Assignment3

May 13, 2024

1 13.4 Nonlinear Autoencoder Using Neural Networks

[520]:
```
import numpy as np
```

[521]:
```
from matplotlib import gridspec
```

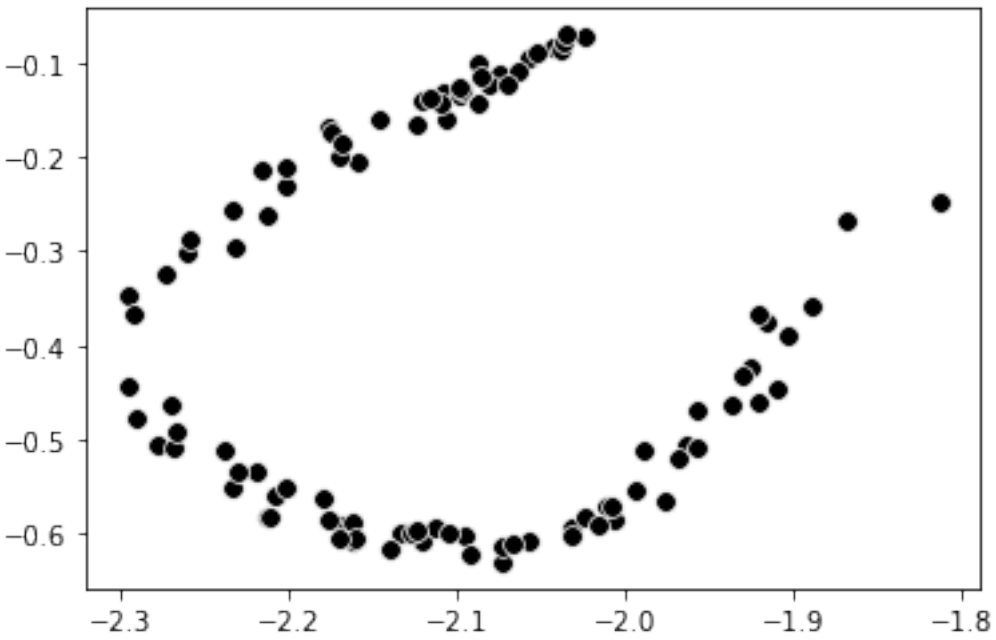
[522]:
```
datapath = '/users/jazz13/Desktop/GitHub_Files/435-deep-learning/'
```

[523]:
```
#datapath = '/home/venkat/Desktop/GitHub_Files/435-deep-learning/'
```

[524]:
```
import matplotlib.pyplot as plt

# import data
X = np.loadtxt(datapath + 'universal_autoencoder_samples.csv', delimiter=',')

plt.scatter(X[0,:], X[1,:], c = 'k', s = 60, linewidth = 0.75, edgecolor = 'w')
plt.show()
```



[525]:
```
import os
import sys
module_path = os.path.abspath(os.path.join('..'))
if module_path not in sys.path:
    sys.path.append(module_path)
```

[526]:
```
import history_plotters
import multilayer_perceptron_batch_normalized
import multilayer_perceptron
import normalizers
import cost_functions
import un_cost_functions
import un_optimizers
```

[527]:
```
import autograd.numpy as np

class Setup:
    def __init__(self,X,**kwargs):
        # link in data
        self.x = X

        # make containers for all histories
        self.weight_histories = []
        self.train_cost_histories = []
        self.train_accuracy_histories = []
        self.val_cost_histories = []
        self.val_accuracy_histories = []
        self.train_costs = []
        self.train_counts = []
        self.val_costs = []
        self.val_counts = []



    #### define preprocessing steps ####
    def preprocessing_steps(self,**kwargs):
        ### produce / use data normalizer ###
        normalizer_name = 'standard'
        if 'normalizer_name' in kwargs:
            normalizer_name = kwargs['normalizer_name']
        self.normalizer_name = normalizer_name

        # produce normalizer / inverse normalizer
        s = normalizers.Setup(self.x,normalizer_name)
        self.normalizer = s.normalizer
```

```
        self.inverse_normalizer = s.inverse_normalizer

        # normalize input
        self.x = self.normalizer(self.x)

    #### split data into training and validation sets ####
    def make_train_val_split(self,train_portion):
        # translate desired training portion into exact indecies
        self.train_portion = train_portion
        r = np.random.permutation(self.x.shape[1])
        train_num = int(np.round(train_portion*len(r)))
        self.train_inds = r[:train_num]
        self.val_inds = r[train_num:]

        # define training and testing sets
        self.x_train = self.x[:,self.train_inds]
        self.x_val = self.x[:,self.val_inds]

    #### define encoder ####
    def choose_encoder(self,**kwargs):
        feature_name = 'multilayer_perceptron'
        if 'name' in kwargs:
            feature_name = kwargs['feature_name']

        transformer = 0
        if feature_name == 'multilayer_perceptron':
            transformer = multilayer_perceptron.Setup(**kwargs)
        elif feature_name == 'multilayer_perceptron_batch_normalized':
            transformer = multilayer_perceptron_batch_normalized.Setup(**kwargs)

        self.feature_transforms = transformer.feature_transforms
        self.initializer_1 = transformer.initializer

    # form decoder
    def choose_decoder(self,**kwargs):
        feature_name = 'multilayer_perceptron'
        if 'name' in kwargs:
            feature_name = kwargs['feature_name']

        transformer = 0
        if feature_name == 'multilayer_perceptron':
            transformer = multilayer_perceptron.Setup(**kwargs)
        elif feature_name == 'multilayer_perceptron_batch_normalized':
            transformer = multilayer_perceptron_batch_normalized.Setup(**kwargs)

        self.feature_transforms_2 = transformer.feature_transforms
        self.initializer_2 = transformer.initializer
```

```
    def choose_cost(self,name,**kwargs):
        # pick cost based on user input
        self.cost_object = un_cost_functions.Setup(name,**kwargs)

        ### with feature transformation constructed, pass on to cost function ###
        self.cost_object.define_encoder_decoder(self.feature_transforms,self.feature_transforms_2)
        self.cost = self.cost_object.cost
        self.cost_name = name
        self.encoder = self.cost_object.encoder
        self.decoder = self.cost_object.decoder

     #### run optimization ####
    def fit(self,**kwargs):
        # basic parameters for gradient descent run (default algorithm)
        max_its = 500; alpha_choice = 10**(-1);
        self.w_init_1 = self.initializer_1()
        self.w_init_2 = self.initializer_2()
        self.w_init = [self.w_init_1,self.w_init_2]

        # set parameters by hand
        if 'max_its' in kwargs:
            self.max_its = kwargs['max_its']
        if 'alpha_choice' in kwargs:
            self.alpha_choice = kwargs['alpha_choice']
        if 'w' in kwargs:
            self.w_init = kwargs['w']

        # batch size for gradient descent?
        self.train_num = np.shape(self.x_train)[1]
        self.val_num = np.shape(self.x_val)[1]
        self.batch_size = np.shape(self.x_train)[1]
        if 'batch_size' in kwargs:
            self.batch_size = min(kwargs['batch_size'],self.batch_size)

        # verbose or not
        verbose = True
        if 'verbose' in kwargs:
            verbose = kwargs['verbose']

        # run gradient descent
        weight_history,train_cost_history,val_cost_history = un_optimizers.gradient_descent(self.cost,self.w_init,self.x_train,self.x_val,self.alpha_choice,self.max_its,self.batch_size,verbose=verbose)
```

```
        # store all new histories
        self.weight_histories.append(weight_history)
        self.train_cost_histories.append(train_cost_history)
        self.val_cost_histories.append(val_cost_history)

    def show_histories(self,**kwargs):
        start = 0
        if 'start' in kwargs:
            start = kwargs['start']
        if self.train_portion == 1:
            self.val_cost_histories = [[] for s in range(len(self.
↪val_cost_histories))]
            self.val_accuracy_histories = [[] for s in range(len(self.
↪val_accuracy_histories))]
        history_plotters.Setup(self.train_cost_histories,self.
↪train_accuracy_histories,self.val_cost_histories,self.
↪val_accuracy_histories,start)
```

