Complexity-Based Code Insights
(and Automatic Algorithm Classification)

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Our objective:

Can we **estimate** what class of problems does a **code** solve?

Mathematical problems

```
if (i % 2 == 0){
        return 4
} else { return 6 }
```

Dynamic programming

```
d[n]=d[n-1]+2*d[n-2]
```

Graph theory

```
for (k =1; k< n; k++) {
a[i][j] = a[i][k] +
              a[k][j]
}
```

Brute force

```
for (i =1; i <n; i++){
 for (j =1; j <n; j++){
  for (k =1; k< n; k++){
;     ...}}}
```

Bigger objective:

Can we solve more general problems regarding code analysis?

Word embeddings: mapping between **words** and **numerical vectors**

```
“mother” = [0.213, 0.002, 0.889, 0.110, 0.553, …, 0.941]
“father” = [0.331, 0.122, 0.189, 0.117, 0.923, …, 0.822]
```

Core idea:

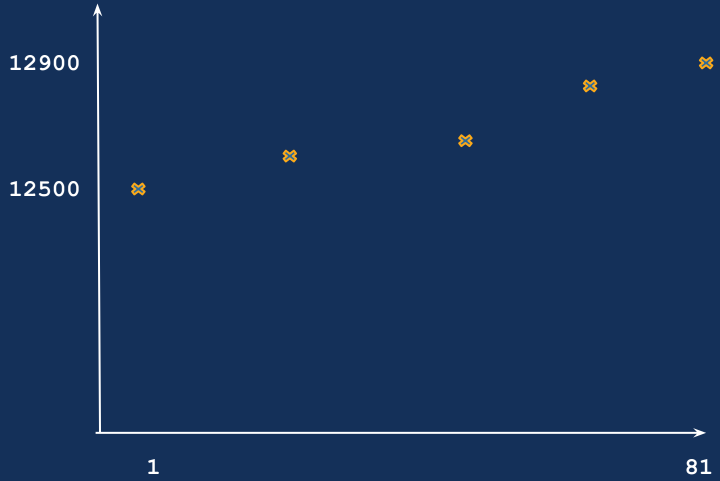
Create code embeddings using dynamic profiling over code snippets.

```
#include <bits/stdc++.h>

using namespace std;

int main() {
    int m, n;
    cin >> n >> m;
    int a;
    cin >> a;
    int k = ((n + (a - 1)) / a)
            * ((m + (a - 1)) / a);
    cout << k;
}
```

0.631	0.431	0.221	0.332	0.209	0.992

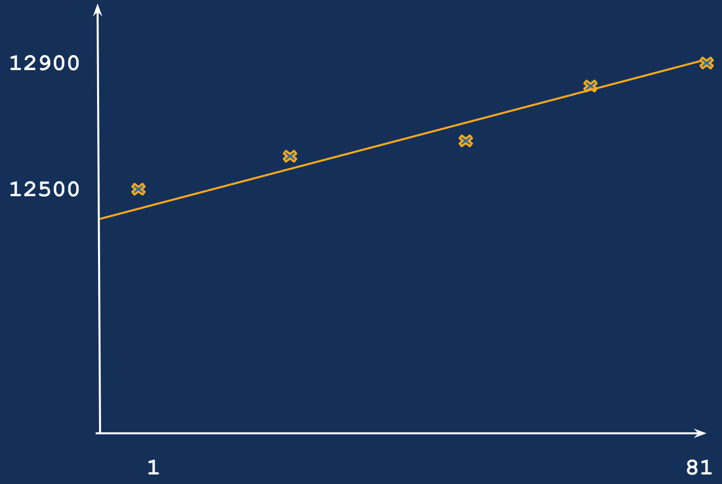
Our solution for creating embeddings: (1)

```
"branch-misses":
{ "1": 12500.0,
 "21": 12605.2,
 "41": 12706.1,
...
```



Our solution for creating embeddings: (2)

```
"branch-misses": {
"FEATURE_CONFIG": 1,
"FEATURE_TYPE": "POLYNOMIAL",
"INTERCEPT": 12475.13,
"R-VAL": 50.56 },
```



