Homework5

Ze Chen
Chunran Yao

In [1]:

```
from keras.models import Sequential, Model
from keras.layers import Dense, Activation, Dropout, BatchNormalization, Input,
add
from keras import regularizers, Model
from keras.datasets import fashion_mnist
import keras
from sklearn.datasets import load_iris
from sklearn.model_selection import GridSearchCV
from sklearn.model_selection import StratifiedShuffleSplit
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import train_test_split
import pandas as pd
import numpy as np
import glob
import os
from keras.layers import Conv2D, MaxPooling2D, Flatten
import matplotlib.pyplot as plt
```

```
Using TensorFlow backend.
```

Task 1

In [0]:

```
def make_model(optimizer = 'adam', hidden_size = 32,regularization_strength = 0.
01):
  model = Sequential()
  model.add(Dense(hidden_size, activation='relu', input_dim=4,kernel_regularizer
=regularizers.l2(regularization_strength)))
  model.add(Dense(hidden_size, activation='relu', kernel_regularizer=regularizer
s.l2(regularization_strength)))
  model.add(Dense(3, activation='softmax'))

  model.compile(optimizer=optimizer,loss="categorical_crossentropy",metrics=['ac
curacy'])
  return model
```

In [0]:

```
clf = KerasClassifier(make_model)
```

In [0]:

```
iris_X, iris_y = load_iris(return_X_y=True)
X_train, X_test, y_train,y_test = train_test_split(iris_X,iris_y)
```

In [0]:

```
ss = StratifiedShuffleSplit(n_splits=5, test_size=0.25)
```

In [0]:

```
param_grid = {'hidden_size': [32, 64, 256],
              'regularization_strength': [0,0.01,0.05,0.1]}
grid = GridSearchCV(clf, param_grid=param_grid, cv=ss)
grid.fit(X_train, y_train,epochs = 10)
```

```
Epoch 1/10
84/84 [==============================] - 19s 226ms/step - loss: 1.19
45 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 258us/step - loss: 1.086
6 - acc: 0.3690
Epoch 3/10
84/84 [==============================] - 0s 262us/step - loss: 0.994
2 - acc: 0.6548
Epoch 4/10
84/84 [==============================] - 0s 245us/step - loss: 0.919
9 - acc: 0.6667
Epoch 5/10
84/84 [==============================] - 0s 239us/step - loss: 0.862
5 - acc: 0.6667
Epoch 6/10
84/84 [==============================] - 0s 258us/step - loss: 0.821
5 - acc: 0.6667
Epoch 7/10
84/84 [==============================] - 0s 252us/step - loss: 0.787
3 - acc: 0.6667
Epoch 8/10
84/84 [==============================] - 0s 266us/step - loss: 0.763
1 - acc: 0.6667
Epoch 9/10
84/84 [==============================] - 0s 266us/step - loss: 0.738
2 - acc: 0.6429
Epoch 10/10
84/84 [==============================] - 0s 241us/step - loss: 0.716
1 - acc: 0.7024
28/28 [==============================] - 8s 277ms/step
84/84 [==============================] - 0s 255us/step
Epoch 1/10
84/84 [==============================] - 18s 210ms/step - loss: 1.34
79 - acc: 0.2976
Epoch 2/10
84/84 [==============================] - 0s 249us/step - loss: 1.159
9 - acc: 0.3214
Epoch 3/10
84/84 [==============================] - 0s 243us/step - loss: 1.035
3 - acc: 0.4524
Epoch 4/10
84/84 [==============================] - 0s 247us/step - loss: 0.929
1 - acc: 0.7143
Epoch 5/10
84/84 [==============================] - 0s 230us/step - loss: 0.868
9 - acc: 0.7024
Epoch 6/10
84/84 [==============================] - 0s 249us/step - loss: 0.820
4 - acc: 0.7024
Epoch 7/10
84/84 [==============================] - 0s 255us/step - loss: 0.789
0 - acc: 0.7143
Epoch 8/10
84/84 [==============================] - 0s 235us/step - loss: 0.764
5 - acc: 0.7024
Epoch 9/10
84/84 [==============================] - 0s 245us/step - loss: 0.742
8 - acc: 0.7024
Epoch 10/10
84/84 [==============================] - 0s 269us/step - loss: 0.723
```

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2 - acc: 0.7024
28/28 [==============================] - 8s 280ms/step
84/84 [==============================] - 0s 220us/step
Epoch 1/10
84/84 [==============================] - 18s 213ms/step - loss: 1.10
36 - acc: 0.3571
Epoch 2/10
84/84 [==============================] - 0s 232us/step - loss: 0.925
7 - acc: 0.6310
Epoch 3/10
84/84 [==============================] - 0s 235us/step - loss: 0.835
1 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 235us/step - loss: 0.783
0 - acc: 0.7143
Epoch 5/10
84/84 [==============================] - 0s 237us/step - loss: 0.751
0 - acc: 0.7857
Epoch 6/10
84/84 [==============================] - 0s 234us/step - loss: 0.723
7 - acc: 0.7738
Epoch 7/10
84/84 [==============================] - 0s 258us/step - loss: 0.693
3 - acc: 0.7619
Epoch 8/10
84/84 [==============================] - 0s 244us/step - loss: 0.661
8 - acc: 0.7619
Epoch 9/10
84/84 [==============================] - 0s 239us/step - loss: 0.637
3 - acc: 0.7143
Epoch 10/10
84/84 [==============================] - 0s 258us/step - loss: 0.611
8 - acc: 0.6905
28/28 [==============================] - 8s 297ms/step
84/84 [==============================] - 0s 276us/step
Epoch 1/10
84/84 [==============================] - 18s 216ms/step - loss: 1.35
15 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 283us/step - loss: 1.246
3 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 266us/step - loss: 1.158
6 - acc: 0.3095
Epoch 4/10
84/84 [==============================] - 0s 265us/step - loss: 1.087
4 - acc: 0.4405
Epoch 5/10
84/84 [==============================] - 0s 236us/step - loss: 1.028
7 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 237us/step - loss: 0.983
4 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 239us/step - loss: 0.941
0 - acc: 0.7381
Epoch 8/10
84/84 [==============================] - 0s 229us/step - loss: 0.902
0 - acc: 0.8095
Epoch 9/10
84/84 [==============================] - 0s 247us/step - loss: 0.861
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4 - acc: 0.8571
Epoch 10/10
84/84 [==============================] - 0s 263us/step - loss: 0.828
7 - acc: 0.8095
28/28 [==============================] - 8s 283ms/step
84/84 [==============================] - 0s 268us/step
Epoch 1/10
84/84 [==============================] - 18s 216ms/step - loss: 1.01
43 - acc: 0.2381
Epoch 2/10
84/84 [==============================] - 0s 252us/step - loss: 0.917
7 - acc: 0.4881
Epoch 3/10
84/84 [==============================] - 0s 241us/step - loss: 0.862
9 - acc: 0.6667
Epoch 4/10
84/84 [==============================] - 0s 231us/step - loss: 0.826
4 - acc: 0.6905
Epoch 5/10
84/84 [==============================] - 0s 253us/step - loss: 0.785
0 - acc: 0.8095
Epoch 6/10
84/84 [==============================] - 0s 236us/step - loss: 0.746
3 - acc: 0.8214
Epoch 7/10
84/84 [==============================] - 0s 232us/step - loss: 0.711
4 - acc: 0.8095
Epoch 8/10
84/84 [==============================] - 0s 234us/step - loss: 0.685
1 - acc: 0.8214
Epoch 9/10
84/84 [==============================] - 0s 260us/step - loss: 0.664
6 - acc: 0.8333
Epoch 10/10
84/84 [==============================] - 0s 247us/step - loss: 0.644
9 - acc: 0.8333
28/28 [==============================] - 8s 284ms/step
84/84 [==============================] - 0s 258us/step
Epoch 1/10
84/84 [==============================] - 18s 217ms/step - loss: 2.05
59 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 232us/step - loss: 1.858
4 - acc: 0.3214
Epoch 3/10
84/84 [==============================] - 0s 267us/step - loss: 1.657
5 - acc: 0.3214
Epoch 4/10
84/84 [==============================] - 0s 245us/step - loss: 1.539
2 - acc: 0.3214
Epoch 5/10
84/84 [==============================] - 0s 228us/step - loss: 1.455
3 - acc: 0.3214
Epoch 6/10
84/84 [==============================] - 0s 244us/step - loss: 1.402
8 - acc: 0.3571
Epoch 7/10
84/84 [==============================] - 0s 246us/step - loss: 1.349
4 - acc: 0.5357
Epoch 8/10
84/84 [==============================] - 0s 229us/step - loss: 1.309
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3 - acc: 0.6429
Epoch 9/10
84/84 [==============================] - 0s 259us/step - loss: 1.275
5 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 247us/step - loss: 1.240
2 - acc: 0.6786
28/28 [==============================] - 9s 304ms/step
84/84 [==============================] - 0s 263us/step
Epoch 1/10
84/84 [==============================] - 18s 220ms/step - loss: 1.72
64 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 243us/step - loss: 1.572
3 - acc: 0.5238
Epoch 3/10
84/84 [==============================] - 0s 242us/step - loss: 1.452
3 - acc: 0.6429
Epoch 4/10
84/84 [==============================] - 0s 233us/step - loss: 1.347
4 - acc: 0.6667
Epoch 5/10
84/84 [==============================] - 0s 229us/step - loss: 1.262
0 - acc: 0.6667
Epoch 6/10
84/84 [==============================] - 0s 234us/step - loss: 1.207
2 - acc: 0.7619
Epoch 7/10
84/84 [==============================] - 0s 231us/step - loss: 1.162
9 - acc: 0.9524
Epoch 8/10
84/84 [==============================] - 0s 234us/step - loss: 1.125
2 - acc: 0.8214
Epoch 9/10
84/84 [==============================] - 0s 267us/step - loss: 1.090
2 - acc: 0.7857
Epoch 10/10
84/84 [==============================] - 0s 237us/step - loss: 1.058
6 - acc: 0.8333
28/28 [==============================] - 8s 288ms/step
84/84 [==============================] - 0s 274us/step
Epoch 1/10
84/84 [==============================] - 19s 224ms/step - loss: 1.73
37 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 263us/step - loss: 1.563
8 - acc: 0.3452
Epoch 3/10
84/84 [==============================] - 0s 251us/step - loss: 1.435
4 - acc: 0.3571
Epoch 4/10
84/84 [==============================] - 0s 248us/step - loss: 1.358
2 - acc: 0.6667
Epoch 5/10
84/84 [==============================] - 0s 236us/step - loss: 1.315
4 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 236us/step - loss: 1.286
9 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 243us/step - loss: 1.260
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5 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 235us/step - loss: 1.234
3 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 254us/step - loss: 1.208
9 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 253us/step - loss: 1.184
7 - acc: 0.6786
28/28 [==============================] - 8s 289ms/step
84/84 [==============================] - 0s 303us/step
Epoch 1/10
84/84 [==============================] - 19s 222ms/step - loss: 1.65
74 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 290us/step - loss: 1.568
4 - acc: 0.3810
Epoch 3/10
84/84 [==============================] - 0s 276us/step - loss: 1.499
0 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 270us/step - loss: 1.449
1 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 290us/step - loss: 1.405
6 - acc: 0.3333
Epoch 6/10
84/84 [==============================] - 0s 290us/step - loss: 1.359
4 - acc: 0.3333
Epoch 7/10
84/84 [==============================] - 0s 387us/step - loss: 1.325
4 - acc: 0.4643
Epoch 8/10
84/84 [==============================] - 0s 317us/step - loss: 1.291
0 - acc: 0.6667
Epoch 9/10
84/84 [==============================] - 0s 271us/step - loss: 1.257
7 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 286us/step - loss: 1.226
4 - acc: 0.6786
28/28 [==============================] - 9s 313ms/step
84/84 [==============================] - 0s 285us/step
Epoch 1/10
84/84 [==============================] - 19s 223ms/step - loss: 2.17
06 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 242us/step - loss: 1.979
6 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 243us/step - loss: 1.803
6 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 238us/step - loss: 1.669
8 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 245us/step - loss: 1.567
6 - acc: 0.3333
Epoch 6/10
84/84 [==============================] - 0s 263us/step - loss: 1.491
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1 - acc: 0.3333
Epoch 7/10
84/84 [==============================] - 0s 255us/step - loss: 1.443
1 - acc: 0.3333
Epoch 8/10
84/84 [==============================] - 0s 243us/step - loss: 1.414
7 - acc: 0.3571
Epoch 9/10
84/84 [==============================] - 0s 261us/step - loss: 1.386
6 - acc: 0.5833
Epoch 10/10
84/84 [==============================] - 0s 274us/step - loss: 1.366
7 - acc: 0.6548
28/28 [==============================] - 8s 294ms/step
84/84 [==============================] - 0s 257us/step
Epoch 1/10
84/84 [==============================] - 19s 224ms/step - loss: 3.96
25 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 251us/step - loss: 3.528
7 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 251us/step - loss: 3.221
9 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 240us/step - loss: 3.038
5 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 238us/step - loss: 2.922
8 - acc: 0.3571
Epoch 6/10
84/84 [==============================] - 0s 240us/step - loss: 2.882
4 - acc: 0.3214
Epoch 7/10
84/84 [==============================] - 0s 277us/step - loss: 2.827
2 - acc: 0.3214
Epoch 8/10
84/84 [==============================] - 0s 253us/step - loss: 2.755
3 - acc: 0.3214
Epoch 9/10
84/84 [==============================] - 0s 246us/step - loss: 2.682
7 - acc: 0.3214
Epoch 10/10
84/84 [==============================] - 0s 270us/step - loss: 2.610
3 - acc: 0.5000
28/28 [==============================] - 8s 295ms/step
84/84 [==============================] - 0s 256us/step
Epoch 1/10
84/84 [==============================] - 19s 228ms/step - loss: 3.45
29 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 294us/step - loss: 3.287
7 - acc: 0.2976
Epoch 3/10
84/84 [==============================] - 0s 301us/step - loss: 3.136
4 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 295us/step - loss: 3.010
4 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 269us/step - loss: 2.906
```

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5 - acc: 0.3333
Epoch 6/10
84/84 [==============================] - 0s 271us/step - loss: 2.818
1 - acc: 0.3333
Epoch 7/10
84/84 [==============================] - 0s 274us/step - loss: 2.746
8 - acc: 0.3333
Epoch 8/10
84/84 [==============================] - 0s 319us/step - loss: 2.673
3 - acc: 0.3333
Epoch 9/10
84/84 [==============================] - 0s 316us/step - loss: 2.604
1 - acc: 0.3333
Epoch 10/10
84/84 [==============================] - 0s 305us/step - loss: 2.542
9 - acc: 0.3333
28/28 [==============================] - 9s 324ms/step
84/84 [==============================] - 0s 296us/step
Epoch 1/10
84/84 [==============================] - 19s 227ms/step - loss: 3.91
67 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 271us/step - loss: 3.498
0 - acc: 0.3214
Epoch 3/10
84/84 [==============================] - 0s 264us/step - loss: 3.193
5 - acc: 0.3214
Epoch 4/10
84/84 [==============================] - 0s 279us/step - loss: 2.970
5 - acc: 0.3214
Epoch 5/10
84/84 [==============================] - 0s 285us/step - loss: 2.803
7 - acc: 0.5952
Epoch 6/10
84/84 [==============================] - 0s 250us/step - loss: 2.717
9 - acc: 0.7024
Epoch 7/10
84/84 [==============================] - 0s 242us/step - loss: 2.643
7 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 236us/step - loss: 2.584
4 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 247us/step - loss: 2.527
1 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 242us/step - loss: 2.470
7 - acc: 0.6786
28/28 [==============================] - 8s 300ms/step
84/84 [==============================] - 0s 258us/step
Epoch 1/10
84/84 [==============================] - 19s 228ms/step - loss: 3.44
92 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 251us/step - loss: 3.198
7 - acc: 0.3452
Epoch 3/10
84/84 [==============================] - 0s 235us/step - loss: 3.021
5 - acc: 0.3571
Epoch 4/10
84/84 [==============================] - 0s 242us/step - loss: 2.890
```

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3 - acc: 0.5952
Epoch 5/10
84/84 [==============================] - 0s 238us/step - loss: 2.798
6 - acc: 0.6548
Epoch 6/10
84/84 [==============================] - 0s 250us/step - loss: 2.727
3 - acc: 0.6190
Epoch 7/10
84/84 [==============================] - 0s 238us/step - loss: 2.657
2 - acc: 0.6310
Epoch 8/10
84/84 [==============================] - 0s 265us/step - loss: 2.591
2 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 267us/step - loss: 2.528
7 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 268us/step - loss: 2.466
0 - acc: 0.6786
28/28 [==============================] - 8s 301ms/step
84/84 [==============================] - 0s 247us/step
Epoch 1/10
84/84 [==============================] - 20s 237ms/step - loss: 3.40
06 - acc: 0.2857
Epoch 2/10
84/84 [==============================] - 0s 275us/step - loss: 3.185
9 - acc: 0.2976
Epoch 3/10
84/84 [==============================] - 0s 271us/step - loss: 3.030
7 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 277us/step - loss: 2.903
2 - acc: 0.5595
Epoch 5/10
84/84 [==============================] - 0s 305us/step - loss: 2.800
7 - acc: 0.6429
Epoch 6/10
84/84 [==============================] - 0s 292us/step - loss: 2.713
6 - acc: 0.6190
Epoch 7/10
84/84 [==============================] - 0s 315us/step - loss: 2.640
5 - acc: 0.6548
Epoch 8/10
84/84 [==============================] - 0s 290us/step - loss: 2.565
2 - acc: 0.6667
Epoch 9/10
84/84 [==============================] - 0s 298us/step - loss: 2.492
6 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 293us/step - loss: 2.421
7 - acc: 0.6429
28/28 [==============================] - 8s 303ms/step
84/84 [==============================] - 0s 254us/step
Epoch 1/10
84/84 [==============================] - 20s 234ms/step - loss: 5.17
95 - acc: 0.6786
Epoch 2/10
84/84 [==============================] - 0s 274us/step - loss: 4.881
7 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 272us/step - loss: 4.643
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4 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 251us/step - loss: 4.454
7 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 263us/step - loss: 4.301
5 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 264us/step - loss: 4.197
4 - acc: 0.7381
Epoch 7/10
84/84 [==============================] - 0s 280us/step - loss: 4.121
2 - acc: 0.7500
Epoch 8/10
84/84 [==============================] - 0s 259us/step - loss: 4.041
5 - acc: 0.7262
Epoch 9/10
84/84 [==============================] - 0s 263us/step - loss: 3.949
9 - acc: 0.7262
Epoch 10/10
84/84 [==============================] - 0s 246us/step - loss: 3.853
8 - acc: 0.8810
28/28 [==============================] - 9s 313ms/step
84/84 [==============================] - 0s 261us/step
Epoch 1/10
84/84 [==============================] - 20s 233ms/step - loss: 5.70
33 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 267us/step - loss: 5.452
7 - acc: 0.4643
Epoch 3/10
84/84 [==============================] - 0s 258us/step - loss: 5.256
2 - acc: 0.3452
Epoch 4/10
84/84 [==============================] - 0s 243us/step - loss: 5.083
9 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 258us/step - loss: 4.903
9 - acc: 0.3333
Epoch 6/10
84/84 [==============================] - 0s 245us/step - loss: 4.750
1 - acc: 0.3333
Epoch 7/10
84/84 [==============================] - 0s 245us/step - loss: 4.615
2 - acc: 0.3333
Epoch 8/10
84/84 [==============================] - 0s 252us/step - loss: 4.489
1 - acc: 0.3333
Epoch 9/10
84/84 [==============================] - 0s 267us/step - loss: 4.371
8 - acc: 0.4286
Epoch 10/10
84/84 [==============================] - 0s 248us/step - loss: 4.257
1 - acc: 0.6429
28/28 [==============================] - 9s 307ms/step
84/84 [==============================] - 0s 261us/step
Epoch 1/10
84/84 [==============================] - 20s 242ms/step - loss: 5.15
37 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 251us/step - loss: 4.999
```