[528]:
```
mylib = Setup(X)
```

[529]:
```
mylib.preprocessing_steps(normalizer = 'standard')
```

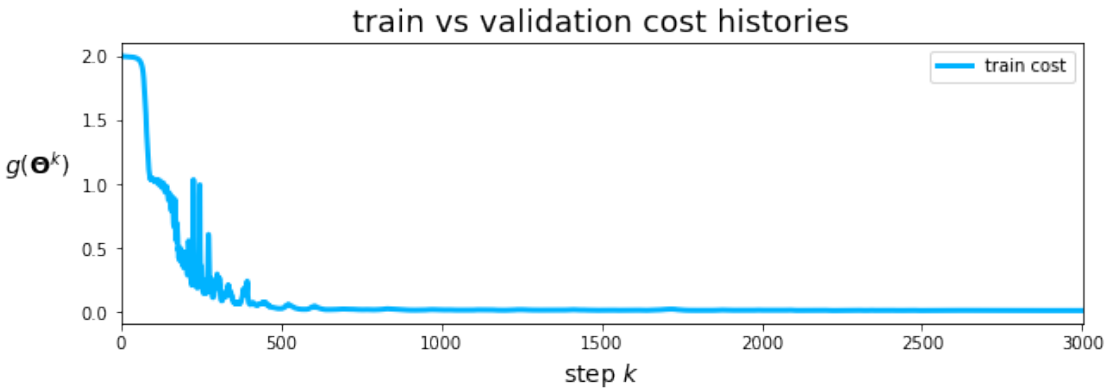
[530]:
```
# split into training and validation sets
mylib.make_train_val_split(train_portion = 1)
```

[531]:
```
# choose features
mylib.choose_encoder(layer_sizes = [2,10,10,1],scale = 0.2)
mylib.choose_decoder(layer_sizes = [1,10,10,2],scale = 0.2)
```

[532]:
```
mylib.choose_cost(name = 'autoencoder')
```

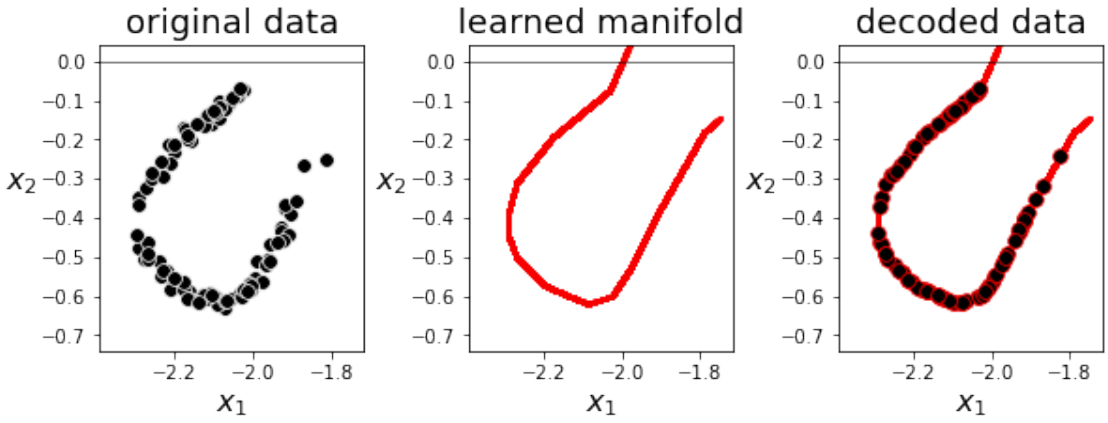
[533]:
```
mylib.fit(max_its = 3000,alpha_choice = 10**(-1),verbose = False)
```

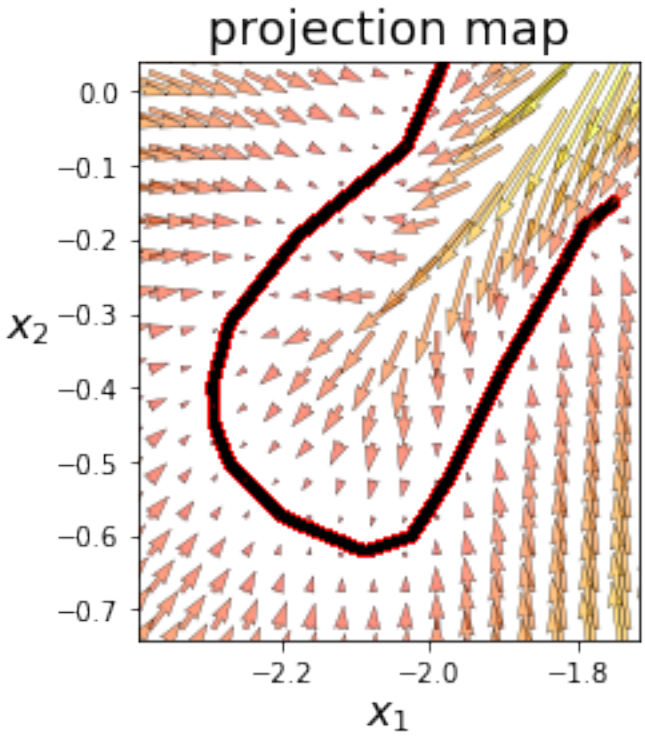
[534]:
```
mylib.show_histories()
```



[535]:
```
import autoencoder_demos
```

[537]:
```
autoencoder_demos.show_encode_decode(X,mylib,projmap = True,scale = 5)
```





2 13.8 Batch Normalization

[538]:
```
import sklearn
sklearn.__version__
```

[538]: '1.0.2'

[539]:
```
conda update scikit-learn
```

```
python(69312) MallocStackLogging: can't turn off malloc stack logging because it
was not enabled.

Collecting package metadata (current_repodata.json): done
Solving environment: |

Updating scikit-learn is constricted by

anaconda -> requires scikit-learn==1.0.2=py39hae1ba45_1

If you are sure you want an update of your package either try `conda update
--all` or install a specific version of the package you want using `conda
install <pkg>=<version>`
```

```
done


==> WARNING: A newer version of conda exists. <==
  current version: 4.13.0
  latest version: 24.5.0

Please update conda by running

    $ conda update -n base -c defaults conda



# All requested packages already installed.


Note: you may need to restart the kernel to use updated packages.
```

[540]:
```
import super_cost_functions
import history_plotters
import multilayer_perceptron_batch_normalized
import multilayer_perceptron
import normalizers
import cost_functions
import super_optimizers
```

[541]:
```
# get MNIST data from online repository
from sklearn.datasets import fetch_openml
x, y = fetch_openml('mnist_784', version=1, return_X_y=True)

# convert string labels to integers
y = np.array([int(v) for v in y])[:,np.newaxis]

print(np.shape(x))
print(np.shape(y))
```

```
(70000, 784)
(70000, 1)
```

[542]:
```
x1 = np.transpose(x)
y1 = np.transpose(y)
```

[553]:
```
x_sample, x_test = x[:50000],x[50000:]
y_sample, y_test=y[:50000],y[50000:]
```

splitting to training and validation, randomly selecting the training set.

[554]:
```
shuffled = np.random.permutation(50000)
x_sample = x_sample.iloc[shuffled]
y_sample = y_sample[shuffled]
```

[555]:
```
print(x_sample.shape)
print(y_sample.shape)
```

```
(50000, 784)
(50000, 1)
```

