In [139]:
```
# Libraries used
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import numpy as np
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow import keras
import pickle
```

read data

In [71]:
```
# check current Directory
import os
os.getcwd()
```

Out[71]:
```
'C:\\Users\\tanch\\OneDrive\\Documents\\Kaggle\\digit-recognizer\\dataset'
```

In [72]:
```
# set directory to the folder containing the dataset
os.chdir('C:\\Users\\tanch\\OneDrive\\Documents\\Kaggle\\digit-recognizer\\dataset')
```

In [73]:
```
# read the csv as data frame
total_training_set = pd.read_csv('train.csv')
total_test_set = pd.read_csv('test.csv')
```

Basic data exploration

In [74]:
```
# first column is the labels
total_training_set.head()
```

Out[74]:

	label	pixel0	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	...	pixel774	pixel775	pixel77
0	1	0	0	0	0	0	0	0	0	0	...	0	0	
1	0	0	0	0	0	0	0	0	0	0	...	0	0	
2	1	0	0	0	0	0	0	0	0	0	...	0	0	
3	4	0	0	0	0	0	0	0	0	0	...	0	0	
4	0	0	0	0	0	0	0	0	0	0	...	0	0	

5 rows × 785 columns

In [75]:
```
total_test_set.head()
```

Out[75]:

	pixel0	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel774	pixel775	pixel7
0	0	0	0	0	0	0	0	0	0	0	...	0	0	
1	0	0	0	0	0	0	0	0	0	0	...	0	0	
2	0	0	0	0	0	0	0	0	0	0	...	0	0	
3	0	0	0	0	0	0	0	0	0	0	...	0	0	
4	0	0	0	0	0	0	0	0	0	0	...	0	0	

5 rows × 784 columns

In [76]:
```
# split predictors from labels
y_train_full = total_training_set['label']
X_train_full = total_training_set.drop(['label'],axis=1)
```

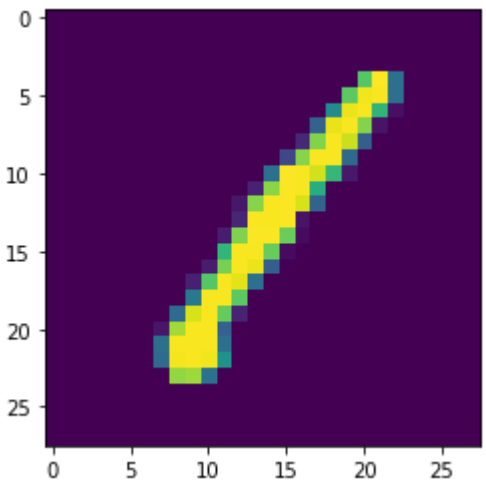
In [77]:
```
print('Training set has {} images with {} pixels.'.format(X_train_full.shape[0],X_train
print('Test set has {} images with {} pixels.'.format(total_test_set.shape[0],total_tes
```

```
Training set has 42000 images with 784 pixels.
Test set has 28000 images with 784 pixels.
```

In [78]:
```
# visualise a row to check validity
row = 0
print('Row {} is number {}.'.format(row,y_train_full[row]))
                                    # reshaped each row to 28 x 28 matrix
plt.imshow(X_train_full.values.reshape((42000,28,28))[row])
```

```
Row 0 is number 1.
```

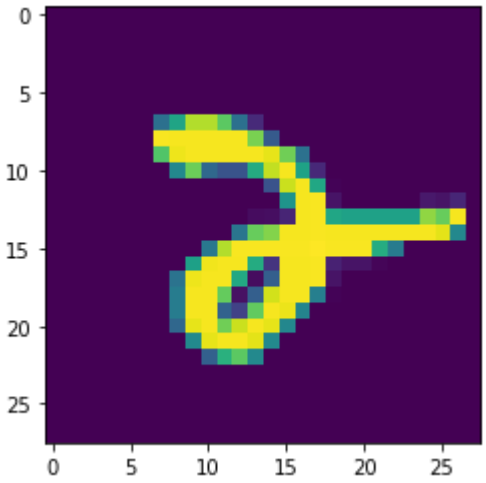
Out[78]:
```
<matplotlib.image.AxesImage at 0x1cdbb78b308>
```



