**Novel hybrid machine learning models for failure mode identification and shear strength prediction of rectangular hollow RC columns subjected to compressive and lateral loads**

Viet-Linh Tran1, Duy-Duan Nguyen1, Van-Tien Phan1, Trong-Ha Nguyen1, Tae-Hyung Lee2\*

1 Department of Civil Engineering, Vinh University, Vinh 461010, Vietnam

2 Department of Civil and Environmental Engineering, Konkuk University, Seoul 05029, Korea

\*Corresponding author

Email addresses: vietlinh.dhv@gmail.com (Viet-Linh Tran); duan468@gmail.com (Duy-Duan Nguyen); vantienkxd@vinhuni.edu.vn (Van-Tien Phan); trongha.kxd@gmail.com (Trong-Ha Nguyen); thlee@konkuk.ac.kr (Tae-Hyung Lee)

**1. Results of shear strength prediction**

**A screenshot of a video game

Description automatically generated with low confidence**

**A picture containing text, screenshot, graphic design, graphics

Description automatically generated**

**Fig. S-1.** Effect of training-test ratios on the MFO-SVM model’s performance with population size of 50.

A screenshot of a video game

Description automatically generated with low confidence

A picture containing text, screenshot, graphic design, graphics

Description automatically generated

**Fig. S-2.** Effect of training-test ratios on the MFO- SVM model’s performance with population size of 100.

A screenshot of a video game

Description automatically generated with low confidence

A picture containing text, screenshot, graphic design, graphics

Description automatically generated

**Fig. S-3.** Effect of training-test ratios on the MFO- SVM model’s performance with population size of 150.

A screenshot of a video game

Description automatically generated with low confidence

A picture containing text, screenshot, graphic design, graphics

Description automatically generated

**Fig. S-4.** Effect of training-test ratios on the MFO- SVM model’s performance with population size of 200.

A screenshot of a video game

Description automatically generated with low confidence

A picture containing text, screenshot, graphic design, graphics

Description automatically generated

**Fig. S-5.** Effect of training-test ratios on the MFO- SVM model’s performance with population size of 250.

A screenshot of a video game

Description automatically generated with low confidence

A picture containing text, screenshot, graphic design, graphics

Description automatically generated

**Fig. S-6.** Effect of training-test ratios on the MFO- SVM model’s performance with population size of 300.

**Table S-1** Performance of MFO- SVM models on the training set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **R2** | **Score** | **A10** | **Score** | **RMSE** | **Score** | **MAE** | **Score** | **Total** |
| 50 | 0.55 | -0.136 | 1 | 0.106 | 1 | 667.673 | 7 | 337.375 | 11 | 20 |
|  | 0.60 | -0.131 | 7 | 0.167 | 43 | 644.763 | 24 | 326.727 | 25 | 99 |
|  | 0.65 | -0.121 | 25 | 0.141 | 37 | 623.806 | 42 | 317.221 | 37 | 141 |
|  | 0.70 | -0.111 | 43 | 0.131 | 25 | 604.739 | 43 | 310.274 | 48 | 159 |
|  | 0.75 | -0.123 | 15 | 0.122 | 19 | 636.536 | 28 | 331.47 | 15 | 77 |
