表1 Accuracy指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.7795 | 0.7359 | 0.8392 | 0.7622 | 0.7476 | 0.9030 | 0.8921 | 0.7174 | 0.8955 | 0.7380 | 0.7352 | 0.8762 | 0.7438 | 0.7853 | 0.7852 |
| abalone\_19 | 0.9078 | 0.9145 | 0.9822 | 0.3137 | 0.6874 | 0.9914 | 0.9923 | 0.7666 | 0.9923 | 0.9187 | 0.8404 | 0.9886 | 0.8724 | 0.7442 | 0.7880 |
| arrhythmia | 0.8146 | 0.9653 | 0.9650 | 0.9659 | 0.7863 | 0.9653 | 0.9721 | 0.9644 | 0.9699 | 0.9675 | 0.9582 | 0.9737 | 0.9677 | 0.9713 | 0.9655 |
| car\_eval\_34 | 0.8950 | 0.9802 | 0.9855 | 0.9361 | 0.9524 | 0.9866 | 0.9878 | 0.9370 | 0.9905 | 0.9803 | 0.9741 | 0.9903 | 0.9854 | 0.9910 | 0.9769 |
| car\_eval\_4 | 0.9766 | 0.9891 | 0.9911 | 0.9885 | 0.9637 | 0.9902 | 0.9955 | 0.9799 | 0.9987 | 0.9896 | 0.9788 | 0.9986 | 0.9904 | 0.9987 | 0.9820 |
| coil\_2000 | 0.8094 | 0.7102 | 0.9014 | 0.6743 | 0.6831 | 0.9394 | 0.9226 | 0.7050 | 0.9177 | 0.7140 | 0.7015 | 0.9216 | 0.8778 | 0.6638 | 0.7747 |
| ecoli | 0.8842 | 0.8991 | 0.9083 | 0.8934 | 0.8586 | 0.9107 | 0.9352 | 0.8783 | 0.9131 | 0.8958 | 0.8857 | 0.9161 | 0.8964 | 0.9131 | 0.8812 |
| isolet | 0.8732 | 0.9548 | 0.9657 | 0.9735 | 0.9424 | 0.9679 | 0.9666 | 0.9259 | 0.9635 | 0.9559 | 0.8865 | 0.9696 | 0.9568 | 0.9778 | 0.9497 |
| letter\_img | 0.8818 | 0.9741 | 0.9880 | 0.9962 | 0.9809 | 0.9925 | 0.9964 | 0.9454 | 0.9962 | 0.9750 | 0.9616 | 0.9968 | 0.9858 | 0.9973 | 0.9842 |
| libras\_move | 0.7683 | 0.9739 | 0.9703 | 0.9694 | 0.9319 | 0.9708 | 0.9603 | 0.9578 | 0.9731 | 0.9711 | 0.9458 | 0.9739 | 0.9683 | 0.9694 | 0.9531 |
| mammography | 0.8567 | 0.9296 | 0.9792 | 0.6871 | 0.9283 | 0.9844 | 0.9872 | 0.8993 | 0.9869 | 0.9332 | 0.8150 | 0.9855 | 0.9264 | 0.9746 | 0.9473 |
| oil | 0.7838 | 0.9533 | 0.9596 | 0.9079 | 0.8406 | 0.9605 | 0.9662 | 0.8910 | 0.9630 | 0.9557 | 0.8909 | 0.9632 | 0.9534 | 0.8939 | 0.8668 |
| optical\_digits | 0.4616 | 0.9587 | 0.9701 | 0.9899 | 0.9768 | 0.9741 | 0.9812 | 0.9382 | 0.9824 | 0.9592 | 0.9337 | 0.9848 | 0.9724 | 0.9914 | 0.9817 |
| ozone\_level | 0.7400 | 0.9383 | 0.9608 | 0.8413 | 0.8217 | 0.9685 | 0.9692 | 0.8620 | 0.9711 | 0.9409 | 0.8548 | 0.9698 | 0.9316 | 0.8668 | 0.8698 |
| pen\_digits | 0.6707 | 0.9722 | 0.9825 | 0.9970 | 0.9968 | 0.9843 | 0.9942 | 0.9428 | 0.9948 | 0.9737 | 0.9561 | 0.9959 | 0.9765 | 0.9968 | 0.9950 |
| protein\_homo | 0.7155 | 0.9732 | 0.9929 | 0.9961 | 0.9755 | 0.9967 | 0.9976 | 0.9643 | 0.9972 | 0.9737 | 0.9444 | 0.9971 | 0.9735 | 0.9971 | 0.9784 |
| satimage | 0.7972 | 0.8559 | 0.9000 | 0.9256 | 0.8677 | 0.9255 | 0.9422 | 0.8490 | 0.9400 | 0.8568 | 0.8441 | 0.9391 | 0.8785 | 0.9224 | 0.8943 |
| scene | 0.6291 | 0.8221 | 0.8804 | 0.7355 | 0.7302 | 0.9104 | 0.9268 | 0.7730 | 0.9265 | 0.8249 | 0.7347 | 0.9192 | 0.8204 | 0.7078 | 0.8114 |
| sick\_euthyroid | 0.8747 | 0.9616 | 0.9665 | 0.9743 | 0.9569 | 0.9703 | 0.9771 | 0.9635 | 0.9761 | 0.9617 | 0.8974 | 0.9764 | 0.9592 | 0.9762 | 0.9650 |
| solar\_flare\_m0 | 0.7667 | 0.7485 | 0.9190 | 0.4901 | 0.6923 | 0.9489 | 0.9377 | 0.7367 | 0.8861 | 0.7452 | 0.6845 | 0.9273 | 0.8937 | 0.7152 | 0.7531 |
| spectrometer | 0.8352 | 0.9701 | 0.9699 | 0.9672 | 0.9467 | 0.9678 | 0.9685 | 0.9570 | 0.9588 | 0.9702 | 0.9461 | 0.9584 | 0.9672 | 0.9687 | 0.9235 |
| thyroid\_sick | 0.8497 | 0.9647 | 0.9720 | 0.9835 | 0.9634 | 0.9726 | 0.9854 | 0.9643 | 0.9867 | 0.9659 | 0.9036 | 0.9847 | 0.9660 | 0.9891 | 0.9721 |
| us\_crime | 0.7523 | 0.8841 | 0.9203 | 0.8895 | 0.8395 | 0.9314 | 0.9371 | 0.8461 | 0.9311 | 0.8907 | 0.8244 | 0.9241 | 0.8920 | 0.8754 | 0.8609 |
| webpage | 0.9252 | 0.9483 | 0.9789 | 0.9389 | 0.9133 | 0.9829 | 0.9860 | 0.9098 | 0.9770 | 0.9484 | 0.8638 | 0.9783 | 0.9634 | 0.9490 | 0.8995 |
| wine\_quality | 0.7880 | 0.8598 | 0.9427 | 0.8574 | 0.8111 | 0.9596 | 0.9658 | 0.8350 | 0.9661 | 0.8610 | 0.7420 | 0.9610 | 0.8423 | 0.8401 | 0.8681 |
| yeast\_me2 | 0.7237 | 0.9112 | 0.9488 | 0.8852 | 0.8407 | 0.9591 | 0.9678 | 0.8840 | 0.9664 | 0.9149 | 0.8423 | 0.9631 | 0.9187 | 0.8849 | 0.8565 |
| yeast\_ml8 | 0.7044 | 0.7402 | 0.8648 | 0.5428 | 0.5804 | 0.9117 | 0.9236 | 0.6917 | 0.9261 | 0.7453 | 0.6655 | 0.9243 | 0.7509 | 0.4769 | 0.7835 |
| abalone | 0.7795 | 0.7359 | 0.8392 | 0.7622 | 0.7476 | 0.9030 | 0.8921 | 0.7174 | 0.8955 | 0.7380 | 0.7352 | 0.8762 | 0.7438 | 0.7853 | 0.7852 |

表2 AUPRC指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.1562 | 0.3037 | 0.3031 | 0.2495 | 0.3122 | 0.3054 | 0.2768 | 0.3077 | 0.2849 | 0.3077 | 0.1994 | 0.2885 | 0.2893 | 0.2862 | 0.3089 |
| abalone\_19 | 0.0410 | 0.0329 | 0.0338 | 0.0304 | 0.0337 | 0.0304 | 0.0325 | 0.0356 | 0.0391 | 0.0327 | 0.0247 | 0.0344 | 0.0273 | 0.0344 | 0.0388 |
| arrhythmia | 0.6646 | 0.7574 | 0.7528 | 0.8014 | 0.5078 | 0.7713 | 0.8134 | 0.8158 | 0.8063 | 0.7697 | 0.7055 | 0.8365 | 0.7749 | 0.8056 | 0.8077 |
| car\_eval\_34 | 0.9276 | 0.9758 | 0.9765 | 0.9522 | 0.9661 | 0.9761 | 0.9650 | 0.9589 | 0.9703 | 0.9759 | 0.9448 | 0.9752 | 0.9745 | 0.9750 | 0.9763 |
| car\_eval\_4 | 0.9190 | 0.9531 | 0.9541 | 0.9947 | 0.9749 | 0.9534 | 0.9890 | 0.9586 | 0.9983 | 0.9529 | 0.8062 | 0.9979 | 0.9504 | 0.9994 | 0.9865 |
| coil\_2000 | 0.1656 | 0.1582 | 0.1563 | 0.1243 | 0.1527 | 0.1578 | 0.1290 | 0.1782 | 0.1274 | 0.1581 | 0.1360 | 0.1265 | 0.1399 | 0.1405 | 0.1538 |
| ecoli | 0.5599 | 0.5459 | 0.5379 | 0.7284 | 0.6154 | 0.5601 | 0.7462 | 0.6832 | 0.6281 | 0.5294 | 0.5187 | 0.6194 | 0.5579 | 0.7271 | 0.6275 |
| isolet | 0.8114 | 0.8608 | 0.8635 | 0.9273 | 0.8761 | 0.8650 | 0.8974 | 0.8390 | 0.8502 | 0.8602 | 0.5139 | 0.8778 | 0.8334 | 0.9479 | 0.8575 |
| letter\_img | 0.5058 | 0.9570 | 0.9541 | 0.9914 | 0.9861 | 0.9543 | 0.9877 | 0.8896 | 0.9864 | 0.9568 | 0.8851 | 0.9903 | 0.9567 | 0.9932 | 0.9827 |
| libras\_move | 0.5959 | 0.8098 | 0.8079 | 0.8772 | 0.8550 | 0.8121 | 0.7180 | 0.8095 | 0.8438 | 0.8221 | 0.6733 | 0.8719 | 0.7998 | 0.8734 | 0.7967 |
| mammography | 0.5216 | 0.6449 | 0.6433 | 0.7072 | 0.6675 | 0.6493 | 0.7262 | 0.6206 | 0.7093 | 0.6416 | 0.3075 | 0.7350 | 0.6432 | 0.7612 | 0.6713 |
| oil | 0.4085 | 0.4216 | 0.4313 | 0.5789 | 0.5019 | 0.4378 | 0.5150 | 0.5525 | 0.5272 | 0.4311 | 0.3057 | 0.5317 | 0.4629 | 0.5734 | 0.5687 |
| optical\_digits | 0.8775 | 0.9374 | 0.9358 | 0.9881 | 0.9768 | 0.9367 | 0.9792 | 0.9022 | 0.9844 | 0.9354 | 0.8686 | 0.9824 | 0.9353 | 0.9910 | 0.9736 |
| ozone\_level | 0.2246 | 0.2792 | 0.2720 | 0.2877 | 0.3344 | 0.2679 | 0.2065 | 0.3546 | 0.2613 | 0.2860 | 0.1186 | 0.2651 | 0.2704 | 0.3265 | 0.3305 |
| pen\_digits | 0.8012 | 0.9688 | 0.9686 | 0.9976 | 0.9978 | 0.9694 | 0.9942 | 0.9187 | 0.9957 | 0.9684 | 0.9285 | 0.9964 | 0.9674 | 0.9973 | 0.9959 |
| protein\_homo | 0.7777 | 0.8342 | 0.8361 | 0.9021 | 0.8675 | 0.8367 | 0.8591 | 0.8151 | 0.8637 | 0.8332 | 0.6154 | 0.8779 | 0.8229 | 0.9029 | 0.8461 |
| satimage | 0.4705 | 0.6386 | 0.6324 | 0.7791 | 0.7322 | 0.6299 | 0.7567 | 0.6570 | 0.7532 | 0.6345 | 0.4984 | 0.7563 | 0.6306 | 0.7829 | 0.7320 |
| scene | 0.1912 | 0.1912 | 0.1871 | 0.2525 | 0.2690 | 0.1917 | 0.2210 | 0.2480 | 0.2469 | 0.1888 | 0.1380 | 0.2309 | 0.1797 | 0.2800 | 0.2649 |
| sick\_euthyroid | 0.5606 | 0.8102 | 0.8081 | 0.9171 | 0.8895 | 0.8143 | 0.8990 | 0.8217 | 0.9070 | 0.8080 | 0.6514 | 0.9081 | 0.8324 | 0.9156 | 0.9108 |
| solar\_flare\_m0 | 0.1820 | 0.2339 | 0.2303 | 0.1123 | 0.1709 | 0.2340 | 0.1478 | 0.2292 | 0.1056 | 0.2347 | 0.1830 | 0.1317 | 0.2034 | 0.1530 | 0.1706 |
| spectrometer | 0.7647 | 0.8647 | 0.8664 | 0.8775 | 0.8858 | 0.8632 | 0.8750 | 0.8756 | 0.8459 | 0.8767 | 0.7536 | 0.8348 | 0.8675 | 0.8988 | 0.8122 |
| thyroid\_sick | 0.2983 | 0.7524 | 0.7506 | 0.9694 | 0.8964 | 0.7490 | 0.9566 | 0.7201 | 0.9616 | 0.7519 | 0.5016 | 0.9569 | 0.7360 | 0.9738 | 0.9454 |
| us\_crime | 0.4531 | 0.5009 | 0.4992 | 0.5244 | 0.5007 | 0.4989 | 0.5461 | 0.5812 | 0.4742 | 0.4920 | 0.2856 | 0.4703 | 0.4796 | 0.5227 | 0.4925 |
| webpage | 0.2392 | 0.7031 | 0.7022 | 0.7058 | 0.6556 | 0.7109 | 0.8059 | 0.3490 | 0.6385 | 0.6992 | 0.3680 | 0.6238 | 0.6073 | 0.7127 | 0.6334 |
| wine\_quality | 0.1895 | 0.2517 | 0.2606 | 0.4077 | 0.2932 | 0.2632 | 0.3917 | 0.2741 | 0.3861 | 0.2457 | 0.1277 | 0.3327 | 0.2382 | 0.4179 | 0.2888 |
| yeast\_me2 | 0.3191 | 0.2722 | 0.2752 | 0.3717 | 0.3427 | 0.2589 | 0.3875 | 0.3540 | 0.3667 | 0.2683 | 0.2081 | 0.3975 | 0.3188 | 0.4104 | 0.3951 |
| yeast\_ml8 | 0.0920 | 0.0867 | 0.0855 | 0.0907 | 0.0993 | 0.0841 | 0.0853 | 0.0965 | 0.1004 | 0.0856 | 0.0878 | 0.0928 | 0.0869 | 0.0990 | 0.0977 |