```
9 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 265us/step - loss: 4.869
3 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 262us/step - loss: 4.749
8 - acc: 0.1905
Epoch 5/10
84/84 [==============================] - 0s 259us/step - loss: 4.635
3 - acc: 0.1190
Epoch 6/10
84/84 [==============================] - 0s 258us/step - loss: 4.531
1 - acc: 0.0952
Epoch 7/10
84/84 [==============================] - 0s 248us/step - loss: 4.427
9 - acc: 0.3452
Epoch 8/10
84/84 [==============================] - 0s 253us/step - loss: 4.323
2 - acc: 0.4643
Epoch 9/10
84/84 [==============================] - 0s 250us/step - loss: 4.221
7 - acc: 0.4405
Epoch 10/10
84/84 [==============================] - 0s 281us/step - loss: 4.124
4 - acc: 0.3929
28/28 [==============================] - 9s 313ms/step
84/84 [==============================] - 0s 273us/step
Epoch 1/10
84/84 [==============================] - 20s 239ms/step - loss: 5.69
42 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 266us/step - loss: 5.413
1 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 250us/step - loss: 5.197
0 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 248us/step - loss: 4.996
1 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 250us/step - loss: 4.835
8 - acc: 0.3333
Epoch 6/10
84/84 [==============================] - 0s 252us/step - loss: 4.688
7 - acc: 0.3333
Epoch 7/10
84/84 [==============================] - 0s 265us/step - loss: 4.569
1 - acc: 0.3333
Epoch 8/10
84/84 [==============================] - 0s 280us/step - loss: 4.459
8 - acc: 0.3333
Epoch 9/10
84/84 [==============================] - 0s 253us/step - loss: 4.356
0 - acc: 0.3333
Epoch 10/10
84/84 [==============================] - 0s 251us/step - loss: 4.253
8 - acc: 0.3333
28/28 [==============================] - 9s 310ms/step
84/84 [==============================] - 0s 260us/step
Epoch 1/10
84/84 [==============================] - 20s 237ms/step - loss: 5.38
```

```
69 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 272us/step - loss: 5.059
3 - acc: 0.3452
Epoch 3/10
84/84 [==============================] - 0s 242us/step - loss: 4.781
6 - acc: 0.3690
Epoch 4/10
84/84 [==============================] - 0s 269us/step - loss: 4.548
6 - acc: 0.5952
Epoch 5/10
84/84 [==============================] - 0s 276us/step - loss: 4.366
0 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 249us/step - loss: 4.216
6 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 269us/step - loss: 4.087
3 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 282us/step - loss: 3.975
4 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 267us/step - loss: 3.885
5 - acc: 0.7143
Epoch 10/10
84/84 [==============================] - 0s 259us/step - loss: 3.801
8 - acc: 0.8690
28/28 [==============================] - 9s 319ms/step
84/84 [==============================] - 0s 280us/step
Epoch 1/10
84/84 [==============================] - 20s 244ms/step - loss: 1.28
80 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 243us/step - loss: 1.046
9 - acc: 0.4881
Epoch 3/10
84/84 [==============================] - 0s 247us/step - loss: 0.940
8 - acc: 0.7857
Epoch 4/10
84/84 [==============================] - 0s 264us/step - loss: 0.886
8 - acc: 0.7143
Epoch 5/10
84/84 [==============================] - 0s 244us/step - loss: 0.859
8 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 250us/step - loss: 0.821
3 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 244us/step - loss: 0.777
3 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 249us/step - loss: 0.739
6 - acc: 0.8333
Epoch 9/10
84/84 [==============================] - 0s 246us/step - loss: 0.714
1 - acc: 0.9524
Epoch 10/10
84/84 [==============================] - 0s 256us/step - loss: 0.685
5 - acc: 0.9762
28/28 [==============================] - 9s 314ms/step
```

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84/84 [==============================] - 0s 261us/step
Epoch 1/10
84/84 [==============================] - 20s 239ms/step - loss: 1.52
76 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 276us/step - loss: 1.243
5 - acc: 0.3214
Epoch 3/10
84/84 [==============================] - 0s 240us/step - loss: 1.084
6 - acc: 0.5000
Epoch 4/10
84/84 [==============================] - 0s 245us/step - loss: 1.006
5 - acc: 0.5833
Epoch 5/10
84/84 [==============================] - 0s 263us/step - loss: 0.976
5 - acc: 0.5833
Epoch 6/10
84/84 [==============================] - 0s 245us/step - loss: 0.955
7 - acc: 0.6190
Epoch 7/10
84/84 [==============================] - 0s 236us/step - loss: 0.921
2 - acc: 0.6548
Epoch 8/10
84/84 [==============================] - 0s 259us/step - loss: 0.878
0 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 251us/step - loss: 0.837
3 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 280us/step - loss: 0.800
1 - acc: 0.6786
28/28 [==============================] - 9s 316ms/step
84/84 [==============================] - 0s 253us/step
Epoch 1/10
84/84 [==============================] - 21s 252ms/step - loss: 1.18
10 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 332us/step - loss: 1.097
1 - acc: 0.4405
Epoch 3/10
84/84 [==============================] - 0s 290us/step - loss: 1.028
1 - acc: 0.5000
Epoch 4/10
84/84 [==============================] - 0s 294us/step - loss: 0.956
4 - acc: 0.5238
Epoch 5/10
84/84 [==============================] - 0s 285us/step - loss: 0.896
9 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 281us/step - loss: 0.842
4 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 282us/step - loss: 0.791
2 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 287us/step - loss: 0.742
4 - acc: 0.7143
Epoch 9/10
84/84 [==============================] - 0s 300us/step - loss: 0.701
5 - acc: 0.8333
Epoch 10/10
```

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84/84 [==============================] - 0s 275us/step - loss: 0.658
7 - acc: 0.8929
28/28 [==============================] - 9s 333ms/step
84/84 [==============================] - 0s 258us/step
Epoch 1/10
84/84 [==============================] - 20s 241ms/step - loss: 1.04
14 - acc: 0.4048
Epoch 2/10
84/84 [==============================] - 0s 292us/step - loss: 0.960
6 - acc: 0.8929
Epoch 3/10
84/84 [==============================] - 0s 257us/step - loss: 0.883
2 - acc: 0.7381
Epoch 4/10
84/84 [==============================] - 0s 263us/step - loss: 0.827
8 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 253us/step - loss: 0.776
3 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 251us/step - loss: 0.723
8 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 243us/step - loss: 0.674
1 - acc: 0.6905
Epoch 8/10
84/84 [==============================] - 0s 257us/step - loss: 0.633
5 - acc: 0.8214
Epoch 9/10
84/84 [==============================] - 0s 248us/step - loss: 0.596
2 - acc: 0.9524
Epoch 10/10
84/84 [==============================] - 0s 253us/step - loss: 0.562
3 - acc: 0.9881
28/28 [==============================] - 9s 320ms/step
84/84 [==============================] - 0s 252us/step
Epoch 1/10
84/84 [==============================] - 20s 241ms/step - loss: 1.61
21 - acc: 0.1071
Epoch 2/10
84/84 [==============================] - 0s 288us/step - loss: 1.360
3 - acc: 0.1548
Epoch 3/10
84/84 [==============================] - 0s 247us/step - loss: 1.152
2 - acc: 0.0833
Epoch 4/10
84/84 [==============================] - 0s 281us/step - loss: 1.083
1 - acc: 0.3095
Epoch 5/10
84/84 [==============================] - 0s 244us/step - loss: 1.054
9 - acc: 0.3333
Epoch 6/10
84/84 [==============================] - 0s 264us/step - loss: 1.007
8 - acc: 0.3333
Epoch 7/10
84/84 [==============================] - 0s 246us/step - loss: 0.949
5 - acc: 0.3929
Epoch 8/10
84/84 [==============================] - 0s 246us/step - loss: 0.902
7 - acc: 0.6667
Epoch 9/10
```

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84/84 [==============================] - 0s 246us/step - loss: 0.854
5 - acc: 0.8810
Epoch 10/10
84/84 [==============================] - 0s 248us/step - loss: 0.815
5 - acc: 0.9762
28/28 [==============================] - 9s 324ms/step
84/84 [==============================] - 0s 246us/step
Epoch 1/10
84/84 [==============================] - 21s 253ms/step - loss: 1.92
11 - acc: 0.6786
Epoch 2/10
84/84 [==============================] - 0s 273us/step - loss: 1.711
1 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 245us/step - loss: 1.560
8 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 248us/step - loss: 1.454
2 - acc: 0.6905
Epoch 5/10
84/84 [==============================] - 0s 258us/step - loss: 1.375
1 - acc: 0.8095
Epoch 6/10
84/84 [==============================] - 0s 242us/step - loss: 1.311
4 - acc: 0.8333
Epoch 7/10
84/84 [==============================] - 0s 248us/step - loss: 1.254
8 - acc: 0.8333
Epoch 8/10
84/84 [==============================] - 0s 250us/step - loss: 1.203
8 - acc: 0.8452
Epoch 9/10
84/84 [==============================] - 0s 255us/step - loss: 1.157
6 - acc: 0.8333
Epoch 10/10
84/84 [==============================] - 0s 266us/step - loss: 1.113
0 - acc: 0.8690
28/28 [==============================] - 9s 321ms/step
84/84 [==============================] - 0s 287us/step
Epoch 1/10
84/84 [==============================] - 21s 245ms/step - loss: 2.26
71 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 270us/step - loss: 1.861
3 - acc: 0.4524
Epoch 3/10
84/84 [==============================] - 0s 251us/step - loss: 1.650
9 - acc: 0.5952
Epoch 4/10
84/84 [==============================] - 0s 260us/step - loss: 1.602
3 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 271us/step - loss: 1.566
1 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 249us/step - loss: 1.491
5 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 257us/step - loss: 1.390
3 - acc: 0.6786
Epoch 8/10
```

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84/84 [==============================] - 0s 272us/step - loss: 1.317
4 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 243us/step - loss: 1.275
3 - acc: 0.8095
Epoch 10/10
84/84 [==============================] - 0s 246us/step - loss: 1.236
1 - acc: 0.7024
28/28 [==============================] - 9s 324ms/step
84/84 [==============================] - 0s 266us/step
Epoch 1/10
84/84 [==============================] - 21s 246ms/step - loss: 1.67
29 - acc: 0.6786
Epoch 2/10
84/84 [==============================] - 0s 255us/step - loss: 1.534
0 - acc: 0.7381
Epoch 3/10
84/84 [==============================] - 0s 244us/step - loss: 1.474
0 - acc: 0.5595
Epoch 4/10
84/84 [==============================] - 0s 263us/step - loss: 1.396
4 - acc: 0.7976
Epoch 5/10
84/84 [==============================] - 0s 266us/step - loss: 1.333
2 - acc: 0.7738
Epoch 6/10
84/84 [==============================] - 0s 249us/step - loss: 1.260
8 - acc: 0.7619
Epoch 7/10
84/84 [==============================] - 0s 251us/step - loss: 1.201
4 - acc: 0.8452
Epoch 8/10
84/84 [==============================] - 0s 265us/step - loss: 1.160
9 - acc: 0.9405
Epoch 9/10
84/84 [==============================] - 0s 259us/step - loss: 1.117
4 - acc: 0.9643
Epoch 10/10
84/84 [==============================] - 0s 252us/step - loss: 1.071
8 - acc: 0.9286
28/28 [==============================] - 9s 339ms/step
84/84 [==============================] - 0s 292us/step
Epoch 1/10
84/84 [==============================] - 21s 255ms/step - loss: 1.86
20 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 294us/step - loss: 1.667
2 - acc: 0.4167
Epoch 3/10
84/84 [==============================] - 0s 253us/step - loss: 1.604
4 - acc: 0.5238
Epoch 4/10
84/84 [==============================] - 0s 267us/step - loss: 1.537
2 - acc: 0.6548
Epoch 5/10
84/84 [==============================] - 0s 294us/step - loss: 1.465
4 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 279us/step - loss: 1.393
4 - acc: 0.7500
Epoch 7/10
```

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84/84 [==============================] - 0s 254us/step - loss: 1.335
2 - acc: 0.8214
Epoch 8/10
84/84 [==============================] - 0s 274us/step - loss: 1.280
9 - acc: 0.9167
Epoch 9/10
84/84 [==============================] - 0s 262us/step - loss: 1.230
0 - acc: 0.8571
Epoch 10/10
84/84 [==============================] - 0s 267us/step - loss: 1.178
0 - acc: 0.8095
28/28 [==============================] - 9s 330ms/step
84/84 [==============================] - 0s 343us/step
Epoch 1/10
84/84 [==============================] - 21s 250ms/step - loss: 1.83
55 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 250us/step - loss: 1.669
8 - acc: 0.5714
Epoch 3/10
84/84 [==============================] - 0s 251us/step - loss: 1.582
5 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 257us/step - loss: 1.520
7 - acc: 0.6667
Epoch 5/10
84/84 [==============================] - 0s 248us/step - loss: 1.462
4 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 253us/step - loss: 1.407
7 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 264us/step - loss: 1.357
8 - acc: 0.9286
Epoch 8/10
84/84 [==============================] - 0s 262us/step - loss: 1.304
0 - acc: 0.9643
Epoch 9/10
84/84 [==============================] - 0s 285us/step - loss: 1.257
2 - acc: 0.8452
Epoch 10/10
84/84 [==============================] - 0s 286us/step - loss: 1.208
1 - acc: 0.8214
28/28 [==============================] - 9s 331ms/step
84/84 [==============================] - 0s 275us/step
Epoch 1/10
84/84 [==============================] - 22s 258ms/step - loss: 4.77
74 - acc: 0.3810
Epoch 2/10
84/84 [==============================] - 0s 293us/step - loss: 4.482
2 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 303us/step - loss: 4.293
2 - acc: 0.3690
Epoch 4/10
84/84 [==============================] - 0s 290us/step - loss: 4.140
1 - acc: 0.4762
Epoch 5/10
84/84 [==============================] - 0s 291us/step - loss: 3.999
3 - acc: 0.5595
Epoch 6/10
```

