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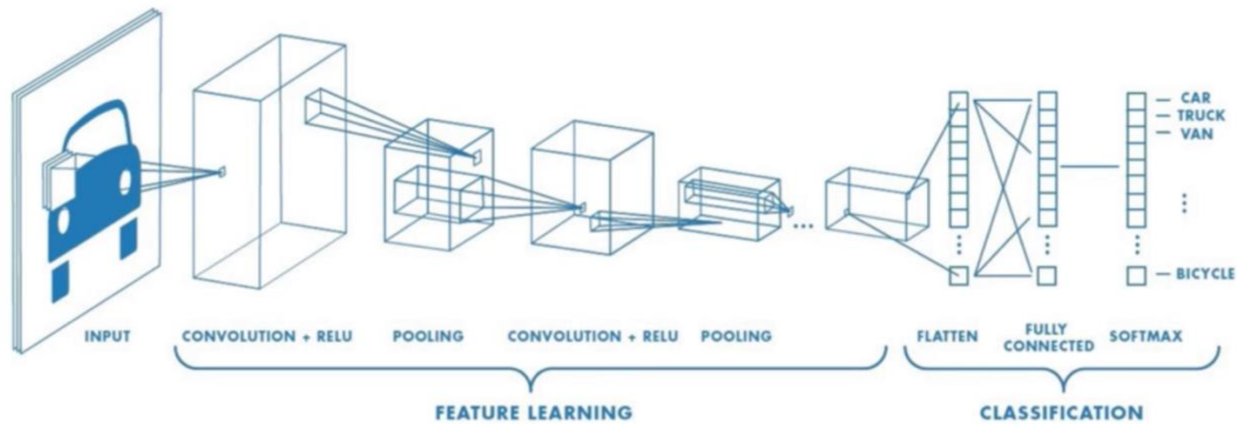
CSE 4310 – Computer Vision
Assignment 4
Image Classification with deep learning

A Basic CNN

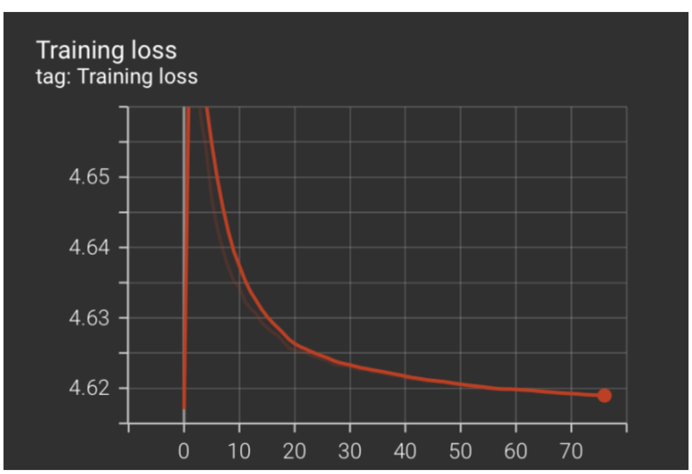


The architecture chosen for the basic convolution neural network for the Food101 dataset is displayed above. First, there is a convolution layer which is followed by a RELU activation function. After this, we apply a max pooling to reduce the size. Then we apply a second convolution with RELU activation function and then max pooling again.

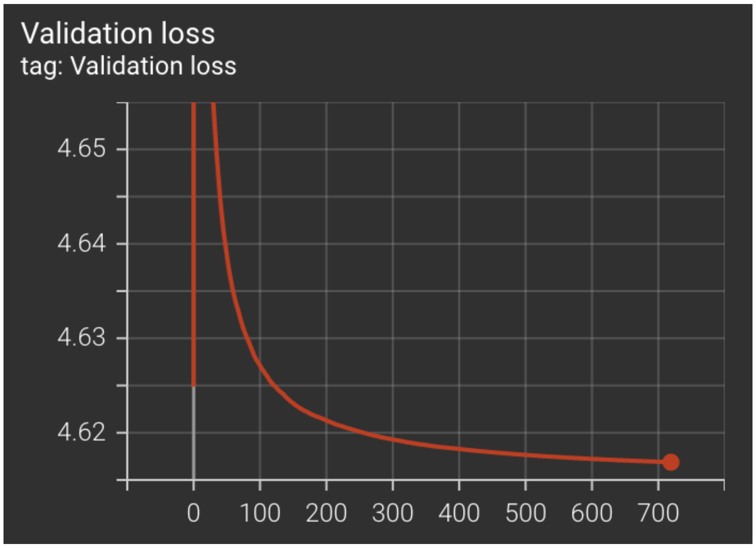
After feature learning, we have three fully connected layers for classification. At the end, we have the output as 101, one for each food category. The code for the convolution neural network architecture for the Food101 dataset is in the cnn.py file.

