**Table 11**. Overall results of eight versions of BSSMA according to S-shaped and V-shaped TFs in terms of the average number of the selected genes

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Datasets | Metrics | BSSMA\_S1 | BSSMA\_S2 | BSSMA\_S3 | BSSMA\_S4 | BSSMA\_V1 | BSSMA\_V2 | BSSMA\_V3 | BSSMA\_V4 |
| **Colon** | std | **19.7058** | 22.0249 | 18.5673 | 12.2537 | 2.2045 | 3.0477 | 2.4041 | 1.6274 |
| avg | **260.9903** | 4298.12 | 4738.099 | 5331.442 | 5057.738 | 518.9675 | 388.2886 | 507.6442 |
| **Brain\_Tumor2** | std | 214.5238 | 62.9072 | 43.1896 | 48.9939 | 5.0089 | 3.1609 | **5.7152** | 5.4913 |
| avg | 1191.06 | 4684.593 | 5273.229 | 5943.725 | 5061.967 | 520.4036 | **392.8672** | 514.7237 |
| **Tumors\_14** | std | 726.9196 | 611.0579 | 210.4332 | 237.8134 | 183.705 | 253.732 | 397.9083 | **193.0634** |
| avg | 6749.389 | 6907.044 | 7364.5 | 7364.809 | 1014.487 | 967.701 | 998.9565 | **946.6399** |
| **Leukemia2** | std | 45.6898 | 24.2587 | 87.2709 | 13.8932 | 0.89755 | **0.76437** | 0.75906 | 0.39472 |
| avg | 5887.458 | 5942.308 | 6846.467 | 6872.633 | 817.4185 | **536.1643** | 668.4718 | 558.2536 |
| **SRBCT** | std | 8.7177 | 23.2061 | 2.6932 | 5.6218 | 0.99567 | **0.36274** | 0.13695 | 0.38218 |
| avg | 5311.098 | 5193.452 | 5774.004 | 5776.753 | 773.2688 | **510.9916** | 638.5588 | 531.9679 |
| **Tumors\_11** | std | 410.7446 | 456.6929 | 250.7403 | 176.1742 | 67.5647 | **59.7402** | 48.7237 | 50.9057 |
| avg | 5115.444 | 5479.021 | 6444.724 | 6369.189 | 668.3305 | **489.8877** | 568.5688 | 498.075 |
| **Brain\_Tumor1** | std | 165.8355 | 157.6661 | 103.0222 | 57.2702 | 5.5198 | 9.4199 | 4.9458 | **4.1365** |
| avg | 4496.821 | 5001.747 | 5584.79 | 5461.897 | 541.2675 | 416.1088 | 542.1214 | **378.6555** |
| **Prostate\_Tumor** | std | 68.4463 | 115.2876 | 81.5458 | 74.7306 | 0.92656 | 3.7039 | 0.26898 | **0.2027** |
| avg | 4494.775 | 5223.732 | 5995.021 | 5959.582 | 516.3247 | 388.1341 | 507.2799 | **359.9744** |
| **Tumors\_9** | std | 67.5621 | 57.5783 | 19.3312 | 18.8365 | 16.4963 | 29.0172 | 21.5801 | **23.6806** |
| avg | 4668.186 | 5113.229 | 5735.123 | 5620.812 | 601.3438 | 466.7838 | 566.1276 | **431.6045** |
| ARV | | 4.7111 | 5.6111 | 7.3111 | 7.4778 | 4.3556 | 2.0778 | 2.6111 | **1.8444** |
| Rank | | 5 | 6 | 7 | 8 | 4 | 2 | 3 | **1** |

**Table 12**. Overall results of eight versions of BSSMA according to S-shaped and V-shaped TFs in terms of average error rate