表3 Balanced Accuracy指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.7184 | 0.7922 | 0.7407 | 0.7132 | 0.7977 | 0.5057 | 0.5450 | 0.7958 | 0.5407 | 0.7911 | 0.7252 | 0.6064 | 0.7887 | 0.7706 | 0.7832 |
| abalone\_19 | 0.5692 | 0.6337 | 0.5183 | 0.5630 | 0.7464 | 0.4995 | 0.5000 | 0.7487 | 0.5000 | 0.6321 | 0.5964 | 0.5026 | 0.6706 | 0.7400 | 0.7278 |
| arrhythmia | 0.8604 | 0.8404 | 0.8252 | 0.9424 | 0.8210 | 0.8272 | 0.9080 | 0.9623 | 0.8843 | 0.8510 | 0.8837 | 0.9145 | 0.8511 | 0.9415 | 0.9629 |
| car\_eval\_34 | 0.9431 | 0.9865 | 0.9768 | 0.9630 | 0.9742 | 0.9508 | 0.9599 | 0.9658 | 0.9698 | 0.9855 | 0.9682 | 0.9690 | 0.9698 | 0.9691 | 0.9875 |
| car\_eval\_4 | 0.9878 | 0.9877 | 0.9688 | 0.9940 | 0.9811 | 0.9328 | 0.9659 | 0.9896 | 0.9897 | 0.9879 | 0.9535 | 0.9896 | 0.9455 | 0.9897 | 0.9906 |
| coil\_2000 | 0.6543 | 0.6758 | 0.5820 | 0.6190 | 0.6709 | 0.5077 | 0.5291 | 0.6902 | 0.5293 | 0.6741 | 0.6472 | 0.5272 | 0.5854 | 0.6698 | 0.6562 |
| ecoli | 0.8230 | 0.7619 | 0.7393 | 0.8787 | 0.8933 | 0.7153 | 0.7732 | 0.8828 | 0.7154 | 0.7575 | 0.7797 | 0.7739 | 0.7983 | 0.8669 | 0.8807 |
| isolet | 0.9173 | 0.9283 | 0.9058 | 0.9517 | 0.9524 | 0.8675 | 0.8030 | 0.9333 | 0.8210 | 0.9258 | 0.8077 | 0.8584 | 0.8980 | 0.9545 | 0.9424 |
| letter\_img | 0.9355 | 0.9726 | 0.9619 | 0.9854 | 0.9845 | 0.9333 | 0.9645 | 0.9586 | 0.9600 | 0.9731 | 0.9554 | 0.9663 | 0.9639 | 0.9778 | 0.9831 |
| libras\_move | 0.7966 | 0.8380 | 0.8022 | 0.9020 | 0.9010 | 0.8067 | 0.7213 | 0.8744 | 0.8187 | 0.8161 | 0.8086 | 0.8321 | 0.8365 | 0.9002 | 0.8589 |
| mammography | 0.8617 | 0.8823 | 0.8315 | 0.7653 | 0.9070 | 0.7440 | 0.7819 | 0.8846 | 0.7620 | 0.8817 | 0.7651 | 0.8427 | 0.8829 | 0.8976 | 0.9069 |
| oil | 0.8184 | 0.7333 | 0.7109 | 0.8360 | 0.8261 | 0.6837 | 0.6960 | 0.8435 | 0.6321 | 0.7430 | 0.7283 | 0.6630 | 0.7564 | 0.8419 | 0.8287 |
| optical\_digits | 0.6995 | 0.9408 | 0.9284 | 0.9706 | 0.9681 | 0.9068 | 0.9095 | 0.9265 | 0.9151 | 0.9386 | 0.9115 | 0.9285 | 0.9262 | 0.9695 | 0.9599 |
| ozone\_level | 0.7697 | 0.7463 | 0.6651 | 0.7875 | 0.8129 | 0.6036 | 0.5149 | 0.8174 | 0.5405 | 0.7404 | 0.6762 | 0.5732 | 0.7158 | 0.8178 | 0.8071 |
| pen\_digits | 0.8157 | 0.9640 | 0.9560 | 0.9899 | 0.9931 | 0.9399 | 0.9720 | 0.9362 | 0.9756 | 0.9634 | 0.9510 | 0.9816 | 0.9614 | 0.9867 | 0.9876 |
| protein\_homo | 0.8485 | 0.9449 | 0.9121 | 0.9380 | 0.9547 | 0.8644 | 0.8746 | 0.9445 | 0.8578 | 0.9443 | 0.9140 | 0.8830 | 0.9412 | 0.9289 | 0.9516 |
| satimage | 0.8528 | 0.8574 | 0.8281 | 0.8684 | 0.8805 | 0.7538 | 0.7592 | 0.8490 | 0.7540 | 0.8566 | 0.8170 | 0.7954 | 0.8413 | 0.8712 | 0.8689 |
| scene | 0.6743 | 0.6305 | 0.5856 | 0.6765 | 0.7131 | 0.5534 | 0.5251 | 0.6798 | 0.5343 | 0.6200 | 0.5917 | 0.5403 | 0.6189 | 0.7253 | 0.6801 |
| sick\_euthyroid | 0.9187 | 0.9304 | 0.9225 | 0.9492 | 0.9465 | 0.9095 | 0.9205 | 0.9386 | 0.9177 | 0.9308 | 0.8637 | 0.9266 | 0.9240 | 0.9298 | 0.9488 |
| solar\_flare\_m0 | 0.6719 | 0.6926 | 0.6367 | 0.5910 | 0.7217 | 0.5296 | 0.5267 | 0.6937 | 0.5591 | 0.6925 | 0.6621 | 0.5220 | 0.6177 | 0.7157 | 0.7109 |
| spectrometer | 0.8656 | 0.8818 | 0.8706 | 0.9176 | 0.9326 | 0.8614 | 0.8477 | 0.9402 | 0.7960 | 0.8829 | 0.8405 | 0.8311 | 0.8994 | 0.9204 | 0.8635 |
| thyroid\_sick | 0.9096 | 0.9280 | 0.9096 | 0.9710 | 0.9617 | 0.8684 | 0.9113 | 0.9397 | 0.9215 | 0.9306 | 0.8437 | 0.9394 | 0.9189 | 0.9520 | 0.9728 |
| us\_crime | 0.8134 | 0.7790 | 0.7480 | 0.8193 | 0.8578 | 0.6947 | 0.6760 | 0.8556 | 0.6382 | 0.7853 | 0.7088 | 0.6791 | 0.7615 | 0.8319 | 0.8430 |
| webpage | 0.7818 | 0.9027 | 0.8483 | 0.9239 | 0.9195 | 0.7639 | 0.8728 | 0.8432 | 0.7712 | 0.9016 | 0.8172 | 0.7567 | 0.8490 | 0.9254 | 0.9079 |
| wine\_quality | 0.7342 | 0.7455 | 0.6667 | 0.7692 | 0.7974 | 0.5785 | 0.6053 | 0.7736 | 0.5805 | 0.7421 | 0.6443 | 0.6338 | 0.7372 | 0.8073 | 0.7952 |
| yeast\_me2 | 0.8351 | 0.7377 | 0.6690 | 0.8057 | 0.8403 | 0.5984 | 0.6439 | 0.8251 | 0.5832 | 0.7270 | 0.7042 | 0.6615 | 0.7605 | 0.8208 | 0.8329 |
| yeast\_ml8 | 0.5346 | 0.5164 | 0.4989 | 0.5260 | 0.5641 | 0.4978 | 0.5001 | 0.5514 | 0.4998 | 0.5107 | 0.5178 | 0.4994 | 0.5255 | 0.5692 | 0.5310 |

