**Experimental result**

Three experiments were conducted to compare the effectiveness of three feature extraction methods (CSP, TDP and PSD) and four classifiers (LSVM, KSVM, GB and SRLDA). In the first experiment, the subjects imagined two binary movements of robot arm. One more imagery task was added in the second experiment to validate the performance of feature extractions and classifiers in ternary classification. In the last experiment, the whole five movements were classified. All classifiers were trained by 5-fold cross validation.

***Experiment 1: Binary classification***

Two task classifying experiments were performed for binary classification (Table 1). The first task was the classification of hand grasping movement, that were closing all the fingers to grab and resting state. The second task was the classification of wrist twisting movement, that were twisting movement and resting state. In the grasping task, SRLDA was the classifier that showed the best performance in all feature extraction methods. Feature extraction methods were performed in the order of TDP, CSP and PSD. The combination of feature extraction and classifier that showed the best performance was TDP and SRLDA. In the twisting task, the best classifier for each feature extraction were different. TDP, PSD and CSP were better in order of highest classifier. Especially, LSVM, the simplest classifier, has the best performance in PSD. The feature extraction with the smallest standard deviation was TDP in both tasks.

.

**Table 1** List of the average accuracy and standard deviation for each subject across all the feature extractions and classifiers in binary grasping (grasp versus rest) and twisting (twist versus rest) task.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Task | Subject | | CSP | | | | | | | | TDP | | | | | | | | PSD | | | | | |
| LSVM | | KSVM | | GB | | SRLDA | | LSVM | | KSVM | | GB | | SRLDA | | LSVM | | KSVM | | GB | SRLDA |
| Grasp | 1 | 51.0±12.4 | | 53.0±13.3 | | 56.0±13.2 | | 52.0±11.7 | | 65.0±6.3 | | 62.0±10.3 | | 64.0±3.7 | | 73.0±6.0 | | 50.0±6.3 | | 54.0±4.9 | | 55.0±2.2 | | 60.0±8.9 |
| 2 | 52.0±8.7 | | 55.0±7.1 | | 53.0±10.3 | | 56.0±10.7 | | 73.0±6.8 | | 69.0±5.8 | | 68.0±13.3 | | 82.0±2.4 | | 74.0±11.6 | | 69.0±10.7 | | 49.0±3.3 | | 51.0±3.7 |
| 3 | 54.0±11.1 | | 56.0±8.0 | | 55.0±6.3 | | 52.0±6.8 | | 78.0±6.8 | | 77.0±5.1 | | 73.0±6.0 | | 79.0±7.3 | | 56.0±8.0 | | 52.0±6.8 | | 48.0±4.9 | | 63.0±12.1 |
| 4 | 74.5±6.2 | | 75.5±5.3 | | 66.5±5.4 | | 74.5±5.8 | | 87.0±2.9 | | 85.5±1.9 | | 81.0±3.4 | | 91.0±5.1 | | 54.5±2.9 | | 51.5±1.2 | | 58.0±3.7 | | 64.0±9.0 |
| 5 | 60.0±4.6 | | 58.3±6.3 | | 56.0±3.7 | | 59.3±4.9 | | 70.0±4.3 | | 70.7±3.9 | | 77.3±5.4 | | 74.7±3.2 | | 53.0±2.4 | | 50.7±2.5 | | 48.3±6.9 | | 60.7±8.3 |
| 6 | 61.3±2.7 | | 59.7±4.5 | | 55.0±4.5 | | 60.0±3.7 | | 74.0±4.0 | | 74.7±4.4 | | 79.3±5.3 | | 76.3±6.3 | | 51.3±2.7 | | 50.3±0.7 | | 52.8±4.3 | | 49.7±1.6 |
| 7 | 85.0±3.2 | | 83.0±6.8 | | 82.0±9.3 | | 89.0±4.9 | | 93.0±5.1 | | 89.0±7.3 | | 92.0±6.8 | | 93.0±2.4 | | 51.0±2.0 | | 51.0±2.0 | | 74.5±5.5 | | 57.0±7.5 |
| 8 | 60.0±5.5 | | 57.0±10.8 | | 57.0±5.1 | | 58.0±6.0 | | 66.0±10.2 | | 59.0±7.3 | | 78.0±12.1 | | 77.0±10.8 | | 54.0±8.0 | | 52.0±4.0 | | 56.0±5.8 | | 56.0±8.6 |
| 9 | 58.0±4.0 | | 61.0±6.6 | | 58.0±15.7 | | 62.0±6.0 | | 67.0±14.4 | | 61.0±16.2 | | 67.0±6.8 | | 65.0±17.0 | | 58.0±9.3 | | 53.0±6.0 | | 60.5±12.2 | | 50.0±3.2 |
| 10 | 88.0±6.8 | | 88.0±5.1 | | 91.0±4.9 | | 93.0±5.1 | | 93.0±8.7 | | 93.0±6.8 | | 95.0±5.5 | | 92.0±6.0 | | 77.0±9.3 | | 61.0±10.7 | | 43.5±12.4 | | 63.0±8.7 |
| Average | 64.4±6.5 | | 64.6±7.4 | | 63.0±7.8 | | **65.6±6.6** | | 76.6±7.0 | | 74.1±6.9 | | 77.5±6.8 | | **80.3±6.6** | | 57.9±6.2 | | 54.4±5.0 | | 54.6±6.1 | | **57.4±7.2** |
| Twist | 1 | 44.0±18.3 | | 43.0±17.5 | | 45.0±12.2 | | 43.0±17.2 | | 68.0±6.8 | | 68.0±8.1 | | 69.0±8.6 | | 71.0±3.7 | | 65.0±5.5 | | 60.0±7.7 | | 56.0±3.2 | | 49.0±3.7 |
| 2 | 46.0±13.9 | | 46.0±11.6 | | 47.0±13.3 | | 47.0±15.0 | | 75.0±8.4 | | 79.0±5.8 | | 78.0±7.5 | | 81.0±9.7 | | 76.0±10.7 | | 77.0±11.7 | | 53.0±5.3 | | 63.0±4.0 |
| 3 | 47.0±5.1 | | 50.0±8.4 | | 46.0±4.9 | | 49.0±3.7 | | 78.0±7.5 | | 72.0±6.0 | | 86.0±3.7 | | 79.0±3.7 | | 71.0±8.0 | | 68.0±6.8 | | 55.0±3.3 | | 59.0±13.2 |
| 4 | 52.5±6.7 | | 56.0±4.4 | | 52.0±3.7 | | 54.0±5.8 | | 83.0±4.8 | | 79.5±4.6 | | 77.5±6.1 | | 85.0±1.6 | | 50.0±0.0 | | 50.0±0.0 | | 66.5±3.4 | | 60.5±7.8 |
| 5 | 54.0±4.4 | | 52.7±2.3 | | 49.3±6.9 | | 54.0±3.6 | | 80.0±7.3 | | 80.3±4.3 | | 77.3±3.7 | | 84.3±2.5 | | 61.0±4.0 | | 53.7±2.4 | | 56.0±3.7 | | 70.7±5.3 |
| 6 | 54.7±3.4 | | 56.3±4.1 | | 52.3±4.3 | | 54.7±4.6 | | 73.3±9.8 | | 72.7±7.0 | | 69.7±5.7 | | 73.7±5.1 | | 51.0±2.0 | | 50.0±0.0 | | 55.0±4.5 | | 58.7±4.9 |
| 7 | 74.0±5.8 | | 74.0±5.8 | | 75.0±10.5 | | 76.0±8.6 | | 83.0±7.5 | | 83.0±5.1 | | 76.0±5.8 | | 85.0±4.5 | | 62.0±6.8 | | 61.0±8.6 | | 72.0±6.3 | | 52.0±4.0 |
| 8 | 50.0±8.9 | | 55.0±11.4 | | 56.0±5.8 | | 53.0±6.8 | | 62.0±7.5 | | 64.0±4.9 | | 70.0±5.5 | | 71.0±3.7 | | 54.0±4.9 | | 55.0±3.2 | | 57.0±5.1 | | 49.0±6.6 |
| 9 | 60.0±13.0 | | 60.0±13.8 | | 60.0±15.2 | | 61.0±9.7 | | 87.0±5.1 | | 84.0±3.7 | | 90.0±4.5 | | 79.0±3.7 | | 60.0±6.3 | | 50.0±0.0 | | 58.0±13.7 | | 77.0±10.8 |
| 10 | 44.0±9.7 | | 42.0±13.3 | | 43.0±14.4 | | 42.0±14.7 | | 81.0±10.7 | | 80.0±11.0 | | 74.0±12.4 | | 82.0±4.0 | | 64.0±8.0 | | 63.0±10.8 | | 71.0±4.9 | | 60.0±3.2 |
| Average | 52.6±8.9 | | **53.5±9.3** | | 52.6±9.1 | | 53.4±9.0 | | 77.0±7.5 | | 76.2±6.0 | | 76.8±6.4 | | **79.1±4.2** | | **61.4±5.6** | | 58.8±5.1 | | 60.0±5.3 | | 59.9±6.4 |

***Experiment 2: Ternary classification***

The performance of feature extraction methods and classifiers for ternary classification were evaluated by including one more class in each task of binary classification (Table 2). A hand stretching class was added to the grasping task, and the twisting task was divided into classes that rotates the wrist to the left or to the right. The combination that showed the best performance in grasping task was TDP and SRLDA as in the binary, but there was a performance drop of about 18.4%. In addition, the performance order of feature extraction was shown in order of TDP, PSD and CSP, so that the feature extraction that is the most affected by the increase in the number of class is CSP. The twisting task also showed performance degradation of more 10% compared to the binary classification, and the combinations that was the best performance were TDP and GB. The feature extraction that showed the minimum standard deviation was CSP in both tasks

***Experiment 3: Quinary classification***

To verify the performance of the quinary classification, an experiment was performed to classify all the classes at once including grasping, opening, left twisting, right twisting and resting (Table 3). The best performance combinations were TDP and GB. The performance was similar to that of the ternary twisting classification (accuracy difference < 0.1%), but there was a performance drop of about 21.1% from binary grasping classification. The performance order of feature extraction was in order of TDP, PSD and CSP. The smallest standard deviation was shown in CSP.

**Table 2** List of the average accuracy and standard deviation for each subject across all the feature extractions and classifiers in ternary grasping (grasp versus open versus rest) and twisting task (left twist versus right twist versus rest).