[556]:
```
class Setup2:
    def __init__(self,x,y,**kwargs):
        # link in data
        self.x = x
        self.y = y

        # make containers for all histories
        self.weight_histories = []
        self.train_cost_histories = []
        self.train_accuracy_histories = []
        self.val_cost_histories = []
        self.val_accuracy_histories = []
        self.train_costs = []
        self.train_counts = []
        self.val_costs = []
        self.val_counts = []


    #### define preprocessing steps ####
    def preprocessing_steps(self,**kwargs):
        ### produce / use data normalizer ###
        normalizer_name = 'standard'
        if 'normalizer_name' in kwargs:
            normalizer_name = kwargs['normalizer_name']
        self.normalizer_name = normalizer_name

        # produce normalizer / inverse normalizer
        s = normalizers.Setup(self.x,normalizer_name)
        self.normalizer = s.normalizer
        self.inverse_normalizer = s.inverse_normalizer

        # normalize input
        self.x = self.normalizer(self.x)

    #### split data into training and validation sets ####
    def make_train_val_split(self,train_portion):
        # translate desired training portion into exact indecies
```

```
        self.train_portion = train_portion
        r = np.random.permutation(self.x.shape[1])
        train_num = int(np.round(train_portion*len(r)))
        self.train_inds = r[:train_num]
        self.val_inds = r[train_num:]

        # define training and testing sets
        self.x_train = self.x[:,self.train_inds]
        self.x_val = self.x[:,self.val_inds]

        self.y_train = self.y[:,self.train_inds]
        self.y_val = self.y[:,self.val_inds]

    #### define cost function ####
    def choose_cost(self,name,**kwargs):
        # create training and testing cost functions
        self.cost_object = super_cost_functions.Setup(name,**kwargs)

        # if the cost function is a two-class classifier, build a counter too
        if name == 'softmax' or name == 'perceptron':
            self.count_object = super_cost_functions.
↪Setup('twoclass_counter',**kwargs)

        if name == 'multiclass_softmax' or name == 'multiclass_perceptron':
            self.count_object = super_cost_functions.
↪Setup('multiclass_counter',**kwargs)

        self.cost_name = name

    #### define feature transformation ####
    def choose_features(self,**kwargs):
        ### select from pre-made feature transforms ###
        layer_sizes = [1]
        if 'layer_sizes' in kwargs:
            layer_sizes = kwargs['layer_sizes']

        # add input and output layer sizes
        input_size = self.x.shape[0]
        layer_sizes.insert(0, input_size)

        # add output size
        if self.cost_name == 'least_squares' or self.cost_name ==␣
↪'least_absolute_deviations':
            layer_sizes.append(self.y.shape[0])
        else:
            num_labels = len(np.unique(self.y))
            if num_labels == 2:
```

```
                layer_sizes.append(1)
            else:
                layer_sizes.append(num_labels)

        # multilayer perceptron #
        feature_name = 'multilayer_perceptron'
        if 'name' in kwargs:
            feature_name = kwargs['feature_name']

        if feature_name == 'multilayer_perceptron':
            transformer = multilayer_perceptron.Setup(**kwargs)
            self.feature_transforms = transformer.feature_transforms
            self.multilayer_initializer = transformer.initializer
            self.layer_sizes = transformer.layer_sizes

        if feature_name == 'multilayer_perceptron_batch_normalized':
            transformer = multilayer_perceptron_batch_normalized.Setup(**kwargs)
            self.feature_transforms = transformer.feature_transforms
            self.multilayer_initializer = transformer.initializer
            self.layer_sizes = transformer.layer_sizes

        self.feature_name = feature_name

        ### with feature transformation constructed, pass on to cost function␣
↪###
        self.cost_object.define_feature_transform(self.feature_transforms)
        self.cost = self.cost_object.cost
        self.model = self.cost_object.model

        # if classification performed, inject feature transforms into counter␣
↪as well
        if self.cost_name == 'softmax' or self.cost_name == 'perceptron' or␣
↪self.cost_name == 'multiclass_softmax' or self.cost_name ==␣
↪'multiclass_perceptron':
            self.count_object.define_feature_transform(self.feature_transforms)
            self.counter = self.count_object.cost

    #### run optimization ####
    def fit(self,**kwargs):
        # basic parameters for gradient descent run (default algorithm)
        max_its = 500; alpha_choice = 10**(-1);

        # set parameters by hand
        if 'max_its' in kwargs:
            self.max_its = kwargs['max_its']
        if 'alpha_choice' in kwargs:
            self.alpha_choice = kwargs['alpha_choice']
```

```
        # set initialization
        self.w_init = self.multilayer_initializer()

        # batch size for gradient descent?
        self.train_num = np.size(self.y_train)
        self.val_num = np.size(self.y_val)
        self.batch_size = np.size(self.y_train)
        if 'batch_size' in kwargs:
            self.batch_size = min(kwargs['batch_size'],self.batch_size)

        # verbose or not
        verbose = True
        if 'verbose' in kwargs:
            verbose = kwargs['verbose']

        # optimize
        weight_history = []
        cost_history = []

        # run gradient descent
        weight_history,train_cost_history,val_cost_history = super_optimizers.
↪gradient_descent(self.cost,self.w_init,self.x_train,self.y_train,self.
↪x_val,self.y_val,self.alpha_choice,self.max_its,self.
↪batch_size,verbose=verbose)

        # store all new histories
        self.weight_histories.append(weight_history)
        self.train_cost_histories.append(train_cost_history)
        self.val_cost_histories.append(val_cost_history)

        # if classification produce count history
        if self.cost_name == 'softmax' or self.cost_name == 'perceptron' or␣
↪self.cost_name == 'multiclass_softmax' or self.cost_name ==␣
↪'multiclass_perceptron':
            train_accuracy_history = [1 - self.counter(v,self.x_train,self.
↪y_train)/float(self.y_train.size) for v in weight_history]
            val_accuracy_history = [1 - self.counter(v,self.x_val,self.y_val)/
↪float(self.y_val.size) for v in weight_history]

            # store count history
            self.train_accuracy_histories.append(train_accuracy_history)
            self.val_accuracy_histories.append(val_accuracy_history)

    #### plot histories ###
    def show_histories(self,**kwargs):
        start = 0
```

```
        if 'start' in kwargs:
            start = kwargs['start']
        if self.train_portion == 1:
            self.val_cost_histories = [[] for s in range(len(self.
↪val_cost_histories))]
            self.val_accuracy_histories = [[] for s in range(len(self.
↪val_accuracy_histories))]
        history_plotters.Setup(self.train_cost_histories,self.
↪train_accuracy_histories,self.val_cost_histories,self.
↪val_accuracy_histories,start)

    #### for batch normalized multilayer architecture only - set normalizers to␣
↪desired settings ####
    def fix_normalizers(self,w):
        ### re-set feature transformation ###
        # fix normalization at each layer by passing data and specific weight␣
↪through network
        self.feature_transforms(self.x,w);

        # re-assign feature transformation based on these settings
        self.testing_feature_transforms = self.transformer.
↪testing_feature_transforms

        ### re-assign cost function (and counter) based on fixed architecture␣
↪###
        funcs = cost_functions.Setup(self.cost_name,self.x,self.y,self.
↪testing_feature_transforms)
        self.model = funcs.model
```