After 10 epochs, which took about 8 hours on my laptop by the way, the results are:

Training Loss: 4.61687



Validation Loss- 4.61512



Test Accuracy- 13.83%

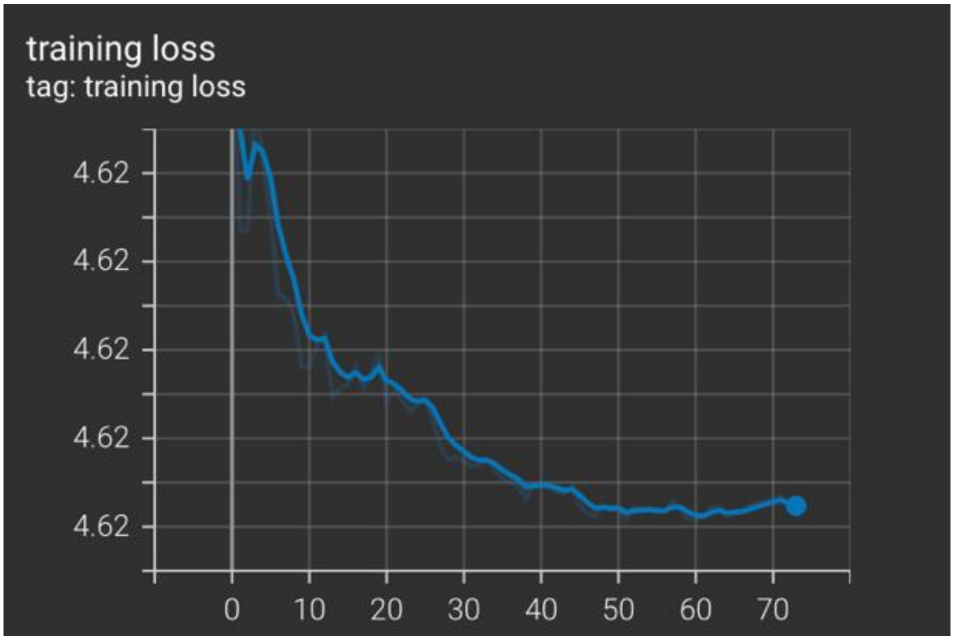
All Convolution Net

For the all-convolution net, I created 3 convolution layers. The first layer had 3 input channels and 6 output channels, with a kernel size of 5 and a padding of 1. The second convolution layer followed with 6 input channels and 16 output channels with the same kernel size and padding. Finally, the last convolution layer had 16 input channels and 101 output channels (for each class in dataset). I added only 3 convolution layers on this one because any more layers with larger value of channels crashed my computer.