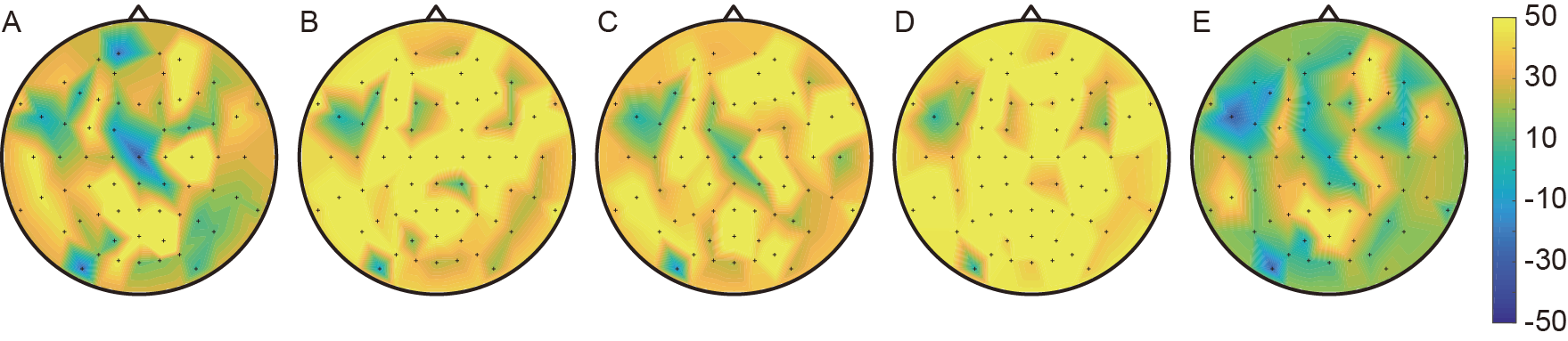
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Task | Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| Grasp | S1 | 39.0±5.8 | 46.0±5.8 | 39.0±6.6 | 40.0±12.2 | 44.0±11.1 | 49.0±6.6 | 45.0±9.5 | 51.0±3.7 | 34.0±8.6 | 35.0±8.4 | 45.0±8.4 | 45.0±11.4 |
| S2 | 45.0±13.0 | 48.0±9.3 | 47.0±4.0 | 48.0±9.3 | 55.0±6.3 | 53.0±7.5 | 48.0±16.0 | 65.0±8.4 | 40.0±16.4 | 41.0±12.4 | 49.0±8.6 | 43.0±9.3 |
| S3 | 44.0±12.8 | 48.0±12.9 | 48.0±6.0 | 44.0±14.6 | 60.0±10.5 | 64.0±10.2 | 55.0±7.1 | 60.0±10.5 | 59.0±8.0 | 50.0±11.8 | 54.0±13.9 | 51.0±13.2 |
| S4 | 49.5±5.8 | 52.5±3.9 | 53.0±4.6 | 52.0±7.6 | 64.0±2.5 | 63.0±6.4 | 61.5±3.4 | 68.0±6.8 | 46.5±6.4 | 43.0±5.6 | 52.5±9.6 | 50.5±6.6 |
| S5 | 46.7±5.3 | 47.7±6.2 | 45.7±4.8 | 50.0±6.8 | 56.3±6.2 | 56.0±8.3 | 59.3±3.9 | 59.7±1.2 | 46.3±10.7 | 47.3±6.7 | 52.3±5.3 | 51.0±10.0 |
| S6 | 50.0±2.4 | 48.0±3.2 | 49.0±2.9 | 51.0±2.5 | 56.0±10.7 | 57.7±8.0 | 63.3±6.4 | 60.3±7.3 | 45.0±10.7 | 49.3±9.6 | 61.0±5.6 | 55.7±7.0 |
| S7 | 57.0±6.8 | 54.0±7.3 | 57.0±10.3 | 64.0±7.3 | 74.0±9.2 | 73.0±6.8 | 70.0±10.0 | 74.0±5.8 | 48.0±9.3 | 44.0±5.8 | 65.0±4.5 | 57.0±9.3 |
| S8 | 30.0±11.0 | 42.0±6.8 | 43.0±6.8 | 34.0±9.2 | 60.0±8.9 | 52.0±9.3 | 70.0±8.9 | 60.0±12.2 | 48.0±6.8 | 41.0±7.3 | 61.0±10.2 | 43.0±10.3 |
| S9 | 37.0±8.7 | 48.0±7.5 | 42.0±11.7 | 50.0±5.5 | 47.0±20.9 | 53.0±20.6 | 47.0±8.1 | 51.0±17.7 | 31.0±6.6 | 34.0±10.7 | 52.0±8.1 | 47.0±13.6 |
| S10 | 63.0±8.1 | 69.0±8.6 | 62.0±11.7 | 67.0±6.8 | 71.0±5.8 | 73.0±6.8 | 72.0±6.0 | 70.0±5.5 | 66.0±13.9 | 67.0±12.9 | 76.0±8.0 | 56.0±4.9 |
| Average | 46.1±8.0 | **50.3±7.2** | 48.6±6.9 | 50.0±8.2 | 58.7±9.2 | 59.4±9.0 | 59.1±7.9 | **61.9±7.9** | 46.4±9.7 | 45.2±9.1 | **56.8±8.2** | 49.9±9.6 |
| Twist | S1 | 33.0±10.3 | 43.0±8.7 | 48.0±2.4 | 33.0±10.3 | 50.0±7.7 | 46.0±8.6 | 57.0±7.5 | 52.0±11.2 | 39.0±3.7 | 33.0±6.8 | 45.0±7.7 | 37.0±18.6 |
| S2 | 35.0±16.4 | 49.0±8.0 | 50.0±3.2 | 48.0±6.0 | 54.0±14.3 | 62.0±10.8 | 62.0±12.9 | 63.0±13.3 | 48.0±11.7 | 47.0±12.9 | 51.0±8.0 | 39.0±10.7 |
| S3 | 41.0±9.7 | 49.0±2.0 | 50.0±5.5 | 47.0±4.0 | 52.0±7.5 | 57.0±11.2 | 61.0±8.6 | 51.0±10.2 | 50.0±11.8 | 46.0±5.8 | 48.0±14.4 | 53.0±6.8 |
| S4 | 36.5±5.8 | 39.5±5.3 | 44.5±4.3 | 41.5±8.5 | 59.5±6.2 | 59.5±8.3 | 55.0±5.0 | 61.5±3.4 | 50.0±4.2 | 45.0±5.2 | 56.0±6.6 | 51.5±5.8 |
| S5 | 42.7±4.4 | 44.3±3.6 | 47.3±4.4 | 46.7±2.4 | 60.3±3.7 | 57.3±5.4 | 55.7±4.3 | 61.3±6.9 | 50.3±4.9 | 52.0±7.0 | 65.7±4.0 | 58.7±4.3 |
| S6 | 40.7±4.3 | 42.3±3.9 | 45.0±5.1 | 44.0±4.8 | 55.0±9.1 | 51.3±6.7 | 55.0±10.8 | 54.7±11.7 | 57.3±3.1 | 56.3±3.9 | 62.3±5.4 | 62.7±6.8 |
| S7 | 48.0±6.8 | 50.0±7.1 | 52.0±5.1 | 52.0±10.8 | 69.0±6.6 | 65.0±10.0 | 60.0±7.1 | 68.0±6.8 | 51.0±11.1 | 48.0±9.8 | 63.0±6.0 | 64.0±10.2 |
| S8 | 36.0±10.7 | 45.0±8.9 | 47.0±2.4 | 39.0±8.6 | 44.0±3.7 | 49.0±8.6 | 60.0±4.5 | 55.0±8.4 | 36.0±2.0 | 31.0±13.6 | 55.0±6.3 | 39.0±5.8 |
| S9 | 47.0±9.8 | 48.0±5.1 | 51.0±10.2 | 38.0±9.3 | 54.0±8.0 | 50.0±6.3 | 64.0±11.1 | 48.0±4.0 | 47.0±5.1 | 37.0±5.1 | 56.0±9.7 | 43.0±12.9 |
| S10 | 39.0±5.8 | 46.0±9.7 | 45.0±3.2 | 44.0±6.6 | 63.0±15.4 | 60.0±13.0 | 61.0±5.8 | 62.0±11.7 | 44.0±3.7 | 45.0±7.1 | 52.0±10.3 | 42.0±5.1 |
| Average | 39.9±8.4 | 45.6±6.2 | **48.0±4.6** | 43.3±7.1 | 56.1±8.2 | 55.7±8.9 | **59.1±7.8** | 57.6±8.8 | 47.3±6.1 | 44.0±7.7 | **55.4±7.8** | 49.0±8.7 |

**Table 3** List of the average accuracy and standard deviation for each subject across all the feature extractions and classifiers in quinary task (grasp versus open versus left twist versus right twist versus rest).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| S1 | 35.5±5.1 | 45.5±3.7 | 46.0±4.6 | 40.0±3.2 | 44.0±6.4 | 57.0±2.7 | 51.5±5.6 | 50.0±8.4 | 38.5±4.6 | 44.5±5.1 | 44.5±2.9 | 38.5±10.1 |
| S2 | 40.5±8.3 | 48.5±3.0 | 50.5±4.3 | 48.5±4.6 | 60.0±6.9 | 43.0±3.6 | 59.5±7.5 | 66.5±8.2 | 31.5±7.2 | 51.0±7.8 | 54.5±9.0 | 39.5±6.8 |
| S3 | 36.5±5.8 | 47.0±5.1 | 51.0±2.5 | 46.0±4.9 | 58.0±4.3 | 56.0±3.4 | 60.0±5.9 | 57.5±10.4 | 49.5±8.6 | 52.0±5.3 | 52.5±4.2 | 48.0±10.9 |
| S4 | 47.0±1.7 | 49.7±2.5 | 50.5±4.9 | 44.0±5.0 | 60.8±2.7 | 50.0±1.5 | 59.7±6.0 | 62.8±3.3 | 41.8±5.0 | 47.5±3.6 | 52.8±3.1 | 47.0±4.9 |
| S5 | 43.7±4.1 | 50.0±1.5 | 46.0±0.6 | 43.7±3.0 | 56.3±2.8 | 50.2±0.3 | 57.3±2.2 | 59.7±4.9 | 45.5±6.6 | 49.3±0.6 | 55.7±0.8 | 56.2±4.9 |
| S6 | 41.8±4.8 | 50.0±4.5 | 47.7±2.7 | 48.2±4.1 | 53.3±7.8 | 53.7±1.5 | 60.0±4.7 | 56.0±5.2 | 47.0±3.5 | 49.8±0.8 | 57.5±7.8 | 57.5±6.5 |
| S7 | 50.5±7.8 | 52.5±6.7 | 53.0±4.0 | 52.5±4.7 | 65.5±5.6 | 64.0±7.2 | 70.0±7.2 | 66.5±9.2 | 45.5±5.1 | 48.0±1.9 | 51.5±6.2 | 52.0±7.8 |
| S8 | 36.0±6.6 | 48.0±2.9 | 44.5±5.8 | 44.0±3.4 | 50.5±12.1 | 50.0±2.2 | 53.5±8.3 | 53.5±8.5 | 32.5±8.2 | 46.0±6.4 | 51.5±3.4 | 45.0±5.7 |
| S9 | 43.0±3.3 | 50.0±3.2 | 46.0±3.4 | 42.5±2.2 | 49.0±12.5 | 51.0±2.0 | 58.5±4.1 | 51.5±10.2 | 36.5±4.1 | 46.5±2.5 | 48.0±4.8 | 46.0±9.4 |
| S10 | 48.5±7.8 | 54.0±3.0 | 52.5±2.7 | 53.5±1.2 | 65.0±8.1 | 62.0±4.8 | 62.5±9.1 | 63.0±8.3 | 54.5±5.3 | 51.5±3.0 | 60.0±8.7 | 48.0±8.1 |
| Average | 42.3±5.5 | **49.5±3.6** | 48.8±3.6 | 46.3±3.6 | 56.2±6.9 | 53.7±2.9 | **59.2±6.1** | 58.7±7.7 | 42.3±5.8 | 48.6±3.7 | **52.8±5.1** | 47.8±7.5 |