[580]:
```
import super_setup
```

[581]:
```
mylib2 = super_setup.Setup(x_sample,y_sample)
```

[582]:
```
mylib2.preprocessing_steps(normalizer = 'standard')
```

[583]:
```
mylib2.make_train_val_split(train_portion = 1)
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/indexes/base.py:
↪3802, in Index.get_loc(self, key, method, tolerance)
   3801 try:
-> 3802     return self._engine.get_loc(casted_key)
   3803 except KeyError as err:
```

```
File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/_libs/index.pyx:138, in
 ↪pandas._libs.index.IndexEngine.get_loc()

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/_libs/index.pyx:144, in
 ↪pandas._libs.index.IndexEngine.get_loc()

TypeError: '(slice(None, None, None), array([469, 531, 229, 350, 564, 684, 464,
 ↪442, 261,  24, 354, 260, 105,
       736, 420, 234, 465, 383, 232,  85,   5, 214, 668, 720, 765, 386,
       268, 633, 431, 300, 425, 599, 181, 576, 435, 473, 215, 253, 318,
       135, 394, 481, 589, 429, 334, 505, 486, 267, 500, 667,   6,  87,
       438, 755, 358,  61, 410,  95, 285, 196, 462, 767, 397, 445, 518,
        65, 244, 502,  81, 372,  10, 550, 359, 128, 758, 570, 451, 414,
       769, 661, 374,  26, 665, 513, 492, 310, 272, 539, 400, 713, 349,
       588, 346, 264, 321, 145, 620, 311, 391, 526, 453, 644, 102, 233,
       412, 273, 193, 711, 117, 362,  59,  34,  13, 460, 730, 634, 293,
        51, 162, 466, 585, 508, 389, 648, 692,   9, 344, 316, 148, 369,
       471, 324, 275, 141, 426,   2, 454, 175, 441, 696, 754, 507, 338,
       738, 123, 560, 291,  71, 559,  21, 618, 527, 118, 495, 119, 554,
       160, 549, 304, 132,  36, 422, 732, 525,  14, 510, 107, 582, 673,
       238, 401,  83, 265, 199, 330, 301, 737, 299, 328, 468, 133, 574,
       491, 756, 187, 726, 725, 694, 168, 750, 583, 664, 379, 688, 129,
       274, 224,  98, 161,  64, 703,  57, 704,  30, 130, 337, 623,  19,
       543, 169, 540, 751, 432,  88, 403, 630, 207, 327, 191, 649, 669,
       523, 289, 343, 749,  75, 779, 760, 256, 573, 222, 146, 562, 279,
       547, 496, 635, 555, 131, 485, 287, 714,  74,  53, 602,  39,  22,
       748, 613, 458, 551,  99, 143, 332, 590, 521, 437, 174, 566, 516,
       357, 155, 104, 619, 638, 467, 100,  56, 452, 381, 257, 434, 771,
       625, 173, 655, 249, 239,   4, 203, 712,  16,  97, 345,  33, 182,
        76, 651,  45,  62, 709,  48, 326, 561, 163, 308, 387, 248, 614,
       627,  86, 483, 517, 715, 757, 753, 245, 641, 368, 341, 190, 329,
       242, 276, 360, 653, 192, 681,  31, 290, 231, 385, 415, 729,  89,
       735, 535, 269, 776,  84,  80, 536, 474, 125, 364, 695, 298,  20,
       195, 246, 739, 306, 743, 448, 584, 171, 382, 419, 493,   8, 591,
        79, 281, 674, 774, 575, 235, 206, 722, 546, 416, 142, 501,  63,
       361, 617,  93, 522, 565, 645, 719, 721, 363, 676, 172, 687, 380,
       377, 157, 677, 459, 761,  28, 201, 134, 252, 666, 611, 140, 430,
       529, 149, 710, 303, 266, 553,  27,  69, 775, 378, 558, 724, 418,
       514,  91, 254, 637, 717, 506, 417, 433, 689, 691, 541, 263,  66,
       600, 159, 323, 587,  52, 646, 700,  11, 367, 658, 405, 482, 731,
       671, 164, 208, 194, 702, 701, 106, 288, 479, 777, 250, 137, 772,
       783,  12, 115, 241, 440, 376, 251, 356, 572, 621, 456, 185, 503,
       631, 497, 728, 487, 247, 533, 331,  42, 511,  72, 686, 563,  18,
         0,  46, 612, 220, 136, 413, 461, 716, 718, 399, 484,  23, 325,
       366, 408, 578, 608, 639, 616, 165, 763, 556, 597, 315, 605,  82,
       138, 342, 150, 577, 654,  68, 449, 305, 370, 601, 183, 524, 225,
       271, 494, 628, 532, 286, 373, 424, 504, 200, 212, 421, 340, 259,
        44, 659, 388,  67, 443, 371, 230, 176, 211,  77, 544, 675, 734,
```

```
       351, 209, 446,  38, 764, 384, 592, 314, 406, 660, 699, 683, 744,
       103, 604, 470, 698, 586, 610, 216, 568, 177, 670, 404, 243, 221,
       213, 427, 109, 114, 690, 579, 685,  35, 151, 348, 678, 530, 571,
       255, 110, 121, 205, 154, 626, 428, 284, 295,  37, 705, 552, 217,
       228,  43, 606, 706, 262, 642, 111, 258, 278, 450, 762, 280,   3,
       607, 393,  47,  55, 476, 569, 534, 598, 594, 746, 499, 112, 270,
       650,  96, 439, 490, 657, 409, 320, 768,  49, 636,  29, 179, 455,
       593, 392, 742,  25, 498, 528, 520, 297, 352,  50,  40, 647, 204,
       302, 353, 782, 632, 237, 317, 515, 580, 463, 609, 557, 108, 198,
       693, 663, 113, 294, 355,  41, 662, 640, 629, 759, 127, 186, 733,
       447, 313, 398, 101, 227, 747, 336, 402, 680, 395, 436, 423, 365,
       477,  15, 153,  73, 727, 202, 679, 166, 457, 741, 309,  78, 167,
       488,  70, 509, 156, 218, 603,   7, 122,  94, 682,  92, 740, 778,
       307, 567, 781,  32, 223,  90, 656, 296, 147, 652, 723, 319, 210,
       411, 475, 512, 596, 766, 189, 697,   1, 643,  58, 124, 624, 396,
       277, 519, 752, 375, 144, 347, 770, 548,  17, 152, 672, 322, 292,
       444, 708, 184, 745, 595, 197, 489, 622,  60, 542, 236, 188, 407,
       538, 219, 170, 390, 335, 339, 120, 139, 226, 158, 478, 537, 472,
       480, 240,  54, 178, 283, 333, 126, 180, 707, 615, 116, 282, 773,
       545, 581, 780, 312]))' is an invalid key

During handling of the above exception, another exception occurred:

InvalidIndexError                         Traceback (most recent call last)
Cell In[583], line 1
----> 1 mylib2.make_train_val_split(train_portion = 1)

File ~/Desktop/GitHub_Files/435-deep-learning/super_setup.py:58, in␣
 ↪make_train_val_split(self, train_portion)
     55     self.y_train = self.y[:,self.train_inds]
     56     self.y_val = self.y[:,self.val_inds]
---> 58 #### define cost function ####
     59 def choose_cost(self,name,**kwargs):
     60     # create training and testing cost functions
     61     self.cost_object = super_cost_functions.Setup(name,**kwargs)

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/frame.py:3807, in␣
 ↪DataFrame.__getitem__(self, key)
   3805 if self.columns.nlevels > 1:
   3806     return self._getitem_multilevel(key)
-> 3807 indexer = self.columns.get_loc(key)
   3808 if is_integer(indexer):
   3809     indexer = [indexer]

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/indexes/base.py:
 ↪3809, in Index.get_loc(self, key, method, tolerance)
   3804         raise KeyError(key) from err
   3805     except TypeError:
```

```
   3806         # If we have a listlike key, _check_indexing_error will raise
   3807         #  InvalidIndexError. Otherwise we fall through and re-raise
   3808         #  the TypeError.
-> 3809         self._check_indexing_error(key)
   3810         raise
   3812 # GH#42269

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/indexes/base.py:
 ↪5925, in Index._check_indexing_error(self, key)
   5921 def _check_indexing_error(self, key):
   5922     if not is_scalar(key):
   5923         # if key is not a scalar, directly raise an error (the code bel w
   5924         # would convert to numpy arrays and raise later any way) -␣
 ↪GH29926
-> 5925         raise InvalidIndexError(key)

InvalidIndexError: (slice(None, None, None), array([469, 531, 229, 350, 564,␣
 ↪684, 464, 442, 261,  24, 354, 260, 105,
       736, 420, 234, 465, 383, 232,  85,   5, 214, 668, 720, 765, 386,
       268, 633, 431, 300, 425, 599, 181, 576, 435, 473, 215, 253, 318,
       135, 394, 481, 589, 429, 334, 505, 486, 267, 500, 667,   6,  87,
       438, 755, 358,  61, 410,  95, 285, 196, 462, 767, 397, 445, 518,
        65, 244, 502,  81, 372,  10, 550, 359, 128, 758, 570, 451, 414,
       769, 661, 374,  26, 665, 513, 492, 310, 272, 539, 400, 713, 349,
       588, 346, 264, 321, 145, 620, 311, 391, 526, 453, 644, 102, 233,
       412, 273, 193, 711, 117, 362,  59,  34,  13, 460, 730, 634, 293,
        51, 162, 466, 585, 508, 389, 648, 692,   9, 344, 316, 148, 369,
       471, 324, 275, 141, 426,   2, 454, 175, 441, 696, 754, 507, 338,
       738, 123, 560, 291,  71, 559,  21, 618, 527, 118, 495, 119, 554,
       160, 549, 304, 132,  36, 422, 732, 525,  14, 510, 107, 582, 673,
       238, 401,  83, 265, 199, 330, 301, 737, 299, 328, 468, 133, 574,
       491, 756, 187, 726, 725, 694, 168, 750, 583, 664, 379, 688, 129,
       274, 224,  98, 161,  64, 703,  57, 704,  30, 130, 337, 623,  19,
       543, 169, 540, 751, 432,  88, 403, 630, 207, 327, 191, 649, 669,
       523, 289, 343, 749,  75, 779, 760, 256, 573, 222, 146, 562, 279,
       547, 496, 635, 555, 131, 485, 287, 714,  74,  53, 602,  39,  22,
       748, 613, 458, 551,  99, 143, 332, 590, 521, 437, 174, 566, 516,
       357, 155, 104, 619, 638, 467, 100,  56, 452, 381, 257, 434, 771,
       625, 173, 655, 249, 239,   4, 203, 712,  16,  97, 345,  33, 182,
        76, 651,  45,  62, 709,  48, 326, 561, 163, 308, 387, 248, 614,
       627,  86, 483, 517, 715, 757, 753, 245, 641, 368, 341, 190, 329,
       242, 276, 360, 653, 192, 681,  31, 290, 231, 385, 415, 729,  89,
       735, 535, 269, 776,  84,  80, 536, 474, 125, 364, 695, 298,  20,
       195, 246, 739, 306, 743, 448, 584, 171, 382, 419, 493,   8, 591,
        79, 281, 674, 774, 575, 235, 206, 722, 546, 416, 142, 501,  63,
       361, 617,  93, 522, 565, 645, 719, 721, 363, 676, 172, 687, 380,
       377, 157, 677, 459, 761,  28, 201, 134, 252, 666, 611, 140, 430,
       529, 149, 710, 303, 266, 553,  27,  69, 775, 378, 558, 724, 418,
```

```
       514,  91, 254, 637, 717, 506, 417, 433, 689, 691, 541, 263,  66,
       600, 159, 323, 587,  52, 646, 700,  11, 367, 658, 405, 482, 731,
       671, 164, 208, 194, 702, 701, 106, 288, 479, 777, 250, 137, 772,
       783,  12, 115, 241, 440, 376, 251, 356, 572, 621, 456, 185, 503,
       631, 497, 728, 487, 247, 533, 331,  42, 511,  72, 686, 563,  18,
         0,  46, 612, 220, 136, 413, 461, 716, 718, 399, 484,  23, 325,
       366, 408, 578, 608, 639, 616, 165, 763, 556, 597, 315, 605,  82,
       138, 342, 150, 577, 654,  68, 449, 305, 370, 601, 183, 524, 225,
       271, 494, 628, 532, 286, 373, 424, 504, 200, 212, 421, 340, 259,
        44, 659, 388,  67, 443, 371, 230, 176, 211,  77, 544, 675, 734,
       351, 209, 446,  38, 764, 384, 592, 314, 406, 660, 699, 683, 744,
       103, 604, 470, 698, 586, 610, 216, 568, 177, 670, 404, 243, 221,
       213, 427, 109, 114, 690, 579, 685,  35, 151, 348, 678, 530, 571,
       255, 110, 121, 205, 154, 626, 428, 284, 295,  37, 705, 552, 217,
       228,  43, 606, 706, 262, 642, 111, 258, 278, 450, 762, 280,   3,
       607, 393,  47,  55, 476, 569, 534, 598, 594, 746, 499, 112, 270,
       650,  96, 439, 490, 657, 409, 320, 768,  49, 636,  29, 179, 455,
       593, 392, 742,  25, 498, 528, 520, 297, 352,  50,  40, 647, 204,
       302, 353, 782, 632, 237, 317, 515, 580, 463, 609, 557, 108, 198,
       693, 663, 113, 294, 355,  41, 662, 640, 629, 759, 127, 186, 733,
       447, 313, 398, 101, 227, 747, 336, 402, 680, 395, 436, 423, 365,
       477,  15, 153,  73, 727, 202, 679, 166, 457, 741, 309,  78, 167,
       488,  70, 509, 156, 218, 603,   7, 122,  94, 682,  92, 740, 778,
       307, 567, 781,  32, 223,  90, 656, 296, 147, 652, 723, 319, 210,
       411, 475, 512, 596, 766, 189, 697,   1, 643,  58, 124, 624, 396,
       277, 519, 752, 375, 144, 347, 770, 548,  17, 152, 672, 322, 292,
       444, 708, 184, 745, 595, 197, 489, 622,  60, 542, 236, 188, 407,
       538, 219, 170, 390, 335, 339, 120, 139, 226, 158, 478, 537, 472,
       480, 240,  54, 178, 283, 333, 126, 180, 707, 615, 116, 282, 773,
       545, 581, 780, 312]))
```

