

# Appendices for “An empirical study of data sampling techniques for just-in-time software defect prediction”

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## I. Comparison results of each data sampling algorithms

Tables I, II, III, IV, V, VI, VII, VIII, IX, X, XI, and XII present detailed Median values for *Recall*, *Precision*, *Pf*, *F-measure*, *AUC*, *MCC*, *P<sub>opt</sub>*, *Recall@20%*, *Precision@20%*, *F-measure@20%*, *PCI@20%*, and *IFA* [1], [2], [3], [4], [5], [6], [7], [8], [9], [10] for each project on each sampling algorithm. The overall mean values across all projects are also provided. Additionally, the table highlights the optimal algorithm for each project.

TABLE I: Median value on *Recall* for each project

| Project   | NONE  | RUM   | NearMiss | ENN          | TomekLink | OSS   | ROM   | SMOTE | BSMOTE       | SMOTE+Tomek  | SMOTE+ENN |
|-----------|-------|-------|----------|--------------|-----------|-------|-------|-------|--------------|--------------|-----------|
| Fabric8   | 0.384 | 0.687 | 0.677    | 0.688        | 0.441     | 0.426 | 0.696 | 0.697 | <b>0.721</b> | 0.714        | 0.685     |
| JGroups   | 0.331 | 0.648 | 0.667    | 0.571        | 0.350     | 0.358 | 0.652 | 0.648 | <b>0.673</b> | 0.652        | 0.577     |
| Camel     | 0.442 | 0.733 | 0.691    | <b>0.782</b> | 0.508     | 0.511 | 0.733 | 0.731 | 0.754        | 0.749        | 0.731     |
| Tomcat    | 0.529 | 0.672 | 0.677    | <b>0.834</b> | 0.561     | 0.563 | 0.676 | 0.676 | 0.711        | 0.689        | 0.650     |
| Brackets  | 0.673 | 0.775 | 0.785    | <b>0.879</b> | 0.689     | 0.691 | 0.783 | 0.776 | 0.818        | 0.783        | 0.765     |
| Neutron   | 0.747 | 0.844 | 0.802    | <b>0.907</b> | 0.764     | 0.819 | 0.844 | 0.844 | 0.883        | 0.852        | 0.849     |
| Spring    | 0.599 | 0.774 | 0.677    | <b>0.878</b> | 0.647     | 0.667 | 0.757 | 0.758 | 0.811        | 0.797        | 0.811     |
| Broadleaf | 0.469 | 0.750 | 0.668    | 0.760        | 0.512     | 0.512 | 0.747 | 0.750 | <b>0.786</b> | 0.763        | 0.722     |
| Nova      | 0.719 | 0.862 | 0.781    | <b>0.919</b> | 0.733     | 0.766 | 0.860 | 0.860 | 0.894        | 0.862        | 0.867     |
| Npm       | 0.288 | 0.667 | 0.667    | 0.667        | 0.333     | 0.358 | 0.667 | 0.662 | 0.686        | <b>0.692</b> | 0.677     |
| Mean      | 0.518 | 0.741 | 0.709    | <b>0.788</b> | 0.554     | 0.567 | 0.741 | 0.740 | 0.774        | 0.755        | 0.733     |

TABLE II: Median value on *Precision* for each project

| Project   | NONE         | RUM   | NearMiss | ENN   | TomekLink    | OSS   | ROM   | SMOTE | BSMOTE | SMOTE+Tomek | SMOTE+ENN |
|-----------|--------------|-------|----------|-------|--------------|-------|-------|-------|--------|-------------|-----------|
| Fabric8   | <b>0.610</b> | 0.510 | 0.518    | 0.522 | 0.586        | 0.586 | 0.513 | 0.510 | 0.503  | 0.509       | 0.522     |
| JGroups   | <b>0.643</b> | 0.457 | 0.452    | 0.533 | 0.625        | 0.636 | 0.456 | 0.456 | 0.438  | 0.455       | 0.487     |
| Camel     | <b>0.600</b> | 0.507 | 0.507    | 0.494 | 0.593        | 0.590 | 0.508 | 0.504 | 0.497  | 0.496       | 0.508     |
| Tomcat    | <b>0.709</b> | 0.641 | 0.638    | 0.564 | 0.689        | 0.690 | 0.641 | 0.641 | 0.624  | 0.638       | 0.665     |
| Brackets  | <b>0.732</b> | 0.677 | 0.675    | 0.634 | 0.728        | 0.717 | 0.680 | 0.680 | 0.655  | 0.676       | 0.694     |
| Neutron   | 0.759        | 0.731 | 0.753    | 0.689 | <b>0.763</b> | 0.741 | 0.731 | 0.731 | 0.717  | 0.722       | 0.731     |
| Spring    | <b>0.729</b> | 0.681 | 0.700    | 0.642 | 0.714        | 0.707 | 0.677 | 0.682 | 0.667  | 0.679       | 0.667     |
| Broadleaf | <b>0.661</b> | 0.538 | 0.540    | 0.521 | 0.635        | 0.631 | 0.537 | 0.533 | 0.524  | 0.525       | 0.535     |
| Nova      | <b>0.747</b> | 0.704 | 0.730    | 0.685 | 0.739        | 0.714 | 0.704 | 0.704 | 0.692  | 0.702       | 0.704     |
| Npm       | 0.581        | 0.481 | 0.500    | 0.476 | <b>0.586</b> | 0.571 | 0.494 | 0.486 | 0.482  | 0.482       | 0.493     |
| Mean      | <b>0.677</b> | 0.593 | 0.601    | 0.576 | 0.666        | 0.658 | 0.594 | 0.593 | 0.580  | 0.588       | 0.600     |

## II. Comparison results with different period lengths

Tables XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI, XXII, XXIII, and XXIV present detailed Median values for *Recall*, *Precision*, *Pf*, *F-measure*, *AUC*, *MCC*, *P<sub>opt</sub>*, *Recall@20%*, *Precision@20%*, *F-measure@20%*, *PCI@20%*, and *IFA* for each project on each sampling algorithm when the time period is two months and six months [11], [12], [13]. The overall mean values across all projects are also provided.

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TABLE III: Median value on  $Pf$  for each project

| Project   | NONE         | RUM   | NearMiss | ENN   | TomekLink | OSS   | ROM   | SMOTE | BSMOTE | SMOTE+Tomek | SMOTE+ENN |
|-----------|--------------|-------|----------|-------|-----------|-------|-------|-------|--------|-------------|-----------|
| Fabric8   | <b>0.084</b> | 0.303 | 0.295    | 0.316 | 0.116     | 0.117 | 0.300 | 0.306 | 0.330  | 0.325       | 0.272     |
| JGroups   | <b>0.061</b> | 0.316 | 0.334    | 0.212 | 0.078     | 0.08  | 0.316 | 0.307 | 0.334  | 0.316       | 0.248     |
| Camel     | <b>0.120</b> | 0.306 | 0.290    | 0.332 | 0.137     | 0.137 | 0.306 | 0.306 | 0.325  | 0.318       | 0.296     |
| Tomcat    | <b>0.172</b> | 0.263 | 0.269    | 0.465 | 0.186     | 0.186 | 0.263 | 0.263 | 0.295  | 0.272       | 0.243     |
| Brackets  | <b>0.138</b> | 0.206 | 0.213    | 0.306 | 0.144     | 0.144 | 0.205 | 0.206 | 0.244  | 0.214       | 0.188     |
| Neutron   | <b>0.122</b> | 0.171 | 0.147    | 0.222 | 0.135     | 0.154 | 0.178 | 0.179 | 0.197  | 0.179       | 0.180     |
| Spring    | <b>0.165</b> | 0.279 | 0.228    | 0.349 | 0.193     | 0.220 | 0.272 | 0.284 | 0.292  | 0.283       | 0.298     |
| Broadleaf | <b>0.088</b> | 0.249 | 0.194    | 0.259 | 0.103     | 0.098 | 0.246 | 0.252 | 0.287  | 0.258       | 0.218     |
| Nova      | <b>0.131</b> | 0.184 | 0.156    | 0.223 | 0.139     | 0.151 | 0.187 | 0.184 | 0.211  | 0.191       | 0.197     |
| Npm       | <b>0.087</b> | 0.313 | 0.313    | 0.342 | 0.097     | 0.119 | 0.319 | 0.319 | 0.333  | 0.339       | 0.316     |
| Mean      | <b>0.117</b> | 0.259 | 0.244    | 0.303 | 0.133     | 0.141 | 0.259 | 0.261 | 0.285  | 0.270       | 0.246     |

TABLE IV: Median value on  $F$ -measure for each project

| Project   | NONE  | RUM   | NearMiss     | ENN          | TomekLink | OSS   | ROM          | SMOTE        | BSMOTE       | SMOTE+Tomek  | SMOTE+ENN |
|-----------|-------|-------|--------------|--------------|-----------|-------|--------------|--------------|--------------|--------------|-----------|
| Fabric8   | 0.450 | 0.564 | 0.556        | 0.557        | 0.483     | 0.479 | 0.564        | <b>0.568</b> | <b>0.568</b> | 0.567        | 0.563     |
| JGroups   | 0.407 | 0.532 | 0.532        | 0.492        | 0.409     | 0.411 | <b>0.533</b> | 0.527        | 0.530        | 0.524        | 0.521     |
| Camel     | 0.514 | 0.599 | 0.582        | 0.600        | 0.533     | 0.537 | <b>0.601</b> | 0.598        | 0.593        | 0.594        | 0.597     |
| Tomcat    | 0.610 | 0.653 | 0.648        | 0.657        | 0.617     | 0.618 | 0.648        | 0.648        | <b>0.658</b> | 0.653        | 0.644     |
| Brackets  | 0.691 | 0.724 | 0.714        | 0.712        | 0.693     | 0.697 | 0.723        | <b>0.725</b> | 0.719        | <b>0.725</b> | 0.717     |
| Neutron   | 0.748 | 0.781 | 0.774        | <b>0.793</b> | 0.753     | 0.759 | 0.778        | 0.778        | 0.780        | 0.783        | 0.781     |
| Spring    | 0.654 | 0.704 | 0.678        | <b>0.713</b> | 0.664     | 0.678 | 0.705        | 0.702        | 0.705        | 0.704        | 0.699     |
| Broadleaf | 0.527 | 0.600 | 0.598        | 0.592        | 0.549     | 0.553 | <b>0.608</b> | <b>0.608</b> | 0.604        | <b>0.608</b> | 0.605     |
| Nova      | 0.734 | 0.760 | 0.760        | <b>0.768</b> | 0.741     | 0.745 | 0.760        | 0.760        | 0.759        | 0.760        | 0.752     |
| Npm       | 0.349 | 0.538 | <b>0.553</b> | 0.527        | 0.411     | 0.411 | 0.545        | 0.544        | 0.547        | 0.545        | 0.524     |
| Mean      | 0.568 | 0.646 | 0.640        | 0.641        | 0.585     | 0.589 | <b>0.647</b> | 0.646        | 0.646        | 0.646        | 0.640     |

TABLE V: Median value on  $AUC$  for each project

| Project   | NONE  | RUM          | NearMiss     | ENN          | TomekLink | OSS   | ROM          | SMOTE        | BSMOTE       | SMOTE+Tomek  | SMOTE+ENN    |
|-----------|-------|--------------|--------------|--------------|-----------|-------|--------------|--------------|--------------|--------------|--------------|
| Fabric8   | 0.632 | 0.702        | 0.704        | 0.692        | 0.651     | 0.652 | 0.706        | 0.706        | 0.704        | 0.706        | <b>0.707</b> |
| JGroups   | 0.614 | 0.665        | 0.664        | 0.648        | 0.623     | 0.623 | 0.665        | 0.666        | <b>0.667</b> | <b>0.667</b> | 0.661        |
| Camel     | 0.656 | <b>0.722</b> | 0.701        | 0.713        | 0.666     | 0.666 | <b>0.722</b> | 0.721        | 0.718        | 0.719        | 0.714        |
| Tomcat    | 0.687 | <b>0.701</b> | <b>0.701</b> | 0.666        | 0.692     | 0.692 | 0.700        | 0.700        | 0.700        | 0.698        | 0.698        |
| Brackets  | 0.771 | 0.789        | <b>0.790</b> | 0.785        | 0.771     | 0.773 | 0.789        | 0.789        | 0.788        | 0.789        | 0.780        |
| Neutron   | 0.809 | 0.833        | 0.823        | <b>0.840</b> | 0.816     | 0.825 | 0.831        | 0.833        | 0.839        | 0.835        | 0.834        |
| Spring    | 0.704 | 0.727        | 0.714        | 0.717        | 0.705     | 0.707 | 0.729        | 0.728        | <b>0.731</b> | 0.730        | 0.728        |
| Broadleaf | 0.683 | 0.750        | 0.733        | 0.735        | 0.696     | 0.696 | 0.751        | <b>0.754</b> | 0.747        | 0.751        | 0.748        |
| Nova      | 0.796 | 0.834        | 0.818        | <b>0.839</b> | 0.806     | 0.805 | 0.834        | 0.833        | 0.835        | 0.834        | 0.834        |
| Npm       | 0.598 | 0.680        | 0.673        | 0.647        | 0.623     | 0.623 | 0.689        | 0.685        | 0.680        | <b>0.694</b> | 0.669        |
| Mean      | 0.695 | 0.740        | 0.732        | 0.728        | 0.705     | 0.706 | 0.741        | <b>0.742</b> | 0.741        | <b>0.742</b> | 0.737        |

TABLE VI: Median value on  $MCC$  for each project

| Project   | NONE  | RUM          | NearMiss     | ENN          | TomekLink | OSS   | ROM          | SMOTE        | BSMOTE       | SMOTE+Tomek | SMOTE+ENN    |
|-----------|-------|--------------|--------------|--------------|-----------|-------|--------------|--------------|--------------|-------------|--------------|
| Fabric8   | 0.310 | 0.371        | 0.363        | 0.376        | 0.322     | 0.318 | 0.364        | 0.360        | 0.369        | 0.373       | <b>0.380</b> |
| JGroups   | 0.296 | 0.298        | 0.301        | 0.285        | 0.296     | 0.298 | 0.306        | 0.301        | 0.302        | 0.297       | <b>0.314</b> |
| Camel     | 0.342 | 0.397        | 0.385        | 0.393        | 0.354     | 0.352 | 0.400        | <b>0.401</b> | <b>0.401</b> | 0.394       | 0.392        |
| Tomcat    | 0.394 | 0.394        | 0.396        | 0.339        | 0.401     | 0.402 | 0.394        | 0.393        | 0.395        | 0.394       | <b>0.403</b> |
| Brackets  | 0.544 | 0.558        | <b>0.563</b> | 0.545        | 0.552     | 0.554 | <b>0.563</b> | 0.561        | 0.557        | 0.56        | 0.554        |
| Neutron   | 0.620 | 0.640        | 0.627        | <b>0.664</b> | 0.627     | 0.642 | 0.638        | 0.643        | 0.645        | 0.643       | 0.644        |
| Spring    | 0.414 | 0.442        | 0.408        | 0.439        | 0.429     | 0.429 | 0.439        | 0.437        | <b>0.453</b> | 0.445       | 0.443        |
| Broadleaf | 0.403 | <b>0.457</b> | 0.430        | 0.416        | 0.414     | 0.417 | 0.455        | <b>0.457</b> | 0.448        | 0.456       | 0.452        |
| Nova      | 0.590 | 0.622        | 0.598        | 0.622        | 0.592     | 0.579 | 0.613        | 0.613        | <b>0.631</b> | 0.623       | 0.623        |
| Npm       | 0.250 | 0.301        | 0.309        | 0.287        | 0.274     | 0.267 | <b>0.313</b> | 0.308        | 0.299        | 0.308       | 0.288        |
| Mean      | 0.416 | 0.448        | 0.438        | 0.436        | 0.426     | 0.426 | 0.448        | 0.447        | <b>0.450</b> | 0.449       | 0.449        |

