

Supplementary Material for

## On the Evaluation of Unsupervised Outlier Detection: Measures, Datasets, and an Empirical Study

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# Waveform (version#01)

This dataset represents 3 classes of waves. Class 0 was defined here as an outlier class and downsampled to 100 objects. After preprocessing, this database has 21 numeric attributes and 3443 instances, divided into 100 outliers (2.9%) and 3343 inliers (97.1%) [1].

References:

[1] A. Zimek, M. Gaudet, R. J. G. B. Campello, and J. Sander. Subsampling for efficient and effective unsupervised outlier detection ensembles. In Proc. KDD, pages 428-436, 2013.

[Download all data set variants used \(5.1 MB\)](#). You can also access the [original data](#). (waveform.data.Z)

- [Normalized, without duplicates](#)
- [Not normalized, without duplicates](#)

## Normalized, without duplicates

This version contains 21 attributes, 3443 objects, 100 outliers (2.90%)

[Download raw algorithm results \(30.1 MB\)](#) [Download raw algorithm evaluation table \(64.1 kB\)](#)

## Best Parameters

The following table contains the best (overall and per-method) results for each method and evaluation measure (when the same score was achieved twice, only the smallest k is given). The Maximum F1-Measure is complimentary in addition to the measures in the original publication.

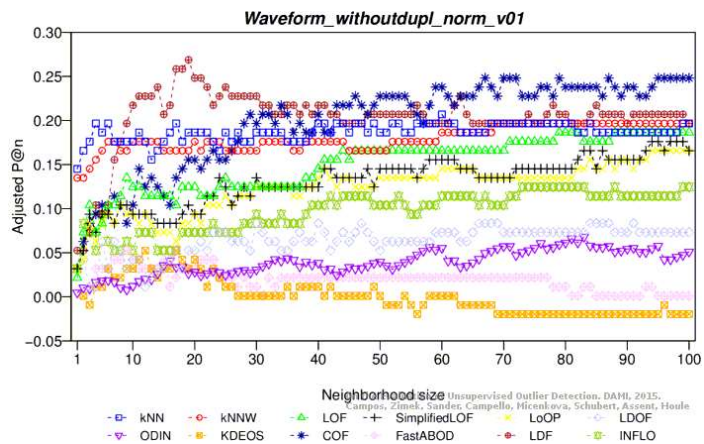
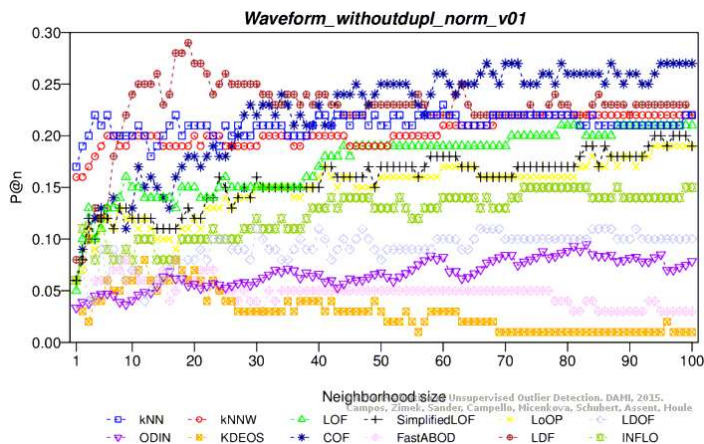
| Algorithm | k          | P@n     | Adj. P@n | AP      | Adj. AP | Max-F1  | Adj. MF1 | ROC AUC |
|-----------|------------|---------|----------|---------|---------|---------|----------|---------|
| KNN       | <b>22</b>  | 0.21000 | 0.18637  | 0.13711 | 0.11130 | 0.23810 | 0.21530  | 0.74646 |
| KNN       | <b>60</b>  | 0.23000 | 0.20697  | 0.14330 | 0.11767 | 0.23077 | 0.20776  | 0.75306 |
| KNN       | <b>97</b>  | 0.21000 | 0.18637  | 0.14767 | 0.12217 | 0.22414 | 0.20093  | 0.76130 |
| KNN       | <b>100</b> | 0.22000 | 0.19667  | 0.14732 | 0.12181 | 0.22222 | 0.19896  | 0.76252 |
| KNNW      | <b>67</b>  | 0.21000 | 0.18637  | 0.13825 | 0.11247 | 0.23529 | 0.21242  | 0.75090 |