[584]:
```
# choose cost
mylib2.choose_cost(name = 'multiclass_softmax')
```

[585]:
```
# choose dimensions of fully connected multilayer perceptron layers
layer_sizes = [10,10,10,10]
mylib2.choose_features(feature_name = 'multilayer_perceptron',layer_sizes =␣
 ↪layer_sizes, activation = 'relu',scale = 0.1)
```

[586]:
```
mylib2.fit(max_its = 10,alpha_choice = 10**(-2),verbose = False,batch_size =␣
 ↪200)
```

```
---------------------------------------------------------------------------
AttributeError                            Traceback (most recent call last)
Cell In[586], line 1
----> 1␣
 ↪mylib2.fit(max_its = 10,alpha_choice = 10**(-2),verbose = False,batch_size =  00)
```

```
File ~/Desktop/GitHub_Files/435-deep-learning/super_setup.py:143, in fit(self,␣
 ↪**kwargs)
    140 if 'batch_size' in kwargs:
    141     self.batch_size = min(kwargs['batch_size'],self.batch_size)
--> 143 # verbose or not
    144 verbose = True
    145 if 'verbose' in kwargs:

AttributeError: 'Setup' object has no attribute 'y_train'
```

[587]:
```
# component-wise normalized version
mylib2.choose_features(feature_name =␣
 ↪'multilayer_perceptron_batch_normalized',layer_sizes =␣
 ↪layer_sizes,activation = 'relu',scale = 0.1)
mylib2.fit(max_its = 10,alpha_choice = 10**(-1),verbose = False,w_init = mylib.
 ↪w_init,batch_size = 200)
```

```
---------------------------------------------------------------------------
AttributeError                            Traceback (most recent call last)
Cell In[587], line 3
      1 # component-wise normalized version
      2 mylib2.choose_features(feature_name =␣
 ↪'multilayer_perceptron_batch_normalized',layer_sizes = layer_sizes,activation␣
 ↪= 'relu',scale = 0.1)
----> 3␣
 ↪mylib2.fit(max_its = 10,alpha_choice = 10**(-1),verbose = False,w_init = myli).w_init,batch

File ~/Desktop/GitHub_Files/435-deep-learning/super_setup.py:143, in fit(self,␣
 ↪**kwargs)
    140 if 'batch_size' in kwargs:
    141     self.batch_size = min(kwargs['batch_size'],self.batch_size)
--> 143 # verbose or not
    144 verbose = True
    145 if 'verbose' in kwargs:

AttributeError: 'Setup' object has no attribute 'y_train'
```

[ ]:
```
 # plot cost function history
labels = ['regular','batch-normalized']
mylib2.show_multirun_histories(start = 0,labels = labels)
```

3 13.9 Early Stopping Cross-Validation

[456]:
```
# load in dataset
csvname = datapath + 'noisy_sin_sample.csv'
data = np.loadtxt(csvname, delimiter = ',')
x = data[:-1,:]
y = data[-1:,:]

print(np.shape(x))
print(np.shape(y))
```

```
(20, 2)
(1, 2)
```