Analysed metrics for building the code embeddings

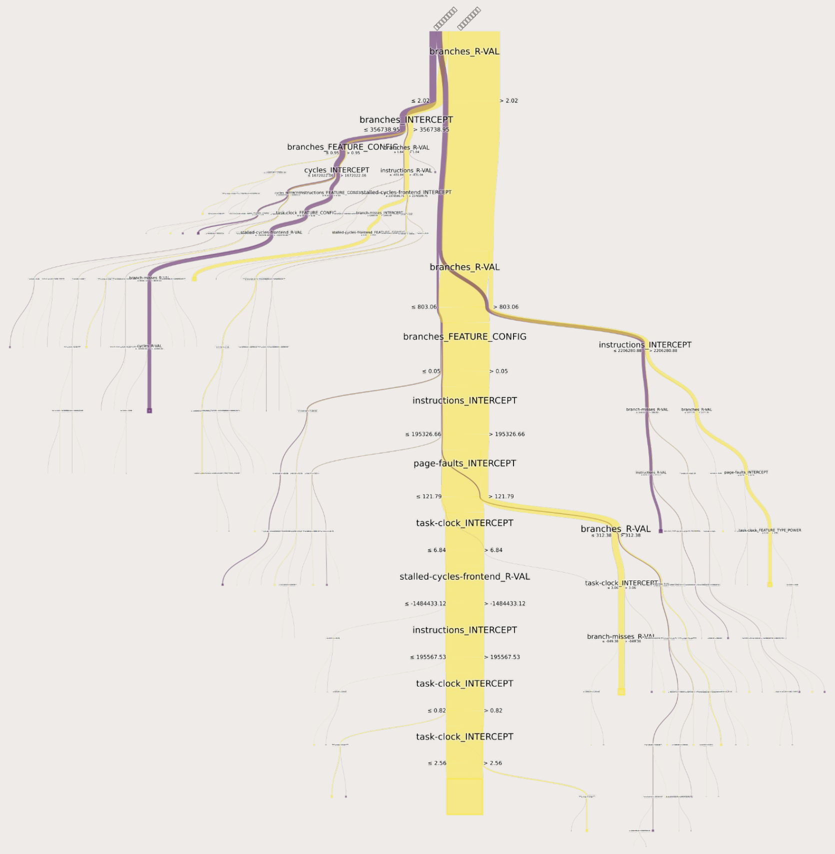
- branch-misses
- branches
- context-switches
- cycles
- instructions
- page-faults

and more ....

With the dynamic code embeddings computed, we can design classification models.

