Machine Learning on Microcontrollers Mini-Project

Adjust the data loaders for the BCI channel selection project such that it works with motor movement data rather than motor imagery data, and run EEGNet. For the implementation, use NNoM.

Flash memory up to 1 Mbyte, up to 128 Kbyte of SRAM

**VALIDATION ACCURACY FROM CHANNEL SELECTION OBTAINED FROM EEGNET WEIGHTS**

***Inter-Subject Statistics***

*Global Model*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. Channels | 4-Class Accuracy (%) [n\_ds = 1] | | | |
| Original Channel Selection (T=3) | EEGNet Weights (T = 3s) | EEGNet Weights (T = 2s) | EEGNet Weights (T = 1s) |
| 8 | 60.27 | 56.20 | 55.42 | 55.85 |
| 16 | - | 62.56 | 62.80 | 61.74 |
| 19 | 63.39 | 63.63 | 62.63 | 62.34 |
| 24 | - | 63.97 | 64.28 | 62.16 |
| 38 | 64.15 | 64.61 | 65.09 | 64.33 |
| 64 | - | 65.54 | 65.90 | 64.99 |

|  |  |  |  |
| --- | --- | --- | --- |
| No. Channels | 4-Class Accuracy (%) [n\_ds = 2] | | |
| EEGNet Weights (T = 3s) | EEGNet Weights (T = 2s) | EEGNet Weights (T = 1s) |
| 8 | 56.36 | 55.92 | 55.62 |
| 16 | 62.73 | 62.86 | 60.91 |
| 19 | 63.54 | 62.92 | 63.12 |
| 24 | 63.57 | 63.53 | 63.02 |
| 38 | 65.48 | 65.00 | 64.33 |
| 64 | 65.33 | 65.93 | 64.65 |

|  |  |  |  |
| --- | --- | --- | --- |
| No. Channels | 4-Class Accuracy (%) [n\_ds = 3] | | |
| EEGNet Weights (T = 3s) | EEGNet Weights (T = 2s) | EEGNet Weights (T = 1s) |
| 8 | 56.70 | 57.42 | 55.51 |
| 16 | 62.45 | 62.62 | 61.50 |
| 19 | 63.12 | 63.24 | 63.17 |
| 24 | 63.12 | 64.39 | 63.68 |
| 38 | 64.71 | 65.30 | 64.10 |
| 64 | 65.73 | 65.62 | 64.78 |

***Intra-Subject Statistics***

*Global Model*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. Channels | 4-Class Accuracy (%) [n\_ds = 1] | | | |
| Original Channel Selection (T=3) | EEGNet Weights (T = 3s) | EEGNet Weights (T = 2s) | EEGNet Weights (T = 1s) |
| 8 | 61.26 | 57.62 | 57.55 | 56.26 |
| 16 | - | 63.44 | 63.40 | 62.21 |
| 19 | 64.42 | 65.54 | 64.21 | 62.96 |
| 24 | - | 65.77 | 64.92 | 64.45 |
| 38 | 66.22 | 66.82 | 66.43 | 66.31 |
| 64 | - | 67.41 | 67.39 | 66.38 |

|  |  |  |  |
| --- | --- | --- | --- |
| No. Channels | 4-Class Accuracy (%) [n\_ds = 2] | | |
| EEGNet Weights (T = 3s) | EEGNet Weights (T = 2s) | EEGNet Weights (T = 1s) |
| 8 | 58.34 | 57.59 | 56.11 |
| 16 | 63.23 | 62.96 | 62.28 |
| 19 | 64.62 | 63.76 | 62.64 |
| 24 | 65.38 | 65.14 | 63.57 |
| 38 | 66.84 | 66.53 | 66.49 |
| 64 | 67.02 | 67.33 | 65.45 |

|  |  |  |  |
| --- | --- | --- | --- |
| No. Channels | 4-Class Accuracy (%) [n\_ds = 3] | | |
| EEGNet Weights (T = 3s) | EEGNet Weights (T = 2s) | EEGNet Weights (T = 1s) |
| 8 | 57.61 | 57.23 | 56.71 |
| 16 | 62.85 | 63.02 | 62.43 |
| 19 | 63.82 | 64.61 | 62.86 |
| 24 | 65.80 | 64.79 | 64.11 |
| 38 | 66.38 | 66.40 | 65.51 |
| 64 | 67.28 | 66.19 | 65.72 |