***Observations***

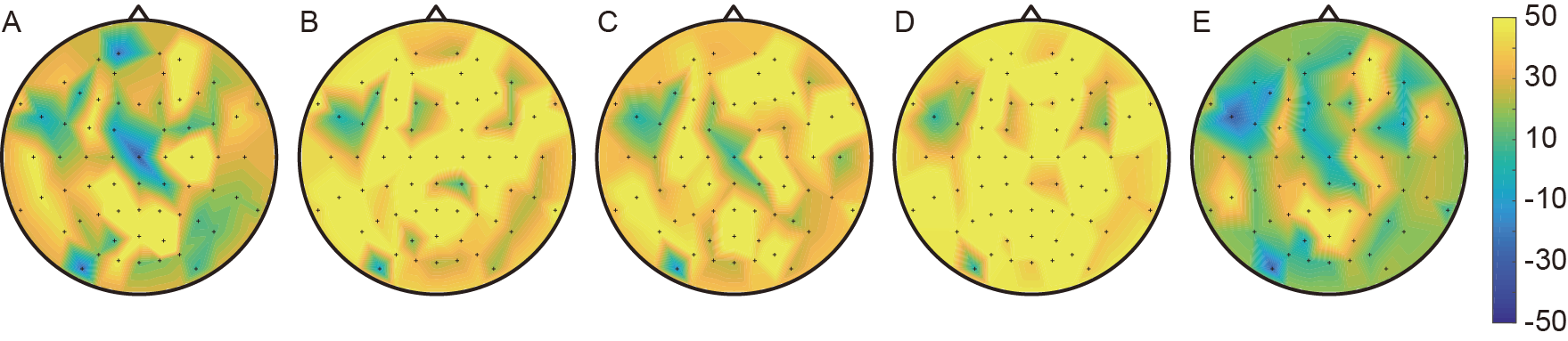
모든 경우의classification에서 가장 좋은 성능을 보여준 S7에 대해서 spatial, temporal and spectral feature가 어떻게 나타나는지에 대한 observation study를 수행해보았다. Figure N presents S7’s topographical spatial patterns in motor imagery tasks. Grasping and resting movements were distinguishable corresponding to neurophysiological area. Twisting task에 포함된 두 가지 동작 left twist와 right twist는 Cz 영역에서 근소한 차이를 보였지만, 전체적으로 유사한 영역이 활성화되어 있는 것을 확인할 수 있다.



**Fig** Topographical mapping of motor imagery class. (A: grasp, B: open, C: left twist, D: right twist and E: rest state)

Figure N presents S7’s distributions of time domain parameters as each classes. Y7

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**Fig** Topographical mapping of motor imagery class. (A: grasp, B: open, C: left twist, D: right twist and E: rest state)

**Figure 2**: Temporal domain parameter distribution

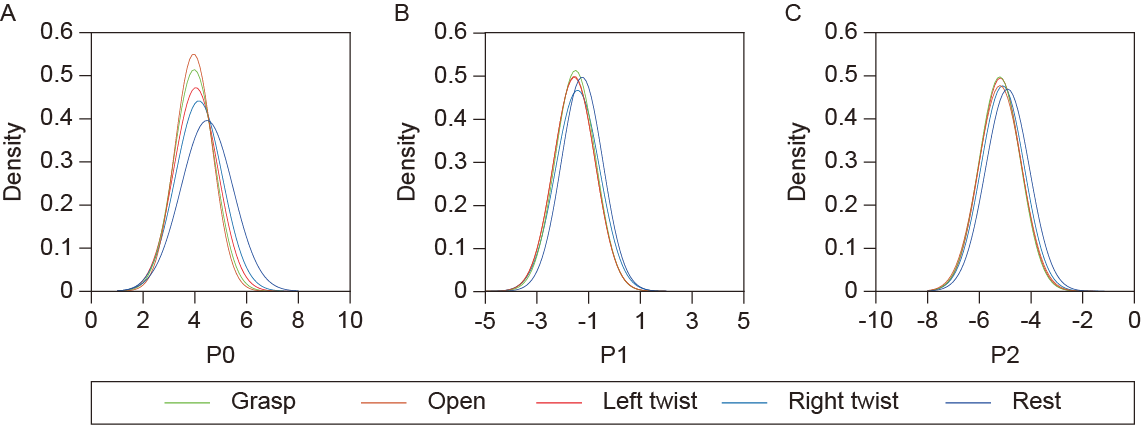
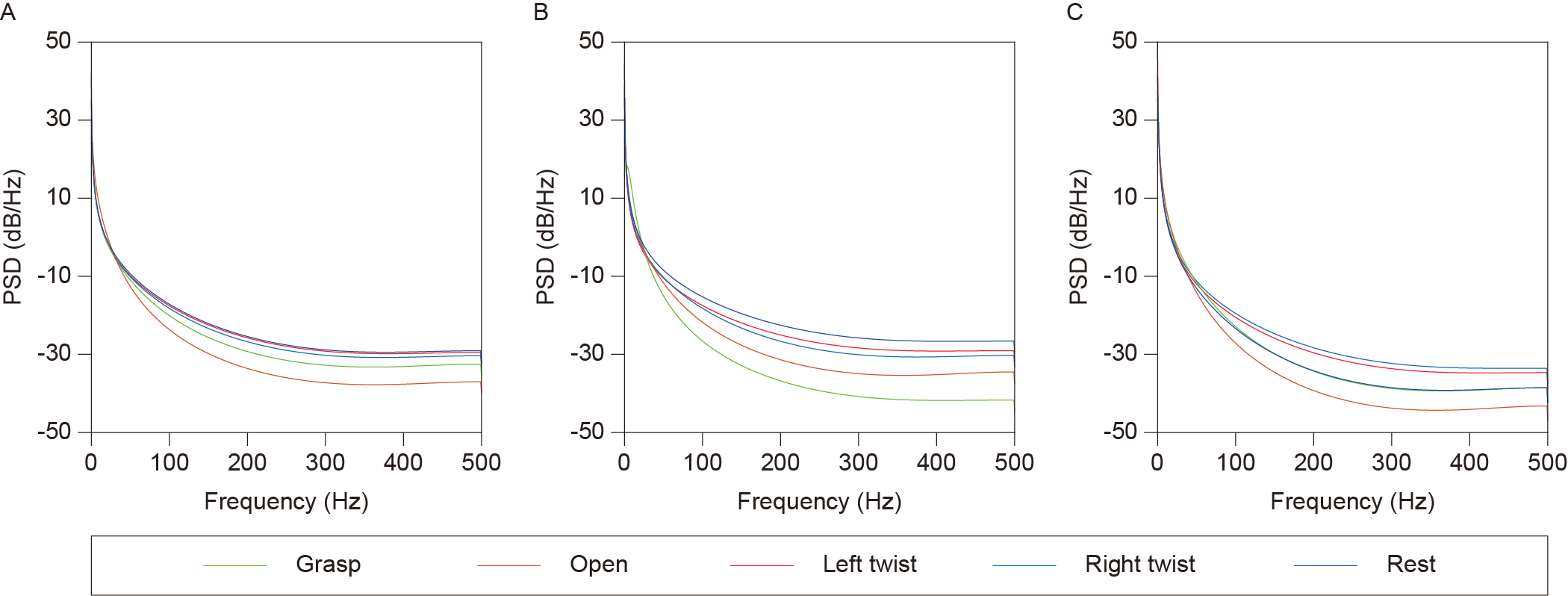
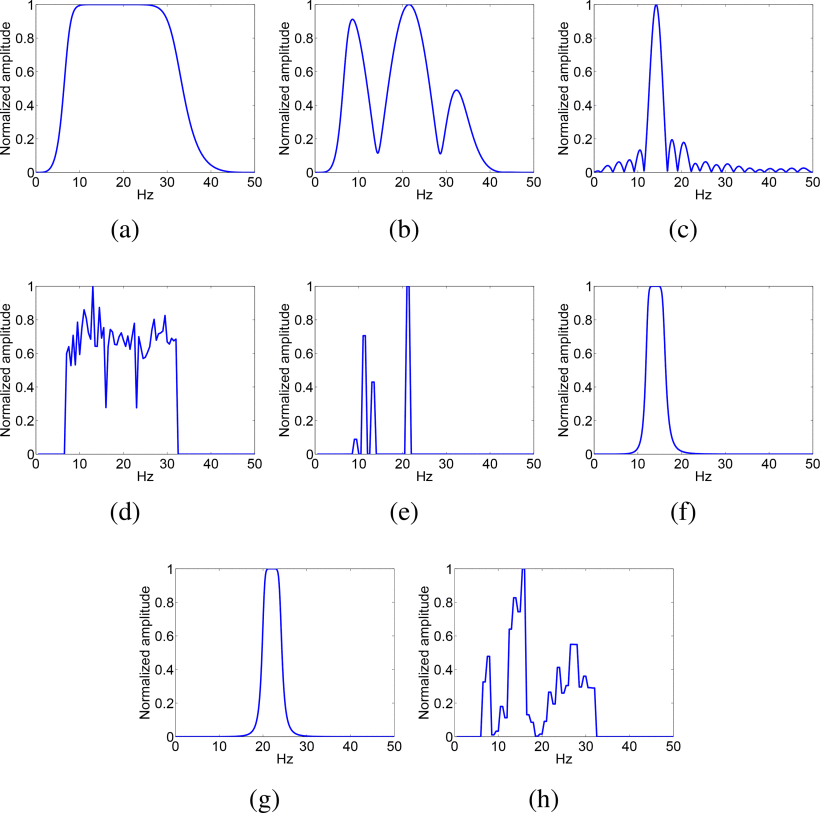


Fig The distribution of the classes around time domain features (A: p0, B: p1 and C)

**Figure 3**: Power spectral density plot



Reference figure



**Fig** The amplitude characteristics of spectral filters designed by each of the comparative methods. (a) CSP (b) CSSP (c) DFBCSP (d) SWCSP (e) ISSPL (f) FBCSP (g) OSSFN (h) MMISS.