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84/84 [==============================] - 0s 288us/step - loss: 3.848
6 - acc: 0.7619
Epoch 7/10
84/84 [==============================] - 0s 308us/step - loss: 3.695
9 - acc: 0.8214
Epoch 8/10
84/84 [==============================] - 0s 302us/step - loss: 3.562
6 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 290us/step - loss: 3.445
0 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 320us/step - loss: 3.336
8 - acc: 0.6786
28/28 [==============================] - 9s 334ms/step
84/84 [==============================] - 0s 260us/step
Epoch 1/10
84/84 [==============================] - 21s 253ms/step - loss: 5.01
14 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 266us/step - loss: 4.608
5 - acc: 0.3452
Epoch 3/10
84/84 [==============================] - 0s 259us/step - loss: 4.334
1 - acc: 0.4762
Epoch 4/10
84/84 [==============================] - 0s 267us/step - loss: 4.146
8 - acc: 0.7024
Epoch 5/10
84/84 [==============================] - 0s 251us/step - loss: 3.995
9 - acc: 0.9405
Epoch 6/10
84/84 [==============================] - 0s 267us/step - loss: 3.850
4 - acc: 0.8929
Epoch 7/10
84/84 [==============================] - 0s 336us/step - loss: 3.726
0 - acc: 0.7262
Epoch 8/10
84/84 [==============================] - 0s 312us/step - loss: 3.599
7 - acc: 0.6905
Epoch 9/10
84/84 [==============================] - 0s 278us/step - loss: 3.482
4 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 280us/step - loss: 3.366
3 - acc: 0.6786
28/28 [==============================] - 9s 334ms/step
84/84 [==============================] - 0s 296us/step
Epoch 1/10
84/84 [==============================] - 22s 264ms/step - loss: 4.76
26 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 256us/step - loss: 4.489
3 - acc: 0.6667
Epoch 3/10
84/84 [==============================] - 0s 279us/step - loss: 4.313
0 - acc: 0.6548
Epoch 4/10
84/84 [==============================] - 0s 244us/step - loss: 4.139
9 - acc: 0.6667
Epoch 5/10
```

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84/84 [==============================] - 0s 236us/step - loss: 3.984
2 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 247us/step - loss: 3.836
4 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 275us/step - loss: 3.696
0 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 268us/step - loss: 3.563
5 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 265us/step - loss: 3.435
1 - acc: 0.6905
Epoch 10/10
84/84 [==============================] - 0s 257us/step - loss: 3.312
0 - acc: 0.7262
28/28 [==============================] - 10s 340ms/step
84/84 [==============================] - 0s 297us/step
Epoch 1/10
84/84 [==============================] - 22s 263ms/step - loss: 4.83
55 - acc: 0.0833
Epoch 2/10
84/84 [==============================] - 0s 279us/step - loss: 4.563
3 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 248us/step - loss: 4.377
2 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 278us/step - loss: 4.204
4 - acc: 0.4286
Epoch 5/10
84/84 [==============================] - 0s 253us/step - loss: 4.035
1 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 269us/step - loss: 3.869
9 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 270us/step - loss: 3.724
3 - acc: 0.7024
Epoch 8/10
84/84 [==============================] - 0s 266us/step - loss: 3.602
6 - acc: 0.7619
Epoch 9/10
84/84 [==============================] - 0s 248us/step - loss: 3.485
0 - acc: 0.7857
Epoch 10/10
84/84 [==============================] - 0s 270us/step - loss: 3.365
0 - acc: 0.8095
28/28 [==============================] - 9s 339ms/step
84/84 [==============================] - 0s 319us/step
Epoch 1/10
84/84 [==============================] - 22s 258ms/step - loss: 5.66
98 - acc: 0.3452
Epoch 2/10
84/84 [==============================] - 0s 282us/step - loss: 4.992
9 - acc: 0.3452
Epoch 3/10
84/84 [==============================] - 0s 286us/step - loss: 4.515
7 - acc: 0.3452
Epoch 4/10
```

```
84/84 [==============================] - 0s 281us/step - loss: 4.209
2 - acc: 0.5833
Epoch 5/10
84/84 [==============================] - 0s 268us/step - loss: 3.994
6 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 268us/step - loss: 3.841
7 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 254us/step - loss: 3.715
8 - acc: 0.6905
Epoch 8/10
84/84 [==============================] - 0s 247us/step - loss: 3.599
4 - acc: 0.7976
Epoch 9/10
84/84 [==============================] - 0s 279us/step - loss: 3.488
6 - acc: 0.9048
Epoch 10/10
84/84 [==============================] - 0s 265us/step - loss: 3.376
3 - acc: 0.9524
28/28 [==============================] - 10s 340ms/step
84/84 [==============================] - 0s 287us/step
Epoch 1/10
84/84 [==============================] - 22s 265ms/step - loss: 8.54
20 - acc: 0.4643
Epoch 2/10
84/84 [==============================] - 0s 290us/step - loss: 8.097
5 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 291us/step - loss: 7.730
9 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 314us/step - loss: 7.423
3 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 307us/step - loss: 7.163
5 - acc: 0.6071
Epoch 6/10
84/84 [==============================] - 0s 312us/step - loss: 6.912
1 - acc: 0.6667
Epoch 7/10
84/84 [==============================] - 0s 285us/step - loss: 6.667
5 - acc: 0.6667
Epoch 8/10
84/84 [==============================] - 0s 313us/step - loss: 6.428
3 - acc: 0.6667
Epoch 9/10
84/84 [==============================] - 0s 314us/step - loss: 6.200
7 - acc: 0.6905
Epoch 10/10
84/84 [==============================] - 0s 372us/step - loss: 5.981
7 - acc: 0.7024
28/28 [==============================] - 10s 348ms/step
84/84 [==============================] - 0s 274us/step
Epoch 1/10
84/84 [==============================] - 22s 260ms/step - loss: 7.99
22 - acc: 0.5119
Epoch 2/10
84/84 [==============================] - 0s 264us/step - loss: 7.681
3 - acc: 0.6071
Epoch 3/10
```

```
84/84 [==============================] - 0s 264us/step - loss: 7.407
5 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 257us/step - loss: 7.140
2 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 260us/step - loss: 6.887
4 - acc: 0.6905
Epoch 6/10
84/84 [==============================] - 0s 248us/step - loss: 6.638
9 - acc: 0.8571
Epoch 7/10
84/84 [==============================] - 0s 266us/step - loss: 6.404
4 - acc: 0.8214
Epoch 8/10
84/84 [==============================] - 0s 262us/step - loss: 6.174
9 - acc: 0.6905
Epoch 9/10
84/84 [==============================] - 0s 263us/step - loss: 5.959
8 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 254us/step - loss: 5.743
9 - acc: 0.6786
28/28 [==============================] - 10s 344ms/step
84/84 [==============================] - 0s 255us/step
Epoch 1/10
84/84 [==============================] - 22s 263ms/step - loss: 8.08
72 - acc: 0.3929
Epoch 2/10
84/84 [==============================] - 0s 339us/step - loss: 7.763
9 - acc: 0.5833
Epoch 3/10
84/84 [==============================] - 0s 291us/step - loss: 7.484
9 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 328us/step - loss: 7.224
0 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 302us/step - loss: 6.968
0 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 313us/step - loss: 6.710
7 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 325us/step - loss: 6.466
0 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 307us/step - loss: 6.228
9 - acc: 0.6786
Epoch 9/10
84/84 [==============================] - 0s 317us/step - loss: 6.001
7 - acc: 0.6786
Epoch 10/10
84/84 [==============================] - 0s 340us/step - loss: 5.785
6 - acc: 0.6786
28/28 [==============================] - 10s 357ms/step
84/84 [==============================] - 0s 307us/step
Epoch 1/10
84/84 [==============================] - 23s 271ms/step - loss: 8.47
85 - acc: 0.3333
Epoch 2/10
```

```
84/84 [==============================] - 0s 280us/step - loss: 8.005
0 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 256us/step - loss: 7.714
1 - acc: 0.3810
Epoch 4/10
84/84 [==============================] - 0s 251us/step - loss: 7.471
0 - acc: 0.3810
Epoch 5/10
84/84 [==============================] - 0s 253us/step - loss: 7.212
2 - acc: 0.6071
Epoch 6/10
84/84 [==============================] - 0s 279us/step - loss: 6.960
4 - acc: 0.7500
Epoch 7/10
84/84 [==============================] - 0s 268us/step - loss: 6.718
6 - acc: 0.6905
Epoch 8/10
84/84 [==============================] - 0s 273us/step - loss: 6.489
5 - acc: 0.6667
Epoch 9/10
84/84 [==============================] - 0s 320us/step - loss: 6.269
7 - acc: 0.6667
Epoch 10/10
84/84 [==============================] - 0s 309us/step - loss: 6.055
5 - acc: 0.6786
28/28 [==============================] - 10s 349ms/step
84/84 [==============================] - 0s 274us/step
Epoch 1/10
84/84 [==============================] - 22s 265ms/step - loss: 8.65
00 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 274us/step - loss: 8.200
7 - acc: 0.3333
Epoch 3/10
84/84 [==============================] - 0s 263us/step - loss: 7.829
9 - acc: 0.3333
Epoch 4/10
84/84 [==============================] - 0s 262us/step - loss: 7.528
4 - acc: 0.3333
Epoch 5/10
84/84 [==============================] - 0s 256us/step - loss: 7.241
5 - acc: 0.5833
Epoch 6/10
84/84 [==============================] - 0s 253us/step - loss: 6.968
3 - acc: 0.6667
Epoch 7/10
84/84 [==============================] - 0s 256us/step - loss: 6.709
8 - acc: 0.6786
Epoch 8/10
84/84 [==============================] - 0s 271us/step - loss: 6.462
5 - acc: 0.7738
Epoch 9/10
84/84 [==============================] - 0s 248us/step - loss: 6.227
1 - acc: 0.6905
Epoch 10/10
84/84 [==============================] - 0s 274us/step - loss: 6.003
7 - acc: 0.6786
28/28 [==============================] - 10s 351ms/step
84/84 [==============================] - 0s 245us/step
Epoch 1/10
```

```
84/84 [==============================] - 23s 274ms/step - loss: 1.00
48 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 271us/step - loss: 0.821
8 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 256us/step - loss: 0.702
0 - acc: 0.6905
Epoch 4/10
84/84 [==============================] - 0s 248us/step - loss: 0.589
6 - acc: 0.9048
Epoch 5/10
84/84 [==============================] - 0s 250us/step - loss: 0.534
1 - acc: 0.7262
Epoch 6/10
84/84 [==============================] - 0s 270us/step - loss: 0.470
6 - acc: 0.8214
Epoch 7/10
84/84 [==============================] - 0s 249us/step - loss: 0.425
9 - acc: 0.9643
Epoch 8/10
84/84 [==============================] - 0s 259us/step - loss: 0.392
8 - acc: 0.9643
Epoch 9/10
84/84 [==============================] - 0s 256us/step - loss: 0.362
6 - acc: 0.9405
Epoch 10/10
84/84 [==============================] - 0s 284us/step - loss: 0.347
4 - acc: 0.9524
28/28 [==============================] - 10s 354ms/step
84/84 [==============================] - 0s 294us/step
Epoch 1/10
84/84 [==============================] - 22s 268ms/step - loss: 1.02
61 - acc: 0.4048
Epoch 2/10
84/84 [==============================] - 0s 253us/step - loss: 0.773
7 - acc: 0.7857
Epoch 3/10
84/84 [==============================] - 0s 249us/step - loss: 0.666
8 - acc: 0.8690
Epoch 4/10
84/84 [==============================] - 0s 259us/step - loss: 0.565
6 - acc: 0.9048
Epoch 5/10
84/84 [==============================] - 0s 267us/step - loss: 0.501
6 - acc: 0.7024
Epoch 6/10
84/84 [==============================] - 0s 275us/step - loss: 0.448
5 - acc: 0.8571
Epoch 7/10
84/84 [==============================] - 0s 274us/step - loss: 0.394
2 - acc: 0.9762
Epoch 8/10
84/84 [==============================] - 0s 269us/step - loss: 0.354
4 - acc: 0.9762
Epoch 9/10
84/84 [==============================] - 0s 253us/step - loss: 0.323
3 - acc: 0.9643
Epoch 10/10
84/84 [==============================] - 0s 253us/step - loss: 0.290
9 - acc: 0.9762
```

```
28/28 [==============================] - 10s 369ms/step
84/84 [==============================] - 0s 309us/step
Epoch 1/10
84/84 [==============================] - 23s 274ms/step - loss: 1.00
12 - acc: 0.5357
Epoch 2/10
84/84 [==============================] - 0s 268us/step - loss: 0.793
9 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 245us/step - loss: 0.680
9 - acc: 0.7976
Epoch 4/10
84/84 [==============================] - 0s 263us/step - loss: 0.587
1 - acc: 0.6905
Epoch 5/10
84/84 [==============================] - 0s 264us/step - loss: 0.512
8 - acc: 0.7143
Epoch 6/10
84/84 [==============================] - 0s 271us/step - loss: 0.451
4 - acc: 0.8571
Epoch 7/10
84/84 [==============================] - 0s 249us/step - loss: 0.410
3 - acc: 0.9643
Epoch 8/10
84/84 [==============================] - 0s 257us/step - loss: 0.363
6 - acc: 0.9762
Epoch 9/10
84/84 [==============================] - 0s 276us/step - loss: 0.348
7 - acc: 0.8333
Epoch 10/10
84/84 [==============================] - 0s 252us/step - loss: 0.316
3 - acc: 0.9167
28/28 [==============================] - 11s 378ms/step
84/84 [==============================] - 0s 312us/step
Epoch 1/10
84/84 [==============================] - 23s 273ms/step - loss: 1.02
33 - acc: 0.4048
Epoch 2/10
84/84 [==============================] - 0s 287us/step - loss: 0.813
7 - acc: 0.7976
Epoch 3/10
84/84 [==============================] - 0s 260us/step - loss: 0.667
7 - acc: 0.8095
Epoch 4/10
84/84 [==============================] - 0s 254us/step - loss: 0.565
0 - acc: 0.7262
Epoch 5/10
84/84 [==============================] - 0s 268us/step - loss: 0.478
9 - acc: 0.9643
Epoch 6/10
84/84 [==============================] - 0s 264us/step - loss: 0.418
3 - acc: 1.0000
Epoch 7/10
84/84 [==============================] - 0s 255us/step - loss: 0.389
4 - acc: 0.8929
Epoch 8/10
84/84 [==============================] - 0s 250us/step - loss: 0.328
2 - acc: 0.9643
Epoch 9/10
84/84 [==============================] - 0s 247us/step - loss: 0.316
0 - acc: 0.9762
```

```
Epoch 10/10
84/84 [==============================] - 0s 270us/step - loss: 0.292
1 - acc: 0.9524
28/28 [==============================] - 10s 359ms/step
84/84 [==============================] - 0s 373us/step
Epoch 1/10
84/84 [==============================] - 23s 273ms/step - loss: 1.08
07 - acc: 0.2738
Epoch 2/10
84/84 [==============================] - 0s 271us/step - loss: 0.854
6 - acc: 0.8810
Epoch 3/10
84/84 [==============================] - 0s 267us/step - loss: 0.751
0 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 257us/step - loss: 0.651
0 - acc: 0.7143
Epoch 5/10
84/84 [==============================] - 0s 281us/step - loss: 0.561
3 - acc: 0.9643
Epoch 6/10
84/84 [==============================] - 0s 264us/step - loss: 0.495
4 - acc: 0.9762
Epoch 7/10
84/84 [==============================] - 0s 269us/step - loss: 0.437
8 - acc: 0.8810
Epoch 8/10
84/84 [==============================] - 0s 269us/step - loss: 0.397
7 - acc: 0.9405
Epoch 9/10
84/84 [==============================] - 0s 266us/step - loss: 0.360
2 - acc: 0.9762
Epoch 10/10
84/84 [==============================] - 0s 265us/step - loss: 0.330
4 - acc: 0.9524
28/28 [==============================] - 10s 361ms/step
84/84 [==============================] - 0s 286us/step
Epoch 1/10
84/84 [==============================] - 24s 282ms/step - loss: 3.68
03 - acc: 0.2738
Epoch 2/10
84/84 [==============================] - 0s 316us/step - loss: 3.301
7 - acc: 0.6190
Epoch 3/10
84/84 [==============================] - 0s 296us/step - loss: 3.020
1 - acc: 0.7857
Epoch 4/10
84/84 [==============================] - 0s 266us/step - loss: 2.772
7 - acc: 0.7024
Epoch 5/10
84/84 [==============================] - 0s 253us/step - loss: 2.583
3 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 251us/step - loss: 2.388
8 - acc: 0.8929
Epoch 7/10
84/84 [==============================] - 0s 256us/step - loss: 2.248
2 - acc: 0.9643
Epoch 8/10
84/84 [==============================] - 0s 263us/step - loss: 2.106
2 - acc: 0.9524
```

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Epoch 9/10
84/84 [==============================] - 0s 265us/step - loss: 1.971
1 - acc: 0.9167
Epoch 10/10
84/84 [==============================] - 0s 261us/step - loss: 1.855
5 - acc: 0.9167
28/28 [==============================] - 10s 362ms/step
84/84 [==============================] - 0s 273us/step
Epoch 1/10
84/84 [==============================] - 23s 275ms/step - loss: 3.64
01 - acc: 0.4405
Epoch 2/10
84/84 [==============================] - 0s 257us/step - loss: 3.312
3 - acc: 0.6071
Epoch 3/10
84/84 [==============================] - 0s 246us/step - loss: 3.005
2 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 261us/step - loss: 2.790
2 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 265us/step - loss: 2.576
8 - acc: 0.8333
Epoch 6/10
84/84 [==============================] - 0s 270us/step - loss: 2.395
6 - acc: 0.9524
Epoch 7/10
84/84 [==============================] - 0s 291us/step - loss: 2.221
9 - acc: 0.8810
Epoch 8/10
84/84 [==============================] - 0s 280us/step - loss: 2.086
7 - acc: 0.8333
Epoch 9/10
84/84 [==============================] - 0s 266us/step - loss: 1.941
6 - acc: 0.9524
Epoch 10/10
84/84 [==============================] - 0s 260us/step - loss: 1.825
6 - acc: 0.9643
28/28 [==============================] - 11s 381ms/step
84/84 [==============================] - 0s 290us/step
Epoch 1/10
84/84 [==============================] - 24s 283ms/step - loss: 3.69
03 - acc: 0.2738
Epoch 2/10
84/84 [==============================] - 0s 342us/step - loss: 3.314
1 - acc: 0.5595
Epoch 3/10
84/84 [==============================] - 0s 332us/step - loss: 3.022
5 - acc: 0.7500
Epoch 4/10
84/84 [==============================] - 0s 307us/step - loss: 2.823
0 - acc: 0.7619
Epoch 5/10
84/84 [==============================] - 0s 295us/step - loss: 2.580
9 - acc: 0.7857
Epoch 6/10
84/84 [==============================] - 0s 317us/step - loss: 2.429
1 - acc: 0.8810
Epoch 7/10
84/84 [==============================] - 0s 291us/step - loss: 2.245
1 - acc: 0.9405
```

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Epoch 8/10
84/84 [==============================] - 0s 322us/step - loss: 2.138
0 - acc: 0.7024
Epoch 9/10
84/84 [==============================] - 0s 343us/step - loss: 1.986
1 - acc: 0.9048
Epoch 10/10
84/84 [==============================] - 0s 342us/step - loss: 1.897
0 - acc: 0.8929
28/28 [==============================] - 11s 377ms/step
84/84 [==============================] - 0s 278us/step
Epoch 1/10
84/84 [==============================] - 23s 279ms/step - loss: 3.63
53 - acc: 0.3690
Epoch 2/10
84/84 [==============================] - 0s 294us/step - loss: 3.282
4 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 264us/step - loss: 3.007
4 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 273us/step - loss: 2.802
8 - acc: 0.8333
Epoch 5/10
84/84 [==============================] - 0s 282us/step - loss: 2.558
7 - acc: 0.9048
Epoch 6/10
84/84 [==============================] - 0s 273us/step - loss: 2.403
7 - acc: 0.7024
Epoch 7/10
84/84 [==============================] - 0s 261us/step - loss: 2.239
9 - acc: 0.7619
Epoch 8/10
84/84 [==============================] - 0s 264us/step - loss: 2.081
6 - acc: 0.9643
Epoch 9/10
84/84 [==============================] - 0s 311us/step - loss: 1.952
9 - acc: 0.9286
Epoch 10/10
84/84 [==============================] - 0s 285us/step - loss: 1.832
3 - acc: 0.8929
28/28 [==============================] - 10s 373ms/step
84/84 [==============================] - 0s 279us/step
Epoch 1/10
84/84 [==============================] - 24s 280ms/step - loss: 3.74
52 - acc: 0.3095
Epoch 2/10
84/84 [==============================] - 0s 281us/step - loss: 3.379
4 - acc: 0.3929
Epoch 3/10
84/84 [==============================] - 0s 258us/step - loss: 3.089
1 - acc: 0.7381
Epoch 4/10
84/84 [==============================] - 0s 268us/step - loss: 2.860
4 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 255us/step - loss: 2.628
7 - acc: 0.8095
Epoch 6/10
84/84 [==============================] - 0s 275us/step - loss: 2.459
4 - acc: 0.8095
```