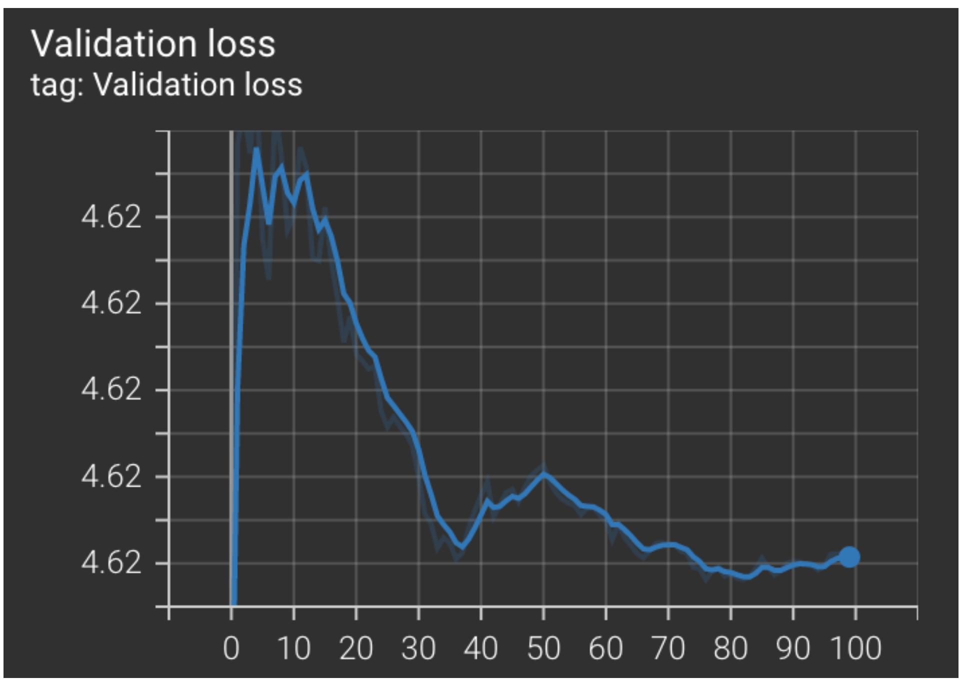
The basic Convolution Neural Network has **951021 parameters** whereas the All-Convolution Net has **4589 parameters**. The basic convolution neural network has far higher number of parameters because it has a fully connected layers for the classification part. The all-convolution net on the other hand has only 3 convolution layers due to my computer's limitation.

The code for this can be found with the file name all_convolution_net.py.

Training Loss- 4.61657



Validation Loss- 4.6109



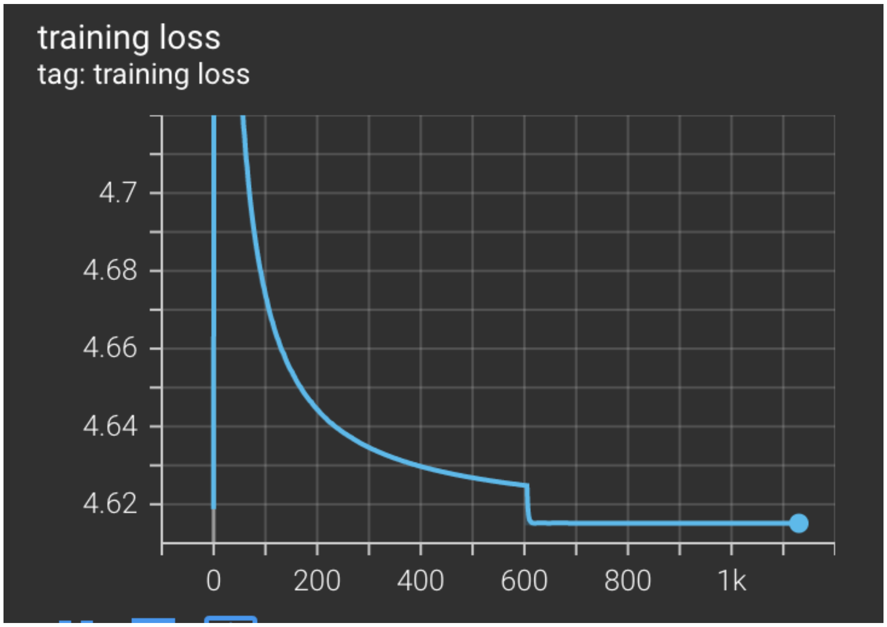
Final test accuracy- 14.24%.

This was lower mostly because it was run with lesser epochs as my laptop could not handle more epochs.