(from Simultaneously Optimizing Spatial Spectral Features Based on Mutual Information for EEG Classification, 2014, IEEE transactions on biomedical engineering)

**Table** Binary classification result 1 (Grasp & Open vs. Rest)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 51.0±12.4 | 53.0±13.3 | 56.0±13.2 | 52.0±11.7 | 65.0±6.3 | 62.0±10.3 | 64.0±3.7 | 73.0±6.0 | 50.0±6.3 | 54.0±4.9 | 55.0±2.2 | 60.0±8.9 |
| 2 | 52.0±8.7 | 55.0±7.1 | 53.0±10.3 | 56.0±10.7 | 73.0±6.8 | 69.0±5.8 | 68.0±13.3 | 82.0±2.4 | 74.0±11.6 | 69.0±10.7 | 49.0±3.3 | 51.0±3.7 |
| 3 | 54.0±11.1 | 56.0±8.0 | 55.0±6.3 | 52.0±6.8 | 78.0±6.8 | 77.0±5.1 | 73.0±6.0 | 79.0±7.3 | 56.0±8.0 | 52.0±6.8 | 48.0±4.9 | 63.0±12.1 |
| 4 | 74.5±6.2 | 75.5±5.3 | 66.5±5.4 | 74.5±5.8 | 87.0±2.9 | 85.5±1.9 | 81.0±3.4 | 91.0±5.1 | 54.5±2.9 | 51.5±1.2 | 58.0±3.7 | 64.0±9.0 |
| 5 | 60.0±4.6 | 58.3±6.3 | 56.0±3.7 | 59.3±4.9 | 70.0±4.3 | 70.7±3.9 | 77.3±5.4 | 74.7±3.2 | 53.0±2.4 | 50.7±2.5 | 48.3±6.9 | 60.7±8.3 |
| 6 | 61.3±2.7 | 59.7±4.5 | 55.0±4.5 | 60.0±3.7 | 74.0±4.0 | 74.7±4.4 | 79.3±5.3 | 76.3±6.3 | 51.3±2.7 | 50.3±0.7 | 52.8±4.3 | 49.7±1.6 |
| 7 | 85.0±3.2 | 83.0±6.8 | 82.0±9.3 | 89.0±4.9 | 93.0±5.1 | 89.0±7.3 | 92.0±6.8 | 93.0±2.4 | 51.0±2.0 | 51.0±2.0 | 74.5±5.5 | 57.0±7.5 |
| 8 | 60.0±5.5 | 57.0±10.8 | 57.0±5.1 | 58.0±6.0 | 66.0±10.2 | 59.0±7.3 | 78.0±12.1 | 77.0±10.8 | 54.0±8.0 | 52.0±4.0 | 56.0±5.8 | 56.0±8.6 |
| 9 | 58.0±4.0 | 61.0±6.6 | 58.0±15.7 | 62.0±6.0 | 67.0±14.4 | 61.0±16.2 | 67.0±6.8 | 65.0±17.0 | 58.0±9.3 | 53.0±6.0 | 60.5±12.2 | 50.0±3.2 |
| 10 | 88.0±6.8 | 88.0±5.1 | 91.0±4.9 | 93.0±5.1 | 93.0±8.7 | 93.0±6.8 | 95.0±5.5 | 92.0±6.0 | 77.0±9.3 | 61.0±10.7 | 43.5±12.4 | 63.0±8.7 |
| Average | 64.4±6.5 | 64.6±7.4 | 63.0±7.8 | **65.6±6.6** | 76.6±7.0 | 74.1±6.9 | 77.5±6.8 | **80.3±6.6** | 57.9±6.2 | 54.4±5.0 | 54.6±6.1 | **57.4±7.2** |

**Table** Binary classification result 2 (Twist vs. Rest)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 44.0±18.3 | 43.0±17.5 | 45.0±12.2 | 43.0±17.2 | 68.0±6.8 | 68.0±8.1 | 69.0±8.6 | 71.0±3.7 | 65.0±5.5 | 60.0±7.7 | 56.0±3.2 | 49.0±3.7 |
| 2 | 46.0±13.9 | 46.0±11.6 | 47.0±13.3 | 47.0±15.0 | 75.0±8.4 | 79.0±5.8 | 78.0±7.5 | 81.0±9.7 | 76.0±10.7 | 77.0±11.7 | 53.0±5.3 | 63.0±4.0 |
| 3 | 47.0±5.1 | 50.0±8.4 | 46.0±4.9 | 49.0±3.7 | 78.0±7.5 | 72.0±6.0 | 86.0±3.7 | 79.0±3.7 | 71.0±8.0 | 68.0±6.8 | 55.0±3.3 | 59.0±13.2 |
| 4 | 52.5±6.7 | 56.0±4.4 | 52.0±3.7 | 54.0±5.8 | 83.0±4.8 | 79.5±4.6 | 77.5±6.1 | 85.0±1.6 | 50.0±0.0 | 50.0±0.0 | 66.5±3.4 | 60.5±7.8 |
| 5 | 54.0±4.4 | 52.7±2.3 | 49.3±6.9 | 54.0±3.6 | 80.0±7.3 | 80.3±4.3 | 77.3±3.7 | 84.3±2.5 | 61.0±4.0 | 53.7±2.4 | 56.0±3.7 | 70.7±5.3 |
| 6 | 54.7±3.4 | 56.3±4.1 | 52.3±4.3 | 54.7±4.6 | 73.3±9.8 | 72.7±7.0 | 69.7±5.7 | 73.7±5.1 | 51.0±2.0 | 50.0±0.0 | 55.0±4.5 | 58.7±4.9 |
| 7 | 74.0±5.8 | 74.0±5.8 | 75.0±10.5 | 76.0±8.6 | 83.0±7.5 | 83.0±5.1 | 76.0±5.8 | 85.0±4.5 | 62.0±6.8 | 61.0±8.6 | 72.0±6.3 | 52.0±4.0 |
| 8 | 50.0±8.9 | 55.0±11.4 | 56.0±5.8 | 53.0±6.8 | 62.0±7.5 | 64.0±4.9 | 70.0±5.5 | 71.0±3.7 | 54.0±4.9 | 55.0±3.2 | 57.0±5.1 | 49.0±6.6 |
| 9 | 60.0±13.0 | 60.0±13.8 | 60.0±15.2 | 61.0±9.7 | 87.0±5.1 | 84.0±3.7 | 90.0±4.5 | 79.0±3.7 | 60.0±6.3 | 50.0±0.0 | 58.0±13.7 | 77.0±10.8 |
| 10 | 44.0±9.7 | 42.0±13.3 | 43.0±14.4 | 42.0±14.7 | 81.0±10.7 | 80.0±11.0 | 74.0±12.4 | 82.0±4.0 | 64.0±8.0 | 63.0±10.8 | 71.0±4.9 | 60.0±3.2 |
| Average | 52.6±8.9 | **53.5±9.3** | 52.6±9.1 | 53.4±9.0 | 77.0±7.5 | 76.2±6.0 | 76.8±6.4 | **79.1±4.2** | **61.4±5.6** | 58.8±5.1 | 60.0±5.3 | 59.9±6.4 |

**Table** Ternary classification result 1 (Grasp vs. Open vs. Rest)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 39.0±5.8 | 46.0±5.8 | 39.0±6.6 | 40.0±12.2 | 44.0±11.1 | 49.0±6.6 | 45.0±9.5 | 51.0±3.7 | 34.0±8.6 | 35.0±8.4 | 45.0±8.4 | 45.0±11.4 |
| 2 | 45.0±13.0 | 48.0±9.3 | 47.0±4.0 | 48.0±9.3 | 55.0±6.3 | 53.0±7.5 | 48.0±16.0 | 65.0±8.4 | 40.0±16.4 | 41.0±12.4 | 49.0±8.6 | 43.0±9.3 |
| 3 | 44.0±12.8 | 48.0±12.9 | 48.0±6.0 | 44.0±14.6 | 60.0±10.5 | 64.0±10.2 | 55.0±7.1 | 60.0±10.5 | 59.0±8.0 | 50.0±11.8 | 54.0±13.9 | 51.0±13.2 |
| 4 | 49.5±5.8 | 52.5±3.9 | 53.0±4.6 | 52.0±7.6 | 64.0±2.5 | 63.0±6.4 | 61.5±3.4 | 68.0±6.8 | 46.5±6.4 | 43.0±5.6 | 52.5±9.6 | 50.5±6.6 |
| 5 | 46.7±5.3 | 47.7±6.2 | 45.7±4.8 | 50.0±6.8 | 56.3±6.2 | 56.0±8.3 | 59.3±3.9 | 59.7±1.2 | 46.3±10.7 | 47.3±6.7 | 52.3±5.3 | 51.0±10.0 |
| 6 | 50.0±2.4 | 48.0±3.2 | 49.0±2.9 | 51.0±2.5 | 56.0±10.7 | 57.7±8.0 | 63.3±6.4 | 60.3±7.3 | 45.0±10.7 | 49.3±9.6 | 61.0±5.6 | 55.7±7.0 |
| 7 | 57.0±6.8 | 54.0±7.3 | 57.0±10.3 | 64.0±7.3 | 74.0±9.2 | 73.0±6.8 | 70.0±10.0 | 74.0±5.8 | 48.0±9.3 | 44.0±5.8 | 65.0±4.5 | 57.0±9.3 |
| 8 | 30.0±11.0 | 42.0±6.8 | 43.0±6.8 | 34.0±9.2 | 60.0±8.9 | 52.0±9.3 | 70.0±8.9 | 60.0±12.2 | 48.0±6.8 | 41.0±7.3 | 61.0±10.2 | 43.0±10.3 |
| 9 | 37.0±8.7 | 48.0±7.5 | 42.0±11.7 | 50.0±5.5 | 47.0±20.9 | 53.0±20.6 | 47.0±8.1 | 51.0±17.7 | 31.0±6.6 | 34.0±10.7 | 52.0±8.1 | 47.0±13.6 |
| 10 | 63.0±8.1 | 69.0±8.6 | 62.0±11.7 | 67.0±6.8 | 71.0±5.8 | 73.0±6.8 | 72.0±6.0 | 70.0±5.5 | 66.0±13.9 | 67.0±12.9 | 76.0±8.0 | 56.0±4.9 |
| Average | 46.1±8.0 | **50.3±7.2** | 48.6±6.9 | 50.0±8.2 | 58.7±9.2 | 59.4±9.0 | 59.1±7.9 | **61.9±7.9** | 46.4±9.7 | 45.2±9.1 | **56.8±8.2** | 49.9±9.6 |

**Table** Ternary classification result 2 (Left twist vs. Right twist vs. Rest)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 33.0±10.3 | 43.0±8.7 | 48.0±2.4 | 33.0±10.3 | 50.0±7.7 | 46.0±8.6 | 57.0±7.5 | 52.0±11.2 | 39.0±3.7 | 33.0±6.8 | 45.0±7.7 | 37.0±18.6 |
| 2 | 35.0±16.4 | 49.0±8.0 | 50.0±3.2 | 48.0±6.0 | 54.0±14.3 | 62.0±10.8 | 62.0±12.9 | 63.0±13.3 | 48.0±11.7 | 47.0±12.9 | 51.0±8.0 | 39.0±10.7 |
| 3 | 41.0±9.7 | 49.0±2.0 | 50.0±5.5 | 47.0±4.0 | 52.0±7.5 | 57.0±11.2 | 61.0±8.6 | 51.0±10.2 | 50.0±11.8 | 46.0±5.8 | 48.0±14.4 | 53.0±6.8 |
| 4 | 36.5±5.8 | 39.5±5.3 | 44.5±4.3 | 41.5±8.5 | 59.5±6.2 | 59.5±8.3 | 55.0±5.0 | 61.5±3.4 | 50.0±4.2 | 45.0±5.2 | 56.0±6.6 | 51.5±5.8 |
| 5 | 42.7±4.4 | 44.3±3.6 | 47.3±4.4 | 46.7±2.4 | 60.3±3.7 | 57.3±5.4 | 55.7±4.3 | 61.3±6.9 | 50.3±4.9 | 52.0±7.0 | 65.7±4.0 | 58.7±4.3 |
| 6 | 40.7±4.3 | 42.3±3.9 | 45.0±5.1 | 44.0±4.8 | 55.0±9.1 | 51.3±6.7 | 55.0±10.8 | 54.7±11.7 | 57.3±3.1 | 56.3±3.9 | 62.3±5.4 | 62.7±6.8 |
| 7 | 48.0±6.8 | 50.0±7.1 | 52.0±5.1 | 52.0±10.8 | 69.0±6.6 | 65.0±10.0 | 60.0±7.1 | 68.0±6.8 | 51.0±11.1 | 48.0±9.8 | 63.0±6.0 | 64.0±10.2 |
| 8 | 36.0±10.7 | 45.0±8.9 | 47.0±2.4 | 39.0±8.6 | 44.0±3.7 | 49.0±8.6 | 60.0±4.5 | 55.0±8.4 | 36.0±2.0 | 31.0±13.6 | 55.0±6.3 | 39.0±5.8 |
| 9 | 47.0±9.8 | 48.0±5.1 | 51.0±10.2 | 38.0±9.3 | 54.0±8.0 | 50.0±6.3 | 64.0±11.1 | 48.0±4.0 | 47.0±5.1 | 37.0±5.1 | 56.0±9.7 | 43.0±12.9 |
| 10 | 39.0±5.8 | 46.0±9.7 | 45.0±3.2 | 44.0±6.6 | 63.0±15.4 | 60.0±13.0 | 61.0±5.8 | 62.0±11.7 | 44.0±3.7 | 45.0±7.1 | 52.0±10.3 | 42.0±5.1 |
| Average | 39.9±8.4 | 45.6±6.2 | **48.0±4.6** | 43.3±7.1 | 56.1±8.2 | 55.7±8.9 | **59.1±7.8** | 57.6±8.8 | 47.3±6.1 | 44.0±7.7 | **55.4±7.8** | 49.0±8.7 |