表4 F1-score指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.3177 | 0.3796 | 0.4190 | 0.3400 | 0.3895 | 0.0304 | 0.1691 | 0.3717 | 0.1556 | 0.3800 | 0.3207 | 0.2921 | 0.3815 | 0.3961 | 0.4052 |
| abalone\_19 | 0.0303 | 0.0584 | 0.0366 | 0.0185 | 0.0379 | 0.0000 | 0.0000 | 0.0459 | 0.0000 | 0.0597 | 0.0345 | 0.0114 | 0.0525 | 0.0419 | 0.0459 |
| arrhythmia | 0.5382 | 0.6863 | 0.6760 | 0.7588 | 0.3176 | 0.6788 | 0.7694 | 0.7598 | 0.7432 | 0.7073 | 0.6851 | 0.7833 | 0.7135 | 0.7850 | 0.7662 |
| car\_eval\_34 | 0.6048 | 0.8877 | 0.9128 | 0.7142 | 0.7681 | 0.9132 | 0.9215 | 0.7131 | 0.9386 | 0.8876 | 0.8548 | 0.9375 | 0.9104 | 0.9419 | 0.8724 |
| car\_eval\_4 | 0.7719 | 0.8749 | 0.8899 | 0.8743 | 0.6824 | 0.8691 | 0.9384 | 0.7952 | 0.9819 | 0.8798 | 0.7710 | 0.9804 | 0.8754 | 0.9818 | 0.8126 |
| coil\_2000 | 0.2317 | 0.2077 | 0.2094 | 0.1691 | 0.1984 | 0.0331 | 0.1122 | 0.2140 | 0.1128 | 0.2077 | 0.1842 | 0.1075 | 0.1981 | 0.1936 | 0.2164 |
| ecoli | 0.5713 | 0.5393 | 0.5325 | 0.6336 | 0.5867 | 0.5143 | 0.6330 | 0.6075 | 0.5164 | 0.5290 | 0.5351 | 0.5863 | 0.5737 | 0.6613 | 0.6117 |
| isolet | 0.5415 | 0.7536 | 0.7894 | 0.8433 | 0.7209 | 0.7819 | 0.7365 | 0.6621 | 0.7327 | 0.7566 | 0.4954 | 0.7856 | 0.7469 | 0.8654 | 0.7413 |
| letter\_img | 0.3828 | 0.7344 | 0.8511 | 0.9495 | 0.7922 | 0.8948 | 0.9499 | 0.5675 | 0.9472 | 0.7408 | 0.6613 | 0.9555 | 0.8294 | 0.9633 | 0.8203 |
| libras\_move | 0.3631 | 0.7691 | 0.7177 | 0.7916 | 0.6439 | 0.7201 | 0.5585 | 0.7166 | 0.7392 | 0.7275 | 0.6075 | 0.7564 | 0.7336 | 0.7925 | 0.6884 |
| mammography | 0.2293 | 0.3559 | 0.6027 | 0.1268 | 0.3657 | 0.5934 | 0.6728 | 0.2876 | 0.6509 | 0.3662 | 0.1924 | 0.6886 | 0.3470 | 0.5997 | 0.4339 |
| oil | 0.2611 | 0.4693 | 0.4772 | 0.4261 | 0.3106 | 0.4454 | 0.5005 | 0.3920 | 0.3759 | 0.4896 | 0.3166 | 0.4332 | 0.4977 | 0.3945 | 0.3425 |
| optical\_digits | 0.2687 | 0.8146 | 0.8526 | 0.9486 | 0.8908 | 0.8622 | 0.8951 | 0.7445 | 0.9025 | 0.8155 | 0.7251 | 0.9171 | 0.8612 | 0.9555 | 0.9094 |
| ozone\_level | 0.1534 | 0.3361 | 0.3361 | 0.2114 | 0.2067 | 0.2740 | 0.0566 | 0.2443 | 0.1367 | 0.3361 | 0.1705 | 0.2160 | 0.2879 | 0.2492 | 0.2477 |
| pen\_digits | 0.3700 | 0.8681 | 0.9099 | 0.9844 | 0.9836 | 0.9153 | 0.9689 | 0.7575 | 0.9722 | 0.8742 | 0.8163 | 0.9782 | 0.8851 | 0.9832 | 0.9742 |
| protein\_homo | 0.0598 | 0.3786 | 0.6749 | 0.8006 | 0.4039 | 0.7968 | 0.8458 | 0.3156 | 0.8216 | 0.3822 | 0.2240 | 0.8269 | 0.3788 | 0.8403 | 0.4324 |
| satimage | 0.4702 | 0.5372 | 0.5897 | 0.6759 | 0.5688 | 0.5846 | 0.6408 | 0.5226 | 0.6281 | 0.5380 | 0.4935 | 0.6630 | 0.5603 | 0.6695 | 0.6068 |
| scene | 0.2249 | 0.2515 | 0.2266 | 0.2527 | 0.2744 | 0.1798 | 0.0949 | 0.2698 | 0.1279 | 0.2419 | 0.1912 | 0.1471 | 0.2384 | 0.2730 | 0.2912 |
| sick\_euthyroid | 0.5922 | 0.8120 | 0.8278 | 0.8692 | 0.8013 | 0.8388 | 0.8726 | 0.8219 | 0.8671 | 0.8125 | 0.6142 | 0.8713 | 0.8003 | 0.8713 | 0.8316 |
| solar\_flare\_m0 | 0.1971 | 0.1966 | 0.2837 | 0.1208 | 0.1937 | 0.1075 | 0.0967 | 0.1931 | 0.1411 | 0.1955 | 0.1744 | 0.0864 | 0.2237 | 0.1984 | 0.2084 |
| spectrometer | 0.4990 | 0.8057 | 0.8006 | 0.8180 | 0.7501 | 0.7848 | 0.7776 | 0.7867 | 0.7023 | 0.8093 | 0.6904 | 0.7274 | 0.8054 | 0.8244 | 0.6396 |
| thyroid\_sick | 0.4464 | 0.7551 | 0.7860 | 0.8771 | 0.7642 | 0.7695 | 0.8735 | 0.7593 | 0.8857 | 0.7624 | 0.5111 | 0.8761 | 0.7578 | 0.9104 | 0.8111 |
| us\_crime | 0.3538 | 0.4610 | 0.5073 | 0.5019 | 0.4529 | 0.4745 | 0.4666 | 0.4599 | 0.3873 | 0.4772 | 0.3328 | 0.4353 | 0.4591 | 0.4868 | 0.4721 |
| webpage | 0.3244 | 0.4834 | 0.6553 | 0.4643 | 0.3763 | 0.6368 | 0.7526 | 0.3259 | 0.5754 | 0.4829 | 0.2747 | 0.5749 | 0.5285 | 0.5016 | 0.3399 |
| wine\_quality | 0.1980 | 0.2493 | 0.3244 | 0.2623 | 0.2369 | 0.2333 | 0.3175 | 0.2431 | 0.2631 | 0.2484 | 0.1405 | 0.3471 | 0.2283 | 0.2653 | 0.2898 |
| yeast\_me2 | 0.1942 | 0.2993 | 0.3309 | 0.3033 | 0.2671 | 0.2521 | 0.3797 | 0.3132 | 0.2468 | 0.2982 | 0.2043 | 0.3799 | 0.3339 | 0.3115 | 0.2803 |
| yeast\_ml8 | 0.1427 | 0.1253 | 0.0690 | 0.1400 | 0.1602 | 0.0203 | 0.0064 | 0.1552 | 0.0000 | 0.1193 | 0.1316 | 0.0022 | 0.1341 | 0.1602 | 0.1371 |

表5 MCC指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.2779 | 0.3619 | 0.3631 | 0.2815 | 0.3721 | 0.0345 | 0.1402 | 0.3602 | 0.1370 | 0.3615 | 0.2811 | 0.2260 | 0.3605 | 0.3586 | 0.3731 |
| abalone\_19 | 0.0384 | 0.0839 | 0.0291 | 0.0242 | 0.0922 | -0.0020 | -0.0001 | 0.1021 | -0.0002 | 0.0847 | 0.0484 | 0.0071 | 0.0887 | 0.0950 | 0.0966 |
| arrhythmia | 0.5406 | 0.6804 | 0.6710 | 0.7590 | 0.3451 | 0.6753 | 0.7658 | 0.7639 | 0.7403 | 0.7018 | 0.6790 | 0.7809 | 0.7057 | 0.7827 | 0.7698 |
| car\_eval\_34 | 0.6212 | 0.8837 | 0.9074 | 0.7194 | 0.7698 | 0.9072 | 0.9158 | 0.7190 | 0.9343 | 0.8833 | 0.8490 | 0.9330 | 0.9043 | 0.9379 | 0.8693 |
| car\_eval\_4 | 0.7851 | 0.8770 | 0.8888 | 0.8780 | 0.7072 | 0.8671 | 0.9380 | 0.8053 | 0.9817 | 0.8815 | 0.7777 | 0.9803 | 0.8729 | 0.9817 | 0.8209 |
| coil\_2000 | 0.1889 | 0.1807 | 0.1574 | 0.1196 | 0.1715 | 0.0666 | 0.0842 | 0.1939 | 0.0769 | 0.1797 | 0.1522 | 0.0780 | 0.1396 | 0.1679 | 0.1764 |
| ecoli | 0.5327 | 0.4952 | 0.4947 | 0.6090 | 0.5755 | 0.4862 | 0.6164 | 0.5872 | 0.4859 | 0.4816 | 0.4913 | 0.5488 | 0.5302 | 0.6313 | 0.5897 |
| isolet | 0.5579 | 0.7412 | 0.7725 | 0.8331 | 0.7199 | 0.7659 | 0.7387 | 0.6618 | 0.7204 | 0.7433 | 0.4673 | 0.7728 | 0.7280 | 0.8558 | 0.7342 |
| letter\_img | 0.4541 | 0.7466 | 0.8487 | 0.9479 | 0.8002 | 0.8915 | 0.9484 | 0.6055 | 0.9458 | 0.7522 | 0.6800 | 0.9542 | 0.8286 | 0.9620 | 0.8247 |
| libras\_move | 0.3651 | 0.7784 | 0.7388 | 0.7854 | 0.6413 | 0.7406 | 0.5871 | 0.7064 | 0.7561 | 0.7429 | 0.5931 | 0.7670 | 0.7407 | 0.7898 | 0.6791 |
| mammography | 0.3045 | 0.4121 | 0.5966 | 0.1821 | 0.4304 | 0.6012 | 0.6807 | 0.3604 | 0.6661 | 0.4197 | 0.2340 | 0.6820 | 0.4055 | 0.6113 | 0.4828 |
| oil | 0.3053 | 0.4497 | 0.4683 | 0.4385 | 0.3446 | 0.4453 | 0.5144 | 0.4150 | 0.4144 | 0.4753 | 0.3057 | 0.4535 | 0.4813 | 0.4164 | 0.3700 |
| optical\_digits | 0.2483 | 0.7984 | 0.8368 | 0.9432 | 0.8807 | 0.8495 | 0.8899 | 0.7268 | 0.8974 | 0.7990 | 0.7039 | 0.9116 | 0.8463 | 0.9510 | 0.8998 |
| ozone\_level | 0.2041 | 0.3367 | 0.3200 | 0.2564 | 0.2643 | 0.2788 | 0.0764 | 0.2953 | 0.1812 | 0.3348 | 0.1747 | 0.2333 | 0.2859 | 0.2993 | 0.2933 |
| pen\_digits | 0.3785 | 0.8572 | 0.9005 | 0.9828 | 0.9818 | 0.9075 | 0.9662 | 0.7427 | 0.9697 | 0.8632 | 0.8040 | 0.9761 | 0.8743 | 0.9815 | 0.9715 |
| protein\_homo | 0.1459 | 0.4600 | 0.6839 | 0.8020 | 0.4835 | 0.7988 | 0.8521 | 0.4105 | 0.8297 | 0.4626 | 0.3241 | 0.8282 | 0.4587 | 0.8393 | 0.5042 |
| satimage | 0.4642 | 0.5168 | 0.5503 | 0.6448 | 0.5545 | 0.5471 | 0.6274 | 0.5004 | 0.6126 | 0.5169 | 0.4607 | 0.6326 | 0.5282 | 0.6393 | 0.5807 |
| scene | 0.1866 | 0.1844 | 0.1630 | 0.2056 | 0.2435 | 0.1498 | 0.1399 | 0.2208 | 0.1684 | 0.1724 | 0.1113 | 0.1452 | 0.1685 | 0.2507 | 0.2390 |
| sick\_euthyroid | 0.5953 | 0.7953 | 0.8107 | 0.8569 | 0.7882 | 0.8229 | 0.8609 | 0.8067 | 0.8548 | 0.7959 | 0.5904 | 0.8589 | 0.7823 | 0.8586 | 0.8184 |
| solar\_flare\_m0 | 0.1779 | 0.1885 | 0.2468 | 0.0802 | 0.2035 | 0.1417 | 0.0833 | 0.1866 | 0.0901 | 0.1876 | 0.1552 | 0.0537 | 0.1816 | 0.2029 | 0.2070 |
| spectrometer | 0.4973 | 0.8003 | 0.7936 | 0.8069 | 0.7402 | 0.7774 | 0.7780 | 0.7768 | 0.7029 | 0.8012 | 0.6727 | 0.7171 | 0.7940 | 0.8125 | 0.6172 |
| thyroid\_sick | 0.4856 | 0.7465 | 0.7734 | 0.8721 | 0.7645 | 0.7561 | 0.8681 | 0.7539 | 0.8805 | 0.7539 | 0.5036 | 0.8686 | 0.7471 | 0.9048 | 0.8099 |
| us\_crime | 0.3629 | 0.4267 | 0.4669 | 0.4783 | 0.4584 | 0.4466 | 0.4580 | 0.4624 | 0.3820 | 0.4435 | 0.2870 | 0.4007 | 0.4196 | 0.4712 | 0.4649 |
| webpage | 0.3418 | 0.5176 | 0.6468 | 0.5122 | 0.4428 | 0.6425 | 0.7457 | 0.3699 | 0.5647 | 0.5168 | 0.3188 | 0.5677 | 0.5330 | 0.5417 | 0.4099 |
| wine\_quality | 0.2171 | 0.2616 | 0.2983 | 0.2828 | 0.2773 | 0.2423 | 0.3541 | 0.2703 | 0.3294 | 0.2593 | 0.1290 | 0.3414 | 0.2414 | 0.3034 | 0.3161 |
| yeast\_me2 | 0.2664 | 0.2999 | 0.3106 | 0.3331 | 0.3219 | 0.2452 | 0.3966 | 0.3495 | 0.2817 | 0.2949 | 0.2100 | 0.3720 | 0.3371 | 0.3463 | 0.3282 |
| yeast\_ml8 | 0.0413 | 0.0203 | -0.0034 | 0.0273 | 0.0677 | -0.0077 | 0.0011 | 0.0589 | -0.0018 | 0.0133 | 0.0201 | -0.0040 | 0.0328 | 0.0728 | 0.0422 |