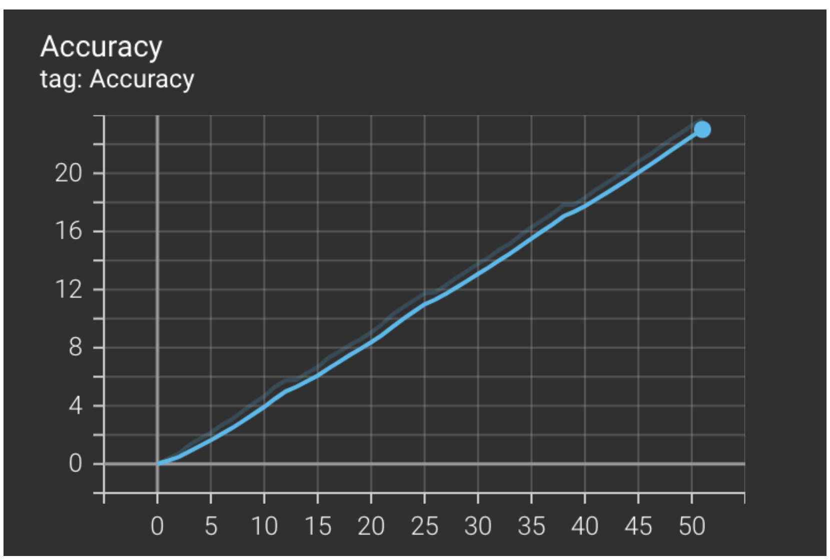
Regularization

For this part, I used the basic convolution network that I used in the previous part. For this, I added regularization in the form of data augmentation and dropouts. The data augmentations include random augmentation, random rotations, randomly resized crips, and random horizontal flips to the images. These augmentations help increase the diversity of data without actually needing more data.

Training Loss- 4.6151



Accuracy- 23.77%



Transfer Learning

The pretrained model I chose for this part was resnet18. This model is a deep residual learning model for image recognition. It has 72-layer architecture with 18 deep layers. The architecture of this network aimed at enabling large amounts of convolution layers to function efficiently.

Fine-tuning the convolution of pretrained model is done by first loading the pretrained model, and the final fully connected layer to the number of classes present in the Food101 data. This is further fine-tuned by decaying the learning rate parameter by a variable gamma for every step size in epoch.

The code for transfer learning is present in the transfer_learning.py file.

Training Loss- 4.87
Model accuracy- 24.68%

Best model weights

```
OrderedDict([('features.0.weight', tensor([[[[-0.0503,  0.0614, -0.0194,  0.0002,  0.0372],
          [-0.0486,  0.0370, -0.0061, -0.0090, -0.0554],
          [ 0.0991, -0.0376,  0.0490, -0.1020,  0.0657],
          [ 0.0004, -0.0948, -0.0578, -0.0287, -0.1004],
          [ 0.1050,  0.0483,  0.0178,  0.0777, -0.0211]],

         [[-0.0592, -0.0525, -0.0297, -0.0960, -0.0608],
          [-0.0307, -0.0725,  0.0050,  0.0532,  0.0072],
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          [-0.0464,  0.0135, -0.0532, -0.0957,  0.0312],
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         [[-0.0495, -0.0029,  0.0042,  0.0494, -0.1145],
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          [ 0.0548, -0.0861,  0.0038,  0.0039, -0.0044],
```

```
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[[[ 0.0739, -0.0786, -0.0587, -0.0425,  0.0369],
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  [ 0.0259, -0.0874, -0.0139,  0.1039, -0.0662]],

 [[ 0.0086,  0.0216, -0.1006,  0.0441, -0.0362],
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  [ 0.1076, -0.0772,  0.1145,  0.0715, -0.0041],
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  [-0.0641, -0.0240, -0.0565,  0.0619, -0.0784]],

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  [-0.0263,  0.0956,  0.0369, -0.0540, -0.0547],
  [ 0.0676, -0.1053,  0.0980,  0.0361,  0.0583],
  [ 0.1084, -0.1125,  0.0517, -0.0368, -0.0451],
  [ 0.0900, -0.0304, -0.0890, -0.0650, -0.0244]]],


[[[ 0.0374, -0.0698, -0.0447,  0.0182, -0.1006],
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```

```
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 [ 0.0158,  0.0225,  0.1069,  0.0909, -0.0501]]],


[[[-0.0432,  0.0824, -0.0858, -0.0308,  0.0903],
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 [ 0.0654, -0.0647, -0.0765, -0.0624, -0.0078]],

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 [-0.1139, -0.0818, -0.0827,  0.1070, -0.0741],
 [-0.1075, -0.0037, -0.0885,  0.0925, -0.0255]]],
```

```
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  [-0.0782,  0.0111,  0.0052,  0.0929,  0.0750],
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```
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[[ 0.0677,  0.0545,  0.0725, -0.0587, -0.0595],
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...,
```

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  [ 0.0277,  0.0092, -0.0585,  0.0176, -0.0647],
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  [-0.0080, -0.0397,  0.0160,  0.0521, -0.0164],
  [-0.0739, -0.0528,  0.0357, -0.0094,  0.0041]],

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```