|  | 0.80 | -0.123 | 15 | 0.115 | 7 | 670.143 | 3 | 343.831 | 4 | 29 |
|  | 0.85 | -0.119 | 31 | 0.137 | 31 | 651.737 | 14 | 330.544 | 23 | 99 |
|  | 0.90 | -0.113 | 37 | 0.12 | 13 | 635.843 | 33 | 321.855 | 34 | 117 |
| 100 | 0.55 | -0.136 | 1 | 0.106 | 1 | 667.666 | 12 | 337.377 | 7 | 21 |
|  | 0.60 | -0.131 | 7 | 0.167 | 43 | 644.768 | 22 | 326.723 | 26 | 98 |
|  | 0.65 | -0.121 | 25 | 0.141 | 37 | 623.81 | 40 | 317.219 | 38 | 140 |
|  | 0.70 | -0.111 | 43 | 0.131 | 25 | 604.7 | 44 | 310.287 | 47 | 159 |
|  | 0.75 | -0.123 | 15 | 0.122 | 19 | 636.527 | 29 | 331.477 | 14 | 77 |
|  | 0.80 | -0.122 | 22 | 0.115 | 7 | 670.118 | 4 | 343.842 | 3 | 36 |
|  | 0.85 | -0.119 | 31 | 0.137 | 31 | 651.731 | 15 | 330.545 | 22 | 99 |
|  | 0.90 | -0.113 | 37 | 0.12 | 13 | 635.861 | 32 | 321.853 | 35 | 117 |
| 150 | 0.55 | -0.136 | 1 | 0.106 | 1 | 667.668 | 10 | 337.376 | 9 | 21 |
|  | 0.60 | -0.131 | 7 | 0.167 | 43 | 644.795 | 20 | 326.703 | 29 | 99 |
|  | 0.65 | -0.121 | 25 | 0.141 | 37 | 623.814 | 37 | 317.218 | 40 | 139 |
|  | 0.70 | -0.111 | 43 | 0.131 | 25 | 604.642 | 47 | 310.314 | 43 | 158 |
|  | 0.75 | -0.124 | 13 | 0.122 | 19 | 636.563 | 25 | 331.455 | 18 | 75 |
|  | 0.80 | -0.122 | 22 | 0.115 | 7 | 670.047 | 6 | 343.916 | 1 | 36 |
|  | 0.85 | -0.119 | 31 | 0.137 | 31 | 651.696 | 17 | 330.551 | 20 | 99 |
|  | 0.90 | -0.113 | 37 | 0.12 | 13 | 635.835 | 34 | 321.856 | 32 | 116 |
| 200 | 0.55 | -0.136 | 1 | 0.106 | 1 | 667.667 | 11 | 337.377 | 7 | 20 |
|  | 0.60 | -0.131 | 7 | 0.167 | 43 | 644.785 | 21 | 326.71 | 28 | 99 |
|  | 0.65 | -0.121 | 25 | 0.141 | 37 | 623.814 | 37 | 317.218 | 40 | 139 |
|  | 0.70 | -0.111 | 43 | 0.131 | 25 | 604.691 | 45 | 310.291 | 46 | 159 |
|  | 0.75 | -0.124 | 13 | 0.122 | 19 | 636.551 | 26 | 331.461 | 17 | 75 |
|  | 0.80 | -0.122 | 22 | 0.115 | 7 | 670.076 | 5 | 343.867 | 2 | 36 |
|  | 0.85 | -0.119 | 31 | 0.137 | 31 | 651.714 | 16 | 330.548 | 21 | 99 |
|  | 0.90 | -0.113 | 37 | 0.12 | 13 | 635.822 | 36 | 321.858 | 31 | 117 |
| 250 | 0.55 | -0.136 | 1 | 0.106 | 1 | 667.672 | 8 | 337.375 | 11 | 21 |
|  | 0.60 | -0.131 | 7 | 0.167 | 43 | 644.768 | 22 | 326.723 | 26 | 98 |
|  | 0.65 | -0.121 | 25 | 0.141 | 37 | 623.814 | 37 | 317.218 | 40 | 139 |
|  | 0.70 | -0.111 | 43 | 0.131 | 25 | 604.65 | 46 | 310.31 | 45 | 159 |
|  | 0.75 | -0.123 | 15 | 0.122 | 19 | 636.545 | 27 | 331.465 | 16 | 77 |
|  | 0.80 | -0.123 | 15 | 0.115 | 7 | 670.152 | 2 | 343.827 | 5 | 29 |
|  | 0.85 | -0.119 | 31 | 0.137 | 31 | 651.744 | 13 | 330.544 | 23 | 98 |
|  | **0.90** | -0.113 | 37 | 0.12 | 13 | 635.862 | 31 | 321.853 | 35 | 116 |
| 300 | 0.55 | -0.136 | 1 | 0.106 | 1 | 667.67 | 9 | 337.376 | 9 | 20 |
|  | 0.60 | -0.131 | 7 | 0.167 | 43 | 644.803 | 19 | 326.698 | 30 | 99 |
|  | 0.65 | -0.121 | 25 | 0.141 | 37 | 623.81 | 40 | 317.219 | 38 | 140 |
|  | 0.70 | -0.111 | 43 | 0.131 | 25 | 604.642 | 47 | 310.314 | 43 | 158 |
|  | 0.75 | -0.123 | 15 | 0.122 | 19 | 636.51 | 30 | 331.491 | 13 | 77 |
|  | 0.80 | -0.123 | 15 | 0.115 | 7 | 670.154 | 1 | 343.826 | 6 | 29 |
|  | 0.85 | -0.119 | 31 | 0.137 | 31 | 651.69 | 18 | 330.553 | 19 | 99 |
|  | 0.90 | -0.113 | 37 | 0.12 | 13 | 635.833 | 35 | 321.856 | 32 | 117 |