In [79]:
```
# visualise a row to check validity
row = 34
print('Row {} is number {}.'.format(row,y_train_full[row]))
                              # reshaped each row to 28 x 28 matrix
plt.imshow(X_train_full.values.reshape((42000,28,28))[row])
```

```
Row 34 is number 2.
```

Out[79]:
```
<matplotlib.image.AxesImage at 0x1cdbb8e2788>
```



Data Preprocessing

In [80]:
```
# reshape data to 28 x 28 x 1 dimension, required by the CNN model
                          # .values turns data frame to a matrix
X_train_full= X_train_full.values.reshape((42000,28,28,1))
X_test= total_test_set.values.reshape((28000,28,28,1))
```

In [81]:
```
# convert pixels to float values within [0,1]
X_train_full=X_train_full/255.
X_test=X_test/255.
```

In [82]:
```
# split to training and validation sets using train_test_split function
X_train, X_valid, y_train, y_valid = train_test_split(X_train_full, y_train_full, test_
```

In [83]:
```
X_train.shape, X_valid.shape, y_train.shape, y_valid.shape
```

Out[83]:
```
((31500, 28, 28, 1), (10500, 28, 28, 1), (31500,), (10500,))
```

In [84]:
```
# check dimensions
print('Training set Dimensions: \n\tX: {}\n\ty: {}'.format(X_train.shape,y_train.shape)
print('Validation set Dimensions: \n\tX: {}\n\ty: {}'.format(X_valid.shape,y_valid.shap
print('Test set Dimensions: \n\tX: {}'.format(X_test.shape))
```

```
Training set Dimensions:
        X: (31500, 28, 28, 1)
        y: (31500,)
Validation set Dimensions:
        X: (10500, 28, 28, 1)
        y: (10500,)
Test set Dimensions:
        X: (28000, 28, 28, 1)
```

Build Convolutional Neural Network

In [85]:
```
# setting seed to make results reproduceable
np.random.seed(1)
tf.random.set_seed(1)
```

In [86]:
```
# create ImageDataGenerator that augments image
train_datagen = ImageDataGenerator( # the generator can choose any value within these r
                                    rotation_range=40,
                                    width_shift_range=0.2,
                                    height_shift_range=0.2,
                                    shear_range=0.2,
                                    zoom_range=0.2,
                                    horizontal_flip=True,
                                    vertical_flip=True  )


# data augmentation NOT required in validation set
test_datagen = ImageDataGenerator()
```

In [87]:
```
# generators to feed data into the model
train_generator = train_datagen.flow(X_train, y_train,
                                     # image will be fed in this batch sizes
                                     batch_size=32)
validation_generator = test_datagen.flow(X_valid, y_valid,
                                     # image will be fed in this batch sizes
                                     batch_size=32)
```

In [98]:
```
# create NN object using sequential API
model=keras.models.Sequential()

# add convolutional layer
model.add(keras.layers.Conv2D(filters=32,
                              # i.e. filter size
                             kernel_size=(3,3),
                              # i.e. number of steps each filter takes
                             strides=1,
                              # this padding ignores input borders
                              padding='valid',
                              activation='relu',
                              # FOR COLORED IMAGES ,28x28x3 instead
                              input_shape=(28,28,1)))

# max pooling taking max value from 2x2 grid
model.add(keras.layers.MaxPooling2D((2,2)))


                         # 64 filters of size 3x3
model.add(keras.layers.Conv2D( 64, (3,3), activation='relu',input_shape=(150,150,3)))
model.add(keras.layers.MaxPooling2D((2,2)))

                         # 128 filters of size 3x3
model.add(keras.layers.Conv2D( 128, (3,3), activation='relu',input_shape=(150,150,3)))
model.add(keras.layers.MaxPooling2D((2,2)))


# flatten into a single array
model.add(keras.layers.Flatten())

# in every epoch a percentage of neurons are deactivated to reduce interneuron dependen
model.add(keras.layers.Dropout(0.4))

# add a hidden layer of 300 neurons with relu activation
model.add(keras.layers.Dense(300,activation='relu'))
# add a hidden layer of 100 neurons with relu activation
model.add(keras.layers.Dense(100,activation='relu'))

# add output layer of 10 neurons(there are 10 classes) with softmax activation
model.add(keras.layers.Dense(10,activation='softmax'))
```