TABLE VII: Median value on  $P_{opt}$  for each project

| Project   | NONE  | RUM   | NearMiss | ENN          | TomekLink | OSS   | ROM   | SMOTE | BSMOTE       | SMOTE+Tomek | SMOTE+ENN    |
|-----------|-------|-------|----------|--------------|-----------|-------|-------|-------|--------------|-------------|--------------|
| Fabric8   | 0.490 | 0.725 | 0.709    | 0.736        | 0.541     | 0.554 | 0.721 | 0.721 | <b>0.748</b> | 0.744       | 0.736        |
| JGroups   | 0.430 | 0.605 | 0.629    | 0.579        | 0.436     | 0.448 | 0.611 | 0.605 | <b>0.632</b> | 0.603       | 0.543        |
| Camel     | 0.489 | 0.716 | 0.680    | <b>0.773</b> | 0.528     | 0.523 | 0.712 | 0.711 | 0.741        | 0.730       | 0.711        |
| Tomcat    | 0.529 | 0.646 | 0.655    | <b>0.804</b> | 0.546     | 0.548 | 0.647 | 0.658 | 0.684        | 0.666       | 0.636        |
| Brackets  | 0.639 | 0.761 | 0.772    | <b>0.858</b> | 0.655     | 0.663 | 0.766 | 0.761 | 0.808        | 0.771       | 0.749        |
| Neutron   | 0.740 | 0.832 | 0.809    | <b>0.902</b> | 0.763     | 0.821 | 0.832 | 0.832 | 0.876        | 0.846       | 0.849        |
| Spring    | 0.614 | 0.748 | 0.684    | <b>0.851</b> | 0.643     | 0.656 | 0.748 | 0.747 | 0.754        | 0.754       | 0.795        |
| Broadleaf | 0.488 | 0.748 | 0.670    | 0.752        | 0.521     | 0.513 | 0.740 | 0.748 | <b>0.756</b> | 0.751       | 0.716        |
| Nova      | 0.719 | 0.850 | 0.762    | <b>0.917</b> | 0.732     | 0.770 | 0.850 | 0.850 | 0.888        | 0.857       | 0.856        |
| Npm       | 0.434 | 0.652 | 0.655    | 0.681        | 0.461     | 0.463 | 0.653 | 0.649 | 0.667        | 0.670       | <b>0.682</b> |
| Mean      | 0.557 | 0.728 | 0.703    | <b>0.785</b> | 0.583     | 0.596 | 0.728 | 0.728 | 0.755        | 0.739       | 0.727        |

TABLE VIII: Median value on  $Recall@20\%$  for each project

| Project   | NONE  | RUM   | NearMiss | ENN          | TomekLink | OSS   | ROM   | SMOTE | BSMOTE       | SMOTE+Tomek  | SMOTE+ENN |
|-----------|-------|-------|----------|--------------|-----------|-------|-------|-------|--------------|--------------|-----------|
| Fabric8   | 0.390 | 0.696 | 0.678    | 0.699        | 0.453     | 0.435 | 0.696 | 0.706 | <b>0.730</b> | 0.719        | 0.699     |
| JGroups   | 0.303 | 0.548 | 0.562    | 0.492        | 0.319     | 0.327 | 0.556 | 0.550 | <b>0.571</b> | 0.549        | 0.475     |
| Camel     | 0.390 | 0.680 | 0.647    | <b>0.711</b> | 0.452     | 0.452 | 0.678 | 0.678 | 0.690        | 0.685        | 0.677     |
| Tomcat    | 0.477 | 0.591 | 0.592    | <b>0.744</b> | 0.494     | 0.494 | 0.597 | 0.592 | 0.624        | 0.613        | 0.577     |
| Brackets  | 0.606 | 0.724 | 0.749    | <b>0.813</b> | 0.627     | 0.630 | 0.725 | 0.728 | 0.764        | 0.733        | 0.707     |
| Neutron   | 0.733 | 0.816 | 0.790    | <b>0.884</b> | 0.744     | 0.787 | 0.814 | 0.814 | 0.853        | 0.827        | 0.822     |
| Spring    | 0.556 | 0.692 | 0.619    | <b>0.762</b> | 0.592     | 0.600 | 0.692 | 0.692 | 0.700        | 0.700        | 0.721     |
| Broadleaf | 0.437 | 0.704 | 0.641    | 0.703        | 0.470     | 0.470 | 0.701 | 0.705 | <b>0.735</b> | 0.710        | 0.671     |
| Nova      | 0.693 | 0.826 | 0.747    | <b>0.882</b> | 0.706     | 0.756 | 0.827 | 0.826 | 0.851        | 0.832        | 0.824     |
| Npm       | 0.294 | 0.615 | 0.618    | 0.622        | 0.348     | 0.348 | 0.612 | 0.615 | 0.640        | <b>0.654</b> | 0.642     |
| Mean      | 0.488 | 0.689 | 0.664    | <b>0.731</b> | 0.520     | 0.530 | 0.690 | 0.691 | 0.716        | 0.702        | 0.682     |

TABLE IX: Median value on  $Precision@20\%$  for each project

| Project   | NONE         | RUM   | NearMiss | ENN   | TomekLink    | OSS          | ROM   | SMOTE | BSMOTE | SMOTE+Tomek | SMOTE+ENN |
|-----------|--------------|-------|----------|-------|--------------|--------------|-------|-------|--------|-------------|-----------|
| Fabric8   | <b>0.603</b> | 0.479 | 0.495    | 0.488 | 0.585        | 0.585        | 0.484 | 0.484 | 0.465  | 0.476       | 0.493     |
| JGroups   | <b>0.571</b> | 0.409 | 0.407    | 0.462 | 0.561        | 0.559        | 0.417 | 0.417 | 0.397  | 0.409       | 0.440     |
| Camel     | <b>0.583</b> | 0.489 | 0.484    | 0.468 | 0.576        | 0.575        | 0.487 | 0.487 | 0.479  | 0.484       | 0.497     |
| Tomcat    | <b>0.684</b> | 0.613 | 0.616    | 0.540 | 0.667        | 0.671        | 0.608 | 0.607 | 0.594  | 0.606       | 0.642     |
| Brackets  | <b>0.712</b> | 0.643 | 0.643    | 0.588 | 0.697        | 0.696        | 0.653 | 0.652 | 0.628  | 0.646       | 0.662     |
| Neutron   | <b>0.766</b> | 0.724 | 0.75     | 0.681 | 0.760        | 0.740        | 0.724 | 0.730 | 0.695  | 0.724       | 0.718     |
| Spring    | 0.712        | 0.656 | 0.683    | 0.628 | <b>0.718</b> | 0.706        | 0.654 | 0.659 | 0.633  | 0.654       | 0.656     |
| Broadleaf | 0.631        | 0.525 | 0.529    | 0.508 | <b>0.635</b> | <b>0.635</b> | 0.525 | 0.519 | 0.506  | 0.511       | 0.523     |
| Nova      | <b>0.714</b> | 0.694 | 0.709    | 0.641 | <b>0.714</b> | 0.707        | 0.695 | 0.699 | 0.676  | 0.695       | 0.676     |
| Npm       | 0.569        | 0.448 | 0.484    | 0.467 | <b>0.584</b> | 0.557        | 0.470 | 0.470 | 0.456  | 0.442       | 0.474     |
| Mean      | <b>0.655</b> | 0.568 | 0.580    | 0.547 | 0.650        | 0.643        | 0.572 | 0.572 | 0.553  | 0.565       | 0.578     |

TABLE X: Median value on  $F-measure@20\%$  for each project

| Project   | NONE  | RUM          | NearMiss     | ENN          | TomekLink | OSS   | ROM          | SMOTE        | BSMOTE       | SMOTE+Tomek  | SMOTE+ENN    |
|-----------|-------|--------------|--------------|--------------|-----------|-------|--------------|--------------|--------------|--------------|--------------|
| Fabric8   | 0.453 | 0.558        | 0.556        | 0.553        | 0.485     | 0.479 | 0.558        | 0.562        | 0.561        | <b>0.564</b> | 0.558        |
| JGroups   | 0.356 | <b>0.471</b> | <b>0.471</b> | 0.430        | 0.353     | 0.353 | <b>0.471</b> | 0.468        | 0.466        | 0.470        | <b>0.471</b> |
| Camel     | 0.492 | 0.562        | 0.548        | <b>0.563</b> | 0.499     | 0.501 | 0.562        | 0.562        | 0.555        | 0.559        | 0.558        |
| Tomcat    | 0.548 | 0.598        | 0.600        | <b>0.614</b> | 0.556     | 0.561 | 0.598        | 0.606        | 0.602        | 0.601        | 0.592        |
| Brackets  | 0.600 | 0.651        | 0.646        | 0.671        | 0.606     | 0.610 | 0.667        | 0.660        | 0.662        | 0.664        | <b>0.674</b> |
| Neutron   | 0.744 | 0.778        | 0.768        | <b>0.781</b> | 0.748     | 0.762 | 0.778        | 0.778        | 0.778        | 0.780        | 0.778        |
| Spring    | 0.611 | 0.661        | 0.611        | <b>0.676</b> | 0.616     | 0.616 | 0.659        | 0.659        | <b>0.676</b> | 0.663        | 0.671        |
| Broadleaf | 0.500 | 0.572        | 0.561        | 0.565        | 0.529     | 0.540 | <b>0.583</b> | 0.577        | 0.570        | 0.576        | 0.576        |
| Nova      | 0.699 | <b>0.734</b> | 0.723        | 0.730        | 0.699     | 0.700 | <b>0.734</b> | <b>0.734</b> | 0.732        | <b>0.734</b> | 0.725        |
| Npm       | 0.340 | 0.511        | <b>0.519</b> | 0.481        | 0.381     | 0.366 | 0.511        | 0.511        | 0.512        | 0.512        | 0.472        |
| Mean      | 0.534 | 0.61         | 0.600        | 0.606        | 0.547     | 0.549 | <b>0.612</b> | <b>0.612</b> | 0.611        | <b>0.612</b> | 0.608        |

TABLE XI: Median value on *PCI@20%* for each project

| Project   | NONE         | RUM   | NearMiss | ENN   | TomekLink | OSS   | ROM   | SMOTE | BSMOTE | SMOTE+Tomek | SMOTE+ENN |
|-----------|--------------|-------|----------|-------|-----------|-------|-------|-------|--------|-------------|-----------|
| Fabric8   | <b>0.182</b> | 0.394 | 0.401    | 0.404 | 0.211     | 0.215 | 0.408 | 0.405 | 0.441  | 0.425       | 0.397     |
| JGroups   | <b>0.14</b>  | 0.364 | 0.384    | 0.313 | 0.158     | 0.158 | 0.370 | 0.370 | 0.392  | 0.373       | 0.315     |
| Camel     | <b>0.209</b> | 0.413 | 0.403    | 0.459 | 0.239     | 0.239 | 0.412 | 0.411 | 0.429  | 0.421       | 0.402     |
| Tomcat    | <b>0.290</b> | 0.395 | 0.408    | 0.561 | 0.302     | 0.305 | 0.396 | 0.396 | 0.429  | 0.409       | 0.370     |
| Brackets  | <b>0.293</b> | 0.385 | 0.392    | 0.477 | 0.307     | 0.313 | 0.383 | 0.384 | 0.420  | 0.389       | 0.368     |
| Neutron   | <b>0.322</b> | 0.396 | 0.364    | 0.449 | 0.339     | 0.366 | 0.394 | 0.394 | 0.422  | 0.399       | 0.399     |
| Spring    | <b>0.315</b> | 0.409 | 0.386    | 0.505 | 0.354     | 0.373 | 0.408 | 0.404 | 0.429  | 0.430       | 0.438     |
| Broadleaf | <b>0.170</b> | 0.358 | 0.329    | 0.372 | 0.204     | 0.204 | 0.359 | 0.362 | 0.394  | 0.378       | 0.349     |
| Nova      | <b>0.366</b> | 0.406 | 0.380    | 0.463 | 0.367     | 0.387 | 0.406 | 0.406 | 0.431  | 0.407       | 0.408     |
| Npm       | <b>0.163</b> | 0.392 | 0.404    | 0.459 | 0.189     | 0.201 | 0.392 | 0.408 | 0.404  | 0.432       | 0.392     |
| Mean      | <b>0.245</b> | 0.391 | 0.385    | 0.446 | 0.267     | 0.276 | 0.393 | 0.394 | 0.419  | 0.406       | 0.384     |

TABLE XII: Median value on *IFA* for each project

| Project   | NONE       | RUM      | NearMiss | ENN      | TomekLink  | OSS      | ROM      | SMOTE    | BSMOTE   | SMOTE+Tomek | SMOTE+ENN |
|-----------|------------|----------|----------|----------|------------|----------|----------|----------|----------|-------------|-----------|
| Fabric8   | <b>2</b>   | 4        | 3.5      | 4        | <b>2</b>   | <b>2</b> | 4        | 4        | 4        | 4.5         | 5         |
| JGroups   | <b>2</b>   | 4        | 5        | 3        | <b>2</b>   | <b>2</b> | 4        | 5        | 5        | 5           | 4         |
| Camel     | <b>2</b>   | 3        | 3        | 3        | <b>2</b>   | <b>2</b> | 3        | 3        | 3        | 3           | 3         |
| Tomcat    | <b>2</b>   | <b>2</b> | <b>2</b> | <b>2</b> | <b>2</b>   | <b>2</b> | <b>2</b> | <b>2</b> | <b>2</b> | <b>2</b>    | <b>2</b>  |
| Brackets  | <b>2</b>   | 3        | 3        | 4        | <b>2</b>   | <b>2</b> | 3        | 3        | 3        | 3           | <b>2</b>  |
| Neutron   | <b>1</b>   | 2        | 2        | 2        | <b>1</b>   | 2        | 2        | 2        | 2        | 2           | 2         |
| Spring    | <b>1</b>   | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b>   | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b>    | <b>1</b>  |
| Broadleaf | <b>2</b>   | 4        | 3        | 3        | <b>2</b>   | <b>2</b> | 4        | 4        | 4        | 4           | 3         |
| Nova      | <b>2</b>   | <b>2</b> | <b>2</b> | 3        | <b>2</b>   | <b>2</b> | <b>2</b> | <b>2</b> | 3        | <b>2</b>    | 3         |
| Npm       | <b>2</b>   | 3        | 3        | 3        | <b>2</b>   | <b>2</b> | 3        | 4        | 4        | 3           | 3         |
| Mean      | <b>1.8</b> | 2.8      | 2.75     | 2.8      | <b>1.8</b> | 1.9      | 2.8      | 3        | 3.1      | 2.95        | 2.8       |

### III. Comparison results with optimized classifiers

Tables XXV, XXVI, XXVII, XXVIII, XXIX, XXX, XXXI, XXXII, XXXIII, XXXIV, XXXV, and XXXVI present detailed Median values for *Recall*, *Precision*, *Pf*, *F-measure*, *AUC*, *MCC*,  $P_{opt}$ , *Recall@20%*, *Precision@20%*, *F-measure@20%*, *PCI@20%*, and *IFA* for each project on each sampling algorithm when applying the default LR classifier and the LR classifier with optimized parameter settings [14], [15]. The overall mean values across all projects are also provided.