表6 Precision\_neg指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.9587 | 0.9806 | 0.9565 | 0.9558 | 0.9807 | 0.9074 | 0.9143 | 0.9844 | 0.9135 | 0.9801 | 0.9636 | 0.9261 | 0.9786 | 0.9687 | 0.9720 |
| abalone\_19 | 0.9935 | 0.9946 | 0.9926 | 0.9954 | 0.9979 | 0.9923 | 0.9923 | 0.9973 | 0.9923 | 0.9945 | 0.9940 | 0.9924 | 0.9953 | 0.9973 | 0.9968 |
| arrhythmia | 0.9746 | 0.9826 | 0.9807 | 0.9950 | 0.9898 | 0.9810 | 0.9904 | 0.9976 | 0.9877 | 0.9837 | 0.9881 | 0.9911 | 0.9837 | 0.9946 | 0.9976 |
| car\_eval\_34 | 1.0000 | 0.9995 | 0.9972 | 0.9995 | 1.0000 | 0.9923 | 0.9939 | 1.0000 | 0.9954 | 0.9993 | 0.9967 | 0.9953 | 0.9959 | 0.9953 | 1.0000 |
| car\_eval\_4 | 1.0000 | 0.9995 | 0.9978 | 1.0000 | 1.0000 | 0.9950 | 0.9974 | 1.0000 | 0.9992 | 0.9995 | 0.9971 | 0.9992 | 0.9960 | 0.9992 | 1.0000 |
| coil\_2000 | 0.9618 | 0.9688 | 0.9502 | 0.9604 | 0.9692 | 0.9412 | 0.9437 | 0.9716 | 0.9437 | 0.9683 | 0.9649 | 0.9435 | 0.9509 | 0.9700 | 0.9631 |
| ecoli | 0.9689 | 0.9520 | 0.9459 | 0.9825 | 0.9915 | 0.9401 | 0.9517 | 0.9857 | 0.9400 | 0.9512 | 0.9578 | 0.9534 | 0.9611 | 0.9769 | 0.9847 |
| isolet | 0.9971 | 0.9911 | 0.9861 | 0.9937 | 0.9968 | 0.9792 | 0.9684 | 0.9948 | 0.9716 | 0.9906 | 0.9743 | 0.9775 | 0.9854 | 0.9938 | 0.9942 |
| letter\_img | 0.9997 | 0.9989 | 0.9975 | 0.9990 | 0.9996 | 0.9950 | 0.9973 | 0.9989 | 0.9970 | 0.9989 | 0.9980 | 0.9975 | 0.9977 | 0.9984 | 0.9993 |
| libras\_move | 0.9836 | 0.9777 | 0.9726 | 0.9872 | 0.9897 | 0.9732 | 0.9616 | 0.9839 | 0.9747 | 0.9746 | 0.9748 | 0.9766 | 0.9776 | 0.9870 | 0.9818 |
| mammography | 0.9963 | 0.9957 | 0.9923 | 0.9947 | 0.9971 | 0.9880 | 0.9898 | 0.9966 | 0.9888 | 0.9956 | 0.9912 | 0.9927 | 0.9959 | 0.9956 | 0.9966 |
| oil | 0.9919 | 0.9767 | 0.9745 | 0.9880 | 0.9898 | 0.9720 | 0.9731 | 0.9895 | 0.9675 | 0.9775 | 0.9779 | 0.9701 | 0.9788 | 0.9892 | 0.9889 |
| optical\_digits | 0.9991 | 0.9909 | 0.9864 | 0.9942 | 0.9952 | 0.9808 | 0.9807 | 0.9899 | 0.9819 | 0.9902 | 0.9867 | 0.9848 | 0.9856 | 0.9937 | 0.9926 |
| ozone\_level | 0.9924 | 0.9859 | 0.9807 | 0.9907 | 0.9930 | 0.9771 | 0.9721 | 0.9922 | 0.9735 | 0.9856 | 0.9827 | 0.9753 | 0.9842 | 0.9921 | 0.9913 |
| pen\_digits | 0.9992 | 0.9950 | 0.9918 | 0.9980 | 0.9988 | 0.9879 | 0.9941 | 0.9920 | 0.9949 | 0.9947 | 0.9939 | 0.9962 | 0.9939 | 0.9973 | 0.9977 |
| protein\_homo | 0.9998 | 0.9992 | 0.9985 | 0.9989 | 0.9994 | 0.9976 | 0.9978 | 0.9993 | 0.9975 | 0.9992 | 0.9989 | 0.9979 | 0.9992 | 0.9987 | 0.9993 |
| satimage | 0.9895 | 0.9826 | 0.9703 | 0.9773 | 0.9873 | 0.9513 | 0.9514 | 0.9812 | 0.9504 | 0.9823 | 0.9735 | 0.9594 | 0.9758 | 0.9783 | 0.9809 |
| scene | 0.9666 | 0.9477 | 0.9392 | 0.9600 | 0.9679 | 0.9340 | 0.9299 | 0.9586 | 0.9312 | 0.9459 | 0.9432 | 0.9321 | 0.9458 | 0.9723 | 0.9569 |
| sick\_euthyroid | 0.9968 | 0.9888 | 0.9865 | 0.9916 | 0.9930 | 0.9832 | 0.9849 | 0.9904 | 0.9844 | 0.9888 | 0.9804 | 0.9863 | 0.9876 | 0.9871 | 0.9926 |
| solar\_flare\_m0 | 0.9721 | 0.9757 | 0.9646 | 0.9691 | 0.9822 | 0.9538 | 0.9536 | 0.9762 | 0.9570 | 0.9758 | 0.9715 | 0.9531 | 0.9631 | 0.9802 | 0.9778 |
| spectrometer | 0.9891 | 0.9797 | 0.9775 | 0.9869 | 0.9919 | 0.9759 | 0.9733 | 0.9925 | 0.9642 | 0.9798 | 0.9736 | 0.9708 | 0.9833 | 0.9873 | 0.9800 |
| thyroid\_sick | 0.9983 | 0.9924 | 0.9894 | 0.9971 | 0.9973 | 0.9837 | 0.9888 | 0.9941 | 0.9901 | 0.9927 | 0.9841 | 0.9927 | 0.9911 | 0.9941 | 0.9982 |
| us\_crime | 0.9880 | 0.9699 | 0.9626 | 0.9768 | 0.9884 | 0.9535 | 0.9504 | 0.9874 | 0.9448 | 0.9706 | 0.9606 | 0.9513 | 0.9664 | 0.9802 | 0.9835 |
| webpage | 0.9886 | 0.9956 | 0.9915 | 0.9972 | 0.9977 | 0.9865 | 0.9928 | 0.9928 | 0.9871 | 0.9955 | 0.9923 | 0.9862 | 0.9919 | 0.9970 | 0.9973 |
| wine\_quality | 0.9844 | 0.9834 | 0.9752 | 0.9856 | 0.9897 | 0.9684 | 0.9703 | 0.9867 | 0.9685 | 0.9831 | 0.9766 | 0.9725 | 0.9831 | 0.9896 | 0.9876 |
| yeast\_me2 | 0.9978 | 0.9831 | 0.9774 | 0.9891 | 0.9934 | 0.9724 | 0.9754 | 0.9906 | 0.9713 | 0.9823 | 0.9819 | 0.9767 | 0.9847 | 0.9903 | 0.9921 |
| yeast\_ml8 | 0.9330 | 0.9293 | 0.9262 | 0.9330 | 0.9418 | 0.9260 | 0.9264 | 0.9364 | 0.9263 | 0.9282 | 0.9299 | 0.9263 | 0.9308 | 0.9474 | 0.9315 |

表7 Precision\_pos指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.2137 | 0.2436 | 0.3180 | 0.2302 | 0.2519 | 0.1989 | 0.3060 | 0.2349 | 0.3201 | 0.2444 | 0.2117 | 0.3148 | 0.2466 | 0.2690 | 0.2738 |
| abalone\_19 | 0.0172 | 0.0319 | 0.0309 | 0.0094 | 0.0194 | 0.0000 | 0.0000 | 0.0237 | 0.0000 | 0.0328 | 0.0183 | 0.0173 | 0.0278 | 0.0216 | 0.0238 |
| arrhythmia | 0.4244 | 0.7174 | 0.7327 | 0.6644 | 0.1969 | 0.7397 | 0.7426 | 0.6386 | 0.7447 | 0.7370 | 0.6257 | 0.7597 | 0.7400 | 0.7067 | 0.6479 |
| car\_eval\_34 | 0.4374 | 0.8040 | 0.8675 | 0.5616 | 0.6259 | 0.9222 | 0.9193 | 0.5555 | 0.9348 | 0.8051 | 0.7758 | 0.9338 | 0.8755 | 0.9436 | 0.7762 |
| car\_eval\_4 | 0.6362 | 0.7919 | 0.8482 | 0.7841 | 0.5228 | 0.8792 | 0.9505 | 0.6653 | 0.9857 | 0.7994 | 0.6805 | 0.9830 | 0.8633 | 0.9857 | 0.6896 |
| coil\_2000 | 0.1548 | 0.1241 | 0.2012 | 0.0998 | 0.1168 | 0.3727 | 0.1787 | 0.1273 | 0.1576 | 0.1244 | 0.1197 | 0.1687 | 0.1636 | 0.1130 | 0.1365 |
| ecoli | 0.4753 | 0.5279 | 0.5812 | 0.5112 | 0.4310 | 0.6326 | 0.7611 | 0.4667 | 0.6238 | 0.5083 | 0.4849 | 0.6079 | 0.5171 | 0.5708 | 0.4742 |
| isolet | 0.3760 | 0.6506 | 0.7496 | 0.7747 | 0.5762 | 0.8194 | 0.9333 | 0.5108 | 0.8377 | 0.6586 | 0.3816 | 0.8563 | 0.6807 | 0.8122 | 0.6152 |
| letter\_img | 0.2373 | 0.5913 | 0.7826 | 0.9268 | 0.6617 | 0.9225 | 0.9712 | 0.4010 | 0.9756 | 0.5993 | 0.5126 | 0.9790 | 0.7426 | 0.9703 | 0.7051 |
| libras\_move | 0.2514 | 0.9413 | 0.9643 | 0.7938 | 0.5340 | 0.9590 | 0.8510 | 0.6975 | 0.9510 | 0.9344 | 0.6140 | 0.9313 | 0.8707 | 0.8120 | 0.6807 |
| mammography | 0.1332 | 0.2266 | 0.5460 | 0.0737 | 0.2309 | 0.7559 | 0.8347 | 0.1725 | 0.8606 | 0.2354 | 0.1141 | 0.6874 | 0.2192 | 0.4754 | 0.2902 |
| oil | 0.1553 | 0.4632 | 0.5615 | 0.3009 | 0.1929 | 0.5885 | 0.7215 | 0.2629 | 0.7179 | 0.5012 | 0.2333 | 0.6880 | 0.4835 | 0.2665 | 0.2203 |
| optical\_digits | 0.1555 | 0.7325 | 0.8312 | 0.9512 | 0.8335 | 0.9065 | 0.9868 | 0.6295 | 0.9886 | 0.7379 | 0.6158 | 0.9853 | 0.8550 | 0.9697 | 0.8881 |
| ozone\_level | 0.0853 | 0.2456 | 0.3358 | 0.1244 | 0.1188 | 0.4151 | 0.2267 | 0.1455 | 0.4573 | 0.2492 | 0.1061 | 0.4099 | 0.2068 | 0.1492 | 0.1491 |
| pen\_digits | 0.2279 | 0.7970 | 0.8975 | 0.9878 | 0.9788 | 0.9484 | 0.9948 | 0.6406 | 0.9935 | 0.8096 | 0.7248 | 0.9930 | 0.8347 | 0.9925 | 0.9702 |
| protein\_homo | 0.0308 | 0.2387 | 0.5692 | 0.7356 | 0.2577 | 0.8783 | 0.9718 | 0.1903 | 0.9650 | 0.2417 | 0.1286 | 0.8979 | 0.2394 | 0.8226 | 0.2823 |
| satimage | 0.3162 | 0.3910 | 0.4916 | 0.5875 | 0.4169 | 0.6396 | 0.8091 | 0.3777 | 0.7898 | 0.3925 | 0.3618 | 0.7188 | 0.4331 | 0.5725 | 0.4763 |
| scene | 0.1334 | 0.1829 | 0.2165 | 0.1599 | 0.1713 | 0.2784 | 0.4961 | 0.1771 | 0.4937 | 0.1782 | 0.1246 | 0.3359 | 0.1739 | 0.1673 | 0.2020 |
| sick\_euthyroid | 0.4269 | 0.7466 | 0.7919 | 0.8262 | 0.7033 | 0.8442 | 0.8972 | 0.7519 | 0.8909 | 0.7469 | 0.5046 | 0.8792 | 0.7348 | 0.8710 | 0.7541 |
| solar\_flare\_m0 | 0.1207 | 0.1167 | 0.2624 | 0.0663 | 0.1113 | 0.4150 | 0.1892 | 0.1138 | 0.1122 | 0.1159 | 0.1023 | 0.1133 | 0.1793 | 0.1155 | 0.1240 |
| spectrometer | 0.3521 | 0.8747 | 0.8823 | 0.8006 | 0.6465 | 0.8710 | 0.9168 | 0.6975 | 0.8846 | 0.8683 | 0.7064 | 0.8194 | 0.8147 | 0.8035 | 0.5497 |
| thyroid\_sick | 0.2901 | 0.6593 | 0.7415 | 0.8109 | 0.6367 | 0.7936 | 0.9285 | 0.6537 | 0.9309 | 0.6681 | 0.3885 | 0.8667 | 0.6759 | 0.9118 | 0.6959 |
| us\_crime | 0.2228 | 0.3569 | 0.4786 | 0.3822 | 0.3055 | 0.5624 | 0.6509 | 0.3137 | 0.5897 | 0.3747 | 0.2382 | 0.5002 | 0.3713 | 0.3548 | 0.3318 |
| webpage | 0.2195 | 0.3373 | 0.6094 | 0.3135 | 0.2362 | 0.7971 | 0.7537 | 0.2066 | 0.6017 | 0.3373 | 0.1725 | 0.6426 | 0.4155 | 0.3489 | 0.2087 |
| wine\_quality | 0.1168 | 0.1561 | 0.2933 | 0.1633 | 0.1397 | 0.4140 | 0.6366 | 0.1470 | 0.7222 | 0.1560 | 0.0814 | 0.4671 | 0.1399 | 0.1604 | 0.1820 |
| yeast\_me2 | 0.1086 | 0.2074 | 0.3158 | 0.1935 | 0.1592 | 0.3458 | 0.5971 | 0.1981 | 0.5425 | 0.2114 | 0.1286 | 0.4649 | 0.2349 | 0.1976 | 0.1702 |
| yeast\_ml8 | 0.0919 | 0.0833 | 0.0693 | 0.0813 | 0.0940 | 0.0598 | 0.0617 | 0.0973 | 0.0000 | 0.0800 | 0.0815 | 0.0400 | 0.0904 | 0.0909 | 0.0972 |