```
[-0.0391,  0.0225, -0.0495,  0.0151, -0.0617]],

[[-0.0485,  0.0539,  0.0757,  0.0237,  0.0576],
 [-0.0486, -0.0228, -0.0297,  0.0563,  0.0443],
 [ 0.0061,  0.0109,  0.0326, -0.0501, -0.0629],
 [ 0.0377,  0.0507,  0.0086,  0.0794, -0.0309],
 [-0.0511,  0.0366, -0.0690,  0.0735, -0.0411]]],


[[[-0.0280,  0.0289,  0.0705,  0.0718, -0.0456],
 [ 0.0172,  0.0302, -0.0564, -0.0053,  0.0013],
 [-0.0724, -0.0601, -0.0161,  0.0403, -0.0504],
 [-0.0109, -0.0637, -0.0304,  0.0302,  0.0809],
 [-0.0797,  0.0742,  0.0657, -0.0500,  0.0683]],

[[-0.0790,  0.0745,  0.0764, -0.0293,  0.0480],
 [-0.0267, -0.0692, -0.0374,  0.0329, -0.0605],
 [-0.0561,  0.0407,  0.0815, -0.0571,  0.0672],
 [ 0.0645, -0.0674, -0.0527, -0.0606,  0.0670],
 [-0.0304,  0.0327,  0.0114,  0.0765,  0.0115]],

[[-0.0376,  0.0752,  0.0368, -0.0152,  0.0392],
 [ 0.0646, -0.0738,  0.0363,  0.0550,  0.0651],
 [ 0.0452, -0.0595,  0.0237, -0.0357, -0.0711],
 [ 0.0426,  0.0523, -0.0760,  0.0416, -0.0539],
 [ 0.0230,  0.0028, -0.0153,  0.0580,  0.0533]],

[[-0.0306, -0.0199,  0.0631, -0.0779,  0.0719],
 [-0.0177,  0.0604, -0.0056, -0.0138, -0.0544],
 [ 0.0412,  0.0258,  0.0324, -0.0699, -0.0440],
```

```
 [ 0.0511,  0.0305,  0.0151, -0.0062, -0.0128],
 [ 0.0188, -0.0137, -0.0669, -0.0273, -0.0415]],

[[-0.0723,  0.0700, -0.0590, -0.0666,  0.0036],
 [ 0.0756,  0.0017,  0.0591, -0.0197,  0.0254],
 [-0.0496,  0.0203, -0.0303, -0.0191,  0.0773],
 [ 0.0059, -0.0222,  0.0083, -0.0709,  0.0673],
 [-0.0129, -0.0155, -0.0062,  0.0589,  0.0331]],

[[ 0.0227, -0.0345,  0.0482,  0.0745,  0.0182],
 [-0.0107,  0.0704,  0.0024, -0.0527, -0.0554],
 [ 0.0221, -0.0698, -0.0024, -0.0509,  0.0608],
 [-0.0215,  0.0278, -0.0547, -0.0363,  0.0041],
 [-0.0283,  0.0112, -0.0690, -0.0323, -0.0563]]],


[[[ 0.0147,  0.0738,  0.0001,  0.0065, -0.0803],
 [ 0.0574, -0.0441, -0.0733,  0.0793,  0.0272],
 [ 0.0250,  0.0060, -0.0640, -0.0479,  0.0563],
 [ 0.0693, -0.0321, -0.0229, -0.0380, -0.0166],
 [ 0.0518,  0.0397, -0.0779,  0.0365, -0.0120]],

[[ 0.0778, -0.0074,  0.0498, -0.0053, -0.0518],
 [ 0.0274,  0.0051,  0.0479, -0.0662, -0.0111],
 [ 0.0033,  0.0717, -0.0121,  0.0687,  0.0435],
 [-0.0222, -0.0227,  0.0211, -0.0552,  0.0549],
 [ 0.0561, -0.0684,  0.0412,  0.0026,  0.0712]],

