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Roll No:- 45

Batch:- E3

Practical 3

Topic:- AutoEncoders

Write a program to implement autoencoders for both binary and real inputs clearly show the loss after each iteration.

Binary input

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In [ ]: import numpy as np
import matplotlib.pyplot as plt

# Define the sigmoid activation function
def sigmoid(x):
    return 1/(1+np.exp(-x))

# Define the derivative of the sigmoid activation function
def sigmoid_derivative(x):
    return sigmoid(x) * (1 - sigmoid(x))

def binary_cross_entropy(y_true, y_pred):
    return -np.mean(y_true * np.log(y_pred) + (1 - y_true) * np.log(1 - y_pred))

def binary_cross_entropy_derivative(y_true, y_pred):
    return -(y_true / y_pred) + (1 - y_true) / (1 - y_pred)

# Define the binary input data
X = np.array([[1,0,1,1],[1,1,0,1]])

# Define the hyperparameters
input_size = X.shape[1]
hidden_size = 4
output_size = input_size
learning_rate = 0.01
num_iterations = 1000

# Initialize the weights randomly
np.random.seed(0)
w1 = np.random.randn(hidden_size, input_size)
w2 = np.random.randn(output_size, hidden_size)

print(w1)
print(w2)
# Training Loop

for i in range(num_iterations):
```

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# Forward pass
hidden_layer = sigmoid(np.dot(X,w1))
output_layer = sigmoid(np.dot(hidden_layer,w2))

# Calculate the Loss
# Loss = np.mean((output_layer - X)**2)
loss=binary_cross_entropy(X,output_layer)
# print(f"Epoch {i}, Loss: {loss}")

# Backward pass
output_error = binary_cross_entropy_derivative(X, output_layer) * sigmoid_derivative(hidden_layer)
hidden_error = np.dot(output_error,w2.T)*sigmoid_derivative(hidden_layer)

# Update the weights
w2 -= learning_rate*np.dot(hidden_layer.T,output_error)
w1 -= learning_rate*np.dot(X.T,hidden_error)

# Print the Loss after every 1000 iterations
if i % 1000 == 0:
    print("Iteration ", i, " Loss: ", loss)

reconstructed = sigmoid(np.dot(sigmoid(np.dot(X, w1)), w2))
# Plot the original and reconstructed data
plt.subplot(1,2,1)
plt.imshow(X, cmap='gray')
plt.title("Original Data")
plt.subplot(1,2,2)
plt.imshow(output_layer, cmap='gray')
plt.title("Reconstructed Data")
plt.show()

print()
print("W1: \n",w1)
print("W2: \n",w2)

print("\n\nActual input:", X)
print("Reconstructed input:", reconstructed)

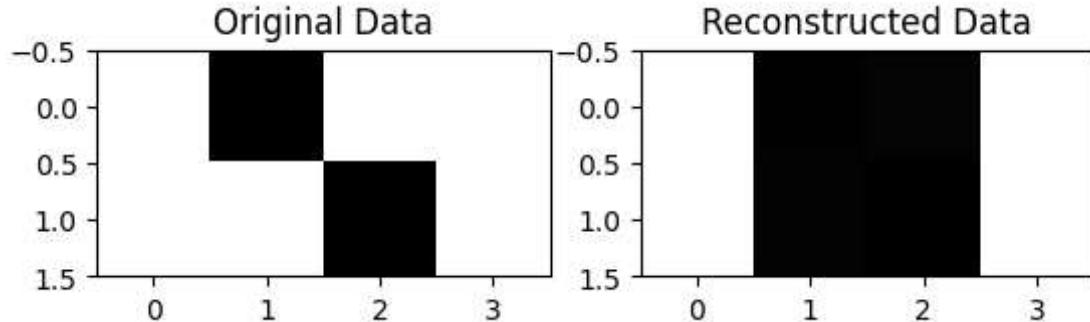
```

```

[[ 1.76405235  0.40015721  0.97873798  2.2408932 ]
 [ 1.86755799 -0.97727788  0.95008842 -0.15135721]
 [-0.10321885  0.4105985   0.14404357  1.45427351]
 [ 0.76103773  0.12167502  0.44386323  0.33367433]]
[[ 1.49407907 -0.20515826  0.3130677  -0.85409574]
 [-2.55298982  0.6536186   0.8644362  -0.74216502]
 [ 2.26975462 -1.45436567  0.04575852 -0.18718385]
 [ 1.53277921  1.46935877  0.15494743  0.37816252]]