[457]:
```
import polys
import cost_functions3
import optimizers
```

[472]:
```
class Setup3:
    def __init__(self,x,y,**kwargs):
        # link in data
        self.x = x
        self.y = y

        # make containers for all histories
        self.weight_histories = []
        self.train_cost_histories = []
        self.train_count_histories = []
        self.valid_cost_histories = []
        self.valid_count_histories = []

    #### define feature transformation ####
    def choose_features(self,name,**kwargs):
        ### select from pre-made feature transforms ###
        # multilayer perceptron #
        if name == 'multilayer_perceptron':
            self.transformer = multilayer_perceptron.Setup(**kwargs)
            self.feature_transforms = self.transformer.feature_transforms
            self.initializer = self.transformer.initializer
            self.layer_sizes = self.transformer.layer_sizes

        if name == 'multilayer_perceptron_batch_normalized':
            self.transformer = multilayer_perceptron_batch_normalized.
 ↪Setup(**kwargs)
            self.feature_transforms = self.transformer.feature_transforms
            self.initializer = self.transformer.initializer
            self.layer_sizes = self.transformer.layer_sizes
```

```
        # polynomials #
        if name == 'polys':
            self.transformer = polys.Setup(self.x,self.y,**kwargs)
            self.feature_transforms = self.transformer.feature_transforms
            self.initializer = self.transformer.initializer
            self.degs = self.transformer.D

        self.feature_name = name

    #### define normalizer ####
    def choose_normalizer(self,name):
        # produce normalizer / inverse normalizer
        s = normalizers.Setup(self.x,name)
        self.normalizer = s.normalizer
        self.inverse_normalizer = s.inverse_normalizer

        # normalize input
        self.x = self.normalizer(self.x)
        self.normalizer_name = name

    #### split data into training and validation sets ####
    def make_train_valid_split(self,train_portion):
        # translate desired training portion into exact indecies
        r = np.random.permutation(self.x.shape[1])
        train_num = int(np.round(train_portion*len(r)))
        self.train_inds = r[:train_num]
        self.valid_inds = r[train_num:]

        # define training and validation sets
        self.x_train = self.x[:,self.train_inds]
        self.x_valid = self.x[:,self.valid_inds]

        self.y_train = self.y[:,self.train_inds]
        self.y_valid = self.y[:,self.valid_inds]

    #### define cost function ####
    def choose_cost(self,name,**kwargs):
        # create cost on entire dataset
        funcs = cost_functions3.Setup(name,self.x,self.y,self.
↪feature_transforms,**kwargs)
        self.full_cost = funcs.cost
        self.full_model = funcs.model

        # create training and validation cost functions
        funcs = cost_functions3.Setup(name,self.x_train,self.y_train,self.
↪feature_transforms,**kwargs)
```

```
        self.cost = funcs.cost
        self.model = funcs.model

        funcs = cost_functions3.Setup(name,self.x_valid,self.y_valid,self.
↪feature_transforms,**kwargs)
        self.valid_cost = funcs.cost
        self.valid_model = funcs.model

        # if the cost function is a two-class classifier, build a counter too
        if name == 'softmax' or name == 'perceptron':
            funcs = cost_functions3.Setup('twoclass_counter',self.x_train,self.
↪y_train,self.feature_transforms,**kwargs)
            self.counter = funcs.cost

            funcs = cost_functions3.Setup('twoclass_counter',self.x_valid,self.
↪y_valid,self.feature_transforms,**kwargs)
            self.valid_counter = funcs.cost

        if name == 'multiclass_softmax' or name == 'multiclass_perceptron':
            funcs = cost_functions3.Setup('multiclass_counter',self.
↪x_train,self.y_train,self.feature_transforms,**kwargs)
            self.counter = funcs.cost

            funcs = cost_functions3.Setup('multiclass_counter',self.
↪x_valid,self.y_valid,self.feature_transforms,**kwargs)
            self.valid_counter = funcs.cost

        self.cost_name = name

    #### run optimization ####
    def fit(self,**kwargs):
        # basic parameters for gradient descent run (default algorithm)
        max_its = 500; alpha_choice = 10**(-1);
        self.w_init = self.initializer()
        optimizer = 'gradient_descent'
        epsilon = 10**(-10)

        # set parameters by hand
        if 'max_its' in kwargs:
            self.max_its = kwargs['max_its']
        if 'alpha_choice' in kwargs:
            self.alpha_choice = kwargs['alpha_choice']
        if 'optimizer' in kwargs:
            optimizer = kwargs['optimizer']
        if 'epsilon' in kwargs:
            epsilon = kwargs['epsilon']
        if 'init' in kwargs:
```

```
            print ('here')
            self.w_init = kwargs['init']

        # batch size for gradient descent?
        self.num_pts = np.size(self.y_train)
        self.batch_size = np.size(self.y_train)
        if 'batch_size' in kwargs:
            self.batch_size = kwargs['batch_size']

        # optimize
        weight_history = []

        # run gradient descent
        if optimizer == 'gradient_descent':
            weight_history = optimizers.gradient_descent(self.cost,self.
↪alpha_choice,self.max_its,self.w_init,self.num_pts,self.batch_size)

        if optimizer == 'RMSprop':
            weight_history = optimizers.RMSprop(self.cost,self.
↪alpha_choice,self.max_its,self.w_init,self.num_pts,self.batch_size)

        # run gradient descent
        if optimizer == 'newtons_method':
            epsilon = 10**(-10)
            if 'epsilon' in kwargs:
                epsilon = kwargs['epsilon']
            weight_history = optimizers.newtons_method(self.cost,epsilon,self.
↪max_its,self.w_init,self.num_pts,self.batch_size)


        # compute training history
        train_cost_history = [self.cost(v,np.arange(np.size(self.y_train))) for␣
↪v in weight_history]

        # store all new histories
        self.weight_histories.append(weight_history)
        self.train_cost_histories.append(train_cost_history)

        # compute validation history
        if len(self.valid_inds) > 0:
            valid_cost_history = [self.valid_cost(v,np.arange(np.size(self.
↪y_valid))) for v in weight_history]
            self.valid_cost_histories.append(valid_cost_history)

        # if classification produce count history
```

```
        if self.cost_name == 'softmax' or self.cost_name == 'perceptron' or␣
↪self.cost_name == 'multiclass_softmax' or self.cost_name ==␣
↪'multiclass_perceptron':
            train_count_history = [self.counter(v) for v in weight_history]
            self.train_count_histories.append(train_count_history)

            if len(self.valid_inds) > 0:
                valid_count_history = [self.valid_counter(v) for v in␣
↪weight_history]
                self.valid_count_histories.append(valid_count_history)

    #### plot histories ###
    def show_histories(self,**kwargs):
        start = 0
        if 'start' in kwargs:
            start = kwargs['start']
        history_plotters.Setup(self.train_cost_histories,self.
↪train_count_histories,self.valid_cost_histories,self.
↪valid_count_histories,start)

    #### for batch normalized multilayer architecture only - set normalizers to␣
↪desired settings ####
    def fix_normalizers(self,w):
        ### re-set feature transformation ###
        # fix normalization at each layer by passing data and specific weight␣
↪through network
        self.feature_transforms(self.x,w);

        # re-assign feature transformation based on these settings
        self.validation_feature_transforms = self.transformer.
↪validation_feature_transforms

        ### re-assign cost function (and counter) based on fixed architecture␣
↪###
        funcs = cost_functions.Setup(self.cost_name,self.x,self.y,self.
↪validation_feature_transforms)
        self.model = funcs.model
```

[473]:
```
mylib3 = Setup3(x,y)
```

[474]:
```
layer_sizes = [1,10,10,10,1]
```

[475]:
```
mylib3.choose_features(name = 'multilayer_perceptron',layer_sizes =␣
 ↪layer_sizes,activation = 'tanh')
```

[476]:
```
mylib3.choose_normalizer(name = 'standard')
```

[477]:
```
mylib3.make_train_valid_split(train_portion = 0.66)
```

[478]:
```
mylib3.choose_cost(name = 'least_squares')
```

[136]:
```
mylib3.fit(max_its = 10000,alpha_choice = 10**(-1))
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Cell In[136], line 1
----> 1 mylib.fit(max_its = 10000,alpha_choice = 10**(-1))

Cell In[120], line 130, in Setup3.fit(self, **kwargs)
    128 # run gradient descent
    129 if optimizer == 'gradient_descent':
--> 130     weight_history =␣
 ↪optimizers.gradient_descent(self.cost,self.alpha_choice,self.max_its,self.w_init,self.num_p
    132 if optimizer == 'RMSprop':
    133     weight_history = optimizers.RMSprop(self.cost,self.alpha_choice,self.
 ↪max_its,self.w_init,self.num_pts,self.batch_size)

File ~/Desktop/GitHub_Files/435-deep-learning/optimizers.py:38, in␣
 ↪gradient_descent(g, alpha, max_its, w, num_pts, batch_size, **kwargs)
     35 batch_inds = np.arange(b*batch_size, min((b+1)*batch_size, num_pts))
     37 # plug in value into func and derivative
---> 38 cost_eval,grad_eval = grad(w,batch_inds)
     39 grad_eval.shape = np.shape(w)
     41 # normalize?

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/wrap_util.py:20, in␣
 ↪unary_to_nary.<locals>.nary_operator.<locals>.nary_f(*args, **kwargs)
     18 else:
     19     x = tuple(args[i] for i in argnum)
---> 20 return unary_operator(unary_f, x, *nary_op_args, **nary_op_kwargs)

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/differential_operators.
 ↪py:138, in value_and_grad(fun, x)
    134 @unary_to_nary
    135 def value_and_grad(fun, x):
    136     """Returns a function that returns both value and gradient. Suitable␣
 ↪for use
    137     in scipy.optimize"""
--> 138     vjp, ans = _make_vjp(fun, x)
    139     if not vspace(ans).size == 1:
    140         raise TypeError("value_and_grad only applies to real␣
 ↪scalar-output "
    141                         "functions. Try jacobian, elementwise_grad or "
    142                         "holomorphic_grad.")
```

```
File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/core.py:10, in␣
 ↪make_vjp(fun, x)
      8 def make_vjp(fun, x):
      9     start_node = VJPNode.new_root()
---> 10     end_value, end_node =  trace(start_node, fun, x)
     11     if end_node is None:
     12         def vjp(g): return vspace(x).zeros()

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/tracer.py:10, in␣
 ↪trace(start_node, fun, x)
      8 with trace_stack.new_trace() as t:
      9     start_box = new_box(x, t, start_node)
---> 10     end_box = fun(start_box)
     11     if isbox(end_box) and end_box._trace == start_box._trace:
     12         return end_box._value, end_box._node

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/wrap_util.py:15, in␣
 ↪unary_to_nary.<locals>.nary_operator.<locals>.nary_f.<locals>.unary_f(x)
     13 else:
     14     subargs = subvals(args, zip(argnum, x))
---> 15 return fun(*subargs, **kwargs)

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/misc/flatten.py:32, i␣
 ↪flatten_func.<locals>.<lambda>(_x, *args)
     30 def flatten_func(func, example):
     31     _ex, unflatten = flatten(example)
---> 32     _func = lambda _x, *args: flatten(func(unflatten(_x), *args))[0]
     33     return _func, unflatten, _ex

File ~/Desktop/GitHub_Files/435-deep-learning/cost_functions3.py:80, in Setup.
 ↪least_squares(self, w, iter)
     77 y_p = self.y[:,iter]
     79 # compute cost
---> 80 cost = np.sum((self.model(x_p,w) - y_p)**2)
     81 return cost/float(np.size(x_p))

File ~/Desktop/GitHub_Files/435-deep-learning/cost_functions3.py:54, in Setup.
 ↪model(self, x, w)
     52 f = 0
     53 if len(self.sig.parameters) == 2:
---> 54     f = self.feature_transforms(x,w[0])
     55 else:
     56     f = self.feature_transforms(x)

File ~/Desktop/GitHub_Files/435-deep-learning/multilayer_perceptron.py:100, in␣
 ↪Setup.standard_feature_transforms(self, a, w)
     96 def standard_feature_transforms(self,a, w):
```

```
     97     # loop through each layer matrix
     98     for W in w:
     99         # compute inner product with current layer weights
--> 100         a = W[0] + np.dot(a.T, W[1:])
    102         # output of layer activation
    103         a = self.activation(a).T

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/tracer.py:44, in␣
 ↪primitive.<locals>.f_wrapped(*args, **kwargs)
     42 parents = tuple(box._node for _      , box in boxed_args)
     43 argnums = tuple(argnum    for argnum, _   in boxed_args)
---> 44 ans = f_wrapped(*argvals, **kwargs)
     45 node = node_constructor(ans, f_wrapped, argvals, kwargs, argnums,␣
 ↪parents)
     46 return new_box(ans, trace, node)

File ~/opt/anaconda3/lib/python3.9/site-packages/autograd/tracer.py:48, in␣
 ↪primitive.<locals>.f_wrapped(*args, **kwargs)
     46     return new_box(ans, trace, node)
     47 else:
---> 48     return f_raw(*args, **kwargs)

File <__array_function__ internals>:200, in dot(*args, **kwargs)

ValueError: shapes (1,20) and (1,10) not aligned: 20 (dim 1) != 1 (dim 0)
```