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TABLE XIII: Median value on *Recall* for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.384 | 0.378 | 0.687 | 0.685 | 0.677    | 0.753 | 0.688 | 0.708 | 0.441     | 0.417 | 0.426 | 0.417 | 0.696 | 0.678 | 0.697 | 0.677 | 0.721  | 0.702 | 0.714        | 0.687 | 0.685      | 0.618 |
| JGroups   | 0.331 | 0.294 | 0.648 | 0.671 | 0.667    | 0.689 | 0.571 | 0.584 | 0.35      | 0.317 | 0.358 | 0.317 | 0.652 | 0.673 | 0.648 | 0.673 | 0.673  | 0.686 | 0.652        | 0.673 | 0.577      | 0.558 |
| Camel     | 0.442 | 0.469 | 0.733 | 0.745 | 0.691    | 0.798 | 0.782 | 0.798 | 0.508     | 0.494 | 0.511 | 0.494 | 0.733 | 0.746 | 0.731 | 0.746 | 0.754  | 0.766 | 0.749        | 0.751 | 0.731      | 0.672 |
| Tomcat    | 0.529 | 0.591 | 0.672 | 0.688 | 0.677    | 0.697 | 0.834 | 0.848 | 0.561     | 0.596 | 0.563 | 0.596 | 0.676 | 0.686 | 0.676 | 0.686 | 0.711  | 0.715 | 0.689        | 0.696 | 0.65       | 0.624 |
| Brackets  | 0.673 | 0.661 | 0.775 | 0.796 | 0.785    | 0.808 | 0.879 | 0.889 | 0.689     | 0.684 | 0.691 | 0.694 | 0.783 | 0.795 | 0.776 | 0.798 | 0.818  | 0.835 | 0.783        | 0.799 | 0.765      | 0.761 |
| Neutron   | 0.747 | 0.761 | 0.844 | 0.837 | 0.802    | 0.8   | 0.907 | 0.916 | 0.764     | 0.772 | 0.819 | 0.836 | 0.844 | 0.837 | 0.844 | 0.837 | 0.883  | 0.874 | 0.852        | 0.843 | 0.849      | 0.839 |
| Spring    | 0.599 | 0.637 | 0.774 | 0.74  | 0.677    | 0.686 | 0.878 | 0.866 | 0.647     | 0.645 | 0.667 | 0.575 | 0.757 | 0.743 | 0.758 | 0.743 | 0.811  | 0.763 | 0.797        | 0.768 | 0.811      | 0.761 |
| Broadleaf | 0.469 | 0.484 | 0.75  | 0.726 | 0.668    | 0.748 | 0.76  | 0.769 | 0.512     | 0.504 | 0.512 | 0.51  | 0.747 | 0.733 | 0.75  | 0.733 | 0.786  | 0.766 | 0.763        | 0.735 | 0.722      | 0.667 |
| Nova      | 0.719 | 0.798 | 0.862 | 0.867 | 0.781    | 0.831 | 0.919 | 0.938 | 0.733     | 0.807 | 0.766 | 0.818 | 0.86  | 0.867 | 0.86  | 0.867 | 0.894  | 0.905 | 0.862        | 0.873 | 0.867      | 0.872 |
| Npm       | 0.288 | 0.311 | 0.667 | 0.708 | 0.667    | 0.739 | 0.667 | 0.735 | 0.333     | 0.361 | 0.358 | 0.362 | 0.667 | 0.707 | 0.662 | 0.712 | 0.686  | 0.716 | 0.692        | 0.717 | 0.677      | 0.663 |
| Mean      | 0.518 | 0.538 | 0.741 | 0.746 | 0.709    | 0.755 | 0.788 | 0.805 | 0.554     | 0.56  | 0.567 | 0.562 | 0.741 | 0.747 | 0.740 | 0.747 | 0.774  | 0.773 | 0.755        | 0.754 | 0.733      | 0.703 |

TABLE XIV: Median value on *Precision* for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.610 | 0.666 | 0.510 | 0.557 | 0.518    | 0.539 | 0.522 | 0.565 | 0.586     | 0.652 | 0.586 | 0.649 | 0.513 | 0.550 | 0.510 | 0.549 | 0.503  | 0.549 | 0.509        | 0.548 | 0.522      | 0.595 |
| JGroups   | 0.643 | 0.627 | 0.457 | 0.447 | 0.452    | 0.433 | 0.533 | 0.478 | 0.625     | 0.620 | 0.636 | 0.611 | 0.456 | 0.443 | 0.456 | 0.447 | 0.438  | 0.441 | 0.455        | 0.444 | 0.487      | 0.478 |
| Camel     | 0.600 | 0.570 | 0.507 | 0.507 | 0.507    | 0.481 | 0.494 | 0.477 | 0.593     | 0.557 | 0.590 | 0.557 | 0.508 | 0.510 | 0.504 | 0.509 | 0.497  | 0.502 | 0.496        | 0.507 | 0.508      | 0.529 |
| Tomcat    | 0.709 | 0.695 | 0.641 | 0.643 | 0.638    | 0.645 | 0.564 | 0.544 | 0.689     | 0.692 | 0.690 | 0.689 | 0.641 | 0.643 | 0.641 | 0.644 | 0.624  | 0.636 | 0.638        | 0.643 | 0.665      | 0.684 |
| Brackets  | 0.732 | 0.701 | 0.677 | 0.630 | 0.675    | 0.644 | 0.634 | 0.592 | 0.728     | 0.690 | 0.717 | 0.690 | 0.680 | 0.630 | 0.680 | 0.630 | 0.655  | 0.616 | 0.676        | 0.627 | 0.694      | 0.651 |
| Neutron   | 0.759 | 0.726 | 0.731 | 0.699 | 0.753    | 0.717 | 0.689 | 0.639 | 0.763     | 0.717 | 0.741 | 0.663 | 0.731 | 0.699 | 0.731 | 0.699 | 0.717  | 0.681 | 0.722        | 0.691 | 0.731      | 0.677 |
| Spring    | 0.729 | 0.770 | 0.681 | 0.702 | 0.700    | 0.729 | 0.642 | 0.672 | 0.714     | 0.760 | 0.707 | 0.757 | 0.677 | 0.702 | 0.682 | 0.702 | 0.667  | 0.688 | 0.679        | 0.692 | 0.667      | 0.705 |
| Broadleaf | 0.661 | 0.710 | 0.538 | 0.592 | 0.540    | 0.542 | 0.521 | 0.566 | 0.635     | 0.710 | 0.631 | 0.710 | 0.537 | 0.590 | 0.533 | 0.587 | 0.524  | 0.576 | 0.525        | 0.587 | 0.535      | 0.611 |
| Nova      | 0.747 | 0.724 | 0.704 | 0.690 | 0.730    | 0.710 | 0.685 | 0.663 | 0.739     | 0.724 | 0.714 | 0.720 | 0.704 | 0.691 | 0.704 | 0.690 | 0.692  | 0.673 | 0.702        | 0.690 | 0.704      | 0.695 |
| Npm       | 0.581 | 0.496 | 0.481 | 0.436 | 0.500    | 0.439 | 0.476 | 0.457 | 0.586     | 0.498 | 0.571 | 0.498 | 0.494 | 0.436 | 0.486 | 0.433 | 0.482  | 0.424 | 0.482        | 0.428 | 0.493      | 0.443 |
| Mean      | 0.677 | 0.669 | 0.593 | 0.590 | 0.601    | 0.588 | 0.576 | 0.565 | 0.666     | 0.662 | 0.658 | 0.654 | 0.594 | 0.589 | 0.593 | 0.589 | 0.580  | 0.579 | 0.588        | 0.586 | 0.600      | 0.607 |

TABLE XV: Median value on  $Pf$  for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.084 | 0.092 | 0.303 | 0.292 | 0.295    | 0.339 | 0.316 | 0.314 | 0.116     | 0.118 | 0.117 | 0.118 | 0.300 | 0.292 | 0.306 | 0.292 | 0.330  | 0.313 | 0.325        | 0.298 | 0.272      | 0.204 |
| JGroups   | 0.061 | 0.060 | 0.316 | 0.307 | 0.334    | 0.371 | 0.212 | 0.216 | 0.078     | 0.071 | 0.080 | 0.071 | 0.316 | 0.306 | 0.307 | 0.306 | 0.334  | 0.327 | 0.316        | 0.310 | 0.248      | 0.210 |
| Camel     | 0.120 | 0.154 | 0.306 | 0.310 | 0.290    | 0.365 | 0.332 | 0.371 | 0.137     | 0.168 | 0.137 | 0.168 | 0.306 | 0.310 | 0.306 | 0.312 | 0.325  | 0.335 | 0.318        | 0.319 | 0.296      | 0.260 |
| Tomcat    | 0.172 | 0.177 | 0.263 | 0.270 | 0.269    | 0.289 | 0.465 | 0.489 | 0.186     | 0.186 | 0.186 | 0.189 | 0.263 | 0.270 | 0.263 | 0.269 | 0.295  | 0.304 | 0.272        | 0.276 | 0.243      | 0.199 |
| Brackets  | 0.138 | 0.149 | 0.206 | 0.212 | 0.213    | 0.226 | 0.306 | 0.334 | 0.144     | 0.160 | 0.144 | 0.161 | 0.205 | 0.213 | 0.206 | 0.213 | 0.244  | 0.254 | 0.214        | 0.213 | 0.188      | 0.198 |
| Neutron   | 0.122 | 0.125 | 0.171 | 0.181 | 0.147    | 0.145 | 0.222 | 0.235 | 0.135     | 0.131 | 0.154 | 0.175 | 0.178 | 0.181 | 0.179 | 0.181 | 0.197  | 0.210 | 0.179        | 0.187 | 0.180      | 0.173 |
| Spring    | 0.165 | 0.124 | 0.279 | 0.238 | 0.228    | 0.179 | 0.349 | 0.256 | 0.193     | 0.133 | 0.220 | 0.133 | 0.272 | 0.238 | 0.228 | 0.228 | 0.292  | 0.253 | 0.283        | 0.247 | 0.298      | 0.247 |
| Broadleaf | 0.088 | 0.086 | 0.249 | 0.210 | 0.194    | 0.236 | 0.259 | 0.249 | 0.103     | 0.096 | 0.098 | 0.094 | 0.246 | 0.212 | 0.252 | 0.214 | 0.287  | 0.263 | 0.258        | 0.223 | 0.218      | 0.181 |
| Nova      | 0.131 | 0.159 | 0.184 | 0.198 | 0.156    | 0.174 | 0.223 | 0.246 | 0.139     | 0.161 | 0.151 | 0.164 | 0.187 | 0.198 | 0.184 | 0.198 | 0.211  | 0.222 | 0.191        | 0.199 | 0.197      | 0.193 |
| Npm       | 0.087 | 0.103 | 0.313 | 0.374 | 0.313    | 0.412 | 0.342 | 0.384 | 0.097     | 0.123 | 0.119 | 0.124 | 0.319 | 0.381 | 0.319 | 0.374 | 0.333  | 0.396 | 0.339        | 0.392 | 0.316      | 0.336 |
| Mean      | 0.117 | 0.123 | 0.259 | 0.259 | 0.244    | 0.274 | 0.303 | 0.310 | 0.133     | 0.135 | 0.141 | 0.139 | 0.259 | 0.260 | 0.261 | 0.259 | 0.285  | 0.288 | 0.270        | 0.266 | 0.246      | 0.220 |

TABLE XVI: Median value on  $F$ -measure for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.450 | 0.407 | 0.564 | 0.588 | 0.556    | 0.603 | 0.557 | 0.590 | 0.483     | 0.432 | 0.479 | 0.433 | 0.564 | 0.589 | 0.568 | 0.587 | 0.568  | 0.597 | 0.567        | 0.595 | 0.563      | 0.566 |
| JGroups   | 0.407 | 0.371 | 0.532 | 0.537 | 0.532    | 0.531 | 0.492 | 0.512 | 0.409     | 0.381 | 0.411 | 0.396 | 0.533 | 0.534 | 0.527 | 0.535 | 0.530  | 0.539 | 0.524        | 0.539 | 0.521      | 0.505 |
| Camel     | 0.514 | 0.520 | 0.599 | 0.597 | 0.582    | 0.598 | 0.600 | 0.594 | 0.533     | 0.529 | 0.537 | 0.530 | 0.601 | 0.595 | 0.598 | 0.597 | 0.593  | 0.597 | 0.594        | 0.600 | 0.597      | 0.589 |
| Tomcat    | 0.610 | 0.635 | 0.653 | 0.660 | 0.648    | 0.663 | 0.657 | 0.663 | 0.617     | 0.637 | 0.618 | 0.637 | 0.648 | 0.660 | 0.648 | 0.660 | 0.658  | 0.663 | 0.653        | 0.661 | 0.644      | 0.650 |
| Brackets  | 0.691 | 0.670 | 0.724 | 0.718 | 0.714    | 0.719 | 0.712 | 0.711 | 0.693     | 0.671 | 0.697 | 0.671 | 0.723 | 0.718 | 0.725 | 0.718 | 0.719  | 0.718 | 0.725        | 0.719 | 0.717      | 0.715 |
| Neutron   | 0.748 | 0.748 | 0.781 | 0.767 | 0.774    | 0.768 | 0.793 | 0.765 | 0.753     | 0.757 | 0.759 | 0.757 | 0.778 | 0.767 | 0.778 | 0.767 | 0.780  | 0.768 | 0.783        | 0.767 | 0.781      | 0.766 |
| Spring    | 0.654 | 0.677 | 0.704 | 0.706 | 0.678    | 0.677 | 0.713 | 0.712 | 0.664     | 0.678 | 0.678 | 0.630 | 0.705 | 0.709 | 0.702 | 0.709 | 0.705  | 0.709 | 0.704        | 0.714 | 0.699      | 0.699 |
| Broadleaf | 0.527 | 0.527 | 0.600 | 0.622 | 0.598    | 0.600 | 0.592 | 0.620 | 0.549     | 0.534 | 0.553 | 0.540 | 0.608 | 0.616 | 0.608 | 0.620 | 0.604  | 0.625 | 0.608        | 0.613 | 0.605      | 0.605 |
| Nova      | 0.734 | 0.757 | 0.760 | 0.765 | 0.760    | 0.766 | 0.768 | 0.771 | 0.741     | 0.757 | 0.745 | 0.757 | 0.760 | 0.765 | 0.760 | 0.765 | 0.759  | 0.768 | 0.760        | 0.765 | 0.752      | 0.764 |
| Npm       | 0.349 | 0.372 | 0.538 | 0.526 | 0.553    | 0.523 | 0.527 | 0.497 | 0.411     | 0.400 | 0.411 | 0.398 | 0.545 | 0.526 | 0.544 | 0.527 | 0.547  | 0.527 | 0.545        | 0.526 | 0.524      | 0.489 |
| Mean      | 0.568 | 0.568 | 0.646 | 0.649 | 0.640    | 0.645 | 0.641 | 0.644 | 0.585     | 0.578 | 0.589 | 0.575 | 0.647 | 0.648 | 0.646 | 0.648 | 0.646  | 0.651 | 0.646        | 0.650 | 0.640      | 0.635 |