**Table** Quinary classification result (Grasp vs. Open vs. Left twist vs. Right twist vs. Rest)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 35.5±5.1 | 45.5±3.7 | 46.0±4.6 | 40.0±3.2 | 44.0±6.4 | 50.0±0.0 | 51.5±5.6 | 50.0±8.4 | 38.5±4.6 | 44.5±5.1 | 44.5±2.9 | 38.5±10.1 |
| 2 | 40.5±8.3 | 48.5±3.0 | 50.5±4.3 | 48.5±4.6 | 60.0±6.9 | 50.0±0.0 | 59.5±7.5 | 66.5±8.2 | 31.5±7.2 | 51.0±7.8 | 54.5±9.0 | 39.5±6.8 |
| 3 | 36.5±5.8 | 47.0±5.1 | 51.0±2.5 | 46.0±4.9 | 58.0±4.3 | 56.0±3.4 | 60.0±5.9 | 57.5±10.4 | 49.5±8.6 | 52.0±5.3 | 52.5±4.2 | 48.0±10.9 |
| 4 | 47.0±1.7 | 49.7±0.5 | 50.5±4.9 | 44.0±5.0 | 60.8±2.7 | 50.0±0.0 | 59.7±6.0 | 62.8±3.3 | 41.8±5.0 | 47.5±3.6 | 52.8±3.1 | 47.0±4.9 |
| 5 | 43.7±4.1 | 50.0±0.5 | 46.0±0.6 | 43.7±3.0 | 56.3±2.8 | 50.2±0.3 | 57.3±2.2 | 59.7±4.9 | 45.5±6.6 | 49.3±0.6 | 55.7±0.8 | 56.2±4.9 |
| 6 | 41.8±4.8 | 50.0±0.0 | 47.7±2.7 | 48.2±4.1 | 53.3±7.8 | 53.7±1.5 | 60.0±4.7 | 56.0±5.2 | 47.0±3.5 | 49.8±0.8 | 57.5±7.8 | 57.5±6.5 |
| 7 | 50.5±7.8 | 52.5±4.2 | 53.0±4.0 | 52.5±4.7 | 65.5±5.6 | 64.0±7.2 | 70.0±7.2 | 66.5±9.2 | 45.5±5.1 | 48.0±1.9 | 51.5±6.2 | 52.0±7.8 |
| 8 | 36.0±6.6 | 48.0±2.9 | 44.5±5.8 | 44.0±3.4 | 50.5±12.1 | 50.0±0.0 | 53.5±8.3 | 53.5±8.5 | 32.5±8.2 | 46.0±6.4 | 51.5±3.4 | 45.0±5.7 |
| 9 | 43.0±3.3 | 50.0±3.2 | 46.0±3.4 | 42.5±2.2 | 49.0±12.5 | 51.0±2.0 | 58.5±4.1 | 51.5±10.2 | 36.5±4.1 | 46.5±2.5 | 48.0±4.8 | 46.0±9.4 |
| 10 | 48.5±7.8 | 54.0±3.0 | 52.5±2.7 | 53.5±1.2 | 65.0±8.1 | 62.0±4.8 | 62.5±9.1 | 63.0±8.3 | 54.5±5.3 | 51.5±3.0 | 60.0±8.7 | 48.0±8.1 |
| Average | 42.3±5.5 | **49.5±2.6** | 48.8±3.6 | 46.3±3.6 | 56.2±6.9 | 53.7±1.9 | **59.2±6.1** | 58.7±7.7 | 42.3±5.8 | 48.6±3.7 | **52.8±5.1** | 47.8±7.5 |

**Table 5**: Classification result applied SMOTE

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 37.0±8.0 | 38.0±4.8 | 40.5±6.0 | 32.0±3.3 | 41.5±6.6 | 31.0±4.1 | 44.5±4.8 | 45.5±9.3 | 30.5±7.3 | 45.5±5.2 | 41.5±2.5 | 37.0±6.2 |
| 2 | 31.0±4.6 | 43.5±5.1 | 46.0±3.4 | 36.0±4.6 | 43.0±7.0 | 44.5±4.3 | 51.5±1.2 | 44.5±7.0 | 36.0±3.7 | 57.5±4.9 | 43.0±8.1 | 37.5±5.5 |
| 3 | 37.0±6.8 | 45.0±5.0 | 42.0±9.9 | 37.0±4.8 | 42.0±10 | 35.5±5.8 | 48.0±5.6 | 47.0±6.0 | 31.5±9.2 | 49.0±4.6 | 43.0±6.6 | 32.5±6.3 |
| 4 | 40.0±8.2 | 48.5±2.5 | 49.0±4.9 | 42.5±6.7 | 57.5±5.7 | 52.5±5.7 | 60.0±5.5 | 64.0±6.0 | 32.0±7.0 | 51.5±6.6 | 47.5±9.7 | 41.5±3.7 |
| 5 | 36.5±3.7 | 47.0±6.8 | 49.0±2.0 | 42.5±3.9 | 59.0±2.5 | 61.5±7.8 | 60.0±5.5 | 56.5±7.2 | 50.0±8.9 | 52.0±5.3 | 55.0±9.5 | 47.5±8.4 |
| 6 | 32.3±6.1 | 33.0±4.2 | 42.5±5.2 | 33.5±6.3 | 60.3±5.0 | 51.8±4.9 | 57.3±5.1 | 60.5±1.5 | 41.0±5.4 | 48.5±3.6 | 47.0±3.9 | 43.0±4.8 |
| 7 | 29.7±4.6 | 30.7±4.9 | 39.3±3.3 | 32.0±3.8 | 51.5±2.9 | 50.3±2.3 | 57.3±3.3 | 54.8±5.4 | 39.0±8.6 | 47.3±1.7 | 53.3±1.9 | 52.8±4.6 |
| 8 | 24.8±3.0 | 29.3±4.0 | 36.8±4.8 | 29.5±5.7 | 50.8±4.8 | 49.5±9.2 | 55.7±4.2 | 51.5±9.5 | 44.2±6.3 | 49.8±1.9 | 54.0±7.0 | 53.5±4.2 |
| 9 | 51.5±5.4 | 56.0±7.3 | 53.5±4.4 | 52.5±6.5 | 68.0±4.3 | 70.0±8.4 | 66.0±5.1 | 66.5±9.8 | 46.0±3.7 | 48.0±1.9 | 55.0±6.5 | 51.5±8.6 |
| 10 | 38.0±1.9 | 45.5±7.0 | 42.5±6.5 | 34.0±7.7 | 50.5±10.4 | 47.0±9.3 | 54.5±8.9 | 47.5±13.1 | 28.5±8.3 | 46.0±6.4 | 50.5±7.6 | 34.5±4.8 |
| 11 | 29.5±4.3 | 35.5±8.0 | 39.0±5.8 | 26.5±7.2 | 24.0±1.2 | 17.0±4.6 | 38.5±4.1 | 28.0±3.3 | 25.5±8.0 | 41.5±4.5 | 33.0±5.8 | 26.0±3.0 |
| 12 | 39.0±6.6 | 42.0±6.4 | 45.5±3.7 | 39.0±8.2 | 45.0±12.7 | 52.0±9.3 | 61.5±4.1 | 48.5±12.7 | 36.0±3.7 | 46.7±3.1 | 48.5±1.2 | 42.0±8.0 |
| 13 | 49.0±7.0 | 45.5±4.3 | 50.0±5.7 | 46.0±2.5 | 66.5±6.2 | 66.5±5.1 | 65.0±9.6 | 59.0±11.0 | 53.0±4.8 | 51.8±3.4 | 65.6±5.4 | 44.5±7.3 |
| Average | 36.6±5.4 | 41.5±5.4 | **44.3±5.0** | 37.2±5.5 | 50.7±6.1 | 48.4±6.2 | **55.4±5.2** | 51.8±7.8 | 37.9±6.5 | 48.9±4.1 | **49.0±5.8** | 41.8±5.8 |

**Table 6**: Classification result merged analysis

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP&TDP | | | | CSP&PSD | | | | TDP&PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 47.5±4.2 | 44.5±7.0 | 48.0±5.6 | 46.5±1.2 | 45.5±4.8 | 39.5±5.3 | 50.0±2.2 | 40.0±4.7 | 43.0±6.2 | 45.0±6.1 | 52.0±4.8 | 40.5±7.0 |
| 2 | 43.0±4.8 | 42.5±3.2 | 46.5±6.4 | 46.0±1.2 | 36.5±5.1 | 44.5±4.8 | 49.0±2.5 | 42.5±4.7 | 45.0±6.9 | 46.5±6.4 | 49.5±4.8 | 48.0±10.3 |
| 3 | 46.0±6.6 | 49.5±4.0 | 50.0±6.5 | 50.5±6.8 | 44.5±5.1 | 43.0±6.0 | 50.0±3.5 | 45.5±6.0 | 52.0±6.2 | 45.0±7.6 | 49.0±5.1 | 41.0±11.2 |
| 4 | 55.5±6.2 | 55.0±5.0 | 52.0±3.7 | 64.5±4.8 | 43.0±9.7 | 48.0±1.9 | 48.5±4.1 | 44.0±5.1 | 59.0±8.6 | 59.5±7.5 | 57.5±7.6 | 53.5±4.9 |
| 5 | 56.5±6.4 | 55.0±5.2 | 50.5±1.9 | 61.0±8.0 | 41.0±3.4 | 46.5±6.6 | 52.5±4.2 | 51.5±4.9 | 56.0±4.6 | 57.5±9.1 | 56.0±5.6 | 54.0±7.7 |
| 6 | 57.2±4.4 | 56.8±7.2 | 60.0±2.9 | 61.0±5.1 | 45.2±4.0 | 40.2±2.5 | 56.8±4.5 | 48.0±2.3 | 60.0±3.2 | 60.7±5.1 | 59.5±4.1 | 53.2±1.3 |
| 7 | 55.3±3.4 | 51.0±3.9 | 56.3±2.3 | 61.0±2.1 | 45.3±2.3 | 41.7±3.4 | 52.5±3.2 | 54.8±3.6 | 56.5±2.1 | 53.3±4.4 | 59.0±2.3 | 58.8±2.8 |
| 8 | 50.3±9.0 | 52.0±3.8 | 57.8±4.8 | 56.8±5.0 | 47.0±4.3 | 47.0±3.3 | 59.2±6.1 | 55.5±6.7 | 55.8±1.4 | 52.3±8.9 | 61.7±6.5 | 60.3±6.3 |
| 9 | 65.0±5.5 | 65.5±6.4 | 58.0±4.3 | 61.5±6.0 | 51.5±6.6 | 56.0±7.3 | 55.5±6.8 | 60.0±8.8 | 69.0±5.6 | 69.5±6.0 | 68.0±4.8 | 61.5±8.2 |
| 10 | 49.0±8.2 | 50.5±2.9 | 52.0±6.2 | 48.5±8.5 | 40.0±4.2 | 46.0±5.1 | 46.5±3.4 | 45.5±6.2 | 53.5±13.1 | 52.5±8.5 | 54.0±7.5 | 49.0±6.6 |
| 11 | 39.0±8.6 | 39.0±7.2 | 41.5±6.4 | 44.5±6.2 | 30.5±4.8 | 35.0±9.2 | 45.5±3.7 | 40.5±4.0 | 37.5±6.7 | 28.0±3.3 | 43.5±5.1 | 38.5±3.4 |
| 12 | 51.5±7.8 | 53.0±4.6 | 53.0±2.9 | 50.5±9.9 | 40.5±3.3 | 43.5±5.1 | 45.0±2.2 | 44.5±8.6 | 48.5±6.6 | 47.5±11.7 | 63.5±7.7 | 50.0±12.0 |
| 13 | 63.5±8.2 | 65.5±9.4 | 57.0±3.7 | 64.0±9.4 | 48.0±8.6 | 46.0±4.4 | 55.5±1.9 | 56.5±3.7 | 65.5±8.0 | 67.5±8.8 | 63.5±7.2 | 58.5±4.6 |
| Average | 52.3±52.3 | 52.3±52.3 | 52.5±52.5 | **55.1±55.1** | 43.0±43.0 | 44.4±44.4 | **51.3±51.3** | 48.4±48.4 | 53.9±53.9 | 52.7±52.7 | **56.7±56.7** | 51.3±51.3 |

