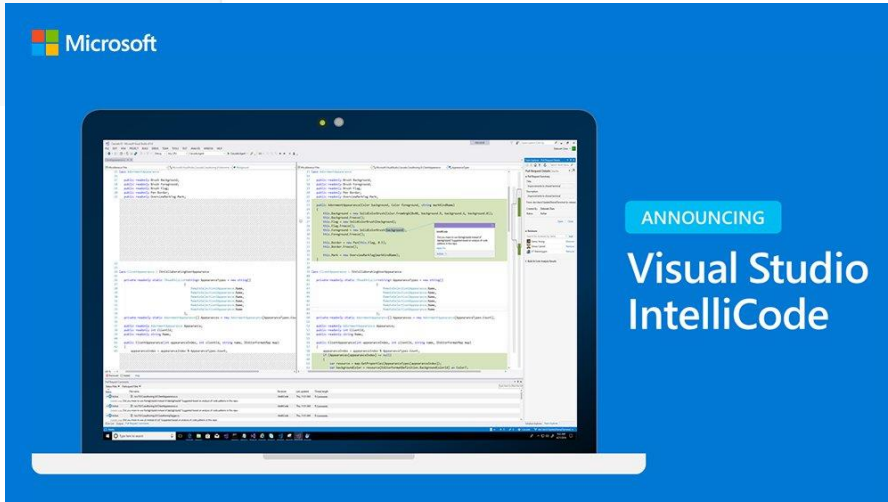
```
// Create or update the document.
var newDocument = await cosmosClient.UpsertDocumentAsync(cosmosDbCollectionUri, document);

if (updateRecord)
{
    logger.WriteLog($"Updated {existingDocument} to {newDocument}");
}
else
{
    logger.WriteLog($"Added {existingDocument}");
```

[redacted] Update 1 1 Resolved

Based on this repo's code patterns, did you intend to use 'newDocument' (confidence 92%) rather than 'existingDocument` (confidence 7%) here? Review is recommended by Research bot's Variable Misuse analysis.

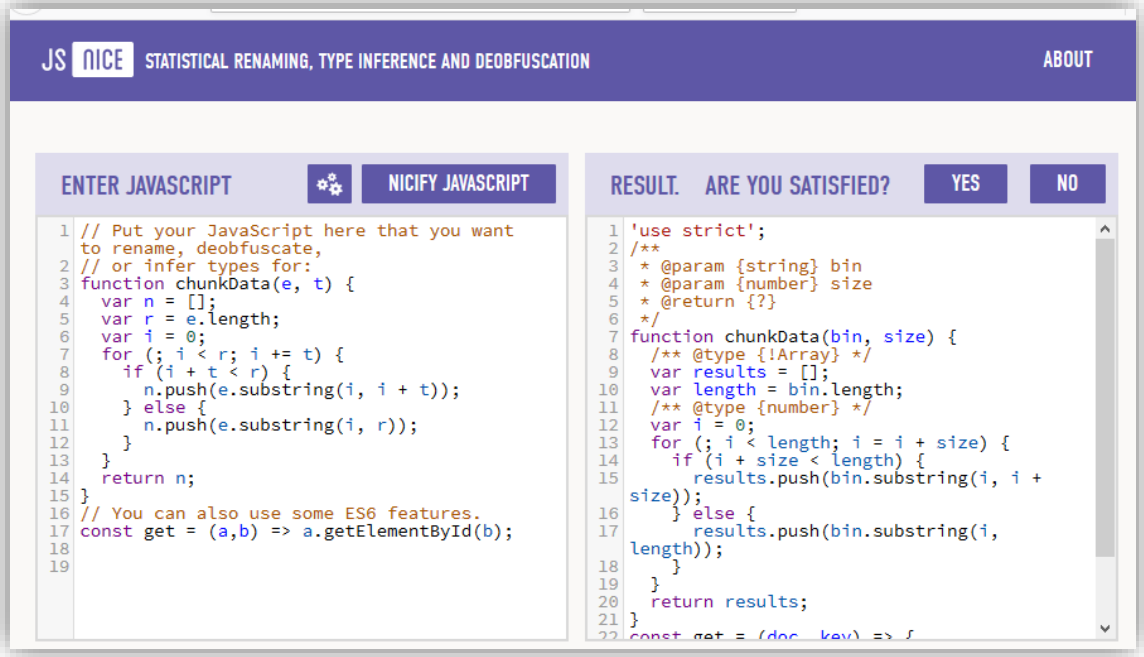
JK [redacted]