TABLE XVII: Median value on *AUC* for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.632 | 0.626 | 0.702 | 0.705 | 0.704    | 0.713 | 0.692 | 0.694 | 0.651     | 0.637 | 0.652 | 0.637 | 0.706 | 0.707 | 0.706 | 0.705 | 0.704  | 0.709 | 0.706        | 0.711 | 0.707      | 0.701 |
| JGroups   | 0.614 | 0.607 | 0.665 | 0.675 | 0.664    | 0.666 | 0.648 | 0.656 | 0.623     | 0.611 | 0.623 | 0.613 | 0.665 | 0.68  | 0.666 | 0.678 | 0.667  | 0.682 | 0.667        | 0.675 | 0.661      | 0.671 |
| Camel     | 0.656 | 0.664 | 0.722 | 0.721 | 0.701    | 0.718 | 0.713 | 0.71  | 0.666     | 0.668 | 0.666 | 0.667 | 0.722 | 0.721 | 0.721 | 0.721 | 0.718  | 0.72  | 0.719        | 0.72  | 0.714      | 0.711 |
| Tomcat    | 0.687 | 0.697 | 0.701 | 0.706 | 0.701    | 0.707 | 0.666 | 0.668 | 0.692     | 0.698 | 0.692 | 0.698 | 0.7   | 0.706 | 0.7   | 0.707 | 0.7    | 0.705 | 0.698        | 0.706 | 0.698      | 0.702 |
| Brackets  | 0.771 | 0.754 | 0.789 | 0.787 | 0.79     | 0.787 | 0.785 | 0.773 | 0.771     | 0.758 | 0.773 | 0.765 | 0.789 | 0.787 | 0.789 | 0.788 | 0.788  | 0.79  | 0.789        | 0.787 | 0.78       | 0.782 |
| Neutron   | 0.809 | 0.807 | 0.833 | 0.83  | 0.823    | 0.828 | 0.84  | 0.838 | 0.816     | 0.811 | 0.825 | 0.832 | 0.831 | 0.83  | 0.833 | 0.83  | 0.839  | 0.834 | 0.835        | 0.833 | 0.834      | 0.832 |
| Spring    | 0.704 | 0.681 | 0.727 | 0.732 | 0.714    | 0.714 | 0.717 | 0.723 | 0.705     | 0.684 | 0.707 | 0.69  | 0.729 | 0.733 | 0.728 | 0.733 | 0.731  | 0.732 | 0.73         | 0.734 | 0.728      | 0.733 |
| Broadleaf | 0.683 | 0.688 | 0.75  | 0.741 | 0.733    | 0.728 | 0.735 | 0.727 | 0.696     | 0.692 | 0.696 | 0.693 | 0.751 | 0.741 | 0.754 | 0.74  | 0.747  | 0.737 | 0.751        | 0.737 | 0.748      | 0.732 |
| Nova      | 0.796 | 0.824 | 0.834 | 0.835 | 0.818    | 0.831 | 0.839 | 0.837 | 0.806     | 0.826 | 0.805 | 0.827 | 0.834 | 0.835 | 0.833 | 0.835 | 0.84   | 0.834 | 0.834        | 0.834 | 0.834      | 0.832 |
| Npm       | 0.598 | 0.605 | 0.68  | 0.678 | 0.673    | 0.67  | 0.647 | 0.653 | 0.623     | 0.612 | 0.623 | 0.615 | 0.689 | 0.677 | 0.685 | 0.68  | 0.68   | 0.676 | 0.694        | 0.672 | 0.669      | 0.667 |
| Mean      | 0.695 | 0.695 | 0.74  | 0.741 | 0.732    | 0.736 | 0.728 | 0.728 | 0.705     | 0.7   | 0.706 | 0.704 | 0.741 | 0.742 | 0.742 | 0.742 | 0.741  | 0.742 | 0.742        | 0.741 | 0.737      | 0.736 |

TABLE XVIII: Median value on *MCC* for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.310 | 0.297 | 0.371 | 0.340 | 0.363    | 0.362 | 0.376 | 0.348 | 0.322     | 0.308 | 0.318 | 0.308 | 0.364 | 0.337 | 0.360 | 0.338 | 0.369  | 0.348 | 0.373        | 0.339 | 0.380      | 0.376 |
| JGroups   | 0.296 | 0.274 | 0.298 | 0.323 | 0.301    | 0.304 | 0.285 | 0.301 | 0.296     | 0.278 | 0.298 | 0.281 | 0.306 | 0.323 | 0.301 | 0.323 | 0.302  | 0.328 | 0.297        | 0.322 | 0.314      | 0.322 |
| Camel     | 0.342 | 0.359 | 0.397 | 0.390 | 0.385    | 0.386 | 0.393 | 0.389 | 0.354     | 0.363 | 0.352 | 0.364 | 0.400 | 0.393 | 0.401 | 0.393 | 0.401  | 0.394 | 0.394        | 0.390 | 0.392      | 0.387 |
| Tomcat    | 0.394 | 0.402 | 0.394 | 0.410 | 0.396    | 0.405 | 0.339 | 0.352 | 0.401     | 0.402 | 0.402 | 0.402 | 0.394 | 0.409 | 0.393 | 0.411 | 0.395  | 0.405 | 0.394        | 0.411 | 0.403      | 0.405 |
| Brackets  | 0.544 | 0.511 | 0.558 | 0.551 | 0.563    | 0.541 | 0.545 | 0.530 | 0.552     | 0.523 | 0.554 | 0.526 | 0.563 | 0.551 | 0.561 | 0.551 | 0.557  | 0.544 | 0.560        | 0.551 | 0.554      | 0.537 |
| Neutron   | 0.620 | 0.603 | 0.640 | 0.641 | 0.627    | 0.641 | 0.664 | 0.642 | 0.627     | 0.619 | 0.642 | 0.628 | 0.638 | 0.641 | 0.643 | 0.641 | 0.645  | 0.645 | 0.643        | 0.647 | 0.644      | 0.646 |
| Spring    | 0.414 | 0.393 | 0.442 | 0.454 | 0.408    | 0.436 | 0.439 | 0.448 | 0.429     | 0.390 | 0.429 | 0.387 | 0.439 | 0.454 | 0.437 | 0.450 | 0.453  | 0.458 | 0.445        | 0.462 | 0.443      | 0.444 |
| Broadleaf | 0.403 | 0.396 | 0.457 | 0.466 | 0.430    | 0.442 | 0.416 | 0.449 | 0.414     | 0.409 | 0.417 | 0.415 | 0.455 | 0.464 | 0.457 | 0.464 | 0.448  | 0.456 | 0.456        | 0.455 | 0.452      | 0.453 |
| Nova      | 0.590 | 0.603 | 0.622 | 0.616 | 0.598    | 0.617 | 0.622 | 0.630 | 0.592     | 0.609 | 0.579 | 0.606 | 0.613 | 0.616 | 0.613 | 0.616 | 0.631  | 0.627 | 0.623        | 0.618 | 0.623      | 0.615 |
| Npm       | 0.250 | 0.225 | 0.301 | 0.304 | 0.309    | 0.308 | 0.287 | 0.293 | 0.274     | 0.246 | 0.267 | 0.246 | 0.313 | 0.301 | 0.308 | 0.302 | 0.299  | 0.303 | 0.308        | 0.299 | 0.288      | 0.305 |
| Mean      | 0.416 | 0.406 | 0.448 | 0.450 | 0.438    | 0.444 | 0.436 | 0.438 | 0.426     | 0.415 | 0.426 | 0.416 | 0.448 | 0.449 | 0.447 | 0.449 | 0.450  | 0.451 | 0.449        | 0.450 | 0.449      | 0.449 |

TABLE XIX: Median value on  $P_{opt}$  for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.490 | 0.593 | 0.725 | 0.732 | 0.709    | 0.806 | 0.736 | 0.828 | 0.541     | 0.609 | 0.554 | 0.609 | 0.721 | 0.736 | 0.721 | 0.723 | 0.748  | 0.777 | 0.744        | 0.744 | 0.736      | 0.674 |
| JGroups   | 0.430 | 0.429 | 0.605 | 0.649 | 0.629    | 0.661 | 0.579 | 0.606 | 0.436     | 0.428 | 0.448 | 0.430 | 0.611 | 0.650 | 0.605 | 0.649 | 0.632  | 0.670 | 0.603        | 0.652 | 0.543      | 0.556 |
| Camel     | 0.489 | 0.533 | 0.716 | 0.736 | 0.680    | 0.786 | 0.773 | 0.798 | 0.528     | 0.545 | 0.523 | 0.545 | 0.712 | 0.735 | 0.711 | 0.736 | 0.741  | 0.753 | 0.730        | 0.741 | 0.711      | 0.664 |
| Tomcat    | 0.529 | 0.592 | 0.646 | 0.677 | 0.655    | 0.689 | 0.804 | 0.830 | 0.546     | 0.597 | 0.548 | 0.604 | 0.647 | 0.675 | 0.658 | 0.677 | 0.684  | 0.706 | 0.666        | 0.680 | 0.636      | 0.621 |
| Brackets  | 0.639 | 0.700 | 0.761 | 0.797 | 0.772    | 0.811 | 0.858 | 0.889 | 0.655     | 0.713 | 0.663 | 0.719 | 0.766 | 0.798 | 0.761 | 0.798 | 0.808  | 0.836 | 0.771        | 0.808 | 0.749      | 0.794 |
| Neutron   | 0.740 | 0.764 | 0.832 | 0.844 | 0.809    | 0.815 | 0.902 | 0.918 | 0.763     | 0.769 | 0.821 | 0.822 | 0.832 | 0.844 | 0.832 | 0.843 | 0.876  | 0.874 | 0.846        | 0.846 | 0.849      | 0.836 |
| Spring    | 0.614 | 0.646 | 0.748 | 0.733 | 0.684    | 0.674 | 0.851 | 0.841 | 0.643     | 0.655 | 0.656 | 0.629 | 0.748 | 0.734 | 0.747 | 0.741 | 0.754  | 0.757 | 0.754        | 0.759 | 0.795      | 0.740 |
| Broadleaf | 0.488 | 0.503 | 0.748 | 0.721 | 0.670    | 0.738 | 0.752 | 0.763 | 0.521     | 0.517 | 0.513 | 0.520 | 0.740 | 0.721 | 0.748 | 0.722 | 0.756  | 0.762 | 0.751        | 0.728 | 0.716      | 0.662 |
| Nova      | 0.719 | 0.793 | 0.850 | 0.879 | 0.762    | 0.826 | 0.917 | 0.939 | 0.732     | 0.801 | 0.770 | 0.817 | 0.850 | 0.879 | 0.850 | 0.879 | 0.888  | 0.908 | 0.857        | 0.879 | 0.856      | 0.871 |
| Npm       | 0.434 | 0.410 | 0.652 | 0.706 | 0.655    | 0.736 | 0.681 | 0.741 | 0.461     | 0.427 | 0.463 | 0.427 | 0.653 | 0.701 | 0.649 | 0.705 | 0.667  | 0.712 | 0.670        | 0.707 | 0.682      | 0.671 |
| Mean      | 0.557 | 0.596 | 0.728 | 0.747 | 0.703    | 0.754 | 0.785 | 0.815 | 0.583     | 0.606 | 0.596 | 0.612 | 0.728 | 0.747 | 0.728 | 0.747 | 0.755  | 0.776 | 0.739        | 0.754 | 0.727      | 0.709 |

TABLE XX: Median value on  $Recall@20\%$  for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.390 | 0.537 | 0.696 | 0.690 | 0.678    | 0.759 | 0.699 | 0.774 | 0.453     | 0.524 | 0.435 | 0.524 | 0.696 | 0.678 | 0.706 | 0.683 | 0.730  | 0.718 | 0.719        | 0.700 | 0.699      | 0.645 |
| JGroups   | 0.303 | 0.286 | 0.548 | 0.600 | 0.562    | 0.627 | 0.492 | 0.548 | 0.319     | 0.310 | 0.327 | 0.302 | 0.556 | 0.600 | 0.550 | 0.600 | 0.571  | 0.630 | 0.549        | 0.606 | 0.475      | 0.533 |
| Camel     | 0.390 | 0.433 | 0.680 | 0.701 | 0.647    | 0.759 | 0.711 | 0.739 | 0.452     | 0.461 | 0.452 | 0.461 | 0.678 | 0.701 | 0.678 | 0.701 | 0.690  | 0.722 | 0.685        | 0.706 | 0.677      | 0.618 |
| Tomcat    | 0.477 | 0.535 | 0.591 | 0.645 | 0.592    | 0.651 | 0.744 | 0.783 | 0.494     | 0.550 | 0.494 | 0.550 | 0.597 | 0.644 | 0.592 | 0.644 | 0.624  | 0.666 | 0.613        | 0.646 | 0.577      | 0.569 |
| Brackets  | 0.606 | 0.684 | 0.724 | 0.790 | 0.749    | 0.801 | 0.813 | 0.876 | 0.627     | 0.684 | 0.630 | 0.684 | 0.725 | 0.790 | 0.728 | 0.791 | 0.764  | 0.817 | 0.733        | 0.791 | 0.707      | 0.753 |
| Neutron   | 0.733 | 0.742 | 0.816 | 0.815 | 0.790    | 0.786 | 0.884 | 0.898 | 0.744     | 0.758 | 0.787 | 0.809 | 0.814 | 0.815 | 0.814 | 0.815 | 0.853  | 0.860 | 0.827        | 0.830 | 0.822      | 0.830 |
| Spring    | 0.556 | 0.612 | 0.692 | 0.693 | 0.619    | 0.647 | 0.762 | 0.796 | 0.592     | 0.615 | 0.600 | 0.543 | 0.692 | 0.696 | 0.692 | 0.696 | 0.700  | 0.717 | 0.700        | 0.713 | 0.721      | 0.695 |
| Broadleaf | 0.437 | 0.475 | 0.704 | 0.713 | 0.641    | 0.723 | 0.703 | 0.742 | 0.470     | 0.497 | 0.470 | 0.498 | 0.701 | 0.713 | 0.705 | 0.711 | 0.735  | 0.752 | 0.710        | 0.723 | 0.671      | 0.648 |
| Nova      | 0.693 | 0.786 | 0.826 | 0.855 | 0.747    | 0.822 | 0.882 | 0.930 | 0.706     | 0.791 | 0.756 | 0.812 | 0.827 | 0.855 | 0.826 | 0.855 | 0.851  | 0.884 | 0.832        | 0.855 | 0.824      | 0.855 |
| Npm       | 0.294 | 0.302 | 0.615 | 0.691 | 0.618    | 0.729 | 0.622 | 0.720 | 0.348     | 0.346 | 0.348 | 0.346 | 0.612 | 0.692 | 0.615 | 0.693 | 0.640  | 0.704 | 0.654        | 0.701 | 0.642      | 0.626 |
| Mean      | 0.488 | 0.539 | 0.689 | 0.719 | 0.664    | 0.730 | 0.731 | 0.781 | 0.520     | 0.554 | 0.530 | 0.553 | 0.690 | 0.718 | 0.691 | 0.719 | 0.716  | 0.747 | 0.702        | 0.727 | 0.682      | 0.677 |