Binary classification

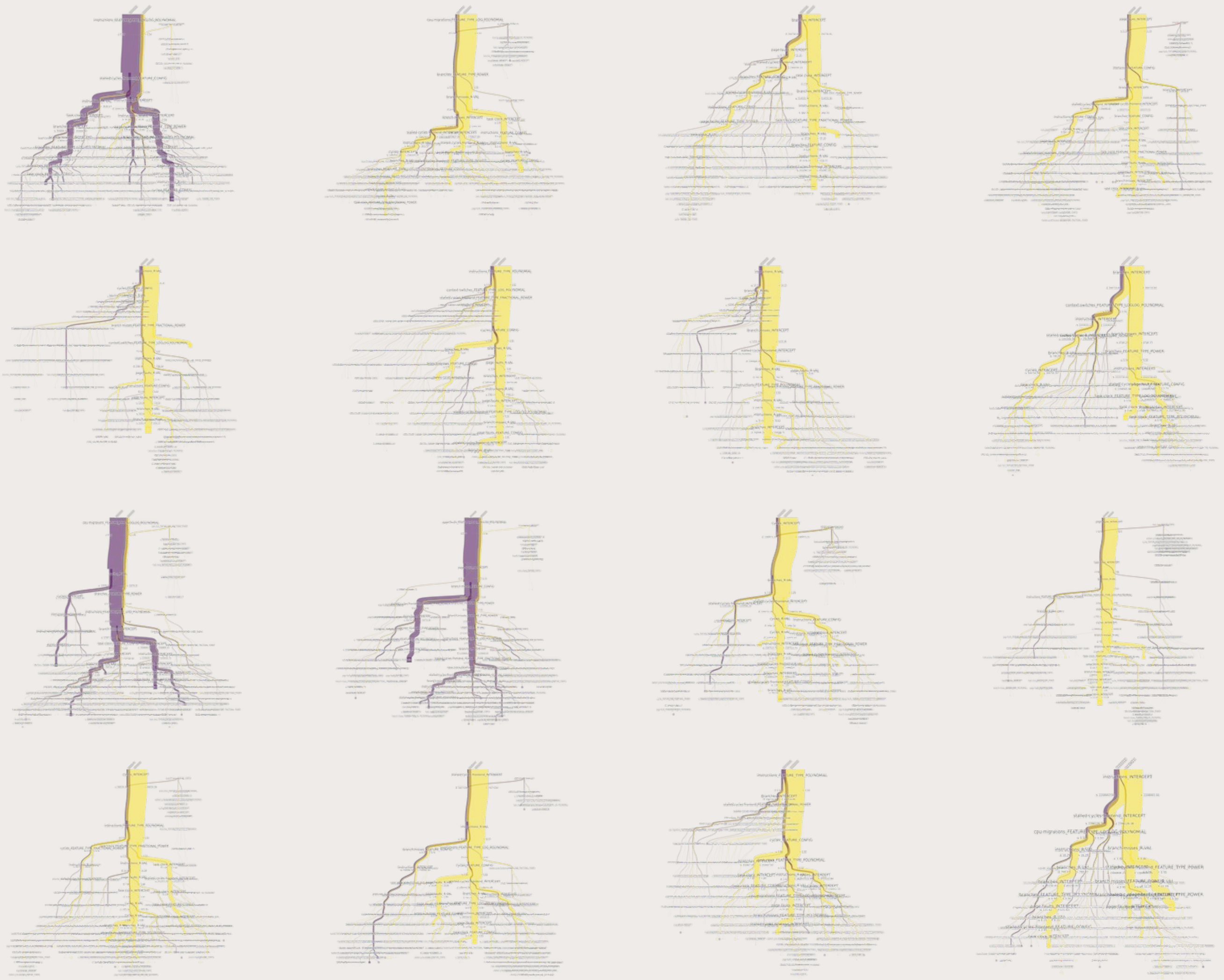
Decisions Tree



- binary math/non-math classification
- 96%+ accuracy on a testing dataset based on 5000+ open-source solutions from Codeforces

Random forest

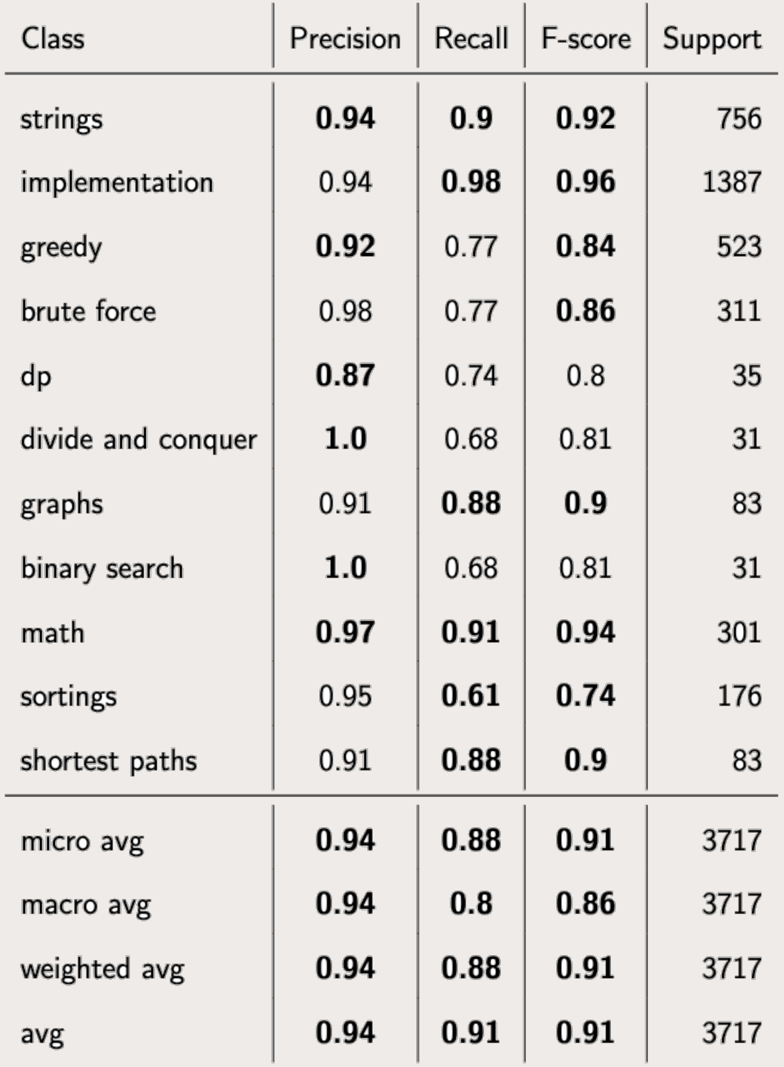
- binary math/non-math classification
- between 16 and 10000 classifiers
- 97%+ accuracy on testing dataset



Multi-label classification

XGBoost

- **Achieving Multi Label Classification by training one classifier per target.**
- **Best performance, in terms of precision, recall and F1-score for the analyzed scenarios.**