|                      |            |         |          |         |         |         |         |         |
|----------------------|------------|---------|----------|---------|---------|---------|---------|---------|
| <b>KNNW</b>          | <b>69</b>  | 0.22000 | 0.19667  | 0.13843 | 0.11265 | 0.23529 | 0.21242 | 0.75102 |
| <b>KNNW</b>          | <b>92</b>  | 0.22000 | 0.19667  | 0.14115 | 0.11546 | 0.23148 | 0.20849 | 0.75339 |
| <b>KNNW</b>          | <b>100</b> | 0.22000 | 0.19667  | 0.14085 | 0.11515 | 0.23256 | 0.20960 | 0.75411 |
| <b>LOF</b>           | <b>79</b>  | 0.21000 | 0.18637  | 0.12718 | 0.10107 | 0.22134 | 0.19805 | 0.74130 |
| <b>LOF</b>           | <b>92</b>  | 0.21000 | 0.18637  | 0.13079 | 0.10479 | 0.22764 | 0.20454 | 0.74281 |
| <b>LOF</b>           | <b>97</b>  | 0.21000 | 0.18637  | 0.13069 | 0.10469 | 0.23431 | 0.21141 | 0.74239 |
| <b>LOF</b>           | <b>100</b> | 0.21000 | 0.18637  | 0.13131 | 0.10533 | 0.23431 | 0.21141 | 0.74246 |
| <b>SimplifiedLOF</b> | <b>94</b>  | 0.20000 | 0.17607  | 0.10539 | 0.07863 | 0.20576 | 0.18200 | 0.72629 |
| <b>SimplifiedLOF</b> | <b>100</b> | 0.19000 | 0.16577  | 0.11283 | 0.08629 | 0.21277 | 0.18922 | 0.72650 |
| <b>LoOP</b>          | <b>91</b>  | 0.17000 | 0.14517  | 0.09940 | 0.07246 | 0.20253 | 0.17868 | 0.71962 |
| <b>LoOP</b>          | <b>94</b>  | 0.19000 | 0.16577  | 0.09913 | 0.07218 | 0.19913 | 0.17518 | 0.71980 |
| <b>LoOP</b>          | <b>99</b>  | 0.19000 | 0.16577  | 0.10194 | 0.07508 | 0.20084 | 0.17693 | 0.72112 |
| <b>LoOP</b>          | <b>100</b> | 0.19000 | 0.16577  | 0.10282 | 0.07598 | 0.20084 | 0.17693 | 0.72040 |
| <b>LDOF</b>          | <b>30</b>  | 0.11000 | 0.08338  | 0.05929 | 0.03115 | 0.12093 | 0.09463 | 0.68413 |
| <b>LDOF</b>          | <b>87</b>  | 0.11000 | 0.08338  | 0.06863 | 0.04077 | 0.14340 | 0.11777 | 0.71994 |
| <b>LDOF</b>          | <b>91</b>  | 0.11000 | 0.08338  | 0.06913 | 0.04129 | 0.13383 | 0.10792 | 0.72125 |
| <b>LDOF</b>          | <b>100</b> | 0.10000 | 0.07308  | 0.06968 | 0.04185 | 0.12583 | 0.09968 | 0.72046 |
| <b>ODIN</b>          | <b>83</b>  | 0.09500 | 0.06793  | 0.05983 | 0.03171 | 0.12658 | 0.10046 | 0.69353 |