[[ 0.0255, -0.0449, -0.0708, -0.0570,  0.0387],
 [-0.0208, -0.0558,  0.0305,  0.0681, -0.0380],
```

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[-0.0378,  0.0684,  0.0589,  0.0563,  0.0656],
[ 0.0809,  0.0389, -0.0180, -0.0544, -0.0653],
[ 0.0613,  0.0799,  0.0666,  0.0043, -0.0379]],

[[ 0.0351, -0.0088,  0.0701,  0.0647, -0.0446],
[-0.0346,  0.0535, -0.0363,  0.0189, -0.0430],
[-0.0074, -0.0454,  0.0128,  0.0502, -0.0750],
[ 0.0572, -0.0037,  0.0198,  0.0721, -0.0586],
[-0.0448, -0.0159,  0.0352, -0.0294, -0.0214]],

[[ 0.0335, -0.0429, -0.0389,  0.0455, -0.0590],
[ 0.0509,  0.0729, -0.0423,  0.0505, -0.0244],
[-0.0135, -0.0789, -0.0794,  0.0551,  0.0227],
[ 0.0635, -0.0367,  0.0785,  0.0099,  0.0482],
[ 0.0805,  0.0437, -0.0451,  0.0701,  0.0413]],

[[-0.0437,  0.0421, -0.0365,  0.0022,  0.0060],
[-0.0140, -0.0025,  0.0039,  0.0778, -0.0495],
[-0.0309, -0.0496, -0.0061,  0.0396, -0.0770],
[ 0.0488, -0.0383, -0.0673, -0.0464, -0.0779],
[-0.0179,  0.0110,  0.0252, -0.0242,  0.0079]]]])), ('features.3.bias', tensor([-0.0034,
0.0360, -0.0762,  0.0026,  0.0369, -0.0363,  0.0684, -0.0357,
-0.0726,  0.0614,  0.0260, -0.0524, -0.0392, -0.0591,  0.0310,  0.0631])),
('estimator.0.weight', tensor([[-2.6122e-03, -1.0487e-02, -1.3590e-04,  ...,  1.0316e-02,
5.9071e-03,  2.7480e-03],
[ 2.1398e-03,  4.0828e-03, -5.3036e-03,  ...,  1.3170e-03,
8.0560e-03, -5.8364e-03],
[ 1.0617e-02,  7.6696e-03, -4.1795e-03,  ..., -3.8112e-05,
1.6905e-03,  5.1725e-03],
...,
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[-5.2499e-03, -6.4048e-03, 4.5538e-03, ..., -4.6762e-03,
9.9406e-03, -7.5171e-03],
[-7.1733e-03, -8.1395e-03, 5.4939e-04, ..., -7.2965e-03,
-6.3076e-03, -1.1203e-02],
[-2.3725e-03, 1.2230e-03, 7.4671e-03, ..., 3.9768e-03,
5.0955e-05, 8.9360e-03]])), ('estimator.0.bias', tensor([9.2100e-03, -1.1273e-02, -2.3817e-03, 3.7625e-03, -7.1775e-03,
5.4028e-03, 1.7618e-03, 1.1324e-02, -7.5420e-05, -1.2961e-03,
-7.3525e-03, -7.4752e-03, 8.6439e-03, 7.4248e-03, -9.8944e-03,
-3.5285e-04, 1.7696e-03, -9.8032e-03, -9.8702e-03, -8.2769e-03,
8.3385e-03, 1.0556e-02, -9.6756e-03, 1.6375e-03, 1.0090e-02,
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-6.0511e-03, -7.8322e-03, -9.6403e-03, -1.1154e-02, 6.9027e-03,
-3.0793e-03, 1.0813e-02, -6.1843e-04, 7.0405e-03, 2.1251e-03,
-1.0009e-02, -6.0463e-03, 1.7532e-03, -2.6352e-03, -5.3630e-03,
-2.2421e-03, 8.9574e-04, -8.9431e-03, 5.1904e-03, 4.9747e-03,
-9.2194e-03, -4.8139e-03, -8.3339e-03, -4.0412e-03, -7.5630e-03,
1.3488e-03, 7.5411e-03, -7.8559e-03, -9.9849e-03, -9.1271e-03,
8.0562e-03, 4.3309e-04, -1.0532e-02, 1.2624e-03, 4.1334e-03,
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-6.5837e-03, -5.0966e-03, 1.1231e-02, -5.1364e-03, -7.8314e-03,