表8 Recall\_neg指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.7936 | 0.7230 | 0.8619 | 0.7734 | 0.7360 | 0.9945 | 0.9720 | 0.6993 | 0.9772 | 0.7258 | 0.7375 | 0.9383 | 0.7335 | 0.7887 | 0.7856 |
| abalone\_19 | 0.9131 | 0.9188 | 0.9895 | 0.3099 | 0.6865 | 0.9991 | 1.0000 | 0.7669 | 0.9999 | 0.9232 | 0.8442 | 0.9962 | 0.8755 | 0.7443 | 0.7889 |
| arrhythmia | 0.8089 | 0.9808 | 0.9824 | 0.9689 | 0.7820 | 0.9824 | 0.9801 | 0.9646 | 0.9806 | 0.9820 | 0.9675 | 0.9810 | 0.9822 | 0.9749 | 0.9658 |
| car\_eval\_34 | 0.8862 | 0.9790 | 0.9871 | 0.9312 | 0.9484 | 0.9932 | 0.9929 | 0.9317 | 0.9942 | 0.9793 | 0.9752 | 0.9942 | 0.9883 | 0.9950 | 0.9750 |
| car\_eval\_4 | 0.9756 | 0.9892 | 0.9929 | 0.9880 | 0.9622 | 0.9948 | 0.9979 | 0.9791 | 0.9994 | 0.9897 | 0.9809 | 0.9993 | 0.9940 | 0.9994 | 0.9813 |
| coil\_2000 | 0.8304 | 0.7148 | 0.9447 | 0.6818 | 0.6847 | 0.9978 | 0.9759 | 0.7070 | 0.9703 | 0.7194 | 0.7089 | 0.9751 | 0.9174 | 0.6630 | 0.7907 |
| ecoli | 0.9003 | 0.9352 | 0.9528 | 0.8973 | 0.8494 | 0.9621 | 0.9777 | 0.8771 | 0.9651 | 0.9322 | 0.9136 | 0.9535 | 0.9223 | 0.9253 | 0.8814 |
| isolet | 0.8652 | 0.9596 | 0.9766 | 0.9774 | 0.9406 | 0.9862 | 0.9963 | 0.9245 | 0.9894 | 0.9613 | 0.9008 | 0.9898 | 0.9674 | 0.9820 | 0.9511 |
| letter\_img | 0.8775 | 0.9743 | 0.9900 | 0.9971 | 0.9806 | 0.9972 | 0.9989 | 0.9444 | 0.9991 | 0.9751 | 0.9621 | 0.9992 | 0.9875 | 0.9989 | 0.9842 |
| libras\_move | 0.7643 | 0.9949 | 0.9964 | 0.9801 | 0.9369 | 0.9964 | 0.9976 | 0.9708 | 0.9973 | 0.9952 | 0.9673 | 0.9961 | 0.9890 | 0.9804 | 0.9679 |
| mammography | 0.8564 | 0.9319 | 0.9864 | 0.6833 | 0.9293 | 0.9961 | 0.9973 | 0.9001 | 0.9979 | 0.9357 | 0.8175 | 0.9924 | 0.9285 | 0.9783 | 0.9492 |
| oil | 0.7805 | 0.9744 | 0.9835 | 0.9149 | 0.8420 | 0.9872 | 0.9921 | 0.8957 | 0.9948 | 0.9762 | 0.9066 | 0.9921 | 0.9724 | 0.8990 | 0.8705 |
| optical\_digits | 0.4032 | 0.9631 | 0.9803 | 0.9946 | 0.9790 | 0.9907 | 0.9988 | 0.9411 | 0.9989 | 0.9642 | 0.9391 | 0.9986 | 0.9837 | 0.9967 | 0.9870 |
| ozone\_level | 0.7382 | 0.9501 | 0.9789 | 0.8446 | 0.8222 | 0.9908 | 0.9969 | 0.8647 | 0.9974 | 0.9531 | 0.8657 | 0.9940 | 0.9448 | 0.8698 | 0.8736 |
| pen\_digits | 0.6362 | 0.9741 | 0.9887 | 0.9987 | 0.9977 | 0.9948 | 0.9995 | 0.9444 | 0.9993 | 0.9762 | 0.9574 | 0.9993 | 0.9800 | 0.9992 | 0.9968 |
| protein\_homo | 0.7131 | 0.9738 | 0.9943 | 0.9972 | 0.9758 | 0.9991 | 0.9998 | 0.9647 | 0.9998 | 0.9742 | 0.9450 | 0.9992 | 0.9741 | 0.9983 | 0.9789 |
| satimage | 0.7837 | 0.8555 | 0.9173 | 0.9395 | 0.8646 | 0.9670 | 0.9863 | 0.8490 | 0.9849 | 0.8569 | 0.8506 | 0.9738 | 0.8875 | 0.9348 | 0.9004 |
| scene | 0.6213 | 0.8551 | 0.9312 | 0.7457 | 0.7332 | 0.9719 | 0.9960 | 0.7891 | 0.9941 | 0.8603 | 0.7594 | 0.9845 | 0.8551 | 0.7048 | 0.8340 |
| sick\_euthyroid | 0.8647 | 0.9687 | 0.9765 | 0.9800 | 0.9592 | 0.9841 | 0.9899 | 0.9691 | 0.9893 | 0.9688 | 0.9050 | 0.9877 | 0.9672 | 0.9867 | 0.9687 |
| solar\_flare\_m0 | 0.7770 | 0.7545 | 0.9497 | 0.4791 | 0.6891 | 0.9944 | 0.9824 | 0.7413 | 0.9216 | 0.7509 | 0.6869 | 0.9713 | 0.9236 | 0.7151 | 0.7578 |
| spectrometer | 0.8290 | 0.9881 | 0.9901 | 0.9774 | 0.9496 | 0.9895 | 0.9932 | 0.9605 | 0.9920 | 0.9881 | 0.9677 | 0.9844 | 0.9811 | 0.9786 | 0.9358 |
| thyroid\_sick | 0.8413 | 0.9698 | 0.9807 | 0.9853 | 0.9636 | 0.9871 | 0.9958 | 0.9677 | 0.9958 | 0.9708 | 0.9120 | 0.9910 | 0.9726 | 0.9942 | 0.9720 |
| us\_crime | 0.7415 | 0.9027 | 0.9508 | 0.9019 | 0.8363 | 0.9733 | 0.9833 | 0.8445 | 0.9830 | 0.9093 | 0.8449 | 0.9675 | 0.9151 | 0.8831 | 0.8640 |
| webpage | 0.9338 | 0.9511 | 0.9867 | 0.9398 | 0.9129 | 0.9960 | 0.9928 | 0.9137 | 0.9893 | 0.9512 | 0.8666 | 0.9915 | 0.9702 | 0.9504 | 0.8989 |
| wine\_quality | 0.7923 | 0.8690 | 0.9650 | 0.8645 | 0.8122 | 0.9904 | 0.9949 | 0.8400 | 0.9973 | 0.8706 | 0.7499 | 0.9874 | 0.8508 | 0.8427 | 0.8740 |
| yeast\_me2 | 0.7154 | 0.9239 | 0.9694 | 0.8911 | 0.8407 | 0.9857 | 0.9917 | 0.8883 | 0.9946 | 0.9287 | 0.8525 | 0.9853 | 0.9304 | 0.8896 | 0.8583 |
| yeast\_ml8 | 0.7336 | 0.7789 | 0.9280 | 0.5457 | 0.5832 | 0.9833 | 0.9968 | 0.7159 | 0.9997 | 0.7858 | 0.6910 | 0.9977 | 0.7899 | 0.4609 | 0.8272 |