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Datasets | Metrics | BSSMA\_S1 | BSSMA\_S2 | BSSMA\_S3 | BSSMA\_S4 | BSSMA\_V1 | BSSMA\_V2 | BSSMA\_V3 | BSSMA\_V4 |
| **Colon** | std | **6.376E-02** | 4.311E-02 | 6.114E-02 | 2.862E-02 | 2.926E-17 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| avg | **0.02016** | 0.16242 | 0.24246 | 0.14751 | 0.13574 | 0.05857 | 0.08479 | 0.06968 |
| **Brain\_Tumor2** | std | **5.100E-02** | 1.335E-02 | 2.933E-02 | 0.000E+00 | 2.926E-17 | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| avg | **0.01613** | 0.14083 | 0.21998 | 0.13955 | 0.13574 | 0.05857 | 0.08479 | 0.06968 |
| **Tumors\_14** | std | 4.642E-02 | 7.726E-02 | 5.576E-02 | 5.228E-02 | **5.691E-02** | 4.834E-02 | 5.777E-02 | 7.913E-02 |
| avg | 0.34840 | 0.32401 | 0.33743 | 0.30711 | **0.18733** | 0.21239 | 0.21611 | 0.23869 |
| **Leukemia2** | std | 3.080E-03 | 5.851E-17 | 8.355E-03 | 2.926E-17 | **1.463E-17** | 0.000E+00 | 0.000E+00 | 5.851E-17 |
| avg | 0.23636 | 0.28297 | 0.23754 | 0.23814 | **0.10390** | 0.15047 | 0.12250 | 0.26511 |
| **SRBCT** | std | 2.926E-17 | 1.540E-03 | 5.851E-17 | 5.851E-17 | **0.000E+00** | 0.000E+00 | 0.000E+00 | 0.000E+00 |
| avg | 0.22440 | 0.27022 | 0.22290 | 0.22715 | **0.09928** | 0.14323 | 0.11726 | 0.25287 |
| **Tumors\_11** | std | 2.894E-02 | 4.270E-02 | 4.154E-02 | 4.166E-02 | **1.910E-03** | 4.996E-03 | 7.658E-03 | 4.082E-03 |
| avg | 0.16177 | 0.22038 | 0.19389 | 0.17963 | **0.05942** | 0.08671 | 0.07263 | 0.15261 |
| **Brain\_Tumor1** | std | 2.888E-02 | 3.168E-02 | 3.920E-02 | 3.511E-02 | **7.451E-03** | 1.543E-02 | 1.164E-02 | 1.571E-02 |
| avg | 0.17314 | 0.23938 | 0.19480 | 0.19795 | **0.06188** | 0.09635 | 0.07611 | 0.16183 |
| **Prostate\_Tumor** | std | 4.672E-02 | 2.567E-03 | 0.000E+00 | 2.926E-17 | **0.000E+00** | 0.000E+00 | 0.000E+00 | 2.926E-17 |
| avg | 0.14927 | 0.18548 | 0.13793 | 0.13574 | **0.05857** | 0.08479 | 0.06968 | 0.15060 |
| **Tumors\_9** | std | 1.860E-02 | 1.813E-02 | 1.703E-02 | 2.115E-02 | **8.780E-03** | 9.444E-03 | 9.608E-03 | 8.740E-03 |
| avg | 0.17574 | 0.22605 | 0.18270 | 0.18080 | **0.08414** | 0.10221 | 0.09183 | 0.17318 |
| ARV | | 4.3778 | 7.0778 | 6.0778 | 6.0000 | **2.2222** | 2.6667 | 2.5222 | 5.0556 |
| Rank | | 4 | 8 | 7 | 6 | **1** | 3 | 2 | 5 |

**Table 13**. Overall results of eight versions of BSSMA according to S-shaped and V-shaped TFs in terms of average fitness