TABLE XXI: Median value on *Precision@20%* for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.603 | 0.593 | 0.479 | 0.510 | 0.495    | 0.499 | 0.488 | 0.511 | 0.585     | 0.594 | 0.585 | 0.590 | 0.484 | 0.507 | 0.484 | 0.505 | 0.465  | 0.506 | 0.476        | 0.506 | 0.493      | 0.528 |
| JGroups   | 0.571 | 0.571 | 0.409 | 0.407 | 0.407    | 0.412 | 0.462 | 0.424 | 0.561     | 0.571 | 0.559 | 0.571 | 0.417 | 0.407 | 0.417 | 0.406 | 0.397  | 0.398 | 0.409        | 0.407 | 0.440      | 0.430 |
| Camel     | 0.583 | 0.550 | 0.489 | 0.498 | 0.484    | 0.467 | 0.468 | 0.466 | 0.576     | 0.547 | 0.575 | 0.547 | 0.487 | 0.498 | 0.487 | 0.498 | 0.479  | 0.489 | 0.484        | 0.499 | 0.497      | 0.514 |
| Tomcat    | 0.684 | 0.684 | 0.613 | 0.635 | 0.616    | 0.631 | 0.540 | 0.528 | 0.667     | 0.679 | 0.671 | 0.676 | 0.608 | 0.635 | 0.607 | 0.632 | 0.594  | 0.625 | 0.606        | 0.631 | 0.642      | 0.672 |
| Brackets  | 0.712 | 0.673 | 0.643 | 0.620 | 0.643    | 0.609 | 0.588 | 0.552 | 0.697     | 0.660 | 0.696 | 0.660 | 0.653 | 0.619 | 0.652 | 0.619 | 0.628  | 0.591 | 0.646        | 0.618 | 0.662      | 0.626 |
| Neutron   | 0.766 | 0.715 | 0.724 | 0.692 | 0.750    | 0.713 | 0.681 | 0.628 | 0.760     | 0.713 | 0.740 | 0.669 | 0.724 | 0.692 | 0.730 | 0.692 | 0.695  | 0.674 | 0.724        | 0.683 | 0.718      | 0.674 |
| Spring    | 0.712 | 0.766 | 0.656 | 0.699 | 0.683    | 0.739 | 0.628 | 0.674 | 0.718     | 0.756 | 0.706 | 0.754 | 0.654 | 0.707 | 0.659 | 0.699 | 0.633  | 0.687 | 0.654        | 0.694 | 0.656      | 0.696 |
| Broadleaf | 0.631 | 0.706 | 0.525 | 0.585 | 0.529    | 0.541 | 0.508 | 0.557 | 0.635     | 0.707 | 0.635 | 0.707 | 0.525 | 0.586 | 0.519 | 0.584 | 0.506  | 0.573 | 0.511        | 0.584 | 0.523      | 0.597 |
| Nova      | 0.714 | 0.720 | 0.694 | 0.691 | 0.709    | 0.709 | 0.641 | 0.663 | 0.714     | 0.719 | 0.707 | 0.713 | 0.695 | 0.692 | 0.699 | 0.691 | 0.676  | 0.674 | 0.695        | 0.691 | 0.676      | 0.695 |
| Npm       | 0.569 | 0.500 | 0.448 | 0.447 | 0.484    | 0.447 | 0.467 | 0.452 | 0.584     | 0.487 | 0.557 | 0.483 | 0.470 | 0.449 | 0.470 | 0.449 | 0.456  | 0.437 | 0.442        | 0.440 | 0.474      | 0.465 |
| Mean      | 0.655 | 0.648 | 0.568 | 0.578 | 0.580    | 0.577 | 0.547 | 0.546 | 0.650     | 0.643 | 0.643 | 0.637 | 0.572 | 0.579 | 0.572 | 0.577 | 0.553  | 0.565 | 0.565        | 0.575 | 0.578      | 0.590 |

TABLE XXII: Median value on *F-measure@20%* for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.453 | 0.500 | 0.558 | 0.584 | 0.556    | 0.591 | 0.553 | 0.589 | 0.485     | 0.510 | 0.479 | 0.515 | 0.558 | 0.584 | 0.562 | 0.584 | 0.561  | 0.587 | 0.564        | 0.584 | 0.558      | 0.581 |
| JGroups   | 0.356 | 0.366 | 0.471 | 0.488 | 0.471    | 0.487 | 0.430 | 0.464 | 0.353     | 0.374 | 0.353 | 0.378 | 0.471 | 0.486 | 0.468 | 0.486 | 0.466  | 0.485 | 0.470        | 0.488 | 0.471      | 0.465 |
| Camel     | 0.492 | 0.481 | 0.562 | 0.568 | 0.548    | 0.564 | 0.563 | 0.560 | 0.499     | 0.489 | 0.501 | 0.489 | 0.562 | 0.566 | 0.562 | 0.568 | 0.555  | 0.567 | 0.559        | 0.568 | 0.558      | 0.554 |
| Tomcat    | 0.548 | 0.596 | 0.598 | 0.627 | 0.600    | 0.631 | 0.614 | 0.638 | 0.556     | 0.599 | 0.561 | 0.599 | 0.598 | 0.598 | 0.606 | 0.625 | 0.602  | 0.632 | 0.601        | 0.630 | 0.592      | 0.612 |
| Brackets  | 0.600 | 0.655 | 0.651 | 0.681 | 0.646    | 0.681 | 0.671 | 0.673 | 0.606     | 0.659 | 0.610 | 0.659 | 0.667 | 0.684 | 0.660 | 0.681 | 0.662  | 0.688 | 0.664        | 0.682 | 0.674      | 0.675 |
| Neutron   | 0.744 | 0.747 | 0.778 | 0.761 | 0.768    | 0.765 | 0.781 | 0.751 | 0.748     | 0.754 | 0.762 | 0.756 | 0.778 | 0.761 | 0.778 | 0.761 | 0.778  | 0.766 | 0.780        | 0.764 | 0.778      | 0.764 |
| Spring    | 0.611 | 0.645 | 0.661 | 0.681 | 0.611    | 0.641 | 0.676 | 0.692 | 0.616     | 0.647 | 0.616 | 0.592 | 0.659 | 0.683 | 0.659 | 0.683 | 0.676  | 0.688 | 0.663        | 0.686 | 0.671      | 0.667 |
| Broadleaf | 0.500 | 0.509 | 0.572 | 0.614 | 0.561    | 0.592 | 0.565 | 0.612 | 0.529     | 0.525 | 0.540 | 0.531 | 0.583 | 0.609 | 0.577 | 0.614 | 0.570  | 0.621 | 0.576        | 0.608 | 0.576      | 0.599 |
| Nova      | 0.699 | 0.751 | 0.734 | 0.765 | 0.723    | 0.763 | 0.730 | 0.771 | 0.699     | 0.751 | 0.700 | 0.751 | 0.734 | 0.765 | 0.734 | 0.765 | 0.732  | 0.768 | 0.734        | 0.765 | 0.725      | 0.762 |
| Npm       | 0.340 | 0.359 | 0.511 | 0.525 | 0.519    | 0.524 | 0.481 | 0.497 | 0.381     | 0.389 | 0.366 | 0.385 | 0.511 | 0.526 | 0.511 | 0.527 | 0.512  | 0.528 | 0.512        | 0.526 | 0.472      | 0.491 |
| Mean      | 0.534 | 0.561 | 0.610 | 0.629 | 0.600    | 0.624 | 0.606 | 0.625 | 0.547     | 0.570 | 0.549 | 0.566 | 0.612 | 0.629 | 0.612 | 0.629 | 0.611  | 0.633 | 0.612        | 0.630 | 0.608      | 0.617 |

TABLE XXIII: Median value on  $PCI@20\%$  for each project when the time period is two months and six months

| Projects  | NONE  |       | RUM   |       | NearMiss |       | ENN   |       | TomekLink |       | OSS   |       | ROM   |       | SMOTE |       | BSMOTE |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|-------|-------|-------|-------|----------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------------|-------|------------|-------|
|           | two   | six   | two   | six   | two      | six   | two   | six   | two       | six   | two   | six   | two   | six   | two   | six   | two    | six   | two          | six   | two        | six   |
| Fabric8   | 0.182 | 0.252 | 0.394 | 0.446 | 0.401    | 0.499 | 0.404 | 0.499 | 0.211     | 0.274 | 0.215 | 0.274 | 0.408 | 0.440 | 0.405 | 0.439 | 0.441  | 0.468 | 0.425        | 0.454 | 0.379      | 0.397 |
| JGroups   | 0.140 | 0.109 | 0.364 | 0.375 | 0.384    | 0.439 | 0.313 | 0.301 | 0.158     | 0.126 | 0.158 | 0.131 | 0.370 | 0.378 | 0.370 | 0.379 | 0.392  | 0.397 | 0.373        | 0.384 | 0.296      | 0.315 |
| Camel     | 0.209 | 0.230 | 0.413 | 0.406 | 0.403    | 0.467 | 0.459 | 0.463 | 0.239     | 0.242 | 0.239 | 0.242 | 0.412 | 0.407 | 0.411 | 0.410 | 0.429  | 0.437 | 0.421        | 0.413 | 0.354      | 0.402 |
| Tomcat    | 0.290 | 0.319 | 0.395 | 0.422 | 0.408    | 0.434 | 0.561 | 0.598 | 0.302     | 0.329 | 0.305 | 0.329 | 0.396 | 0.419 | 0.396 | 0.422 | 0.429  | 0.444 | 0.409        | 0.423 | 0.349      | 0.370 |
| Brackets  | 0.293 | 0.321 | 0.385 | 0.422 | 0.392    | 0.432 | 0.477 | 0.528 | 0.307     | 0.345 | 0.313 | 0.345 | 0.383 | 0.422 | 0.384 | 0.423 | 0.420  | 0.448 | 0.389        | 0.423 | 0.397      | 0.368 |
| Neutron   | 0.322 | 0.345 | 0.396 | 0.393 | 0.364    | 0.379 | 0.449 | 0.460 | 0.339     | 0.353 | 0.366 | 0.357 | 0.394 | 0.393 | 0.394 | 0.393 | 0.422  | 0.423 | 0.399        | 0.400 | 0.401      | 0.399 |
| Spring    | 0.315 | 0.332 | 0.409 | 0.408 | 0.386    | 0.360 | 0.505 | 0.470 | 0.354     | 0.337 | 0.373 | 0.329 | 0.408 | 0.409 | 0.404 | 0.409 | 0.429  | 0.425 | 0.430        | 0.421 | 0.397      | 0.438 |
| Broadleaf | 0.170 | 0.210 | 0.358 | 0.362 | 0.329    | 0.377 | 0.372 | 0.387 | 0.204     | 0.223 | 0.204 | 0.225 | 0.359 | 0.363 | 0.362 | 0.359 | 0.394  | 0.398 | 0.378        | 0.370 | 0.305      | 0.349 |
| Nova      | 0.366 | 0.383 | 0.406 | 0.421 | 0.380    | 0.397 | 0.463 | 0.479 | 0.367     | 0.383 | 0.387 | 0.389 | 0.406 | 0.421 | 0.406 | 0.421 | 0.431  | 0.441 | 0.407        | 0.421 | 0.405      | 0.408 |
| Npm       | 0.163 | 0.147 | 0.392 | 0.467 | 0.404    | 0.495 | 0.459 | 0.486 | 0.189     | 0.179 | 0.201 | 0.180 | 0.392 | 0.467 | 0.408 | 0.463 | 0.404  | 0.477 | 0.432        | 0.475 | 0.406      | 0.392 |
| Mean      | 0.245 | 0.265 | 0.391 | 0.412 | 0.385    | 0.428 | 0.446 | 0.467 | 0.267     | 0.279 | 0.276 | 0.280 | 0.393 | 0.412 | 0.394 | 0.412 | 0.419  | 0.436 | 0.406        | 0.418 | 0.369      | 0.384 |

TABLE XXIV: Median value on  $IFA$  for each project when the time period is two months and six months

| Projects  | NONE |     |  | RUM |     |  | NearMiss |     |  | ENN |     |  | TomekLink |     |  | OSS |     |  | ROM |     |  | SMOTE |     |  | BSMOTE |     |  | SMOTE+ Tomek |     |  | SMOTE+ ENN |  |  |
|-----------|------|-----|--|-----|-----|--|----------|-----|--|-----|-----|--|-----------|-----|--|-----|-----|--|-----|-----|--|-------|-----|--|--------|-----|--|--------------|-----|--|------------|--|--|
|           | two  | six |  | two | six |  | two      | six |  | two | six |  | two       | six |  | two | six |  | two | six |  | two   | six |  | two    | six |  | two          | six |  |            |  |  |
| Fabric8   | 2.0  | 3.0 |  | 4.0 | 4.0 |  | 3.5      | 5.0 |  | 4.0 | 4.0 |  | 2.0       | 4.0 |  | 4.0 | 4.0 |  | 4.0 | 4.0 |  | 4.5   | 5.0 |  | 4.0    | 4.0 |  | 5.0          | 5.0 |  | 3.0        |  |  |
| JGroups   | 2.0  | 2.0 |  | 4.0 | 5.0 |  | 5.0      | 4.0 |  | 3.0 | 4.0 |  | 2.0       | 2.0 |  | 2.0 | 2.0 |  | 5.0 | 5.0 |  | 5.0   | 5.0 |  | 5.0    | 5.0 |  | 5.0          | 4.0 |  | 4.0        |  |  |
| Camel     | 2.0  | 2.0 |  | 3.0 | 3.0 |  | 3.0      | 4.0 |  | 3.0 | 4.0 |  | 2.0       | 2.0 |  | 2.0 | 2.0 |  | 3.0 | 3.0 |  | 3.0   | 3.0 |  | 3.0    | 3.0 |  | 3.0          | 3.0 |  | 4.0        |  |  |
| Tomcat    | 2.0  | 3.0 |  | 2.0 | 3.0 |  | 2.0      | 3.0 |  | 2.0 | 3.0 |  | 2.0       | 3.0 |  | 2.0 | 3.0 |  | 2.0 | 3.0 |  | 2.0   | 3.0 |  | 2.0    | 3.0 |  | 2.0          | 2.0 |  | 3.0        |  |  |
| Brackets  | 2.0  | 3.0 |  | 3.0 | 4.0 |  | 3.0      | 4.0 |  | 4.0 | 6.0 |  | 2.0       | 3.0 |  | 3.0 | 3.0 |  | 3.0 | 4.0 |  | 3.0   | 5.0 |  | 3.0    | 4.0 |  | 2.0          | 2.0 |  | 4.0        |  |  |
| Neutron   | 1.0  | 2.0 |  | 2.0 | 2.0 |  | 2.0      | 2.0 |  | 2.0 | 3.0 |  | 1.0       | 2.0 |  | 2.0 | 2.0 |  | 2.0 | 2.0 |  | 2.0   | 3.0 |  | 2.0    | 2.0 |  | 2.0          | 2.0 |  | 3.0        |  |  |
| Spring    | 1.0  | 1.0 |  | 1.0 | 2.0 |  | 1.0      | 1.0 |  | 1.0 | 2.0 |  | 1.0       | 1.0 |  | 1.0 | 1.0 |  | 1.0 | 2.0 |  | 1.0   | 2.0 |  | 1.0    | 2.0 |  | 2.0          | 1.0 |  | 2.0        |  |  |
| Broadleaf | 2.0  | 3.0 |  | 4.0 | 4.0 |  | 3.0      | 4.0 |  | 3.0 | 5.0 |  | 2.0       | 2.0 |  | 2.0 | 2.0 |  | 4.0 | 4.0 |  | 4.0   | 4.0 |  | 4.0    | 4.0 |  | 4.0          | 3.0 |  | 3.0        |  |  |
| Nova      | 2.0  | 2.0 |  | 2.0 | 3.0 |  | 2.0      | 2.0 |  | 3.0 | 5.0 |  | 2.0       | 2.0 |  | 2.0 | 2.5 |  | 2.0 | 3.0 |  | 2.0   | 3.0 |  | 3.0    | 3.0 |  | 2.0          | 3.0 |  | 3.0        |  |  |
| Npm       | 2.0  | 3.0 |  | 3.0 | 5.0 |  | 3.0      | 5.0 |  | 3.0 | 4.0 |  | 2.0       | 3.0 |  | 2.0 | 3.0 |  | 3.0 | 5.0 |  | 4.0   | 5.0 |  | 4.0    | 5.0 |  | 3.0          | 4.5 |  | 4.0        |  |  |
| Mean      | 1.8  | 2.4 |  | 2.8 | 3.5 |  | 2.8      | 3.4 |  | 2.8 | 4.0 |  | 1.8       | 2.4 |  | 1.9 | 2.5 |  | 2.8 | 3.5 |  | 3.0   | 3.5 |  | 3.1    | 3.7 |  | 3.0          | 3.6 |  | 3.3        |  |  |