```

Iteration 0 Loss: 0.7330419200458681



```
w1:
[[ 5.57870666 -1.93881993  5.93201472  7.21409795]
 [ 3.59980997 -3.32508599  2.23652077  3.70688972]
 [ 1.97918348  0.41942947  3.81088796  2.56923132]
 [ 4.57569204 -2.21730212  5.39713997  5.30687907]]

w2:
[[ 5.39075359e+00 -8.79338067e-02  8.01922083e-02  3.54019781e+00]
 [-2.04769295e+00 -3.50452522e-02  1.39304679e+00 -5.22733253e-03]
 [ 6.13729431e+00 -1.37915080e+00 -1.32921243e-01  4.14932387e+00]
 [ 5.45024279e+00  1.46736568e+00  2.83942289e-02  4.79855849e+00]]
```

Actual input: [[1 0 1 1]
[1 1 0 1]]
Reconstructed input: [[0.9999996 0.49986643 0.50202303 0.99999623]
[0.9999996 0.50006577 0.49411275 0.99999623]]

Real valued Input

```
In [ ]: import numpy as np
import matplotlib.pyplot as plt

def linear(x):
    return x

def linear_derivative(x):
    return np.ones_like(x)

def mse(y_true, y_pred):
    return np.mean(np.square(y_true - y_pred))

def mse_derivative(y_true, y_pred):
    return 2 * (y_pred - y_true) / len(y_true)

# Define the real-valued input data
X = np.array([[1,1,2,3],[2,1, 3, 4],[1,3,3,4]])

# Define the hyperparameters
input_size = X.shape[1]
hidden_size = 4
output_size = input_size
learning_rate = 0.001
num_iterations = 500

# Initialize the weights randomly
np.random.seed(0)
w1 = np.random.randn(hidden_size, input_size)
w2 = np.random.randn(output_size, hidden_size)

# Training Loop
for i in range(num_iterations):
    # Forward pass
    hidden_layer = linear(np.dot(X, w1))
    output_layer = linear(np.dot(hidden_layer, w2))

    # Calculate the loss
    loss = mse(X, output_layer)
```

```
print(f"Epoch {i}, Loss: {loss}")

# Backward pass
output_error = mse_derivative(X, output_layer) * linear_derivative(output_layer)
hidden_error = np.dot(output_error, w2.T) * linear_derivative(hidden_layer)

# Update the weights
w2 -= learning_rate*np.dot(hidden_layer.T,output_error)
w1 -= learning_rate*np.dot(X.T,hidden_error)

# Print the loss after every 1000 iterations
if i % 1000 == 0:
    print("Iteration ", i, " Loss: ", loss)

# Plot the original and reconstructed data
plt.subplot(1,2,1)
plt.imshow(X, cmap='gray')
plt.title("Original Data")
plt.subplot(1,2,2)
plt.imshow(output_layer, cmap='gray')
plt.title("Reconstructed Data")
plt.show()

# output
reconstructed = linear(np.dot(linear(np.dot(X, w1)), w2))
print()
print("W1: \n",w1)
print("W2: \n",w2)

print("\n\nActual input:", X)
print("Reconstructed input:", reconstructed)
```

