Train on 50000 samples, validate on 10000 samples

Epoch 1/15

50000/50000 [==============================] - 29s 576us/step - loss: 0.0877 - mean\_squared\_error: 0.0877 - acc: 0.3056 - val\_loss: 0.1024 - val\_mean\_squared\_error: 0.1024 - val\_acc: 0.4719

Epoch 2/15

50000/50000 [==============================] - 24s 481us/step - loss: 0.0810 - mean\_squared\_error: 0.0810 - acc: 0.4917 - val\_loss: 0.0875 - val\_mean\_squared\_error: 0.0875 - val\_acc: 0.5572

Epoch 3/15

50000/50000 [==============================] - 24s 486us/step - loss: 0.0676 - mean\_squared\_error: 0.0676 - acc: 0.6146 - val\_loss: 0.0549 - val\_mean\_squared\_error: 0.0549 - val\_acc: 0.7237

Epoch 4/15

50000/50000 [==============================] - 24s 476us/step - loss: 0.0500 - mean\_squared\_error: 0.0500 - acc: 0.7476 - val\_loss: 0.0348 - val\_mean\_squared\_error: 0.0348 - val\_acc: 0.8249

Epoch 5/15

50000/50000 [==============================] - 26s 513us/step - loss: 0.0357 - mean\_squared\_error: 0.0357 - acc: 0.8330 - val\_loss: 0.0258 - val\_mean\_squared\_error: 0.0258 - val\_acc: 0.8703

Epoch 6/15

50000/50000 [==============================] - 25s 505us/step - loss: 0.0275 - mean\_squared\_error: 0.0275 - acc: 0.8615 - val\_loss: 0.0228 - val\_mean\_squared\_error: 0.0228 - val\_acc: 0.8851

Epoch 7/15

50000/50000 [==============================] - 32s 648us/step - loss: 0.0232 - mean\_squared\_error: 0.0232 - acc: 0.8751 - val\_loss: 0.0209 - val\_mean\_squared\_error: 0.0209 - val\_acc: 0.8950

Epoch 8/15

50000/50000 [==============================] - 59s 1ms/step - loss: 0.0206 - mean\_squared\_error: 0.0206 - acc: 0.8851 - val\_loss: 0.0201 - val\_mean\_squared\_error: 0.0201 - val\_acc: 0.8990

Epoch 9/15

50000/50000 [==============================] - 52s 1ms/step - loss: 0.0188 - mean\_squared\_error: 0.0188 - acc: 0.8914 - val\_loss: 0.0187 - val\_mean\_squared\_error: 0.0187 - val\_acc: 0.9060

Epoch 10/15

50000/50000 [==============================] - 52s 1ms/step - loss: 0.0176 - mean\_squared\_error: 0.0176 - acc: 0.8960 - val\_loss: 0.0187 - val\_mean\_squared\_error: 0.0187 - val\_acc: 0.9063

Epoch 11/15

50000/50000 [==============================] - 54s 1ms/step - loss: 0.0167 - mean\_squared\_error: 0.0167 - acc: 0.8998 - val\_loss: 0.0176 - val\_mean\_squared\_error: 0.0176 - val\_acc: 0.9117

Epoch 12/15

50000/50000 [==============================] - 51s 1ms/step - loss: 0.0159 - mean\_squared\_error: 0.0159 - acc: 0.9034 - val\_loss: 0.0169 - val\_mean\_squared\_error: 0.0169 - val\_acc: 0.9155

Epoch 13/15

50000/50000 [==============================] - 54s 1ms/step - loss: 0.0153 - mean\_squared\_error: 0.0153 - acc: 0.9070 - val\_loss: 0.0167 - val\_mean\_squared\_error: 0.0167 - val\_acc: 0.9161

Epoch 14/15

50000/50000 [==============================] - 57s 1ms/step - loss: 0.0148 - mean\_squared\_error: 0.0148 - acc: 0.9090 - val\_loss: 0.0162 - val\_mean\_squared\_error: 0.0162 - val\_acc: 0.9187

Epoch 15/15

50000/50000 [==============================] - 52s 1ms/step - loss: 0.0144 - mean\_squared\_error: 0.0144 - acc: 0.9119 - val\_loss: 0.0157 - val\_mean\_squared\_error: 0.0157 - val\_acc: 0.9211

10000/10000 [==============================] - 3s 296us/step

The testing accuracy metric for momentum 0.1 is : [0.013270610525133088, 0.013270610525133088, 0.9199]