**Table S-2** Performance of MFO-SVM models on the test set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **R2** | **Score** | **A10** | **Score** | **RMSE** | **Score** | **MAE** | **Score** | **Total** |
| 50 | 0.55 | -0.139 | 37 | 0.145 | 25 | 731.87 | 43 | 367.893 | 45 | 150 |
|  | 0.60 | -0.124 | 43 | 0.061 | 1 | 761.846 | 42 | 386.422 | 31 | 117 |
|  | 0.65 | -0.151 | 19 | 0.116 | 13 | 809.907 | 30 | 411.068 | 19 | 81 |
|  | 0.70 | -0.175 | 7 | 0.135 | 19 | 866.787 | 13 | 440.621 | 16 | 55 |
|  | 0.75 | -0.141 | 31 | 0.161 | 37 | 840.591 | 22 | 403.151 | 27 | 117 |
|  | 0.80 | -0.142 | 25 | 0.2 | 43 | 780.595 | 33 | 370.966 | 40 | 141 |
|  | 0.85 | -0.164 | 13 | 0.105 | 7 | 887.792 | 8 | 448.504 | 8 | 36 |
|  | 0.90 | -0.255 | 1 | 0.154 | 31 | 1063.558 | 3 | 571.976 | 4 | 39 |
| 100 | 0.55 | -0.139 | 37 | 0.145 | 25 | 731.865 | 47 | 367.894 | 43 | 152 |
|  | 0.60 | -0.124 | 43 | 0.061 | 1 | 761.851 | 40 | 386.42 | 32 | 116 |
|  | 0.65 | -0.151 | 19 | 0.116 | 13 | 809.91 | 28 | 411.067 | 20 | 80 |
|  | 0.70 | -0.175 | 7 | 0.135 | 19 | 866.748 | 14 | 440.62 | 17 | 57 |
|  | 0.75 | -0.141 | 31 | 0.161 | 37 | 840.585 | 23 | 403.157 | 26 | 117 |
|  | 0.80 | -0.142 | 25 | 0.2 | 43 | 780.571 | 34 | 370.975 | 39 | 141 |
|  | 0.85 | -0.164 | 13 | 0.105 | 7 | 887.787 | 9 | 448.504 | 8 | 37 |
|  | 0.90 | -0.255 | 1 | 0.154 | 31 | 1063.578 | 2 | 571.973 | 5 | 39 |
| **150** | **0.55** | **-0.139** | **37** | **0.145** | **25** | **731.866** | **46** | **367.893** | **45** | **153** |
|  | 0.60 | -0.124 | 43 | 0.061 | 1 | 761.879 | 38 | 386.406 | 35 | 117 |
|  | 0.65 | -0.151 | 19 | 0.116 | 13 | 809.914 | 25 | 411.067 | 20 | 77 |
|  | 0.70 | -0.175 | 7 | 0.135 | 19 | 866.688 | 17 | 440.623 | 13 | 56 |
|  | 0.75 | -0.141 | 31 | 0.161 | 37 | 840.608 | 19 | 403.136 | 30 | 117 |
|  | 0.80 | -0.142 | 25 | 0.2 | 43 | 780.492 | 36 | 371.029 | 37 | 141 |