Epoch 0, Loss: 303.6834611792738
Iteration 0 Loss: 303.6834611792738
Epoch 1, Loss: 32.47467849864457
Epoch 2, Loss: 20.445193134914998
Epoch 3, Loss: 15.361749188669613
Epoch 4, Loss: 12.199006568612234
Epoch 5, Loss: 10.042500125012745
Epoch 6, Loss: 8.484726850525659
Epoch 7, Loss: 7.312258204354308
Epoch 8, Loss: 6.402564563687291
Epoch 9, Loss: 5.680200320716598
Epoch 10, Loss: 5.0960317473610335
Epoch 11, Loss: 4.616562277793767
Epoch 12, Loss: 4.218080883722384
Epoch 13, Loss: 3.883277737725619
Epoch 14, Loss: 3.5991949733134554
Epoch 15, Loss: 3.355934659018431
Epoch 16, Loss: 3.1458138754222347
Epoch 17, Loss: 2.962793329278258
Epoch 18, Loss: 2.8020788288512537
Epoch 19, Loss: 2.659835388319691
Epoch 20, Loss: 2.5329769129662996
Epoch 21, Loss: 2.4190080782114483
Epoch 22, Loss: 2.3159032591381177
Epoch 23, Loss: 2.2220124486667356
Epoch 24, Loss: 2.1359872990886237
Epoch 25, Loss: 2.056722474438469
Epoch 26, Loss: 1.9833088489480633
Epoch 27, Loss: 1.9149959934222658
Epoch 28, Loss: 1.851162017468195
Epoch 29, Loss: 1.791289279951074
Epoch 30, Loss: 1.7349448043000173
Epoch 31, Loss: 1.6817644779816001
Epoch 32, Loss: 1.631440301233929
Epoch 33, Loss: 1.5837100950080611
Epoch 34, Loss: 1.5383491926318387
Epoch 35, Loss: 1.495163731266692
Epoch 36, Loss: 1.453985232904879
Epoch 37, Loss: 1.4146662241994339
Epoch 38, Loss: 1.3770766926516778
Epoch 39, Loss: 1.3411012157820077
Epoch 40, Loss: 1.3066366316011961
Epoch 41, Loss: 1.273590144363627
Epoch 42, Loss: 1.2418777803407317
Epoch 43, Loss: 1.211423125116195
Epoch 44, Loss: 1.1821562874214897
Epoch 45, Loss: 1.1540130454129092
Epoch 46, Loss: 1.1269341400401018
Epoch 47, Loss: 1.1008646871799397
Epoch 48, Loss: 1.0757536858417518
Epoch 49, Loss: 1.0515536042613864
Epoch 50, Loss: 1.0282200293120616
Epoch 51, Loss: 1.0057113675474099
Epoch 52, Loss: 0.9839885884998849
Epoch 53, Loss: 0.963015002701742
Epoch 54, Loss: 0.9427560683687489
Epoch 55, Loss: 0.9231792218635366
Epoch 56, Loss: 0.9042537279956373
Epoch 57, Loss: 0.8859505469667829
Epoch 58, Loss: 0.8682422153710133