[138]:

4 13.10 Hand Written Digit Recognition Using Neural Networks

[183]:
```
from sklearn.model_selection import train_test_split
```

[279]:
```
# get MNIST data from online repository
from sklearn.datasets import fetch_openml
x, y = fetch_openml('mnist_784', version=1, return_X_y=True)
```

[280]:
```
# convert string labels to integers
y = np.array([int(v) for v in y])[:,np.newaxis]

print(np.shape(x))
print(np.shape(y))
```

```
(70000, 784)
(70000, 1)
```

[285]:
```
x1 = x.T
y1  = y.T
```

[286]:
```
# standard normalization function - with nan checker / filler in-er

def standard_normalizer(x1):
    # compute the mean and standard deviation of the input
    x_means = np.nanmean(x1,axis = 1)[:,np.newaxis]
    x_stds = np.nanstd(x1,axis = 1)[:,np.newaxis]

    # create standard normalizer function

    normalizer = lambda data: (data - x_means)/x_stds # create inverse standard␣
 ↪normalizer
    inverse_normalizer = lambda data: data*x_stds + x_means # return normalizer

    return normalizer,inverse_normalizer

normalizer,inverse_normalizer = standard_normalizer(x1.T)
x1 = normalizer(x1.T).T
```

[331]:
```
x_sample, x_test = x[:50000],x[50000:]
y_sample, y_test=y[:50000],y[50000:]
```

[332]:
```
shuffled = np.random.permutation(50000)
x_sample = x_sample.iloc[shuffled]
y_sample = y_sample[shuffled]
```

[333]:
```
mylib4 = Setup3(x_sample,y_sample)
```

[334]:
```
layer_sizes = [784,100,100,10]
```

[335]:
```
mylib4.choose_features(name = 'multilayer_perceptron',layer_sizes =␣
 ↪layer_sizes,activation = 'maxout',scale=0.1)
```