|  | 0.85 | -0.164 | 13 | 0.105 | 7 | 887.751 | 11 | 448.504 | 8 | 39 |
|  | 0.90 | -0.255 | 1 | 0.154 | 31 | 1063.548 | 4 | 571.977 | 3 | 39 |
| 200 | 0.55 | -0.139 | 37 | 0.145 | 25 | 731.865 | 47 | 367.894 | 43 | 152 |
|  | 0.60 | -0.124 | 43 | 0.061 | 1 | 761.868 | 39 | 386.411 | 34 | 117 |
|  | 0.65 | -0.151 | 19 | 0.116 | 13 | 809.914 | 25 | 411.067 | 20 | 77 |
|  | 0.70 | -0.175 | 7 | 0.135 | 19 | 866.739 | 15 | 440.62 | 17 | 58 |
|  | 0.75 | -0.141 | 31 | 0.161 | 37 | 840.601 | 20 | 403.142 | 29 | 117 |
|  | 0.80 | -0.142 | 25 | 0.2 | 43 | 780.529 | 35 | 370.993 | 38 | 141 |
|  | 0.85 | -0.164 | 13 | 0.105 | 7 | 887.769 | 10 | 448.504 | 8 | 38 |
|  | 0.90 | -0.255 | 1 | 0.154 | 31 | 1063.533 | 6 | 571.981 | 1 | 39 |
| 250 | 0.55 | -0.139 | 37 | 0.145 | 25 | 731.869 | 44 | 367.893 | 45 | 151 |
|  | 0.60 | -0.124 | 43 | 0.061 | 1 | 761.851 | 40 | 386.42 | 32 | 116 |
|  | 0.65 | -0.151 | 19 | 0.116 | 13 | 809.914 | 25 | 411.067 | 20 | 77 |
|  | 0.70 | -0.175 | 7 | 0.135 | 19 | 866.696 | 16 | 440.622 | 15 | 57 |
|  | 0.75 | -0.141 | 31 | 0.161 | 37 | 840.597 | 21 | 403.146 | 28 | 117 |
|  | 0.80 | -0.142 | 25 | 0.2 | 43 | 780.604 | 32 | 370.963 | 41 | 141 |
|  | 0.85 | -0.164 | 13 | 0.105 | 7 | 887.798 | 7 | 448.504 | 8 | 35 |
|  | 0.90 | -0.255 | 1 | 0.154 | 31 | 1063.579 | 1 | 571.973 | 5 | 38 |
| 300 | 0.55 | -0.139 | 37 | 0.145 | 25 | 731.867 | 45 | 367.893 | 45 | 152 |
|  | 0.60 | -0.124 | 43 | 0.061 | 1 | 761.886 | 37 | 386.403 | 36 | 117 |
|  | 0.65 | -0.151 | 19 | 0.116 | 13 | 809.91 | 28 | 411.067 | 20 | 80 |
|  | 0.70 | -0.175 | 7 | 0.135 | 19 | 866.688 | 17 | 440.623 | 13 | 56 |
|  | 0.75 | -0.141 | 31 | 0.161 | 37 | 840.573 | 24 | 403.17 | 25 | 117 |
|  | 0.80 | -0.142 | 25 | 0.2 | 43 | 780.606 | 31 | 370.962 | 42 | 141 |
|  | 0.85 | -0.164 | 13 | 0.105 | 7 | 887.745 | 12 | 448.505 | 7 | 39 |
|  | 0.90 | -0.255 | 1 | 0.154 | 31 | 1063.546 | 5 | 571.978 | 2 | 39 |