Epoch 59, Loss: 0.8511027391402745
Epoch 60, Loss: 0.8345074967116326
Epoch 61, Loss: 0.8184331510015314
Epoch 62, Loss: 0.8028575690210756
Epoch 63, Loss: 0.7877597481664088
Epoch 64, Loss: 0.773119748379739
Epoch 65, Loss: 0.7589186295071669
Epoch 66, Loss: 0.7451383932854353
Epoch 67, Loss: 0.7317619294759612
Epoch 68, Loss: 0.7187729657349742
Epoch 69, Loss: 0.7061560208663603
Epoch 70, Loss: 0.6938963611514416
Epoch 71, Loss: 0.68197995948932
Epoch 72, Loss: 0.6703934571142458
Epoch 73, Loss: 0.6591241276839183
Epoch 74, Loss: 0.6481598435557544
Epoch 75, Loss: 0.6374890440877378
Epoch 76, Loss: 0.6271007058171761
Epoch 77, Loss: 0.6169843143850119
Epoch 78, Loss: 0.607129838085709
Epoch 79, Loss: 0.5975277029335051
Epoch 80, Loss: 0.5881687691452266
Epoch 81, Loss: 0.579044308948152
Epoch 82, Loss: 0.5701459856287485
Epoch 83, Loss: 0.5614658337446367
Epoch 84, Loss: 0.5529962404280023
Epoch 85, Loss: 0.544729927713912
Epoch 86, Loss: 0.5366599358317802
Epoch 87, Loss: 0.5287796074025204
Epoch 88, Loss: 0.5210825724878708
Epoch 89, Loss: 0.5135627344419625
Epoch 90, Loss: 0.5062142565185082
Epoch 91, Loss: 0.49903154919001436
Epoch 92, Loss: 0.49200925813821933
Epoch 93, Loss: 0.48514225287753404
Epoch 94, Loss: 0.4784256159756666
Epoch 95, Loss: 0.4718546328378177
Epoch 96, Loss: 0.46542478202289955
Epoch 97, Loss: 0.4591317260621435
Epoch 98, Loss: 0.4529713027522491
Epoch 99, Loss: 0.4469395168968993
Epoch 100, Loss: 0.44103253247199586
Epoch 101, Loss: 0.4352466651914512
Epoch 102, Loss: 0.4295783754517147
Epoch 103, Loss: 0.42402426163447254
Epoch 104, Loss: 0.41858105374817667
Epoch 105, Loss: 0.4132456073901429
Epoch 106, Loss: 0.40801489801202534
Epoch 107, Loss: 0.40288601547244945
Epoch 108, Loss: 0.39785615886149683
Epoch 109, Loss: 0.3929226315826126
Epoch 110, Loss: 0.38808283667831
Epoch 111, Loss: 0.3833342723868162
Epoch 112, Loss: 0.3786745279175076
Epoch 113, Loss: 0.37410127943367605
Epoch 114, Loss: 0.3696122862317914
Epoch 115, Loss: 0.3652053871070184
Epoch 116, Loss: 0.36087849689532425
Epoch 117, Loss: 0.35662960318302717
Epoch 118, Loss: 0.35245676317514496

Epoch 119, Loss: 0.3483581007143668
Epoch 120, Loss: 0.34433180344292175
Epoch 121, Loss: 0.3403761201000302
Epoch 122, Loss: 0.33648935794801127
Epoch 123, Loss: 0.332669880320516
Epoch 124, Loss: 0.32891610428666973
Epoch 125, Loss: 0.32522649842527274
Epoch 126, Loss: 0.3215995807035004
Epoch 127, Loss: 0.31803391645484225
Epoch 128, Loss: 0.3145281164513014
Epoch 129, Loss: 0.3110808350651394
Epoch 130, Loss: 0.3076907685156914
Epoch 131, Loss: 0.30435665319702315
Epoch 132, Loss: 0.30107726408241337