| <b>ODIN</b>          | <b>100</b> | 0.07857 | 0.05101  | 0.06429 | 0.03630 | 0.13889 | 0.11313 | 0.69925 |
| <b>FastABOD</b>      | <b>9</b>   | 0.08000 | 0.05248  | 0.04962 | 0.02119 | 0.09645 | 0.06943 | 0.64648 |
| <b>FastABOD</b>      | <b>21</b>  | 0.07000 | 0.04218  | 0.05138 | 0.02300 | 0.10498 | 0.07821 | 0.67682 |
| <b>FastABOD</b>      | <b>45</b>  | 0.05000 | 0.02158  | 0.05031 | 0.02190 | 0.11409 | 0.08759 | 0.67136 |
| <b>KDEOS</b>         | <b>12</b>  | 0.08000 | 0.05248  | 0.04131 | 0.01264 | 0.08372 | 0.05631 | 0.59580 |
| <b>KDEOS</b>         | <b>17</b>  | 0.08000 | 0.05248  | 0.04102 | 0.01233 | 0.09434 | 0.06725 | 0.59032 |
| <b>KDEOS</b>         | <b>21</b>  | 0.06000 | 0.03188  | 0.04666 | 0.01814 | 0.07143 | 0.04365 | 0.57432 |
| <b>KDEOS</b>         | <b>100</b> | 0.01000 | -0.01961 | 0.03639 | 0.00757 | 0.08013 | 0.05261 | 0.61206 |
| <b>LDF</b>           | <b>19</b>  | 0.29000 | 0.26876  | 0.21289 | 0.18934 | 0.29146 | 0.27026 | 0.76427 |
| <b>LDF</b>           | <b>24</b>  | 0.25000 | 0.22757  | 0.21998 | 0.19665 | 0.30968 | 0.28903 | 0.76640 |
| <b>LDF</b>           | <b>29</b>  | 0.25000 | 0.22757  | 0.21541 | 0.19194 | 0.28090 | 0.25939 | 0.77617 |
| <b>INFLO</b>         | <b>73</b>  | 0.15000 | 0.12457  | 0.08461 | 0.05722 | 0.16988 | 0.14505 | 0.70853 |
| <b>INFLO</b>         | <b>94</b>  | 0.14000 | 0.11427  | 0.09177 | 0.06460 | 0.18113 | 0.15664 | 0.71460 |
| <b>INFLO</b>         | <b>99</b>  | 0.15000 | 0.12457  | 0.09821 | 0.07124 | 0.19048 | 0.16626 | 0.71265 |
| <b>INFLO</b>         | <b>100</b> | 0.15000 | 0.12457  | 0.09874 | 0.07178 | 0.19048 | 0.16626 | 0.70931 |
| <b>COF</b>           | <b>36</b>  | 0.21000 | 0.18637  | 0.18006 | 0.15553 | 0.23276 | 0.20981 | 0.75882 |
| <b>COF</b>           | <b>67</b>  | 0.27000 | 0.24816  | 0.20574 | 0.18198 | 0.27225 | 0.25048 | 0.73926 |
| <b>COF</b>           | <b>80</b>  | 0.26000 | 0.23786  | 0.21165 | 0.18806 | 0.28188 | 0.26040 | 0.73945 |
| <b>COF</b>           | <b>97</b>  | 0.27000 | 0.24816  | 0.20435 | 0.18055 | 0.29885 | 0.27788 | 0.73544 |

