cost ratio adaptively chosen for classifiers. The experimental results have shown the proposed approach can achieve the superior performance. In the future, the performance of the proposed approach will be further improved, with more effective yet efficient under-sampling and over-sampling methods.

**Table 3: *AUC* of 14 methods.**

| | SVM | Bagg | Ada | Asym | Under | SMOTE | Chan | RF | BRF | Under-RF | Over-RF | Cascade | Easy | My approach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| car | 0.991 | 0.995 | 0.998 | 0.998 | 0.988 | 0.995 | 0.996 | 0.984 | 0.946 | 0.987 | 0.985 | 0.996 | 0.994 | 0.993 |
| ionosphere | 0.980 | 0.962 | 0.976 | 0.975 | 0.973 | 0.976 | 0.975 | 0.963 | 0.969 | 0.970 | 0.981 | 0.970 | 0.974 | 0.984 |
| letter | 0.992 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.993 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| phoneme | 0.910 | 0.955 | 0.965 | 0.965 | 0.953 | 0.964 | 0.960 | 0.965 | 0.960 | 0.952 | 0.964 | 0.962 | 0.958 | 0.911 |
| satimage | 0.930 | 0.940 | 0.953 | 0.953 | 0.941 | 0.940 | 0.953 | 0.961 | 0.952 | 0.953 | 0.962 | 0.945 | 0.947 | 0.947 |
| wdbc | 0.995 | 0.987 | 0.994 | 0.994 | 0.993 | 0.992 | 0.993 | 0.991 | 0.990 | 0.991 | 0.991 | 0.994 | 0.993 | 0.995 |
| abalone | 0.770 | 0.822 | 0.611 | 0.611 | 0.830 | 0.831 | 0.830 | 0.822 | 0.853 | 0.842 | 0.823 | 0.826 | 0.847 | 0.865 |
| balance | 0.618 | 0.739 | 0.610 | 0.615 | 0.617 | 0.617 | 0.653 | 0.734 | 0.758 | 0.793 | 0.758 | 0.637 | 0.633 | 0.890 |
| cmc | 0.692 | 0.704 | 0.672 | 0.675 | 0.671 | 0.680 | 0.699 | 0.660 | 0.682 | 0.674 | 0.660 | 0.680 | 0.704 | 0.726 |
| haberman | 0.600 | 0.669 | 0.641 | 0.639 | 0.646 | 0.647 | 0.635 | 0.644 | 0.677 | 0.643 | 0.641 | 0.653 | 0.666 | 0.706 |
| housing | 0.801 | 0.824 | 0.813 | 0.815 | 0.805 | 0.813 | 0.803 | 0.798 | 0.826 | 0.820 | 0.820 | 0.808 | 0.825 | 0.839 |
| mf-morph | 0.917 | 0.667 | 0.668 | 0.689 | 0.910 | 0.912 | 0.912 | 0.660 | 0.901 | 0.91 | 0.881 | 0.903 | 0.918 | 0.931 |
| mf-zernike | 0.906 | 0.857 | 0.751 | 0.761 | 0.861 | 0.862 | 0.840 | 0.660 | 0.869 | 0.869 | 0.855 | 0.891 | 0.904 | 0.928 |
| pima | 0.828 | 0.821 | 0.788 | 0.786 | 0.798 | 0.792 | 0.786 | 0.821 | 0.809 | 0.818 | 0.810 | 0.798 | 0.806 | 0.828 |
| vehicle | 0.852 | 0.855 | 0.654 | 0.655 | 0.840 | 0.850 | 0.850 | 0.865 | 0.850 | 0.852 | 0.860 | 0.850 | 0.859 | 0.879 |
| wpbc | 0.628 | 0.686 | 0.710 | 0.721 | 0.700 | 0.700 | 0.700 | 0.677 | 0.740 | 0.661 | 0.670 | 0.712 | 0.707 | 0.728 |
| average | 0.851 | 0.838 | 0.842 | 0.843 | 0.840 | 0.850 | 0.851 | 0.823 | 0.826 | 0.833 | 0.823 | 0.853 | 0.856 | **0.884** |