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4.3624e-03, 1.6603e-04, 6.5100e-03, -8.7874e-03, -1.6562e-03,
1.0870e-02, -4.9019e-03, 3.6779e-03, -3.8714e-03, -5.9614e-03,

-5.2433e-03, 4.1790e-04, -1.0241e-03, -5.3221e-03, 1.1089e-02])), ('estimator.2.weight', tensor([[-0.0229, -0.0244, -0.0877, ..., -0.0158, 0.0317, -0.0391],

[0.0078, -0.0300, -0.0086, ..., -0.0737, 0.0684, 0.0209],

[-0.0805, -0.0636, 0.0280, ..., -0.0338, -0.0670, -0.0763],

...,

[0.0593, 0.0506, -0.0797, ..., 0.0409, 0.0132, -0.0351],

[0.0611, -0.0435, 0.0831, ..., 0.0246, -0.0833, 0.0514],

[-0.0723, -0.0398, 0.0301, ..., -0.0194, 0.0359, 0.0126]])), ('estimator.2.bias', tensor([0.0238, 0.0886, 0.0038, -0.0868, -0.0165, -0.0668, 0.0671, -0.0901,

0.0896, -0.0366, 0.0050, 0.0636, 0.0525, -0.0009, -0.0409, 0.0555,

0.0296, 0.0697, 0.0057, -0.0219, 0.0433, 0.0372, -0.0178, -0.0263,

0.0689, 0.0508, 0.0246, -0.0314, 0.0796, -0.0121, 0.0301, 0.0802,

0.0855, -0.0164, 0.0076, -0.0220, 0.0676, -0.0113, 0.0654, 0.0910,

-0.0017, -0.0512, 0.0600, 0.0467, -0.0642, 0.0252, 0.0827, -0.0032,

-0.0285, 0.0315, 0.0417, -0.0632, -0.0892, -0.0008, -0.0810, -0.0664,

-0.0236, -0.0813, 0.0170, -0.0232, 0.0528, 0.0541, 0.0678, 0.0650,

0.0209, 0.0016, -0.0710, 0.0740, 0.0166, -0.0385, -0.0415, 0.0869,

0.0787, 0.0855, -0.0534, -0.0658, 0.0061, 0.0378, -0.0665, 0.0408,

-0.0147, 0.0735, 0.0096, 0.0142])), ('estimator.4.weight', tensor([[-0.0614, -0.1024, -0.1090, ..., 0.0607, 0.0786, 0.0730],

[0.0406, 0.0173, 0.0270, ..., 0.0182, -0.0462, -0.1069],

[-0.0313, -0.0880, 0.0580, ..., -0.0570, 0.0066, -0.0573],

...,

[0.0564, -0.0299, 0.0326, ..., 0.0085, 0.0989, 0.1030],

[0.0543, 0.0719, -0.0855, ..., -0.0762, 0.0719, 0.0434],

[-0.0163, 0.0449, -0.0032, ..., 0.0657, -0.0029, 0.0021]])), ('estimator.4.bias', tensor([-0.0496, 0.0882, -0.0364, 0.0696, -0.0103, -0.0229, -0.0291, -0.0560,

-0.0684, -0.0281, -0.0430, -0.0264, -0.0331, -0.0938, 0.0533, 0.0817,

-0.0413, -0.1074, 0.0311, 0.0819, 0.0384, 0.0445, -0.0236, -0.0050,

0.0282, 0.0996, 0.0490, 0.0125, -0.0935, 0.0529, -0.1034, -0.0133,

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-0.0583,  0.0475, -0.0583,  0.0777,  0.0570, -0.1046,  0.0618, -0.0420,
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-0.1027,  0.0764, -0.0077, -0.0722,  0.1005,  0.0859,  0.0106, -0.0474,
 0.0558, -0.0517, -0.0942,  0.0812,  0.0753, -0.0263,  0.0359,  0.0021,
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-0.0662,  0.0676,  0.0966, -0.0038,  0.0815, -0.0956,  0.0710,  0.0901,
 0.0358,  0.0695, -0.0468, -0.0348, -0.0394,  0.0813, -0.0038,  0.0331,
 0.0262, -0.0454, -0.1011,  0.0825, -0.0288, -0.0322,  0.0940, -0.0336,
 0.0731,  0.0047, -0.1085,  0.0056, -0.0067]))])
```