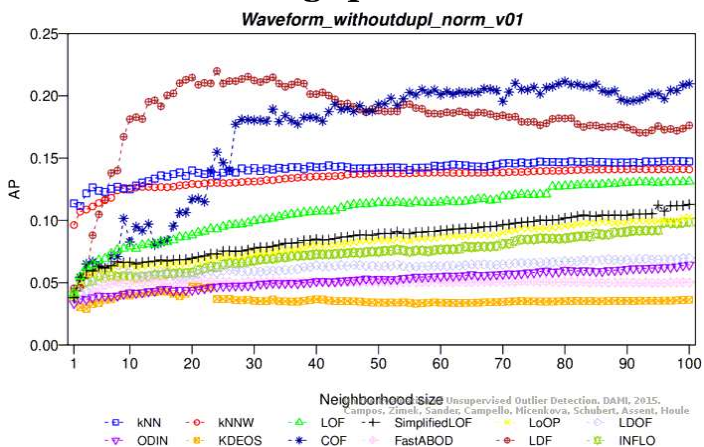
## Plots

Precision at  $n$

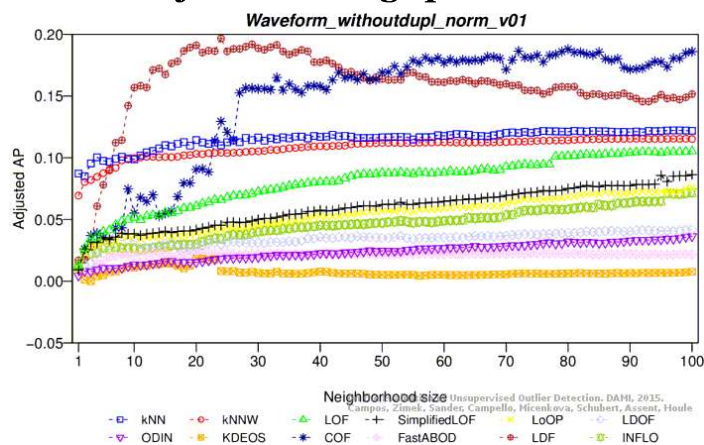
Adjusted precision at  $n$



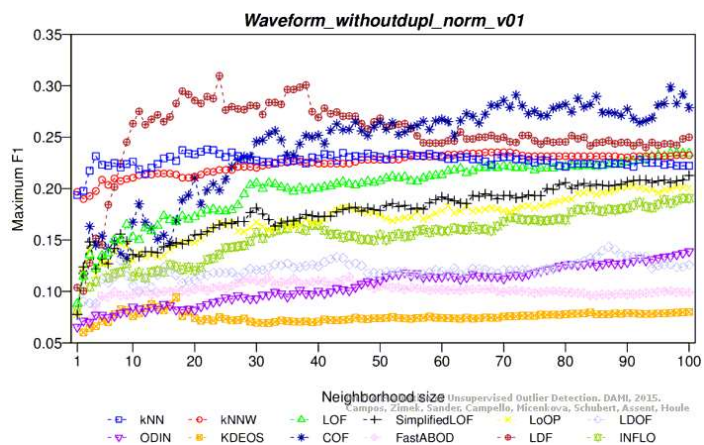
## Average precision



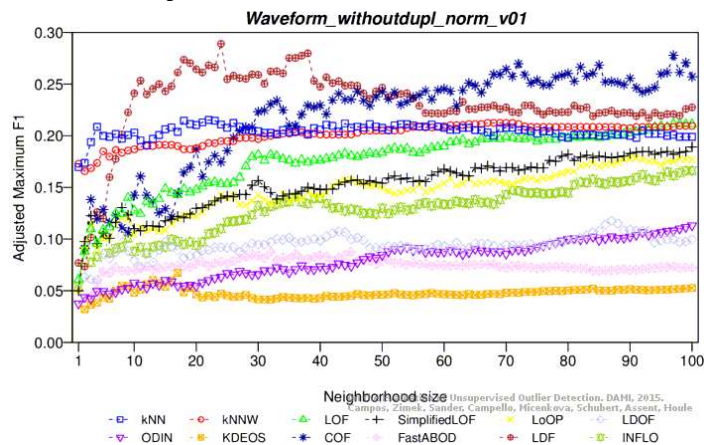
## Adjusted average precision



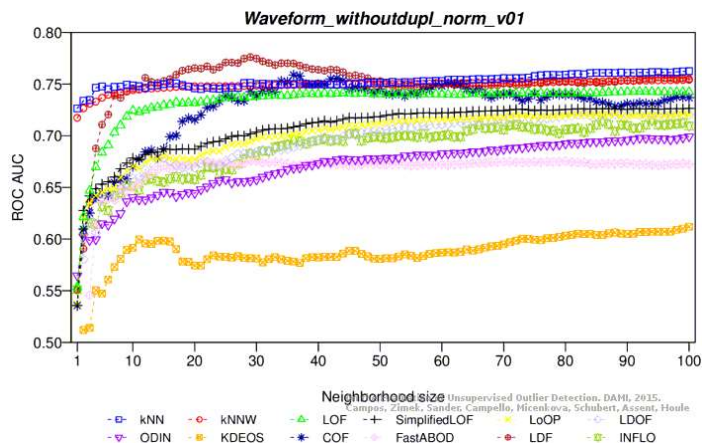
## Maximum F1 score



## Adjusted maximum F1 score

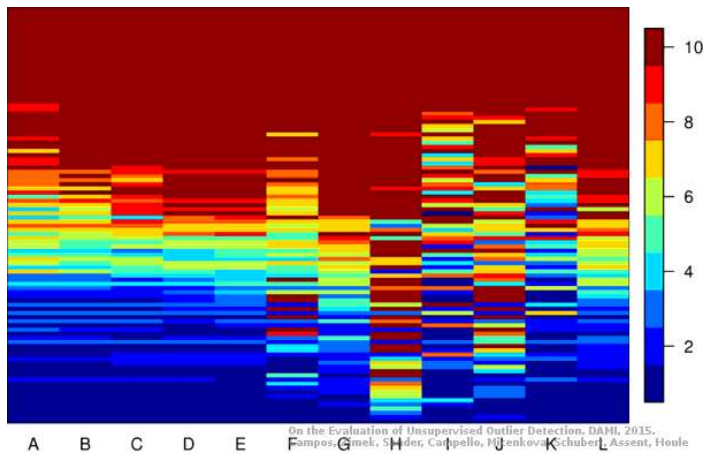


## ROC AUC



## Diversity





Waveform  