**2. Results of failure modes identification**

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

A picture containing screenshot, text, colorfulness, graphic design

Description automatically generated

**Fig. S-7.** Effect of training-test ratios on the MFO- SVM model’s performance with population size of 50.

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

A picture containing screenshot, text, colorfulness, graphic design

Description automatically generated

**Fig. S-8.** Effect of training-test ratios on the MFO-SVM model’s performance with population size of 100.

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

**Fig. S-9.** Effect of training-test ratios on the MFO-SVM model’s performance with population size of 150.

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

A picture containing screenshot, text, colorfulness, graphic design

Description automatically generated

**Fig. S-10.** Effect of training-test ratios on the MFO-SVM model’s performance with population size of 200.

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

A picture containing screenshot, text, colorfulness, graphic design

Description automatically generated

**Fig. S-11.** Effect of training-test ratios on the MFO-SVM model’s performance with population size of 250.

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

A picture containing text, screenshot, colorfulness, graphic design

Description automatically generated

**Fig. S-12.** Effect of training-test ratios on the MFO-SVM model’s performance with population size of 300.

**Table S-3** Performance of MFO-SVM models on the training set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **Acc** | **Score** | **Pre** | **Score** | **Re** | **Score** | **f1** | **Score** | **Total** |
| 50 | 0.55 | 0.78 | 2 | 0.789 | 2 | 0.78 | 2 | 0.78 | 2 | 8 |
|  | 0.60 | 0.807 | 8 | 0.812 | 11 | 0.807 | 8 | 0.807 | 8 | 35 |
|  | 0.65 | 0.814 | 19 | 0.82 | 21 | 0.814 | 19 | 0.813 | 19 | 78 |
|  | 0.70 | 0.836 | 41 | 0.84 | 39 | 0.836 | 41 | 0.835 | 41 | 162 |
|  | 0.75 | 0.825 | 31 | 0.827 | 31 | 0.825 | 31 | 0.824 | 31 | 124 |
|  | 0.80 | 0.829 | 36 | 0.831 | 36 | 0.829 | 36 | 0.828 | 36 | 144 |
|  | 0.85 | 0.819 | 29 | 0.823 | 29 | 0.819 | 29 | 0.818 | 29 | 116 |
|  | 0.90 | 0.841 | 45 | 0.846 | 45 | 0.841 | 45 | 0.841 | 45 | 180 |
| 100 | 0.55 | 0.78 | 2 | 0.789 | 2 | 0.78 | 2 | 0.78 | 2 | 8 |
|  | 0.60 | 0.807 | 8 | 0.812 | 11 | 0.807 | 8 | 0.807 | 8 | 35 |
|  | 0.65 | 0.814 | 19 | 0.82 | 21 | 0.814 | 19 | 0.813 | 19 | 78 |
|  | 0.70 | 0.812 | 17 | 0.818 | 17 | 0.812 | 17 | 0.812 | 17 | 68 |
|  | 0.75 | 0.818 | 24 | 0.82 | 26 | 0.818 | 24 | 0.817 | 26 | 100 |
|  | 0.80 | 0.836 | 40 | 0.837 | 38 | 0.836 | 40 | 0.835 | 40 | 158 |
|  | 0.85 | 0.826 | 32 | 0.83 | 32 | 0.826 | 32 | 0.825 | 32 | 128 |
|  | 0.90 | 0.841 | 45 | 0.846 | 45 | 0.841 | 45 | 0.841 | 45 | 180 |
| 150 | 0.55 | 0.78 | 2 | 0.789 | 2 | 0.78 | 2 | 0.78 | 2 | 8 |
|  | 0.60 | 0.807 | 8 | 0.812 | 11 | 0.807 | 8 | 0.807 | 8 | 35 |
|  | 0.65 | 0.797 | 7 | 0.8 | 7 | 0.797 | 7 | 0.795 | 7 | 28 |
|  | 0.70 | 0.836 | 41 | 0.84 | 39 | 0.836 | 41 | 0.835 | 41 | 162 |
|  | 0.75 | 0.818 | 24 | 0.819 | 19 | 0.818 | 24 | 0.816 | 24 | 91 |
|  | 0.80 | 0.808 | 14 | 0.81 | 8 | 0.808 | 14 | 0.807 | 14 | 50 |
|  | 0.85 | 0.826 | 32 | 0.83 | 32 | 0.826 | 32 | 0.825 | 32 | 128 |
|  | 0.90 | 0.835 | 38 | 0.842 | 43 | 0.835 | 38 | 0.834 | 38 | 157 |
| 200 | 0.55 | 0.78 | 2 | 0.789 | 2 | 0.78 | 2 | 0.78 | 2 | 8 |
|  | 0.60 | 0.807 | 8 | 0.812 | 11 | 0.807 | 8 | 0.807 | 8 | 35 |
|  | 0.65 | 0.814 | 19 | 0.82 | 21 | 0.814 | 19 | 0.813 | 19 | 78 |
|  | 0.70 | 0.812 | 17 | 0.818 | 17 | 0.812 | 17 | 0.812 | 17 | 68 |
|  | 0.75 | 0.818 | 24 | 0.82 | 26 | 0.818 | 24 | 0.817 | 26 | 100 |
|  | 0.80 | 0.808 | 14 | 0.81 | 8 | 0.808 | 14 | 0.807 | 14 | 50 |
|  | 0.85 | 0.826 | 32 | 0.83 | 32 | 0.826 | 32 | 0.825 | 32 | 128 |
|  | 0.90 | 0.841 | 45 | 0.846 | 45 | 0.841 | 45 | 0.841 | 45 | 180 |
| 250 | 0.55 | 0.77 | 1 | 0.778 | 1 | 0.77 | 1 | 0.769 | 1 | 4 |
|  | 0.60 | 0.807 | 8 | 0.812 | 11 | 0.807 | 8 | 0.807 | 8 | 35 |
|  | 0.65 | 0.814 | 19 | 0.82 | 21 | 0.814 | 19 | 0.813 | 19 | 78 |
|  | 0.70 | 0.836 | 41 | 0.84 | 39 | 0.836 | 41 | 0.835 | 41 | 162 |
|  | 0.75 | 0.818 | 24 | 0.82 | 26 | 0.818 | 24 | 0.817 | 26 | 100 |
|  | 0.80 | 0.829 | 36 | 0.831 | 36 | 0.829 | 36 | 0.828 | 36 | 144 |
|  | 0.85 | 0.819 | 29 | 0.823 | 29 | 0.819 | 29 | 0.818 | 29 | 116 |
|  | 0.90 | 0.835 | 38 | 0.842 | 43 | 0.835 | 38 | 0.834 | 38 | 157 |
| 300 | 0.55 | 0.78 | 2 | 0.789 | 2 | 0.78 | 2 | 0.78 | 2 | 8 |
|  | 0.60 | 0.807 | 8 | 0.812 | 11 | 0.807 | 8 | 0.807 | 8 | 35 |
|  | 0.65 | 0.814 | 19 | 0.82 | 21 | 0.814 | 19 | 0.813 | 19 | 78 |
|  | 0.70 | 0.836 | 41 | 0.84 | 39 | 0.836 | 41 | 0.835 | 41 | 162 |
|  | 0.75 | 0.818 | 24 | 0.819 | 19 | 0.818 | 24 | 0.816 | 24 | 91 |
|  | 0.80 | 0.808 | 14 | 0.81 | 8 | 0.808 | 14 | 0.807 | 14 | 50 |
|  | 0.85 | 0.826 | 32 | 0.83 | 32 | 0.826 | 32 | 0.825 | 32 | 128 |
|  | 0.90 | 0.841 | 45 | 0.848 | 48 | 0.841 | 45 | 0.841 | 48 | 186 |

**Table S-4** Performance of MFO-SVM models on the test set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **Acc** | **Score** | **Pre** | **Score** | **Re** | **Score** | **f1** | **Score** | **Total** |
| 50 | 0.55 | 0.807 | 1 | 0.807 | 1 | 0.807 | 1 | 0.806 | 1 | 4 |
|  | 0.60 | 0.811 | 7 | 0.81 | 7 | 0.811 | 7 | 0.81 | 7 | 28 |
|  | 0.65 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 52 |
|  | 0.70 | 0.836 | 25 | 0.849 | 25 | 0.836 | 25 | 0.838 | 25 | 100 |
|  | **0.75** | **0.87** | **43** | **0.879** | **43** | **0.87** | **43** | **0.871** | **43** | **172** |
|  | 0.80 | 0.838 | 31 | 0.854 | 37 | 0.838 | 31 | 0.842 | 31 | 130 |
|  | 0.85 | 0.821 | 19 | 0.837 | 19 | 0.821 | 19 | 0.822 | 19 | 76 |
|  | 0.90 | 0.842 | 37 | 0.854 | 31 | 0.842 | 37 | 0.843 | 37 | 142 |
| 100 | 0.55 | 0.807 | 1 | 0.807 | 1 | 0.807 | 1 | 0.806 | 1 | 4 |
|  | 0.60 | 0.811 | 7 | 0.81 | 7 | 0.811 | 7 | 0.81 | 7 | 28 |
|  | 0.65 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 52 |
|  | 0.70 | 0.836 | 25 | 0.849 | 25 | 0.836 | 25 | 0.838 | 25 | 100 |
|  | 0.75 | 0.87 | 43 | 0.879 | 43 | 0.87 | 43 | 0.871 | 43 | 172 |
|  | 0.80 | 0.838 | 31 | 0.854 | 37 | 0.838 | 31 | 0.842 | 31 | 130 |
|  | 0.85 | 0.821 | 19 | 0.837 | 19 | 0.821 | 19 | 0.822 | 19 | 76 |
|  | 0.90 | 0.842 | 37 | 0.854 | 31 | 0.842 | 37 | 0.843 | 37 | 142 |
| 150 | 0.55 | 0.807 | 1 | 0.807 | 1 | 0.807 | 1 | 0.806 | 1 | 4 |
|  | 0.60 | 0.811 | 7 | 0.81 | 7 | 0.811 | 7 | 0.81 | 7 | 28 |
|  | 0.65 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 52 |
|  | 0.70 | 0.836 | 25 | 0.849 | 25 | 0.836 | 25 | 0.838 | 25 | 100 |
|  | 0.75 | 0.87 | 43 | 0.879 | 43 | 0.87 | 43 | 0.871 | 43 | 172 |
|  | 0.80 | 0.838 | 31 | 0.854 | 37 | 0.838 | 31 | 0.842 | 31 | 130 |
|  | 0.85 | 0.821 | 19 | 0.837 | 19 | 0.821 | 19 | 0.822 | 19 | 76 |
|  | 0.90 | 0.842 | 37 | 0.854 | 31 | 0.842 | 37 | 0.843 | 37 | 142 |
| 200 | 0.55 | 0.807 | 1 | 0.807 | 1 | 0.807 | 1 | 0.806 | 1 | 4 |
|  | 0.60 | 0.811 | 7 | 0.81 | 7 | 0.811 | 7 | 0.81 | 7 | 28 |
|  | 0.65 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 52 |
|  | 0.70 | 0.836 | 25 | 0.849 | 25 | 0.836 | 25 | 0.838 | 25 | 100 |
|  | 0.75 | 0.87 | 43 | 0.879 | 43 | 0.87 | 43 | 0.871 | 43 | 172 |
|  | 0.80 | 0.838 | 31 | 0.854 | 37 | 0.838 | 31 | 0.842 | 31 | 130 |
|  | 0.85 | 0.821 | 19 | 0.837 | 19 | 0.821 | 19 | 0.822 | 19 | 76 |
|  | 0.90 | 0.842 | 37 | 0.854 | 31 | 0.842 | 37 | 0.843 | 37 | 142 |
| 250 | 0.55 | 0.807 | 1 | 0.807 | 1 | 0.807 | 1 | 0.806 | 1 | 4 |
|  | 0.60 | 0.811 | 7 | 0.81 | 7 | 0.811 | 7 | 0.81 | 7 | 28 |
|  | 0.65 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 52 |
|  | 0.70 | 0.836 | 25 | 0.849 | 25 | 0.836 | 25 | 0.838 | 25 | 100 |
|  | 0.75 | 0.87 | 43 | 0.879 | 43 | 0.87 | 43 | 0.871 | 43 | 172 |
|  | 0.80 | 0.838 | 31 | 0.854 | 37 | 0.838 | 31 | 0.842 | 31 | 130 |
|  | 0.85 | 0.821 | 19 | 0.837 | 19 | 0.821 | 19 | 0.822 | 19 | 76 |
|  | 0.90 | 0.842 | 37 | 0.854 | 31 | 0.842 | 37 | 0.843 | 37 | 142 |
| 300 | 0.55 | 0.807 | 1 | 0.807 | 1 | 0.807 | 1 | 0.806 | 1 | 4 |
|  | 0.60 | 0.811 | 7 | 0.81 | 7 | 0.811 | 7 | 0.81 | 7 | 28 |
|  | 0.65 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 0.815 | 13 | 52 |
|  | 0.70 | 0.836 | 25 | 0.849 | 25 | 0.836 | 25 | 0.838 | 25 | 100 |
|  | 0.75 | 0.87 | 43 | 0.879 | 43 | 0.87 | 43 | 0.871 | 43 | 172 |
|  | 0.80 | 0.838 | 31 | 0.854 | 37 | 0.838 | 31 | 0.842 | 31 | 130 |
|  | 0.85 | 0.821 | 19 | 0.837 | 19 | 0.821 | 19 | 0.822 | 19 | 76 |
|  | 0.90 | 0.842 | 37 | 0.854 | 31 | 0.842 | 37 | 0.843 | 37 | 142 |

A screenshot of a computer

Description automatically generated with low confidenceA picture containing screenshot, square, rectangle, design

Description automatically generated

**Fig. S-13.** Performance of MFO-SVM models.