***Intra-Subject Statistics***

*Global Model*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. Channels | 3-Class Accuracy (%) [n\_ds = 1] | | | | | |
| EEGNet Weights (T = 3s) | | EEGNet Weights (T = 2s) | | EEGNet Weights (T = 1s) | |
| 8 | 66.47 | 66.86 | 66.80 | 66.52 | 64.52 | 69.09 |
| 16 | 72.52 | 71.44 | 72.49 | 71.96 | 71.40 | 71.76 |
| 19 | 72.88 | 72.46 | 72.96 | 71.91 | 71.58 | 71.79 |
| 24 | 74.33 | 73.24 | 73.97 | 73.50 | 72.53 | 72.47 |
| 38 | 75.18 | 75.28 | 75.16 | 73.95 | 73.68 | 75.09 |
| 64 | 76.37 | 76.37 | 75.90 | 75.90 | 74.09 | 74.09 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. Channels | 3-Class Accuracy (%) [n\_ds = 2] | | | | | |
| EEGNet Weights (T = 3s) | | EEGNet Weights (T = 2s) | | EEGNet Weights (T = 1s) | |
| 8 | 66.70 | 68.10 | 66.95 | 67.35 | 65.06 | 66.83 |
| 16 | 72.12 | 72.44 | 71.07 | 71.64 | 71.13 | 70.57 |
| 19 | 72.86 | 73.26 | 72.32 | 72.59 | 71.53 | 71.70 |
| 24 | 74.54 | 73.32 | 73.74 | 73.36 | 73.98 | 72.74 |
| 38 | 75.43 | 75.89 | 74.07 | 75.51 | 73.50 | 73.89 |
| 64 | 75.60 | 75.60 | 74.71 | 74.71 | 73.98 | 73.98 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. Channels | 3-Class Accuracy (%) [n\_ds = 3] | | | | | |
| EEGNet Weights (T = 3s) | | EEGNet Weights (T = 2s) | | EEGNet Weights (T = 1s) | |
| 8 | 67.06 | 66.46 | 66.83 | 67.39 | 65.14 | 65.84 |
| 16 | 71.41 | 72.46 | 72.82 | 72.94 | 71.43 | 71.28 |
| 19 | 72.62 | 73.02 | 72.58 | 72.43 | 71.76 | 71.58 |
| 24 | 74.00 | 73.45 | 73.41 | 72.93 | 73.15 | 73.30 |
| 38 | 74.56 | 75.57 | 74.66 | 74.78 | 74.06 | 74.56 |
| 64 | 75.78 | 75.78 | 75.89 | 75.89 | 73.88 | 73.88 |

***Intra-Subject Statistics***

*Global Model*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. Channels | 2-Class Accuracy (%) [n\_ds = 1] | | | | | |
| EEGNet Weights (T = 3s) | | EEGNet Weights (T = 2s) | | EEGNet Weights (T = 1s) | |
| 8 | 79.30 | 80.57 | 79.21 | 79.25 | 78.19 | 79.37 |
| 16 | 82.00 | 82.56 | 81.45 | 81.79 | 81.16 | 81.72 |
| 19 | 82.13 | 82.24 | 82.06 | 82.02 | 82.13 | 82.79 |
| 24 | 82.93 | 82.95 | 82.27 | 82.83 | 81.95 | 82.81 |
| 38 | 83.99 | 83.81 | 84.49 | 83.56 | 83.06 | 82.86 |
| 64 | 83.72 | 83.72 | 83.58 | 83.58 | 83.08 | 83.08 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. Channels | 2-Class Accuracy (%) [n\_ds = 2] | | | | | |
| EEGNet Weights (T = 3s) | | EEGNet Weights (T = 2s) | | EEGNet Weights (T = 1s) | |
| 8 | 79.39 | 79.46 | 79.05 | 79.18 | 78.30 | 78.93 |
| 16 | 81.63 | 81.59 | 81.34 | 82.79 | 81.04 | 81.50 |
| 19 | 82.29 | 82.34 | 82.24 | 82.97 | 81.50 | 82.13 |
| 24 | 82.61 | 83.27 | 82.88 | 82.86 | 82.13 | 82.27 |
| 38 | 83.99 | 83.31 | 84.01 | 84.60 | 83.40 | 82.70 |
| 64 | 83.40 | 83.40 | 83.47 | 83.47 | 83.04 | 83.04 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. Channels | 2-Class Accuracy (%) [n\_ds = 3] | | | | | |
| EEGNet Weights (T = 3s) | | EEGNet Weights (T = 2s) | | EEGNet Weights (T = 1s) | |
| 8 | 79.34 | 79.89 | 79.43 | 79.34 | 78.91 | 77.69 |
| 16 | 82.22 | 82.72 | 81.86 | 82.83 | 80.29 | 81.59 |
| 19 | 82.65 | 82.22 | 82.24 | 82.63 | 81.25 | 82.43 |
| 24 | 83.02 | 82.95 | 82.70 | 83.79 | 81.77 | 82.56 |
| 38 | 84.20 | 84.04 | 83.54 | 83.47 | 83.58 | 83.36 |
| 64 | 83.33 | 83.33 | 83.42 | 83.42 | 82.95 | 82.95 |

**>> For 2,3,4 class, get accuracy for 64ch, t=3, ds=1.**

Choose highest

|  |  |  |
| --- | --- | --- |
|  | Inter-Subject | Intra-Subject |
| 2 | 82.09 | 83.72 |
| 3 | 74.53 | 76.37 |
| 4 | 65.54 | 67.19 |



Intra-subject gives a higher accuracy than inter-subject for all classes.

**>> Pick the optimum combo (ch, ds, t) from the RAM vs accuracy graph that fits in the microcontroller for 2, 3, and 4-class intra-subject. Get it to work on the MCU.**

****

The highest accuracy for 2-class is obtained by the 24ch, ds=3, T=2s use split1

****

The highest accuracy for 3-class is obtained by the 38ch, ds=3, T=1s use split0 (nnom) use split1 (cubeai)



The highest accuracy for 4-class is obtained by the 38ch, ds=2, T=1s (before) use split0

**>> Compare with NNoM and CubeAI.**

For presentation:

-explain what bci is

-explain eeg model doesn’t fit on microcontroller, so need for ds, t, ch. Explain how each work.

-explain inter and intra and show why I pick intra.

-pick optimum model for 2,3,4 class, show results on mcu (energy) for cubeai vs nnom.