TABLE XXV: Median value on *Recall* for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.384   | 0.350 | 0.687   | 0.817 | 0.677    | 0.831 | 0.688   | 0.828 | 0.441     | 0.412 | 0.426   | 0.412 | 0.696   | 0.808 | 0.697   | 0.817 | 0.721   | 0.885 | 0.714        | 0.810 | 0.685      | 0.744 |
| JGroups   | 0.331   | 0.250 | 0.648   | 0.722 | 0.667    | 0.753 | 0.571   | 0.573 | 0.350     | 0.283 | 0.358   | 0.294 | 0.652   | 0.709 | 0.648   | 0.706 | 0.673   | 0.786 | 0.652        | 0.709 | 0.577      | 0.629 |
| Camel     | 0.442   | 0.426 | 0.733   | 0.801 | 0.691    | 0.858 | 0.782   | 0.827 | 0.508     | 0.477 | 0.511   | 0.484 | 0.733   | 0.807 | 0.731   | 0.808 | 0.754   | 0.860 | 0.749        | 0.814 | 0.731      | 0.785 |
| Tomcat    | 0.529   | 0.540 | 0.672   | 0.726 | 0.677    | 0.735 | 0.834   | 0.861 | 0.561     | 0.600 | 0.563   | 0.578 | 0.676   | 0.720 | 0.676   | 0.724 | 0.711   | 0.778 | 0.689        | 0.727 | 0.650      | 0.709 |
| Brackets  | 0.673   | 0.737 | 0.775   | 0.849 | 0.785    | 0.829 | 0.879   | 0.923 | 0.689     | 0.748 | 0.691   | 0.756 | 0.783   | 0.842 | 0.776   | 0.849 | 0.818   | 0.923 | 0.783        | 0.843 | 0.765      | 0.791 |
| Neutron   | 0.747   | 0.890 | 0.844   | 0.956 | 0.802    | 0.890 | 0.907   | 0.960 | 0.764     | 0.891 | 0.819   | 0.879 | 0.844   | 0.959 | 0.844   | 0.974 | 0.883   | 0.987 | 0.852        | 0.968 | 0.849      | 0.891 |
| Spring    | 0.599   | 0.693 | 0.774   | 0.883 | 0.677    | 0.779 | 0.878   | 0.892 | 0.647     | 0.714 | 0.667   | 0.739 | 0.757   | 0.855 | 0.758   | 0.862 | 0.811   | 0.894 | 0.797        | 0.836 | 0.811      | 0.833 |
| Broadleaf | 0.469   | 0.441 | 0.750   | 0.795 | 0.668    | 0.760 | 0.760   | 0.821 | 0.512     | 0.477 | 0.512   | 0.500 | 0.747   | 0.786 | 0.750   | 0.795 | 0.786   | 0.888 | 0.763        | 0.791 | 0.722      | 0.750 |
| Nova      | 0.719   | 0.828 | 0.862   | 0.958 | 0.781    | 0.844 | 0.919   | 0.950 | 0.733     | 0.849 | 0.766   | 0.834 | 0.860   | 0.947 | 0.860   | 0.947 | 0.894   | 0.981 | 0.862        | 0.954 | 0.867      | 0.898 |
| Npm       | 0.288   | 0.304 | 0.667   | 0.833 | 0.667    | 0.706 | 0.667   | 0.788 | 0.333     | 0.333 | 0.358   | 0.351 | 0.667   | 0.824 | 0.662   | 0.833 | 0.686   | 0.851 | 0.692        | 0.827 | 0.677      | 0.735 |
| Mean      | 0.518   | 0.546 | 0.741   | 0.834 | 0.709    | 0.798 | 0.788   | 0.843 | 0.554     | 0.579 | 0.567   | 0.583 | 0.741   | 0.826 | 0.740   | 0.832 | 0.774   | 0.885 | 0.755        | 0.828 | 0.733      | 0.777 |

TABLE XXVI: Median value on *Precision* for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.610   | 0.606 | 0.510   | 0.468 | 0.461    | 0.539 | 0.522   | 0.457 | 0.586     | 0.585 | 0.586   | 0.585 | 0.513   | 0.466 | 0.510   | 0.457 | 0.503   | 0.438 | 0.509        | 0.497 | 0.522      | 0.500 |
| JGroups   | 0.643   | 0.648 | 0.457   | 0.399 | 0.403    | 0.433 | 0.533   | 0.500 | 0.625     | 0.667 | 0.636   | 0.674 | 0.456   | 0.404 | 0.456   | 0.417 | 0.438   | 0.384 | 0.455        | 0.404 | 0.487      | 0.427 |
| Camel     | 0.600   | 0.586 | 0.507   | 0.470 | 0.457    | 0.481 | 0.494   | 0.454 | 0.593     | 0.589 | 0.590   | 0.585 | 0.508   | 0.474 | 0.504   | 0.470 | 0.497   | 0.436 | 0.496        | 0.474 | 0.508      | 0.482 |
| Tomcat    | 0.709   | 0.683 | 0.641   | 0.609 | 0.619    | 0.645 | 0.564   | 0.535 | 0.689     | 0.670 | 0.690   | 0.682 | 0.641   | 0.610 | 0.641   | 0.603 | 0.624   | 0.584 | 0.638        | 0.608 | 0.665      | 0.625 |
| Brackets  | 0.732   | 0.694 | 0.677   | 0.637 | 0.648    | 0.644 | 0.634   | 0.590 | 0.728     | 0.698 | 0.717   | 0.697 | 0.680   | 0.631 | 0.680   | 0.644 | 0.655   | 0.577 | 0.676        | 0.635 | 0.694      | 0.669 |
| Neutron   | 0.759   | 0.696 | 0.731   | 0.671 | 0.692    | 0.717 | 0.689   | 0.671 | 0.763     | 0.696 | 0.741   | 0.702 | 0.731   | 0.692 | 0.731   | 0.692 | 0.717   | 0.682 | 0.722        | 0.674 | 0.731      | 0.695 |
| Spring    | 0.729   | 0.679 | 0.681   | 0.612 | 0.653    | 0.729 | 0.642   | 0.591 | 0.714     | 0.678 | 0.707   | 0.682 | 0.677   | 0.620 | 0.682   | 0.620 | 0.667   | 0.555 | 0.679        | 0.607 | 0.667      | 0.613 |
| Broadleaf | 0.661   | 0.652 | 0.538   | 0.483 | 0.471    | 0.542 | 0.521   | 0.500 | 0.635     | 0.636 | 0.631   | 0.625 | 0.537   | 0.500 | 0.533   | 0.494 | 0.524   | 0.429 | 0.525        | 0.471 | 0.535      | 0.494 |
| Nova      | 0.747   | 0.708 | 0.704   | 0.634 | 0.711    | 0.710 | 0.685   | 0.628 | 0.739     | 0.697 | 0.714   | 0.711 | 0.704   | 0.634 | 0.704   | 0.671 | 0.692   | 0.658 | 0.702        | 0.634 | 0.704      | 0.669 |
| Npm       | 0.581   | 0.583 | 0.481   | 0.433 | 0.494    | 0.439 | 0.476   | 0.468 | 0.586     | 0.587 | 0.571   | 0.588 | 0.494   | 0.465 | 0.486   | 0.465 | 0.482   | 0.441 | 0.482        | 0.457 | 0.493      | 0.476 |
| Mean      | 0.677   | 0.654 | 0.593   | 0.542 | 0.561    | 0.588 | 0.576   | 0.539 | 0.666     | 0.650 | 0.658   | 0.653 | 0.594   | 0.550 | 0.593   | 0.553 | 0.580   | 0.519 | 0.588        | 0.546 | 0.600      | 0.565 |

TABLE XXVII: Median value on  $P_f$  for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.084   | 0.075 | 0.303   | 0.398 | 0.295    | 0.433 | 0.316   | 0.372 | 0.116     | 0.093 | 0.117   | 0.093 | 0.300   | 0.352 | 0.306   | 0.376 | 0.330   | 0.444 | 0.325        | 0.355 | 0.272      | 0.321 |
| JGroups   | 0.061   | 0.057 | 0.316   | 0.401 | 0.334    | 0.431 | 0.212   | 0.212 | 0.078     | 0.056 | 0.080   | 0.060 | 0.316   | 0.372 | 0.307   | 0.396 | 0.334   | 0.463 | 0.316        | 0.391 | 0.248      | 0.330 |
| Camel     | 0.120   | 0.112 | 0.306   | 0.375 | 0.290    | 0.420 | 0.332   | 0.413 | 0.137     | 0.139 | 0.137   | 0.132 | 0.306   | 0.373 | 0.306   | 0.367 | 0.325   | 0.471 | 0.318        | 0.373 | 0.296      | 0.344 |
| Tomcat    | 0.172   | 0.189 | 0.263   | 0.329 | 0.269    | 0.330 | 0.465   | 0.498 | 0.186     | 0.219 | 0.186   | 0.211 | 0.263   | 0.320 | 0.263   | 0.318 | 0.295   | 0.382 | 0.272        | 0.331 | 0.243      | 0.307 |
| Brackets  | 0.138   | 0.190 | 0.206   | 0.265 | 0.213    | 0.245 | 0.306   | 0.378 | 0.144     | 0.198 | 0.144   | 0.203 | 0.205   | 0.251 | 0.206   | 0.265 | 0.244   | 0.378 | 0.214        | 0.268 | 0.188      | 0.213 |
| Neutron   | 0.122   | 0.191 | 0.171   | 0.263 | 0.147    | 0.214 | 0.222   | 0.267 | 0.135     | 0.198 | 0.154   | 0.198 | 0.178   | 0.265 | 0.179   | 0.277 | 0.197   | 0.328 | 0.179        | 0.256 | 0.180      | 0.205 |
| Spring    | 0.165   | 0.198 | 0.279   | 0.327 | 0.228    | 0.278 | 0.349   | 0.362 | 0.193     | 0.223 | 0.220   | 0.215 | 0.272   | 0.335 | 0.284   | 0.334 | 0.292   | 0.402 | 0.283        | 0.339 | 0.298      | 0.322 |
| Broadleaf | 0.088   | 0.070 | 0.249   | 0.283 | 0.194    | 0.295 | 0.259   | 0.301 | 0.103     | 0.090 | 0.098   | 0.093 | 0.246   | 0.280 | 0.252   | 0.283 | 0.287   | 0.426 | 0.258        | 0.288 | 0.218      | 0.250 |
| Nova      | 0.131   | 0.194 | 0.184   | 0.262 | 0.156    | 0.195 | 0.223   | 0.261 | 0.139     | 0.199 | 0.151   | 0.181 | 0.187   | 0.262 | 0.184   | 0.253 | 0.211   | 0.310 | 0.191        | 0.266 | 0.197      | 0.221 |
| Npm       | 0.087   | 0.089 | 0.313   | 0.437 | 0.313    | 0.374 | 0.342   | 0.427 | 0.097     | 0.095 | 0.119   | 0.097 | 0.319   | 0.419 | 0.319   | 0.455 | 0.333   | 0.489 | 0.339        | 0.438 | 0.316      | 0.376 |
| Mean      | 0.117   | 0.137 | 0.259   | 0.334 | 0.244    | 0.322 | 0.303   | 0.349 | 0.133     | 0.151 | 0.141   | 0.148 | 0.259   | 0.323 | 0.261   | 0.332 | 0.285   | 0.409 | 0.270        | 0.330 | 0.246      | 0.289 |

TABLE XXVIII: Median value on  $F$ -measure for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.450   | 0.448 | 0.564   | 0.566 | 0.556    | 0.568 | 0.557   | 0.557 | 0.483     | 0.463 | 0.479   | 0.459 | 0.564   | 0.575 | 0.568   | 0.563 | 0.568   | 0.568 | 0.567        | 0.569 | 0.563      | 0.562 |
| JGroups   | 0.407   | 0.341 | 0.532   | 0.512 | 0.532    | 0.523 | 0.492   | 0.456 | 0.409     | 0.378 | 0.411   | 0.374 | 0.533   | 0.520 | 0.527   | 0.522 | 0.530   | 0.507 | 0.524        | 0.521 | 0.521      | 0.493 |
| Camel     | 0.514   | 0.500 | 0.599   | 0.584 | 0.582    | 0.580 | 0.600   | 0.582 | 0.533     | 0.528 | 0.537   | 0.530 | 0.601   | 0.593 | 0.598   | 0.590 | 0.593   | 0.574 | 0.594        | 0.593 | 0.597      | 0.586 |
| Tomcat    | 0.610   | 0.601 | 0.653   | 0.649 | 0.648    | 0.655 | 0.657   | 0.642 | 0.617     | 0.623 | 0.618   | 0.619 | 0.648   | 0.644 | 0.648   | 0.651 | 0.658   | 0.653 | 0.653        | 0.653 | 0.644      | 0.653 |
| Brackets  | 0.691   | 0.705 | 0.724   | 0.719 | 0.714    | 0.714 | 0.712   | 0.710 | 0.693     | 0.702 | 0.697   | 0.705 | 0.723   | 0.719 | 0.725   | 0.722 | 0.719   | 0.705 | 0.725        | 0.714 | 0.717      | 0.711 |
| Neutron   | 0.748   | 0.774 | 0.781   | 0.798 | 0.774    | 0.780 | 0.793   | 0.780 | 0.753     | 0.774 | 0.759   | 0.774 | 0.778   | 0.780 | 0.778   | 0.806 | 0.780   | 0.810 | 0.783        | 0.775 | 0.781      | 0.776 |
| Spring    | 0.654   | 0.676 | 0.704   | 0.696 | 0.678    | 0.698 | 0.713   | 0.698 | 0.664     | 0.697 | 0.678   | 0.698 | 0.705   | 0.691 | 0.702   | 0.697 | 0.705   | 0.682 | 0.704        | 0.694 | 0.699      | 0.686 |
| Broadleaf | 0.527   | 0.504 | 0.600   | 0.602 | 0.598    | 0.583 | 0.592   | 0.583 | 0.549     | 0.524 | 0.553   | 0.533 | 0.608   | 0.606 | 0.608   | 0.596 | 0.604   | 0.557 | 0.608        | 0.598 | 0.605      | 0.590 |
| Nova      | 0.734   | 0.749 | 0.760   | 0.755 | 0.760    | 0.770 | 0.768   | 0.754 | 0.741     | 0.750 | 0.745   | 0.763 | 0.760   | 0.750 | 0.760   | 0.763 | 0.759   | 0.764 | 0.760        | 0.750 | 0.752      | 0.752 |
| Npm       | 0.349   | 0.350 | 0.538   | 0.575 | 0.553    | 0.564 | 0.527   | 0.538 | 0.411     | 0.400 | 0.411   | 0.414 | 0.545   | 0.571 | 0.544   | 0.577 | 0.547   | 0.574 | 0.545        | 0.575 | 0.524      | 0.551 |
| Mean      | 0.568   | 0.565 | 0.646   | 0.645 | 0.640    | 0.643 | 0.641   | 0.630 | 0.585     | 0.584 | 0.589   | 0.587 | 0.647   | 0.645 | 0.646   | 0.649 | 0.646   | 0.639 | 0.646        | 0.644 | 0.640      | 0.636 |

TABLE XXIX: Median value on *AUC* for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.632   | 0.639 | 0.702   | 0.711 | 0.704    | 0.700 | 0.692   | 0.689 | 0.651     | 0.649 | 0.652   | 0.647 | 0.706   | 0.716 | 0.706   | 0.706 | 0.704   | 0.707 | 0.706        | 0.706 | 0.707      | 0.706 |
| JGroups   | 0.614   | 0.596 | 0.665   | 0.650 | 0.664    | 0.640 | 0.648   | 0.633 | 0.623     | 0.603 | 0.623   | 0.605 | 0.665   | 0.655 | 0.666   | 0.656 | 0.667   | 0.629 | 0.667        | 0.655 | 0.661      | 0.651 |
| Camel     | 0.656   | 0.653 | 0.722   | 0.705 | 0.701    | 0.693 | 0.713   | 0.702 | 0.666     | 0.663 | 0.666   | 0.661 | 0.722   | 0.713 | 0.721   | 0.709 | 0.718   | 0.700 | 0.719        | 0.715 | 0.714      | 0.718 |
| Tomcat    | 0.687   | 0.680 | 0.701   | 0.691 | 0.701    | 0.694 | 0.666   | 0.642 | 0.692     | 0.685 | 0.692   | 0.684 | 0.700   | 0.691 | 0.700   | 0.691 | 0.700   | 0.680 | 0.698        | 0.694 | 0.698      | 0.692 |
| Brackets  | 0.771   | 0.781 | 0.789   | 0.789 | 0.790    | 0.793 | 0.785   | 0.770 | 0.771     | 0.782 | 0.773   | 0.782 | 0.789   | 0.786 | 0.789   | 0.790 | 0.788   | 0.776 | 0.789        | 0.787 | 0.780      | 0.784 |
| Neutron   | 0.809   | 0.839 | 0.833   | 0.843 | 0.823    | 0.839 | 0.840   | 0.832 | 0.816     | 0.839 | 0.825   | 0.830 | 0.831   | 0.838 | 0.833   | 0.842 | 0.839   | 0.825 | 0.835        | 0.842 | 0.834      | 0.839 |
| Spring    | 0.704   | 0.714 | 0.727   | 0.730 | 0.714    | 0.731 | 0.717   | 0.712 | 0.705     | 0.703 | 0.707   | 0.726 | 0.729   | 0.733 | 0.728   | 0.733 | 0.731   | 0.728 | 0.730        | 0.736 | 0.728      | 0.733 |
| Broadleaf | 0.683   | 0.682 | 0.750   | 0.743 | 0.733    | 0.726 | 0.735   | 0.720 | 0.696     | 0.686 | 0.696   | 0.691 | 0.751   | 0.745 | 0.754   | 0.744 | 0.747   | 0.721 | 0.751        | 0.743 | 0.748      | 0.744 |
| Nova      | 0.796   | 0.814 | 0.834   | 0.841 | 0.818    | 0.834 | 0.836   | 0.836 | 0.806     | 0.828 | 0.805   | 0.814 | 0.834   | 0.841 | 0.833   | 0.836 | 0.835   | 0.828 | 0.834        | 0.841 | 0.834      | 0.838 |
| Npm       | 0.598   | 0.602 | 0.680   | 0.662 | 0.673    | 0.663 | 0.647   | 0.647 | 0.623     | 0.602 | 0.623   | 0.613 | 0.689   | 0.669 | 0.685   | 0.667 | 0.680   | 0.668 | 0.694        | 0.659 | 0.669      | 0.665 |
| Mean      | 0.695   | 0.700 | 0.740   | 0.737 | 0.732    | 0.731 | 0.728   | 0.718 | 0.705     | 0.704 | 0.706   | 0.705 | 0.741   | 0.739 | 0.742   | 0.737 | 0.741   | 0.726 | 0.742        | 0.738 | 0.737      | 0.737 |

TABLE XXX: Median value on *MCC* for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.310   | 0.324 | 0.371   | 0.387 | 0.363    | 0.363 | 0.376   | 0.372 | 0.322     | 0.338 | 0.318   | 0.336 | 0.364   | 0.395 | 0.360   | 0.380 | 0.369   | 0.369 | 0.373        | 0.386 | 0.380      | 0.378 |
| JGroups   | 0.296   | 0.261 | 0.298   | 0.270 | 0.301    | 0.263 | 0.285   | 0.276 | 0.296     | 0.286 | 0.298   | 0.288 | 0.306   | 0.273 | 0.301   | 0.274 | 0.302   | 0.247 | 0.297        | 0.273 | 0.314      | 0.279 |
| Camel     | 0.342   | 0.339 | 0.397   | 0.372 | 0.385    | 0.361 | 0.393   | 0.380 | 0.354     | 0.349 | 0.352   | 0.349 | 0.400   | 0.375 | 0.401   | 0.379 | 0.401   | 0.355 | 0.394        | 0.379 | 0.392      | 0.393 |
| Tomcat    | 0.394   | 0.383 | 0.394   | 0.383 | 0.396    | 0.381 | 0.339   | 0.309 | 0.401     | 0.389 | 0.402   | 0.388 | 0.394   | 0.383 | 0.393   | 0.381 | 0.395   | 0.358 | 0.394        | 0.386 | 0.403      | 0.389 |
| Brackets  | 0.544   | 0.543 | 0.558   | 0.551 | 0.563    | 0.557 | 0.545   | 0.522 | 0.552     | 0.543 | 0.554   | 0.551 | 0.563   | 0.551 | 0.561   | 0.557 | 0.557   | 0.522 | 0.560        | 0.550 | 0.554      | 0.558 |
| Neutron   | 0.620   | 0.649 | 0.640   | 0.667 | 0.627    | 0.655 | 0.664   | 0.650 | 0.627     | 0.655 | 0.642   | 0.649 | 0.638   | 0.649 | 0.643   | 0.663 | 0.645   | 0.683 | 0.643        | 0.656 | 0.644      | 0.646 |
| Spring    | 0.414   | 0.419 | 0.442   | 0.465 | 0.408    | 0.455 | 0.439   | 0.445 | 0.429     | 0.442 | 0.429   | 0.454 | 0.439   | 0.465 | 0.437   | 0.452 | 0.453   | 0.433 | 0.445        | 0.461 | 0.443      | 0.449 |
| Broadleaf | 0.403   | 0.396 | 0.457   | 0.437 | 0.430    | 0.423 | 0.416   | 0.408 | 0.414     | 0.405 | 0.417   | 0.398 | 0.455   | 0.444 | 0.457   | 0.448 | 0.448   | 0.380 | 0.456        | 0.442 | 0.452      | 0.458 |
| Nova      | 0.590   | 0.596 | 0.622   | 0.612 | 0.598    | 0.609 | 0.622   | 0.621 | 0.592     | 0.599 | 0.579   | 0.596 | 0.613   | 0.618 | 0.613   | 0.587 | 0.631   | 0.590 | 0.623        | 0.613 | 0.623      | 0.633 |
| Npm       | 0.250   | 0.260 | 0.301   | 0.295 | 0.309    | 0.311 | 0.287   | 0.295 | 0.274     | 0.267 | 0.267   | 0.275 | 0.313   | 0.313 | 0.308   | 0.316 | 0.299   | 0.284 | 0.308        | 0.302 | 0.288      | 0.296 |
| Mean      | 0.416   | 0.417 | 0.448   | 0.444 | 0.438    | 0.438 | 0.436   | 0.428 | 0.426     | 0.427 | 0.426   | 0.428 | 0.448   | 0.447 | 0.447   | 0.444 | 0.450   | 0.422 | 0.449        | 0.445 | 0.449      | 0.448 |

TABLE XXXI: Median value on  $P_{opt}$  for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.490   | 0.489 | 0.725   | 0.859 | 0.709    | 0.852 | 0.736   | 0.812 | 0.541     | 0.531 | 0.554   | 0.545 | 0.721   | 0.815 | 0.721   | 0.839 | 0.748   | 0.886 | 0.744        | 0.814 | 0.736      | 0.777 |
| JGroups   | 0.430   | 0.436 | 0.605   | 0.656 | 0.629    | 0.725 | 0.579   | 0.578 | 0.436     | 0.434 | 0.448   | 0.443 | 0.611   | 0.655 | 0.605   | 0.656 | 0.632   | 0.735 | 0.603        | 0.659 | 0.543      | 0.579 |
| Camel     | 0.489   | 0.474 | 0.716   | 0.812 | 0.680    | 0.839 | 0.773   | 0.819 | 0.528     | 0.500 | 0.523   | 0.509 | 0.712   | 0.811 | 0.711   | 0.801 | 0.741   | 0.863 | 0.730        | 0.823 | 0.711      | 0.762 |
| Tomecat   | 0.529   | 0.546 | 0.646   | 0.695 | 0.655    | 0.716 | 0.804   | 0.844 | 0.546     | 0.568 | 0.548   | 0.564 | 0.647   | 0.684 | 0.658   | 0.688 | 0.684   | 0.745 | 0.666        | 0.704 | 0.636      | 0.675 |
| Brackets  | 0.639   | 0.745 | 0.761   | 0.846 | 0.772    | 0.818 | 0.858   | 0.913 | 0.655     | 0.745 | 0.663   | 0.745 | 0.766   | 0.831 | 0.761   | 0.839 | 0.808   | 0.912 | 0.771        | 0.825 | 0.749      | 0.783 |
| Neutron   | 0.740   | 0.890 | 0.832   | 0.952 | 0.809    | 0.887 | 0.902   | 0.959 | 0.763     | 0.890 | 0.821   | 0.874 | 0.832   | 0.953 | 0.832   | 0.965 | 0.876   | 0.995 | 0.846        | 0.959 | 0.849      | 0.892 |
| Spring    | 0.614   | 0.693 | 0.748   | 0.839 | 0.684    | 0.767 | 0.851   | 0.870 | 0.643     | 0.727 | 0.656   | 0.739 | 0.748   | 0.828 | 0.747   | 0.834 | 0.754   | 0.849 | 0.754        | 0.804 | 0.795      | 0.816 |
| Broadleaf | 0.488   | 0.459 | 0.748   | 0.777 | 0.670    | 0.775 | 0.752   | 0.796 | 0.521     | 0.502 | 0.513   | 0.513 | 0.740   | 0.779 | 0.748   | 0.774 | 0.756   | 0.890 | 0.751        | 0.763 | 0.716      | 0.739 |
| Nova      | 0.719   | 0.839 | 0.850   | 0.955 | 0.762    | 0.867 | 0.917   | 0.946 | 0.732     | 0.869 | 0.770   | 0.835 | 0.850   | 0.944 | 0.850   | 0.931 | 0.888   | 0.974 | 0.857        | 0.947 | 0.856      | 0.885 |
| Npm       | 0.434   | 0.446 | 0.652   | 0.817 | 0.655    | 0.700 | 0.681   | 0.795 | 0.461     | 0.501 | 0.463   | 0.469 | 0.653   | 0.802 | 0.649   | 0.811 | 0.667   | 0.835 | 0.670        | 0.809 | 0.682      | 0.742 |
| Mean      | 0.557   | 0.602 | 0.728   | 0.821 | 0.703    | 0.795 | 0.785   | 0.833 | 0.583     | 0.627 | 0.596   | 0.624 | 0.728   | 0.810 | 0.728   | 0.814 | 0.755   | 0.868 | 0.739        | 0.811 | 0.727      | 0.765 |

TABLE XXXII: Median value on  $Recall@20\%$  for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.390   | 0.370 | 0.696   | 0.811 | 0.678    | 0.819 | 0.699   | 0.806 | 0.453     | 0.400 | 0.435   | 0.400 | 0.696   | 0.787 | 0.706   | 0.798 | 0.730   | 0.875 | 0.719        | 0.788 | 0.699      | 0.738 |
| JGroups   | 0.303   | 0.263 | 0.548   | 0.600 | 0.562    | 0.634 | 0.492   | 0.492 | 0.319     | 0.263 | 0.327   | 0.273 | 0.556   | 0.608 | 0.550   | 0.606 | 0.571   | 0.667 | 0.549        | 0.605 | 0.475      | 0.531 |
| Camel     | 0.390   | 0.363 | 0.680   | 0.770 | 0.647    | 0.779 | 0.711   | 0.767 | 0.452     | 0.417 | 0.452   | 0.417 | 0.678   | 0.750 | 0.678   | 0.745 | 0.690   | 0.816 | 0.685        | 0.750 | 0.677      | 0.718 |
| Tomecat   | 0.477   | 0.495 | 0.591   | 0.643 | 0.592    | 0.641 | 0.744   | 0.772 | 0.494     | 0.518 | 0.494   | 0.518 | 0.597   | 0.637 | 0.592   | 0.621 | 0.624   | 0.691 | 0.613        | 0.647 | 0.577      | 0.629 |
| Brackets  | 0.606   | 0.682 | 0.724   | 0.791 | 0.749    | 0.773 | 0.813   | 0.902 | 0.627     | 0.695 | 0.630   | 0.667 | 0.725   | 0.785 | 0.728   | 0.793 | 0.764   | 0.886 | 0.733        | 0.793 | 0.707      | 0.741 |
| Neutron   | 0.733   | 0.882 | 0.816   | 0.934 | 0.790    | 0.865 | 0.884   | 0.938 | 0.744     | 0.865 | 0.787   | 0.837 | 0.814   | 0.917 | 0.814   | 0.934 | 0.853   | 0.981 | 0.827        | 0.931 | 0.822      | 0.868 |
| Spring    | 0.556   | 0.605 | 0.692   | 0.768 | 0.619    | 0.707 | 0.762   | 0.785 | 0.592     | 0.618 | 0.600   | 0.634 | 0.692   | 0.758 | 0.692   | 0.756 | 0.700   | 0.780 | 0.700        | 0.760 | 0.721      | 0.750 |
| Broadleaf | 0.437   | 0.417 | 0.704   | 0.755 | 0.641    | 0.723 | 0.703   | 0.782 | 0.470     | 0.444 | 0.470   | 0.458 | 0.701   | 0.752 | 0.705   | 0.739 | 0.735   | 0.830 | 0.710        | 0.739 | 0.671      | 0.705 |
| Nova      | 0.693   | 0.810 | 0.826   | 0.932 | 0.747    | 0.818 | 0.882   | 0.935 | 0.706     | 0.841 | 0.756   | 0.810 | 0.827   | 0.927 | 0.826   | 0.904 | 0.851   | 0.946 | 0.832        | 0.927 | 0.824      | 0.867 |
| Npm       | 0.294   | 0.304 | 0.615   | 0.789 | 0.618    | 0.667 | 0.622   | 0.710 | 0.348     | 0.353 | 0.348   | 0.353 | 0.612   | 0.765 | 0.615   | 0.797 | 0.640   | 0.808 | 0.654        | 0.776 | 0.642      | 0.706 |
| Mean      | 0.488   | 0.519 | 0.689   | 0.779 | 0.664    | 0.743 | 0.731   | 0.789 | 0.520     | 0.542 | 0.530   | 0.537 | 0.690   | 0.768 | 0.691   | 0.769 | 0.716   | 0.828 | 0.702        | 0.771 | 0.682      | 0.725 |

