In [1]:
```
### BREAST CANCER CASES ###
###### CONVOLUTIONAL NEURAL NETWORK CODE IN JUPYTER NOTEBOOK FOR BOTH SEX #####
```

In [2]:
```
## Modules required
import pandas as pd
import numpy as np
from scipy import misc
from PIL import Image
import glob
from matplotlib.pyplot import imshow
import seaborn as sn
import pickle
from keras.preprocessing import image
from keras.preprocessing.image import load_img
from keras.preprocessing.image import img_to_array
from keras.applications.imagenet_utils import decode_predictions
from keras.utils import layer_utils, np_utils
from keras.utils.data_utils import get_file
from keras.applications.imagenet_utils import preprocess_input
from keras.utils.vis_utils import model_to_dot
from keras.utils import plot_model
from keras.initializers import glorot_uniform
from keras import losses
import keras.backend as K
from keras.callbacks import ModelCheckpoint
from sklearn.metrics import confusion_matrix, classification_report
from keras import layers
from IPython.display import SVG
import matplotlib.pyplot as plt
%matplotlib inline
import keras
import tensorflow as tf
from tensorflow.keras.models import Sequential, Model, load_model
from tensorflow.keras.layers import Dense,Dropout, Activation, Flatten, Input, Add,
ZeroPadding2D, Conv2D, MaxPooling2D
from hyperopt import Trials, STATUS_OK, tpe
from hyperas import optim
from hyperas.distributions import choice, uniform
```

In [3]:
```
# Code
BC = (pd.read_excel('cancer.xlsx'))
```

In [4]:
```
BC.head()
```

Out[4]:

	PatStatus	Race	MarST	Gender	AgeDiag	Grade	Stability	No.Visits	Lstay	Laterality	...	LyNode	Amorp
0	1	3	1	0	52	3	0	5	1	4	...	1	
1	1	3	1	0	48	3	0	4	3	5	...	1	
2	0	3	0	0	69	2	0	7	9	8	...	1	
3	1	3	0	0	47	2	0	15	9	9	...	1	
4	1	3	0	0	66	3	0	9	5	4	...	1	

5 rows × 25 columns

In [5]:
```
## Reshaping into array
import random
random.seed(30)
BC.iloc[3,1:].values.reshape(6,4).astype('int8')
```

Out[5]:
```
array([[ 3,  0,  0, 47],
       [ 2,  0, 15,  9],
       [ 9,  1,  1,  0],
       [ 3,  1,  1,  1],
       [ 2,  0,  1,  1],
       [ 0,  1,  0,  1]], dtype=int8)
```

In [6]:
```
## Preprocessing the data
```

In [7]:
```
## Storing the independent variables array in form length, width, height into df_x
random.seed(31)
df_x = BC.iloc[:,1:].values.reshape(len(BC), 6, 4, 1)

## Storing the dependent variables in y
y = BC.iloc[:,0].values
```

In [8]:
```
# converting y to categorical
df_y = keras.utils.to_categorical(y, num_classes = 2)
```

In [9]:
```
df_x =np.array(df_x)
df_y = np.array(df_y)
```

In [10]:
```
df_y
```

Out[10]:
```
array([[0., 1.],
       [0., 1.],
       [1., 0.],
       ...,
       [1., 0.],
       [1., 0.],
       [1., 0.]], dtype=float32)
```

In [11]:
```
df_x.shape
```

Out[11]:
```
(100002, 6, 4, 1)
```

In [12]:
```
df_y.shape
```

Out[12]:
```
(100002, 2)
```

In [13]:
```
#Import 'train_test_split' from 'sklearn.model_selection'
from sklearn.model_selection import train_test_split

#Import numpy#
import numpy as np
random.seed(32)
#Split the data into train and test sets #
x_train, x_test, y_train, y_test=train_test_split(df_x,df_y, test_size=0.2, random_
state=123)
```

In [14]:
```
x_test.shape
```

Out[14]:
```
(20001, 6, 4, 1)
```

In [15]:
```
y_test.shape
```

Out[15]:
```
(20001, 2)
```

In [16]:
```
### CNN Model
random.seed(33)
model = Sequential()
model.add(Conv2D(64, (3,3), input_shape = (6, 4, 1)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(1,1)))
model.add(Dropout(0.25))

model.add(Flatten())
model.add(Dense(64))
model.add(Dropout(0.25))

model.add(Dense(2))
model.add(Activation('sigmoid'))
model.compile(loss="categorical_crossentropy", optimizer="adam", metrics=['accuracy
'])
```

In [17]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 4, 2, 64)          640
_________________________________________________________________
activation (Activation)      (None, 4, 2, 64)          0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 4, 2, 64)          0
_________________________________________________________________
dropout (Dropout)            (None, 4, 2, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 512)               0
_________________________________________________________________
dense (Dense)                (None, 64)                32832
_________________________________________________________________
dropout_1 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 130
_________________________________________________________________
activation_1 (Activation)    (None, 2)                 0
=================================================================
Total params: 33,602
Trainable params: 33,602
Non-trainable params: 0
_________________________________________________________________
```

In [18]:
```
## fitting the model with
CNN_MODEL = model.fit(x_train, y_train, batch_size=40, epochs=10, validation_data=
(x_test, y_test))
```