In [97]:
```
model.summary()
```

```
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_9 (Conv2D)            (None, 26, 26, 32)        320
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 13, 13, 32)        0
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 11, 11, 64)        18496
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 5, 5, 64)          0
_________________________________________________________________
flatten_4 (Flatten)          (None, 1600)              0
_________________________________________________________________
dropout_3 (Dropout)          (None, 1600)              0
_________________________________________________________________
dense_12 (Dense)             (None, 300)               480300
_________________________________________________________________
dense_13 (Dense)             (None, 100)               30100
_________________________________________________________________
dense_14 (Dense)             (None, 10)                1010
=================================================================
Total params: 530,226
Trainable params: 530,226
Non-trainable params: 0
_________________________________________________________________
```

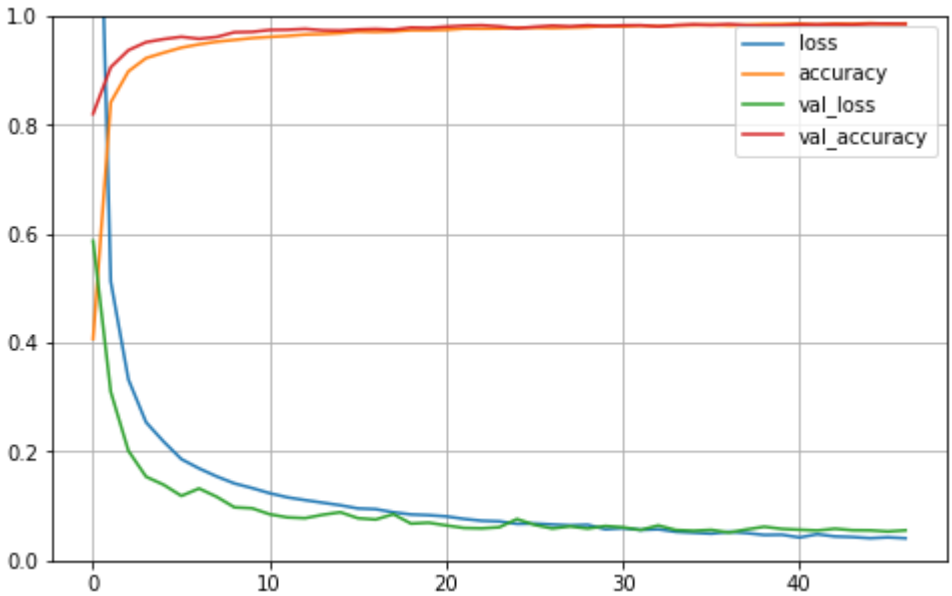
In [99]:
```
# setting parameters
model.compile(loss='sparse_categorical_crossentropy',
              # sgd refers to stochastic gradient descent
              optimizer='sgd',
              metrics=['accuracy'])
```

In [100]:
```
# model is saved when validation accuracy does not improve after the patience value
checkpoint_cb = keras.callbacks.ModelCheckpoint('CNN_early_stopping_model.h5',save_best
                                                # if there are no improvements after 10
early_stopping_cb = keras.callbacks.EarlyStopping(patience = 10,
                                                  restore_best_weights = True)
```

In [101]:
```
# training the model
number_of_epochs = 1000
model_history = model.fit(X_train,y_train,
                          validation_data=(X_valid,y_valid),
                          epochs=number_of_epochs,
                          callbacks= [checkpoint_cb, early_stopping_cb])
```

```
Train on 31500 samples, validate on 10500 samples
Epoch 1/1000
31500/31500 [==============================] - 38s 1ms/sample - loss: 1.7504 - accu
racy: 0.4070 - val_loss: 0.5869 - val_accuracy: 0.8203
Epoch 2/1000
31500/31500 [==============================] - 38s 1ms/sample - loss: 0.5127 - accu
racy: 0.8416 - val_loss: 0.3100 - val_accuracy: 0.9060
Epoch 3/1000
31500/31500 [==============================] - 39s 1ms/sample - loss: 0.3325 - accu
racy: 0.8985 - val_loss: 0.2014 - val_accuracy: 0.9372
Epoch 4/1000
31500/31500 [==============================] - 39s 1ms/sample - loss: 0.2538 - accu
racy: 0.9227 - val_loss: 0.1539 - val_accuracy: 0.9520
Epoch 5/1000
31500/31500 [==============================] - 41s 1ms/sample - loss: 0.2182 - accu
racy: 0.9327 - val_loss: 0.1390 - val_accuracy: 0.9576
Epoch 6/1000
31500/31500 [==============================] - 43s 1ms/sample - loss: 0.1862 - accu
racy: 0.9420 - val_loss: 0.1187 - val_accuracy: 0.9618
```

In [102]:
```
# visualise the training progression
pd.DataFrame(model_history.history).plot(figsize=(8,5))
plt.grid(True)
plt.gca().set_ylim(0,1)
plt.show()
```



In [114]:
```
with open('trainHistoryDict.pickle', 'wb') as file_pi:
    pickle.dump(model_history.history, file_pi)
```

- evidently, there is **very little overfitting** because the difference in train and validation accuracy is little

Make Predictions

In [118]:
```
# the test set
total_test_set.head()
```

Out[118]:

	pixel0	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	...	pixel774	pixel775	pixel7
0	0	0	0	0	0	0	0	0	0	0	...	0	0	
1	0	0	0	0	0	0	0	0	0	0	...	0	0	
2	0	0	0	0	0	0	0	0	0	0	...	0	0	
3	0	0	0	0	0	0	0	0	0	0	...	0	0	
4	0	0	0	0	0	0	0	0	0	0	...	0	0	

5 rows × 784 columns

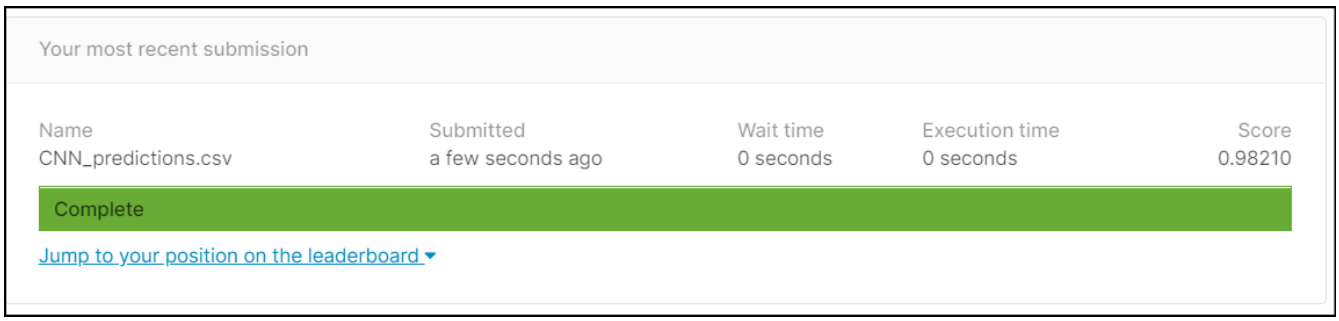
In [119]:
```
# make class predictions
y_pred = model.predict_classes(X_test)
y_pred
```

Out[119]:
```
array([2, 0, 9, ..., 3, 9, 2], dtype=int64)
```

In [128]:
```
# create the output in required format
predictions_dict={'ImageId':range(1,28001),'Label':y_pred}
output_df = pd.DataFrame(predictions_dict).set_index('ImageId')
```

In [136]:
```
# set directory and output the predictions
os.chdir('C:\\Users\\tanch\\OneDrive\\Documents\\Kaggle\\digit-recognizer')
output_df.to_csv('CNN_predictions.csv')
```

results



- not too bad for first try
- ranking is 1725 out of 2900+

reload model and training history in future

In [137]:
```
# # delete model
# del model
# keras.backend.clear_session()
```

In [115]:
```
# to load the model and history again
# model = keras.models.load_model('CNN_early_stopping_model.h5')
# with open('trainHistoryDict.pickle', 'rb') as file_pi:
#     new_hist=pickle.load(file_pi, encoding='bytes')
```

In [ ]:
```

```