Epoch 133, Loss: 0.29785141320185765
Epoch 134, Loss: 0.2946779481889946
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Epoch 136, Loss: 0.28848373605939837
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Epoch 253, Loss: 0.11604779646465314
Epoch 254, Loss: 0.11542147552310757
Epoch 255, Loss: 0.11480236655459246
Epoch 256, Loss: 0.11419036802872334
Epoch 257, Loss: 0.11358537995082023
Epoch 258, Loss: 0.11298730383656685
Epoch 259, Loss: 0.11239604268717081
Epoch 260, Loss: 0.11181150096500497
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Epoch 262, Loss: 0.1106622008148272
Epoch 263, Loss: 0.11009725840470837
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Epoch 303, Loss: 0.09188322587169344
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Epoch 310, Loss: 0.08940280299829005
Epoch 311, Loss: 0.08906215671039329
Epoch 312, Loss: 0.0887247996883414
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Epoch 314, Loss: 0.08805977965068161
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Epoch 316, Loss: 0.08740740153801037
Epoch 317, Loss: 0.08708584921163054
Epoch 318, Loss: 0.08676733377182912
Epoch 319, Loss: 0.0864518152502829
Epoch 320, Loss: 0.08613925425360554
Epoch 321, Loss: 0.08582961195480499
Epoch 322, Loss: 0.08552285008487515
Epoch 323, Loss: 0.08521893092451488
Epoch 324, Loss: 0.0849178172959779
Epoch 325, Loss: 0.0846194725550465
Epoch 326, Loss: 0.08432386058312946
Epoch 327, Loss: 0.0840309457794819
Epoch 328, Loss: 0.08374069305354453
Epoch 329, Loss: 0.08345306781739986
Epoch 330, Loss: 0.08316803597834511
Epoch 331, Loss: 0.08288556393157658
Epoch 332, Loss: 0.0826056185529889
Epoch 333, Loss: 0.08232816719207973
Epoch 334, Loss: 0.08205317766496825
Epoch 335, Loss: 0.08178061824751448
Epoch 336, Loss: 0.0815104576685461
Epoch 337, Loss: 0.08124266510318733
Epoch 338, Loss: 0.08097721016628881
Epoch 339, Loss: 0.08071406290595688
Epoch 340, Loss: 0.08045319379718194
Epoch 341, Loss: 0.08019457373556088
Epoch 342, Loss: 0.07993817403111599
Epoch 343, Loss: 0.07968396640220544
Epoch 344, Loss: 0.07943192296952926
Epoch 345, Loss: 0.07918201625021923
Epoch 346, Loss: 0.07893421915202324
Epoch 347, Loss: 0.07868850496757523
Epoch 348, Loss: 0.07844484736874945
Epoch 349, Loss: 0.07820322040110159
Epoch 350, Loss: 0.0779635984783915
Epoch 351, Loss: 0.0777259563771894
Epoch 352, Loss: 0.07749026923156191
Epoch 353, Loss: 0.07725651252783812
Epoch 354, Loss: 0.07702466209945141
Epoch 355, Loss: 0.07679469412186281
Epoch 356, Loss: 0.07656658510755511
Epoch 357, Loss: 0.07634031190110516
Epoch 358, Loss: 0.07611585167432829

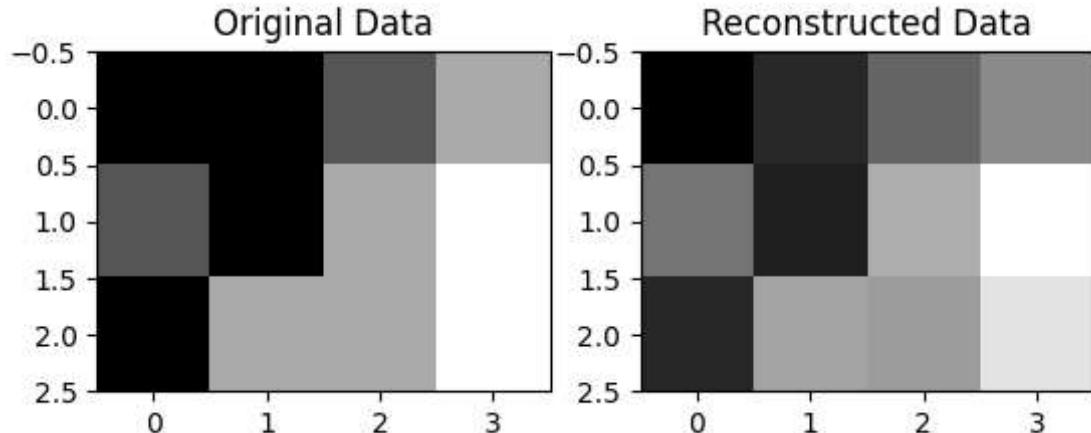
Epoch 359, Loss: 0.07589318192149407
Epoch 360, Loss: 0.07567228045461485
Epoch 361, Loss: 0.0754531253988038
Epoch 362, Loss: 0.07523569518770074
Epoch 363, Loss: 0.07501996855896738
Epoch 364, Loss: 0.07480592454985018
Epoch 365, Loss: 0.07459354249280473
Epoch 366, Loss: 0.07438280201119096
Epoch 367, Loss: 0.07417368301502798
Epoch 368, Loss: 0.07396616569681233
Epoch 369, Loss: 0.07376023052739984
Epoch 370, Loss: 0.07355585825194645
Epoch 371, Loss: 0.07335302988591173
Epoch 372, Loss: 0.07315172671111676
Epoch 373, Loss: 0.07295193027186579
Epoch 374, Loss: 0.07275362237112151
Epoch 375, Loss: 0.0725567850667388
Epoch 376, Loss: 0.07236140066775083
Epoch 377, Loss: 0.07216745173071591
Epoch 378, Loss: 0.07197492105611131
Epoch 379, Loss: 0.07178379168478555
Epoch 380, Loss: 0.07159404689446018
Epoch 381, Loss: 0.0714056701962837
Epoch 382, Loss: 0.07121864533143818
Epoch 383, Loss: 0.07103295626779141
Epoch 384, Loss: 0.07084858719660325
Epoch 385, Loss: 0.07066552252927762
Epoch 386, Loss: 0.07048374689416297
Epoch 387, Loss: 0.07030324513339901
Epoch 388, Loss: 0.07012400229981307
Epoch 389, Loss: 0.06994600365385535
Epoch 390, Loss: 0.06976923466058829
Epoch 391, Loss: 0.06959368098671308
Epoch 392, Loss: 0.06941932849764133
Epoch 393, Loss: 0.06924616325461248
Epoch 394, Loss: 0.06907417151185102
Epoch 395, Loss: 0.06890333971376587
Epoch 396, Loss: 0.06873365449219172
Epoch 397, Loss: 0.06856510266366982
Epoch 398, Loss: 0.06839767122676985
Epoch 399, Loss: 0.06823134735944997
Epoch 400, Loss: 0.068066118416456
Epoch 401, Loss: 0.06790197192675966
Epoch 402, Loss: 0.06773889559103269
Epoch 403, Loss: 0.0675768772791598
Epoch 404, Loss: 0.06741590502778626
Epoch 405, Loss: 0.0672559670379032
Epoch 406, Loss: 0.0670970516724678
Epoch 407, Loss: 0.06693914745405695
Epoch 408, Loss: 0.0667822430625578
Epoch 409, Loss: 0.06662632733289038
Epoch 410, Loss: 0.06647138925276376
Epoch 411, Loss: 0.0663174179604664
Epoch 412, Loss: 0.06616440274268628
Epoch 413, Loss: 0.06601233303236642
Epoch 414, Loss: 0.06586119840658937
Epoch 415, Loss: 0.06571098858449238
Epoch 416, Loss: 0.06556169342521603
Epoch 417, Loss: 0.06541330292587895
Epoch 418, Loss: 0.06526580721958614

Epoch 419, Loss: 0.06511919657346305
Epoch 420, Loss: 0.06497346138672068
Epoch 421, Loss: 0.06482859218874858
Epoch 422, Loss: 0.06468457963723459
Epoch 423, Loss: 0.06454141451631454
Epoch 424, Loss: 0.0643990877347455
Epoch 425, Loss: 0.06425759032411055
Epoch 426, Loss: 0.06411691343704432
Epoch 427, Loss: 0.0639770483454891
Epoch 428, Loss: 0.06383798643897483
Epoch 429, Loss: 0.06369971922292296
Epoch 430, Loss: 0.06356223831697697
Epoch 431, Loss: 0.06342553545335781
Epoch 432, Loss: 0.06328960247523956
Epoch 433, Loss: 0.06315443133515543
Epoch 434, Loss: 0.06302001409341987
Epoch 435, Loss: 0.06288634291657877
Epoch 436, Loss: 0.06275341007588126
Epoch 437, Loss: 0.0626212079457726
Epoch 438, Loss: 0.06248972900241006
Epoch 439, Loss: 0.062358965822200456
Epoch 440, Loss: 0.062228911080359724
Epoch 441, Loss: 0.062099557549491875
Epoch 442, Loss: 0.06197089809819064
Epoch 443, Loss: 0.061842925689659996
Epoch 444, Loss: 0.061715633380356676
Epoch 445, Loss: 0.061589014318650354
Epoch 446, Loss: 0.061463061743505194
Epoch 447, Loss: 0.06133776898318025
Epoch 448, Loss: 0.061213129453948224
Epoch 449, Loss: 0.061089136658834677
Epoch 450, Loss: 0.06096578418637147
Epoch 451, Loss: 0.060843065709376205
Epoch 452, Loss: 0.06072097498374051
Epoch 453, Loss: 0.06059950584724267
Epoch 454, Loss: 0.06047865221837422
Epoch 455, Loss: 0.06035840809518598
Epoch 456, Loss: 0.06023876755414901
Epoch 457, Loss: 0.060119724749032405
Epoch 458, Loss: 0.060001273909799695
Epoch 459, Loss: 0.05988340934151865
Epoch 460, Loss: 0.059766125423288796
Epoch 461, Loss: 0.05964941660718348
Epoch 462, Loss: 0.05953327741720873
Epoch 463, Loss: 0.0594177024482764
Epoch 464, Loss: 0.05930268636519179
Epoch 465, Loss: 0.05918822390165814
Epoch 466, Loss: 0.059074309859292747
Epoch 467, Loss: 0.05896093910666136
Epoch 468, Loss: 0.05884810657832166
Epoch 469, Loss: 0.058735807273886415
Epoch 470, Loss: 0.05862403625709525
Epoch 471, Loss: 0.05851278865490328
Epoch 472, Loss: 0.05840205965658115
Epoch 473, Loss: 0.05829184451283045
Epoch 474, Loss: 0.0581821385349095
Epoch 475, Loss: 0.058072937093773896
Epoch 476, Loss: 0.05796423561922794
Epoch 477, Loss: 0.057856029599090135
Epoch 478, Loss: 0.05774831457837007

```

Epoch 479, Loss: 0.05764108615845736
Epoch 480, Loss: 0.05753433999632185
Epoch 481, Loss: 0.0574280718037276
Epoch 482, Loss: 0.057322277346455536
Epoch 483, Loss: 0.05721695244353902
Epoch 484, Loss: 0.0571120929665118
Epoch 485, Loss: 0.05700769483866375
Epoch 486, Loss: 0.056903754034310174
Epoch 487, Loss: 0.05680026657807172
Epoch 488, Loss: 0.05669722854416184
Epoch 489, Loss: 0.0565946360556894
Epoch 490, Loss: 0.05649248528396746
Epoch 491, Loss: 0.05639077244783389
Epoch 492, Loss: 0.056289493812981234
Epoch 493, Loss: 0.05618864569129834
Epoch 494, Loss: 0.05608822444021789
Epoch 495, Loss: 0.05598822646207786
Epoch 496, Loss: 0.05588864820348788
Epoch 497, Loss: 0.055789486154708606
Epoch 498, Loss: 0.05569073684903819
Epoch 499, Loss: 0.05559239686220821

```



W1:

```

[[ 1.62408599  0.4500411   1.22114869  1.76319764]
 [ 1.27406033 -0.30524016 -0.29333366  0.26057586]
 [-0.60131109  0.7456799  -0.20389792  1.17507669]
 [ 0.1401914   0.35511372  0.15863943  0.03954192]]

```

W2:

```

[[ 6.63477248e-01 -2.03420261e-01  2.62849224e-01  1.29910275e-03]
 [-2.57522100e+00  1.20439301e-01  7.05853217e-01 -4.21400636e-01]
 [ 1.84305287e+00 -1.72426616e+00 -8.31016406e-02 -9.71733657e-02]
 [ 9.39972387e-01  6.51932561e-01 -7.70303846e-02  8.48939044e-01]]

```

Actual input: [[1 1 2 3]

```

[2 1 3 4]
[1 3 3 4]

```

Reconstructed input: [[0.50545958 1.10648978 2.03425151 2.58145918]

```

[2.249612  0.97048801 3.10749724 4.34316653]
[1.09437567 2.96221797 2.84771433 3.91252164]]

```