表9 Recall\_pos指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.6432 | 0.8614 | 0.6195 | 0.6529 | 0.8593 | 0.0169 | 0.1179 | 0.8923 | 0.1041 | 0.8565 | 0.7129 | 0.2745 | 0.8440 | 0.7524 | 0.7808 |
| abalone\_19 | 0.2252 | 0.3486 | 0.0471 | 0.8162 | 0.8062 | 0.0000 | 0.0000 | 0.7305 | 0.0000 | 0.3410 | 0.3486 | 0.0090 | 0.4657 | 0.7357 | 0.6667 |
| arrhythmia | 0.9120 | 0.7000 | 0.6680 | 0.9160 | 0.8600 | 0.6720 | 0.8360 | 0.9600 | 0.7880 | 0.7200 | 0.8000 | 0.8480 | 0.7200 | 0.9080 | 0.9600 |
| car\_eval\_34 | 1.0000 | 0.9940 | 0.9664 | 0.9948 | 1.0000 | 0.9083 | 0.9270 | 1.0000 | 0.9454 | 0.9918 | 0.9612 | 0.9439 | 0.9514 | 0.9432 | 1.0000 |
| car\_eval\_4 | 1.0000 | 0.9862 | 0.9446 | 1.0000 | 1.0000 | 0.8708 | 0.9338 | 1.0000 | 0.9800 | 0.9862 | 0.9262 | 0.9800 | 0.8969 | 0.9800 | 1.0000 |
| coil\_2000 | 0.4782 | 0.6368 | 0.2193 | 0.5561 | 0.6571 | 0.0176 | 0.0822 | 0.6734 | 0.0882 | 0.6288 | 0.5855 | 0.0793 | 0.2534 | 0.6766 | 0.5217 |
| ecoli | 0.7457 | 0.5886 | 0.5257 | 0.8600 | 0.9371 | 0.4686 | 0.5686 | 0.8886 | 0.4657 | 0.5829 | 0.6457 | 0.5943 | 0.6743 | 0.8086 | 0.8800 |
| isolet | 0.9693 | 0.8970 | 0.8350 | 0.9260 | 0.9642 | 0.7488 | 0.6097 | 0.9422 | 0.6527 | 0.8902 | 0.7147 | 0.7270 | 0.8285 | 0.9270 | 0.9337 |
| letter\_img | 0.9935 | 0.9709 | 0.9338 | 0.9737 | 0.9884 | 0.8693 | 0.9300 | 0.9729 | 0.9209 | 0.9711 | 0.9487 | 0.9334 | 0.9403 | 0.9567 | 0.9819 |
| libras\_move | 0.8290 | 0.6810 | 0.6080 | 0.8240 | 0.8650 | 0.6170 | 0.4450 | 0.7780 | 0.6400 | 0.6370 | 0.6500 | 0.6680 | 0.6840 | 0.8200 | 0.7500 |
| mammography | 0.8669 | 0.8327 | 0.6765 | 0.8473 | 0.8846 | 0.4919 | 0.5665 | 0.8692 | 0.5262 | 0.8277 | 0.7127 | 0.6931 | 0.8373 | 0.8169 | 0.8646 |
| oil | 0.8564 | 0.4922 | 0.4383 | 0.7572 | 0.8103 | 0.3803 | 0.4000 | 0.7914 | 0.2694 | 0.5097 | 0.5500 | 0.3339 | 0.5403 | 0.7847 | 0.7869 |
| optical\_digits | 0.9959 | 0.9186 | 0.8765 | 0.9466 | 0.9572 | 0.8229 | 0.8202 | 0.9119 | 0.8313 | 0.9130 | 0.8839 | 0.8585 | 0.8688 | 0.9422 | 0.9327 |
| ozone\_level | 0.8011 | 0.5426 | 0.3512 | 0.7304 | 0.8036 | 0.2163 | 0.0329 | 0.7701 | 0.0835 | 0.5276 | 0.4867 | 0.1523 | 0.4869 | 0.7658 | 0.7406 |
| pen\_digits | 0.9951 | 0.9539 | 0.9233 | 0.9810 | 0.9884 | 0.8850 | 0.9445 | 0.9280 | 0.9519 | 0.9505 | 0.9446 | 0.9639 | 0.9428 | 0.9741 | 0.9784 |
| protein\_homo | 0.9838 | 0.9160 | 0.8299 | 0.8789 | 0.9336 | 0.7298 | 0.7493 | 0.9242 | 0.7159 | 0.9143 | 0.8830 | 0.7668 | 0.9083 | 0.8596 | 0.9243 |
| satimage | 0.9219 | 0.8594 | 0.7388 | 0.7973 | 0.8965 | 0.5405 | 0.5321 | 0.8489 | 0.5230 | 0.8564 | 0.7834 | 0.6171 | 0.7952 | 0.8077 | 0.8374 |
| scene | 0.7272 | 0.4058 | 0.2401 | 0.6073 | 0.6930 | 0.1350 | 0.0543 | 0.5705 | 0.0746 | 0.3797 | 0.4240 | 0.0961 | 0.3827 | 0.7458 | 0.5262 |
| sick\_euthyroid | 0.9727 | 0.8921 | 0.8685 | 0.9184 | 0.9338 | 0.8348 | 0.8511 | 0.9081 | 0.8460 | 0.8928 | 0.8224 | 0.8654 | 0.8809 | 0.8730 | 0.9290 |
| solar\_flare\_m0 | 0.5668 | 0.6308 | 0.3237 | 0.7030 | 0.7543 | 0.0648 | 0.0711 | 0.6460 | 0.1965 | 0.6340 | 0.6373 | 0.0726 | 0.3118 | 0.7163 | 0.6641 |
| spectrometer | 0.9022 | 0.7756 | 0.7511 | 0.8578 | 0.9156 | 0.7333 | 0.7022 | 0.9200 | 0.6000 | 0.7778 | 0.7133 | 0.6778 | 0.8178 | 0.8622 | 0.7911 |
| thyroid\_sick | 0.9779 | 0.8861 | 0.8385 | 0.9567 | 0.9598 | 0.7497 | 0.8268 | 0.9117 | 0.8471 | 0.8905 | 0.7753 | 0.8878 | 0.8653 | 0.9099 | 0.9736 |
| us\_crime | 0.8853 | 0.6553 | 0.5453 | 0.7367 | 0.8793 | 0.4160 | 0.3687 | 0.8667 | 0.2933 | 0.6613 | 0.5727 | 0.3907 | 0.6080 | 0.7807 | 0.8220 |
| webpage | 0.6298 | 0.8543 | 0.7099 | 0.9081 | 0.9260 | 0.5317 | 0.7528 | 0.7727 | 0.5531 | 0.8520 | 0.7678 | 0.5219 | 0.7277 | 0.9003 | 0.9169 |
| wine\_quality | 0.6760 | 0.6219 | 0.3685 | 0.6739 | 0.7825 | 0.1666 | 0.2156 | 0.7071 | 0.1638 | 0.6137 | 0.5388 | 0.2802 | 0.6236 | 0.7718 | 0.7164 |
| yeast\_me2 | 0.9547 | 0.5515 | 0.3687 | 0.7204 | 0.8400 | 0.2111 | 0.2962 | 0.7618 | 0.1718 | 0.5253 | 0.5560 | 0.3378 | 0.5907 | 0.7520 | 0.8075 |
| yeast\_ml8 | 0.3357 | 0.2540 | 0.0698 | 0.5062 | 0.5449 | 0.0124 | 0.0034 | 0.3870 | 0.0000 | 0.2356 | 0.3445 | 0.0011 | 0.2611 | 0.6775 | 0.2348 |

表10 ROC\_AUC指标的集成算法均值

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 数据集 | AdaCost | AdaUBoost | AsymBoost | BalanceCascade | BalancedRandomForest | CompatibleAdaBoost | CompatibleBagging | EasyEnsemble | OverBagging | OverBoost | RUSBoost | SMOTEBagging | SMOTEBoost | SelfPacedEnsemble | UnderBagging |
| abalone | 0.8085 | 0.8529 | 0.8533 | 0.7673 | 0.8573 | 0.8531 | 0.8290 | 0.8562 | 0.8313 | 0.8528 | 0.7906 | 0.8387 | 0.8465 | 0.8444 | 0.8549 |
| abalone\_19 | 0.7801 | 0.7640 | 0.7521 | 0.6096 | 0.8070 | 0.7596 | 0.6517 | 0.8153 | 0.6451 | 0.7575 | 0.6802 | 0.7440 | 0.7633 | 0.8103 | 0.8171 |
| arrhythmia | 0.9342 | 0.9737 | 0.9703 | 0.9721 | 0.9053 | 0.9737 | 0.9621 | 0.9692 | 0.9701 | 0.9737 | 0.9578 | 0.9714 | 0.9765 | 0.9699 | 0.9675 |
| car\_eval\_34 | 0.9937 | 0.9980 | 0.9981 | 0.9952 | 0.9976 | 0.9981 | 0.9977 | 0.9970 | 0.9981 | 0.9980 | 0.9955 | 0.9983 | 0.9979 | 0.9982 | 0.9983 |
| car\_eval\_4 | 0.9969 | 0.9982 | 0.9982 | 0.9997 | 0.9991 | 0.9982 | 0.9995 | 0.9985 | 0.9999 | 0.9982 | 0.9932 | 0.9999 | 0.9981 | 1.0000 | 0.9995 |
| coil\_2000 | 0.7421 | 0.7314 | 0.7311 | 0.6681 | 0.7335 | 0.7304 | 0.6783 | 0.7539 | 0.6808 | 0.7319 | 0.7092 | 0.6781 | 0.6970 | 0.7229 | 0.7311 |
| ecoli | 0.9255 | 0.9046 | 0.9130 | 0.9522 | 0.9405 | 0.9154 | 0.9404 | 0.9480 | 0.9133 | 0.9068 | 0.8930 | 0.9252 | 0.9111 | 0.9506 | 0.9335 |
| isolet | 0.9772 | 0.9775 | 0.9783 | 0.9927 | 0.9878 | 0.9784 | 0.9846 | 0.9779 | 0.9839 | 0.9775 | 0.9092 | 0.9878 | 0.9754 | 0.9944 | 0.9857 |
| letter\_img | 0.9768 | 0.9972 | 0.9972 | 0.9994 | 0.9992 | 0.9971 | 0.9978 | 0.9921 | 0.9972 | 0.9973 | 0.9925 | 0.9987 | 0.9969 | 0.9997 | 0.9990 |
| libras\_move | 0.8753 | 0.8953 | 0.9052 | 0.9519 | 0.9587 | 0.9005 | 0.9374 | 0.9325 | 0.9472 | 0.8984 | 0.9048 | 0.9574 | 0.8909 | 0.9484 | 0.9380 |
| mammography | 0.9250 | 0.9319 | 0.9347 | 0.8994 | 0.9524 | 0.9335 | 0.9241 | 0.9359 | 0.9057 | 0.9321 | 0.8285 | 0.9371 | 0.9353 | 0.9513 | 0.9486 |
| oil | 0.9042 | 0.8202 | 0.8341 | 0.9220 | 0.9174 | 0.8257 | 0.8795 | 0.9284 | 0.8919 | 0.8261 | 0.8270 | 0.9076 | 0.8468 | 0.9261 | 0.9200 |
| optical\_digits | 0.9759 | 0.9860 | 0.9858 | 0.9982 | 0.9968 | 0.9856 | 0.9965 | 0.9804 | 0.9976 | 0.9857 | 0.9720 | 0.9965 | 0.9860 | 0.9987 | 0.9957 |
| ozone\_level | 0.8418 | 0.8431 | 0.8389 | 0.8647 | 0.8902 | 0.8456 | 0.8298 | 0.8969 | 0.8288 | 0.8504 | 0.7711 | 0.8540 | 0.8429 | 0.8904 | 0.8822 |
| pen\_digits | 0.9726 | 0.9938 | 0.9936 | 0.9997 | 0.9998 | 0.9938 | 0.9986 | 0.9852 | 0.9986 | 0.9937 | 0.9871 | 0.9990 | 0.9934 | 0.9996 | 0.9995 |
| protein\_homo | 0.9798 | 0.9886 | 0.9887 | 0.9879 | 0.9907 | 0.9884 | 0.9604 | 0.9876 | 0.9718 | 0.9887 | 0.9738 | 0.9853 | 0.9879 | 0.9908 | 0.9884 |
| satimage | 0.9192 | 0.9338 | 0.9339 | 0.9579 | 0.9530 | 0.9343 | 0.9480 | 0.9338 | 0.9510 | 0.9336 | 0.8983 | 0.9543 | 0.9319 | 0.9615 | 0.9511 |
| scene | 0.7307 | 0.7102 | 0.7109 | 0.7457 | 0.7958 | 0.7188 | 0.7187 | 0.7762 | 0.7748 | 0.7088 | 0.6474 | 0.7684 | 0.7099 | 0.8032 | 0.7932 |
| sick\_euthyroid | 0.9542 | 0.9686 | 0.9686 | 0.9855 | 0.9820 | 0.9691 | 0.9767 | 0.9756 | 0.9797 | 0.9680 | 0.9322 | 0.9836 | 0.9676 | 0.9852 | 0.9860 |
| solar\_flare\_m0 | 0.7438 | 0.7662 | 0.7647 | 0.6404 | 0.7884 | 0.7659 | 0.7335 | 0.7661 | 0.7106 | 0.7657 | 0.7186 | 0.7328 | 0.7556 | 0.7797 | 0.7815 |
| spectrometer | 0.9403 | 0.9660 | 0.9610 | 0.9698 | 0.9732 | 0.9657 | 0.9577 | 0.9718 | 0.9651 | 0.9710 | 0.9489 | 0.9623 | 0.9617 | 0.9757 | 0.9557 |
| thyroid\_sick | 0.9260 | 0.9564 | 0.9580 | 0.9976 | 0.9922 | 0.9563 | 0.9918 | 0.9737 | 0.9899 | 0.9579 | 0.9144 | 0.9928 | 0.9599 | 0.9979 | 0.9945 |
| us\_crime | 0.8920 | 0.8775 | 0.8775 | 0.8904 | 0.9158 | 0.8784 | 0.8969 | 0.9226 | 0.8895 | 0.8786 | 0.7995 | 0.8987 | 0.8779 | 0.9091 | 0.9097 |
| webpage | 0.9077 | 0.9594 | 0.9588 | 0.9710 | 0.9724 | 0.9589 | 0.9528 | 0.9242 | 0.9539 | 0.9594 | 0.8949 | 0.9543 | 0.9366 | 0.9744 | 0.9623 |
| wine\_quality | 0.8053 | 0.8223 | 0.8210 | 0.8341 | 0.8654 | 0.8212 | 0.8624 | 0.8426 | 0.8571 | 0.8180 | 0.7011 | 0.8705 | 0.8138 | 0.8774 | 0.8671 |
| yeast\_me2 | 0.9122 | 0.7968 | 0.7937 | 0.9106 | 0.9201 | 0.7953 | 0.8799 | 0.9141 | 0.8779 | 0.7911 | 0.7913 | 0.9133 | 0.8219 | 0.9306 | 0.9300 |
| yeast\_ml8 | 0.5774 | 0.5527 | 0.5510 | 0.5381 | 0.5996 | 0.5368 | 0.5395 | 0.5894 | 0.5821 | 0.5446 | 0.5363 | 0.5790 | 0.5476 | 0.5925 | 0.5991 |