---------------------------------------------------

Train on 50000 samples, validate on 10000 samples

Epoch 1/15

50000/50000 [==============================] - 55s 1ms/step - loss: 0.0879 - mean\_squared\_error: 0.0879 - acc: 0.2549 - val\_loss: 0.1230 - val\_mean\_squared\_error: 0.1230 - val\_acc: 0.3746

Epoch 2/15

50000/50000 [==============================] - 79s 2ms/step - loss: 0.0795 - mean\_squared\_error: 0.0795 - acc: 0.5370 - val\_loss: 0.0643 - val\_mean\_squared\_error: 0.0643 - val\_acc: 0.6739

Epoch 3/15

50000/50000 [==============================] - 85s 2ms/step - loss: 0.0620 - mean\_squared\_error: 0.0620 - acc: 0.6917 - val\_loss: 0.0464 - val\_mean\_squared\_error: 0.0464 - val\_acc: 0.7658ean\_squared\_error: 0.0630 - acc: 0.6868

Epoch 4/15

50000/50000 [==============================] - 90s 2ms/step - loss: 0.0418 - mean\_squared\_error: 0.0418 - acc: 0.7756 - val\_loss: 0.0328 - val\_mean\_squared\_error: 0.0328 - val\_acc: 0.8349

Epoch 5/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0301 - mean\_squared\_error: 0.0301 - acc: 0.8373 - val\_loss: 0.0253 - val\_mean\_squared\_error: 0.0253 - val\_acc: 0.8732

Epoch 6/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0242 - mean\_squared\_error: 0.0242 - acc: 0.8627 - val\_loss: 0.0221 - val\_mean\_squared\_error: 0.0221 - val\_acc: 0.8892

Epoch 7/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0210 - mean\_squared\_error: 0.0210 - acc: 0.8761 - val\_loss: 0.0206 - val\_mean\_squared\_error: 0.0206 - val\_acc: 0.8963

Epoch 8/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0189 - mean\_squared\_error: 0.0189 - acc: 0.8862 - val\_loss: 0.0194 - val\_mean\_squared\_error: 0.0194 - val\_acc: 0.9025

Epoch 9/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0175 - mean\_squared\_error: 0.0175 - acc: 0.8937 - val\_loss: 0.0185 - val\_mean\_squared\_error: 0.0185 - val\_acc: 0.9070

Epoch 10/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0164 - mean\_squared\_error: 0.0164 - acc: 0.8987 - val\_loss: 0.0177 - val\_mean\_squared\_error: 0.0177 - val\_acc: 0.9112

Epoch 11/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0156 - mean\_squared\_error: 0.0156 - acc: 0.9033 - val\_loss: 0.0172 - val\_mean\_squared\_error: 0.0172 - val\_acc: 0.9136

Epoch 12/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0149 - mean\_squared\_error: 0.0149 - acc: 0.9075 - val\_loss: 0.0165 - val\_mean\_squared\_error: 0.0165 - val\_acc: 0.9171

Epoch 13/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0143 - mean\_squared\_error: 0.0143 - acc: 0.9112 - val\_loss: 0.0164 - val\_mean\_squared\_error: 0.0164 - val\_acc: 0.9178

Epoch 14/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0138 - mean\_squared\_error: 0.0138 - acc: 0.9141 - val\_loss: 0.0157 - val\_mean\_squared\_error: 0.0157 - val\_acc: 0.9212

Epoch 15/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0133 - mean\_squared\_error: 0.0133 - acc: 0.9167 - val\_loss: 0.0154 - val\_mean\_squared\_error: 0.0154 - val\_acc: 0.9231

10000/10000 [==============================] - 5s 464us/step

The testing accuracy metric for momentum 0.3 is : [0.012533952592080459, 0.012533952592080459, 0.9224]

---------------------------------------------------

Train on 50000 samples, validate on 10000 samples

Epoch 1/15

50000/50000 [==============================] - 84s 2ms/step - loss: 0.0870 - mean\_squared\_error: 0.0870 - acc: 0.3081 - val\_loss: 0.0969 - val\_mean\_squared\_error: 0.0969 - val\_acc: 0.5040- mean\_squared\_error: 0.0906 - acc: 0.0958

Epoch 2/15

50000/50000 [==============================] - 80s 2ms/step - loss: 0.0655 - mean\_squared\_error: 0.0655 - acc: 0.6539 - val\_loss: 0.0442 - val\_mean\_squared\_error: 0.0442 - val\_acc: 0.7772

