

Machine Learning CS 453X

Homework 6

Part I

(a)

I modify the parameters for the **train** function so that we do not have to pass in the initial weights. The weights will be initialized inside the function depending on the parameters, in particular the number of neurons in the hidden layer. This change will make it easier for me to structure my code.

(b)

Sample output:

1.5857297054763504e-06

(c)

I performed a randomized search for the optimal parameters. For each of the parameters, I printed out some first and last epochs results. Please note that my first epoch starts at "epoch 0". Rarely in one of the configurations of the parameters, there will a chance of the gradient descent to overshoot to infinity or nan in the code. If so, please just rerun the code or just find the optimal solution of 5 configurations at a time.

Best parameters:

- Batch size: 32
- Number of epochs: 25
- Epsilon: 0.01
- Number of neurons in hidden layer: 50
- Alpha: 0.01

Parameters:

{'batch_size': 256, 'num_epochs': 25, 'EPSILON': 0.005, 'NUM_HIDDEN': 50, 'alpha': 10.0}

Epoch 0

Cross entropy loss: 2.0369909169413223

Train Accuracy: 0.6340181818181818

Test Accuracy: 0.6284

Epoch 1

Cross entropy loss: 1.6461133955648912

Train Accuracy: 0.7168545454545454

Test Accuracy: 0.7188

Epoch 2

Cross entropy loss: 1.2538896929872834

Train Accuracy: 0.7667818181818182

Test Accuracy: 0.768

Epoch 3

Cross entropy loss: 0.9672843001765951

Train Accuracy: 0.8013818181818182

Test Accuracy: 0.8006

Epoch 4

Cross entropy loss: 0.7802576472689093

Train Accuracy: 0.8233272727272727

Test Accuracy: 0.823

Epoch 5

Cross entropy loss: 0.657358171653997

Train Accuracy: 0.8382181818181819

Test Accuracy: 0.8424

Epoch 20

Cross entropy loss: 0.36316455845825185

Train Accuracy: 0.9001272727272728

Test Accuracy: 0.9082

Epoch 21

Cross entropy loss: 0.3698206779355936

Train Accuracy: 0.9014363636363636

Test Accuracy: 0.9092

Epoch 22

Cross entropy loss: 0.3778628397342774

Train Accuracy: 0.9029454545454545

Test Accuracy: 0.9102

Epoch 23

Cross entropy loss: 0.3873300405686998

Train Accuracy: 0.9038545454545455

Test Accuracy: 0.912

Epoch 24

Cross entropy loss: 0.39813331167165056

Train Accuracy: 0.905
Test Accuracy: 0.9138

Parameters:

{'batch_size': 32, 'num_epochs': 25, 'EPSILON': 0.01, 'NUM_HIDDEN': 50, 'alpha': 0.01}

Epoch 0

Cross entropy loss: 0.4395304421961455
Train Accuracy: 0.8747818181818182
Test Accuracy: 0.8802

Epoch 1

Cross entropy loss: 0.3361399360221236
Train Accuracy: 0.8979272727272727
Test Accuracy: 0.9048

Epoch 2

Cross entropy loss: 0.2999922830179163
Train Accuracy: 0.9075636363636364
Test Accuracy: 0.9144

Epoch 3

Cross entropy loss: 0.27786621603335665
Train Accuracy: 0.9148181818181819
Test Accuracy: 0.922

Epoch 4

Cross entropy loss: 0.26094349413383405
Train Accuracy: 0.9201636363636364
Test Accuracy: 0.9272

Epoch 5

Cross entropy loss: 0.24642191027701343
Train Accuracy: 0.9251818181818182
Test Accuracy: 0.9308

Epoch 20

Cross entropy loss: 0.14118792165407248
Train Accuracy: 0.9623272727272727
Test Accuracy: 0.9626

Epoch 21

Cross entropy loss: 0.13817841230552178
Train Accuracy: 0.9634727272727273

Test Accuracy: 0.9636

Epoch 22

Cross entropy loss: 0.1353169638643092

Train Accuracy: 0.9643636363636363

Test Accuracy: 0.9648

Epoch 23

Cross entropy loss: 0.13268043813472785

Train Accuracy: 0.9655454545454546

Test Accuracy: 0.965

Epoch 24

Cross entropy loss: 0.13026226673381577

Train Accuracy: 0.9664

Test Accuracy: 0.9668

Parameters:

{'batch_size': 64, 'num_epochs': 50, 'EPSILON': 0.01, 'NUM_HIDDEN': 30, 'alpha': 0.1}

Epoch 0

Cross entropy loss: 0.6387150828078563

Train Accuracy: 0.8457454545454546

Test Accuracy: 0.8546

Epoch 1

Cross entropy loss: 0.42507660573258804

Train Accuracy: 0.8792181818181818

Test Accuracy: 0.8868

Epoch 2

Cross entropy loss: 0.36120539136212343

Train Accuracy: 0.8928727272727273

Test Accuracy: 0.8988

Epoch 3

Cross entropy loss: 0.32757663101960166

Train Accuracy: 0.8998545454545455

Test Accuracy: 0.9042

Epoch 4

Cross entropy loss: 0.30547959745314623

Train Accuracy: 0.9059636363636364

Test Accuracy: 0.9112

Epoch 5
Cross entropy loss: 0.28960438151434664
Train Accuracy: 0.9109090909090909
Test Accuracy: 0.9182

Epoch 45
Cross entropy loss: 0.15344495096237343
Train Accuracy: 0.9625818181818182
Test Accuracy: 0.9612

Epoch 46
Cross entropy loss: 0.1530653508087627
Train Accuracy: 0.9629818181818182
Test Accuracy: 0.9616

Epoch 47
Cross entropy loss: 0.1527612526727916
Train Accuracy: 0.9632909090909091
Test Accuracy: 0.961

Epoch 48
Cross entropy loss: 0.15250960552191356
Train Accuracy: 0.9637454545454546
Test Accuracy: 0.9608

Epoch 49
Cross entropy loss: 0.15230019235677802
Train Accuracy: 0.9643272727272727
Test Accuracy: 0.9606

Parameters:

{'batch_size': 256, 'num_epochs': 75, 'EPSILON': 0.001, 'NUM_HIDDEN': 30, 'alpha': 0.1}

Epoch 0
Cross entropy loss: 2.2607041375917203
Train Accuracy: 0.18301818181818183
Test Accuracy: 0.1796

Epoch 1
Cross entropy loss: 2.2205715142924443
Train Accuracy: 0.30561818181818184
Test Accuracy: 0.3062

Epoch 2

Cross entropy loss: 2.178583181727464

Train Accuracy: 0.376945454545453

Test Accuracy: 0.3728

Epoch 3

Cross entropy loss: 2.133580322183171

Train Accuracy: 0.42052727272727275

Test Accuracy: 0.4166

Epoch 4

Cross entropy loss: 2.085758639494131

Train Accuracy: 0.4551272727272727

Test Accuracy: 0.4536

Epoch 5

Cross entropy loss: 2.035231098225931

Train Accuracy: 0.48667272727272726

Test Accuracy: 0.4834

Epoch 70

Cross entropy loss: 0.44846804770791915

Train Accuracy: 0.8799272727272728

Test Accuracy: 0.8854

Epoch 71

Cross entropy loss: 0.44529879395843647

Train Accuracy: 0.8806

Test Accuracy: 0.886

Epoch 72

Cross entropy loss: 0.4422286223214409

Train Accuracy: 0.8811818181818182

Test Accuracy: 0.8866

Epoch 73

Cross entropy loss: 0.43925380191062935

Train Accuracy: 0.8816

Test Accuracy: 0.8866

Epoch 74

Cross entropy loss: 0.4363698752165194

Train Accuracy: 0.8819636363636364

Test Accuracy: 0.8876

Parameters:

{'batch_size': 32, 'num_epochs': 75, 'EPSILON': 0.005, 'NUM_HIDDEN': 50, 'alpha': 1.0}

Epoch 0

Cross entropy loss: 0.5556891858841408

Train Accuracy: 0.8501454545454545

Test Accuracy: 0.8552

Epoch 1

Cross entropy loss: 0.36084510659493496

Train Accuracy: 0.8875818181818181

Test Accuracy: 0.897

Epoch 2

Cross entropy loss: 0.3493638772459646

Train Accuracy: 0.9015818181818182

Test Accuracy: 0.9106

Epoch 3

Cross entropy loss: 0.400427847567585

Train Accuracy: 0.9100363636363636

Test Accuracy: 0.9156

Epoch 4

Cross entropy loss: 0.503099828164561

Train Accuracy: 0.9158181818181819

Test Accuracy: 0.9212

Epoch 5

Cross entropy loss: 0.6729370433302968

Train Accuracy: 0.9193454545454546

Test Accuracy: 0.9244

Epoch 70

Cross entropy loss: nan

Train Accuracy: 0.09898181818181818

Test Accuracy: 0.0958

Epoch 71

Cross entropy loss: nan

Train Accuracy: 0.09898181818181818

Test Accuracy: 0.0958

Epoch 72
Cross entropy loss: nan
Train Accuracy: 0.09898181818181818
Test Accuracy: 0.0958

Epoch 73
Cross entropy loss: nan
Train Accuracy: 0.09898181818181818
Test Accuracy: 0.0958

Epoch 74
Cross entropy loss: nan
Train Accuracy: 0.09898181818181818
Test Accuracy: 0.0958

Parameters:
{'batch_size': 128, 'num_epochs': 25, 'EPSILON': 0.005, 'NUM_HIDDEN': 50, 'alpha': 1.0}

Epoch 5
Cross entropy loss: 0.4762092053521477
Train Accuracy: 0.8724727272727273
Test Accuracy: 0.8798

Epoch 20
Cross entropy loss: 0.2860255585599831
Train Accuracy: 0.9121272727272727
Test Accuracy: 0.9186

Epoch 21
Cross entropy loss: 0.2823016263740769
Train Accuracy: 0.913309090909091
Test Accuracy: 0.9202

Epoch 22
Cross entropy loss: 0.27883061552820176
Train Accuracy: 0.9149272727272727
Test Accuracy: 0.9206

Epoch 23
Cross entropy loss: 0.27551640580491793
Train Accuracy: 0.9158727272727273
Test Accuracy: 0.9218

Epoch 24

Cross entropy loss: 0.2723453731818069

Train Accuracy: 0.9168727272727273

Test Accuracy: 0.923

(d)

Parameters:

- Batch size: 32
- Number of epochs: 25
- Epsilon: 0.01
- Number of neurons in hidden layer: 50
- Alpha: 0.01

Epoch 5

Cross entropy loss: 0.24964573552993416

Train Accuracy: 0.9243272727272728

Test Accuracy: 0.9294

Epoch 6

Cross entropy loss: 0.23663449841495449

Train Accuracy: 0.9284545454545454

Test Accuracy: 0.9324

Epoch 7

Cross entropy loss: 0.22478828224644715

Train Accuracy: 0.9319272727272727

Test Accuracy: 0.9352

Epoch 8

Cross entropy loss: 0.21406457414561397

Train Accuracy: 0.9357090909090909

Test Accuracy: 0.9394

Epoch 9

Cross entropy loss: 0.20446950033465264

Train Accuracy: 0.9388909090909091

Test Accuracy: 0.9426

Epoch 10

Cross entropy loss: 0.19567073266358118

Train Accuracy: 0.9422727272727273

Test Accuracy: 0.9452

Epoch 11

Cross entropy loss: 0.18762480210282345

Train Accuracy: 0.9448909090909091
Test Accuracy: 0.95

Epoch 12
Cross entropy loss: 0.1803949464421005
Train Accuracy: 0.9471636363636363
Test Accuracy: 0.9524

Epoch 13
Cross entropy loss: 0.17396779284643987
Train Accuracy: 0.9493090909090909
Test Accuracy: 0.9544

Epoch 14
Cross entropy loss: 0.16816804570549568
Train Accuracy: 0.9514181818181818
Test Accuracy: 0.9556

Epoch 15
Cross entropy loss: 0.16257244600204343
Train Accuracy: 0.9533090909090909
Test Accuracy: 0.9568

Epoch 16
Cross entropy loss: 0.15753906918746924
Train Accuracy: 0.9549818181818182
Test Accuracy: 0.9576

Epoch 17
Cross entropy loss: 0.15305523859339226
Train Accuracy: 0.9564363636363636
Test Accuracy: 0.959

Epoch 18
Cross entropy loss: 0.14888681432217607
Train Accuracy: 0.9579090909090909
Test Accuracy: 0.96

Epoch 19
Cross entropy loss: 0.14524794187079168
Train Accuracy: 0.9595090909090909
Test Accuracy: 0.9606

Epoch 20

Cross entropy loss: 0.14197836943658035
Train Accuracy: 0.9609090909090909
Test Accuracy: 0.9612

Epoch 21
Cross entropy loss: 0.13891821960002748
Train Accuracy: 0.9623454545454545
Test Accuracy: 0.963

Epoch 22
Cross entropy loss: 0.13606958687037954
Train Accuracy: 0.9634727272727273
Test Accuracy: 0.9636

Epoch 23
Cross entropy loss: 0.1334216024394082
Train Accuracy: 0.9644909090909091
Test Accuracy: 0.9648

Epoch 24
Cross entropy loss: 0.13100837008318214
Train Accuracy: 0.9656363636363636
Test Accuracy: 0.9652

Part II