TABLE XXXIII: Median value on *Precision@20%* for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.603   | 0.582 | 0.479   | 0.434 | 0.495    | 0.441 | 0.488   | 0.435 | 0.585     | 0.571 | 0.585   | 0.574 | 0.484   | 0.447 | 0.484   | 0.434 | 0.465   | 0.426 | 0.476        | 0.438 | 0.493      | 0.474 |
| JGroups   | 0.571   | 0.571 | 0.409   | 0.369 | 0.407    | 0.370 | 0.462   | 0.440 | 0.561     | 0.615 | 0.559   | 0.600 | 0.417   | 0.378 | 0.417   | 0.381 | 0.397   | 0.336 | 0.409        | 0.378 | 0.440      | 0.387 |
| Camel     | 0.583   | 0.554 | 0.489   | 0.443 | 0.484    | 0.435 | 0.468   | 0.446 | 0.576     | 0.571 | 0.575   | 0.564 | 0.487   | 0.451 | 0.487   | 0.453 | 0.479   | 0.412 | 0.484        | 0.451 | 0.497      | 0.467 |
| Tomcat    | 0.684   | 0.657 | 0.613   | 0.585 | 0.616    | 0.589 | 0.540   | 0.508 | 0.667     | 0.654 | 0.671   | 0.658 | 0.608   | 0.590 | 0.607   | 0.590 | 0.594   | 0.557 | 0.606        | 0.588 | 0.642      | 0.600 |
| Brackets  | 0.712   | 0.666 | 0.643   | 0.605 | 0.643    | 0.609 | 0.588   | 0.562 | 0.697     | 0.668 | 0.696   | 0.668 | 0.653   | 0.599 | 0.652   | 0.612 | 0.628   | 0.555 | 0.646        | 0.605 | 0.662      | 0.617 |
| Neutron   | 0.766   | 0.702 | 0.724   | 0.658 | 0.750    | 0.692 | 0.681   | 0.664 | 0.760     | 0.698 | 0.740   | 0.716 | 0.724   | 0.690 | 0.730   | 0.695 | 0.695   | 0.696 | 0.724        | 0.653 | 0.718      | 0.691 |
| Spring    | 0.712   | 0.679 | 0.656   | 0.594 | 0.683    | 0.631 | 0.628   | 0.579 | 0.718     | 0.687 | 0.706   | 0.690 | 0.654   | 0.594 | 0.659   | 0.594 | 0.633   | 0.538 | 0.654        | 0.590 | 0.656      | 0.587 |
| Broadleaf | 0.631   | 0.627 | 0.525   | 0.473 | 0.529    | 0.453 | 0.508   | 0.497 | 0.635     | 0.635 | 0.635   | 0.632 | 0.525   | 0.497 | 0.519   | 0.485 | 0.506   | 0.398 | 0.511        | 0.466 | 0.523      | 0.486 |
| Nova      | 0.714   | 0.682 | 0.694   | 0.616 | 0.709    | 0.681 | 0.641   | 0.612 | 0.714     | 0.671 | 0.707   | 0.691 | 0.695   | 0.626 | 0.699   | 0.633 | 0.676   | 0.593 | 0.695        | 0.633 | 0.676      | 0.663 |
| Npm       | 0.569   | 0.583 | 0.448   | 0.425 | 0.484    | 0.484 | 0.467   | 0.462 | 0.584     | 0.571 | 0.557   | 0.586 | 0.470   | 0.442 | 0.470   | 0.446 | 0.456   | 0.427 | 0.442        | 0.438 | 0.474      | 0.474 |
| Mean      | 0.655   | 0.630 | 0.568   | 0.520 | 0.580    | 0.538 | 0.547   | 0.521 | 0.650     | 0.634 | 0.643   | 0.638 | 0.572   | 0.531 | 0.572   | 0.532 | 0.553   | 0.494 | 0.565        | 0.524 | 0.578      | 0.545 |

TABLE XXXIV: Median value on *F-measure@20%* for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |       | RUM     |       | NearMiss |       | ENN     |       | TomekLink |       | OSS     |       | ROM     |       | SMOTE   |       | BSMOTE  |       | SMOTE+ Tomek |       | SMOTE+ ENN |       |
|-----------|---------|-------|---------|-------|----------|-------|---------|-------|-----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|--------------|-------|------------|-------|
|           | default | opt   | default | opt   | default  | opt   | default | opt   | default   | opt   | default | opt   | default | opt   | default | opt   | default | opt   | default      | opt   | default    | opt   |
| Fabric8   | 0.453   | 0.429 | 0.558   | 0.552 | 0.556    | 0.565 | 0.553   | 0.545 | 0.485     | 0.449 | 0.479   | 0.454 | 0.558   | 0.557 | 0.562   | 0.550 | 0.561   | 0.548 | 0.564        | 0.557 | 0.558      | 0.557 |
| JGroups   | 0.356   | 0.333 | 0.471   | 0.452 | 0.471    | 0.480 | 0.430   | 0.407 | 0.353     | 0.333 | 0.353   | 0.337 | 0.471   | 0.469 | 0.468   | 0.465 | 0.466   | 0.446 | 0.470        | 0.459 | 0.471      | 0.436 |
| Camel     | 0.492   | 0.470 | 0.562   | 0.541 | 0.548    | 0.538 | 0.563   | 0.550 | 0.499     | 0.488 | 0.501   | 0.494 | 0.562   | 0.550 | 0.562   | 0.552 | 0.555   | 0.537 | 0.559        | 0.552 | 0.558      | 0.562 |
| Tomcat    | 0.548   | 0.545 | 0.598   | 0.607 | 0.600    | 0.607 | 0.614   | 0.586 | 0.556     | 0.560 | 0.561   | 0.558 | 0.598   | 0.610 | 0.606   | 0.610 | 0.602   | 0.610 | 0.601        | 0.609 | 0.592      | 0.610 |
| Brackets  | 0.600   | 0.634 | 0.651   | 0.679 | 0.646    | 0.644 | 0.671   | 0.683 | 0.606     | 0.626 | 0.610   | 0.626 | 0.667   | 0.660 | 0.660   | 0.653 | 0.662   | 0.665 | 0.664        | 0.667 | 0.674      | 0.657 |
| Neutron   | 0.744   | 0.766 | 0.778   | 0.772 | 0.768    | 0.766 | 0.781   | 0.761 | 0.748     | 0.766 | 0.762   | 0.769 | 0.778   | 0.780 | 0.778   | 0.783 | 0.778   | 0.821 | 0.780        | 0.763 | 0.778      | 0.771 |
| Spring    | 0.611   | 0.624 | 0.661   | 0.663 | 0.611    | 0.626 | 0.676   | 0.658 | 0.616     | 0.627 | 0.616   | 0.629 | 0.659   | 0.628 | 0.659   | 0.638 | 0.676   | 0.625 | 0.663        | 0.627 | 0.671      | 0.632 |
| Broadleaf | 0.500   | 0.497 | 0.572   | 0.567 | 0.561    | 0.556 | 0.565   | 0.559 | 0.529     | 0.491 | 0.540   | 0.500 | 0.583   | 0.573 | 0.577   | 0.577 | 0.570   | 0.535 | 0.576        | 0.571 | 0.576      | 0.571 |
| Nova      | 0.699   | 0.722 | 0.734   | 0.714 | 0.723    | 0.722 | 0.730   | 0.723 | 0.699     | 0.720 | 0.700   | 0.722 | 0.734   | 0.714 | 0.734   | 0.710 | 0.732   | 0.702 | 0.734        | 0.714 | 0.725      | 0.734 |
| Npm       | 0.340   | 0.345 | 0.511   | 0.539 | 0.519    | 0.544 | 0.481   | 0.526 | 0.381     | 0.400 | 0.366   | 0.405 | 0.511   | 0.552 | 0.511   | 0.532 | 0.512   | 0.532 | 0.512        | 0.536 | 0.472      | 0.521 |
| Mean      | 0.534   | 0.537 | 0.610   | 0.609 | 0.600    | 0.605 | 0.606   | 0.600 | 0.547     | 0.546 | 0.549   | 0.549 | 0.612   | 0.609 | 0.612   | 0.607 | 0.611   | 0.602 | 0.612        | 0.605 | 0.608      | 0.605 |

TABLE XXXV: Median value on  $PCI@20\%$  for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |         | RUM   |         | NearMiss |         | ENN     |         | TomekLink |         | OSS     |         | ROM     |         | SMOTE   |         | BSMOTE  |         | SMOTE+ Tomek |         | SMOTE+ ENN |         |
|-----------|---------|---------|-------|---------|----------|---------|---------|---------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------------|---------|------------|---------|
|           | default |         | opt   |         | default  |         | default |         | default   |         | default |         | default |         | default |         | default |         | default      |         | default    |         |
|           | opt     | default | opt   | default | opt      | default | opt     | default | opt       | default | opt     | default | opt     | default | opt     | default | opt     | default | opt          | default | opt        | default |
| Fabric8   | 0.182   | 0.149   | 0.394 | 0.525   | 0.401    | 0.537   | 0.404   | 0.472   | 0.211     | 0.172   | 0.215   | 0.174   | 0.408   | 0.497   | 0.405   | 0.523   | 0.441   | 0.554   | 0.425        | 0.503   | 0.379      | 0.445   |
| JGroups   | 0.140   | 0.121   | 0.364 | 0.452   | 0.384    | 0.481   | 0.313   | 0.321   | 0.158     | 0.131   | 0.158   | 0.139   | 0.370   | 0.444   | 0.370   | 0.444   | 0.392   | 0.537   | 0.373        | 0.445   | 0.296      | 0.375   |
| Camel     | 0.209   | 0.200   | 0.413 | 0.498   | 0.403    | 0.534   | 0.459   | 0.512   | 0.239     | 0.233   | 0.239   | 0.224   | 0.412   | 0.497   | 0.411   | 0.489   | 0.429   | 0.563   | 0.421        | 0.492   | 0.354      | 0.452   |
| Tomcat    | 0.290   | 0.311   | 0.395 | 0.437   | 0.408    | 0.465   | 0.561   | 0.631   | 0.302     | 0.335   | 0.305   | 0.337   | 0.396   | 0.434   | 0.396   | 0.431   | 0.429   | 0.507   | 0.409        | 0.444   | 0.349      | 0.435   |
| Brackets  | 0.293   | 0.373   | 0.385 | 0.470   | 0.392    | 0.431   | 0.477   | 0.571   | 0.307     | 0.373   | 0.313   | 0.367   | 0.383   | 0.456   | 0.384   | 0.470   | 0.420   | 0.574   | 0.389        | 0.460   | 0.397      | 0.397   |
| Neutron   | 0.322   | 0.436   | 0.396 | 0.507   | 0.364    | 0.431   | 0.449   | 0.506   | 0.339     | 0.436   | 0.366   | 0.405   | 0.394   | 0.492   | 0.394   | 0.509   | 0.422   | 0.553   | 0.399        | 0.506   | 0.401      | 0.426   |
| Spring    | 0.315   | 0.407   | 0.409 | 0.491   | 0.386    | 0.458   | 0.505   | 0.522   | 0.354     | 0.407   | 0.373   | 0.402   | 0.408   | 0.474   | 0.404   | 0.506   | 0.429   | 0.534   | 0.430        | 0.475   | 0.397      | 0.455   |
| Broadleaf | 0.170   | 0.153   | 0.358 | 0.420   | 0.329    | 0.454   | 0.372   | 0.468   | 0.204     | 0.177   | 0.204   | 0.186   | 0.359   | 0.403   | 0.362   | 0.411   | 0.394   | 0.543   | 0.378        | 0.424   | 0.305      | 0.368   |
| Nova      | 0.366   | 0.421   | 0.406 | 0.481   | 0.380    | 0.421   | 0.463   | 0.490   | 0.367     | 0.429   | 0.387   | 0.421   | 0.406   | 0.478   | 0.406   | 0.470   | 0.431   | 0.506   | 0.407        | 0.481   | 0.405      | 0.428   |
| Npm       | 0.163   | 0.157   | 0.392 | 0.525   | 0.404    | 0.469   | 0.459   | 0.545   | 0.189     | 0.189   | 0.201   | 0.201   | 0.392   | 0.500   | 0.408   | 0.549   | 0.404   | 0.563   | 0.432        | 0.536   | 0.406      | 0.473   |
| Mean      | 0.245   | 0.273   | 0.391 | 0.481   | 0.385    | 0.468   | 0.446   | 0.504   | 0.267     | 0.288   | 0.276   | 0.285   | 0.393   | 0.468   | 0.394   | 0.480   | 0.419   | 0.543   | 0.406        | 0.477   | 0.369      | 0.425   |

TABLE XXXVI: Median value on  $IFA$  for each project when applying the default LR classifier and the LR classifier with optimized parameter settings

| Projects  | NONE    |         | RUM |         | NearMiss |         | ENN     |         | TomekLink |         | OSS     |         | ROM     |         | SMOTE   |         | BSMOTE  |         | SMOTE+ Tomek |         | SMOTE+ ENN |         |
|-----------|---------|---------|-----|---------|----------|---------|---------|---------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------------|---------|------------|---------|
|           | default |         | opt |         | default  |         | default |         | default   |         | default |         | default |         | default |         | default |         | default      |         | default    |         |
|           | opt     | default | opt | default | opt      | default | opt     | default | opt       | default | opt     | default | opt     | default | opt     | default | opt     | default | opt          | default | opt        | default |
| Fabric8   | 2.0     | 2.0     | 4.0 | 5.0     | 3.5      | 5.0     | 4.0     | 4.0     | 2.0       | 2.0     | 2.0     | 2.0     | 4.0     | 5.0     | 4.0     | 5.0     | 4.0     | 6.0     | 4.5          | 5.0     | 5.0        | 4.0     |
| JGroups   | 2.0     | 1.0     | 4.0 | 5.0     | 5.0      | 5.0     | 3.0     | 3.0     | 2.0       | 1.0     | 2.0     | 2.0     | 4.0     | 5.0     | 5.0     | 5.0     | 5.0     | 5.0     | 5.0          | 5.0     | 4.0        | 5.0     |
| Camel     | 2.0     | 2.0     | 3.0 | 4.0     | 3.0      | 4.0     | 3.0     | 3.0     | 2.0       | 2.0     | 2.0     | 2.0     | 3.0     | 3.0     | 3.0     | 4.0     | 3.0     | 4.0     | 3.0          | 3.0     | 3.0        | 3.0     |
| Tomcat    | 2.0     | 2.0     | 2.0 | 2.0     | 2.0      | 2.0     | 2.0     | 2.0     | 2.0       | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0          | 2.0     | 2.0        | 2.0     |
| Brackets  | 2.0     | 3.0     | 3.0 | 3.0     | 3.0      | 3.0     | 4.0     | 6.0     | 2.0       | 3.0     | 2.0     | 3.0     | 3.0     | 3.0     | 3.0     | 3.0     | 3.0     | 5.0     | 3.0          | 3.0     | 2.0        | 3.0     |
| Neutron   | 1.0     | 2.0     | 2.0 | 2.0     | 2.0      | 2.0     | 2.0     | 3.0     | 1.0       | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 4.0     | 2.0          | 3.0     | 2.0        | 2.0     |
| Spring    | 1.0     | 1.0     | 1.0 | 2.0     | 1.0      | 2.0     | 1.0     | 2.0     | 1.0       | 1.0     | 1.0     | 1.0     | 1.0     | 3.0     | 1.0     | 2.5     | 1.0     | 3.0     | 1.0          | 2.0     | 1.0        | 2.5     |
| Broadleaf | 2.0     | 2.0     | 4.0 | 4.0     | 3.0      | 4.0     | 3.0     | 4.0     | 2.0       | 2.0     | 2.0     | 2.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0          | 4.0     | 3.0        | 4.0     |
| Nova      | 2.0     | 2.0     | 3.0 | 3.0     | 2.0      | 3.0     | 3.0     | 4.0     | 2.0       | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 2.0     | 3.0     | 4.0     | 2.0          | 4.0     | 3.0        | 3.0     |
| Npm       | 2.0     | 2.0     | 3.0 | 4.0     | 3.0      | 4.0     | 3.0     | 3.0     | 2.0       | 2.0     | 2.0     | 2.0     | 3.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     | 3.0          | 4.0     | 3.0        | 3.0     |
| Mean      | 1.8     | 1.9     | 2.8 | 3.4     | 2.8      | 3.4     | 2.8     | 3.4     | 1.8       | 1.9     | 1.9     | 2.0     | 2.8     | 3.4     | 3.0     | 3.7     | 3.1     | 4.1     | 3.0          | 3.5     | 2.8        | 3.2     |