 A: KNN, B: KNNW, C: LOF, D: SimplifiedLOF, E: LoOP, F: LDOF  
 G: ODIN, H: KDEOS, I: COF, J: FastABOD, K: LDF, L: INFLO

# Not normalized, without duplicates

This version contains 21 attributes, 3443 objects, 100 outliers (2.90%)

[Download raw algorithm results \(30.2 MB\)](#) [Download raw algorithm evaluation table \(64.3 kB\)](#)

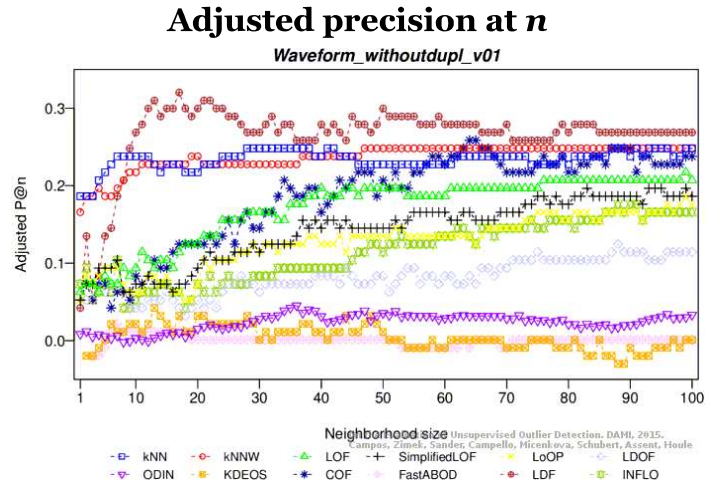
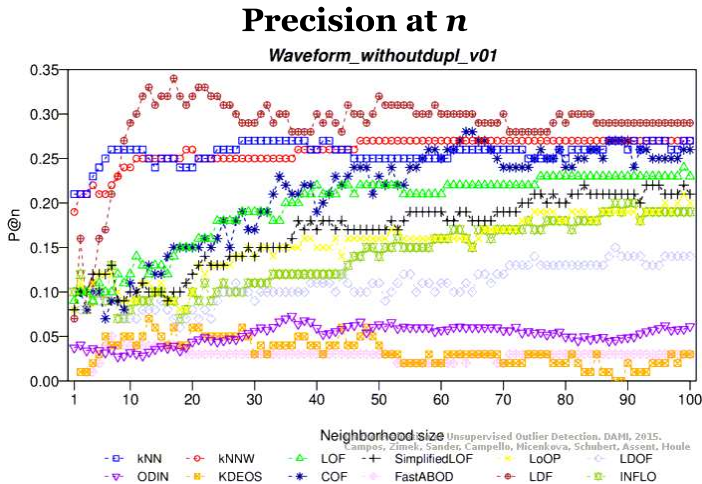
## Best Parameters