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Datasets | Metrics | BSSMA\_S1 | BSSMA\_S2 | BSSMA\_S3 | BSSMA\_S4 | BSSMA\_V1 | BSSMA\_V2 | BSSMA\_V3 | BSSMA\_V4 |
| **Colon** | std | **6.034E-02** | 4.102E-02 | 5.807E-02 | 2.718E-02 | 5.511E-05 | 7.619E-05 | 6.010E-05 | 4.069E-05 |
| avg | **0.02568** | 0.17201 | 0.25082 | 0.16306 | 0.14742 | 0.05748 | 0.08193 | 0.06798 |
| **Brain\_Tumor2** | std | **4.808E-02** | 1.263E-02 | 2.792E-02 | 2.363E-04 | 2.416E-05 | 1.525E-05 | 2.757E-05 | 2.648E-05 |
| avg | **0.02197** | 0.15146 | 0.22943 | 0.15584 | 0.14741 | 0.05742 | 0.08193 | 0.06801 |
| **Tumors\_14** | std | 4.304E-02 | 7.161E-02 | 5.280E-02 | 4.974E-02 | **5.372E-02** | 4.556E-02 | 5.479E-02 | 7.492E-02 |
| avg | 0.35347 | 0.33082 | 0.34509 | 0.31628 | **0.18134** | 0.20499 | 0.20863 | 0.22991 |
| **Leukemia2** | std | 3.088E-03 | 1.081E-04 | 8.318E-03 | 6.189E-05 | **3.998E-06** | 3.405E-06 | 3.381E-06 | 1.758E-06 |
| avg | 0.24458 | 0.28939 | 0.24962 | 0.25033 | **0.10143** | 0.14474 | 0.11861 | 0.25372 |
| **SRBCT** | std | 1.889E-04 | 1.958E-03 | 5.835E-05 | 1.218E-04 | **2.157E-05** | 7.858E-06 | 2.967E-06 | 8.279E-06 |
| avg | 0.23240 | 0.27707 | 0.23508 | 0.23958 | **0.09692** | 0.13779 | 0.11354 | 0.24202 |
| **Tumors\_11** | std | 2.669E-02 | 4.073E-02 | 3.945E-02 | 4.007E-02 | **1.862E-03** | 4.824E-03 | 7.328E-03 | 3.942E-03 |
| avg | 0.17206 | 0.22923 | 0.20771 | 0.19389 | **0.05882** | 0.08412 | 0.07101 | 0.14675 |
| **Brain\_Tumor1** | std | 2.631E-02 | 2.939E-02 | 3.667E-02 | 3.341E-02 | **7.084E-03** | 1.469E-02 | 1.107E-02 | 1.493E-02 |
| avg | 0.18202 | 0.24792 | 0.20830 | 0.21106 | **0.06071** | 0.09307 | 0.07429 | 0.15510 |
| **Prostate\_Tumor** | std | 4.434E-02 | 2.899E-03 | 3.880E-04 | 3.556E-04 | **4.408E-06** | 1.762E-05 | 1.280E-06 | 9.644E-07 |
| avg | 0.15809 | 0.19581 | 0.15377 | 0.15168 | **0.05740** | 0.08190 | 0.06796 | 0.14429 |
| **Tumors\_9** | std | 1.723E-02 | 1.704E-02 | 1.610E-02 | 2.000E-02 | **8.384E-03** | 8.844E-03 | 9.162E-03 | 8.153E-03 |
| avg | 0.18598 | 0.23585 | 0.19723 | 0.19498 | **0.08244** | 0.09914 | 0.08952 | 0.16637 |
| ARV | | 4.3000 | 7.1111 | 6.5000 | 6.1778 | **2.2111** | 2.6556 | 2.5222 | 4.5222 |
| Rank | | 4 | 8 | 7 | 6 | **1** | 3 | 2 | 5 |

**Table 14**. Overall results of eight versions of BSSMA according to S-shaped and V-shaped TFs in terms of average computational time