表11 Accuracy和Balanced Accuracy指标分类器排名

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Accuracy | | Balanced Accuracy | |
| 排名 | 分类器 | 平均排序 | 分类器 | 平均排序 |
| 1 | CompatibleBagging | 2.78 | BalancedRandomForest | 2.93 |
| 2 | SMOTEBagging | 3.15 | UnderBagging | 3.48 |
| 3 | OverBagging | 3.26 | SelfPacedEnsemble | 3.52 |
| 4 | CompatibleAdaBoost | 4.56 | EasyEnsemble | 4.78 |
| 5 | AsymBoost | 5.93 | BalanceCascade | 5.04 |
| 6 | SelfPacedEnsemble | 6.63 | AdaUBoost | 6.48 |
| 7 | SMOTEBoost | 8.07 | OverBoost | 7.00 |
| 8 | OverBoost | 8.11 | SMOTEBoost | 8.19 |
| 9 | BalanceCascade | 8.78 | AdaCost | 9.33 |
| 10 | AdaUBoost | 9.00 | AsymBoost | 10.33 |
| 11 | UnderBagging | 9.26 | SMOTEBagging | 10.56 |
| 12 | BalancedRandomForest | 12.04 | RUSBoost | 10.78 |
| 13 | EasyEnsemble | 12.07 | CompatibleBagging | 11.93 |
| 14 | RUSBoost | 13.07 | OverBagging | 12.00 |
| 15 | AdaCost | 13.26 | CompatibleAdaBoost | 13.67 |

表12 ROC-AUC和AUPRC指标分类器排名

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ROC-AUC | | AUPRC | |
| 排名 | 分类器 | 平均排序 | 分类器 | 平均排序 |
| 1 | SelfPacedEnsemble | 2.70 | SelfPacedEnsemble | 3.19 |
| 2 | BalancedRandomForest | 3.70 | BalanceCascade | 5.07 |
| 3 | UnderBagging | 4.44 | BalancedRandomForest | 6.04 |
| 4 | SMOTEBagging | 6.11 | SMOTEBagging | 6.11 |
| 5 | EasyEnsemble | 6.70 | UnderBagging | 6.11 |
| 6 | BalanceCascade | 6.78 | CompatibleBagging | 6.70 |
| 7 | OverBagging | 8.41 | OverBagging | 6.70 |
| 8 | CompatibleAdaBoost | 8.89 | EasyEnsemble | 7.63 |
| 9 | CompatibleBagging | 9.11 | AdaUBoost | 8.56 |
| 10 | AsymBoost | 9.11 | CompatibleAdaBoost | 8.67 |
| 11 | AdaUBoost | 9.11 | AsymBoost | 9.15 |
| 12 | OverBoost | 9.37 | OverBoost | 9.19 |
| 13 | SMOTEBoost | 10.37 | SMOTEBoost | 10.59 |
| 14 | AdaCost | 11.33 | AdaCost | 12.44 |
| 15 | RUSBoost | 13.85 | RUSBoost | 13.85 |

表13 F1-score和MCC指标分类器排名

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | F1-score | | MCC | |
| 排名 | 分类器 | 平均排序 | 分类器 | 平均排序 |
| 1 | SelfPacedEnsemble | 3.30 | SelfPacedEnsemble | 2.93 |
| 2 | AsymBoost | 5.96 | BalanceCascade | 6.26 |
| 3 | BalanceCascade | 6.22 | SMOTEBagging | 6.33 |
| 4 | SMOTEBagging | 6.33 | CompatibleBagging | 6.44 |
| 5 | UnderBagging | 6.85 | UnderBagging | 6.52 |
| 6 | CompatibleBagging | 6.89 | AsymBoost | 6.96 |
| 7 | SMOTEBoost | 7.56 | BalancedRandomForest | 8.11 |
| 8 | OverBoost | 7.67 | OverBagging | 8.11 |
| 9 | AdaUBoost | 8.15 | OverBoost | 8.19 |
| 10 | OverBagging | 8.41 | AdaUBoost | 8.22 |
| 11 | CompatibleAdaBoost | 8.96 | SMOTEBoost | 8.48 |
| 12 | BalancedRandomForest | 9.15 | EasyEnsemble | 8.70 |
| 13 | EasyEnsemble | 9.30 | CompatibleAdaBoost | 9.41 |
| 14 | AdaCost | 12.56 | AdaCost | 12.37 |
| 15 | RUSBoost | 12.59 | RUSBoost | 12.96 |

表14 Precision\_neg和Recall\_neg指标分类器排名

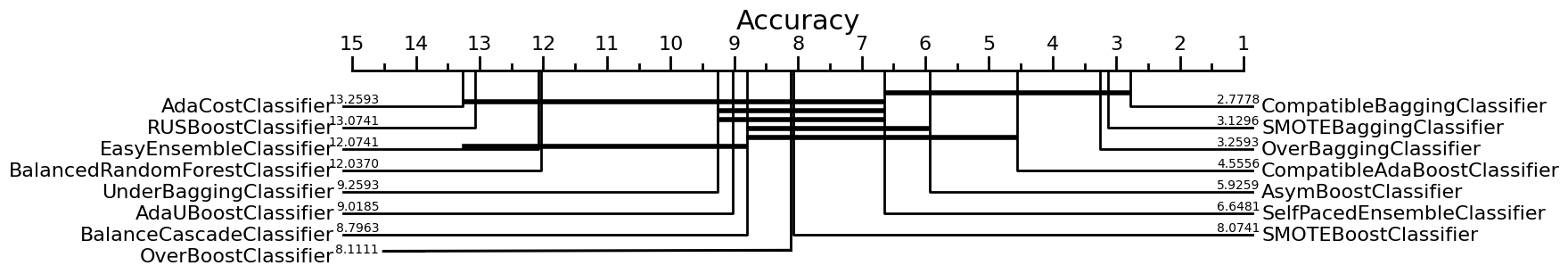
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Precision\_neg | | Recall\_neg | |
| 排名 | 分类器 | 平均排序 | 分类器 | 平均排序 |
| 1 | BalancedRandomForest | 1.85 | CompatibleBagging | 2.11 |
| 2 | EasyEnsemble | 3.78 | OverBagging | 2.19 |
| 3 | UnderBagging | 3.89 | SMOTEBagging | 3.44 |
| 4 | AdaCost | 4.04 | CompatibleAdaBoost | 3.56 |
| 5 | SelfPacedEnsemble | 5.11 | AsymBoost | 5.59 |
| 6 | BalanceCascade | 5.30 | SelfPacedEnsemble | 8.00 |
| 7 | AdaUBoost | 6.96 | SMOTEBoost | 8.00 |
| 8 | OverBoost | 7.56 | OverBoost | 8.19 |
| 9 | SMOTEBoost | 8.74 | AdaUBoost | 9.07 |
| 10 | RUSBoost | 9.96 | UnderBagging | 9.78 |
| 11 | AsymBoost | 11.19 | BalanceCascade | 9.78 |
| 12 | SMOTEBagging | 11.48 | EasyEnsemble | 12.30 |
| 13 | CompatibleBagging | 12.67 | RUSBoost | 12.37 |
| 14 | OverBagging | 13.04 | BalancedRandomForest | 12.44 |
| 15 | CompatibleAdaBoost | 13.81 | AdaCost | 13.15 |

表15 Precision\_pos和Recall\_pos指标分类器排名

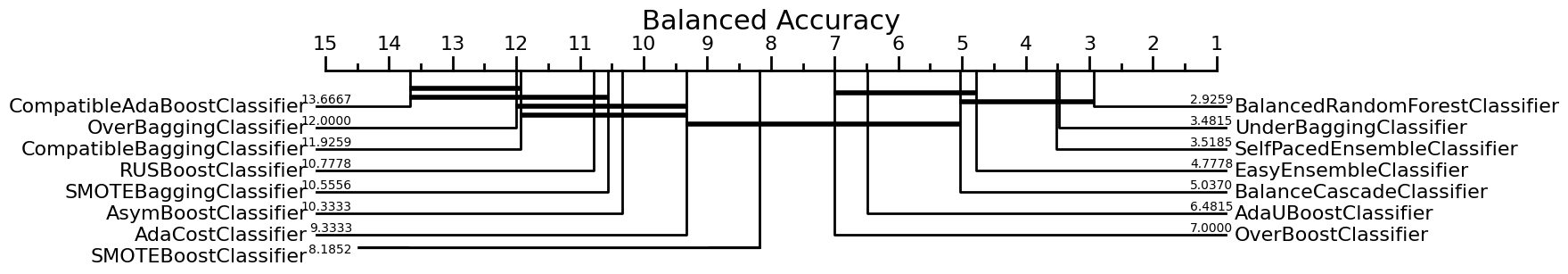
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Precision\_pos | | Recall\_pos | |
| 排名 | 分类器 | 平均排序 | 分类器 | 平均排序 |
| 1 | CompatibleBagging | 3.19 | BalancedRandomForest | 1.96 |
| 2 | OverBagging | 3.37 | AdaCost | 3.56 |
| 3 | SMOTEBagging | 4.22 | EasyEnsemble | 3.93 |
| 4 | CompatibleAdaBoost | 4.96 | UnderBagging | 4.19 |
| 5 | AsymBoost | 5.52 | BalanceCascade | 4.70 |
| 6 | SelfPacedEnsemble | 6.78 | SelfPacedEnsemble | 5.26 |
| 7 | SMOTEBoost | 7.74 | AdaUBoost | 7.22 |
| 8 | OverBoost | 8.30 | OverBoost | 7.74 |
| 9 | AdaUBoost | 8.70 | SMOTEBoost | 8.74 |
| 10 | UnderBagging | 8.89 | RUSBoost | 9.30 |
| 11 | BalanceCascade | 9.30 | AsymBoost | 11.19 |
| 12 | EasyEnsemble | 11.22 | SMOTEBagging | 11.56 |
| 13 | BalancedRandomForest | 11.37 | CompatibleBagging | 12.96 |
| 14 | RUSBoost | 13.00 | OverBagging | 13.11 |
| 15 | AdaCost | 13.30 | CompatibleAdaBoost | 13.67 |