The following table contains the best (overall and per-method) results for each method and evaluation measure (when the same score was achieved twice, only the smallest k is given). The Maximum F1-Measure is complimentary in addition to the measures in the original publication.

| Algorithm     | k   | P@n     | Adj. P@n | AP      | Adj. AP | Max-F1  | Adj. MF1 | ROC AUC |
|---------------|-----|---------|----------|---------|---------|---------|----------|---------|
| KNN           | 28  | 0.27000 | 0.24816  | 0.17335 | 0.14863 | 0.27551 | 0.25384  | 0.75712 |
| KNN           | 31  | 0.27000 | 0.24816  | 0.17443 | 0.14974 | 0.28421 | 0.26280  | 0.75710 |
| KNN           | 91  | 0.27000 | 0.24816  | 0.20048 | 0.17657 | 0.27000 | 0.24816  | 0.77143 |
| KNN           | 99  | 0.27000 | 0.24816  | 0.19939 | 0.17544 | 0.27879 | 0.25721  | 0.77452 |
| KNNW          | 47  | 0.27000 | 0.24816  | 0.16560 | 0.14064 | 0.27230 | 0.25053  | 0.75715 |
| KNNW          | 53  | 0.27000 | 0.24816  | 0.16944 | 0.14460 | 0.28125 | 0.25975  | 0.75812 |
| KNNW          | 100 | 0.27000 | 0.24816  | 0.18210 | 0.15763 | 0.27723 | 0.25561  | 0.76379 |
| LOF           | 87  | 0.23000 | 0.20697  | 0.15926 | 0.13411 | 0.25862 | 0.23644  | 0.75476 |
| LOF           | 92  | 0.23000 | 0.20697  | 0.15934 | 0.13419 | 0.25439 | 0.23208  | 0.75584 |
| LOF           | 98  | 0.23000 | 0.20697  | 0.16261 | 0.13756 | 0.25000 | 0.22757  | 0.75581 |
| LOF           | 99  | 0.24000 | 0.21727  | 0.16181 | 0.13674 | 0.25455 | 0.23225  | 0.75576 |
| SimplifiedLOF | 83  | 0.22000 | 0.19667  | 0.12427 | 0.09807 | 0.22707 | 0.20395  | 0.73207 |
| SimplifiedLOF | 95  | 0.22000 | 0.19667  | 0.12577 | 0.09962 | 0.22831 | 0.20523  | 0.73337 |
| SimplifiedLOF | 99  | 0.22000 | 0.19667  | 0.12789 | 0.10180 | 0.22430 | 0.20110  | 0.73359 |
| SimplifiedLOF | 100 | 0.21000 | 0.18637  | 0.12768 | 0.10158 | 0.22326 | 0.20002  | 0.73386 |
| LoOP          | 95  | 0.19000 | 0.16577  | 0.11681 | 0.09039 | 0.21918 | 0.19582  | 0.72548 |
| LoOP          | 99  | 0.21000 | 0.18637  | 0.11861 | 0.09225 | 0.21739 | 0.19398  | 0.72580 |