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Epoch 7/10
84/84 [==============================] - 0s 273us/step - loss: 2.277
2 - acc: 0.9643
Epoch 8/10
84/84 [==============================] - 0s 306us/step - loss: 2.144
2 - acc: 0.7738
Epoch 9/10
84/84 [==============================] - 0s 258us/step - loss: 2.004
5 - acc: 0.8571
Epoch 10/10
84/84 [==============================] - 0s 261us/step - loss: 1.888
5 - acc: 0.9881
28/28 [==============================] - 11s 391ms/step
84/84 [==============================] - 0s 313us/step
Epoch 1/10
84/84 [==============================] - 24s 284ms/step - loss: 13.9
387 - acc: 0.5952
Epoch 2/10
84/84 [==============================] - 0s 273us/step - loss: 12.85
41 - acc: 0.6786
Epoch 3/10
84/84 [==============================] - 0s 270us/step - loss: 11.89
92 - acc: 0.6786
Epoch 4/10
84/84 [==============================] - 0s 277us/step - loss: 10.98
11 - acc: 0.8929
Epoch 5/10
84/84 [==============================] - 0s 267us/step - loss: 10.15
67 - acc: 0.9524
Epoch 6/10
84/84 [==============================] - 0s 291us/step - loss: 9.379
5 - acc: 0.8690
Epoch 7/10
84/84 [==============================] - 0s 267us/step - loss: 8.660
1 - acc: 0.7857
Epoch 8/10
84/84 [==============================] - 0s 273us/step - loss: 7.986
0 - acc: 0.9048
Epoch 9/10
84/84 [==============================] - 0s 284us/step - loss: 7.360
3 - acc: 0.9405
Epoch 10/10
84/84 [==============================] - 0s 284us/step - loss: 6.784
0 - acc: 0.9286
28/28 [==============================] - 11s 391ms/step
84/84 [==============================] - 0s 328us/step
Epoch 1/10
84/84 [==============================] - 24s 288ms/step - loss: 13.9
875 - acc: 0.3214
Epoch 2/10
84/84 [==============================] - 0s 273us/step - loss: 12.89
02 - acc: 0.5595
Epoch 3/10
84/84 [==============================] - 0s 284us/step - loss: 11.90
21 - acc: 0.8452
Epoch 4/10
84/84 [==============================] - 0s 266us/step - loss: 10.99
43 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 272us/step - loss: 10.14
60 - acc: 0.6786
```

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Epoch 6/10
84/84 [==============================] - 0s 274us/step - loss: 9.348
9 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 265us/step - loss: 8.613
6 - acc: 0.7143
Epoch 8/10
84/84 [==============================] - 0s 285us/step - loss: 7.929
9 - acc: 0.7619
Epoch 9/10
84/84 [==============================] - 0s 276us/step - loss: 7.292
0 - acc: 0.8929
Epoch 10/10
84/84 [==============================] - 0s 273us/step - loss: 6.706
9 - acc: 0.9643
28/28 [==============================] - 11s 379ms/step
84/84 [==============================] - 0s 297us/step
Epoch 1/10
84/84 [==============================] - 25s 293ms/step - loss: 14.0
356 - acc: 0.5476
Epoch 2/10
84/84 [==============================] - 0s 304us/step - loss: 12.94
14 - acc: 0.4881
Epoch 3/10
84/84 [==============================] - 0s 289us/step - loss: 11.95
34 - acc: 0.9524
Epoch 4/10
84/84 [==============================] - 0s 280us/step - loss: 11.05
03 - acc: 0.8810
Epoch 5/10
84/84 [==============================] - 0s 273us/step - loss: 10.21
90 - acc: 0.8214
Epoch 6/10
84/84 [==============================] - 0s 262us/step - loss: 9.430
1 - acc: 0.7381
Epoch 7/10
84/84 [==============================] - 0s 276us/step - loss: 8.707
8 - acc: 0.7500
Epoch 8/10
84/84 [==============================] - 0s 274us/step - loss: 8.034
3 - acc: 0.8452
Epoch 9/10
84/84 [==============================] - 0s 285us/step - loss: 7.417
3 - acc: 0.7857
Epoch 10/10
84/84 [==============================] - 0s 282us/step - loss: 6.827
0 - acc: 0.8333
28/28 [==============================] - 11s 380ms/step
84/84 [==============================] - 0s 306us/step
Epoch 1/10
84/84 [==============================] - 24s 286ms/step - loss: 13.9
820 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 270us/step - loss: 12.90
74 - acc: 0.5952
Epoch 3/10
84/84 [==============================] - 0s 282us/step - loss: 11.93
62 - acc: 0.6905
Epoch 4/10
84/84 [==============================] - 0s 262us/step - loss: 11.02
53 - acc: 0.7262
```

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Epoch 5/10
84/84 [==============================] - 0s 267us/step - loss: 10.18
97 - acc: 0.9405
Epoch 6/10
84/84 [==============================] - 0s 274us/step - loss: 9.389
9 - acc: 0.9167
Epoch 7/10
84/84 [==============================] - 0s 270us/step - loss: 8.668
2 - acc: 0.6905
Epoch 8/10
84/84 [==============================] - 0s 271us/step - loss: 7.984
4 - acc: 0.7738
Epoch 9/10
84/84 [==============================] - 0s 271us/step - loss: 7.365
3 - acc: 0.9643
Epoch 10/10
84/84 [==============================] - 0s 273us/step - loss: 6.770
1 - acc: 0.9762
28/28 [==============================] - 11s 382ms/step
84/84 [==============================] - 0s 306us/step
Epoch 1/10
84/84 [==============================] - 25s 296ms/step - loss: 14.0
000 - acc: 0.2143
Epoch 2/10
84/84 [==============================] - 0s 276us/step - loss: 12.90
40 - acc: 0.7262
Epoch 3/10
84/84 [==============================] - 0s 279us/step - loss: 11.94
58 - acc: 0.9524
Epoch 4/10
84/84 [==============================] - 0s 280us/step - loss: 11.04
03 - acc: 0.7738
Epoch 5/10
84/84 [==============================] - 0s 276us/step - loss: 10.19
52 - acc: 0.6905
Epoch 6/10
84/84 [==============================] - 0s 276us/step - loss: 9.412
0 - acc: 0.8810
Epoch 7/10
84/84 [==============================] - 0s 327us/step - loss: 8.674
3 - acc: 0.9762
Epoch 8/10
84/84 [==============================] - 0s 318us/step - loss: 7.991
0 - acc: 0.8571
Epoch 9/10
84/84 [==============================] - 0s 276us/step - loss: 7.365
6 - acc: 0.8333
Epoch 10/10
84/84 [==============================] - 0s 275us/step - loss: 6.794
0 - acc: 0.9048
28/28 [==============================] - 11s 386ms/step
84/84 [==============================] - 0s 279us/step
Epoch 1/10
84/84 [==============================] - 25s 294ms/step - loss: 26.7
891 - acc: 0.3333
Epoch 2/10
84/84 [==============================] - 0s 307us/step - loss: 24.67
44 - acc: 0.6667
Epoch 3/10
84/84 [==============================] - 0s 283us/step - loss: 22.71
22 - acc: 0.7381
```

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Epoch 4/10
84/84 [==============================] - 0s 267us/step - loss: 20.88
93 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 262us/step - loss: 19.18
63 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 275us/step - loss: 17.59
99 - acc: 0.6786
Epoch 7/10
84/84 [==============================] - 0s 287us/step - loss: 16.12
68 - acc: 0.7738
Epoch 8/10
84/84 [==============================] - 0s 276us/step - loss: 14.76
88 - acc: 0.8810
Epoch 9/10
84/84 [==============================] - 0s 274us/step - loss: 13.51
15 - acc: 0.7024
Epoch 10/10
84/84 [==============================] - 0s 270us/step - loss: 12.34
57 - acc: 0.6905
28/28 [==============================] - 11s 386ms/step
84/84 [==============================] - 0s 288us/step
Epoch 1/10
84/84 [==============================] - 25s 294ms/step - loss: 26.9
749 - acc: 0.4286
Epoch 2/10
84/84 [==============================] - 0s 340us/step - loss: 24.89
61 - acc: 0.7976
Epoch 3/10
84/84 [==============================] - 0s 324us/step - loss: 22.95
60 - acc: 0.8810
Epoch 4/10
84/84 [==============================] - 0s 297us/step - loss: 21.14
63 - acc: 0.6905
Epoch 5/10
84/84 [==============================] - 0s 309us/step - loss: 19.45
31 - acc: 0.6905
Epoch 6/10
84/84 [==============================] - 0s 308us/step - loss: 17.86
68 - acc: 0.8214
Epoch 7/10
84/84 [==============================] - 0s 307us/step - loss: 16.38
90 - acc: 0.8810
Epoch 8/10
84/84 [==============================] - 0s 314us/step - loss: 15.02
22 - acc: 0.8571
Epoch 9/10
84/84 [==============================] - 0s 320us/step - loss: 13.75
22 - acc: 0.8214
Epoch 10/10
84/84 [==============================] - 0s 323us/step - loss: 12.58
93 - acc: 0.7619
28/28 [==============================] - 11s 398ms/step
84/84 [==============================] - 0s 278us/step
Epoch 1/10
84/84 [==============================] - 25s 293ms/step - loss: 26.8
597 - acc: 0.5476
Epoch 2/10
84/84 [==============================] - 0s 292us/step - loss: 24.76
91 - acc: 0.6786
```

```
Epoch 3/10
84/84 [==============================] - 0s 260us/step - loss: 22.84
47 - acc: 0.7143
Epoch 4/10
84/84 [==============================] - 0s 264us/step - loss: 21.04
91 - acc: 0.9405
Epoch 5/10
84/84 [==============================] - 0s 265us/step - loss: 19.36
34 - acc: 0.8929
Epoch 6/10
84/84 [==============================] - 0s 256us/step - loss: 17.79
07 - acc: 0.8452
Epoch 7/10
84/84 [==============================] - 0s 258us/step - loss: 16.32
97 - acc: 0.7976
Epoch 8/10
84/84 [==============================] - 0s 297us/step - loss: 14.96
99 - acc: 0.8214
Epoch 9/10
84/84 [==============================] - 0s 262us/step - loss: 13.70
88 - acc: 0.7976
Epoch 10/10
84/84 [==============================] - 0s 260us/step - loss: 12.53
97 - acc: 0.8214
28/28 [==============================] - 11s 393ms/step
84/84 [==============================] - 0s 284us/step
Epoch 1/10
84/84 [==============================] - 25s 295ms/step - loss: 26.7
798 - acc: 0.5714
Epoch 2/10
84/84 [==============================] - 0s 272us/step - loss: 24.70
64 - acc: 0.5476
Epoch 3/10
84/84 [==============================] - 0s 258us/step - loss: 22.80
58 - acc: 0.8571
Epoch 4/10
84/84 [==============================] - 0s 276us/step - loss: 21.00
78 - acc: 0.8095
Epoch 5/10
84/84 [==============================] - 0s 260us/step - loss: 19.34
55 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 290us/step - loss: 17.78
13 - acc: 0.7619
Epoch 7/10
84/84 [==============================] - 0s 271us/step - loss: 16.33
55 - acc: 0.9643
Epoch 8/10
84/84 [==============================] - 0s 281us/step - loss: 14.97
93 - acc: 0.9524
Epoch 9/10
84/84 [==============================] - 0s 267us/step - loss: 13.73
31 - acc: 0.7500
Epoch 10/10
84/84 [==============================] - 0s 285us/step - loss: 12.59
41 - acc: 0.7857
28/28 [==============================] - 12s 417ms/step
84/84 [==============================] - 0s 335us/step
Epoch 1/10
84/84 [==============================] - 26s 306ms/step - loss: 26.8
165 - acc: 0.5238
```

```
Epoch 2/10
84/84 [==============================] - 0s 346us/step - loss: 24.77
41 - acc: 0.6310
Epoch 3/10
84/84 [==============================] - 0s 310us/step - loss: 22.85
31 - acc: 0.7143
Epoch 4/10
84/84 [==============================] - 0s 324us/step - loss: 21.08
02 - acc: 0.6786
Epoch 5/10
84/84 [==============================] - 0s 320us/step - loss: 19.42
38 - acc: 0.6786
Epoch 6/10
84/84 [==============================] - 0s 320us/step - loss: 17.87
20 - acc: 0.7976
Epoch 7/10
84/84 [==============================] - 0s 300us/step - loss: 16.41
63 - acc: 0.9167
Epoch 8/10
84/84 [==============================] - 0s 281us/step - loss: 15.07
56 - acc: 0.7143
Epoch 9/10
84/84 [==============================] - 0s 303us/step - loss: 13.82
03 - acc: 0.7738
Epoch 10/10
84/84 [==============================] - 0s 328us/step - loss: 12.68
19 - acc: 0.9167
28/28 [==============================] - 11s 396ms/step
84/84 [==============================] - 0s 295us/step
Epoch 1/10
112/112 [==============================] - 25s 223ms/step - loss: 0.
9878 - acc: 0.4375
Epoch 2/10
112/112 [==============================] - 0s 263us/step - loss: 0.7
943 - acc: 0.6875
Epoch 3/10
112/112 [==============================] - 0s 254us/step - loss: 0.6
042 - acc: 0.6875
Epoch 4/10
112/112 [==============================] - 0s 283us/step - loss: 0.5
094 - acc: 0.9018
Epoch 5/10
112/112 [==============================] - 0s 268us/step - loss: 0.4
287 - acc: 0.8929
Epoch 6/10
112/112 [==============================] - 0s 265us/step - loss: 0.3
840 - acc: 0.8750
Epoch 7/10
112/112 [==============================] - 0s 265us/step - loss: 0.3
543 - acc: 0.9554
Epoch 8/10
112/112 [==============================] - 0s 261us/step - loss: 0.3
115 - acc: 0.9375
Epoch 9/10
112/112 [==============================] - 0s 256us/step - loss: 0.2
925 - acc: 0.9018
Epoch 10/10
112/112 [==============================] - 0s 269us/step - loss: 0.2
581 - acc: 0.9732
```

Out[0]:

```
GridSearchCV(cv=StratifiedShuffleSplit(n_splits=5, random_state=Non
e, test_size=0.25,
            train_size=None),
       error_score='raise-deprecating',
       estimator=<keras.wrappers.scikit_learn.KerasClassifier object
at 0x7f066b1b1be0>,
       fit_params=None, iid='warn', n_jobs=None,
       param_grid={'hidden_size': [32, 64, 256], 'regularization_str
ength': [0, 0.01, 0.05, 0.1]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='war
n',
       scoring=None, verbose=0)
```

In [0]:

```
res = pd.DataFrame(grid.cv_results_)
res.pivot_table(index=["param_hidden_size",'param_regularization_strength'],
                values=['mean_train_score', "mean_test_score"])
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('split0_trai
n_score'), which will not be available by default any more in 0.21.
If you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('split1_trai
n_score'), which will not be available by default any more in 0.21.
If you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('split2_trai
n_score'), which will not be available by default any more in 0.21.
If you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('split3_trai
n_score'), which will not be available by default any more in 0.21.
If you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('split4_trai
n_score'), which will not be available by default any more in 0.21.
If you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('mean_train_
score'), which will not be available by default any more in 0.21. If
you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
/usr/local/lib/python3.6/dist-packages/sklearn/utils/deprecation.py:
125: FutureWarning: You are accessing a training score ('std_train_s
core'), which will not be available by default any more in 0.21. If
you need training scores, please set return_train_score=True
  warnings.warn(*warn_args, **warn_kwargs)
```

Out[0]:

		mean_test_score	mean_train_score
param_hidden_size	param_regularization_strength		
32	**0.00**	0.735714	0.740476
	0.01	0.735714	0.733333
	0.05	0.600000	0.602381
	0.10	0.692857	0.661905
64	**0.00**	0.914286	0.883333
	0.01	0.892857	0.838095
	0.05	0.764286	0.771429
	0.10	0.692857	0.685714
256	**0.00**	0.971429	0.961905
	0.01	0.964286	0.966667
	0.05	0.950000	0.923810
	0.10	0.914286	0.902381

Task 2

In [5]:

```
(X_train, y_train), (X_test, y_test) = fashion_mnist.load_data()
X_train = X_train.reshape(60000, 784)
X_test = X_test.reshape(10000, 784)
X_train = X_train.astype('float32')
X_test = X_test.astype('float32')
X_train /= 255
X_test /= 255
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)
```

```
Downloading data from http://fashion-mnist.s3-website.eu-central-1.a
mazonaws.com/train-labels-idx1-ubyte.gz
32768/29515 [================================] - 0s 3us/step
Downloading data from http://fashion-mnist.s3-website.eu-central-1.a
mazonaws.com/train-images-idx3-ubyte.gz
26427392/26421880 [==============================] - 2s 0us/step
Downloading data from http://fashion-mnist.s3-website.eu-central-1.a
mazonaws.com/t10k-labels-idx1-ubyte.gz
8192/5148 [===============================================] - 0s 0u
s/step
Downloading data from http://fashion-mnist.s3-website.eu-central-1.a
mazonaws.com/t10k-images-idx3-ubyte.gz
4423680/4422102 [==============================] - 1s 0us/step
```

In [0]:

```
def make_model(drop_out = 0, hidden_size = 32, hidden_layes = 1):
  model = Sequential()
  model.add(Dense(hidden_size, input_dim=784, activation='relu'))
  model.add(Dropout(drop_out))
  for i in range(1, hidden_layes):
    model.add(Dense(hidden_size, activation='relu'))
    model.add(Dropout(drop_out))
  model.add(Dense(10, activation='softmax'))

  model.compile(optimizer='adam',loss="categorical_crossentropy",metrics=['accur
acy'])
  return model
```