+1



Allamanis *et al.* "Learning to Represent Programs with Graphs". 2018

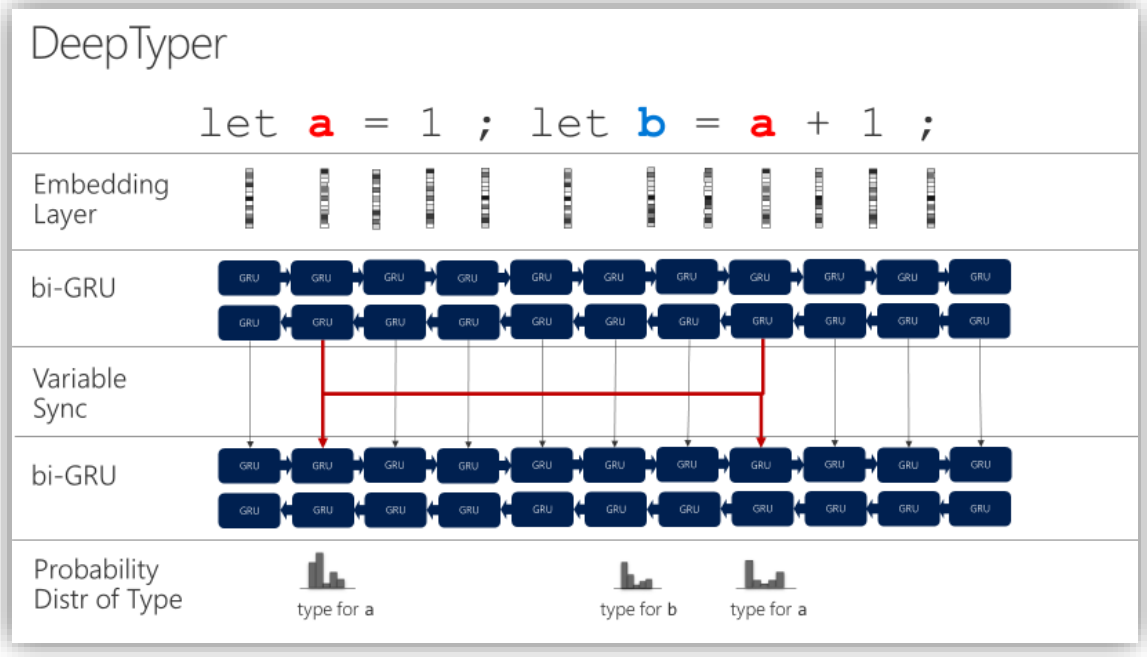
Predicting Types



Predicting Program Properties from Code

V. Raychev, M. Vechev, A. Krause. 2015

http://jsnice.org/



Deep Learning Type Inference

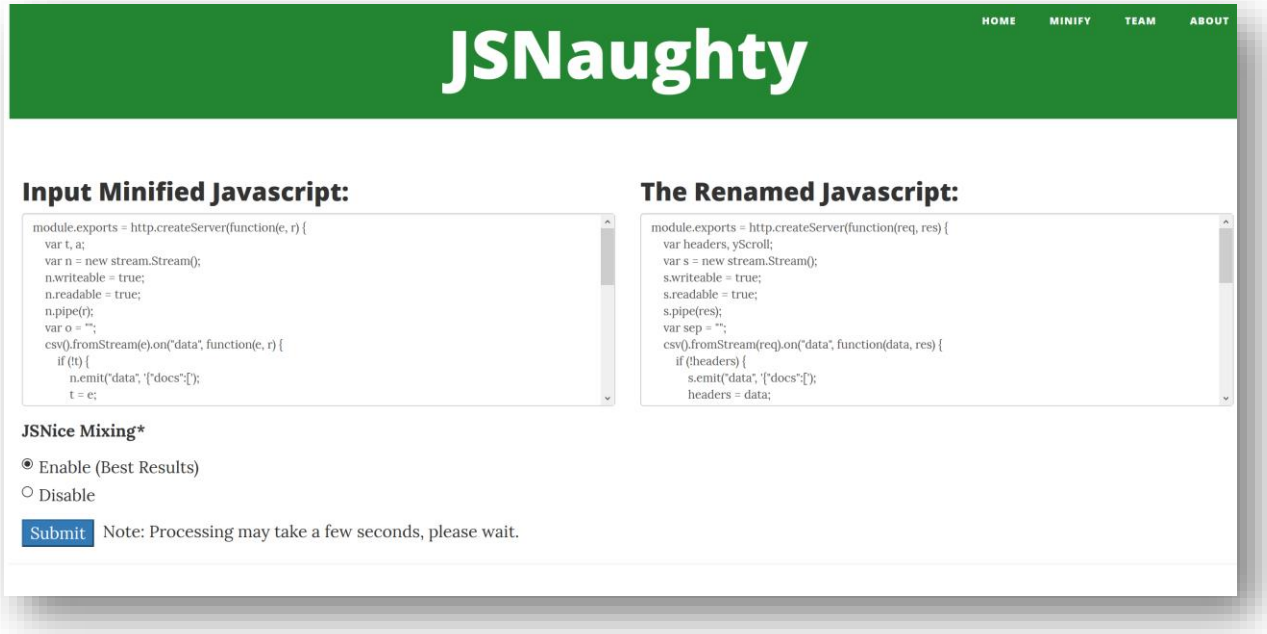
V. Hellendoorn, C. Bird, E.T. Barr, M. Allamanis. 2018

Predicting Names (Deobfuscation)

Predicting Program Properties from Code

V. Raychev, M. Vechev, A. Krause. 2015

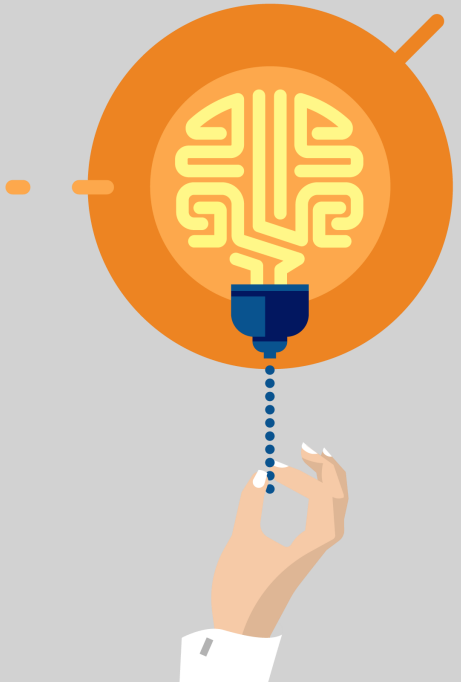
http://jsnice.org/



Recovering Clear, Natural Identifiers from Obfuscated JS Names B. Vasilescu, C. Casalnuovo, P. Devanbu. 2017

http://tardigrade.andrew.cmu.edu:8000/get_js/

… in most cases we want to make suggestions for *new, previously unseen* code.



How does duplication bias learning/evaluation?

$$\hat{f} = \frac{1}{|D|} \sum_{x_i \in D} f(x_i)$$

$$X = \{(x_i, c_i)\}$$

$$\hat{f} = (1 - d) \underbrace{\frac{1}{|X|} \sum_{x_i \in X} f(x_i)}_{\text{unbiased estimate } \bar{f}} + d \underbrace{\frac{1}{|D| - |X|} \sum_{x_i \in X} (c_i - 1) f(x_i)}_{\text{duplication bias } \beta}$$

But I've deduplicated the corpus!

… that's what I thought too!

```
1  public void execute(Runnable task) {
2      if (task == null)
3          throw new NullPointerException();
4      ForkJoinTask<?> job;
5      if (task instanceof ForkJoinTask<?>) // avoid re-wrap
6          job = (ForkJoinTask<?>) task;
7      else
8          job = new ForkJoinTask.AdaptedRunnableAction(task);
9      doSubmit(job);
10 }
```

```
public void execute(Runnable task) {
    if (task == null)
        throw new NullPointerException();
    ForkJoinTask<?> job;
    if (task instanceof ForkJoinTask<?>) // avoid re-wrap
        job = (ForkJoinTask<?>) task;
    else
        job = new ForkJoinTask.AdaptedRunnableAction(task);
    doSubmit(job);
}
```

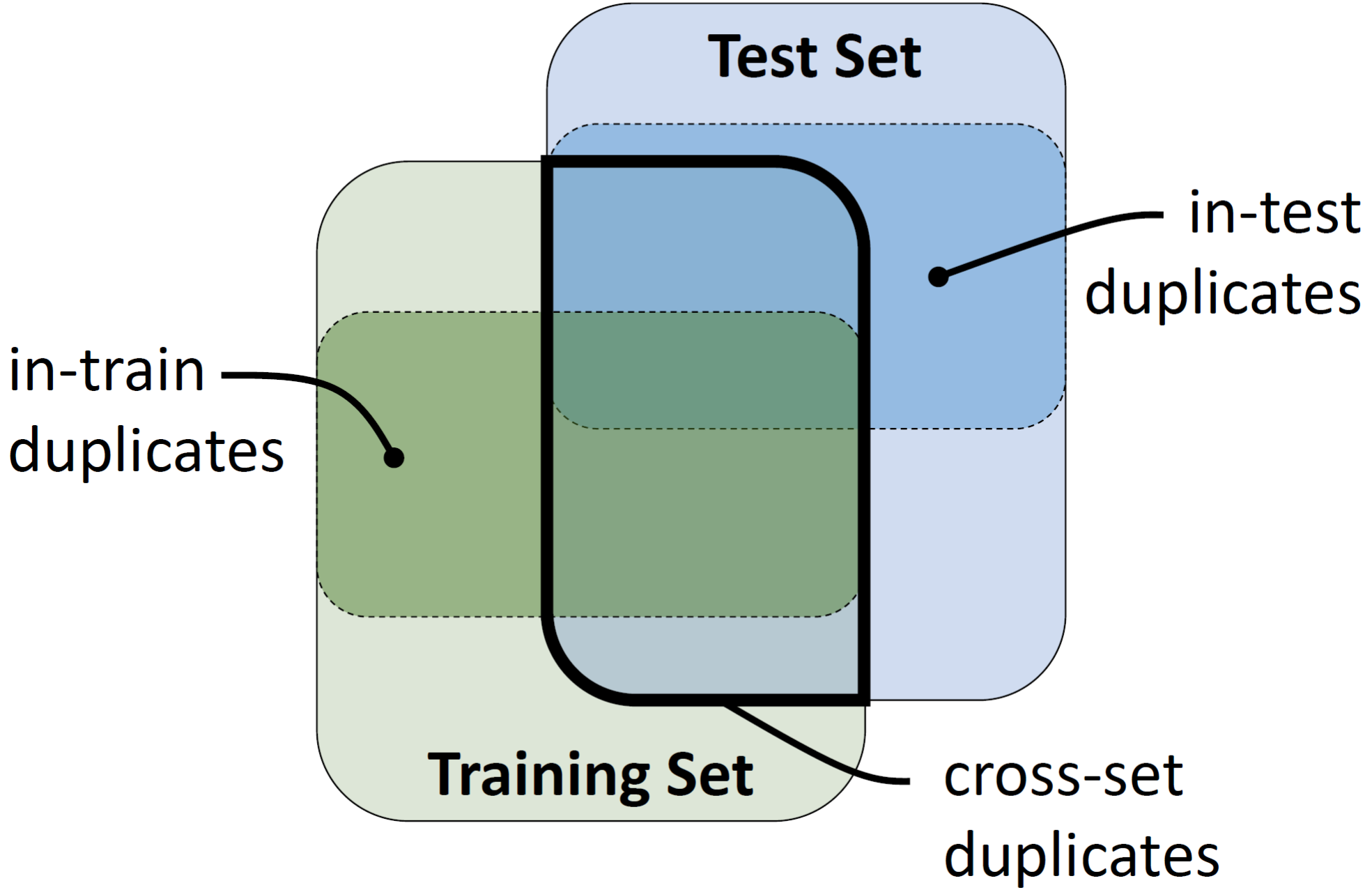
Allamanis & Sutton 2013

- 24.8% duplicates
- Each duplicate file appears ~x2

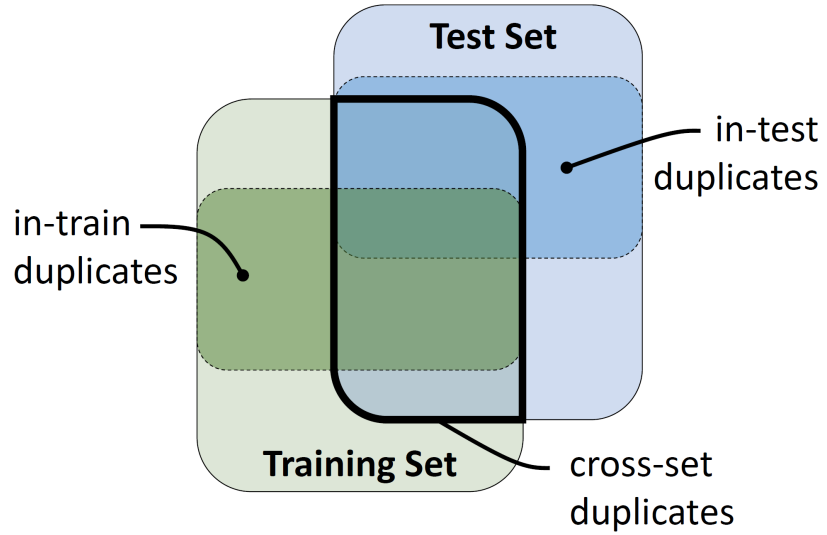
Commonly Used Datasets

Dataset	# Files (x1000)	% duplicates
C# ICLR'19	28.3	10.6
Concode- Java*	229.3	68.7
Java GitHub Corpus	1853.7	24.8
Java-Small	79.8	4.7
Java-Large	1863.4	20.2
JavaScript-150k	112.0	20.7
Python-150k	126.0	6.6
Python docstrings v1*	105.2	9.2
Python docstrings v2*	194.6	31.5

* Dataset is per-function not per-file.


Test Set
in-test
duplicates
in-train
duplicates
Training Set
cross-set
duplicates

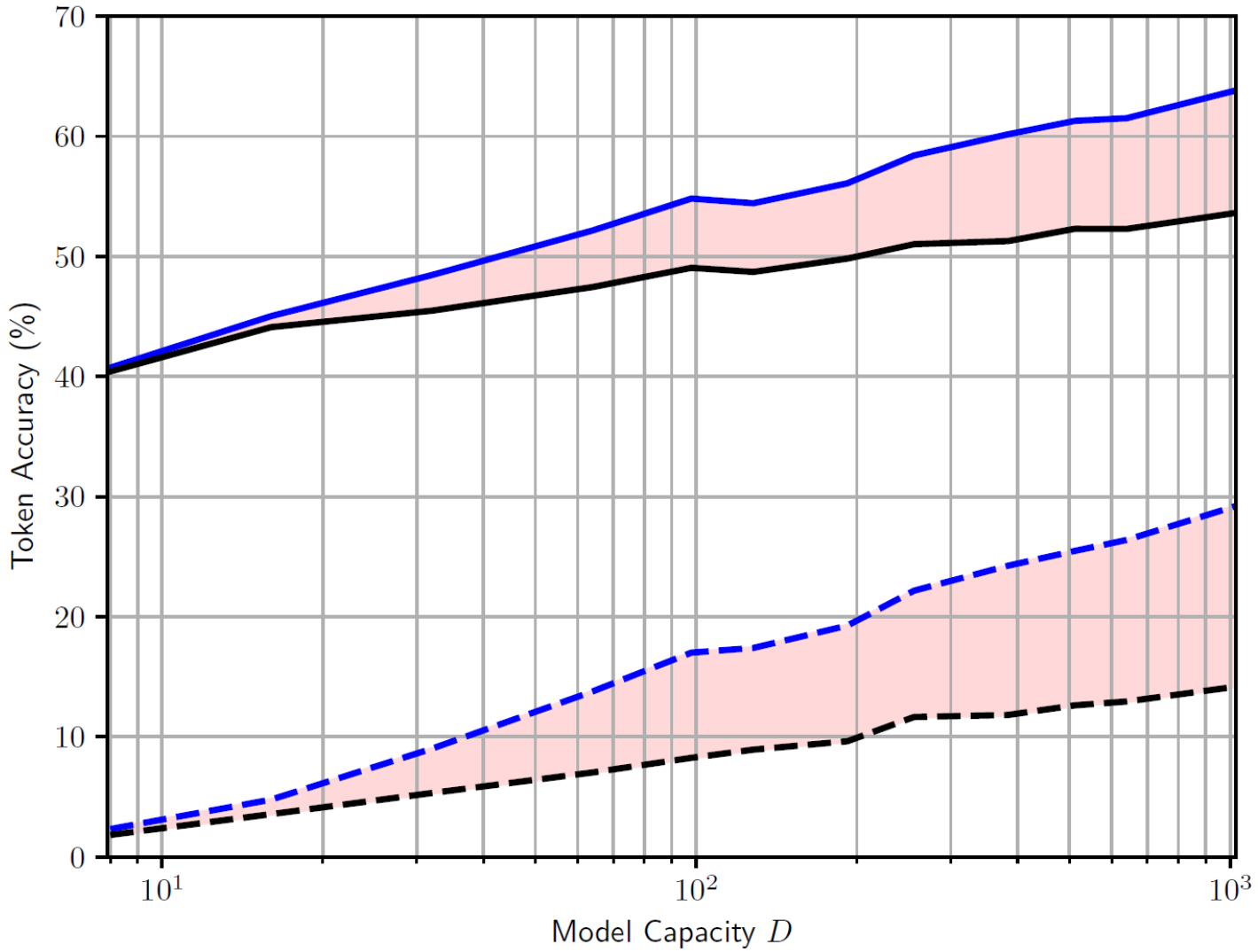
Training	Test Set		
	no dups	w/ cross-set dups	w/ all dups
Biased	Unbiased Test	Cross-Set Biased	Fully Biased
Unbiased	Fully Unbiased	–	–



Case Study: A Simple Language Model

Metric	Performance			
			Δ( , )	
Acc (%)	49.1	55.1	-10.9%	49.2
Acc-ID (%)	8.6	17.7	-51.4%	8.3
MRR	0.674	0.710	-5.1%	0.674
MRR-ID	0.136	0.224	-39.3%	0.132
PPL	9.4	7.5	+25.3%	9.4
PPL-ID	76.1	55.4	+37.4%	82.3

Case Study: A Simple Language Model



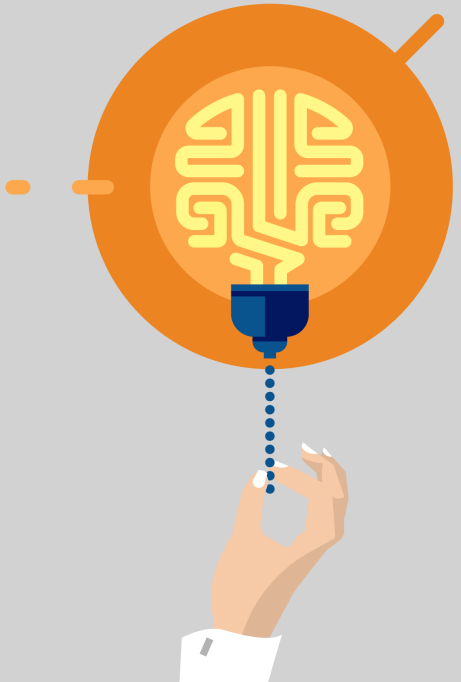
All tokens

Identifiers

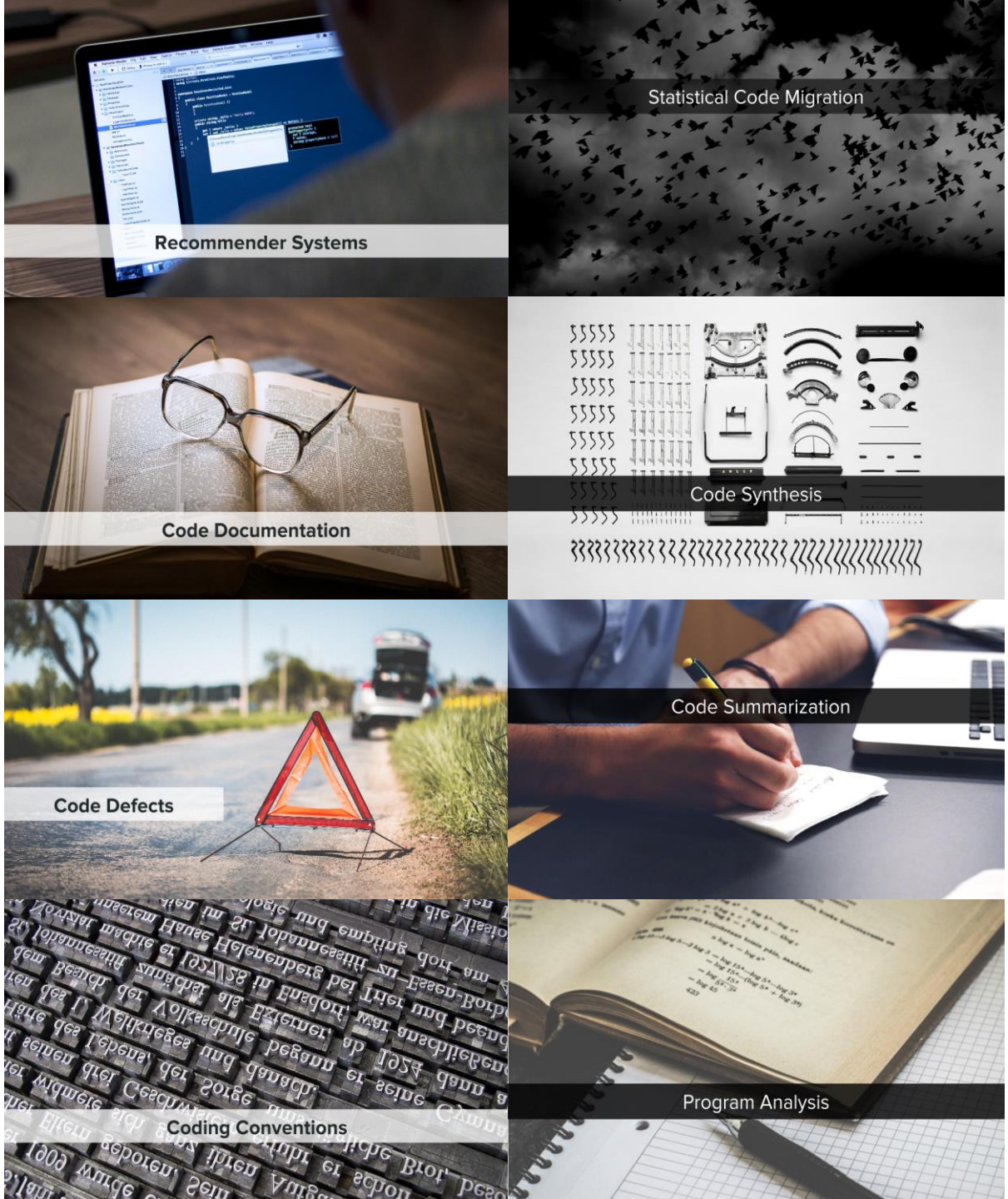
Other Models

Metric	Performance			
Task: Method Naming Model: code2vec [6]				
Dataset: Reshuffled Java-Large [5]				
F1 (%)	44.71	50.98	-12.3%	46.04
Precision (%)	53.00	58.92	-10.5%	54.51
Recall (%)	38.67	44.93	-13.9%	39.85
Task: Variable Naming Model: JsNice [22]				
Dataset : Reshuffled & Reduced JavaScript-150k [21]				
Accuracy (%)	34.44	55.04	-37.4%	29.41
Task: Code Autocompletion Model: PHOG [9]				
Dataset : Reshuffled & Reduced JavaScript-150k [21]				
Accuracy (%) – Types	71.80	75.69	-5.1%	72.95
Accuracy (%) – Values	71.19	77.75	-8.4%	71.35
– Identifiers	48.94	61.43	-20.3%	49.05
– String Literal	25.62	43.89	-41.6%	24.51
Task: Docstring Prediction Model: Seq2Seq [7]				
Dataset: Python Docstrings v1 [7]				
BLEU	12.32	13.86	-11.1%	—

Some Best Practices to Avoid Issues with Duplication



Does the target application contain duplicates?



Careful Data Collection / Use of Existing Data

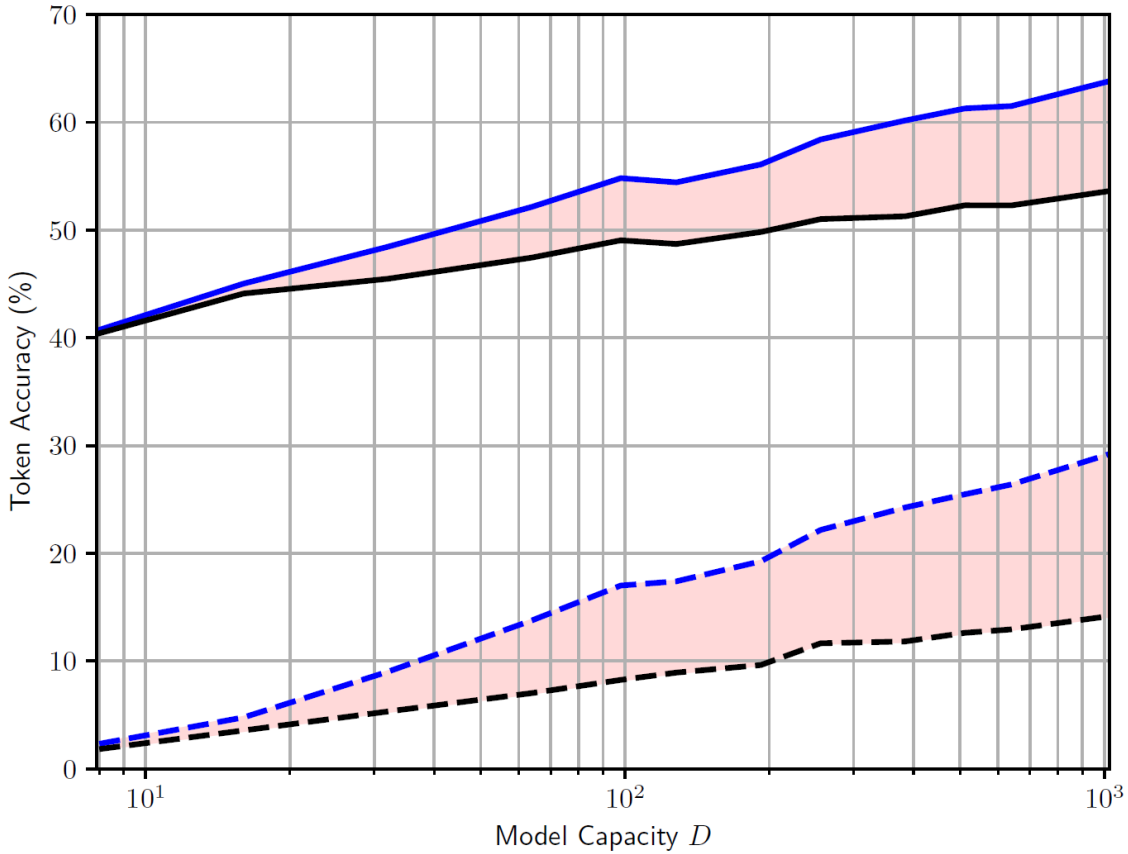
- Use a method to deduplicate collected data:
  - `SourcererCC`
  - `github.com/Microsoft/near-duplicate-code-detector`
  - `github.com/Microsoft/dpu-utils`

- Use duplication index

```
$ pip install dpu-utils

$ run-tokenizer-for-lang

$ deduplicationcli DATA_PATH OUT_JSON
```

Model Capacity

- Use strong baselines.
- Try baselines that memorize well.



Some Best Practices to Avoid Issues with Duplication

- Does the target application contain duplicates?
- Careful data collection or use of existing data.
- Be cautious of model capacity.

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