Epoch 3/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0340 - mean\_squared\_error: 0.0340 - acc: 0.8191 - val\_loss: 0.0249 - val\_mean\_squared\_error: 0.0249 - val\_acc: 0.8753

Epoch 4/15

50000/50000 [==============================] - 80s 2ms/step - loss: 0.0225 - mean\_squared\_error: 0.0225 - acc: 0.8720 - val\_loss: 0.0197 - val\_mean\_squared\_error: 0.0197 - val\_acc: 0.9012

Epoch 5/15

50000/50000 [==============================] - 80s 2ms/step - loss: 0.0184 - mean\_squared\_error: 0.0184 - acc: 0.8905 - val\_loss: 0.0181 - val\_mean\_squared\_error: 0.0181 - val\_acc: 0.9089

Epoch 6/15

50000/50000 [==============================] - 67s 1ms/step - loss: 0.0163 - mean\_squared\_error: 0.0163 - acc: 0.9004 - val\_loss: 0.0171 - val\_mean\_squared\_error: 0.0171 - val\_acc: 0.9141

Epoch 7/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0150 - mean\_squared\_error: 0.0150 - acc: 0.9072 - val\_loss: 0.0164 - val\_mean\_squared\_error: 0.0164 - val\_acc: 0.9175

Epoch 8/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0141 - mean\_squared\_error: 0.0141 - acc: 0.9121 - val\_loss: 0.0155 - val\_mean\_squared\_error: 0.0155 - val\_acc: 0.9224

Epoch 9/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0133 - mean\_squared\_error: 0.0133 - acc: 0.9169 - val\_loss: 0.0146 - val\_mean\_squared\_error: 0.0146 - val\_acc: 0.9268

Epoch 10/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0127 - mean\_squared\_error: 0.0127 - acc: 0.9206 - val\_loss: 0.0146 - val\_mean\_squared\_error: 0.0146 - val\_acc: 0.9268

Epoch 11/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0122 - mean\_squared\_error: 0.0122 - acc: 0.9243 - val\_loss: 0.0140 - val\_mean\_squared\_error: 0.0140 - val\_acc: 0.9298

Epoch 12/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0117 - mean\_squared\_error: 0.0117 - acc: 0.9269 - val\_loss: 0.0134 - val\_mean\_squared\_error: 0.0134 - val\_acc: 0.9328

Epoch 13/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0113 - mean\_squared\_error: 0.0113 - acc: 0.9295 - val\_loss: 0.0132 - val\_mean\_squared\_error: 0.0132 - val\_acc: 0.9340

Epoch 14/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0109 - mean\_squared\_error: 0.0109 - acc: 0.9320 - val\_loss: 0.0126 - val\_mean\_squared\_error: 0.0126 - val\_acc: 0.9368

Epoch 15/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0106 - mean\_squared\_error: 0.0106 - acc: 0.9338 - val\_loss: 0.0126 - val\_mean\_squared\_error: 0.0126 - val\_acc: 0.9370

10000/10000 [==============================] - 5s 475us/step

The testing accuracy metric for momentum 0.6 is : [0.010164116041152738, 0.010164116041152738, 0.9361]

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Train on 50000 samples, validate on 10000 samples

Epoch 1/15

50000/50000 [==============================] - 85s 2ms/step - loss: 0.0493 - mean\_squared\_error: 0.0493 - acc: 0.6869 - val\_loss: 0.0213 - val\_mean\_squared\_error: 0.0213 - val\_acc: 0.8932

Epoch 2/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0160 - mean\_squared\_error: 0.0160 - acc: 0.9013 - val\_loss: 0.0156 - val\_mean\_squared\_error: 0.0156 - val\_acc: 0.9216

Epoch 3/15

50000/50000 [==============================] - 80s 2ms/step - loss: 0.0127 - mean\_squared\_error: 0.0127 - acc: 0.9197 - val\_loss: 0.0140 - val\_mean\_squared\_error: 0.0140 - val\_acc: 0.9293

Epoch 4/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0110 - mean\_squared\_error: 0.0110 - acc: 0.9302 - val\_loss: 0.0123 - val\_mean\_squared\_error: 0.0123 - val\_acc: 0.9383

Epoch 5/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0098 - mean\_squared\_error: 0.0098 - acc: 0.9389 - val\_loss: 0.0113 - val\_mean\_squared\_error: 0.0113 - val\_acc: 0.9436

Epoch 6/15

50000/50000 [==============================] - 80s 2ms/step - loss: 0.0089 - mean\_squared\_error: 0.0089 - acc: 0.9440 - val\_loss: 0.0103 - val\_mean\_squared\_error: 0.0103 - val\_acc: 0.9482