|                 |            |         |         |         |         |         |         |         |
|-----------------|------------|---------|---------|---------|---------|---------|---------|---------|
| <b>LoOP</b>     | <b>100</b> | 0.20000 | 0.17607 | 0.11822 | 0.09185 | 0.21552 | 0.19205 | 0.72708 |
| <b>LDOF</b>     | <b>88</b>  | 0.15000 | 0.12457 | 0.07642 | 0.04879 | 0.15000 | 0.12457 | 0.72468 |
| <b>LDOF</b>     | <b>97</b>  | 0.14000 | 0.11427 | 0.07561 | 0.04796 | 0.15439 | 0.12909 | 0.72553 |
| <b>ODIN</b>     | <b>36</b>  | 0.07299 | 0.04526 | 0.04937 | 0.02094 | 0.09796 | 0.07098 | 0.65986 |
| <b>ODIN</b>     | <b>97</b>  | 0.05708 | 0.02888 | 0.05833 | 0.03016 | 0.12756 | 0.10147 | 0.69957 |
| <b>ODIN</b>     | <b>100</b> | 0.06136 | 0.03329 | 0.05856 | 0.03040 | 0.11905 | 0.09270 | 0.70041 |
| <b>FastABOD</b> | <b>6</b>   | 0.04000 | 0.01128 | 0.03463 | 0.00575 | 0.07598 | 0.04834 | 0.54433 |
| <b>FastABOD</b> | <b>7</b>   | 0.05000 | 0.02158 | 0.03250 | 0.00356 | 0.06347 | 0.03545 | 0.52943 |
| <b>KDEOS</b>    | <b>13</b>  | 0.07000 | 0.04218 | 0.04150 | 0.01283 | 0.07958 | 0.05204 | 0.57795 |
| <b>KDEOS</b>    | <b>25</b>  | 0.05000 | 0.02158 | 0.04810 | 0.01963 | 0.08197 | 0.05451 | 0.57610 |
| <b>KDEOS</b>    | <b>26</b>  | 0.05000 | 0.02158 | 0.03811 | 0.00933 | 0.08389 | 0.05648 | 0.57742 |
| <b>KDEOS</b>    | <b>100</b> | 0.03000 | 0.00098 | 0.03476 | 0.00589 | 0.07620 | 0.04857 | 0.59604 |
| <b>LDF</b>      | <b>14</b>  | 0.31000 | 0.28936 | 0.26513 | 0.24315 | 0.37037 | 0.35154 | 0.76577 |
| <b>LDF</b>      | <b>17</b>  | 0.34000 | 0.32026 | 0.27551 | 0.25383 | 0.34555 | 0.32597 | 0.76975 |
| <b>LDF</b>      | <b>22</b>  | 0.33000 | 0.30996 | 0.28026 | 0.25873 | 0.34524 | 0.32565 | 0.77378 |
| <b>LDF</b>      | <b>26</b>  | 0.31000 | 0.28936 | 0.27291 | 0.25116 | 0.32461 | 0.30440 | 0.78374 |
| <b>INFLO</b>    | <b>88</b>  | 0.20000 | 0.17607 | 0.10239 | 0.07554 | 0.20952 | 0.18588 | 0.71645 |
| <b>INFLO</b>    | <b>89</b>  | 0.19000 | 0.16577 | 0.10203 | 0.07517 | 0.21569 | 0.19222 | 0.71592 |
| <b>INFLO</b>    | <b>93</b>  | 0.19000 | 0.16577 | 0.10339 | 0.07657 | 0.21359 | 0.19007 | 0.71742 |
| <b>INFLO</b>    | <b>98</b>  | 0.19000 | 0.16577 | 0.10551 | 0.07875 | 0.21053 | 0.18691 | 0.71225 |
| <b>COF</b>      | <b>64</b>  | 0.28000 | 0.25846 | 0.23025 | 0.20722 | 0.28283 | 0.26138 | 0.74962 |
| <b>COF</b>      | <b>72</b>  | 0.24000 | 0.21727 | 0.23469 | 0.21180 | 0.30216 | 0.28128 | 0.76023 |
| <b>COF</b>      | <b>79</b>  | 0.26000 | 0.23786 | 0.23800 | 0.21521 | 0.27545 | 0.25378 | 0.76365 |
| <b>COF</b>      | <b>85</b>  | 0.26000 | 0.23786 | 0.24787 | 0.22537 | 0.27972 | 0.25817 | 0.74793 |

## Plots



## Average precision