**Table 4: *F-measure* of 14 methods.**

| | SVM | Bagg | Ada | Asym | Under | SMOTE | Chan | RF | BRF | Under-RF | Over-RF | Cascade | Easy | My approach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| car | 0.909 | 0.933 | **0.967** | 0.966 | 0.884 | 0.930 | 0.916 | 0.307 | 0.521 | 0.513 | 0.518 | 0.945 | 0.917 | 0.943 |
| ionosphere | 0.926 | 0.883 | 0.907 | 0.910 | 0.900 | 0.907 | 0.910 | 0.906 | 0.887 | 0.895 | 0.904 | 0.903 | 0.903 | **0.929** |
| letter | 0.961 | 0.962 | 0.988 | 0.987 | 0.903 | 0.954 | 0.905 | 0.979 | 0.889 | 0.895 | 0.986 | 0.979 | 0.909 | **0.990** |
| phoneme | 0.726 | 0.834 | 0.850 | **0.852** | 0.819 | 0.847 | 0.837 | 0.850 | 0.821 | 0.813 | 0.851 | 0.833 | 0.822 | 0.730 |
| satimage | 0.582 | 0.641 | 0.664 | 0.668 | 0.546 | 0.610 | 0.607 | 0.666 | 0.553 | 0.557 | **0.689** | 0.647 | 0.572 | 0.607 |
| wdbc | 0.965 | 0.938 | 0.956 | 0.956 | 0.952 | 0.957 | 0.954 | 0.954 | 0.945 | 0.948 | 0.955 | 0.951 | 0.951 | **0.965** |
| abalone | 0.025 | 0.170 | 0.210 | 0.222 | 0.367 | 0.379 | 0.400 | 0.189 | 0.382 | 0.375 | 0.253 | 0.378 | 0.375 | **0.432** |
| balance | 0.000 | 0.000 | 0.000 | 0.000 | 0.175 | 0.149 | 0.156 | 0.000 | 0.167 | 0.168 | 0.000 | 0.198 | 0.161 | **0.443** |
| cmc | 0.137 | 0.362 | 0.388 | 0.400 | 0.429 | 0.421 | 0.437 | 0.347 | 0.441 | 0.435 | 0.408 | 0.437 | 0.453 | **0.473** |
| haberman | 0.204 | 0.334 | 0.348 | 0.360 | 0.442 | 0.405 | 0.380 | 0.321 | 0.468 | 0.445 | 0.348 | 0.431 | 0.463 | **0.470** |
| housing | 0.264 | 0.419 | 0.475 | 0.485 | 0.529 | 0.532 | 0.523 | 0.445 | 0.515 | 0.537 | 0.490 | 0.516 | 0.523 | **0.558** |
| mf-morph | 0.011 | 0.263 | 0.321 | 0.344 | 0.579 | 0.560 | 0.635 | 0.261 | 0.627 | 0.602 | 0.349 | 0.587 | 0.623 | **0.650** |
| mf-zernike | 0.087 | 0.183 | 0.188 | 0.191 | 0.538 | 0.538 | 0.577 | 0.144 | 0.500 | 0.530 | 0.292 | 0.538 | 0.567 | **0.603** |
| pima | 0.612 | 0.644 | 0.611 | 0.613 | 0.644 | 0.627 | 0.618 | 0.641 | 0.663 | 0.668 | 0.656 | 0.648 | 0.654 | **0.669** |
| vehicle | 0.477 | 0.526 | 0.545 | 0.561 | 0.623 | 0.615 | 0.608 | 0.544 | 0.633 | 0.633 | 0.564 | 0.618 | 0.637 | **0.669** |
| wpbc | 0.301 | 0.410 | 0.432 | 0.444 | 0.449 | **0.459** | 0.448 | 0.393 | 0.401 | 0.419 | 0.397 | 0.450 | 0.438 | 0.396 |
| average | 0.449 | 0.531 | 0.553 | 0.559 | 0.611 | 0.618 | 0.619 | 0.496 | 0.588 | 0.589 | 0.541 | 0.628 | 0.623 | **0.658** |