Epoch 7/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0081 - mean\_squared\_error: 0.0081 - acc: 0.9493 - val\_loss: 0.0095 - val\_mean\_squared\_error: 0.0095 - val\_acc: 0.9526

Epoch 8/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0075 - mean\_squared\_error: 0.0075 - acc: 0.9539 - val\_loss: 0.0088 - val\_mean\_squared\_error: 0.0088 - val\_acc: 0.9559

Epoch 9/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0069 - mean\_squared\_error: 0.0069 - acc: 0.9569 - val\_loss: 0.0080 - val\_mean\_squared\_error: 0.0080 - val\_acc: 0.9600

Epoch 10/15

50000/50000 [==============================] - 64s 1ms/step - loss: 0.0064 - mean\_squared\_error: 0.0064 - acc: 0.9606 - val\_loss: 0.0079 - val\_mean\_squared\_error: 0.0079 - val\_acc: 0.9603

Epoch 11/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0060 - mean\_squared\_error: 0.0060 - acc: 0.9636 - val\_loss: 0.0073 - val\_mean\_squared\_error: 0.0073 - val\_acc: 0.9635

Epoch 12/15

50000/50000 [==============================] - 82s 2ms/step - loss: 0.0056 - mean\_squared\_error: 0.0056 - acc: 0.9661 - val\_loss: 0.0068 - val\_mean\_squared\_error: 0.0068 - val\_acc: 0.9657

Epoch 13/15

50000/50000 [==============================] - 81s 2ms/step - loss: 0.0053 - mean\_squared\_error: 0.0053 - acc: 0.9685 - val\_loss: 0.0070 - val\_mean\_squared\_error: 0.0070 - val\_acc: 0.9652

Epoch 14/15

50000/50000 [==============================] - 83s 2ms/step - loss: 0.0049 - mean\_squared\_error: 0.0049 - acc: 0.9713 - val\_loss: 0.0065 - val\_mean\_squared\_error: 0.0065 - val\_acc: 0.9673

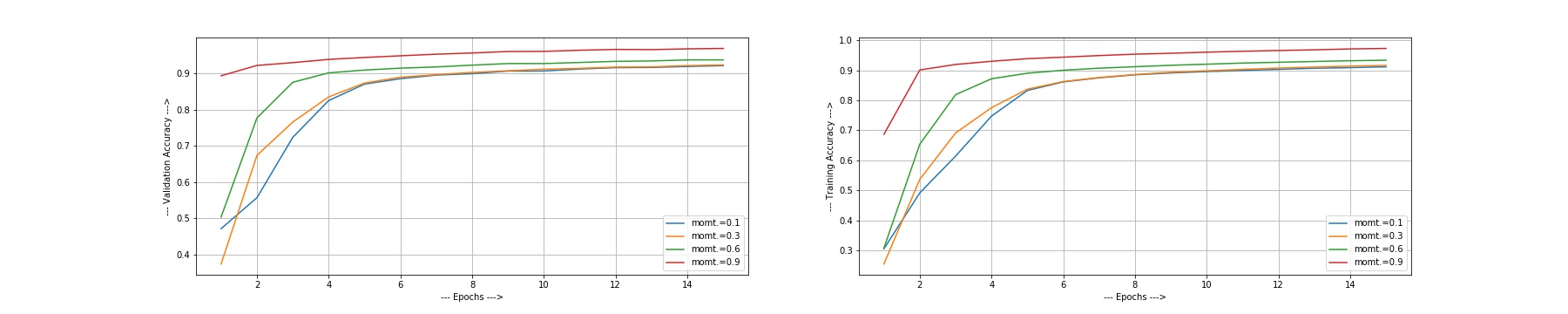
Epoch 15/15

50000/50000 [==============================] - 85s 2ms/step - loss: 0.0046 - mean\_squared\_error: 0.0046 - acc: 0.9730 - val\_loss: 0.0063 - val\_mean\_squared\_error: 0.0063 - val\_acc: 0.9684

10000/10000 [==============================] - 4s 448us/step

The testing accuracy metric for momentum 0.9 is : [0.005462492938021023, 0.005462492938021023, 0.9642]

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**OBSERVATION:**

We saw that as weincreased the momentum parameter, all three validation, test and training accuracy of the model increased maintaining equal number of epochs. This is because SGD with momentum is method which helps accelerate gradients vectors in the right directions, thus leading to faster converging. By observing above graphs, we can say that the model with higher momentum is converging very quickly.