[336]:
```
mylib4.choose_normalizer(name = 'standard')
```

[337]:
```
# split into training and testing sets
mylib4.make_train_valid_split(train_portion = 5/6)
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/indexes/base.py:
 ↪3802, in Index.get_loc(self, key, method, tolerance)
   3801 try:
-> 3802     return self._engine.get_loc(casted_key)
   3803 except KeyError as err:
```

```
File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/_libs/index.pyx:138, in
 ↪pandas._libs.index.IndexEngine.get_loc()

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/_libs/index.pyx:144, in
 ↪pandas._libs.index.IndexEngine.get_loc()

TypeError: '(slice(None, None, None), array([ 99, 223, 442, 376, 273, 643, 676,
 ↪702, 758, 204, 503,  19, 760,
       186, 306,  53, 599, 363, 148, 578, 713,  28, 261,  51, 238, 270,
         8, 312,  43,   4, 123, 766,  49, 726, 263, 604, 337, 269, 408,
       111, 315, 600, 492, 521, 745, 241, 354, 341, 386, 747, 725, 342,
        98, 384,  18,  86,  58,  64, 519, 455, 209, 479, 449, 407, 562,
       162, 170, 303, 765, 435, 338, 775, 268, 502, 310,  25, 611, 200,
       551, 552, 563, 731, 727,  69, 180, 323, 271, 360, 374, 299, 582,
       151, 752, 179, 137, 232,  65, 222, 633,  15, 567,  61, 608,  20,
       368, 672, 473,  93, 436,  80, 644, 149, 730, 501, 739, 593, 350,
       524, 656,  76,   6, 175, 668,   1, 772, 509, 249, 565, 622, 348,
       667, 700, 635, 648, 534, 533, 580,  67, 680, 621, 570,  88, 743,
       486, 296, 738, 734,   7, 712, 532, 220, 441, 693, 741, 471, 781,
       305, 185, 451, 462, 413,  23, 227, 681, 707, 780, 541, 155, 483,
       757, 344, 389, 367, 579, 729, 477, 545, 601, 456, 419, 591, 352,
       660, 345, 433, 634, 507, 301, 395,  35, 630, 645, 674, 288, 230,
       432, 557,  24, 658,   3, 158, 587, 429, 121, 401, 190, 602, 351,
       210, 242, 778,  92, 671, 276, 112, 317, 556, 423, 682, 612, 213,
       536, 214, 128, 623, 629, 328, 628,  52, 168, 688, 539, 188, 197,
       160, 259, 358, 690,  83, 239, 625, 718, 504, 133, 475, 490, 603,
       382, 670, 192, 246, 616, 464, 516, 706, 349, 701, 531, 698, 357,
       711, 481,  81, 549, 280, 617, 217,  73, 147, 231, 176, 225, 443,
       257,  63,  85, 618, 664, 764,  32,  29, 145, 560, 181, 476, 282,
        12,  16, 383, 588, 695,  96, 542, 398, 759, 109, 219,  27, 169,
       446, 346, 125, 403, 347,  33, 590,  54,  71, 138, 548,   5, 669,
       453, 773, 639, 171,  44, 189, 334, 636, 245, 653, 420,  82, 640,
       375, 102, 777,  13, 550, 466, 183, 251, 364, 172, 748, 585,  22,
       416, 140, 292, 697, 428, 275, 184, 229, 381, 330, 500, 196, 233,
       592, 610, 152, 447, 744, 584, 746, 320, 256, 683, 353, 498, 207,
       546, 448, 146, 515, 400, 325,  47, 626,  10, 234, 377, 212, 321,
       710, 355, 465, 526, 525, 583, 289, 517, 696, 411, 182, 421, 414,
       201, 285, 167,  38, 685, 326, 356, 136,  37, 405, 283, 689, 756,
       637, 115, 117, 324, 371, 218, 114, 751, 426,  46, 547, 692,  75,
       412, 119, 762, 512, 569, 393, 753, 108, 537, 332,  56, 215, 409,
       763, 161, 106, 216, 104, 553,  62, 571, 253, 694, 776, 596, 373,
       632, 107, 704, 703, 445, 638, 522, 771, 613, 540, 679,  77, 422,
       736, 627, 424, 150, 474, 173, 783, 723, 506, 318, 675, 478, 406,
       372, 410, 165,  94, 495, 469, 298, 397, 237, 459, 686, 425, 122,
       770, 394, 178, 388, 174, 605, 430, 308,   2, 194, 530, 529, 359,
       365, 597, 316, 313, 266, 740, 304, 663, 508, 513, 262, 472, 450,
       258, 576, 684,  36, 291, 418, 458, 641, 143, 272, 124, 101, 295,
```

```
       715, 568, 208, 652, 646, 520, 768, 720, 333, 699, 260, 485, 457,
       221, 614, 387, 755, 651, 714, 279, 392, 236, 415, 286, 586, 577,
       113,  90, 255, 678, 717, 572, 566, 491, 615, 440, 362, 244, 437,
       366, 749, 267,  45, 322, 631, 518, 293, 274, 264, 100, 226,  41,
        48, 103, 370, 254, 110, 211,  66, 380, 224, 131, 494, 277, 127,
       493, 203, 735, 132, 199, 470, 129, 339, 467, 589,  17, 620, 497,
        91, 284, 336, 116, 118, 126, 452, 558, 166, 454, 206,  95, 319,
       535,  74, 654, 574, 659, 327, 737, 278, 544, 724,  39, 561, 297,
       135, 157, 708, 732, 191, 647,  72,  79, 677, 156, 378, 527, 774,
       650, 559, 307,  78,  87, 281, 329, 489, 141, 139, 294, 595,  97,
       510, 673, 484]))' is an invalid key

During handling of the above exception, another exception occurred:

InvalidIndexError                         Traceback (most recent call last)
Cell In[337], line 2
      1 # split into training and testing sets
----> 2 mylib4.make_train_valid_split(train_portion = 5/6)

Cell In[330], line 59, in Setup3.make_train_valid_split(self, train_portion)
     56 self.valid_inds = r[train_num:]
     58 # define training and validation sets
---> 59 self.x_train = self.x[:,self.train_inds]
     60 self.x_valid = self.x[:,self.valid_inds]
     62 self.y_train = self.y[:,self.train_inds]

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/frame.py:3807, in␣
 ↪DataFrame.__getitem__(self, key)
   3805 if self.columns.nlevels > 1:
   3806     return self._getitem_multilevel(key)
-> 3807 indexer = self.columns.get_loc(key)
   3808 if is_integer(indexer):
   3809     indexer = [indexer]

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/indexes/base.py:
 ↪3809, in Index.get_loc(self, key, method, tolerance)
   3804         raise KeyError(key) from err
   3805     except TypeError:
   3806         # If we have a listlike key, _check_indexing_error will raise
   3807         #  InvalidIndexError. Otherwise we fall through and re-raise
   3808         #  the TypeError.
-> 3809         self._check_indexing_error(key)
   3810         raise
   3812 # GH#42269

File ~/opt/anaconda3/lib/python3.9/site-packages/pandas/core/indexes/base.py:
 ↪5925, in Index._check_indexing_error(self, key)
   5921 def _check_indexing_error(self, key):
```

```
   5922     if not is_scalar(key):
   5923         # if key is not a scalar, directly raise an error (the code bel w
   5924         # would convert to numpy arrays and raise later any way) -␣
 ↪GH29926
-> 5925         raise InvalidIndexError(key)

InvalidIndexError: (slice(None, None, None), array([ 99, 223, 442, 376, 273,␣
 ↪643, 676, 702, 758, 204, 503,  19, 760,
       186, 306,  53, 599, 363, 148, 578, 713,  28, 261,  51, 238, 270,
         8, 312,  43,   4, 123, 766,  49, 726, 263, 604, 337, 269, 408,
       111, 315, 600, 492, 521, 745, 241, 354, 341, 386, 747, 725, 342,
        98, 384,  18,  86,  58,  64, 519, 455, 209, 479, 449, 407, 562,
       162, 170, 303, 765, 435, 338, 775, 268, 502, 310,  25, 611, 200,
       551, 552, 563, 731, 727,  69, 180, 323, 271, 360, 374, 299, 582,
       151, 752, 179, 137, 232,  65, 222, 633,  15, 567,  61, 608,  20,
       368, 672, 473,  93, 436,  80, 644, 149, 730, 501, 739, 593, 350,
       524, 656,  76,   6, 175, 668,   1, 772, 509, 249, 565, 622, 348,
       667, 700, 635, 648, 534, 533, 580,  67, 680, 621, 570,  88, 743,
       486, 296, 738, 734,   7, 712, 532, 220, 441, 693, 741, 471, 781,
       305, 185, 451, 462, 413,  23, 227, 681, 707, 780, 541, 155, 483,
       757, 344, 389, 367, 579, 729, 477, 545, 601, 456, 419, 591, 352,
       660, 345, 433, 634, 507, 301, 395,  35, 630, 645, 674, 288, 230,
       432, 557,  24, 658,   3, 158, 587, 429, 121, 401, 190, 602, 351,
       210, 242, 778,  92, 671, 276, 112, 317, 556, 423, 682, 612, 213,
       536, 214, 128, 623, 629, 328, 628,  52, 168, 688, 539, 188, 197,
       160, 259, 358, 690,  83, 239, 625, 718, 504, 133, 475, 490, 603,
       382, 670, 192, 246, 616, 464, 516, 706, 349, 701, 531, 698, 357,
       711, 481,  81, 549, 280, 617, 217,  73, 147, 231, 176, 225, 443,
       257,  63,  85, 618, 664, 764,  32,  29, 145, 560, 181, 476, 282,
        12,  16, 383, 588, 695,  96, 542, 398, 759, 109, 219,  27, 169,
       446, 346, 125, 403, 347,  33, 590,  54,  71, 138, 548,   5, 669,
       453, 773, 639, 171,  44, 189, 334, 636, 245, 653, 420,  82, 640,
       375, 102, 777,  13, 550, 466, 183, 251, 364, 172, 748, 585,  22,
       416, 140, 292, 697, 428, 275, 184, 229, 381, 330, 500, 196, 233,
       592, 610, 152, 447, 744, 584, 746, 320, 256, 683, 353, 498, 207,
       546, 448, 146, 515, 400, 325,  47, 626,  10, 234, 377, 212, 321,
       710, 355, 465, 526, 525, 583, 289, 517, 696, 411, 182, 421, 414,
       201, 285, 167,  38, 685, 326, 356, 136,  37, 405, 283, 689, 756,
       637, 115, 117, 324, 371, 218, 114, 751, 426,  46, 547, 692,  75,
       412, 119, 762, 512, 569, 393, 753, 108, 537, 332,  56, 215, 409,
       763, 161, 106, 216, 104, 553,  62, 571, 253, 694, 776, 596, 373,
       632, 107, 704, 703, 445, 638, 522, 771, 613, 540, 679,  77, 422,
       736, 627, 424, 150, 474, 173, 783, 723, 506, 318, 675, 478, 406,
       372, 410, 165,  94, 495, 469, 298, 397, 237, 459, 686, 425, 122,
       770, 394, 178, 388, 174, 605, 430, 308,   2, 194, 530, 529, 359,
       365, 597, 316, 313, 266, 740, 304, 663, 508, 513, 262, 472, 450,
       258, 576, 684,  36, 291, 418, 458, 641, 143, 272, 124, 101, 295,
       715, 568, 208, 652, 646, 520, 768, 720, 333, 699, 260, 485, 457,
```

```
       221, 614, 387, 755, 651, 714, 279, 392, 236, 415, 286, 586, 577,
       113,  90, 255, 678, 717, 572, 566, 491, 615, 440, 362, 244, 437,
       366, 749, 267,  45, 322, 631, 518, 293, 274, 264, 100, 226,  41,
        48, 103, 370, 254, 110, 211,  66, 380, 224, 131, 494, 277, 127,
       493, 203, 735, 132, 199, 470, 129, 339, 467, 589,  17, 620, 497,
        91, 284, 336, 116, 118, 126, 452, 558, 166, 454, 206,  95, 319,
       535,  74, 654, 574, 659, 327, 737, 278, 544, 724,  39, 561, 297,
       135, 157, 708, 732, 191, 647,  72,  79, 677, 156, 378, 527, 774,
       650, 559, 307,  78,  87, 281, 329, 489, 141, 139, 294, 595,  97,
       510, 673, 484]))
```

[338]:
```
# choose cost
mylib4.choose_cost(name = 'multiclass_softmax')
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
Cell In[338], line 2
      1 # choose cost
----> 2 mylib4.choose_cost(name = 'multiclass_softmax')

Cell In[330], line 68, in Setup3.choose_cost(self, name, **kwargs)
     66 def choose_cost(self,name,**kwargs):
     67     # create cost on entire dataset
---> 68     funcs =␣
 ↪cost_functions.Setup(name,self.x,self.y,self.feature_transforms,**kwargs)
     69     self.full_cost = funcs.cost
     70     self.full_model = funcs.model

TypeError: __init__() takes 2 positional arguments but 5 were given
```

[340]:
```
# fit an optimization
mylib4.fit(optimizer = 'gradient_descent',max_its = 100,alpha_choice =␣
 ↪10**(-1),b atch_size = 500,verbose = True,version = 'standard')
```

```
  Cell In[340], line 2
    mylib4.fit(optimizer = 'gradient_descent',max_its = 100,alpha_choice =␣
 ↪10**(-1),b atch_size = 500,verbose = True,version = 'standard')

 ↪      ^
SyntaxError: positional argument follows keyword argument
```

[ ]: