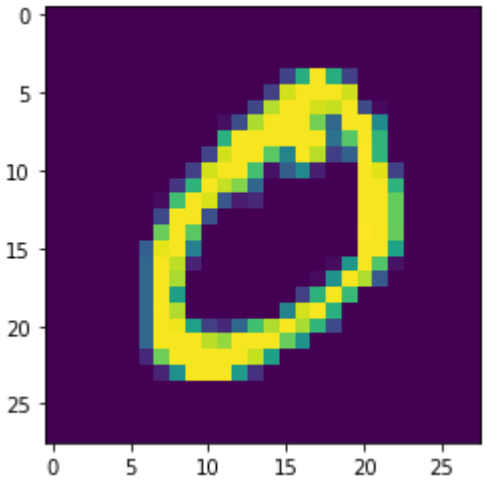
In [113]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

In [114]:
```
from keras.datasets import mnist
```

In [115]:
```
(X_train, y_train), (X_test, y_test) = mnist.load_data()
```

In [116]:
```
plt.imshow(X_train[1])
```

Out[116]:
```
<matplotlib.image.AxesImage at 0x181178ed908>
```



In [117]:
```
print(X_train[1].max(), X_train[1].min())
```

```
255 0
```

In [118]:
```
y_train
```

Out[118]:
```
array([5, 0, 4, ..., 5, 6, 8], dtype=uint8)
```

In [119]:
```
X_train = X_train/255
```

In [120]:
```
X_test = X_test/255
```

In [121]:
```
from keras.utils import to_categorical
```

In [122]:
```
y_cat_train = to_categorical(y_train)
```

In [123]:
```
y_cat_train
```

Out[123]:
```
array([[0., 0., 0., ..., 0., 0., 0.],
       [1., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 1., 0.]], dtype=float32)
```

In [124]:
```
y_cat_test = to_categorical(y_test)
```

In [125]:
```
X_train = X_train.reshape(60000, 28, 28, 1)
```

In [126]:
```
X_test = X_test.reshape(10000, 28, 28, 1)
```

In [127]:
```
from keras.models import Sequential
from keras.layers import Dense, Conv2D, MaxPool2D, Flatten, Dropout
from keras.callbacks import EarlyStopping
```

In [128]:
```
model = Sequential()
```

In [129]:
```
model.add(Conv2D(filters=32, kernel_size=(4,4), activation='relu', padding='sa
me', input_shape=(28,28,1)))
model.add(MaxPool2D())
model.add(Flatten())
model.add(Dense(units=64, activation='relu'))
model.add(Dense(units=32, activation='relu'))
model.add(Dense(units=10, activation='softmax'))
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc
uracy'])
```

In [132]:
```
early_stop = EarlyStopping(monitor='val_loss', patience=4)
```

In [133]:
```
model.fit(X_train, y_cat_train, batch_size=200, epochs=15, validation_data=(X_
test, y_cat_test), callbacks=[early_stop])
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/15
60000/60000 [==============================] - 71s 1ms/step - loss: 0.2985 -
accuracy: 0.9143 - val_loss: 0.0896 - val_accuracy: 0.9732
Epoch 2/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0840 -
accuracy: 0.9747 - val_loss: 0.0655 - val_accuracy: 0.9789
Epoch 3/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0565 -
accuracy: 0.9825 - val_loss: 0.0501 - val_accuracy: 0.9836
Epoch 4/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0431 -
accuracy: 0.9866 - val_loss: 0.0441 - val_accuracy: 0.9846
Epoch 5/15
60000/60000 [==============================] - 70s 1ms/step - loss: 0.0347 -
accuracy: 0.9896 - val_loss: 0.0420 - val_accuracy: 0.9856
Epoch 6/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0286 -
accuracy: 0.9911 - val_loss: 0.0431 - val_accuracy: 0.9863
Epoch 7/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0226 -
accuracy: 0.9930 - val_loss: 0.0459 - val_accuracy: 0.9850
Epoch 8/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0180 -
accuracy: 0.9946 - val_loss: 0.0528 - val_accuracy: 0.9839
Epoch 9/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0156 -
accuracy: 0.9954 - val_loss: 0.0407 - val_accuracy: 0.9862
Epoch 10/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0119 -
accuracy: 0.9964 - val_loss: 0.0427 - val_accuracy: 0.9869
Epoch 11/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0095 -
accuracy: 0.9973 - val_loss: 0.0418 - val_accuracy: 0.9869
Epoch 12/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0087 -
accuracy: 0.9974 - val_loss: 0.0540 - val_accuracy: 0.9843
Epoch 13/15
60000/60000 [==============================] - 69s 1ms/step - loss: 0.0079 -
accuracy: 0.9976 - val_loss: 0.0501 - val_accuracy: 0.9861
```

Out[133]:
```
<keras.callbacks.callbacks.History at 0x1811977a448>
```

In [134]:
```
model_hist = pd.DataFrame(model.history.history)
```

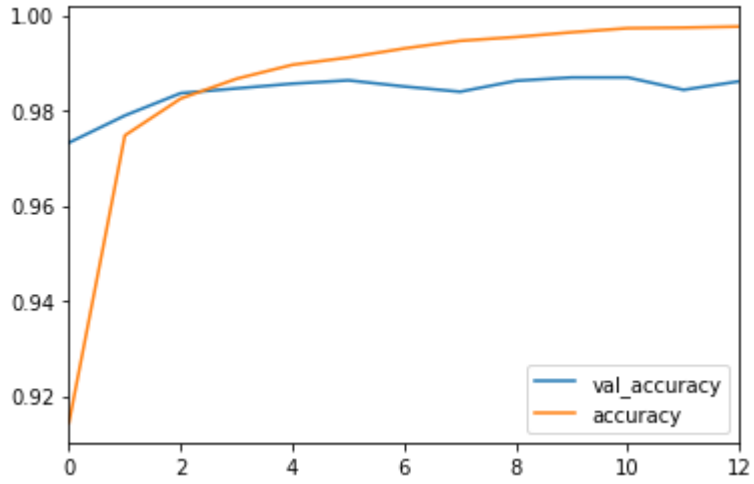
In [135]:
```
model_hist.head()
```

Out[135]:

	val_loss	val_accuracy	loss	accuracy
0	0.089607	0.9732	0.298495	0.914350
1	0.065522	0.9789	0.084036	0.974717
2	0.050092	0.9836	0.056484	0.982467
3	0.044078	0.9846	0.043068	0.986633
4	0.042035	0.9856	0.034715	0.989567

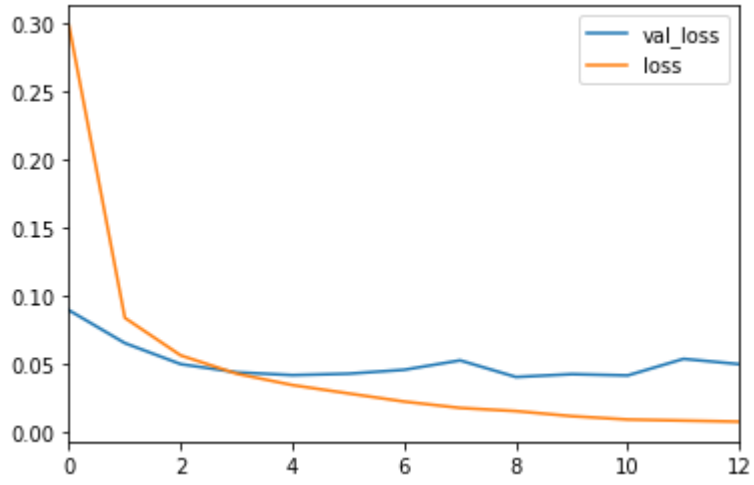
In [136]:
```
model_hist[['val_accuracy','accuracy']].plot()
```

Out[136]: <matplotlib.axes._subplots.AxesSubplot at 0x18119286f88>



In [137]:
```
model_hist[['val_loss','loss']].plot()
```

Out[137]: <matplotlib.axes._subplots.AxesSubplot at 0x18142ed37c8>



In [138]:
```
y_pred = model.predict_classes(X_test)
```

In [139]:
```
from sklearn.metrics import classification_report, confusion_matrix, accuracy_
score
```

In [141]:
```
accuracy_score(y_test, y_pred)
```

Out[141]:
```
0.9861
```

In [142]:
```
confusion_matrix(y_test, y_pred)
```

Out[142]:
```
array([[ 977,    0,    1,    1,    0,    0,    1,    0,    0,    0],
       [   0, 1125,    3,    2,    0,    0,    2,    1,    2,    0],
       [   0,    1, 1023,    0,    1,    0,    0,    7,    0,    0],
       [   0,    0,    4, 1002,    0,    3,    0,    1,    0,    0],
       [   2,    1,    6,    0,  948,    0,    3,    1,    3,   18],
       [   2,    0,    0,    8,    0,  880,    1,    0,    0,    1],
       [   5,    2,    1,    0,    1,    1,  947,    0,    1,    0],
       [   0,    0,    7,    0,    0,    0,    0, 1015,    2,    4],
       [   5,    0,    7,    2,    0,    2,    1,    1,  951,    5],
       [   0,    1,    0,    4,    3,    2,    0,    5,    1,  993]],
      dtype=int64)
```

In [144]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.99      1.00      0.99       980
           1       1.00      0.99      0.99      1135
           2       0.97      0.99      0.98      1032
           3       0.98      0.99      0.99      1010
           4       0.99      0.97      0.98       982
           5       0.99      0.99      0.99       892
           6       0.99      0.99      0.99       958
           7       0.98      0.99      0.99      1028
           8       0.99      0.98      0.98       974
           9       0.97      0.98      0.98      1009

    accuracy                           0.99     10000
   macro avg       0.99      0.99      0.99     10000
weighted avg       0.99      0.99      0.99     10000
```

In [ ]: