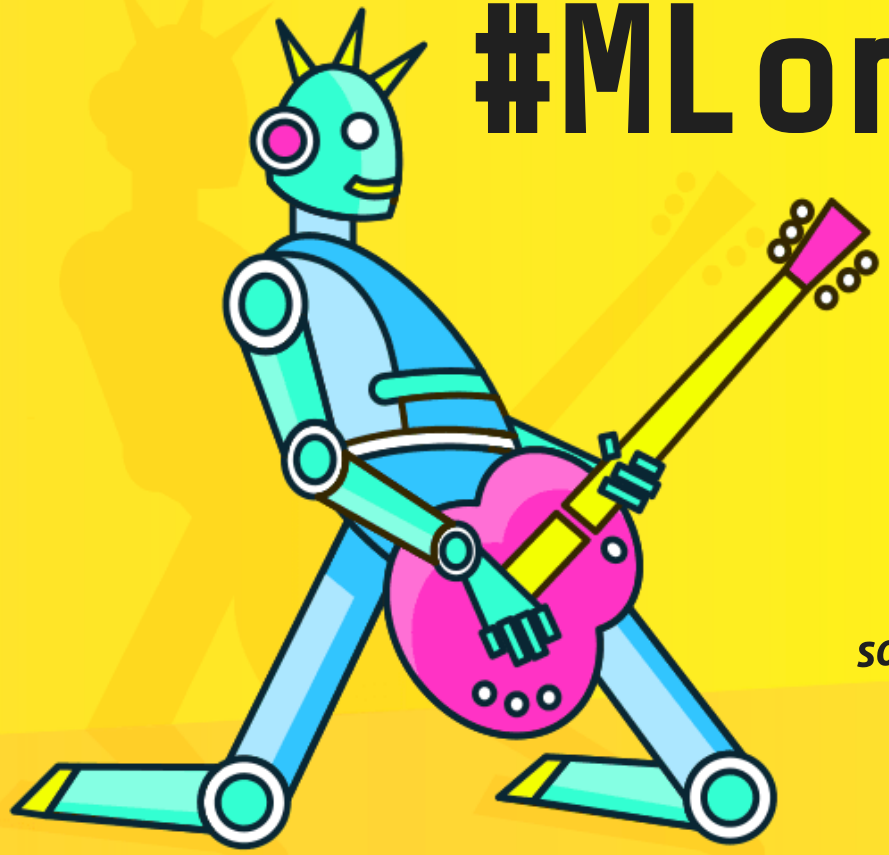
Machine Learning for Code

Egor Bulychev

UseData Conf 2019

Профессиональная конференция для специалистов по машинному обучению и анализу данных

#MLonCode



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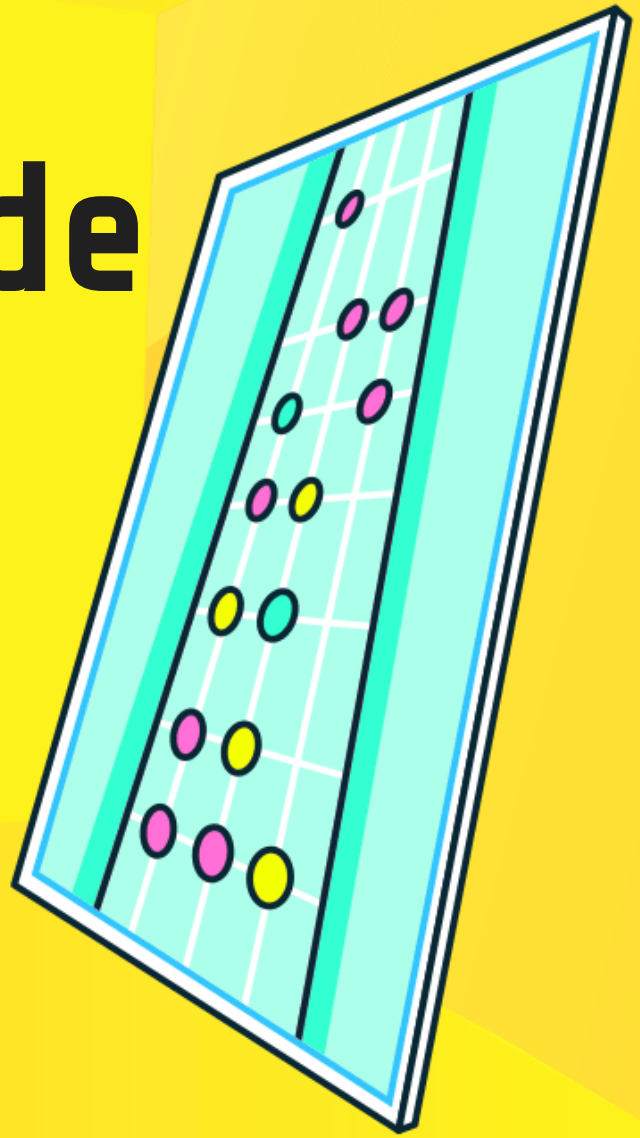
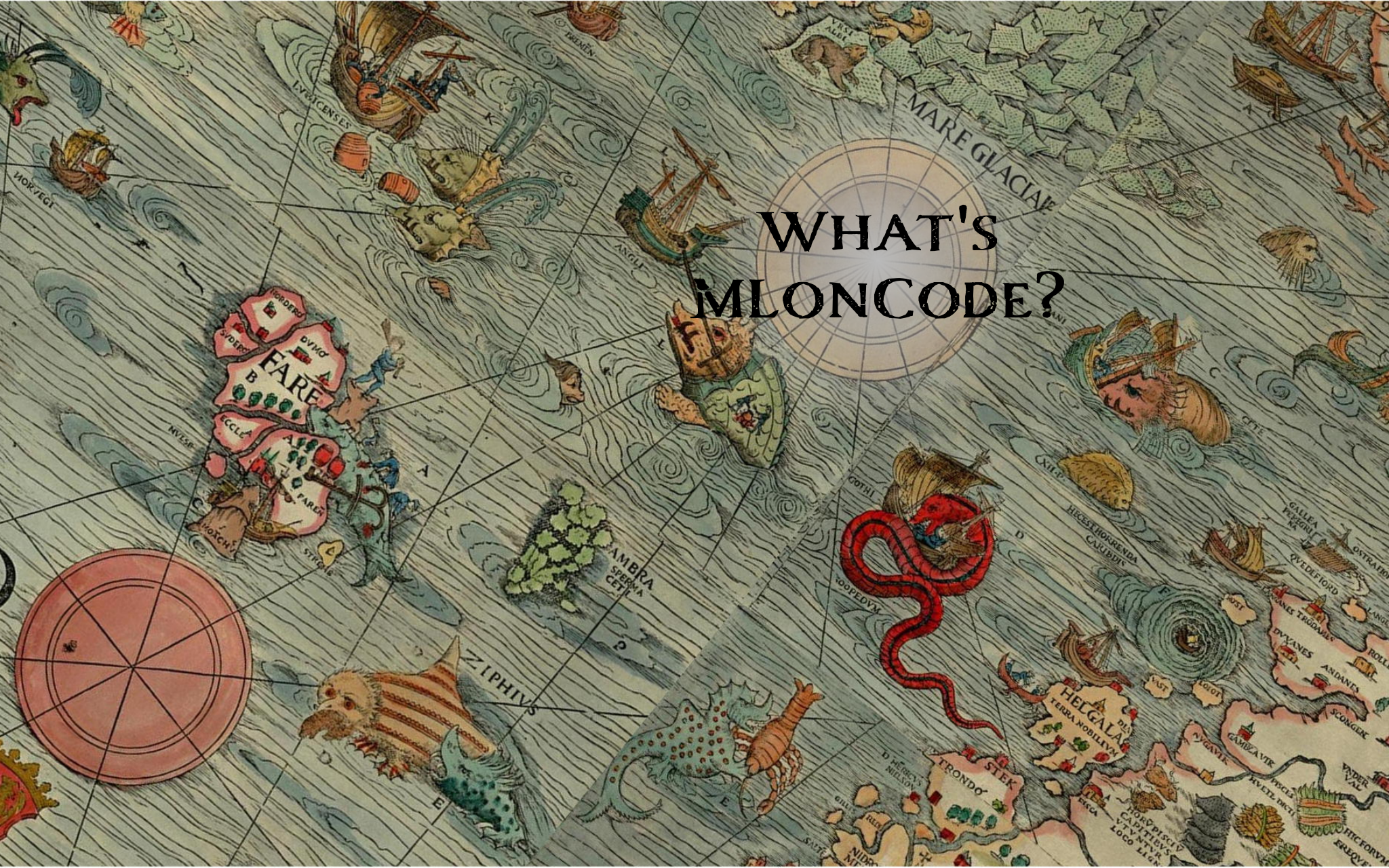


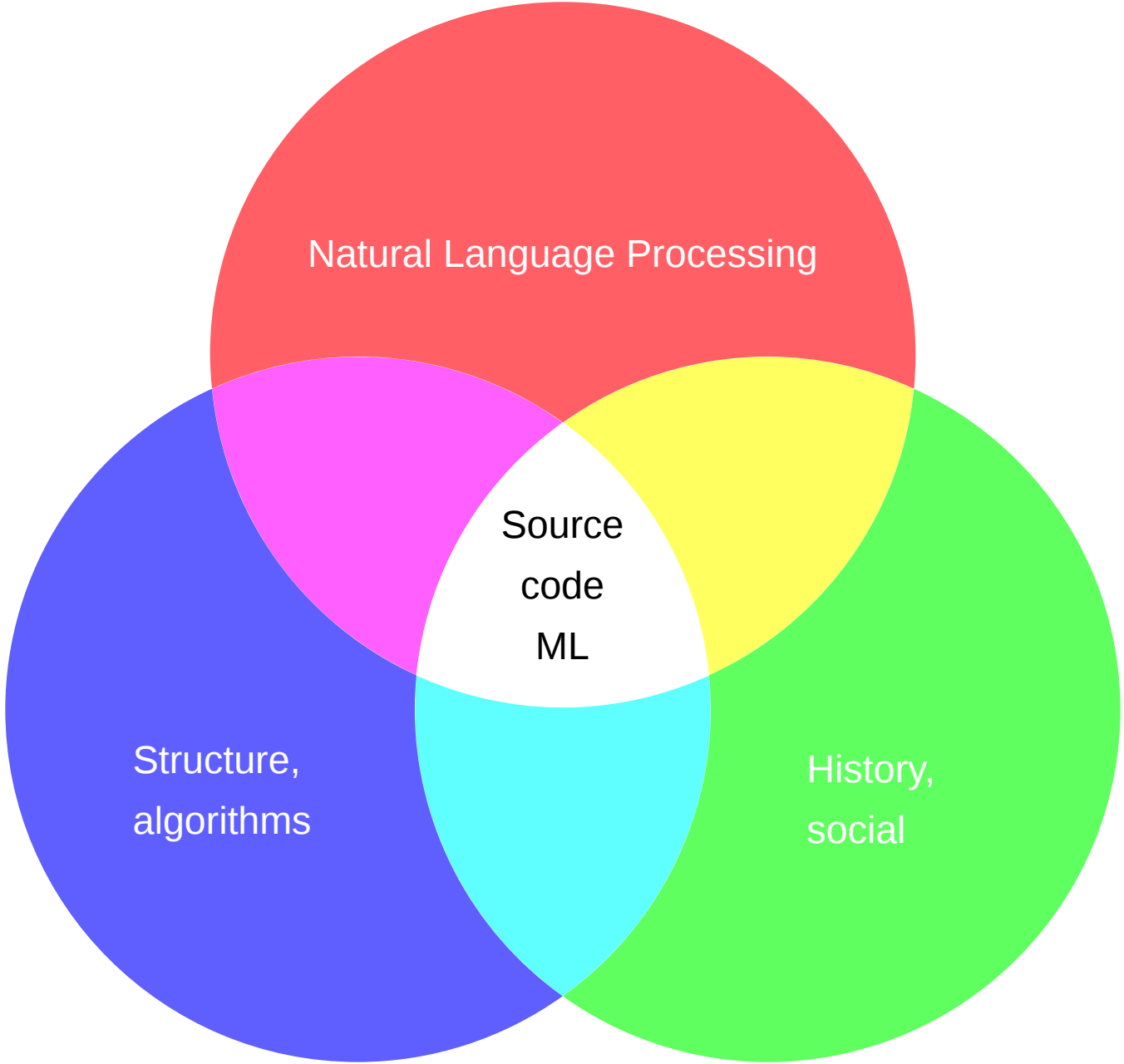
Plan

- What's MLonCode?
- Why MLonCode hard?
- Basics
- Similar repository search
- Code review
- Developer similarity


What's
MLonCode?
MARE GLACIALE
FARE
HELGALA
TERRA NOBILIVM
TRONDO
SIEK
ZIPHIVS
AMBRA
SPERMA
CETI
GOTHI
ANGLI
NORVEGI

Stereotypes

- Program Synthesis
- Program Translation
- Code Suggestion and Completion
- Program Repair and Bug Detection


Natural Language Processing
Source
code
ML
Structure,
algorithms
History,
social


Why MLonCode
hard?

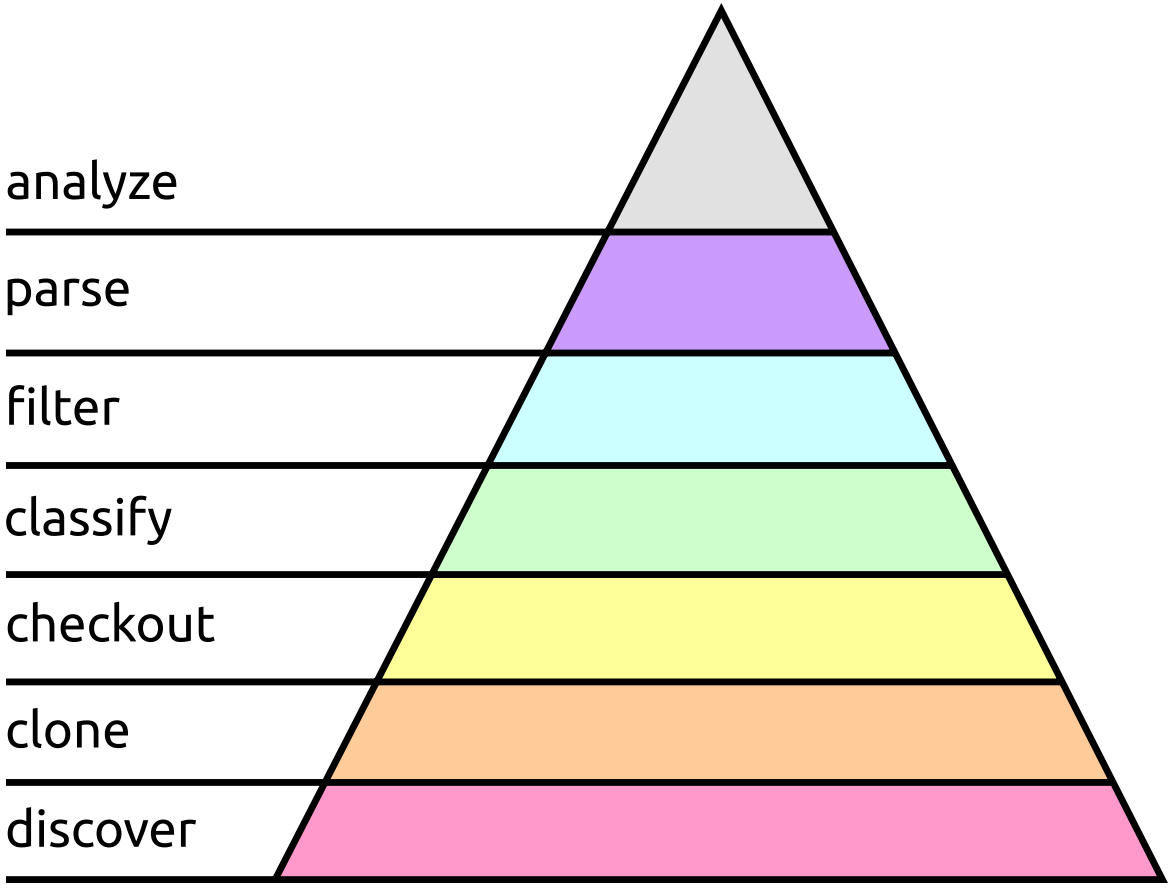

Data

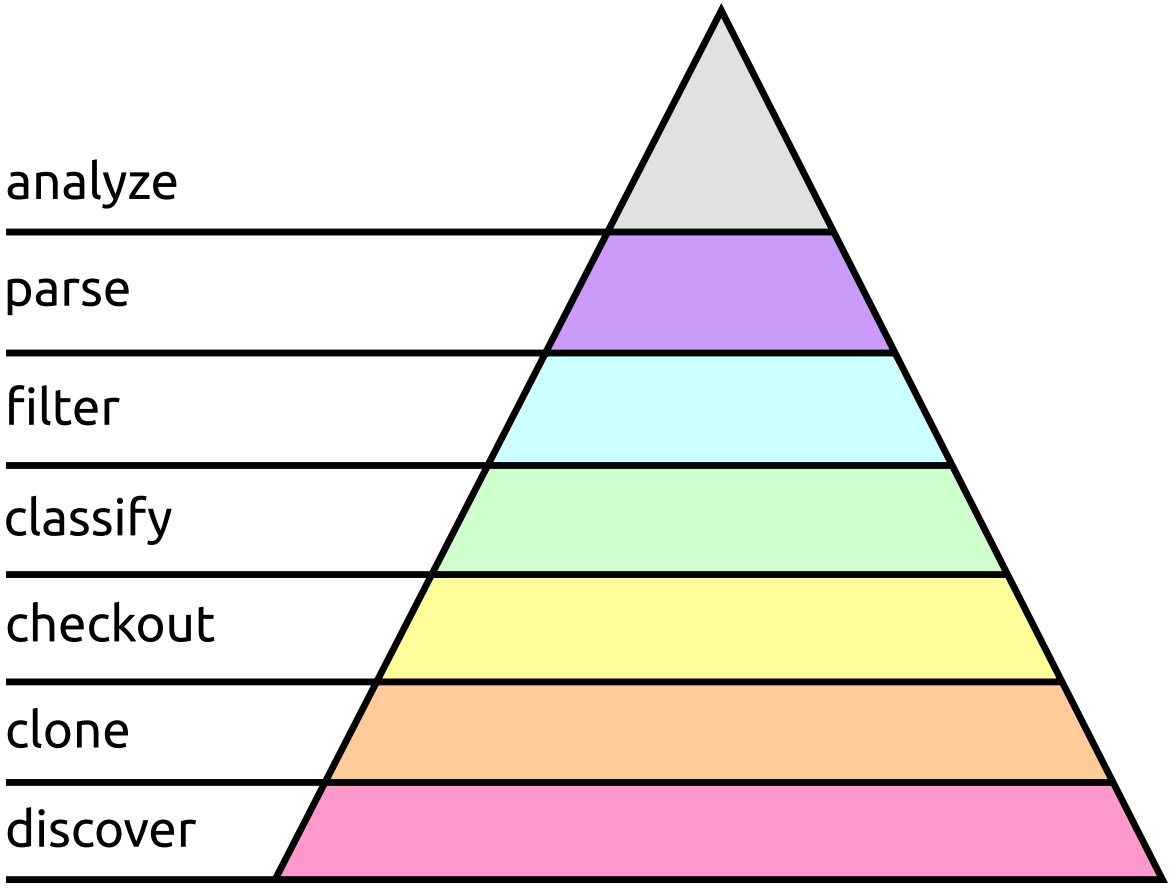
Common datasets

-
-
-

- Size: 6 TB
- Number of repositories: 260k+ (out of 96 M+) from GitHub
- Number of files: 136M+ files
- LOC: ~28 billions

Tools


analyze
parse
filter
classify
checkout
clone
discover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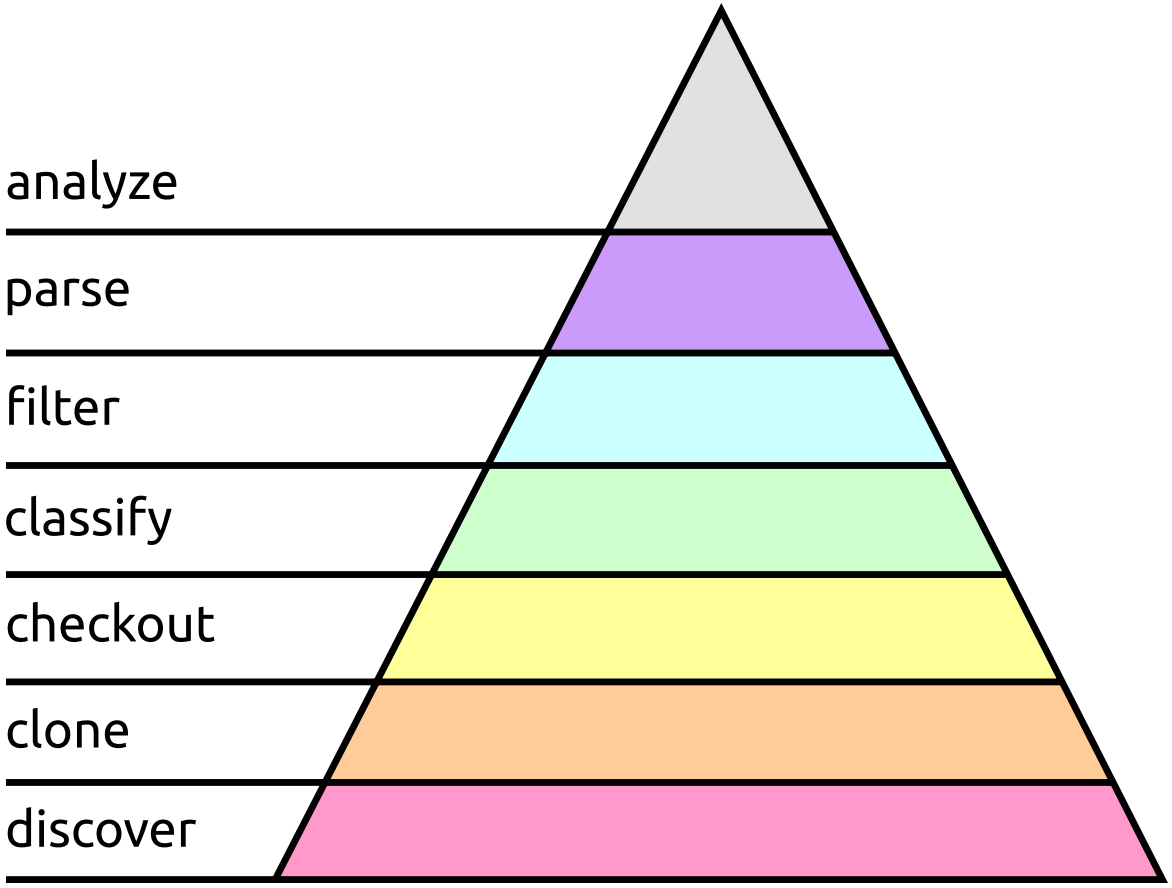
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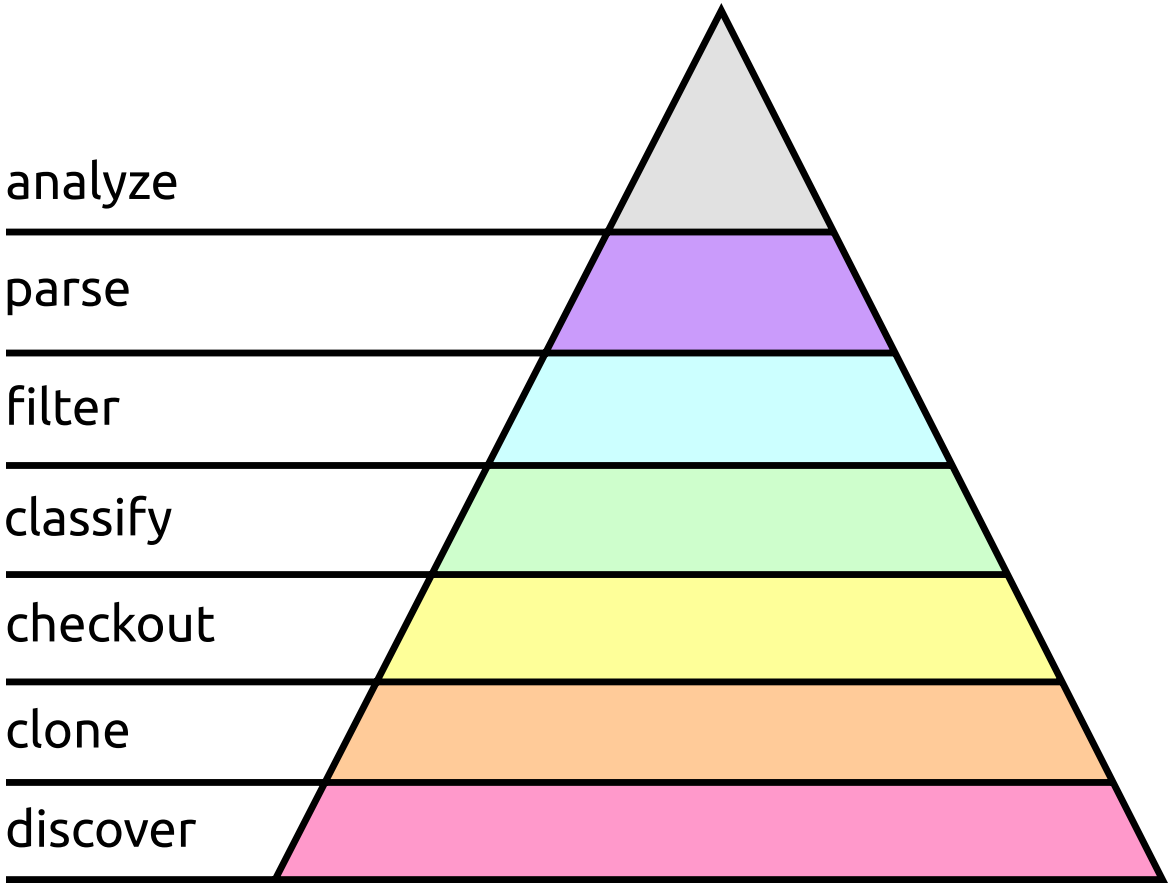
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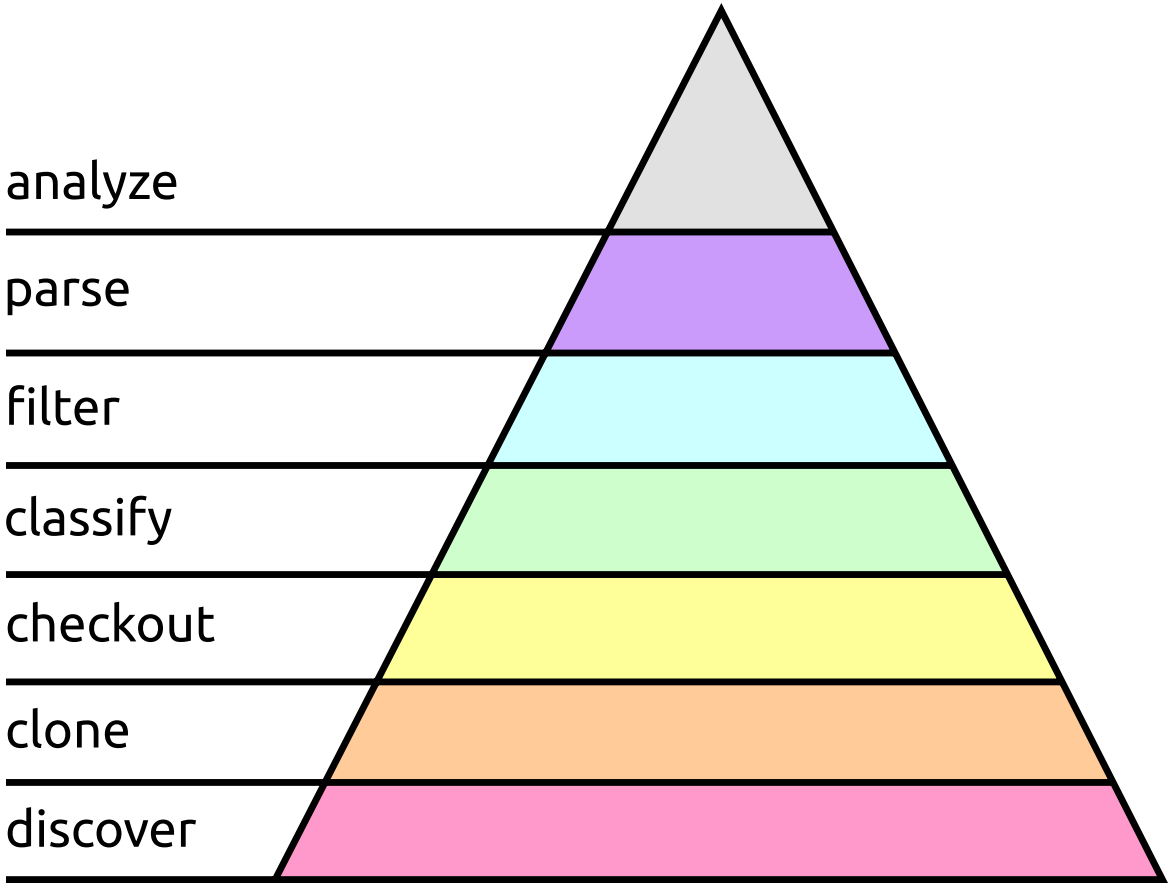
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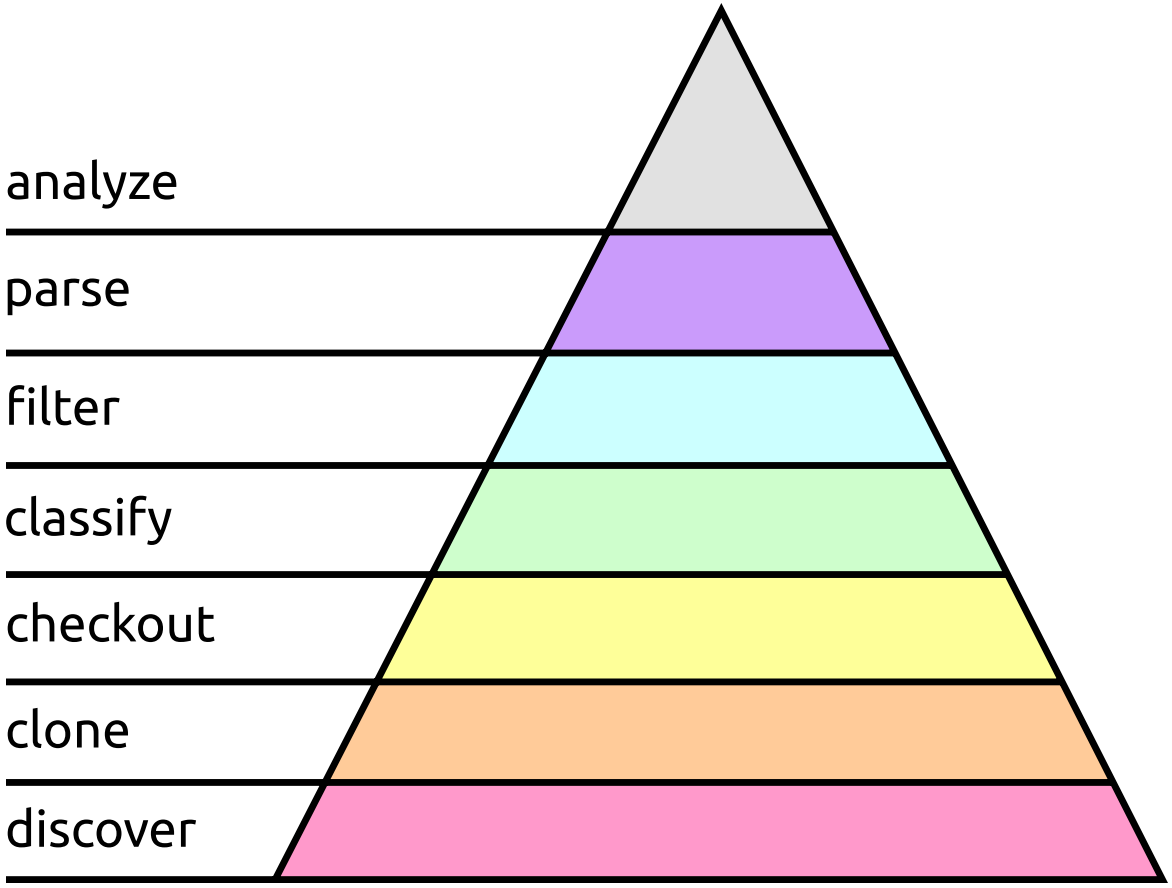
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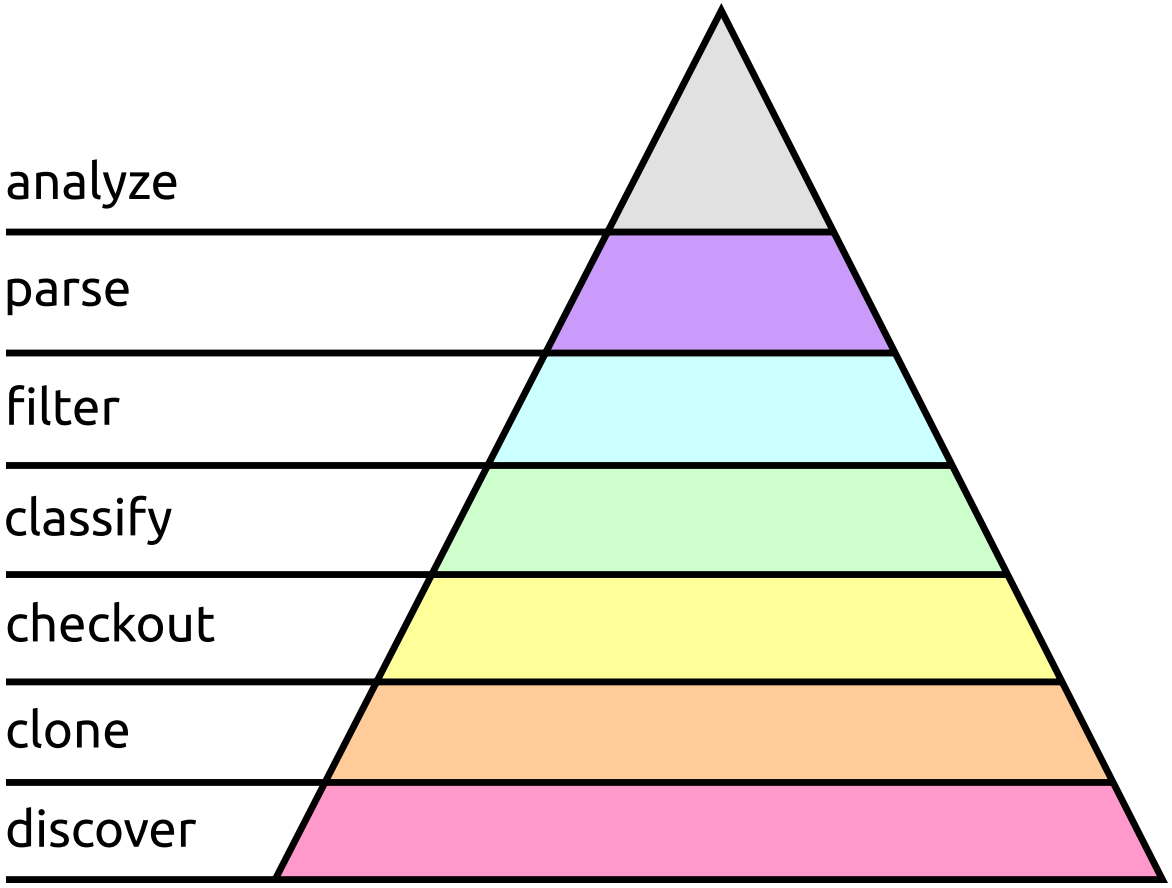
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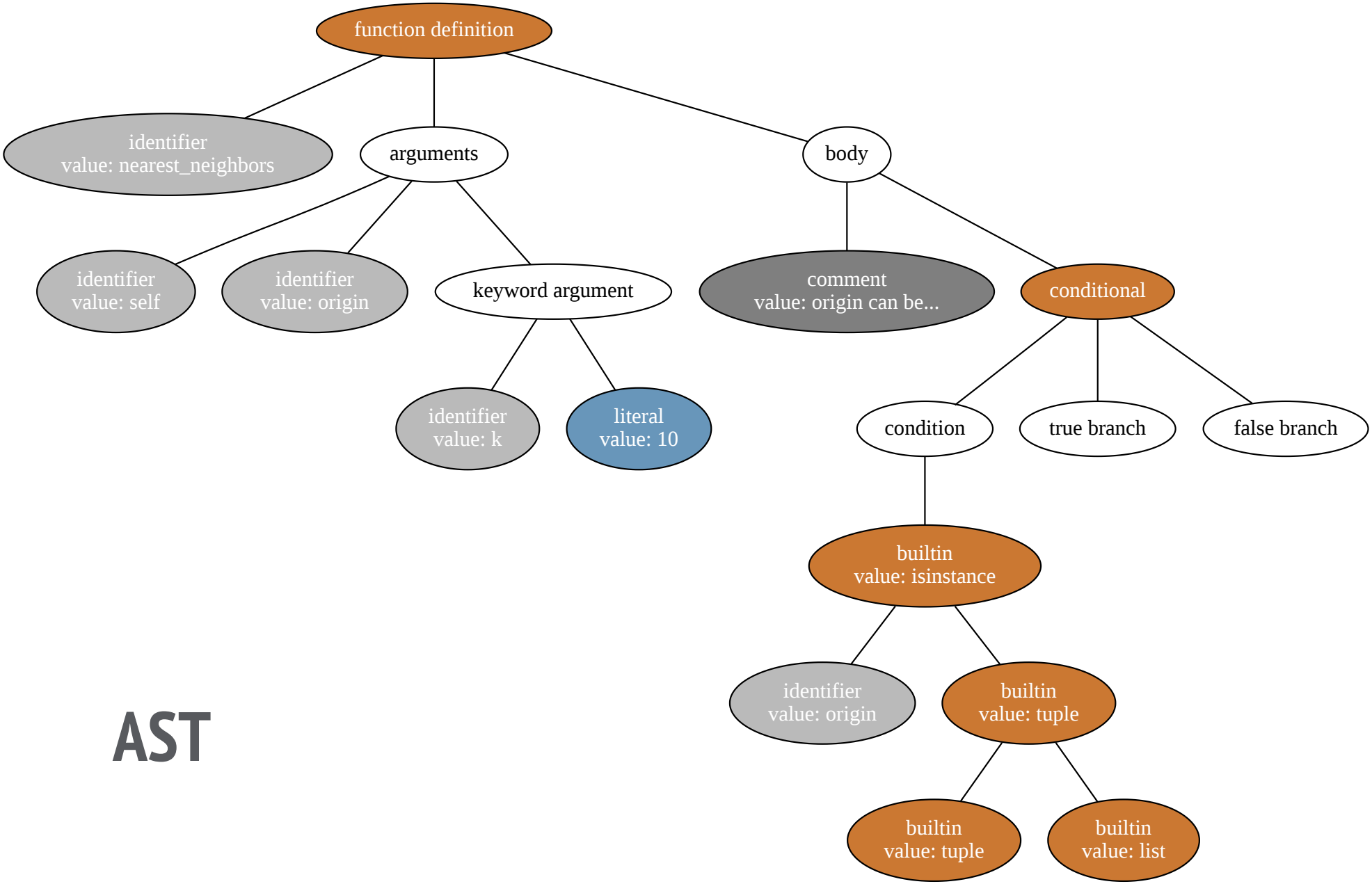
Parsing

```
def nearest_neighbors(self, origin, k=10,
                      skipped_stop=0.99, throw=True):
    # origin can be either a text query or an id
    if isinstance(origin, (tuple, list):
         words, weights = origin
         weights = numpy.array(weights, dtype=numpy.float32)
         index = None
         avg = self._get_centroid(words, weights, force=True)
    else:
         index = origin
         words, weights = self._get_vocabulary(index)
         avg = self._get_centroid_by_index(index)
    if avg is None:
         raise ValueError(
             "Too little vocabulary for %s: %d" % (index, len(words)))
```

Parsing

```
01. def nearest_neighbors(self, origin, k=10,
02.                       skipped_stop=0.99, throw=True):
03.     # origin can be either a text query or an id
04.     if isinstance(origin, (tuple, list):
05.         words, weights = origin
06.         weights = numpy.array(weights, dtype=numpy.float32)
07.         index = None
08.         avg = self._get_centroid(words, weights, force=True)
09.     else:
10.         index = origin
11.         words, weights = self._get_vocabulary(index)
12.         avg = self._get_centroid_by_index(index)
13.     if avg is None:
14.         raise ValueError(
15.             "Too little vocabulary for %s: %d" % (index, len(words)))
```

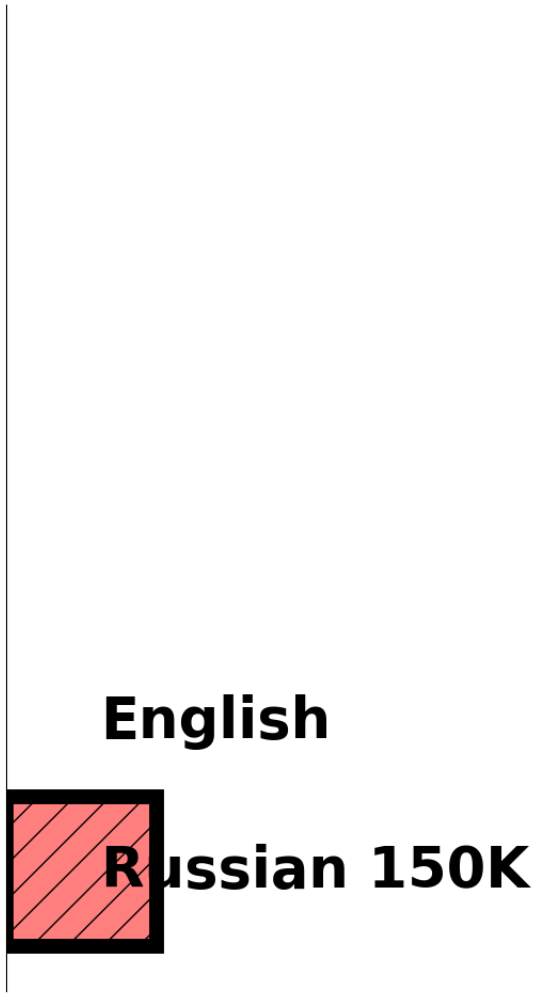
- keywords
- identifiers
- literals
- strings
- comments
- reserved


function definition
identifier
value: nearest_neighbors
arguments
body
identifier
value: self
identifier
value: origin
keyword argument
comment
value: origin can be...
conditional
identifier
value: k
literal
value: 10
condition
true branch
false branch
builtin
value: isinstance
identifier
value: origin
builtin
value: tuple
builtin
value: tuple
builtin
value: list
AST

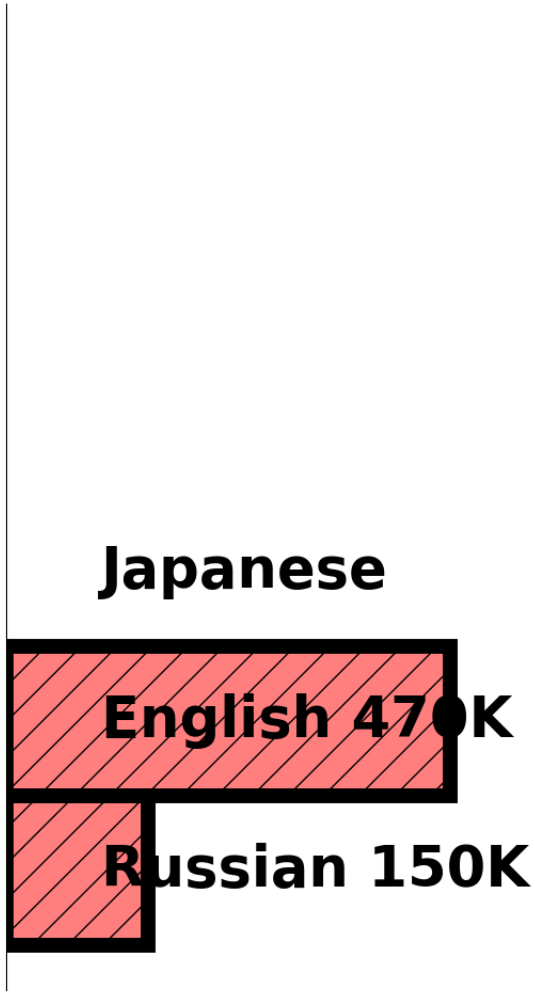
#words

Russian

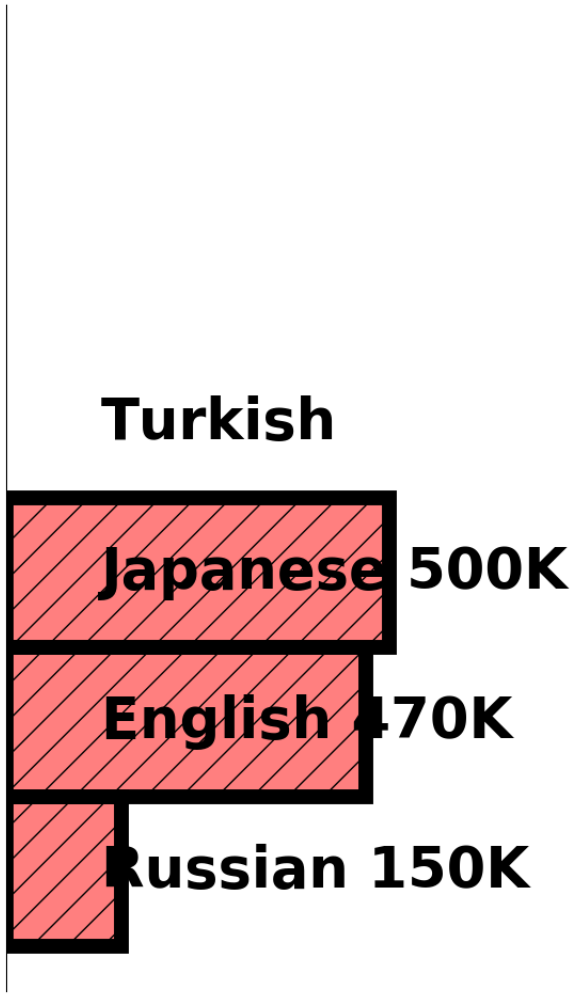
#words



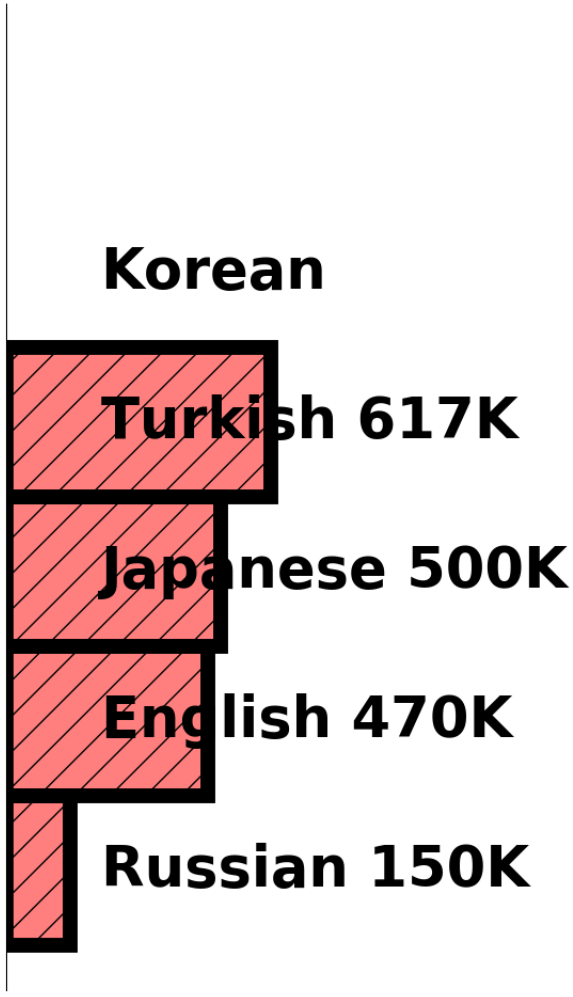
#words

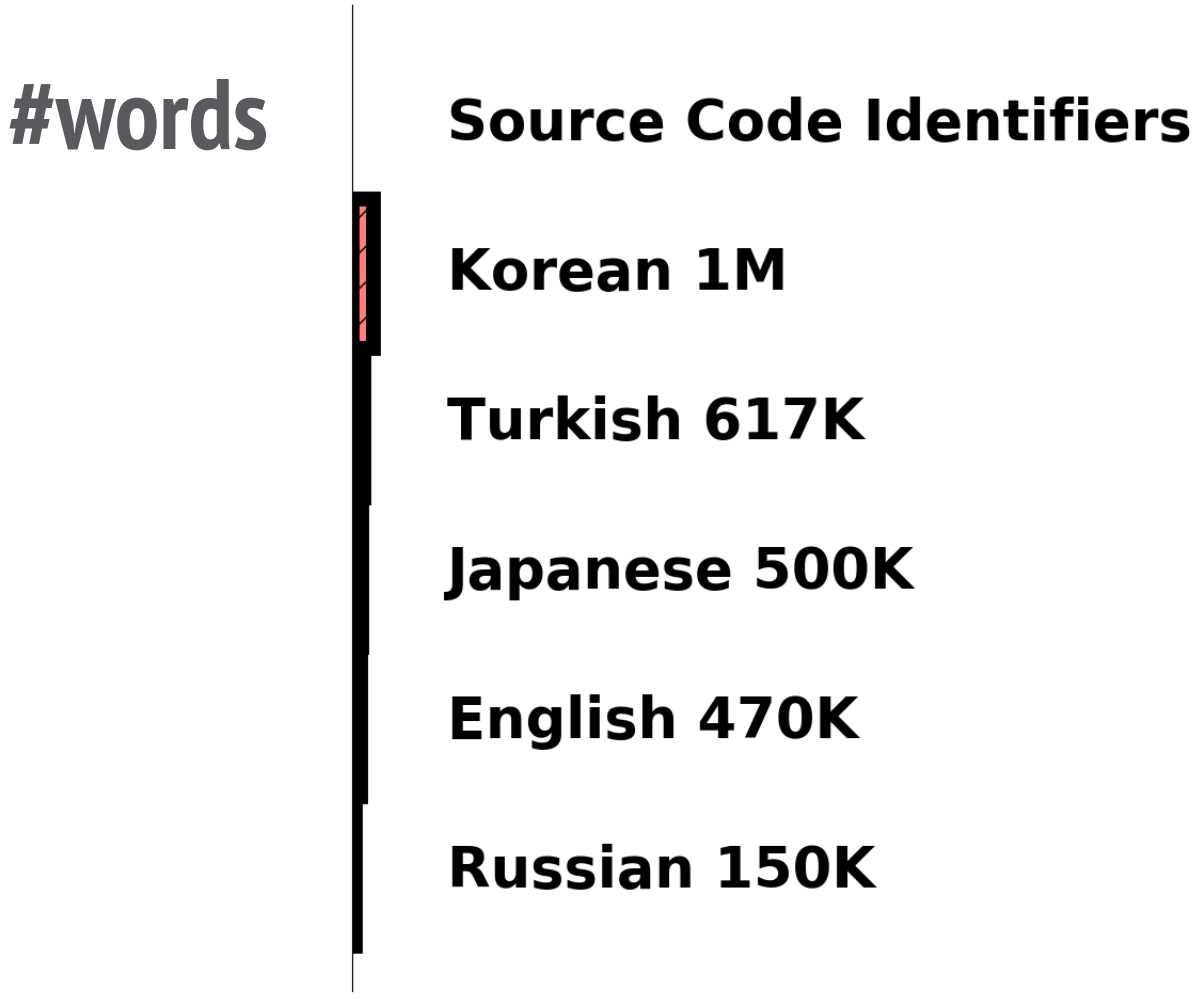


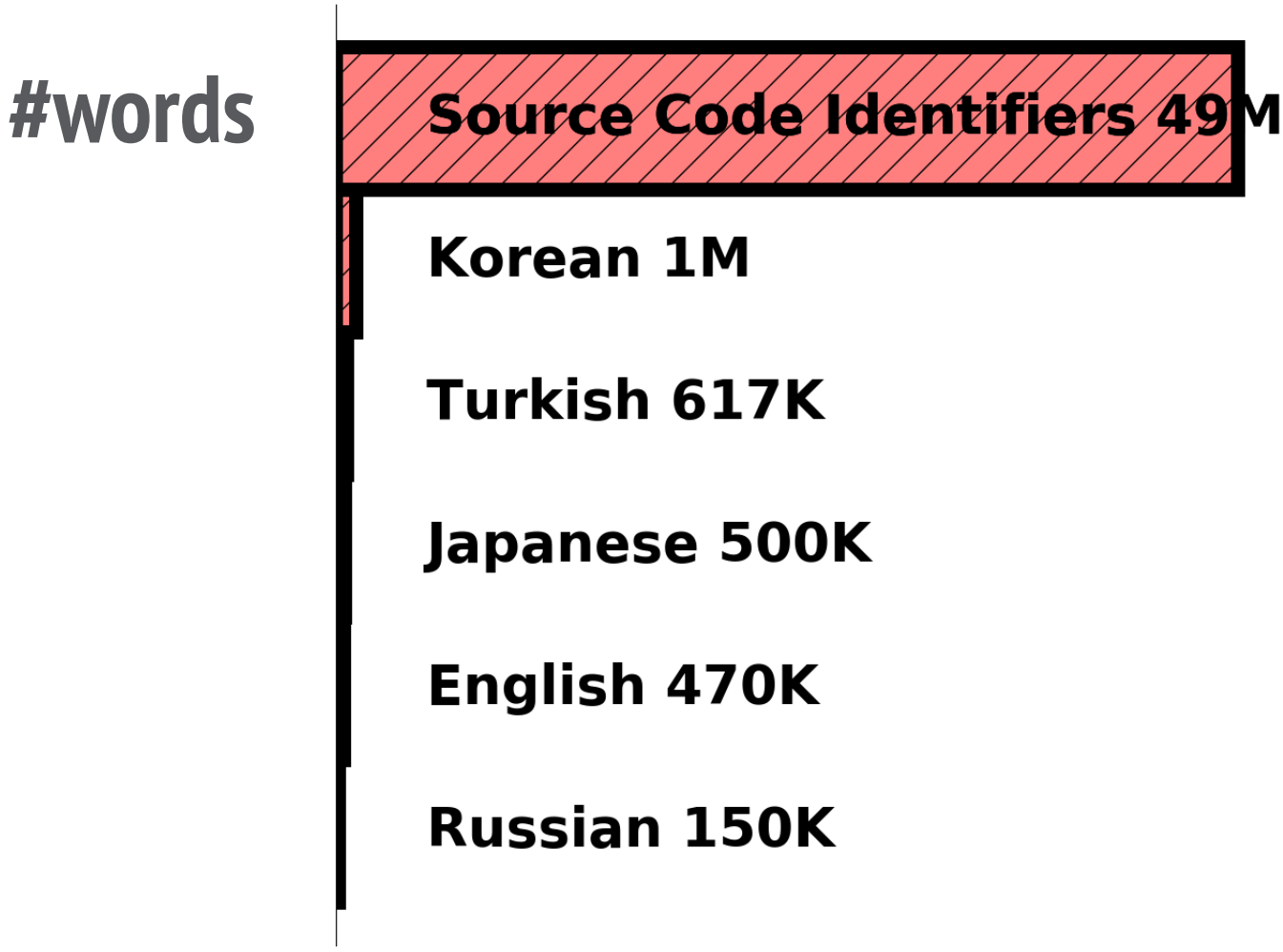
#words



#words


Korean
Turkish 617K
Japanese 500K
English 470K
Russian 150K


#words
Source Code Identifiers
Korean 1M
Turkish 617K
Japanese 500K
English 470K
Russian 150K


#words
Source Code Identifiers 49M
Korean 1M
Turkish 617K
Japanese 500K
English 470K
Russian 150K

Why so many identifiers?

```
01. _tcp_socket_connect -> [tcp, socket, connect]
02. AuthenticationError -> [authentication, error]
03. set_visible -> [set, visible]
```


Code naturalness

```
01. class ???:
02.     def connect(self, dbname, user, password, host, port):
03.         # ...
04.     def query(self, sql):
05.         # ...
06.     def close(self):
07.         # ...
```

```
01. class Database:
02.     def connect(self, dbname, user, password, host, port):
03.         # ...
04.     def query(self, sql):
05.         # ...
06.     def close(self):
07.         # ...
```

Take away

- Identifier ~ combinations of words
- Raw code is text
- Parsed code is AST
- Non-linear structure of AST
- Code naturalness
- 370 programming languages

Basics

Identifier splitter

Approaches

- Heuristic
- Machine Learning

Heuristic - split by

- underscore `set_name -> [set, name]`
- changing of cases `SetName -> [set, name]`
- etc

Result: 49M -> 3M, but...

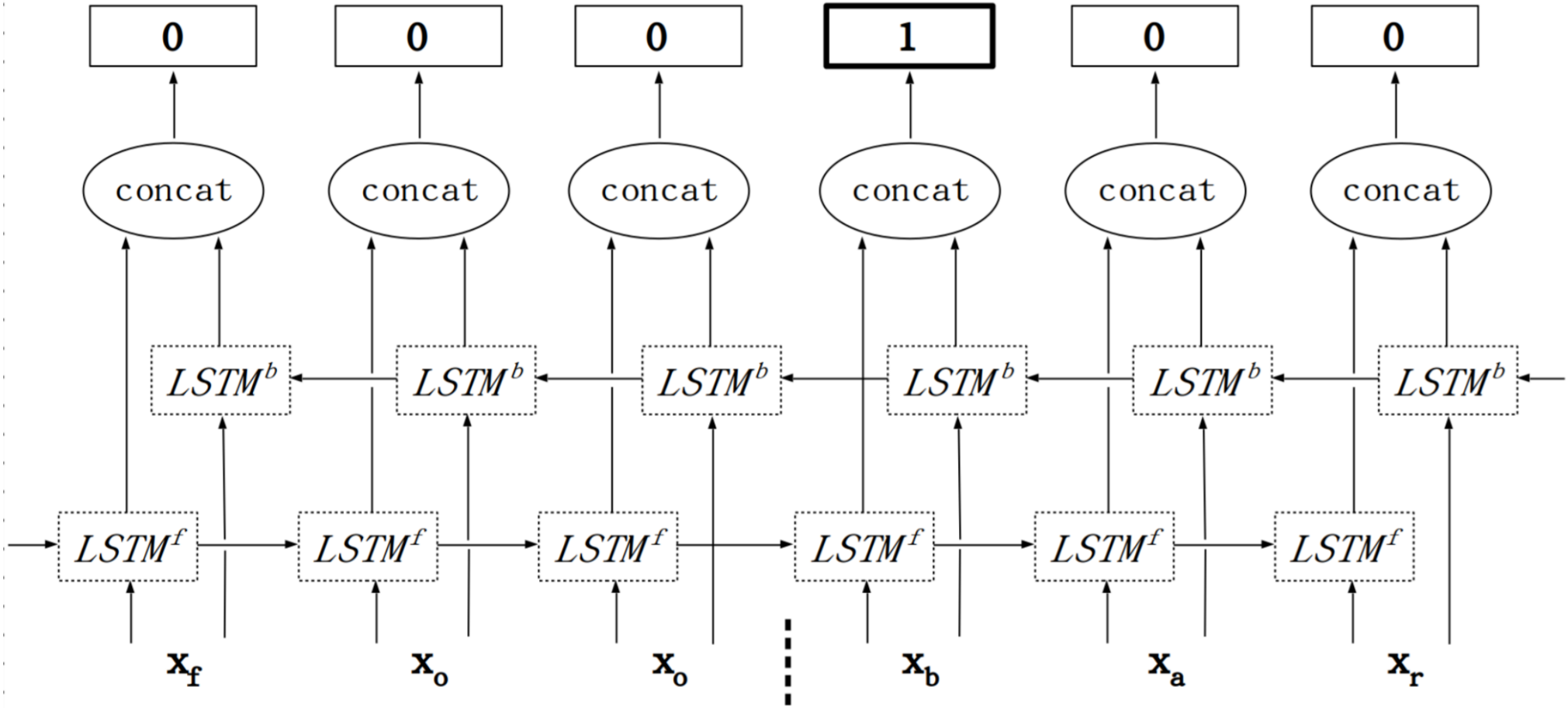
- `BUFFERFLAG_CODECCONFIG -> [bufferflag, codecconfig]`
- `metamodelength -> [metamodelength]`

- - 49M of identifiers
- Preprocessing
- Train NN

FooBar -> X, y

- f
- o
- o
- b
- a
- r

- 0
- 0
- 0
- 1
- 0
- 0


0
0
0
1
0
0
concat
concat
concat
concat
concat
concat
LSTM^b
LSTM^b
LSTM^b
LSTM^b
LSTM^b
LSTM^b
LSTM^f
LSTM^f
LSTM^f
LSTM^f
LSTM^f
LSTM^f
x_f
x_o
x_o
x_b
x_a
x_r

BiLSTM

Result: 49M -> 1M

- `BUFFERFLAG_CODECCONFIG -> [buffer, flag, codec, config]`
- `metamodelength -> [meta, mode, length]`

Identifier embeddings

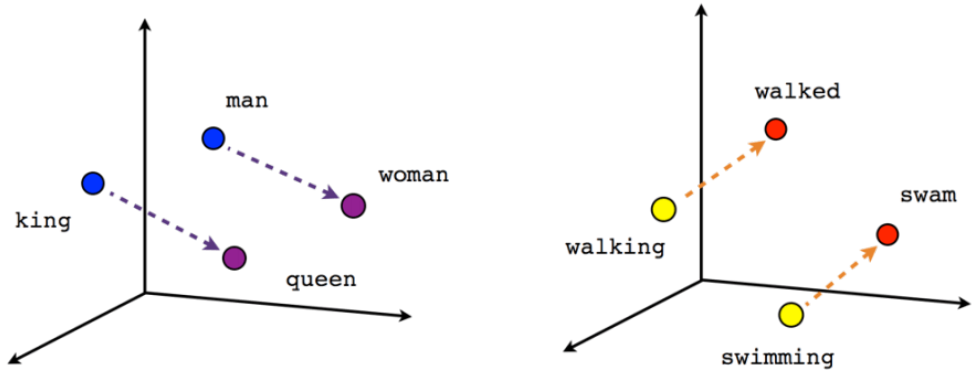
Nearest to “foo”

- afoo
- myfoo
- mfoo
- dofoo
- qux
- baz
- wibble
- quux
- testing

Analogies

“send” - “receive” + “pop” = “push”

“database” - “query” + “tune” = “settings”



$V_1 \Leftrightarrow$ `"foo"`

$V_2 \Leftrightarrow$ `"bar"`

$V_3 \Leftrightarrow$ `"integrate"`

$$distance(V_1, V_2) < distance(V_1, V_3)$$

$$distance(V_i, V_j) = \arccos \frac{V_i \cdot V_j}{\|V_i\| \|V_j\|}$$

Scalar product / Norm

How to estimate

$$V_i \cdot V_j \, ?$$

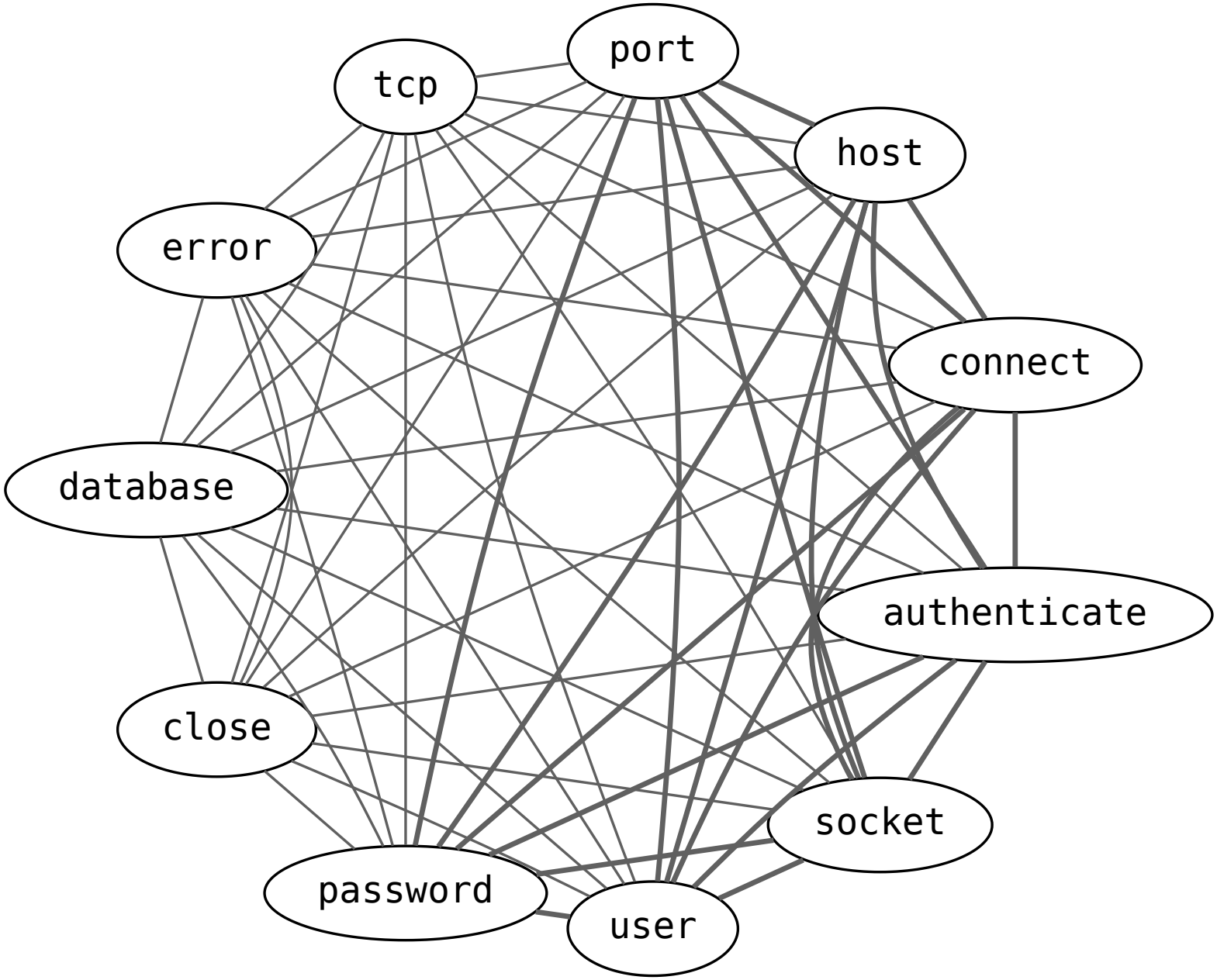
```
class Database:
    def connect(self, user, password, host, port):
        self._tcp_socket_connect(host, port)
        try:
            self._authenticate(user, password)
        except AuthenticationError as e:
            self.socket.close()
            raise e from None
```

Splitting and normalization

```
01. _tcp_socket_connect -> [tcp, socket, connect]
02. AuthenticationError -> [authentication, error]
03. authentication, authenticate -> authenticate
```

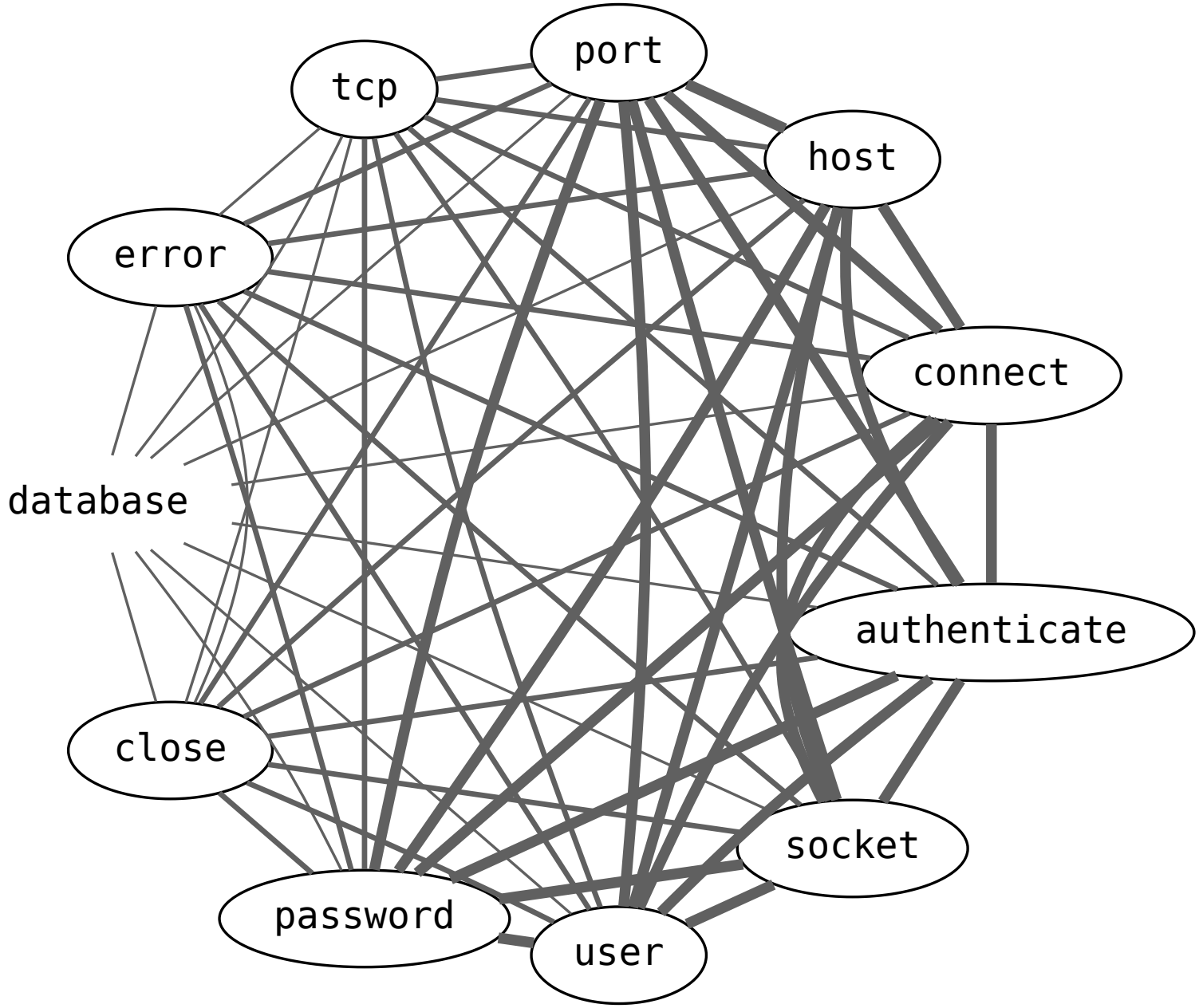
```
01. class Database:
02.     def connect(self, user, password, host, port):
03.         self._tcp_socket_connect(host, port)
04.         try:
05.             self._authenticate(user, password)
06.         except AuthenticationError as e:
07.             self.socket.close()
08.             raise e from None
```

```
>>> database, connect², user², password², host², port²,
    tcp, socket², authenticate², error, close
```


port
tcp
host
error
connect
database
authenticate
close
socket
password
user

```
01. class Database:
02.     def connect(self, user, password, host, port):
03.         self._tcp_socket_connect(host, port)
04.         try:
05.             self._authenticate(user, password)
06.         except AuthenticationError as e:
07.             self.socket.close()
08.             raise e from None
```

```
>>> connect², user², password², host², port², tcp, socket²,
    authenticate², error, close
```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04.         try:
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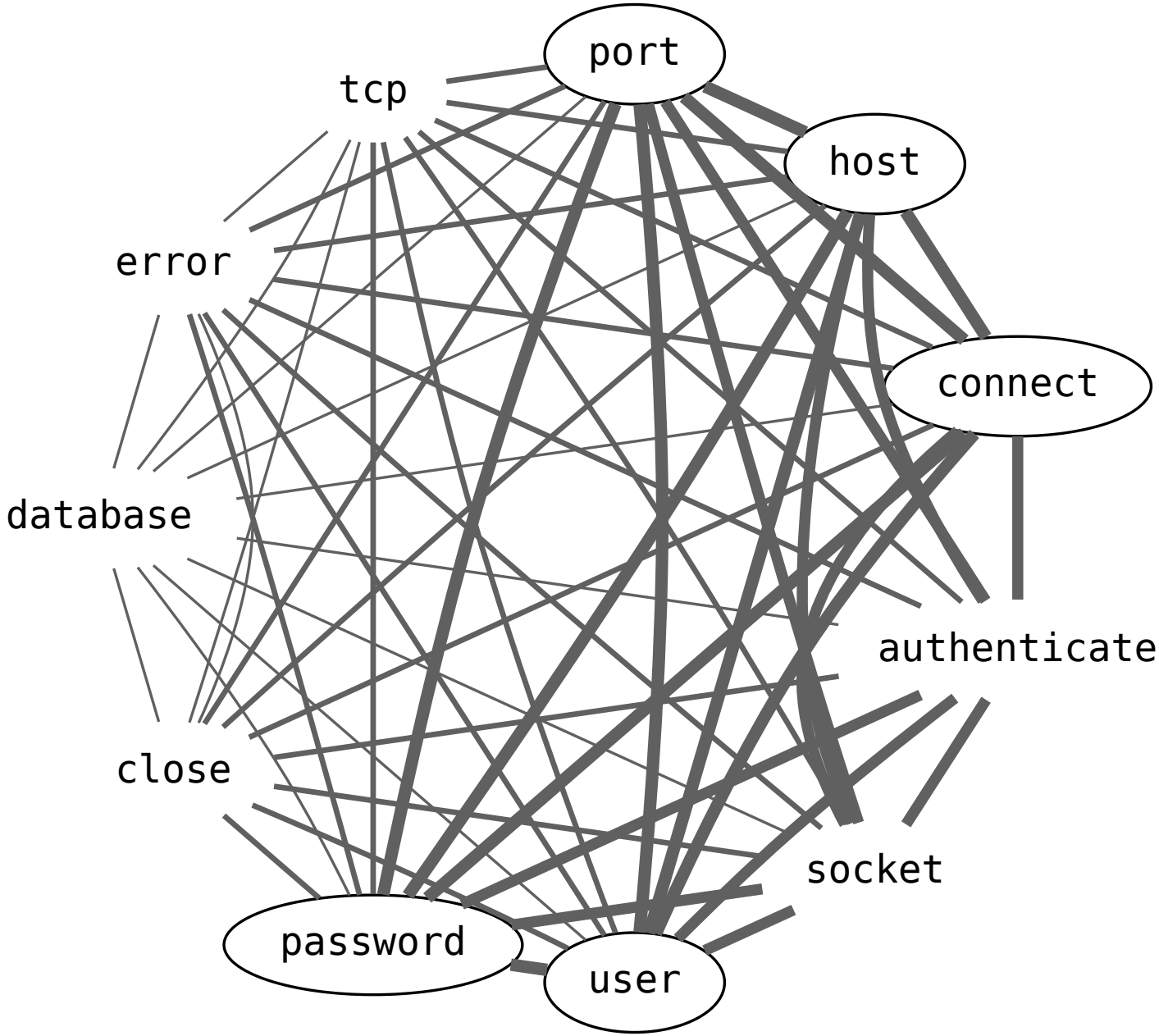
08.             raise e from None

>>> connect, user, password, host, port
```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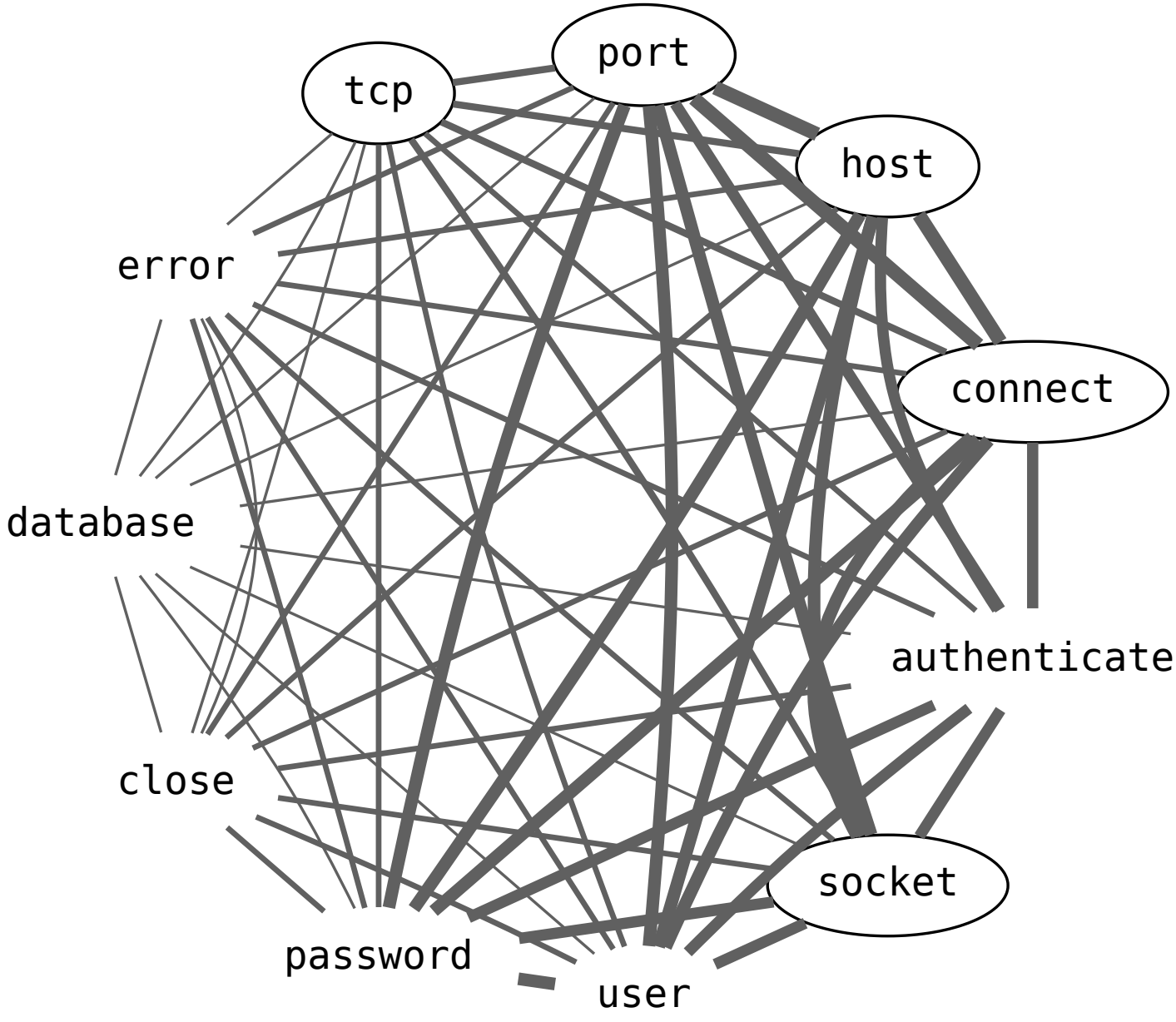
>>> tcp, socket, connect, host, port
```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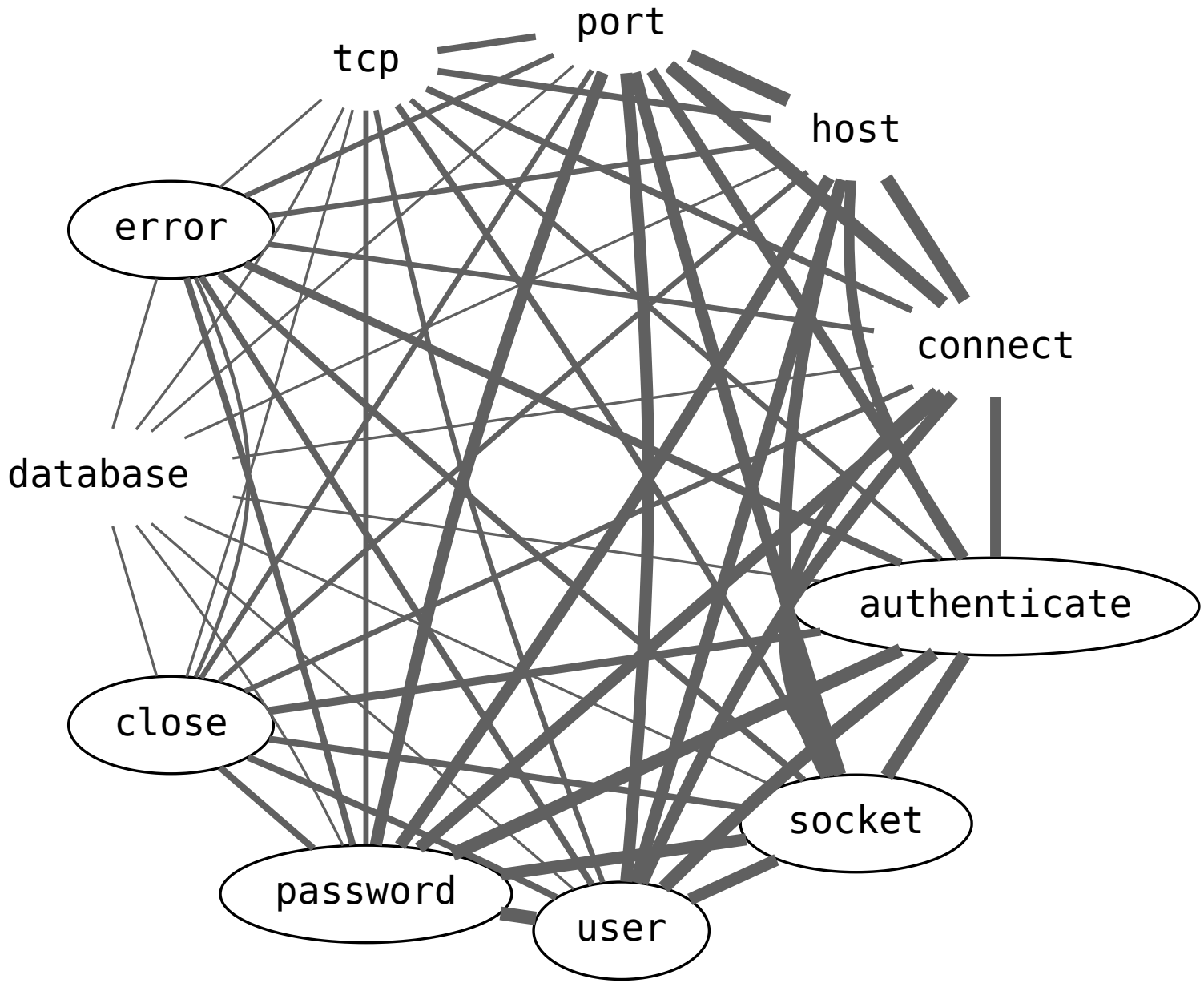
04.         try:
05.             self._authenticate(user, password)
06.         except AuthenticationError as e:
07.             self.socket.close()
08.             raise e from None
```

```
>>> authenticate², user, password, error, socket, close
```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04.         try:
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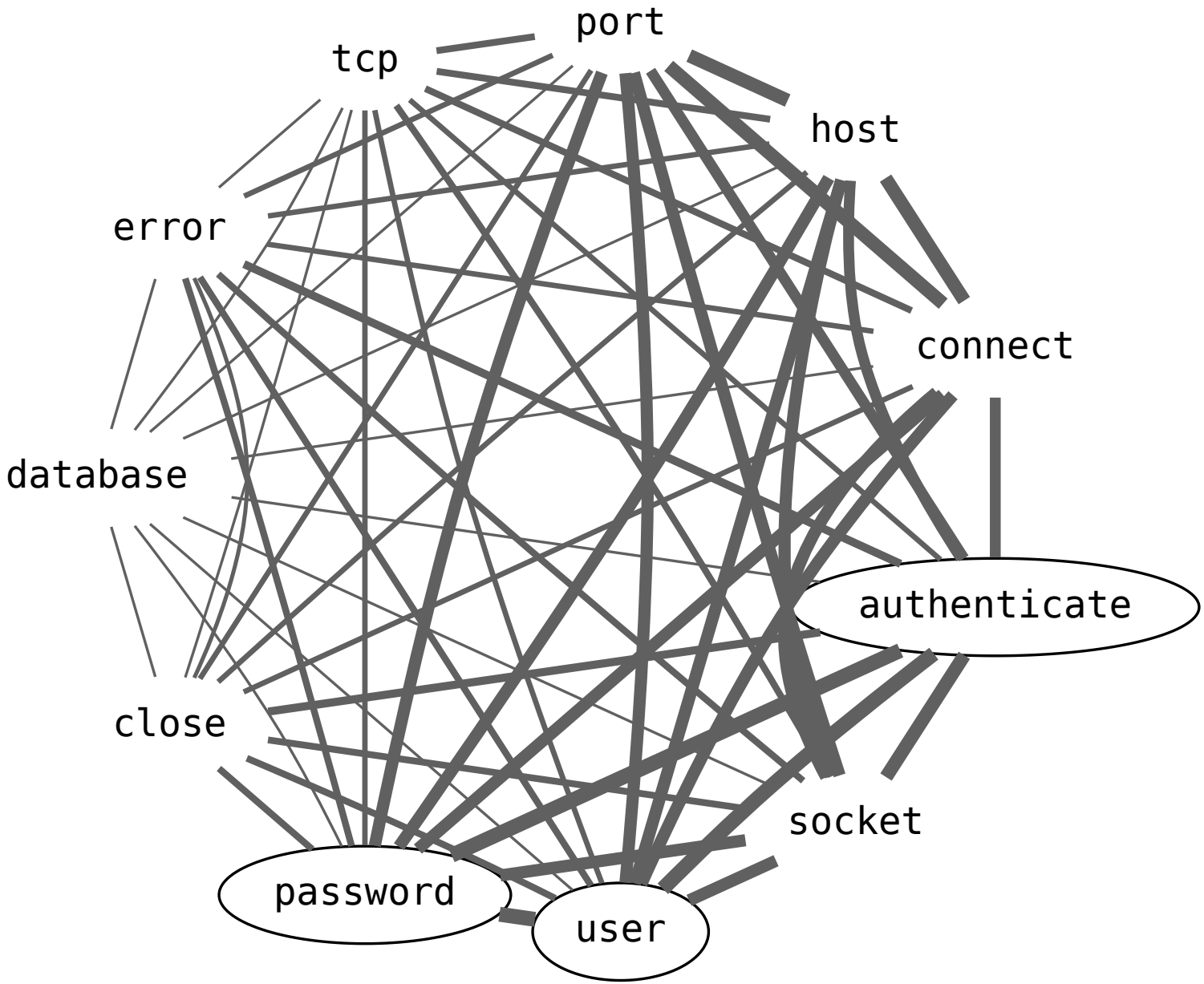
06.         except AuthenticationError as e:
07.             self.socket.close()
08.             raise e from None

>>> authenticate, user, password
```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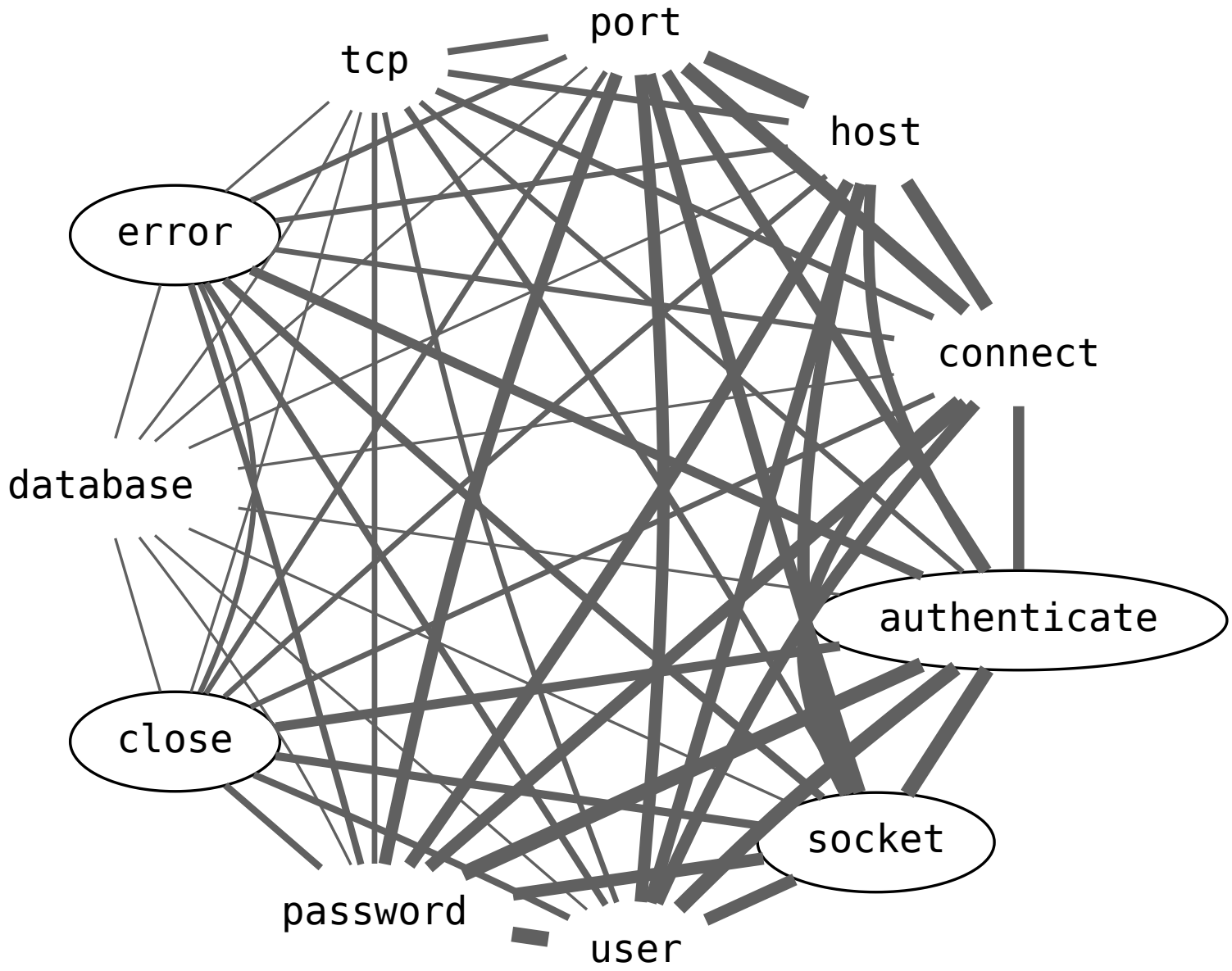
08.             raise e from None
```

```
>>> authenticate, error, socket, close
```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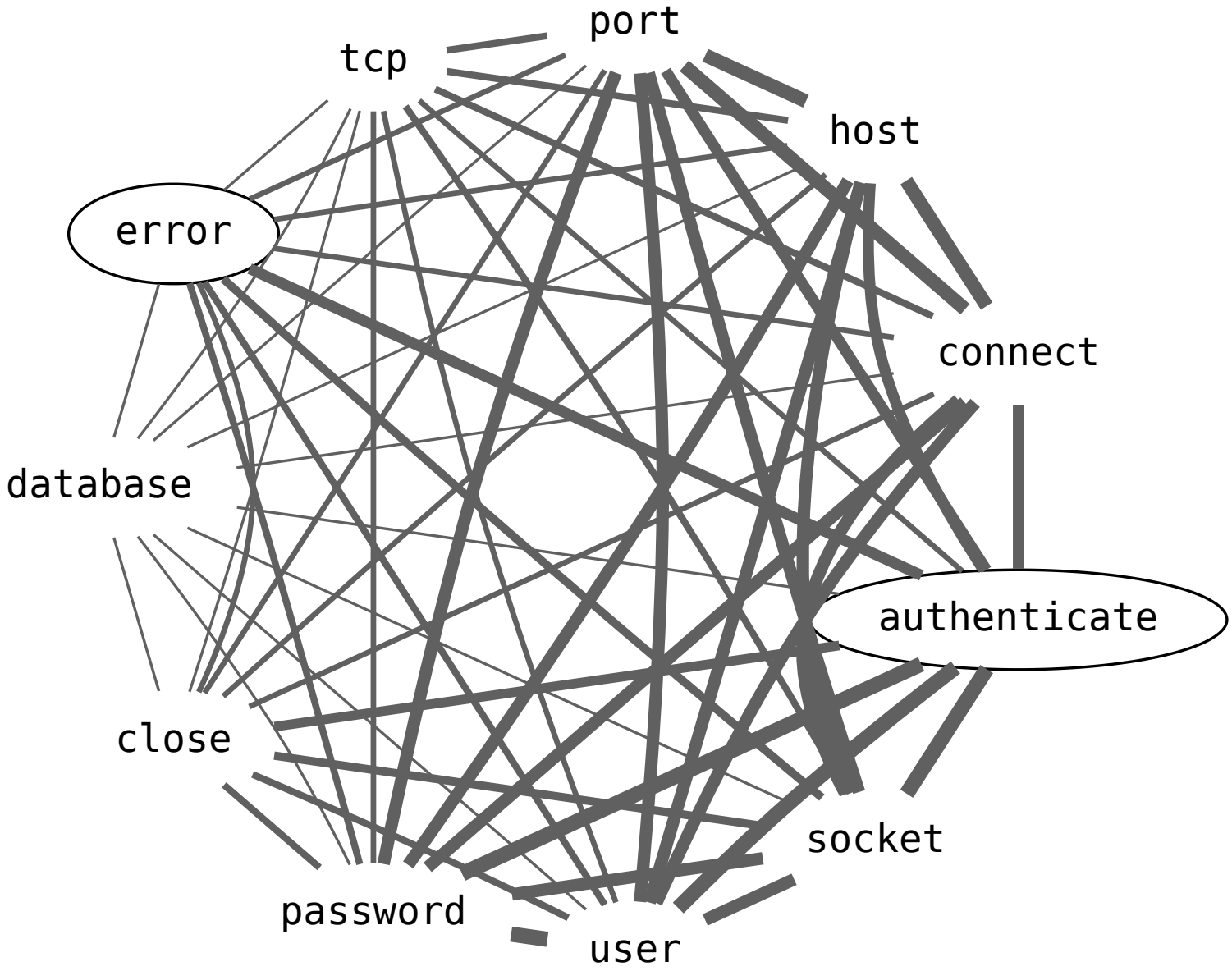
06.         except AuthenticationError as e:
07.             self.socket.close()
08.             raise e from None

>>> authenticate, error
```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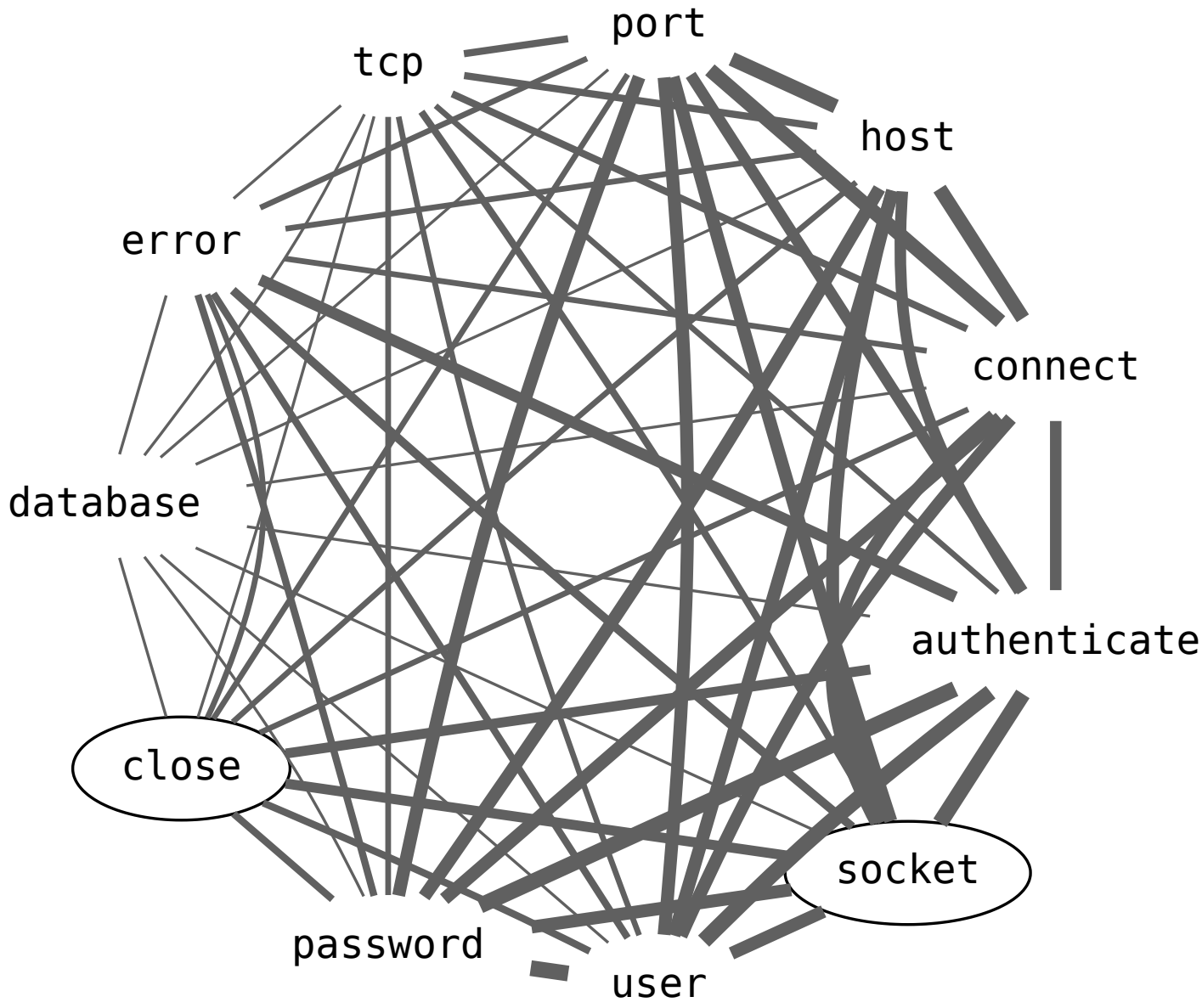
08.             raise e from None

>>> socket, close
```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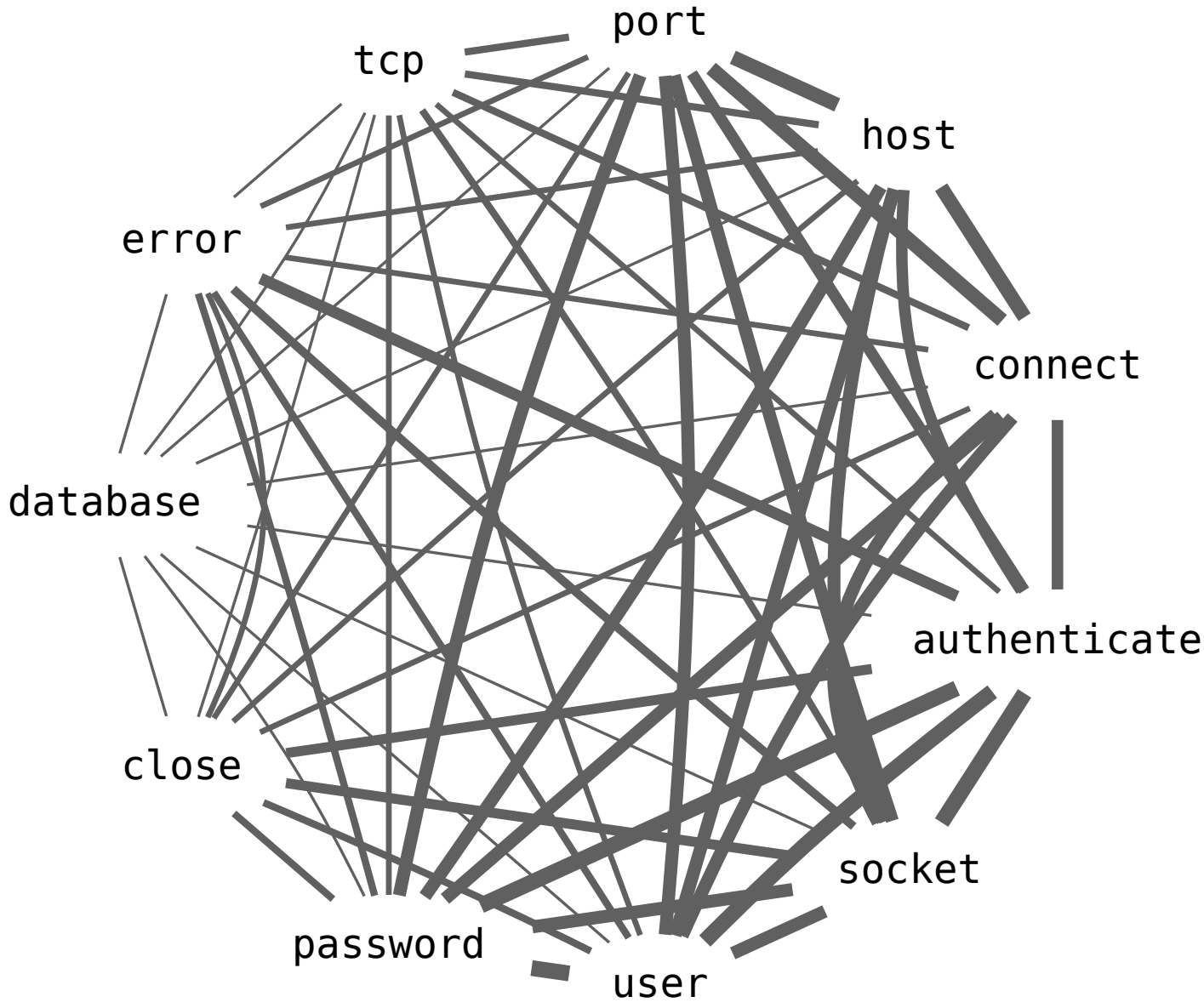
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Incidence matrix C_{ij}

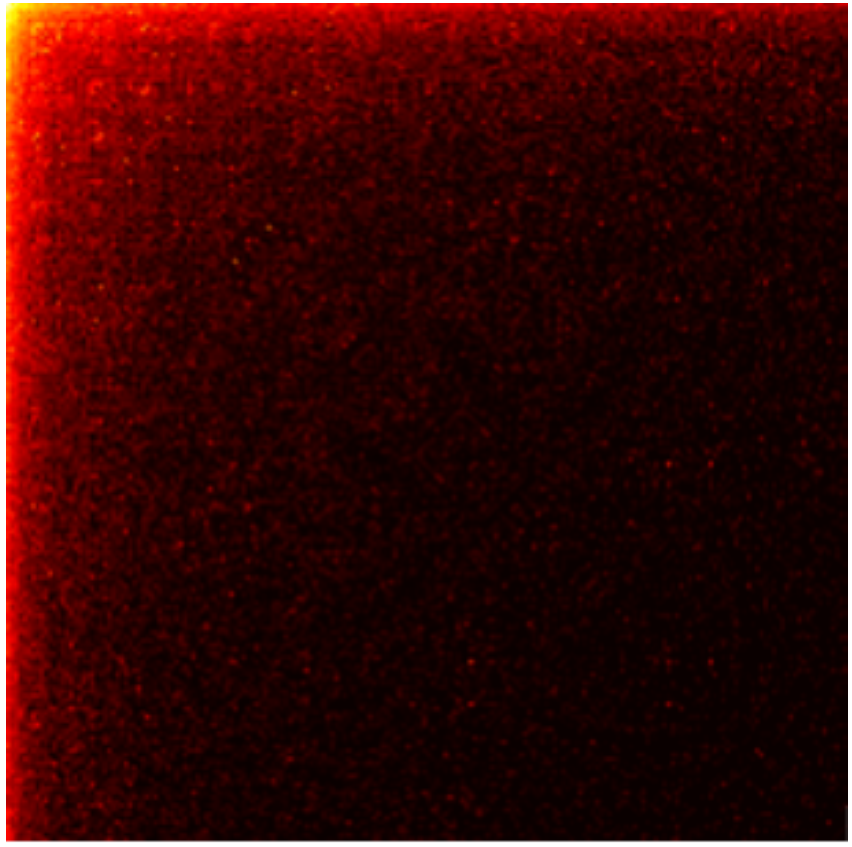
- $C_{ij} =$ number of times i and j were together ❤
- Also known as the **co-occurrence matrix**

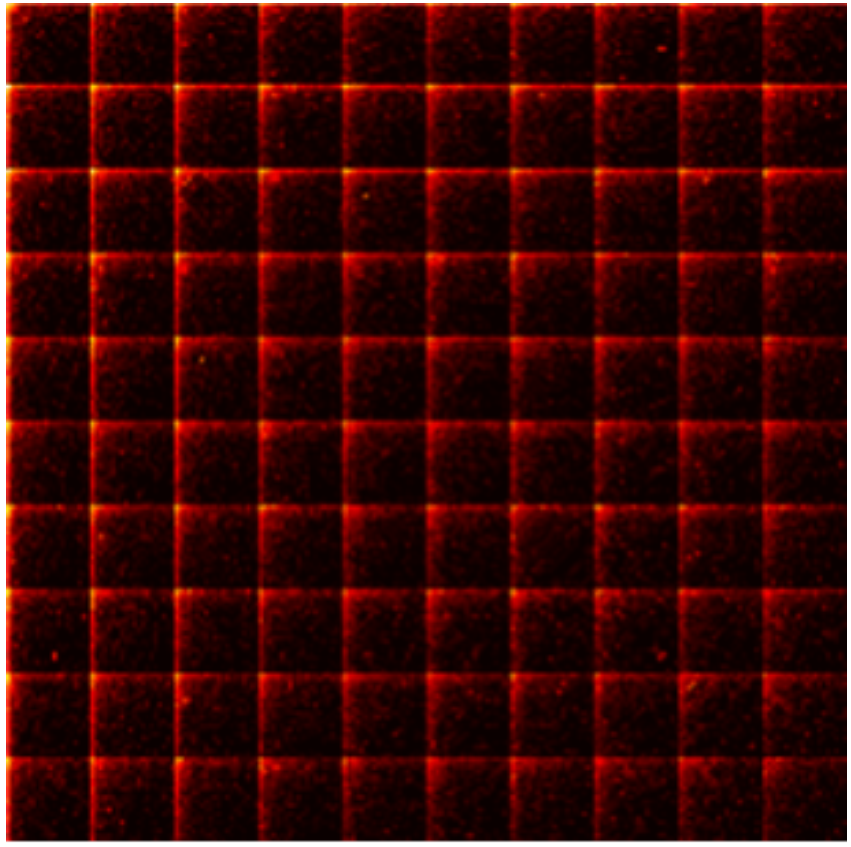
Pointwise Mutual Information (PMI)

$$V_i \cdot V_j = PMI_{ij} = \log \frac{C_{ij} \sum C}{\sum_{k=1}^{N} C_{ik} \sum_{k=1}^{N} C_{jk}}$$

Representation Learning on Explicit Matrix

Stochastic Gradient Descent





Swivel

- ✔ Multi-GPU
- ✔ Multi-node
- ✔ Quality tricks
- ✔
- ✔

Similar repository search

torch/nn

src-d/go-git

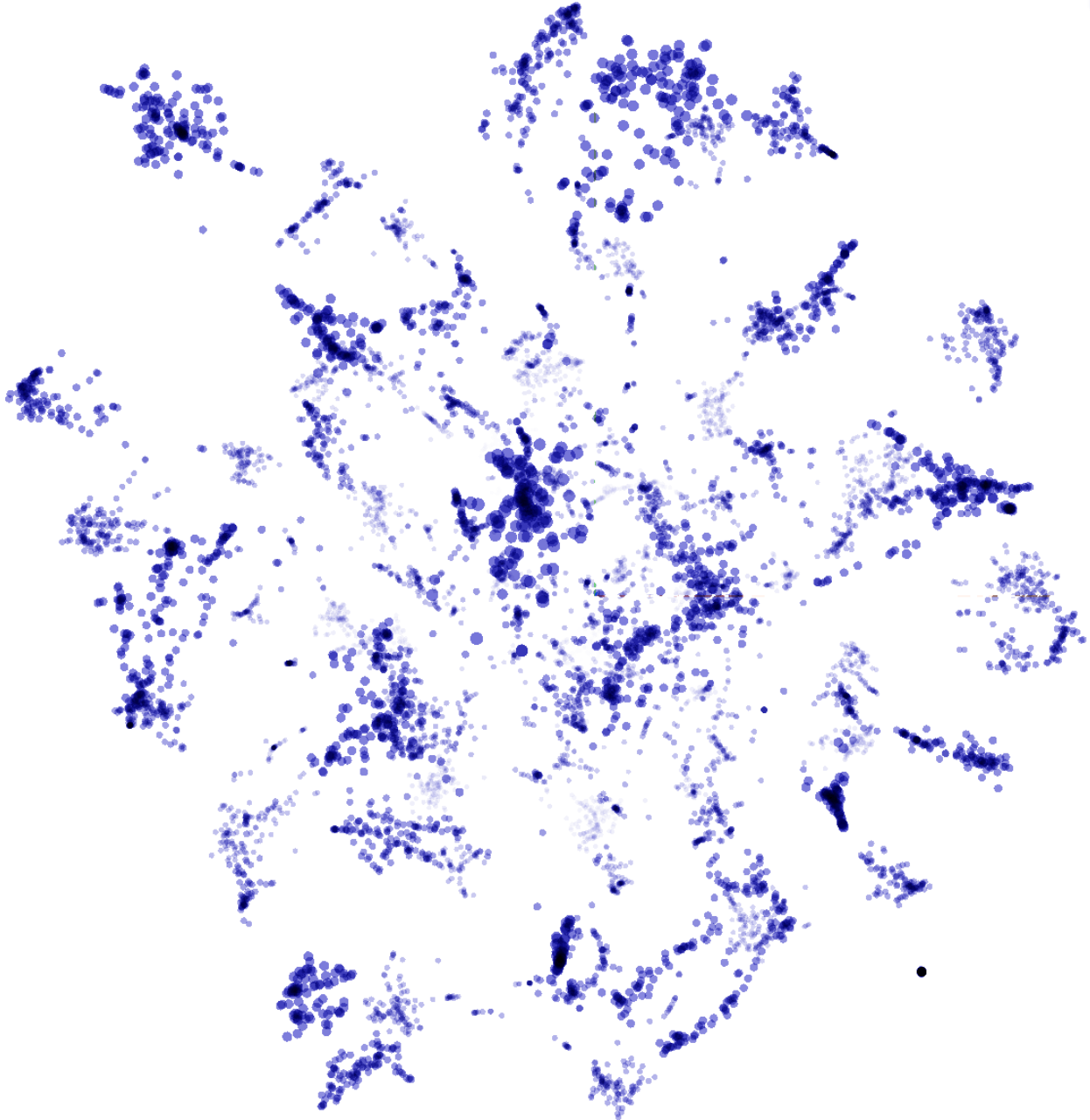
Pipeline

1. Clone the repositories.
2. Classify and parse source code.
3. Preprocess identifiers: split, normalize, filter, stem.
4. Prepare embeddings - cooc matrix & Swivel.
5. Weighted BOW per repository.
6. WMD.

Training identifier embeddings

Stage	Time	Resources	Size on disk
Cloning 143k repos	3 days	20x2 cores, 256 GB RAM	2.6 TB
Dataset	4 days	20x2 cores, 256 GB RAM	2TB (31GB in xz)
fastprep	2 days	16x2 cores, 256 GB RAM	20 GB
Swivel	14 hours	2 Titan X'2016 + 2 1080Ti	5.6 GB

Embeddings



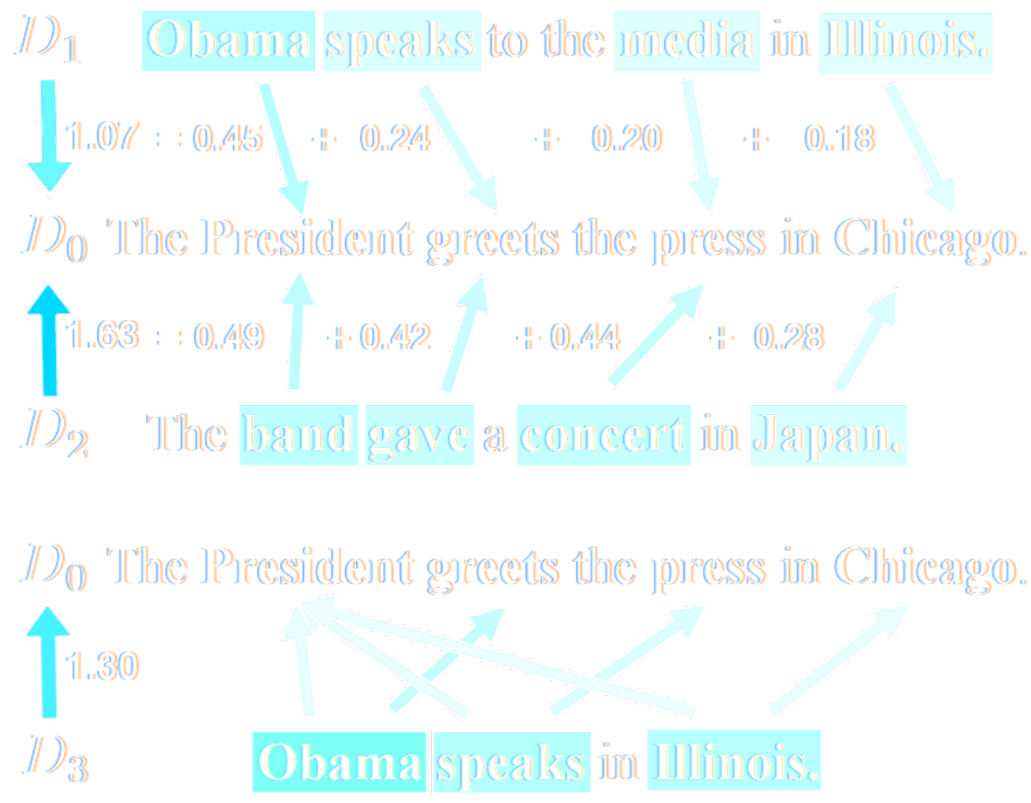
Weighted nBOW

Let's interpret every repository as the weighted bag-of-words.

We calculate TF-IDF to weight the occurring identifiers.

`tensorflow/tensorflow:`

tfreturn	67.780249
oprequires	63.968142
doblas	63.714424
gputools	62.337396
tfassign	61.545926
opkernel	60.721556
sycl	57.064558
hlo	55.723587
libxsmm	54.820668
tfdisallow	53.666890


D_1 Obama speaks to the media in Illinois.
1.07
0.45
0.24
0.20
0.18
D_0 The President greets the press in Chicago.
1.63
0.49
0.42
0.44
0.28
D_2 The band gave a concert in Japan.
D_0 The President greets the press in Chicago.
1.30
D_3 Obama speaks in Illinois.

WMD calculation in a nutshell

WMD evaluation is $O(N^3)$, becomes slow on $N \approx 100$.

1. Sort samples by centroid distance.
2. Evaluate first k WMDs.
3. For every subsequent sample, solve the relaxed LP which gives an upper estimation.
4. If it is greater than the farthest among the k NN, go next.
5. Otherwise, evaluate the WMD.

This allows to avoid 95% WMD evaluations on average.

Code review

5K

7M+

25M+

1M

0

109

14K

495

1,054,066

121,280

1,175,346 issues

So

Typo

"Use the get keyword to make a getter method isValid that checks if the the given 4 side
is valid. A square is valid when the lengths of all sides are equal." Bolded section should

learn-co-curriculum/fewpjs-class-extensions-extends-lab Opened by RylanBauermeister 2 days ag

typo

ThinkR-open/building-shiny-apps-workflow Opened by tellyshia a day ago

Typo

Label above JSON example for filtering by Subject reads "The JSON syntax for filtering b
is:". It should read "The JSON syntax for filtering by subject is:" Document Details ...

MicrosoftDocs/azure-docs Opened by rajues 3 days ago • 2 comments

Typos correction inside code identifiers

```
01. class ClasName:
02.     @classmethod
03.     def function_name(cls) -> str:
04.         varyable_name = "Hello, I'm ClassName object!"
05.         return varyable_name
```

Typos correction

funktion → function

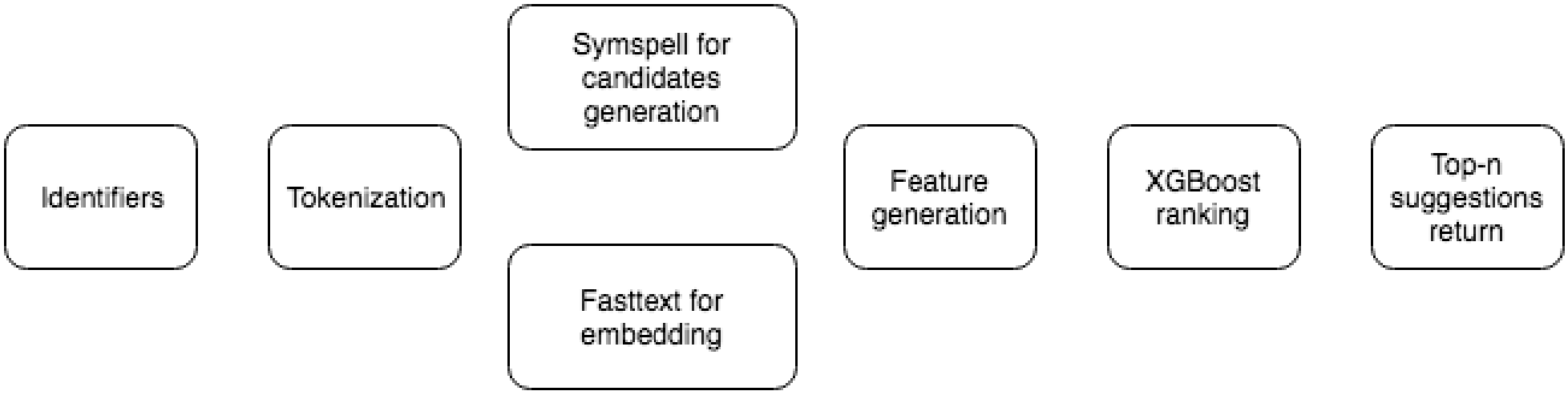
GetValu → GetValue

str_lenght → str_length

Typos correction inside code identifiers

```
01. class ClassName:
02.     @classmethod
03.     def function_name(cls) -> str:
04.         variable_name = "Hello, I'm ClassName object!"
05.         return variable_name
```

The correction pipeline



Candidates generation

1. Find candidates with the
2. Identifier to which the token belongs - a context
3. Features: based on the frequencies, embeddings, similarity and edit distance between the elements

Candidates ranking

- Binary classification model on tuples `(identifier, token, candidate)`:
  - `label=1` if the candidate is the correct suggestion
  - `label=0` otherwise
- Group by the token and sort
- is used for binary classification

Suggestions

- Suggested token itself - not correcting
- Otherwise return corrections

Training and testing

- Train and test datasets are sampled from the dataset of identifiers
- Random artificial typos
- **Dataset itself contains typos**

Results on a token level

- Detection precision - 98%
- Detection recall - 82%
- Top3 correction accuracy - 95%

Note: the test dataset is not a ground truth.

Developer similarity

Pipeline

1. Clone the organization.
2. Classify and parse source code.
3. Extract identifiers per file.
4. Extract experience per developer - languages, files, etc.
5. Topic modeling.
6. Usage: KD-tree, clustering and so on.

From git history

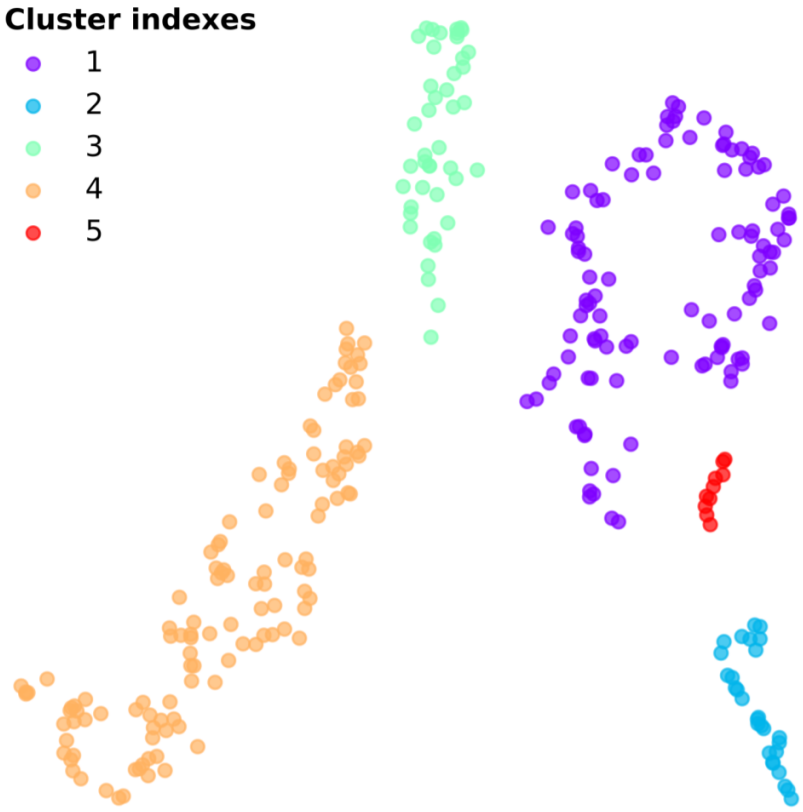
Dev\Files	File 1	File 2	File 3
Dev 1	0	0.1	0.8
Dev 2	0.4	0.1	0.5

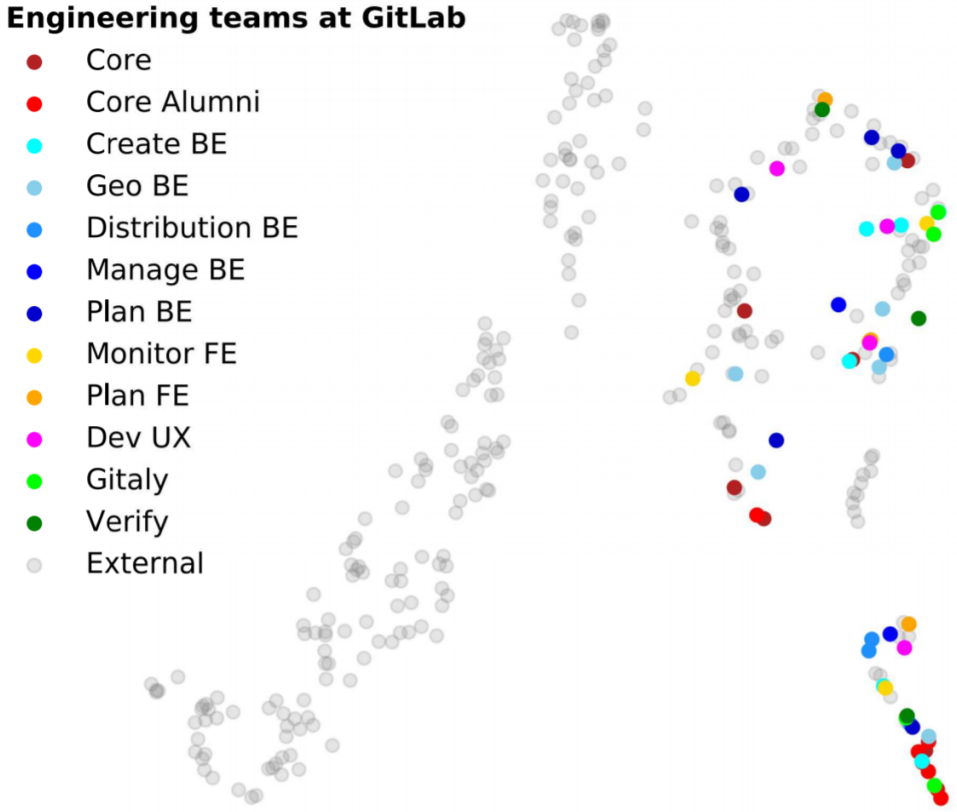
From head revision

Files\Tokens	Token 1	Token 2	Token 3
File 1	0	0.1	0.8
File 2	0.4	0.1	0.56
File 3	0.43	0.18	0.9

Result after multiplication

Dev\Token	Token 1	Token 2	Token 3
Dev 1	0	0.1	0.8
Dev 2	0.4	0.1	0.5


Cluster indexes
1
2
3
4
5


Engineering teams at GitLab
Core
Core Alumni
Create BE
Geo BE
Distribution BE
Manage BE
Plan BE
Monitor FE
Plan FE
Dev UX
Gitaly
Verify
External

Summary

- MLonCode is fun
- There is data
- There are tools
- Community is forming

Idea? Doubt? Write us!

Thank you