**Table 5: *G-mean* of 14 methods.**

| | SVM | Bagg | Ada | Asym | Under | SMOTE | Chan | RF | BRF | Under-RF | Over-RF | Cascade | Easy | My approach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| car | 0.944 | 0.964 | 0.980 | 0.981 | 0.956 | 0.969 | 0.970 | 0.452 | 0.693 | 0.687 | 0.690 | 0.980 | 0.973 | **0.982** |
| ionosphere | 0.941 | 0.906 | 0.820 | 0.922 | 0.918 | 0.922 | 0.923 | 0.918 | 0.911 | 0.916 | 0.918 | 0.920 | 0.921 | **0.941** |
| letter | 0.972 | 0.972 | 0.989 | 0.988 | 0.994 | 0.995 | 0.992 | 0.980 | 0.989 | 0.993 | 0.987 | **0.996** | 0.994 | 0.988 |
| phoneme | 0.796 | 0.880 | 0.8901 | 0.892 | 0.889 | **0.899** | 0.897 | 0.892 | 0.893 | 0.887 | 0.897 | 0.894 | 0.892 | 0.826 |
| satimage | 0.703 | 0.729 | 0.754 | 0.761 | 0.871 | 0.862 | 0.881 | 0.744 | 0.881 | 0.883 | 0.782 | 0.875 | 0.887 | **0.890** |
| wdbc | 0.972 | 0.950 | 0.963 | 0.963 | 0.963 | 0.964 | 0.962 | 0.962 | 0.957 | 0.960 | 0.963 | 0.962 | 0.963 | **0.972** |
| abalone | 0.076 | 0.337 | 0.396 | 0.412 | 0.765 | 0.742 | 0.778 | 0.363 | 0.790 | 0.778 | 0.457 | 0.752 | 0.780 | **0.792** |
| balance | 0.000 | 0.000 | 0.001 | 0.002 | 0.560 | 0.465 | 0.465 | 0.000 | 0.548 | 0.548 | 0.000 | 0.610 | 0.580 | **0.807** |
| cmc | 0.268 | 0.509 | 0.561 | 0.577 | 0.623 | 0.605 | 0.622 | 0.516 | 0.634 | 0.627 | 0.587 | 0.631 | 0.647 | **0.666** |
| haberman | 0.307 | 0.476 | 0.502 | 0.515 | 0.592 | 0.562 | 0.536 | 0.476 | **0.618** | 0.593 | 0.504 | 0.585 | 0.611 | 0.587 |
| housing | 0.382 | 0.553 | 0.615 | 0.627 | 0.725 | 0.710 | 0.698 | 0.580 | 0.718 | 0.735 | 0.638 | 0.710 | 0.730 | **0.738** |
| mf-morph | 0.018 | 0.483 | 0.560 | 0.594 | 0.873 | 0.841 | 0.920 | 0.479 | 0.918 | 0.888 | 0.597 | 0.863 | 0.914 | **0.926** |
| mf-zernike | 0.185 | 0.378 | 0.386 | 0.392 | 0.848 | 0.813 | 0.854 | 0.326 | 0.831 | 0.844 | 0.519 | 0.817 | 0.870 | **0.874** |
| pima | 0.690 | 0.720 | 0.694 | 0.696 | 0.719 | 0.708 | 0.700 | 0.717 | 0.735 | **0.740** | 0.731 | 0.728 | 0.732 | 0.730 |
| vehicle | 0.588 | 0.642 | 0.664 | 0.679 | 0.768 | 0.743 | 0.738 | 0.659 | 0.780 | 0.779 | 0.689 | 0.757 | 0.780 | **0.805** |
| wpbc | 0.378 | 0.510 | 0.537 | 0.549 | 0.617 | 0.610 | 0.585 | 0.477 | 0.567 | 0.588 | 0.494 | **0.630** | 0.628 | 0.598 |
| average | 0.513 | 0.625 | 0.644 | 0.659 | 0.792 | 0.775 | 0.782 | 0.596 | 0.778 | 0.777 | 0.653 | 0.794 | 0.806 | **0.820** |