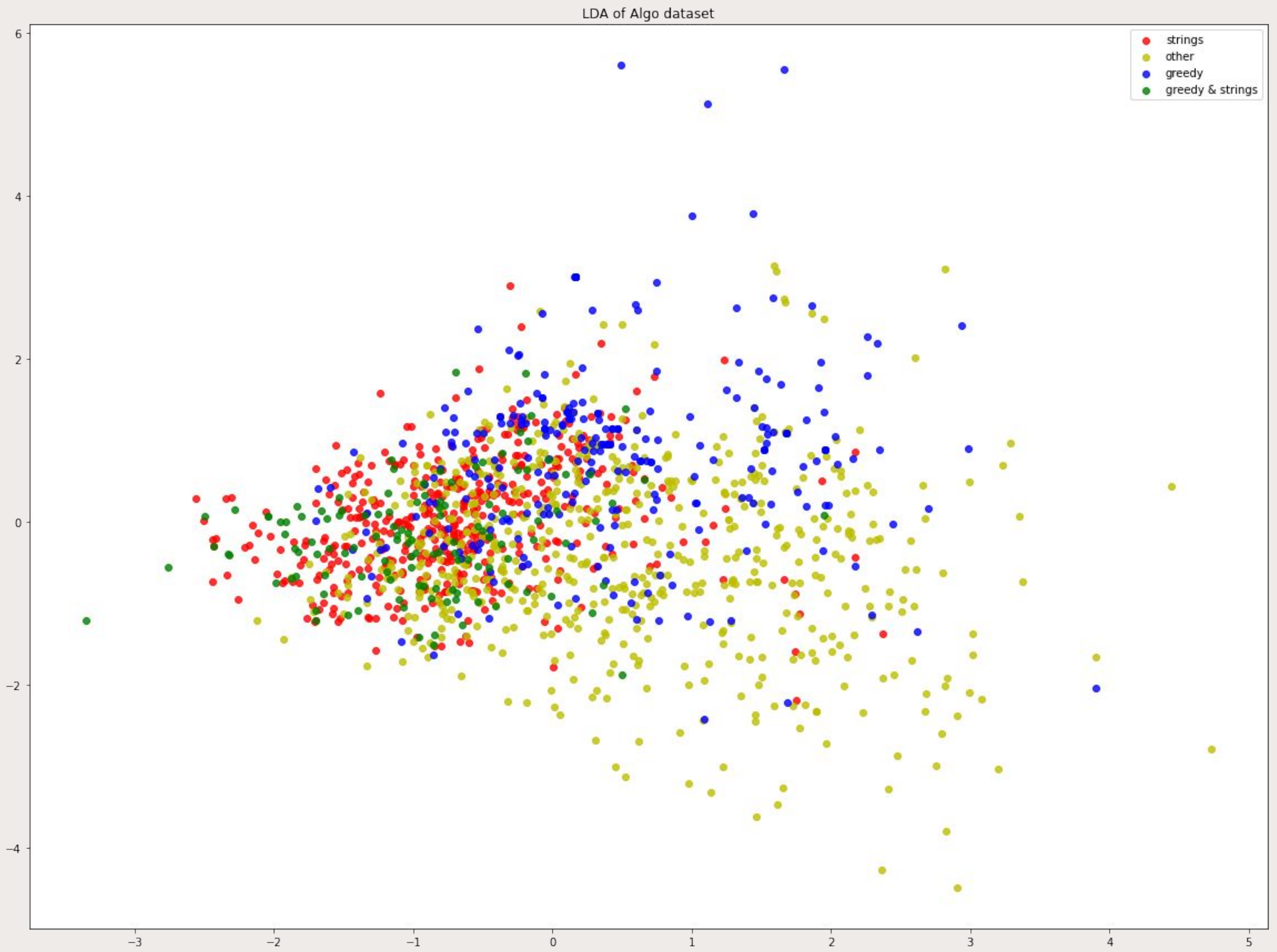


Class	Precision	Recall	F-score	Support
strings	**0.94**	**0.9**	**0.92**	756
implementation	0.94	**0.98**	**0.96**	1387
greedy	**0.92**	0.77	**0.84**	523
brute force	0.98	0.77	**0.86**	311
dp	**0.87**	0.74	0.8	35
divide and conquer	**1.0**	0.68	0.81	31
graphs	0.91	**0.88**	**0.9**	83
binary search	**1.0**	0.68	0.81	31
math	**0.97**	**0.91**	**0.94**	301
sortings	0.95	**0.61**	**0.74**	176
shortest paths	0.91	**0.88**	**0.9**	83
micro avg	**0.94**	**0.88**	**0.91**	3717
macro avg	**0.94**	**0.8**	**0.86**	3717
weighted avg	**0.94**	**0.88**	**0.91**	3717
avg	**0.94**	**0.91**	**0.91**	3717

Dataset visualisation

(using Linear Discriminant Analysis technique)

Projection of the dataset, with the split between greedy, strings, mixed and other solutions.



Thank you!

Follow the models research development:
https://github.com/raresraf/AlgoRAF/

Follow the embeddings research development:
https://github.com/raresraf/rafPipeline/

Contribute to our dataset:
https://github.com/raresraf/TheInputsCodeforces