Vanilla Model

In [0]:

```
vanilla_model = make_model()
history_callback = vanilla_model.fit(X_train, y_train, batch_size=128, epochs=50
, verbose=1,validation_split=1/6)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/framework/op_def_library.py:263: colocate_with (from te
nsorflow.python.framework.ops) is deprecated and will be removed in
a future version.
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.
ops.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 50000 samples, validate on 10000 samples
Epoch 1/50
50000/50000 [==============================] - 4s 77us/step - loss:
0.7045 - acc: 0.7660 - val_loss: 0.5054 - val_acc: 0.8231
Epoch 2/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.4648 - acc: 0.8390 - val_loss: 0.4541 - val_acc: 0.8404
Epoch 3/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.4263 - acc: 0.8516 - val_loss: 0.4214 - val_acc: 0.8531
Epoch 4/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.3975 - acc: 0.8620 - val_loss: 0.4068 - val_acc: 0.8588
Epoch 5/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.3823 - acc: 0.8662 - val_loss: 0.4011 - val_acc: 0.8563
Epoch 6/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.3656 - acc: 0.8725 - val_loss: 0.3971 - val_acc: 0.8585
Epoch 7/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.3582 - acc: 0.8740 - val_loss: 0.3795 - val_acc: 0.8637
Epoch 8/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.3471 - acc: 0.8779 - val_loss: 0.3760 - val_acc: 0.8669
Epoch 9/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.3384 - acc: 0.8794 - val_loss: 0.3801 - val_acc: 0.8643
Epoch 10/50
50000/50000 [==============================] - 2s 30us/step - loss:
0.3327 - acc: 0.8821 - val_loss: 0.3675 - val_acc: 0.8707
Epoch 11/50
50000/50000 [==============================] - 1s 30us/step - loss:
0.3283 - acc: 0.8821 - val_loss: 0.3711 - val_acc: 0.8678
Epoch 12/50
50000/50000 [==============================] - 2s 30us/step - loss:
0.3192 - acc: 0.8874 - val_loss: 0.3836 - val_acc: 0.8667
Epoch 13/50
50000/50000 [==============================] - 2s 30us/step - loss:
0.3147 - acc: 0.8871 - val_loss: 0.3763 - val_acc: 0.8675
Epoch 14/50
50000/50000 [==============================] - 2s 30us/step - loss:
0.3125 - acc: 0.8890 - val_loss: 0.3682 - val_acc: 0.8704
Epoch 15/50
50000/50000 [==============================] - 2s 30us/step - loss:
0.3068 - acc: 0.8910 - val_loss: 0.3595 - val_acc: 0.8709
Epoch 16/50
50000/50000 [==============================] - 1s 30us/step - loss:
0.3033 - acc: 0.8908 - val_loss: 0.3626 - val_acc: 0.8718
Epoch 17/50
```

```
50000/50000 [==============================] - 1s 26us/step - loss:
0.2998 - acc: 0.8928 - val_loss: 0.3601 - val_acc: 0.8736
Epoch 18/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2949 - acc: 0.8935 - val_loss: 0.3694 - val_acc: 0.8689
Epoch 19/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2918 - acc: 0.8963 - val_loss: 0.3742 - val_acc: 0.8653
Epoch 20/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2901 - acc: 0.8958 - val_loss: 0.3751 - val_acc: 0.8699
Epoch 21/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2865 - acc: 0.8974 - val_loss: 0.3552 - val_acc: 0.8751
Epoch 22/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2830 - acc: 0.8982 - val_loss: 0.3741 - val_acc: 0.8692
Epoch 23/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2801 - acc: 0.8985 - val_loss: 0.3705 - val_acc: 0.8708
Epoch 24/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2776 - acc: 0.9010 - val_loss: 0.3640 - val_acc: 0.8725
Epoch 25/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2736 - acc: 0.9015 - val_loss: 0.3544 - val_acc: 0.8760
Epoch 26/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2709 - acc: 0.9012 - val_loss: 0.3520 - val_acc: 0.8738
Epoch 27/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2662 - acc: 0.9048 - val_loss: 0.3607 - val_acc: 0.8742
Epoch 28/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2667 - acc: 0.9022 - val_loss: 0.3571 - val_acc: 0.8777
Epoch 29/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2629 - acc: 0.9057 - val_loss: 0.3761 - val_acc: 0.8675
Epoch 30/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2618 - acc: 0.9064 - val_loss: 0.3530 - val_acc: 0.8769
Epoch 31/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2611 - acc: 0.9053 - val_loss: 0.3721 - val_acc: 0.8685
Epoch 32/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2588 - acc: 0.9066 - val_loss: 0.3595 - val_acc: 0.8768
Epoch 33/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2545 - acc: 0.9086 - val_loss: 0.3534 - val_acc: 0.8790
Epoch 34/50
50000/50000 [==============================] - 1s 27us/step - loss:
0.2503 - acc: 0.9097 - val_loss: 0.3617 - val_acc: 0.8718
Epoch 35/50
50000/50000 [==============================] - 1s 27us/step - loss:
0.2521 - acc: 0.9077 - val_loss: 0.3560 - val_acc: 0.8785
Epoch 36/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2476 - acc: 0.9098 - val_loss: 0.3564 - val_acc: 0.8788
Epoch 37/50
50000/50000 [==============================] - 1s 26us/step - loss:
```

```
0.2445 - acc: 0.9114 - val_loss: 0.3596 - val_acc: 0.8776
Epoch 38/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2445 - acc: 0.9115 - val_loss: 0.3680 - val_acc: 0.8752
Epoch 39/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2398 - acc: 0.9138 - val_loss: 0.3535 - val_acc: 0.8791
Epoch 40/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2411 - acc: 0.9125 - val_loss: 0.3555 - val_acc: 0.8773
Epoch 41/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2383 - acc: 0.9148 - val_loss: 0.3738 - val_acc: 0.8758
Epoch 42/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2368 - acc: 0.9148 - val_loss: 0.3721 - val_acc: 0.8740
Epoch 43/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2356 - acc: 0.9148 - val_loss: 0.3534 - val_acc: 0.8783
Epoch 44/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2347 - acc: 0.9145 - val_loss: 0.3619 - val_acc: 0.8783
Epoch 45/50
50000/50000 [==============================] - 1s 27us/step - loss:
0.2324 - acc: 0.9167 - val_loss: 0.3672 - val_acc: 0.8753
Epoch 46/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2312 - acc: 0.9163 - val_loss: 0.3659 - val_acc: 0.8747
Epoch 47/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2299 - acc: 0.9177 - val_loss: 0.3700 - val_acc: 0.8770
Epoch 48/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2258 - acc: 0.9188 - val_loss: 0.3774 - val_acc: 0.8722
Epoch 49/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2246 - acc: 0.9185 - val_loss: 0.3880 - val_acc: 0.8689
Epoch 50/50
50000/50000 [==============================] - 1s 26us/step - loss:
0.2257 - acc: 0.9188 - val_loss: 0.3669 - val_acc: 0.8782
```

In [0]:

```
vanilla_model.summary()
```

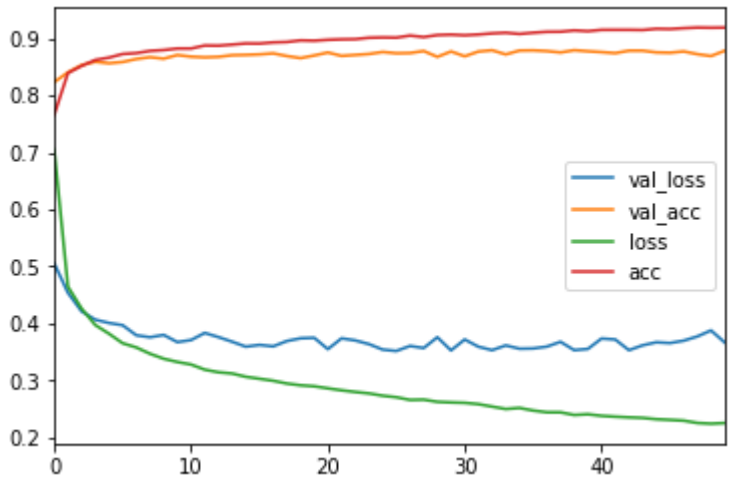
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_1 (Dense)              (None, 32)                25120
_________________________________________________________________
dropout_1 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_2 (Dense)              (None, 10)                330
=================================================================
Total params: 25,450
Trainable params: 25,450
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
pd.DataFrame(history_callback.history).plot()
```

Out[0]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f0474626278>
```



A model using drop-out

In [14]:

```
drop_out_model = make_model(drop_out=0.5, hidden_size= 1024, hidden_layes= 2)
history_callback = drop_out_model.fit(X_train, y_train, batch_size=128, epochs=5
0, verbose=1,validation_split=1/6)
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/50
50000/50000 [==============================] - 3s 54us/step - loss:
0.5923 - acc: 0.7856 - val_loss: 0.4191 - val_acc: 0.8435
Epoch 2/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.4509 - acc: 0.8359 - val_loss: 0.4031 - val_acc: 0.8530
Epoch 3/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.4181 - acc: 0.8492 - val_loss: 0.3615 - val_acc: 0.8652
Epoch 4/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3985 - acc: 0.8535 - val_loss: 0.3637 - val_acc: 0.8691
Epoch 5/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3898 - acc: 0.8575 - val_loss: 0.3487 - val_acc: 0.8739
Epoch 6/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3728 - acc: 0.8630 - val_loss: 0.3483 - val_acc: 0.8697
Epoch 7/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3637 - acc: 0.8666 - val_loss: 0.3338 - val_acc: 0.8748
Epoch 8/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3563 - acc: 0.8688 - val_loss: 0.3354 - val_acc: 0.8765
Epoch 9/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3471 - acc: 0.8722 - val_loss: 0.3459 - val_acc: 0.8728
Epoch 10/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3416 - acc: 0.8733 - val_loss: 0.3214 - val_acc: 0.8836
Epoch 11/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3314 - acc: 0.8772 - val_loss: 0.3243 - val_acc: 0.8805
Epoch 12/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3307 - acc: 0.8770 - val_loss: 0.3236 - val_acc: 0.8819
Epoch 13/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3241 - acc: 0.8782 - val_loss: 0.3169 - val_acc: 0.8847
Epoch 14/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3184 - acc: 0.8833 - val_loss: 0.3225 - val_acc: 0.8837
Epoch 15/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3191 - acc: 0.8808 - val_loss: 0.3136 - val_acc: 0.8873
Epoch 16/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3184 - acc: 0.8815 - val_loss: 0.3295 - val_acc: 0.8836
Epoch 17/50
50000/50000 [==============================] - 2s 37us/step - loss:
0.3146 - acc: 0.8832 - val_loss: 0.3206 - val_acc: 0.8854
Epoch 18/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3049 - acc: 0.8857 - val_loss: 0.3205 - val_acc: 0.8864
Epoch 19/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3013 - acc: 0.8876 - val_loss: 0.3328 - val_acc: 0.8828
Epoch 20/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.3000 - acc: 0.8880 - val_loss: 0.3140 - val_acc: 0.8866
```

```
Epoch 21/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2993 - acc: 0.8887 - val_loss: 0.3085 - val_acc: 0.8895
Epoch 22/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2933 - acc: 0.8904 - val_loss: 0.3127 - val_acc: 0.8872
Epoch 23/50
50000/50000 [==============================] - 2s 37us/step - loss:
0.2940 - acc: 0.8902 - val_loss: 0.3123 - val_acc: 0.8853
Epoch 24/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2907 - acc: 0.8920 - val_loss: 0.3163 - val_acc: 0.8858
Epoch 25/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2853 - acc: 0.8939 - val_loss: 0.3148 - val_acc: 0.8896
Epoch 26/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2841 - acc: 0.8936 - val_loss: 0.3053 - val_acc: 0.8886
Epoch 27/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2815 - acc: 0.8937 - val_loss: 0.3086 - val_acc: 0.8897
Epoch 28/50
50000/50000 [==============================] - 2s 40us/step - loss:
0.2823 - acc: 0.8932 - val_loss: 0.3017 - val_acc: 0.8950
Epoch 29/50
50000/50000 [==============================] - 2s 42us/step - loss:
0.2772 - acc: 0.8967 - val_loss: 0.3199 - val_acc: 0.8843
Epoch 30/50
50000/50000 [==============================] - 2s 42us/step - loss:
0.2752 - acc: 0.8952 - val_loss: 0.3064 - val_acc: 0.8889
Epoch 31/50
50000/50000 [==============================] - 2s 42us/step - loss:
0.2732 - acc: 0.8987 - val_loss: 0.3144 - val_acc: 0.8865
Epoch 32/50
50000/50000 [==============================] - 2s 42us/step - loss:
0.2713 - acc: 0.8984 - val_loss: 0.3010 - val_acc: 0.8911
Epoch 33/50
50000/50000 [==============================] - 2s 39us/step - loss:
0.2702 - acc: 0.8986 - val_loss: 0.2996 - val_acc: 0.8928
Epoch 34/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2636 - acc: 0.9004 - val_loss: 0.2973 - val_acc: 0.8913
Epoch 35/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2665 - acc: 0.9002 - val_loss: 0.2984 - val_acc: 0.8935
Epoch 36/50
50000/50000 [==============================] - 2s 37us/step - loss:
0.2631 - acc: 0.9015 - val_loss: 0.3024 - val_acc: 0.8896
Epoch 37/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2648 - acc: 0.9001 - val_loss: 0.2992 - val_acc: 0.8952
Epoch 38/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2631 - acc: 0.9010 - val_loss: 0.2999 - val_acc: 0.8940
Epoch 39/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2605 - acc: 0.9016 - val_loss: 0.2949 - val_acc: 0.8945
Epoch 40/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2615 - acc: 0.9040 - val_loss: 0.3066 - val_acc: 0.8921
Epoch 41/50
```

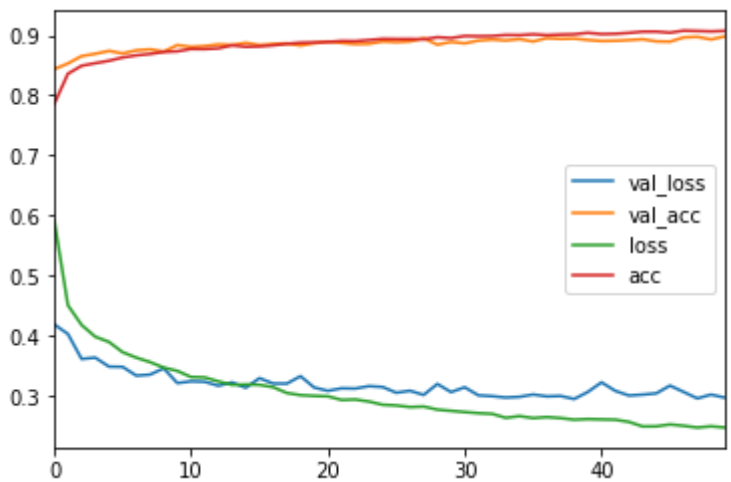
```
50000/50000 [==============================] - 2s 38us/step - loss:
0.2609 - acc: 0.9019 - val_loss: 0.3226 - val_acc: 0.8904
Epoch 42/50
50000/50000 [==============================] - 2s 37us/step - loss:
0.2604 - acc: 0.9024 - val_loss: 0.3085 - val_acc: 0.8908
Epoch 43/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2568 - acc: 0.9039 - val_loss: 0.3007 - val_acc: 0.8919
Epoch 44/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2492 - acc: 0.9059 - val_loss: 0.3022 - val_acc: 0.8933
Epoch 45/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2494 - acc: 0.9060 - val_loss: 0.3043 - val_acc: 0.8898
Epoch 46/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2526 - acc: 0.9043 - val_loss: 0.3172 - val_acc: 0.8893
Epoch 47/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2503 - acc: 0.9076 - val_loss: 0.3066 - val_acc: 0.8964
Epoch 48/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2474 - acc: 0.9071 - val_loss: 0.2959 - val_acc: 0.8973
Epoch 49/50
50000/50000 [==============================] - 2s 38us/step - loss:
0.2495 - acc: 0.9064 - val_loss: 0.3022 - val_acc: 0.8930
Epoch 50/50
50000/50000 [==============================] - 2s 37us/step - loss:
0.2474 - acc: 0.9072 - val_loss: 0.2972 - val_acc: 0.8980
```

In [15]:

```
pd.DataFrame(history_callback.history).plot()
```

Out[15]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f8240616080>
```



In [16]:

```
drop_out_model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_19 (Dense)             (None, 1024)              803840
_________________________________________________________________
dropout_4 (Dropout)          (None, 1024)              0
_________________________________________________________________
dense_20 (Dense)             (None, 1024)              1049600
_________________________________________________________________
dropout_5 (Dropout)          (None, 1024)              0
_________________________________________________________________
dense_21 (Dense)             (None, 10)                10250
=================================================================
Total params: 1,863,690
Trainable params: 1,863,690
Non-trainable params: 0
_________________________________________________________________
```

a model using batch normalization and residual connections

In [0]:

```
inputs = Input(shape=(784,))
h1_1 = Dense(128, activation='relu')(inputs)
h1_2 = BatchNormalization()(h1_1)
h2_1 = Dense(128, activation='relu')(h1_2)
h2_2 = BatchNormalization()(h2_1)
h3_1 = Dense(128, activation='relu')(h2_2)
h3_2 = BatchNormalization()(h3_1)

skip1 = add([h1_2,h3_2])
skip1_bn = BatchNormalization()(skip1)

h4_1 = Dense(128, activation = 'relu')(skip1_bn)
h4_2 = BatchNormalization()(h4_1)

h5_1 = Dense(128, activation = 'relu')(h4_2)
h5_2 = BatchNormalization()(h5_1)

skip2 = add([skip1_bn, h5_2])
skip2_bn = BatchNormalization()(skip2)

h6_1 = Dense(128, activation = 'relu')(skip2_bn)
h6_2 = BatchNormalization()(h6_1)

predictions = Dense(10, activation='softmax')(h6_2)
```

In [7]:

```
model = Model(inputs=inputs, outputs=predictions)
model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accurac
y'])
history_callback = model.fit(X_train, y_train, batch_size=128, epochs=50, verbos
e=1,validation_split=1/6)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.
ops.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 50000 samples, validate on 10000 samples
Epoch 1/50
50000/50000 [==============================] - 10s 200us/step - los
s: 0.4924 - acc: 0.8241 - val_loss: 0.4546 - val_acc: 0.8290
Epoch 2/50
50000/50000 [==============================] - 6s 127us/step - loss:
0.3566 - acc: 0.8695 - val_loss: 0.3755 - val_acc: 0.8637
Epoch 3/50
50000/50000 [==============================] - 6s 120us/step - loss:
0.3205 - acc: 0.8809 - val_loss: 0.4132 - val_acc: 0.8445
Epoch 4/50
50000/50000 [==============================] - 6s 113us/step - loss:
0.2944 - acc: 0.8911 - val_loss: 0.3867 - val_acc: 0.8544
Epoch 5/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.2785 - acc: 0.8957 - val_loss: 0.3690 - val_acc: 0.8661
Epoch 6/50
50000/50000 [==============================] - 6s 114us/step - loss:
0.2629 - acc: 0.9028 - val_loss: 0.3555 - val_acc: 0.8674
Epoch 7/50
50000/50000 [==============================] - 6s 113us/step - loss:
0.2519 - acc: 0.9071 - val_loss: 0.3475 - val_acc: 0.8727
Epoch 8/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.2364 - acc: 0.9124 - val_loss: 0.3445 - val_acc: 0.8752
Epoch 9/50
50000/50000 [==============================] - 6s 113us/step - loss:
0.2240 - acc: 0.9161 - val_loss: 0.3688 - val_acc: 0.8736
Epoch 10/50
50000/50000 [==============================] - 6s 114us/step - loss:
0.2138 - acc: 0.9195 - val_loss: 0.3370 - val_acc: 0.8793
Epoch 11/50
50000/50000 [==============================] - 6s 113us/step - loss:
0.2057 - acc: 0.9224 - val_loss: 0.3506 - val_acc: 0.8806
Epoch 12/50
50000/50000 [==============================] - 6s 114us/step - loss:
0.1987 - acc: 0.9252 - val_loss: 0.3312 - val_acc: 0.8849
Epoch 13/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.1923 - acc: 0.9268 - val_loss: 0.3541 - val_acc: 0.8774
Epoch 14/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.1811 - acc: 0.9312 - val_loss: 0.3523 - val_acc: 0.8766
Epoch 15/50
50000/50000 [==============================] - 6s 115us/step - loss:
0.1670 - acc: 0.9371 - val_loss: 0.4050 - val_acc: 0.8687
Epoch 16/50
50000/50000 [==============================] - 6s 127us/step - loss:
0.1625 - acc: 0.9377 - val_loss: 0.3836 - val_acc: 0.8747
Epoch 17/50
50000/50000 [==============================] - 6s 118us/step - loss:
0.1540 - acc: 0.9413 - val_loss: 0.3742 - val_acc: 0.8779
Epoch 18/50
50000/50000 [==============================] - 6s 114us/step - loss:
0.1484 - acc: 0.9428 - val_loss: 0.3785 - val_acc: 0.8752
Epoch 19/50
```