表16 数据集的基本信息

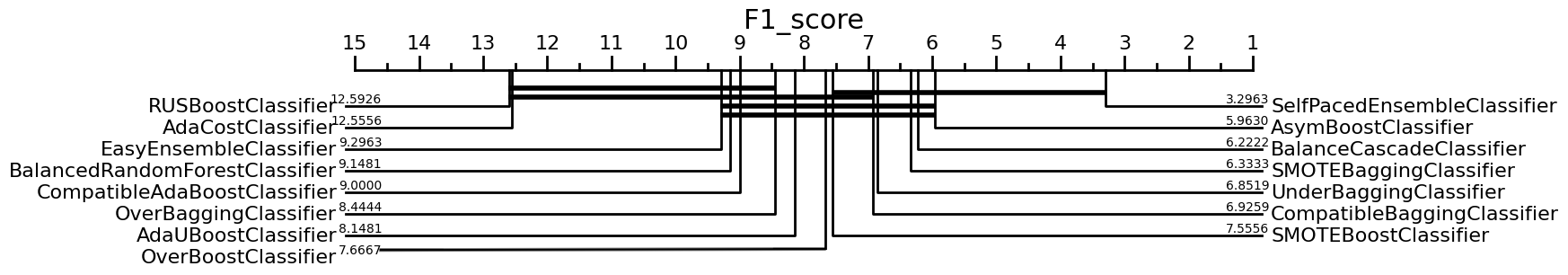
|  |  |  |  |
| --- | --- | --- | --- |
| 数据集 | 不平衡比率 | 样本数 | 特征数 |
| ecoli | 8.6:1 | 336 | 7 |
| optical\_digits | 9.1:1 | 5,620 | 64 |
| satimage | 9.3:1 | 6,435 | 36 |
| pen\_digits | 9.4:1 | 10,992 | 16 |
| abalone | 9.7:1 | 4,177 | 10 |
| sick\_euthyroid | 9.8:1 | 3,163 | 42 |
| spectrometer | 11:1 | 531 | 93 |
| car\_eval\_34 | 12:1 | 1,728 | 21 |
| isolet | 12:1 | 7,797 | 617 |
| us\_crime | 12:1 | 1,994 | 100 |
| yeast\_ml8 | 13:1 | 2,417 | 103 |
| scene | 13:1 | 2,407 | 294 |
| libras\_move | 14:1 | 360 | 90 |
| thyroid\_sick | 15:1 | 3,772 | 52 |
| coil\_2000 | 16:1 | 9,822 | 85 |
| arrhythmia | 17:1 | 452 | 278 |
| solar\_flare\_m0 | 19:1 | 1,389 | 32 |
| oil | 22:1 | 937 | 49 |
| car\_eval\_4 | 26:1 | 1,728 | 21 |
| wine\_quality | 26:1 | 4,898 | 11 |
| letter\_img | 26:1 | 20,000 | 16 |
| yeast\_me2 | 28:1 | 1,484 | 8 |
| webpage | 33:1 | 34,780 | 300 |
| ozone\_level | 34:1 | 2,536 | 72 |
| mammography | 42:1 | 11,183 | 6 |
| protein\_homo | 111:1 | 145,751 | 74 |
| abalone\_19 | 130:1 | 4,177 | 10 |



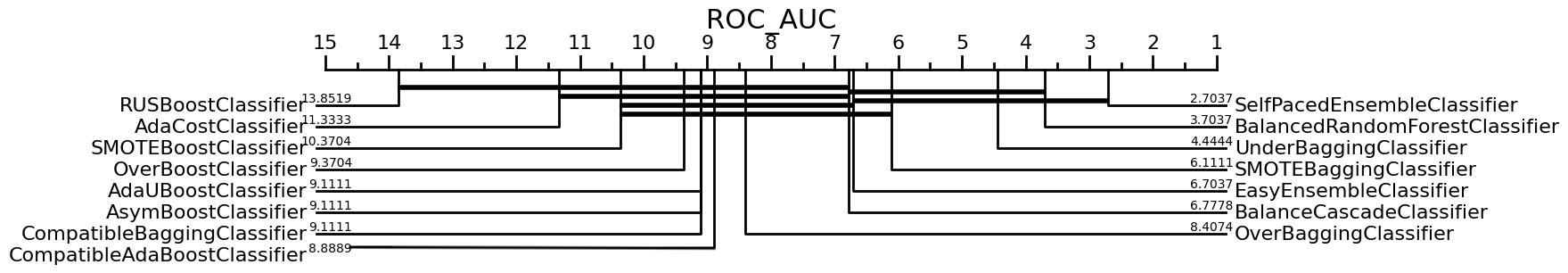
(a) 准确率关键差异图



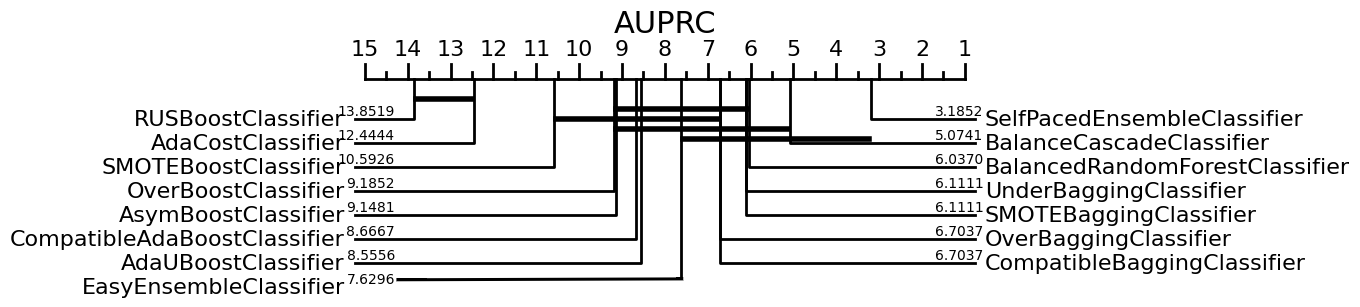
(b) 平衡准确率关键差异图



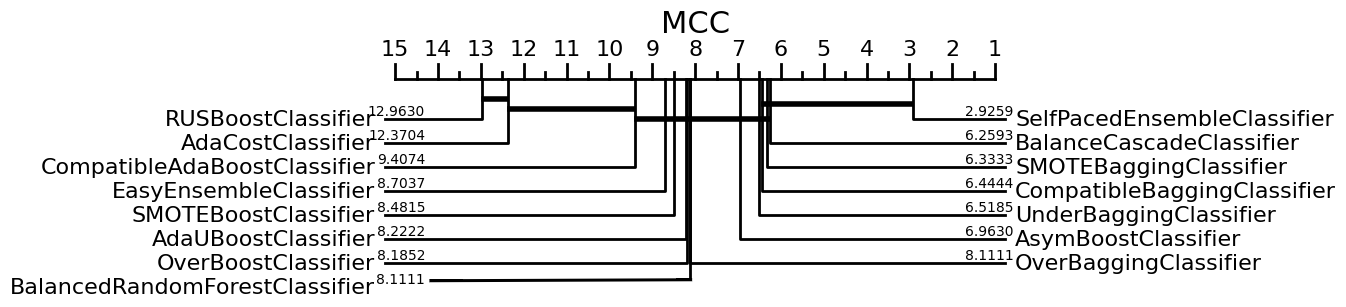
(c) F1值关键差异图



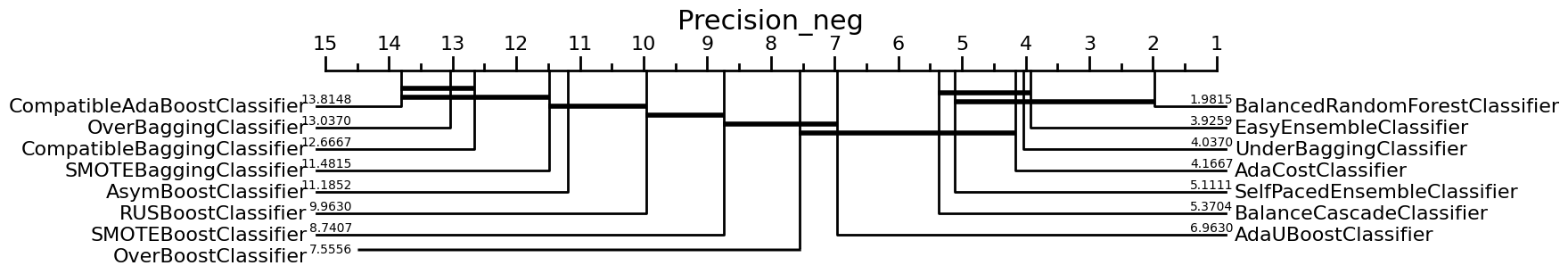
(d) ROC-AUC关键差异图



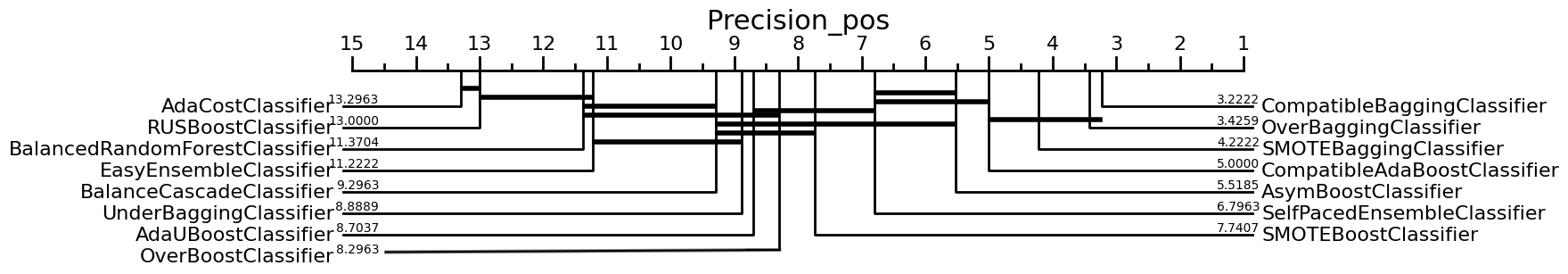
(e) AUPRC关键差异图



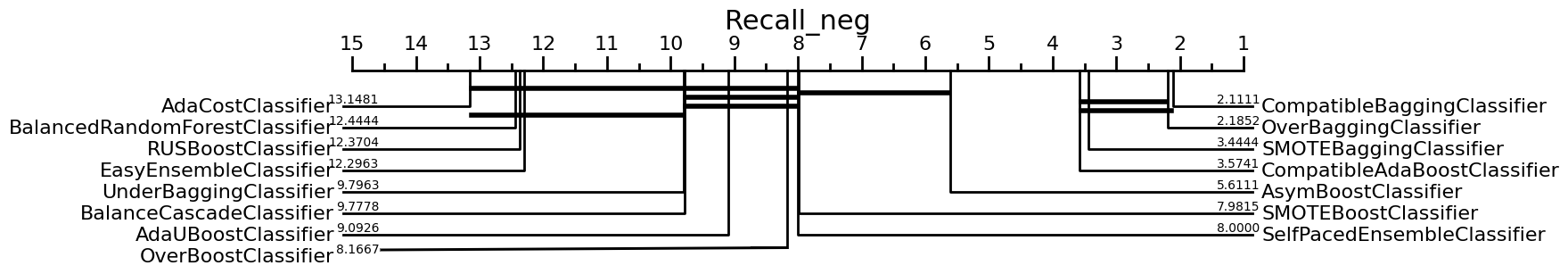
(f) MCC关键差异图



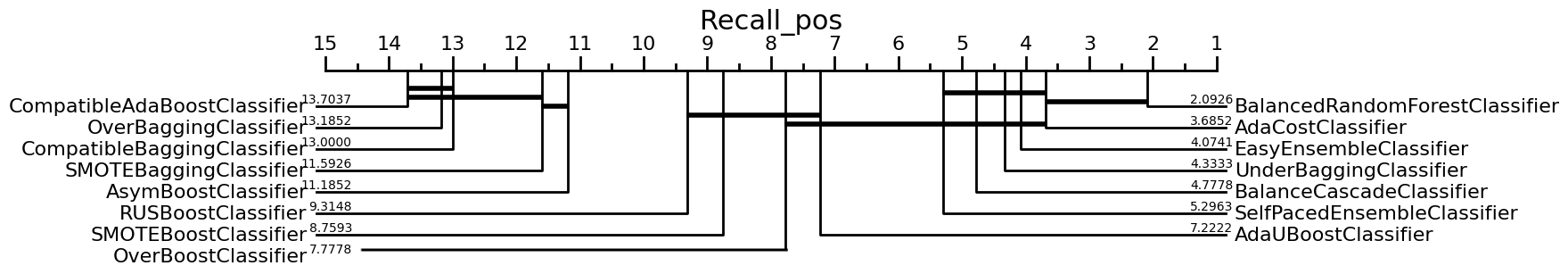
(g) 多数类精确率关键差异图



(h) 少数类精确率关键差异图



(i) 多数类召回率关键差异图



(j) 少数类召回率关键差异图

图1 性能指标关键差异图