**Table 7**: Classification result (3 class, grasp)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 41.0±12.0 | 45.0±10.5 | 42.0±10.3 | 44.0±4.9 | 50.0±10.5 | 40.0±10.5 | 42.0±6.8 | 48.0±12.9 | 39.0±4.9 | 39.0±8.6 | 49.0±3.7 | 47.0±4.0 |
| 2 | 39.0±5.8 | 46.0±5.8 | 39.0±6.6 | 40.0±12.2 | 44.0±11.1 | 49.0±6.6 | 45.0±9.5 | 51.0±3.7 | 34.0±8.6 | 35.0±8.4 | 45.0±8.4 | 45.0±11.4 |
| 3 | 28.0±12.9 | 37.0±13.6 | 38.0±6.8 | 37.0±13.6 | 53.0±20.6 | 50.0±17.9 | 55.0±4.5 | 53.0±17.8 | 40.0±11.0 | 41.0±9.7 | 41.0±2.0 | 33.0±10.8 |
| 4 | 45.0±13.0 | 48.0±9.3 | 47.0±4.0 | 48.0±9.3 | 55.0±6.3 | 53.0±7.5 | 48.0±16.0 | 65.0±8.4 | 40.0±16.4 | 41.0±12.4 | 49.0±8.6 | 43.0±9.3 |
| 5 | 44.0±12.8 | 48.0±12.9 | 48.0±6.0 | 44.0±14.6 | 60.0±10.5 | 64.0±10.2 | 55.0±7.1 | 60.0±10.5 | 59.0±8.0 | 50.0±11.8 | 54.0±13.9 | 51.0±13.2 |
| 6 | 49.5±5.8 | 52.5±3.9 | 53.0±4.6 | 52.0±7.6 | 64.0±2.5 | 63.0±6.4 | 61.5±3.4 | 68.0±6.8 | 46.5±6.4 | 43.0±5.6 | 52.5±9.6 | 50.5±6.6 |
| 7 | 46.7±5.3 | 47.7±6.2 | 45.7±4.8 | 50.0±6.8 | 56.3±6.2 | 56.0±8.3 | 59.3±3.9 | 59.7±1.2 | 46.3±10.7 | 47.3±6.7 | 52.3±5.3 | 51.0±10.0 |
| 8 | 50.0±2.4 | 48.0±3.2 | 49.0±2.9 | 51.0±2.5 | 56.0±10.7 | 57.7±8.0 | 63.3±6.4 | 60.3±7.3 | 45.0±10.7 | 49.3±9.6 | 61.0±5.6 | 55.7±7.0 |
| 9 | 57.0±6.8 | 54.0±7.3 | 57.0±10.3 | 64.0±7.3 | 74.0±9.2 | 73.0±6.8 | 70.0±10.0 | 74.0±5.8 | 48.0±9.3 | 44.0±5.8 | 65.0±4.5 | 57.0±9.3 |
| 10 | 30.0±11.0 | 42.0±6.8 | 43.0±6.8 | 34.0±9.2 | 60.0±8.9 | 52.0±9.3 | 70.0±8.9 | 60.0±12.2 | 48.0±6.8 | 41.0±7.3 | 61.0±10.2 | 43.0±10.3 |
| 11 | 40.0±7.1 | 40.0±11.0 | 39.0±9.7 | 41.0±3.7 | 33.0±4.0 | 38.0±6.0 | 31.0±7.3 | 41.0±9.7 | 35.0±12.6 | 39.0±7.3 | 38.0±8.7 | 39.0±8.6 |
| 12 | 37.0±8.7 | 48.0±7.5 | 42.0±11.7 | 50.0±5.5 | 47.0±20.9 | 53.0±20.6 | 47.0±8.1 | 51.0±17.7 | 31.0±6.6 | 34.0±10.7 | 52.0±8.1 | 47.0±13.6 |
| 13 | 63.0±8.1 | 69.0±8.6 | 62.0±11.7 | 67.0±6.8 | 71.0±5.8 | 73.0±6.8 | 72.0±6.0 | 70.0±5.5 | 66.0±13.9 | 67.0±12.9 | 76.0±8.0 | 56.0±4.9 |
| Average | 43.9±43.9 | **48.1±48.1** | 46.5±46.5 | 47.8±47.8 | 55.6±55.6 | 55.5±55.5 | 55.3±55.3 | **58.5±58.5** | 44.4±44.4 | 43.9±43.9 | **53.5±53.5** | 47.6±47.6 |

**Table 8**: Classification result (3 class, twist)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 32.0±9.3 | 36.0±3.7 | 43.0±6.8 | 37.0±5.1 | 50.0±10.5 | 42.0±6.0 | 57.0±8.1 | 45.0±13.0 | 41.0±8.0 | 41.0±8.0 | 50.0±7.1 | 40.0±12.6 |
| 2 | 33.0±10.3 | 43.0±8.7 | 48.0±2.4 | 33.0±10.3 | 50.0±7.7 | 46.0±8.6 | 57.0±7.5 | 52.0±11.2 | 39.0±3.7 | 33.0±6.8 | 45.0±7.7 | 37.0±18.6 |
| 3 | 43.0±7.5 | 38.0±5.1 | 51.0±8.0 | 41.0±6.6 | 53.0±5.1 | 50.0±7.7 | 45.0±7.1 | 53.0±5.1 | 49.0±12.0 | 45.0±14.1 | 47.0±7.5 | 53.0±6.8 |
| 4 | 35.0±16.4 | 49.0±8.0 | 50.0±3.2 | 48.0±6.0 | 54.0±14.3 | 62.0±10.8 | 62.0±12.9 | 63.0±13.3 | 48.0±11.7 | 47.0±12.9 | 51.0±8.0 | 39.0±10.7 |
| 5 | 41.0±9.7 | 49.0±2.0 | 50.0±5.5 | 47.0±4.0 | 52.0±7.5 | 57.0±11.2 | 61.0±8.6 | 51.0±10.2 | 50.0±11.8 | 46.0±5.8 | 48.0±14.4 | 53.0±6.8 |
| 6 | 36.5±5.8 | 39.5±5.3 | 44.5±4.3 | 41.5±8.5 | 59.5±6.2 | 59.5±8.3 | 55.0±5.0 | 61.5±3.4 | 50.0±4.2 | 45.0±5.2 | 56.0±6.6 | 51.5±5.8 |
| 7 | 42.7±4.4 | 44.3±3.6 | 47.3±4.4 | 46.7±2.4 | 60.3±3.7 | 57.3±5.4 | 55.7±4.3 | 61.3±6.9 | 50.3±4.9 | 52.0±7.0 | 65.7±4.0 | 58.7±4.3 |
| 8 | 40.7±4.3 | 42.3±3.9 | 45.0±5.1 | 44.0±4.8 | 55.0±9.1 | 51.3±6.7 | 55.0±10.8 | 54.7±11.7 | 57.3±3.1 | 56.3±3.9 | 62.3±5.4 | 62.7±6.8 |
| 9 | 48.0±6.8 | 50.0±7.1 | 52.0±5.1 | 52.0±10.8 | 69.0±6.6 | 65.0±10.0 | 60.0±7.1 | 68.0±6.8 | 51.0±11.1 | 48.0±9.8 | 63.0±6.0 | 64.0±10.2 |
| 10 | 36.0±10.7 | 45.0±8.9 | 47.0±2.4 | 39.0±8.6 | 44.0±3.7 | 49.0±8.6 | 60.0±4.5 | 55.0±8.4 | 36.0±2.0 | 31.0±13.6 | 55.0±6.3 | 39.0±5.8 |
| 11 | 30.0±5.5 | 43.0±6.8 | 45.0±5.5 | 40.0±4.5 | 38.0±10.3 | 39.0±7.3 | 49.0±11.6 | 42.0±11.2 | 27.0±13.6 | 23.0±9.3 | 40.0±7.1 | 31.0±13.2 |
| 12 | 47.0±9.8 | 48.0±5.1 | 51.0±10.2 | 38.0±9.3 | 54.0±8.0 | 50.0±6.3 | 64.0±11.1 | 48.0±4.0 | 47.0±5.1 | 37.0±5.1 | 56.0±9.7 | 43.0±12.9 |
| 13 | 39.0±5.8 | 46.0±9.7 | 45.0±3.2 | 44.0±6.6 | 63.0±15.4 | 60.0±13.0 | 61.0±5.8 | 62.0±11.7 | 44.0±3.7 | 45.0±7.1 | 52.0±10.3 | 42.0±5.1 |
| Average | 38.8±38.8 | 44.1±44.1 | **47.6±47.6** | 42.4±42.4 | 54.0±54.0 | 52.9±52.9 | 57.1±57.1 | **55.1±55.1** | 45.4±45.4 | 42.3±42.3 | **53.2±53.2** | 47.2±47.2 |

**Table 9**: Classification result applied SMOTE (3 class, grasp)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 39.0±13.9 | 45.0±13.0 | 38.0±10.3 | 44.0±15.0 | 47.0±12.1 | 42.0±11.2 | 41.0±8.6 | 47.0±13.3 | 35.0±5.5 | 39.0±8.6 | 45.0±13.0 | 46.0±4.9 |
| 2 | 37.0±5.1 | 47.0±6.0 | 45.0±8.4 | 38.0±8.7 | 43.0±9.8 | 49.0±6.6 | 41.0±3.7 | 49.0±3.7 | 38.0±7.5 | 35.0±8.4 | 39.0±9.2 | 40.0±6.3 |
| 3 | 27.0±12.5 | 36.0±12.0 | 37.0±8.7 | 30.0±13.0 | 56.0±13.6 | 50.0±18.4 | 53.0±6.0 | 54.0±18.8 | 41.0±11.6 | 41.0±9.7 | 39.0±8.0 | 35.0±7.7 |
| 4 | 44.0±12.4 | 48.0±9.3 | 47.0±4.0 | 49.0±4.9 | 58.0±8.7 | 53.0±7.5 | 53.0±17.5 | 66.0±4.9 | 39.0±15.6 | 41.0±12.4 | 48.0±10.3 | 43.0±8.7 |
| 5 | 44.0±12.8 | 48.0±12.9 | 49.0±7.3 | 46.0±15.0 | 59.0±13.2 | 64.0±10.2 | 58.0±4.0 | 59.0±10.2 | 58.0±12.5 | 50.0±11.8 | 55.0±11.8 | 46.0±16.2 |
| 6 | 50.0±9.4 | 52.0±7.3 | 50.0±6.1 | 51.0±8.7 | 65.5±6.0 | 63.5±4.6 | 61.5±4.9 | 68.0±6.2 | 47.0±8.0 | 43.0±5.6 | 55.0±8.9 | 49.5±7.3 |
| 7 | 40.7±7.6 | 38.3±9.7 | 46.0±7.5 | 43.7±6.2 | 55.0±7.2 | 56.7±7.7 | 62.0±6.1 | 59.7±3.2 | 44.0±8.9 | 46.7±6.8 | 51.7±9.3 | 48.7±8.4 |
| 8 | 44.0±2.5 | 44.0±3.9 | 44.3±3.4 | 45.3±1.2 | 58.7±9.6 | 58.3±7.7 | 60.7±2.7 | 58.7±8.8 | 44.0±9.0 | 49.7±8.8 | 59.3±6.0 | 55.7±6.0 |
| 9 | 58.0±6.8 | 54.0±7.3 | 57.0±8.1 | 63.0±8.1 | 75.0±8.4 | 73.0±6.8 | 71.0±9.7 | 78.0±5.1 | 44.0±11.1 | 44.0±5.8 | 63.0±12.1 | 56.0±9.7 |
| 10 | 32.0±12.1 | 41.0±8.0 | 42.0±7.5 | 38.0±7.5 | 61.0±9.7 | 52.0±9.3 | 65.0±14.8 | 57.0±9.3 | 46.0±10.2 | 41.0±7.3 | 59.0±8.6 | 45.0±9.5 |
| 11 | 40.0±7.1 | 42.0±6.8 | 40.0±7.1 | 36.0±8.0 | 32.0±4.0 | 37.0±6.8 | 32.0±4.0 | 36.0±5.8 | 34.0±11.6 | 39.0±7.3 | 42.0±10.3 | 40.0±10.0 |
| 12 | 38.0±9.8 | 48.0±7.5 | 46.0±8.6 | 48.0±6.0 | 49.0±18.5 | 52.0±22.0 | 48.0±10.3 | 49.0±18.3 | 29.0±7.3 | 34.0±10.7 | 53.0±9.3 | 37.0±10.3 |
| 13 | 63.0±8.1 | 69.0±8.6 | 65.0±11.4 | 67.0±2.4 | 70.0±6.3 | 73.0±6.8 | 75.0±8.4 | 70.0±3.2 | 66.0±13.9 | 67.0±12.9 | 72.0±9.3 | 55.0±6.3 |
| Average | 42.8±42.8 | **47.1±47.1** | 46.6±46.6 | 46.1±46.1 | 56.1±56.1 | 55.7±55.7 | 55.5±55.5 | **57.8±57.8** | 43.5±43.5 | 43.9±43.9 | **52.4±52.4** | 45.9±45.9 |

**Table 10**: Classification result applied SMOTE (3 class, twist)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP | | | | TDP | | | | PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 28.0±4.0 | 36.0±5.8 | 41.0±4.9 | 33.0±5.1 | 43.0±6.8 | 43.0±6.8 | 47.0±6.8 | 46.0±10.7 | 38.0±9.3 | 41.0±8.0 | 43.0±2.4 | 39.0±14.6 |
| 2 | 33.0±5.1 | 44.0±8.6 | 49.0±2.0 | 36.0±5.8 | 51.0±11.6 | 45.0±7.1 | 60.0±5.5 | 53.0±11.7 | 39.0±3.7 | 33.0±6.8 | 49.0±11.1 | 38.0±18.6 |
| 3 | 45.0±6.3 | 41.0±6.6 | 46.0±5.8 | 42.0±9.3 | 55.0±7.1 | 50.0±7.7 | 48.0±9.3 | 54.0±3.7 | 47.0±13.6 | 45.0±14.1 | 47.0±10.3 | 55.0±3.2 |
| 4 | 35.0±15.8 | 49.0±8.0 | 49.0±5.8 | 50.0±5.5 | 57.0±11.2 | 62.0±10.8 | 58.0±13.6 | 63.0±13.6 | 49.0±13.2 | 47.0±12.9 | 48.0±12.9 | 37.0±11.7 |
| 5 | 40.0±10.5 | 49.0±2.0 | 49.0±5.8 | 44.0±3.7 | 52.0±7.5 | 57.0±11.2 | 64.0±7.3 | 52.0±9.3 | 49.0±13.2 | 46.0±5.8 | 52.0±9.8 | 50.0±5.5 |
| 6 | 34.0±4.6 | 36.0±1.2 | 42.0±5.6 | 38.5±4.6 | 58.5±3.0 | 60.5±7.3 | 58.0±7.5 | 61.5±3.7 | 44.5±4.3 | 45.0±5.2 | 52.5±7.1 | 49.0±7.2 |
| 7 | 39.3±3.4 | 39.7±6.6 | 43.3±5.9 | 40.0±3.0 | 57.3±6.2 | 57.7±4.5 | 55.7±2.5 | 58.3±6.2 | 52.0±6.4 | 52.0±7.0 | 63.3±2.8 | 57.3±3.1 |
| 8 | 37.3±4.3 | 42.3±6.2 | 43.3±7.7 | 41.3±4.5 | 55.3±8.9 | 50.7±8.1 | 53.0±7.6 | 49.7±6.2 | 56.3±6.4 | 56.3±3.9 | 62.3±5.0 | 60.3±6.5 |
| 9 | 46.0±8.0 | 49.0±8.6 | 53.0±5.1 | 54.0±6.6 | 68.0±6.8 | 65.0±10.0 | 63.0±5.1 | 65.0±10.0 | 50.0±13.4 | 48.0±9.8 | 50.0±8.9 | 63.0±9.3 |
| 10 | 30.0±3.2 | 46.0±9.2 | 48.0±8.1 | 38.0±6.0 | 47.0±5.1 | 48.0±8.1 | 69.0±7.3 | 54.0±12.0 | 34.0±4.9 | 31.0±13.6 | 55.0±8.4 | 32.0±4.0 |
| 11 | 29.0±8.0 | 38.0±5.1 | 44.0±3.7 | 36.0±2.0 | 36.0±13.6 | 39.0±7.3 | 47.0±6.8 | 39.0±8.6 | 27.0±13.6 | 23.0±9.3 | 28.0±7.5 | 30.0±14.1 |
| 12 | 48.0±8.1 | 48.0±5.1 | 54.0±5.8 | 47.0±9.8 | 52.0±6.8 | 50.0±6.3 | 59.0±12.0 | 54.0±6.6 | 45.0±3.2 | 37.0±5.1 | 54.0±9.2 | 43.0±12.1 |
| 13 | 37.0±5.1 | 47.0±9.8 | 46.0±2.0 | 39.0±7.3 | 62.0±14.7 | 60.0±13.0 | 57.0±13.6 | 60.0±11.4 | 44.0±3.7 | 45.0±7.1 | 56.0±12.4 | 43.0±5.1 |
| Average | 37.0±37.0 | 43.5±43.5 | **46.7±46.7** | 41.4±41.4 | 53.4±53.4 | 52.9±52.9 | **56.8±56.8** | 54.6±54.6 | 44.2±44.2 | 42.3±42.3 | **50.8±50.8** | 45.9±45.9 |

**Table 11**: Classification result merged analysis (3 class, grasp)

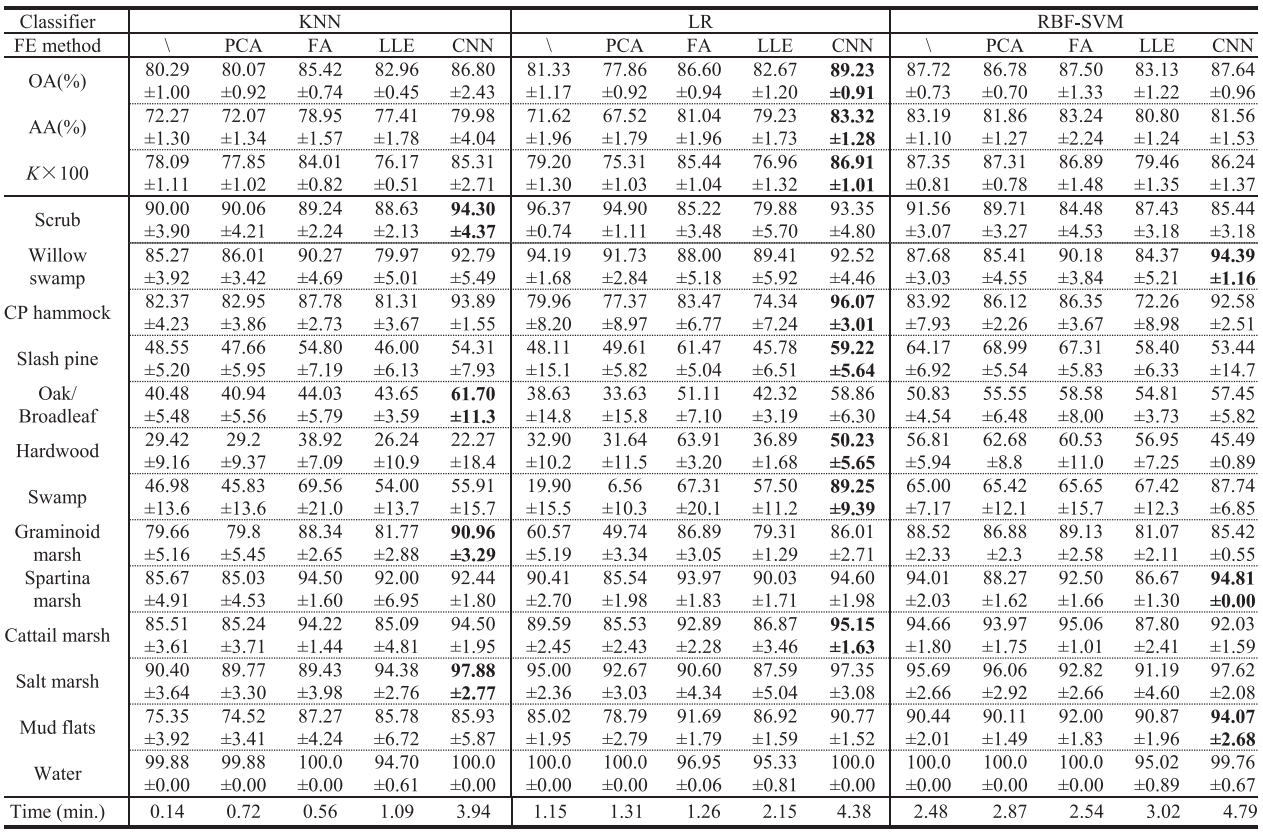
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP&TDP | | | | CSP&PSD | | | | TDP&PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 47.0±14.0 | 43.0±6.0 | 46.0±13.9 | 44.0±13.2 | 35.0±5.5 | 39.0±8.6 | 46.0±6.6 | 45.0±4.5 | 37.0±5.1 | 39.0±8.6 | 54.0±11.6 | 44.0±7.3 |
| 2 | 54.0±3.7 | 54.0±10.2 | 44.0±8.6 | 51.0±12.0 | 32.0±12.1 | 35.0±8.4 | 52.0±5.1 | 43.0±9.8 | 30.0±6.3 | 35.0±8.4 | 45.0±5.5 | 45.0±11.4 |
| 3 | 43.0±12.5 | 43.0±9.3 | 50.0±8.4 | 44.0±13.2 | 41.0±10.2 | 41.0±9.7 | 40.0±8.4 | 34.0±10.2 | 40.0±11.0 | 41.0±9.7 | 46.0±7.3 | 34.0±14.6 |
| 4 | 53.0±9.3 | 59.0±7.3 | 48.0±5.1 | 59.0±9.7 | 38.0±14.7 | 41.0±12.4 | 48.0±4.0 | 47.0±8.1 | 38.0±14.7 | 41.0±12.4 | 57.0±11.7 | 52.0±10.3 |
| 5 | 54.0±8.6 | 58.0±7.5 | 55.0±4.5 | 57.0±8.1 | 60.0±8.9 | 50.0±11.8 | 50.0±8.4 | 51.0±5.8 | 62.0±9.3 | 50.0±11.8 | 57.0±9.8 | 49.0±15.3 |
| 6 | 65.0±5.5 | 63.0±4.0 | 60.0±5.2 | 63.5±6.2 | 43.5±7.3 | 43.0±5.6 | 53.5±3.0 | 49.0±7.3 | 43.5±8.6 | 43.0±5.6 | 59.0±6.0 | 48.0±6.6 |
| 7 | 50.3±8.6 | 51.0±7.0 | 60.7±6.8 | 60.0±5.5 | 46.0±11.4 | 47.3±6.7 | 55.3±10.3 | 50.0±8.2 | 46.0±7.6 | 47.3±6.7 | 56.0±8.7 | 53.3±5.5 |
| 8 | 57.7±4.0 | 59.7±4.4 | 60.7±7.7 | 60.7±7.3 | 47.3±5.4 | 49.3±9.6 | 62.0±4.6 | 58.7±9.9 | 47.3±9.8 | 49.7±10.1 | 63.0±2.2 | 57.0±7.7 |
| 9 | 64.0±2.0 | 65.0±7.1 | 57.0±8.7 | 72.0±4.0 | 51.0±11.1 | 44.0±5.8 | 60.0±8.4 | 62.0±9.3 | 53.0±10.3 | 44.0±5.8 | 73.0±7.5 | 63.0±7.5 |
| 10 | 43.0±10.3 | 49.0±5.8 | 47.0±9.3 | 46.0±5.8 | 45.0±5.5 | 41.0±7.3 | 46.0±5.8 | 42.0±6.8 | 49.0±8.6 | 41.0±7.3 | 59.0±13.6 | 45.0±9.5 |
| 11 | 42.0±8.7 | 40.0±7.1 | 43.0±8.1 | 39.0±5.8 | 31.0±9.7 | 39.0±7.3 | 43.0±4.0 | 41.0±8.6 | 35.0±8.4 | 39.0±7.3 | 36.0±10.7 | 37.0±6.8 |
| 12 | 52.0±6.8 | 50.0±7.1 | 47.0±11.7 | 54.0±12.0 | 31.0±6.6 | 34.0±10.7 | 51.0±6.6 | 47.0±13.6 | 34.0±8.0 | 34.0±10.7 | 53.0±8.7 | 47.0±11.7 |
| 13 | 69.0±5.8 | 69.0±10.7 | 65.0±3.2 | 72.0±7.5 | 65.0±13.8 | 67.0±12.9 | 61.0±10.2 | 64.0±3.7 | 66.0±13.9 | 67.0±12.9 | 73.0±9.3 | 72.0±6.8 |
| Average | 53.4±53.4 | 54.1±54.1 | 52.6±52.6 | **55.6±55.6** | 43.5±43.5 | 43.9±43.9 | **51.4±51.4** | 48.7±48.7 | 44.7±44.7 | 43.9±43.9 | **56.2±56.2** | 49.7±49.7 |

**Table 12**: Classification result merged analysis (3 class, twist)

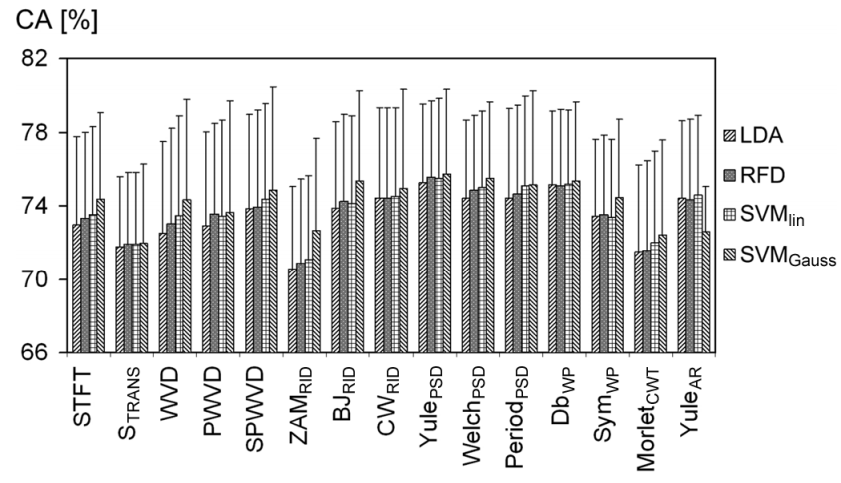
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Subject | CSP&TDP | | | | CSP&PSD | | | | TDP&PSD | | | |
| LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA | LSVM | KSVM | GB | SRLDA |
| 1 | 38.0±7.5 | 42.0±6.8 | 44.0±9.7 | 38.0±10.3 | 39.0±5.8 | 41.0±8.0 | 41.0±5.8 | 40.0±8.4 | 42.0±5.1 | 41.0±8.0 | 51.0±8.6 | 37.0±10.8 |
| 2 | 46.0±6.6 | 43.0±6.8 | 48.0±5.1 | 47.0±9.3 | 39.0±3.7 | 33.0±6.8 | 46.0±6.6 | 40.0±17.6 | 39.0±3.7 | 33.0±6.8 | 56.0±3.7 | 45.0±15.8 |
| 3 | 49.0±3.7 | 52.0±4.0 | 45.0±7.1 | 50.0±10.0 | 48.0±12.9 | 45.0±14.1 | 46.0±3.7 | 47.0±6.8 | 49.0±11.6 | 45.0±14.1 | 48.0±6.0 | 56.0±5.8 |
| 4 | 57.0±7.5 | 54.0±9.2 | 49.0±2.0 | 61.0±6.6 | 48.0±13.6 | 47.0±12.9 | 47.0±4.0 | 39.0±14.6 | 48.0±11.7 | 47.0±12.9 | 48.0±11.2 | 41.0±13.6 |
| 5 | 51.0±7.3 | 52.0±5.1 | 55.0±0.0 | 49.0±2.0 | 47.0±12.9 | 46.0±5.8 | 52.0±4.0 | 52.0±8.1 | 48.0±11.7 | 46.0±5.8 | 66.0±8.6 | 52.0±4.0 |
| 6 | 58.0±11.7 | 58.0±8.9 | 52.0±5.1 | 57.0±2.4 | 51.0±5.1 | 45.0±5.2 | 57.0±5.8 | 49.5±6.2 | 50.5±2.4 | 45.0±5.2 | 55.0±7.4 | 48.5±9.4 |
| 7 | 60.7±7.3 | 54.0±5.1 | 59.0±4.3 | 63.3±5.1 | 51.7±6.0 | 52.0±7.0 | 64.7±3.9 | 57.3±5.4 | 54.7±4.9 | 52.0±7.0 | 64.7±3.6 | 59.7±5.8 |
| 8 | 55.7±7.8 | 53.0±5.8 | 54.7±9.6 | 54.7±7.0 | 54.0±6.3 | 56.3±3.9 | 61.0±5.4 | 61.3±5.3 | 56.3±1.9 | 56.3±3.9 | 64.3±5.1 | 62.7±3.6 |
| 9 | 62.0±9.3 | 67.0±6.8 | 62.0±7.5 | 64.0±5.8 | 51.0±10.2 | 48.0±9.8 | 58.0±13.6 | 65.0±7.1 | 50.0±11.4 | 48.0±9.8 | 59.0±3.7 | 65.0±10.5 |
| 10 | 49.0±7.3 | 51.0±8.6 | 48.0±6.8 | 51.0±5.8 | 32.0±5.1 | 31.0±13.6 | 52.0±4.0 | 38.0±8.1 | 35.0±6.3 | 31.0±13.6 | 61.0±10.2 | 37.0±6.8 |
| 11 | 43.0±15.4 | 45.0±10.0 | 46.0±5.8 | 47.0±8.1 | 24.0±10.2 | 23.0±9.3 | 49.0±5.8 | 34.0±13.2 | 27.0±14.4 | 23.0±9.3 | 40.0±7.1 | 32.0±12.9 |
| 12 | 52.0±8.1 | 59.0±6.6 | 59.0±8.0 | 56.0±10.2 | 47.0±2.4 | 37.0±5.1 | 59.0±7.3 | 43.0±12.1 | 46.0±2.0 | 37.0±5.1 | 65.0±3.2 | 47.0±4.0 |
| 13 | 58.0±9.8 | 57.0±4.0 | 61.0±5.8 | 57.0±7.5 | 42.0±5.1 | 45.0±7.1 | 50.0±5.5 | 43.0±5.1 | 44.0±3.7 | 45.0±7.1 | 52.0±13.6 | 43.0±5.1 |
| Average | 52.3±52.3 | 52.8±52.8 | 52.5±52.5 | **53.5±53.5** | 44.1±44.1 | 42.3±42.3 | **52.5±52.5** | 46.9±46.9 | 45.3±45.3 | 42.3±42.3 | **56.2±56.2** | 48.1±48.1 |

Reference table

**Tab** Classification result obtained by different feature extraction approach on the KSC dataset



(From Deep feature extraction and classification of hyperspectral images based on convolutional neural network, 2016, IEEE Geoscience)



**Fig** Mean CA rates obtained on Session I data using the inner–outer CV scheme (five-fold splits with multiple runs) and averaged over 11 subjects. Vertical lines denote the inter-subject standard deviations of the respective mean CA values.

(From Comparative analysis of spectral approaches to feature extraction for EEG-based motor imagery classification, 2008, IEEE Rehab)