```
50000/50000 [==============================] - 6s 113us/step - loss:
0.1446 - acc: 0.9449 - val_loss: 0.4523 - val_acc: 0.8545
Epoch 20/50
50000/50000 [==============================] - 6s 119us/step - loss:
0.1369 - acc: 0.9481 - val_loss: 0.3829 - val_acc: 0.8786
Epoch 21/50
50000/50000 [==============================] - 6s 118us/step - loss:
0.1286 - acc: 0.9511 - val_loss: 0.3895 - val_acc: 0.8816
Epoch 22/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.1263 - acc: 0.9522 - val_loss: 0.3980 - val_acc: 0.8885
Epoch 23/50
50000/50000 [==============================] - 6s 119us/step - loss:
0.1169 - acc: 0.9546 - val_loss: 0.4135 - val_acc: 0.8757
Epoch 24/50
50000/50000 [==============================] - 6s 128us/step - loss:
0.1150 - acc: 0.9556 - val_loss: 0.4353 - val_acc: 0.8735
Epoch 25/50
50000/50000 [==============================] - 6s 116us/step - loss:
0.1177 - acc: 0.9552 - val_loss: 0.4077 - val_acc: 0.8824
Epoch 26/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.1050 - acc: 0.9597 - val_loss: 0.4175 - val_acc: 0.8828
Epoch 27/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.1003 - acc: 0.9608 - val_loss: 0.4234 - val_acc: 0.8856
Epoch 28/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0964 - acc: 0.9630 - val_loss: 0.4271 - val_acc: 0.8836
Epoch 29/50
50000/50000 [==============================] - 6s 117us/step - loss:
0.0906 - acc: 0.9658 - val_loss: 0.4557 - val_acc: 0.8824
Epoch 30/50
50000/50000 [==============================] - 6s 127us/step - loss:
0.0899 - acc: 0.9657 - val_loss: 0.4676 - val_acc: 0.8801
Epoch 31/50
50000/50000 [==============================] - 6s 115us/step - loss:
0.0858 - acc: 0.9675 - val_loss: 0.4892 - val_acc: 0.8765
Epoch 32/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.0863 - acc: 0.9671 - val_loss: 0.4927 - val_acc: 0.8764
Epoch 33/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.0800 - acc: 0.9689 - val_loss: 0.4682 - val_acc: 0.8838
Epoch 34/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.0783 - acc: 0.9704 - val_loss: 0.4880 - val_acc: 0.8803
Epoch 35/50
50000/50000 [==============================] - 6s 110us/step - loss:
0.0718 - acc: 0.9731 - val_loss: 0.4976 - val_acc: 0.8826
Epoch 36/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0740 - acc: 0.9715 - val_loss: 0.5178 - val_acc: 0.8809
Epoch 37/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0719 - acc: 0.9723 - val_loss: 0.5041 - val_acc: 0.8840
Epoch 38/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0691 - acc: 0.9734 - val_loss: 0.5224 - val_acc: 0.8794
Epoch 39/50
50000/50000 [==============================] - 6s 110us/step - loss:
```

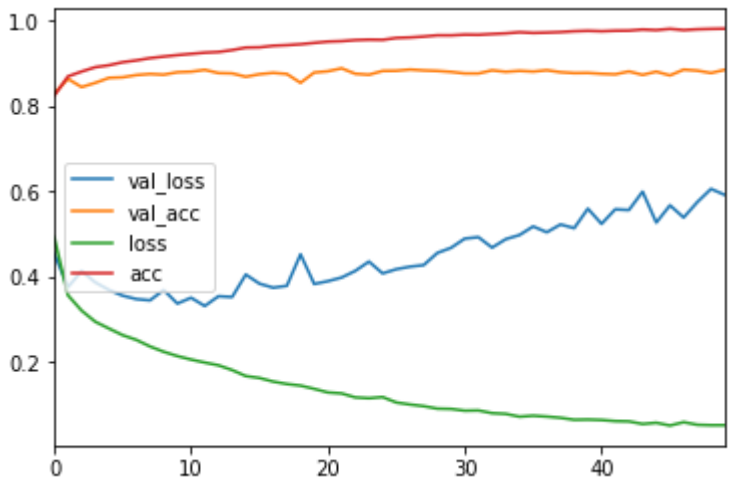
```
0.0645 - acc: 0.9754 - val_loss: 0.5138 - val_acc: 0.8774
Epoch 40/50
50000/50000 [==============================] - 5s 110us/step - loss:
0.0650 - acc: 0.9764 - val_loss: 0.5594 - val_acc: 0.8777
Epoch 41/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0640 - acc: 0.9754 - val_loss: 0.5238 - val_acc: 0.8756
Epoch 42/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.0614 - acc: 0.9766 - val_loss: 0.5579 - val_acc: 0.8744
Epoch 43/50
50000/50000 [==============================] - 6s 114us/step - loss:
0.0607 - acc: 0.9769 - val_loss: 0.5562 - val_acc: 0.8812
Epoch 44/50
50000/50000 [==============================] - 6s 126us/step - loss:
0.0546 - acc: 0.9794 - val_loss: 0.5993 - val_acc: 0.8731
Epoch 45/50
50000/50000 [==============================] - 6s 118us/step - loss:
0.0574 - acc: 0.9781 - val_loss: 0.5268 - val_acc: 0.8807
Epoch 46/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0510 - acc: 0.9810 - val_loss: 0.5673 - val_acc: 0.8719
Epoch 47/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0589 - acc: 0.9781 - val_loss: 0.5387 - val_acc: 0.8854
Epoch 48/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.0527 - acc: 0.9800 - val_loss: 0.5749 - val_acc: 0.8831
Epoch 49/50
50000/50000 [==============================] - 6s 111us/step - loss:
0.0517 - acc: 0.9809 - val_loss: 0.6057 - val_acc: 0.8775
Epoch 50/50
50000/50000 [==============================] - 6s 112us/step - loss:
0.0518 - acc: 0.9815 - val_loss: 0.5918 - val_acc: 0.8850
```

In [8]:

```
pd.DataFrame(history_callback.history).plot()
```

Out[8]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f8257909320>
```



In [9]:

```
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   Con
nected to
==================================================================
input_2 (InputLayer)         (None, 784)               0
_________________________________________________________________
dense_8 (Dense)              (None, 128)               100480    inp
ut_2[0][0]
_________________________________________________________________
batch_normalization_9 (BatchNor (None, 128)            512       den
se_8[0][0]
_________________________________________________________________
dense_9 (Dense)              (None, 128)               16512     bat
ch_normalization_9[0][0]
_________________________________________________________________
batch_normalization_10 (BatchNo (None, 128)            512       den
se_9[0][0]
_________________________________________________________________
dense_10 (Dense)             (None, 128)               16512     bat
ch_normalization_10[0][0]
_________________________________________________________________
batch_normalization_11 (BatchNo (None, 128)            512       den
se_10[0][0]
_________________________________________________________________
add_3 (Add)                  (None, 128)               0         bat
ch_normalization_9[0][0]
                                                                  bat
ch_normalization_11[0][0]
_________________________________________________________________
batch_normalization_12 (BatchNo (None, 128)            512       add
_3[0][0]
_________________________________________________________________
dense_11 (Dense)             (None, 128)               16512     bat
ch_normalization_12[0][0]
_________________________________________________________________
batch_normalization_13 (BatchNo (None, 128)            512       den
se_11[0][0]
_________________________________________________________________
dense_12 (Dense)             (None, 128)               16512     bat
ch_normalization_13[0][0]
_________________________________________________________________
batch_normalization_14 (BatchNo (None, 128)            512       den
se_12[0][0]
_________________________________________________________________
add_4 (Add)                  (None, 128)               0         bat
ch_normalization_12[0][0]
```

```
                                                                    bat
ch_normalization_14[0][0]
__________________________________________________________________________
_____________________________
batch_normalization_15 (BatchNo (None, 128)          512         add
_4[0][0]
__________________________________________________________________________
_____________________________
dense_13 (Dense)                (None, 128)          16512       bat
ch_normalization_15[0][0]
__________________________________________________________________________
_____________________________
batch_normalization_16 (BatchNo (None, 128)          512         den
se_13[0][0]
__________________________________________________________________________
_____________________________
dense_14 (Dense)                (None, 10)           1290        bat
ch_normalization_16[0][0]
==========================================================================
==============================
Total params: 188,426
Trainable params: 186,378
Non-trainable params: 2,048
__________________________________________________________________________
_____________________________
```

HW5 Preparation

April 27, 2019

1 HW5 Data Preparation

```
In [282]: from sklearn.model_selection import train_test_split
          import pandas as pd
          import numpy as np
          import os
          from glob import glob
          import matplotlib.pylab as plt
          %matplotlib inline
```

reference: http://www.degeneratestate.org/posts/2016/Oct/23/image-processing-with-numpy/

```
In [8]: print(os.listdir("IDC_regular_ps50_idx5"))
```

```
['9036', '10268', '10257', '8913', '13613', '8914', '15510', '10259', '16165', '10292', '12951
```

```
In [20]: Data = glob('IDC_regular_ps50_idx5/**/*.png', recursive=True)

In [23]: len(Data)

Out[23]: 277524

In [27]: pwd

Out[27]: '/Users/zechen/Desktop/AML/Homework/HW5'

In [46]: import cv2
         import glob
         import numpy as np

In [71]: folder_lst = os.listdir("IDC_regular_ps50_idx5")

In [73]: train = []
         train_labels = []

In [181]: image_train  =  np.ndarray((277524, 50, 50,3),dtype = np.uint8)
          image_train.shape
```

```
Out[181]: (277524, 50, 50, 3)

In [62]: img = cv2.imread('IDC_regular_ps50_idx5/9036/0/9036_idx5_x2151_y1301_class0.png')

In [ ]: files = glob.glob ("/data/train/class1/*.png") # your image path
        for myFile in files:
            image = cv2.imread (myFile)
            train.append (image)
            train_labels.append([1., 0.])

In [198]: folder_lst = os.listdir("IDC_regular_ps50_idx5")
          image_train  =  np.ndarray((277524, 50, 50,3),dtype = np.uint8)
          train = []
          train_labels = []
          i=0
          for item in folder_lst:
              path = "IDC_regular_ps50_idx5/*"+item+"/1/*.png"
              files = glob.glob(path) # your image path
              for myFile in files:
                  image = cv2.imread(myFile)
                  #print(type(train))
                  #print(train)
                  image_train[i] = cv2.resize(image,(50,50))
                  train_labels.append([1., 0.])
                  i+=1

              path2 = "IDC_regular_ps50_idx5/*"+item+"/0/*.png"
              files2 = glob.glob(path2)
              for myFile2 in files2:
                  image2 = cv2.imread(myFile2)
                  image_train[i] = cv2.resize(image2,(50,50))
                  train_labels.append([0., 1.])
                  i+=1


In [207]: train_labels = np.array(train_labels)
          np.save('train',train)
          np.save('train_labels',train_labels)
          np.save('image_train',image_train)

In [304]: image_train = np.load('image_train.npy')
          train_labels = np.load('train_labels.npy')

In [326]: X_train_sub, X_test_sub, y_train_sub, y_test_sub = train_test_split(image_train,trai

In [327]: X_train_sub.shape

Out[327]: (61055, 50, 50, 3)

In [328]: X_test_sub.shape
```

```
Out[328]: (216469, 50, 50, 3)
```

```
In [329]: np.save('X_train_sub',X_train_sub)
          np.save('y_train_sub',y_train_sub)
```

Plot numpy array to image to double check

```
In [261]: def plti(im, h=8, **kwargs):
              """
              Helper function to plot an image.
              """
              y = im.shape[0]
              x = im.shape[1]
              w = (y/x) * h
              plt.figure(figsize=(w,h))
              plt.imshow(im, interpolation="none", **kwargs)
              plt.axis('off')
```

```
In [260]: im = plt.imread("IDC_regular_ps50_idx5/9036/0/9036_idx5_x2151_y1301_class0.png")
          im
```

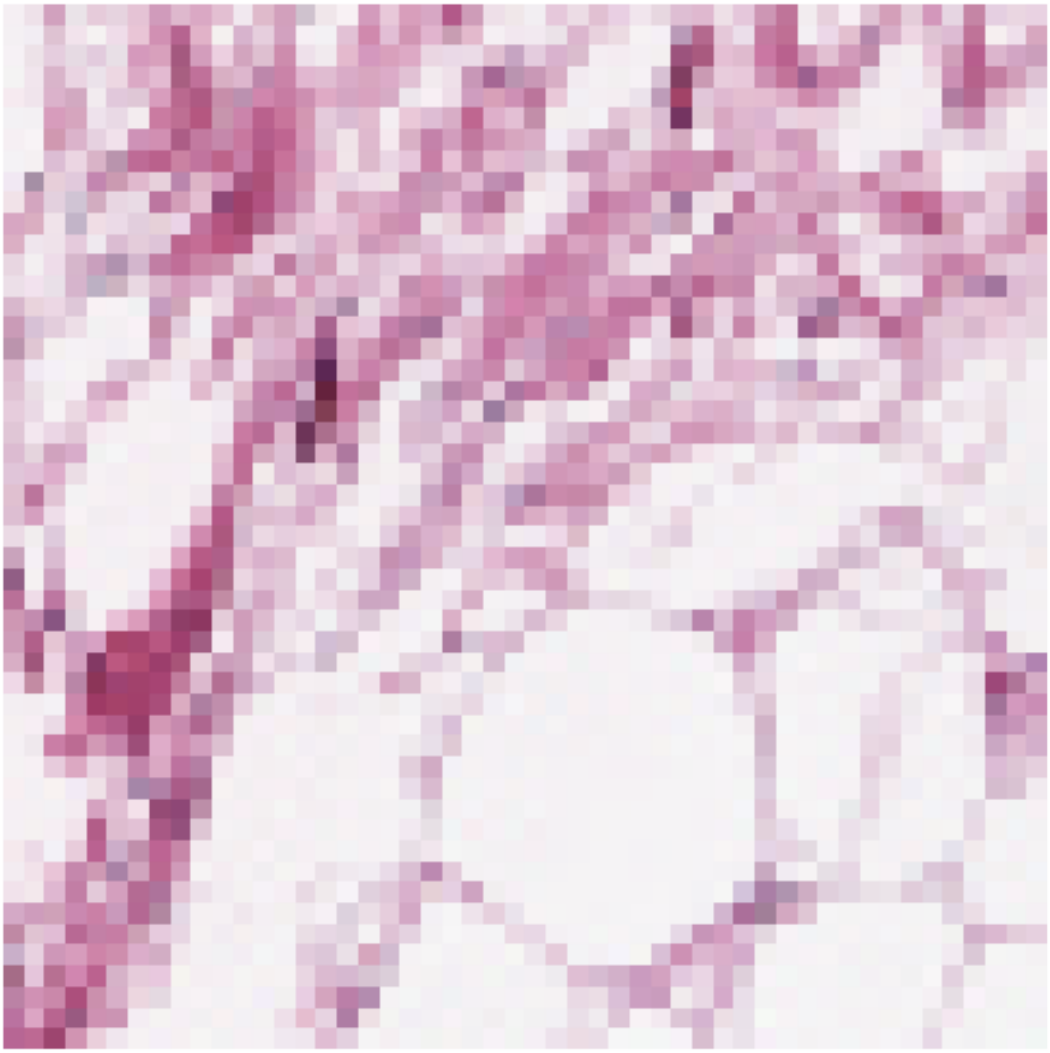
```
Out[260]: array([[[0.9607843 , 0.9372549 , 0.9529412 ],
                  [0.93333334, 0.88235295, 0.9137255 ],
                  [0.81960785, 0.6313726 , 0.74509805],
                  ...,
                  [0.8980392 , 0.8117647 , 0.88235295],
                  [0.91764706, 0.8392157 , 0.88235295],
                  [0.9137255 , 0.8235294 , 0.8862745 ]],

                 [[0.95686275, 0.9411765 , 0.9529412 ],
                  [0.9490196 , 0.92941177, 0.9529412 ],
                  [0.87058824, 0.7607843 , 0.8235294 ],
                  ...,
                  [0.9647059 , 0.9372549 , 0.9411765 ],
                  [0.9372549 , 0.8745098 , 0.92156863],
                  [0.84313726, 0.654902  , 0.7490196 ]],

                 [[0.9647059 , 0.94509804, 0.9607843 ],
                  [0.92941177, 0.8862745 , 0.9098039 ],
                  [0.8980392 , 0.8039216 , 0.87058824],
                  ...,
                  [0.8627451 , 0.70980394, 0.8039216 ],
                  [0.8235294 , 0.64705884, 0.76862746],
                  [0.79607844, 0.61960787, 0.73333335]],

                 ...,

                 [[0.73333335, 0.50980395, 0.64705884],
                  [0.8156863 , 0.5686275 , 0.7058824 ],
```

```
 [0.7921569 , 0.53333336, 0.6666667 ],
 ...,
 [0.9529412 , 0.94509804, 0.9529412 ],
 [0.9490196 , 0.9607843 , 0.94509804],
 [0.9607843 , 0.9490196 , 0.96862745]],

[[0.7294118 , 0.44705883, 0.627451  ],
 [0.8627451 , 0.64705884, 0.76862746],
 [0.72156864, 0.39607844, 0.5647059 ],
 ...,
 [0.95686275, 0.9607843 , 0.95686275],
 [0.9607843 , 0.9490196 , 0.9607843 ],
 [0.95686275, 0.94509804, 0.95686275]],

[[0.7176471 , 0.4       , 0.5803922 ],
 [0.7411765 , 0.4117647 , 0.5764706 ],
 [0.6156863 , 0.27058825, 0.43529412],
 ...,
 [0.95686275, 0.9607843 , 0.95686275],
 [0.9647059 , 0.95686275, 0.96862745],
 [0.94509804, 0.9647059 , 0.95686275]]], dtype=float32)
```

```
In [161]: train.shape
```

```
Out[161]: (277524,)
```

```
In [262]: plti(im)
```



Task 3

In [0]:

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/au
th?client_id=947318989803-6bn6qk8qdgf4n4g3pfee6491hc0brc4i.apps.goog
leusercontent.com&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&s
cope=email%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdocs.test%20h
ttps%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive%20https%3A%2F%2Fwww.g
oogleapis.com%2Fauth%2Fdrive.photos.readonly%20https%3A%2F%2Fwww.goo
gleapis.com%2Fauth%2Fpeopleapi.readonly&response_type=code

Enter your authorization code:
··········
Mounted at /content/drive
```

In [0]:

```
cd "/content/drive/My Drive/Colab Notebooks"
```

```
/content/drive/My Drive/Colab Notebooks
```

In [0]:

```
pwd
```

Out[0]:

```
'/content/drive/My Drive/Colab Notebooks'
```

In [0]:

```
image_train =np.load('image_train.npy')
```

In [0]:

```
image_label = np.load('train_labels.npy')
```

In [0]:

```
image_train.shape
```

Out[0]:

```
(277524, 50, 50, 3)
```

In [0]:

```
image_label.shape
```

Out[0]:

```
(277524, 2)
```

In [0]:

```
X_train, X_test, y_train, y_test = train_test_split(image_train,image_label)
```

In [0]:

```
X_train.shape
```

Out[0]:

```
(208143, 50, 50, 3)
```

3.1 Start with a model without residual connections (using batch normalization is likely to be helpful and you should try it, whether you use dropout is your choice)

Scenario1: use all data

Build CNN Model: use Batch Normalization and Dropout

In [0]:

```
from keras.layers import Conv2D, MaxPooling2D, Flatten

input_shape = (50,50,3)
num_classes = 2
cnn = Sequential()
cnn.add(Conv2D(32, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
cnn.add(BatchNormalization())
cnn.add(MaxPooling2D(pool_size=(2, 2)))
cnn.add(Dropout(0.2))
cnn.add(Conv2D(32, (3, 3), activation='relu'))
cnn.add(BatchNormalization())
cnn.add(MaxPooling2D(pool_size=(2, 2)))
cnn.add(Dropout(0.2))
cnn.add(Flatten())
cnn.add(Dense(64, activation='relu'))
cnn.add(Dense(num_classes, activation='softmax'))
```

In [0]:

```
cnn.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_3 (Conv2D)            (None, 48, 48, 32)        896
_________________________________________________________________
batch_normalization_3 (Batch (None, 48, 48, 32)        128
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 24, 24, 32)        0
_________________________________________________________________
dropout_3 (Dropout)          (None, 24, 24, 32)        0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 22, 22, 32)        9248
_________________________________________________________________
batch_normalization_4 (Batch (None, 22, 22, 32)        128
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 11, 11, 32)        0
_________________________________________________________________
dropout_4 (Dropout)          (None, 11, 11, 32)        0
_________________________________________________________________
flatten_2 (Flatten)          (None, 3872)              0
_________________________________________________________________
dense_3 (Dense)              (None, 64)                247872
_________________________________________________________________
dense_4 (Dense)              (None, 2)                 130
=================================================================
Total params: 258,402
Trainable params: 258,274
Non-trainable params: 128
_________________________________________________________________
```

In [0]:

```
cnn.compile("adam", "categorical_crossentropy", metrics=['accuracy'])
```

In [0]:

```
history_cnn = cnn.fit(X_train, y_train,
                      batch_size=128, epochs=20, verbose=1, validation_split=.1)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.
ops.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 187328 samples, validate on 20815 samples
Epoch 1/20
187328/187328 [==============================] - 24s 128us/step - lo
ss: 0.3555 - acc: 0.8501 - val_loss: 0.5466 - val_acc: 0.7074
Epoch 2/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.3185 - acc: 0.8655 - val_loss: 0.4521 - val_acc: 0.8310
Epoch 3/20
187328/187328 [==============================] - 20s 108us/step - lo
ss: 0.3060 - acc: 0.8714 - val_loss: 0.4079 - val_acc: 0.8251
Epoch 4/20
187328/187328 [==============================] - 20s 107us/step - lo
ss: 0.2971 - acc: 0.8748 - val_loss: 0.3517 - val_acc: 0.8480
Epoch 5/20
187328/187328 [==============================] - 20s 108us/step - lo
ss: 0.2862 - acc: 0.8794 - val_loss: 0.3880 - val_acc: 0.8276
Epoch 6/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.2735 - acc: 0.8851 - val_loss: 0.5506 - val_acc: 0.8051
Epoch 7/20
187328/187328 [==============================] - 20s 108us/step - lo
ss: 0.2599 - acc: 0.8909 - val_loss: 0.3313 - val_acc: 0.8618
Epoch 8/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.2431 - acc: 0.8990 - val_loss: 0.3370 - val_acc: 0.8588
Epoch 9/20
187328/187328 [==============================] - 20s 107us/step - lo
ss: 0.2254 - acc: 0.9071 - val_loss: 0.6006 - val_acc: 0.7821
Epoch 10/20
187328/187328 [==============================] - 20s 109us/step - lo
ss: 0.2078 - acc: 0.9148 - val_loss: 0.4527 - val_acc: 0.8449
Epoch 11/20
187328/187328 [==============================] - 20s 109us/step - lo
ss: 0.1908 - acc: 0.9223 - val_loss: 0.6321 - val_acc: 0.8492
Epoch 12/20
187328/187328 [==============================] - 20s 107us/step - lo
ss: 0.1746 - acc: 0.9289 - val_loss: 0.4963 - val_acc: 0.8359
Epoch 13/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.1601 - acc: 0.9352 - val_loss: 0.5364 - val_acc: 0.8464
Epoch 14/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.1467 - acc: 0.9413 - val_loss: 0.5272 - val_acc: 0.8429
Epoch 15/20
187328/187328 [==============================] - 20s 108us/step - lo
ss: 0.1345 - acc: 0.9464 - val_loss: 0.5776 - val_acc: 0.8341
Epoch 16/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.1232 - acc: 0.9505 - val_loss: 0.6100 - val_acc: 0.7970
Epoch 17/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.1142 - acc: 0.9541 - val_loss: 0.6027 - val_acc: 0.8312
Epoch 18/20
187328/187328 [==============================] - 20s 106us/step - lo
ss: 0.1076 - acc: 0.9570 - val_loss: 0.7718 - val_acc: 0.8174
Epoch 19/20
```

```
187328/187328 [==============================] - 20s 108us/step - lo
ss: 0.0994 - acc: 0.9605 - val_loss: 0.7617 - val_acc: 0.8479
Epoch 20/20
187328/187328 [==============================] - 20s 108us/step - lo
ss: 0.0925 - acc: 0.9635 - val_loss: 0.7913 - val_acc: 0.8189
```

In [0]:

```
score = cnn.evaluate(X_test, y_test, verbose=0)
print("Test loss: {:.3f}".format(score[0]))
print("Test Accuracy: {:.3f}".format(score[1]))
```

```
Test loss: 0.780
Test Accuracy: 0.824
```

Scenario2: Use Subsample for Task3.1

In [0]:

```
X_train_sub =np.load('X_train_sub.npy')
```

In [0]:

```
y_train_sub =np.load('y_train_sub.npy')
```

In [0]:

```
X_train_sub, X_test_sub, y_train_sub, y_test_sub = train_test_split(X_train_sub,
y_train_sub)
```

In [0]:

```
X_train_sub.shape
```

Out[0]:

```
(45791, 50, 50, 3)
```

In [0]:

```
history_cnn_subsample = cnn.fit(X_train_sub, y_train_sub,
                        batch_size=128, epochs=50, verbose=1,
                        validation_data=[X_test_sub, y_test_sub])
```

```
Train on 45791 samples, validate on 15264 samples
Epoch 1/50
45791/45791 [==============================] - 15s 317us/step - los
s: 0.3916 - acc: 0.8350 - val_loss: 0.9729 - val_acc: 0.7536
Epoch 2/50
45791/45791 [==============================] - 7s 143us/step - loss:
0.3479 - acc: 0.8515 - val_loss: 0.3942 - val_acc: 0.8346
Epoch 3/50
45791/45791 [==============================] - 7s 149us/step - loss:
0.3359 - acc: 0.8572 - val_loss: 0.5593 - val_acc: 0.7846
Epoch 4/50
45791/45791 [==============================] - 7s 143us/step - loss:
0.3291 - acc: 0.8598 - val_loss: 0.4644 - val_acc: 0.8318
Epoch 5/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.3241 - acc: 0.8634 - val_loss: 0.6799 - val_acc: 0.7937
Epoch 6/50
45791/45791 [==============================] - 6s 142us/step - loss:
0.3136 - acc: 0.8687 - val_loss: 0.6957 - val_acc: 0.7936
Epoch 7/50
45791/45791 [==============================] - 7s 142us/step - loss:
0.3054 - acc: 0.8733 - val_loss: 0.5825 - val_acc: 0.7936
Epoch 8/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.2937 - acc: 0.8765 - val_loss: 0.4609 - val_acc: 0.7934
Epoch 9/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.2875 - acc: 0.8798 - val_loss: 0.4353 - val_acc: 0.8219
Epoch 10/50
45791/45791 [==============================] - 6s 142us/step - loss:
0.2784 - acc: 0.8838 - val_loss: 0.3600 - val_acc: 0.8497
Epoch 11/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.2649 - acc: 0.8905 - val_loss: 0.7892 - val_acc: 0.6985
Epoch 12/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.2537 - acc: 0.8953 - val_loss: 0.5498 - val_acc: 0.7740
Epoch 13/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.2414 - acc: 0.9012 - val_loss: 0.4692 - val_acc: 0.8339
Epoch 14/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.2309 - acc: 0.9057 - val_loss: 1.0478 - val_acc: 0.6468
Epoch 15/50
45791/45791 [==============================] - 7s 148us/step - loss:
0.2196 - acc: 0.9117 - val_loss: 0.4777 - val_acc: 0.8388
Epoch 16/50
45791/45791 [==============================] - 7s 146us/step - loss:
0.2045 - acc: 0.9164 - val_loss: 0.5328 - val_acc: 0.8244
Epoch 17/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1940 - acc: 0.9210 - val_loss: 0.4414 - val_acc: 0.8407
Epoch 18/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.1864 - acc: 0.9254 - val_loss: 0.4724 - val_acc: 0.8318
Epoch 19/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1712 - acc: 0.9310 - val_loss: 0.4837 - val_acc: 0.8349
Epoch 20/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.1688 - acc: 0.9320 - val_loss: 1.1887 - val_acc: 0.6885
```

```
Epoch 21/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1597 - acc: 0.9352 - val_loss: 0.6234 - val_acc: 0.8413
Epoch 22/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1514 - acc: 0.9397 - val_loss: 1.4490 - val_acc: 0.6929
Epoch 23/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1415 - acc: 0.9434 - val_loss: 0.6517 - val_acc: 0.8443
Epoch 24/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1375 - acc: 0.9456 - val_loss: 0.4853 - val_acc: 0.8277
Epoch 25/50
45791/45791 [==============================] - 7s 142us/step - loss:
0.1302 - acc: 0.9481 - val_loss: 1.1942 - val_acc: 0.7744
Epoch 26/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.1234 - acc: 0.9505 - val_loss: 0.6204 - val_acc: 0.8064
Epoch 27/50
45791/45791 [==============================] - 7s 150us/step - loss:
0.1198 - acc: 0.9518 - val_loss: 1.1603 - val_acc: 0.7250
Epoch 28/50
45791/45791 [==============================] - 7s 149us/step - loss:
0.1193 - acc: 0.9522 - val_loss: 0.8342 - val_acc: 0.7938
Epoch 29/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1113 - acc: 0.9556 - val_loss: 1.2644 - val_acc: 0.8013
Epoch 30/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.1086 - acc: 0.9565 - val_loss: 0.7301 - val_acc: 0.8362
Epoch 31/50
45791/45791 [==============================] - 6s 142us/step - loss:
0.1017 - acc: 0.9598 - val_loss: 0.8843 - val_acc: 0.8333
Epoch 32/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0982 - acc: 0.9610 - val_loss: 1.1191 - val_acc: 0.7497
Epoch 33/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.0975 - acc: 0.9618 - val_loss: 1.8316 - val_acc: 0.7798
Epoch 34/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0941 - acc: 0.9630 - val_loss: 1.1207 - val_acc: 0.7819
Epoch 35/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0912 - acc: 0.9643 - val_loss: 0.9404 - val_acc: 0.7990
Epoch 36/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0932 - acc: 0.9636 - val_loss: 0.9926 - val_acc: 0.8153
Epoch 37/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0892 - acc: 0.9648 - val_loss: 2.0138 - val_acc: 0.7678
Epoch 38/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.0866 - acc: 0.9656 - val_loss: 0.6101 - val_acc: 0.8394
Epoch 39/50
45791/45791 [==============================] - 7s 142us/step - loss:
0.0817 - acc: 0.9680 - val_loss: 0.6695 - val_acc: 0.8276
Epoch 40/50
45791/45791 [==============================] - 7s 149us/step - loss:
0.0792 - acc: 0.9696 - val_loss: 0.7427 - val_acc: 0.8411
Epoch 41/50
```

```
45791/45791 [==============================] - 7s 144us/step - loss:
0.0792 - acc: 0.9686 - val_loss: 0.8608 - val_acc: 0.8241
Epoch 42/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.0786 - acc: 0.9693 - val_loss: 0.6481 - val_acc: 0.8126
Epoch 43/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0737 - acc: 0.9714 - val_loss: 0.7935 - val_acc: 0.8001
Epoch 44/50
45791/45791 [==============================] - 7s 142us/step - loss:
0.0768 - acc: 0.9696 - val_loss: 0.9980 - val_acc: 0.8176
Epoch 45/50
45791/45791 [==============================] - 6s 140us/step - loss:
0.0735 - acc: 0.9702 - val_loss: 1.1493 - val_acc: 0.7911
Epoch 46/50
45791/45791 [==============================] - 7s 148us/step - loss:
0.0725 - acc: 0.9721 - val_loss: 0.6474 - val_acc: 0.8382
Epoch 47/50
45791/45791 [==============================] - 7s 150us/step - loss:
0.0671 - acc: 0.9731 - val_loss: 0.6795 - val_acc: 0.8429
Epoch 48/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0699 - acc: 0.9728 - val_loss: 0.7817 - val_acc: 0.8214
Epoch 49/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0676 - acc: 0.9733 - val_loss: 0.7673 - val_acc: 0.8484
Epoch 50/50
45791/45791 [==============================] - 6s 141us/step - loss:
0.0674 - acc: 0.9738 - val_loss: 1.2057 - val_acc: 0.8204
```

In [0]:

```
score = cnn.evaluate(X_test_sub, y_test_sub, verbose=0)
print("Test loss: {:.3f}".format(score[0]))
print("Test Accuracy: {:.3f}".format(score[1]))
```

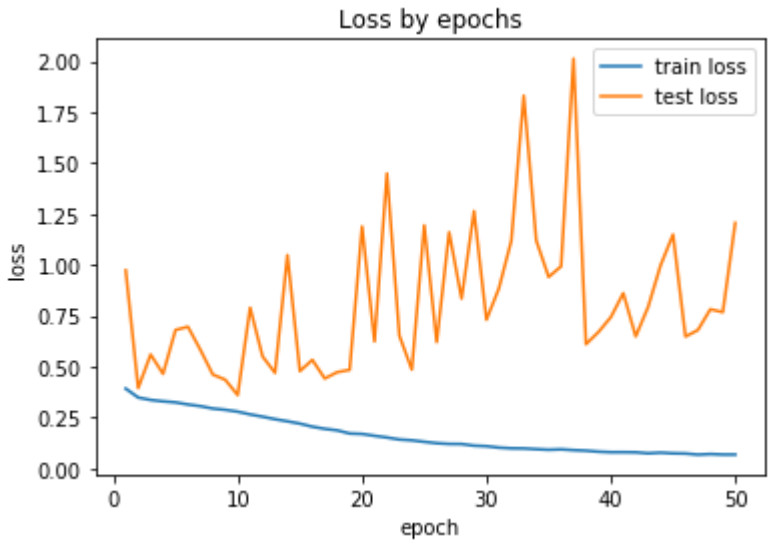
```
Test loss: 1.206
Test Accuracy: 0.820
```

In [0]:

```
x=np.arange(1,51)
plt.plot(x,history_cnn_subsample.history['loss'],label='train loss')
plt.plot(x,history_cnn_subsample.history['val_loss'], label = 'test loss')
plt.legend()
plt.xlabel('epoch')
plt.ylabel('loss')
plt.title('Loss by epochs')
```

Out[0]:

```
Text(0.5, 1.0, 'Loss by epochs')
```

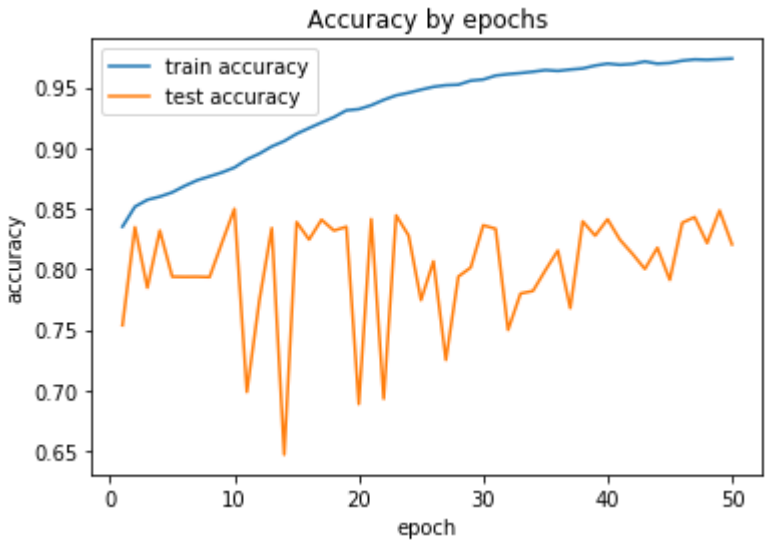


In [0]:

```
x=np.arange(1,51)
plt.plot(x,history_cnn_subsample.history['acc'],label='train accuracy')
plt.plot(x,history_cnn_subsample.history['val_acc'], label = 'test accuracy')
plt.legend()
plt.xlabel('epoch')
plt.ylabel('accuracy')
plt.title('Accuracy by epochs')
```

Out[0]:

```
Text(0.5, 1.0, 'Accuracy by epochs')
```



3.2 Augment the data using rotations, mirroring and possibly other transformations. How much can you improve your original model by data augmentation?

In [0]:

```
input_shape = (50,50,3)
num_classes = 2
cnn = Sequential()
cnn.add(Conv2D(32, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
cnn.add(BatchNormalization())
cnn.add(MaxPooling2D(pool_size=(2, 2)))
cnn.add(Dropout(0.2))
cnn.add(Conv2D(32, (3, 3), activation='relu'))
cnn.add(BatchNormalization())
cnn.add(MaxPooling2D(pool_size=(2, 2)))
cnn.add(Dropout(0.2))
cnn.add(Flatten())
cnn.add(Dense(64, activation='relu'))
cnn.add(Dense(num_classes, activation='softmax'))

cnn.compile("adam", "categorical_crossentropy", metrics=['accuracy'])
```

In [0]:

```
from keras.preprocessing.image import ImageDataGenerator, array_to_img, img_to_a
rray, load_img

datagen2 = ImageDataGenerator(
    featurewise_center=True,
    featurewise_std_normalization=True,
    rotation_range=20,
    width_shift_range=0.2,
    height_shift_range=0.2,
    horizontal_flip=True)
```

In [0]:

```
history_cnn_datagen2 = cnn.fit_generator(datagen2.flow(X_train_sub, y_train_sub,
batch_size=128),
                    steps_per_epoch=len(X_train_sub)/32, epochs=20, validation_d
ata=[X_test_sub, y_test_sub])
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tenso
rflow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.
ops.math_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.cast instead.
Epoch 1/20

/usr/local/lib/python3.6/dist-packages/keras_preprocessing/image/ima
ge_data_generator.py:699: UserWarning: This ImageDataGenerator speci
fies `featurewise_center`, but it hasn't been fit on any training da
ta. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
/usr/local/lib/python3.6/dist-packages/keras_preprocessing/image/ima
ge_data_generator.py:707: UserWarning: This ImageDataGenerator speci
fies `featurewise_std_normalization`, but it hasn't been fit on any
training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
```

```
1431/1430 [==============================] - 128s 90ms/step - loss:
0.3690 - acc: 0.8442 - val_loss: 0.3614 - val_acc: 0.8470
Epoch 2/20
1431/1430 [==============================] - 126s 88ms/step - loss:
0.3417 - acc: 0.8543 - val_loss: 0.4654 - val_acc: 0.8274
Epoch 3/20
1431/1430 [==============================] - 126s 88ms/step - loss:
0.3308 - acc: 0.8589 - val_loss: 0.3374 - val_acc: 0.8609
Epoch 4/20
1431/1430 [==============================] - 126s 88ms/step - loss:
0.3258 - acc: 0.8613 - val_loss: 0.4197 - val_acc: 0.8475
Epoch 5/20
1431/1430 [==============================] - 124s 87ms/step - loss:
0.3219 - acc: 0.8627 - val_loss: 0.8340 - val_acc: 0.7742
Epoch 6/20
1431/1430 [==============================] - 127s 89ms/step - loss:
0.3189 - acc: 0.8644 - val_loss: 0.3524 - val_acc: 0.8578
Epoch 7/20
1431/1430 [==============================] - 123s 86ms/step - loss:
0.3160 - acc: 0.8654 - val_loss: 0.3353 - val_acc: 0.8566
Epoch 8/20
1431/1430 [==============================] - 127s 89ms/step - loss:
0.3131 - acc: 0.8664 - val_loss: 0.4391 - val_acc: 0.8380
Epoch 9/20
1431/1430 [==============================] - 125s 88ms/step - loss:
0.3101 - acc: 0.8676 - val_loss: 0.4995 - val_acc: 0.8466
Epoch 10/20
1431/1430 [==============================] - 127s 89ms/step - loss:
0.3086 - acc: 0.8682 - val_loss: 0.4923 - val_acc: 0.8445
Epoch 11/20
1431/1430 [==============================] - 126s 88ms/step - loss:
0.3059 - acc: 0.8689 - val_loss: 0.6132 - val_acc: 0.6944
Epoch 12/20
1431/1430 [==============================] - 123s 86ms/step - loss:
0.3043 - acc: 0.8696 - val_loss: 0.3482 - val_acc: 0.8549
Epoch 13/20
1431/1430 [==============================] - 126s 88ms/step - loss:
0.3009 - acc: 0.8714 - val_loss: 0.3905 - val_acc: 0.8362
Epoch 14/20
1431/1430 [==============================] - 125s 87ms/step - loss:
0.3004 - acc: 0.8714 - val_loss: 0.3578 - val_acc: 0.8620
Epoch 15/20
1431/1430 [==============================] - 126s 88ms/step - loss:
0.2980 - acc: 0.8724 - val_loss: 0.6110 - val_acc: 0.8394
Epoch 16/20
1431/1430 [==============================] - 124s 87ms/step - loss:
0.2955 - acc: 0.8738 - val_loss: 0.4092 - val_acc: 0.8272
Epoch 17/20
1431/1430 [==============================] - 125s 87ms/step - loss:
0.2951 - acc: 0.8726 - val_loss: 0.4071 - val_acc: 0.8286
Epoch 18/20
1431/1430 [==============================] - 124s 87ms/step - loss:
0.2931 - acc: 0.8745 - val_loss: 0.3563 - val_acc: 0.8500
Epoch 19/20
1431/1430 [==============================] - 125s 87ms/step - loss:
0.2917 - acc: 0.8753 - val_loss: 0.2986 - val_acc: 0.8761
Epoch 20/20
1431/1430 [==============================] - 127s 88ms/step - loss:
0.2911 - acc: 0.8756 - val_loss: 0.3873 - val_acc: 0.8469
```

In [0]:

```
score = cnn.evaluate(X_test_sub, y_test_sub, verbose=0)
print("Test loss: {:.3f}".format(score[0]))
print("Test Accuracy: {:.3f}".format(score[1]))
```

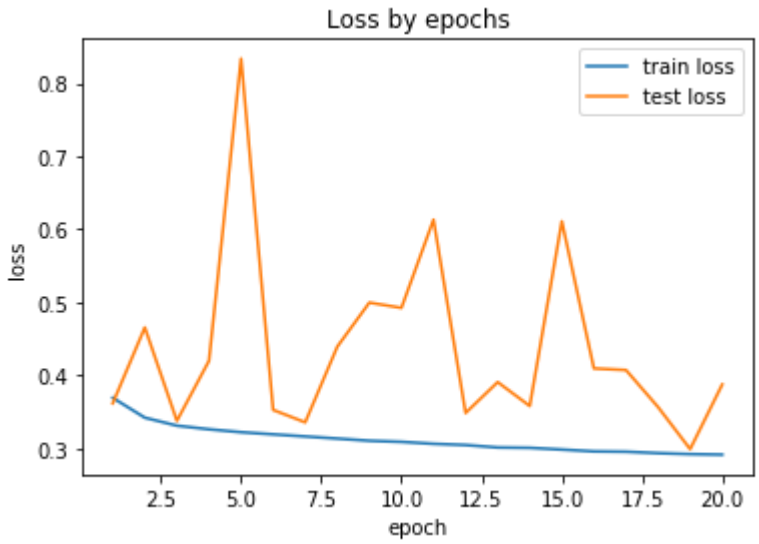
```
Test loss: 0.387
Test Accuracy: 0.847
```

In [0]:

```
x=np.arange(1,21)
plt.plot(x,history_cnn_datagen2.history['loss'],label='train loss')
plt.plot(x,history_cnn_datagen2.history['val_loss'], label = 'test loss')
plt.legend()
plt.xlabel('epoch')
plt.ylabel('loss')
plt.title('Loss by epochs')
```

Out[0]:

```
Text(0.5, 1.0, 'Loss by epochs')
```

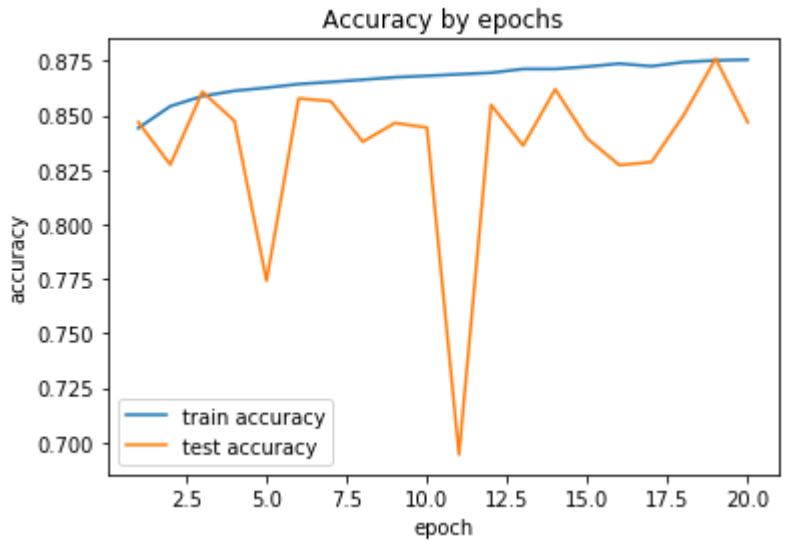


In [0]:

```
x=np.arange(1,21)
plt.plot(x,history_cnn_datagen2.history['acc'],label='train accuracy')
plt.plot(x,history_cnn_datagen2.history['val_acc'], label = 'test accuracy')
plt.legend()
plt.xlabel('epoch')
plt.ylabel('accuracy')
plt.title('Accuracy by epochs')
```

Out[0]:

```
Text(0.5, 1.0, 'Accuracy by epochs')
```



Comments:

Yes, data augmentation improves accuracy a bit, from 0.82 to 0.84.

3.3 Build a deeper model using residual connections. Show that you can build a deep model that would not be able to learn if you remove the residual connections (i.e. compare a deep model with and without residual connections while the rest of the architecture is constant).

With residual connection

In [0]:

```
from keras.layers import Input, Conv2D, MaxPooling2D, Flatten, add
from keras.models import Model

num_classes = 2
inputs = Input(shape=(50, 50, 3))
#next
conv1_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(inputs)
conv1_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv1_1)
conv1_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv1_2)
maxpool1 = MaxPooling2D(pool_size=(2, 2))(conv1_3)
conv2_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool1)
conv2_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv2_1)
skip1 = add([maxpool1, conv2_2])
conv2_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(skip1)
maxpool2 = MaxPooling2D(pool_size=(2, 2))(conv2_3)

conv3_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool2)
conv3_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv3_1)
conv3_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv3_2)
skip2 = add([conv3_1, conv3_3])
maxpool3 = MaxPooling2D(pool_size=(2, 2))(skip2)

conv4_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool3)
conv4_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv4_1)
conv4_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv4_2)
skip3 = add([conv4_1, conv4_3])
maxpool4 = MaxPooling2D(pool_size=(2, 2))(skip3)

conv5_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool4)
conv5_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv5_1)
conv5_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv5_2)
skip4 = add([conv5_1, conv5_3])
maxpool5 = MaxPooling2D(pool_size=(2, 2))(skip4)

flat = Flatten()(maxpool5)
dense = Dense(64, activation='relu')(flat)
predictions = Dense(num_classes, activation='softmax')(dense)
model_resnet = Model(inputs=inputs, outputs=predictions)
```

In [0]:

```
model_resnet.compile(optimizer='adam',loss='categorical_crossentropy',
                     metrics=['accuracy'])
```

In [0]:

```
history_callback_resnet = model_resnet.fit(X_train_sub, y_train_sub, batch_size=
256,
                                    epochs=20, verbose=1,
                                    validation_data = [X_test_sub, y_test_sub])
```

```
Train on 45791 samples, validate on 15264 samples
Epoch 1/20
45791/45791 [==============================] - 20s 445us/step - los
s: 0.5364 - acc: 0.7674 - val_loss: 0.3943 - val_acc: 0.8253
Epoch 2/20
45791/45791 [==============================] - 13s 292us/step - los
s: 0.3963 - acc: 0.8278 - val_loss: 0.3739 - val_acc: 0.8364
Epoch 3/20
45791/45791 [==============================] - 14s 295us/step - los
s: 0.3751 - acc: 0.8367 - val_loss: 0.3689 - val_acc: 0.8434
Epoch 4/20
45791/45791 [==============================] - 14s 295us/step - los
s: 0.3609 - acc: 0.8449 - val_loss: 0.3617 - val_acc: 0.8446
Epoch 5/20
45791/45791 [==============================] - 14s 295us/step - los
s: 0.3504 - acc: 0.8494 - val_loss: 0.3481 - val_acc: 0.8501
Epoch 6/20
45791/45791 [==============================] - 13s 292us/step - los
s: 0.3464 - acc: 0.8502 - val_loss: 0.3358 - val_acc: 0.8568
Epoch 7/20
45791/45791 [==============================] - 13s 289us/step - los
s: 0.3354 - acc: 0.8549 - val_loss: 0.3387 - val_acc: 0.8518
Epoch 8/20
45791/45791 [==============================] - 13s 290us/step - los
s: 0.3307 - acc: 0.8581 - val_loss: 0.3684 - val_acc: 0.8391
Epoch 9/20
45791/45791 [==============================] - 13s 294us/step - los
s: 0.3244 - acc: 0.8609 - val_loss: 0.3393 - val_acc: 0.8558
Epoch 10/20
45791/45791 [==============================] - 13s 291us/step - los
s: 0.3249 - acc: 0.8625 - val_loss: 0.3304 - val_acc: 0.8540
Epoch 11/20
45791/45791 [==============================] - 13s 291us/step - los
s: 0.3121 - acc: 0.8663 - val_loss: 0.3261 - val_acc: 0.8575
Epoch 12/20
45791/45791 [==============================] - 13s 291us/step - los
s: 0.3088 - acc: 0.8679 - val_loss: 0.3318 - val_acc: 0.8565
Epoch 13/20
45791/45791 [==============================] - 13s 292us/step - los
s: 0.3003 - acc: 0.8731 - val_loss: 0.3253 - val_acc: 0.8593
Epoch 14/20
45791/45791 [==============================] - 13s 292us/step - los
s: 0.2990 - acc: 0.8727 - val_loss: 0.3358 - val_acc: 0.8549
Epoch 15/20
45791/45791 [==============================] - 13s 293us/step - los
s: 0.2915 - acc: 0.8772 - val_loss: 0.3439 - val_acc: 0.8494
Epoch 16/20
45791/45791 [==============================] - 13s 292us/step - los
s: 0.2892 - acc: 0.8783 - val_loss: 0.3465 - val_acc: 0.8531
Epoch 17/20
45791/45791 [==============================] - 13s 290us/step - los
s: 0.2800 - acc: 0.8819 - val_loss: 0.3437 - val_acc: 0.8531
Epoch 18/20
45791/45791 [==============================] - 13s 291us/step - los
s: 0.2749 - acc: 0.8855 - val_loss: 0.3570 - val_acc: 0.8481
Epoch 19/20
45791/45791 [==============================] - 13s 290us/step - los
s: 0.2697 - acc: 0.8875 - val_loss: 0.3527 - val_acc: 0.8494
Epoch 20/20
45791/45791 [==============================] - 13s 291us/step - los
s: 0.2631 - acc: 0.8903 - val_loss: 0.3736 - val_acc: 0.8477
```

In [0]:

```
score = model_resnet.evaluate(X_test_sub, y_test_sub, verbose=0)
print("Test loss: {:.3f}".format(score[0]))
print("Test Accuracy: {:.3f}".format(score[1]))
```

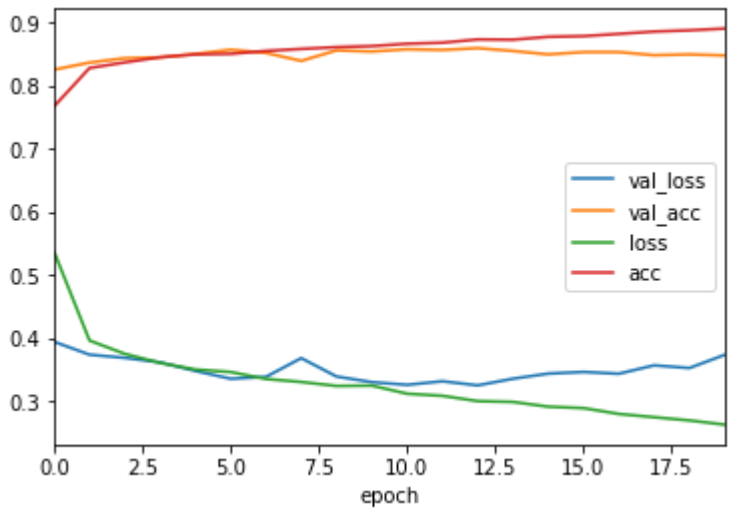
```
Test loss: 0.374
Test Accuracy: 0.848
```

In [0]:

```
pd.DataFrame(history_callback_resnet.history).plot()
plt.xlabel('epoch')
```

Out[0]:

```
Text(0.5, 0, 'epoch')
```



Without Residual Connection

In [0]:

```
from keras.layers import Input, Conv2D, MaxPooling2D, Flatten, add
from keras.models import Model

num_classes = 2
inputs = Input(shape=(50, 50, 3))
#next
conv1_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(inputs)
conv1_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv1_1)
conv1_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv1_2)
maxpool1 = MaxPooling2D(pool_size=(2, 2))(conv1_3)
conv2_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool1)
conv2_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv2_1)
conv2_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv2_2)
maxpool2 = MaxPooling2D(pool_size=(2, 2))(conv2_3)

conv3_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool2)
conv3_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv3_1)
conv3_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv3_2)
maxpool3 = MaxPooling2D(pool_size=(2, 2))(conv3_3)

conv4_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool3)
conv4_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv4_1)
conv4_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv4_2)
maxpool4 = MaxPooling2D(pool_size=(2, 2))(conv4_3)

conv5_1 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(maxpool4)
conv5_2 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv5_1)
conv5_3 = Conv2D(32, (3, 3), activation='relu',
                 padding='same')(conv5_2)
maxpool5 = MaxPooling2D(pool_size=(2, 2))(conv5_3)

flat = Flatten()(maxpool5)
dense = Dense(64, activation='relu')(flat)
predictions = Dense(num_classes, activation='softmax')(dense)
model_noresnet = Model(inputs=inputs, outputs=predictions)
```

In [0]:

```
model_noresnet.compile(optimizer='adam',loss='categorical_crossentropy',
                       metrics=['accuracy'])
```

In [0]:

```
history_callback_noresnet = model_noresnet.fit(X_train_sub, y_train_sub, batch_s
ize=256,
                                    epochs=20, verbose=1,
                                    validation_data = [X_test_sub, y_test_sub])
```

```
Train on 45791 samples, validate on 15264 samples
Epoch 1/20
45791/45791 [==============================] - 21s 469us/step - los
s: 0.5039 - acc: 0.7578 - val_loss: 0.3937 - val_acc: 0.8252
Epoch 2/20
45791/45791 [==============================] - 14s 304us/step - los
s: 0.3948 - acc: 0.8270 - val_loss: 0.3657 - val_acc: 0.8391
Epoch 3/20
45791/45791 [==============================] - 14s 307us/step - los
s: 0.3705 - acc: 0.8387 - val_loss: 0.3603 - val_acc: 0.8411
Epoch 4/20
45791/45791 [==============================] - 14s 307us/step - los
s: 0.3612 - acc: 0.8437 - val_loss: 0.3851 - val_acc: 0.8362
Epoch 5/20
45791/45791 [==============================] - 14s 310us/step - los
s: 0.3592 - acc: 0.8430 - val_loss: 0.3338 - val_acc: 0.8551
Epoch 6/20
45791/45791 [==============================] - 14s 311us/step - los
s: 0.3496 - acc: 0.8491 - val_loss: 0.3410 - val_acc: 0.8529
Epoch 7/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.3449 - acc: 0.8522 - val_loss: 0.3331 - val_acc: 0.8523
Epoch 8/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.3399 - acc: 0.8544 - val_loss: 0.3658 - val_acc: 0.8348
Epoch 9/20
45791/45791 [==============================] - 14s 307us/step - los
s: 0.3327 - acc: 0.8568 - val_loss: 0.3436 - val_acc: 0.8517
Epoch 10/20
45791/45791 [==============================] - 14s 308us/step - los
s: 0.3302 - acc: 0.8587 - val_loss: 0.3309 - val_acc: 0.8579
Epoch 11/20
45791/45791 [==============================] - 14s 308us/step - los
s: 0.3231 - acc: 0.8619 - val_loss: 0.3395 - val_acc: 0.8555
Epoch 12/20
45791/45791 [==============================] - 14s 308us/step - los
s: 0.3171 - acc: 0.8646 - val_loss: 0.3304 - val_acc: 0.8539
Epoch 13/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.3093 - acc: 0.8674 - val_loss: 0.3261 - val_acc: 0.8595
Epoch 14/20
45791/45791 [==============================] - 14s 313us/step - los
s: 0.3118 - acc: 0.8667 - val_loss: 0.3098 - val_acc: 0.8652
Epoch 15/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.3032 - acc: 0.8704 - val_loss: 0.3105 - val_acc: 0.8665
Epoch 16/20
45791/45791 [==============================] - 14s 307us/step - los
s: 0.2977 - acc: 0.8750 - val_loss: 0.3295 - val_acc: 0.8564
Epoch 17/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.2955 - acc: 0.8750 - val_loss: 0.3245 - val_acc: 0.8572
Epoch 18/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.2914 - acc: 0.8772 - val_loss: 0.3152 - val_acc: 0.8674
Epoch 19/20
45791/45791 [==============================] - 14s 309us/step - los
s: 0.2863 - acc: 0.8784 - val_loss: 0.3061 - val_acc: 0.8706
Epoch 20/20
45791/45791 [==============================] - 14s 311us/step - los
s: 0.2844 - acc: 0.8807 - val_loss: 0.3133 - val_acc: 0.8645
```

In [0]:

```
score = model_noresnet.evaluate(X_test_sub, y_test_sub, verbose=0)
print("Test loss: {:.3f}".format(score[0]))
print("Test Accuracy: {:.3f}".format(score[1]))
```

```
Test loss: 0.313
Test Accuracy: 0.864
```

In [0]:

```
pd.DataFrame(history_callback_noresnet.history).plot()
plt.xlabel('epoch')
```

Out[0]:

```
Text(0.5, 0, 'epoch')
```