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Datasets | Metrics | BSSMA\_S1 | BSSMA\_S2 | BSSMA\_S3 | BSSMA\_S4 | BSSMA\_V1 | BSSMA\_V2 | BSSMA\_V3 | BSSMA\_V4 |
| **Colon** | std | **0.6183** | 0.0162 | 0.0074 | 0.0090 | 0.0336 | 0.0204 | 0.0097 | 0.0091 |
| avg | **10.7771** | 217.5316 | 201.6031 | 194.2575 | 189.096 | 107.7751 | 90.4676 | 92.8098 |
| **Brain\_Tumor2** | std | **0.4114** | 0.0953 | 0.0406 | 0.0514 | 0.0914 | 0.0579 | 0.0220 | 0.0830 |
| avg | **37.6781** | 223.127 | 207.0841 | 199.7006 | 194.6068 | 111.5399 | 94.1581 | 96.4895 |
| **Tumors\_14** | std | 7.7795 | 6.3478 | 5.0867 | 4.3486 | 11.9219 | 10.6855 | 13.9252 | **8.0732** |
| avg | 408.5232 | 383.1298 | 359.7082 | 348.5146 | 189.8167 | 170.0089 | 167.9614 | **166.1755** |
| **Leukemia2** | std | 0.1352 | 0.2034 | 0.0692 | 0.0852 | 0.0812 | **0.1364** | 0.1255 | 0.0988 |
| avg | 331.0028 | 301.9078 | 287.0312 | 278.7047 | 156.0169 | **129.4519** | 133.9778 | 129.8412 |
| **SRBCT** | std | 0.0199 | 0.0445 | 0.0091 | 0.0099 | 0.0176 | **0.0163** | 0.0116 | 0.0141 |
| avg | 307.03 | 277.777 | 264.3992 | 257.2232 | 140.9733 | **118.1448** | 122.7165 | 118.3387 |
| **Tumors\_11** | std | 2.6657 | 1.7671 | 0.6657 | 0.7685 | 1.6581 | 1.3763 | 1.4048 | **1.6349** |
| avg | 253.0241 | 235.0671 | 226.5466 | 220.013 | 128.1415 | 105.6225 | 107.7287 | **105.3999** |
| **Brain\_Tumor1** | std | 0.2400 | 0.1303 | 0.1091 | 0.0551 | 0.1067 | 0.0971 | 0.0904 | **0.1121** |
| avg | 223.1625 | 206.9299 | 199.6826 | 193.9751 | 111.2453 | 93.0315 | 95.691 | **91.4514** |
| **Prostate\_Tumor** | std | 0.2480 | 0.2804 | 0.2870 | 0.1751 | 0.4128 | 0.4190 | 0.3046 | **0.2953** |
| avg | 228.189 | 212.2478 | 204.7651 | 199.047 | 115.99 | 96.0338 | 98.5334 | **94.4438** |
| **Tumors\_9** | std | 0.0691 | 0.0446 | 0.0332 | 0.0154 | 0.0676 | 0.0777 | 0.0690 | **0.0737** |
| avg | 222.0424 | 205.9072 | 198.4233 | 192.7774 | 111.9928 | 93.163 | 95.4458 | **91.7375** |
| ARV | | 6.4444 | 7.2222 | 6.2222 | 5.2222 | 4.2000 | 2.2222 | 2.6000 | **1.8667** |
| Rank | | 7 | 8 | 6 | 5 | 4 | 2 | 3 | **1** |

Fig. 10 Bonferroni-Dunn test for comparing BSSMA\_V4 with other versions of BSSMA in terms of the average number of selected genes

Fig. 11 Bonferroni-Dunn test for comparing BSSMA\_V1 with other versions of BSSMA in terms of average error rate

Fig. 12 Bonferroni-Dunn test for comparing BSSMA\_V1 with other versions of BSSMA in terms of average fitness

Fig. 13 Bonferroni-Dunn test for comparing BSSMA\_V4 with other versions of BSSMA in terms of computational time