```
Epoch 1/10
2001/2001 [==============================] - 13s 7ms/step - loss: 0.3387 - accur
acy: 0.8379 - val_loss: 0.2326 - val_accuracy: 0.8915
Epoch 2/10
2001/2001 [==============================] - 14s 7ms/step - loss: 0.2471 - accur
acy: 0.8881 - val_loss: 0.2079 - val_accuracy: 0.9009
Epoch 3/10
2001/2001 [==============================] - 13s 7ms/step - loss: 0.2326 - accur
acy: 0.8909 - val_loss: 0.2095 - val_accuracy: 0.8984
Epoch 4/10
2001/2001 [==============================] - 16s 8ms/step - loss: 0.2242 - accur
acy: 0.8943 - val_loss: 0.1988 - val_accuracy: 0.9043
Epoch 5/10
2001/2001 [==============================] - 13s 7ms/step - loss: 0.2198 - accur
acy: 0.8934 - val_loss: 0.1974 - val_accuracy: 0.9044
Epoch 6/10
2001/2001 [==============================] - 14s 7ms/step - loss: 0.2145 - accur
acy: 0.8953 - val_loss: 0.1952 - val_accuracy: 0.8992
Epoch 7/10
2001/2001 [==============================] - 14s 7ms/step - loss: 0.2141 - accur
acy: 0.8957 - val_loss: 0.1913 - val_accuracy: 0.9083
Epoch 8/10
2001/2001 [==============================] - 13s 7ms/step - loss: 0.2089 - accur
acy: 0.8982 - val_loss: 0.1913 - val_accuracy: 0.9082
Epoch 9/10
2001/2001 [==============================] - 14s 7ms/step - loss: 0.2079 - accur
acy: 0.8986 - val_loss: 0.1884 - val_accuracy: 0.9079
Epoch 10/10
2001/2001 [==============================] - 15s 7ms/step - loss: 0.2078 - accur
acy: 0.8973 - val_loss: 0.1882 - val_accuracy: 0.9075
```

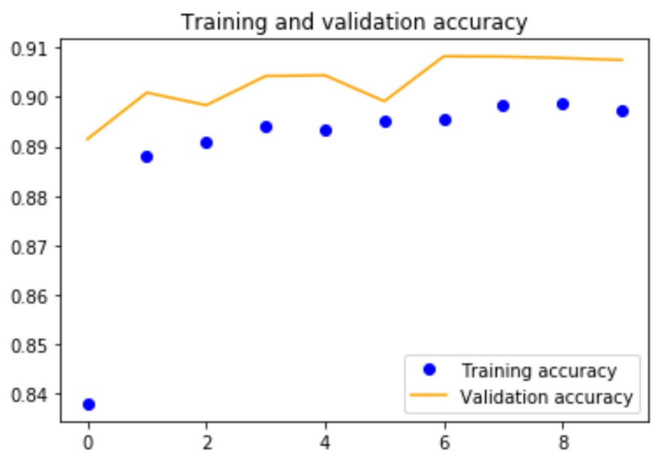
In [19]:
```
## MODEL EVALUATION FOR BOTH SEX
```

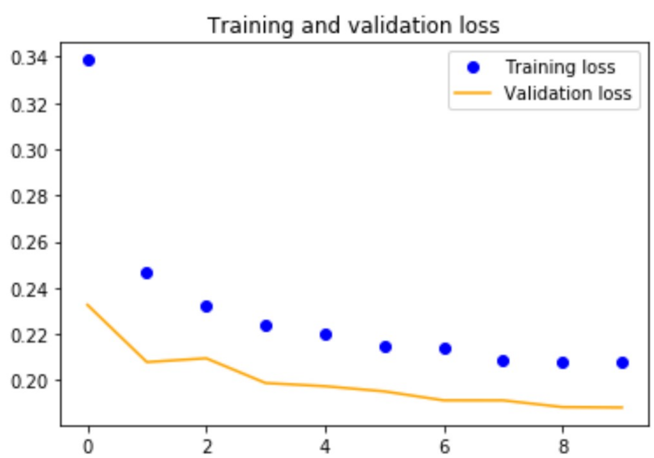
In [20]:
```
## Prediction loss and accuracy
test_eval = model.evaluate(x_test, y_test, verbose=0)[1]
```

In [21]:
```
print('Test accuracy:', test_eval)
```

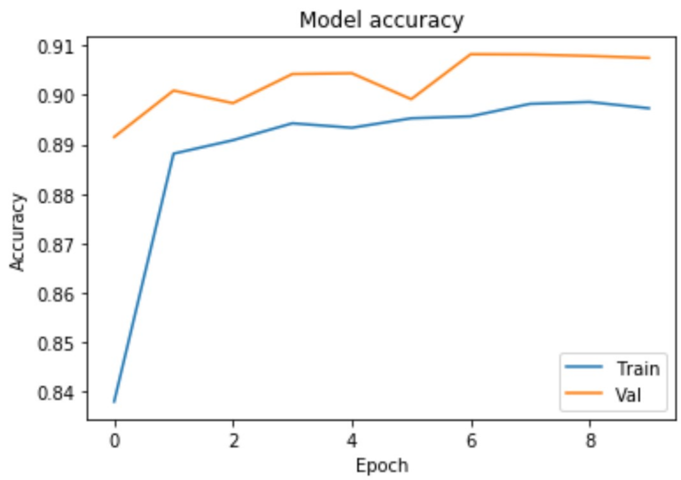
```
Test accuracy: 0.9075046181678772
```

In [22]:
```
##plot the accuracy and loss plots between training and validation data to check fo
r over-fitting

import numpy as np
from keras.utils import to_categorical
import matplotlib.pyplot as plt
%matplotlib inline

accuracy = CNN_MODEL.history['accuracy']
val_accuracy = CNN_MODEL.history['val_accuracy']
loss = CNN_MODEL.history['loss']
val_loss = CNN_MODEL.history['val_loss']
epochs = range(len(accuracy))
plt.plot(epochs, accuracy, 'bo', label='Training accuracy')
plt.plot(epochs, val_accuracy, 'orange', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'orange', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```





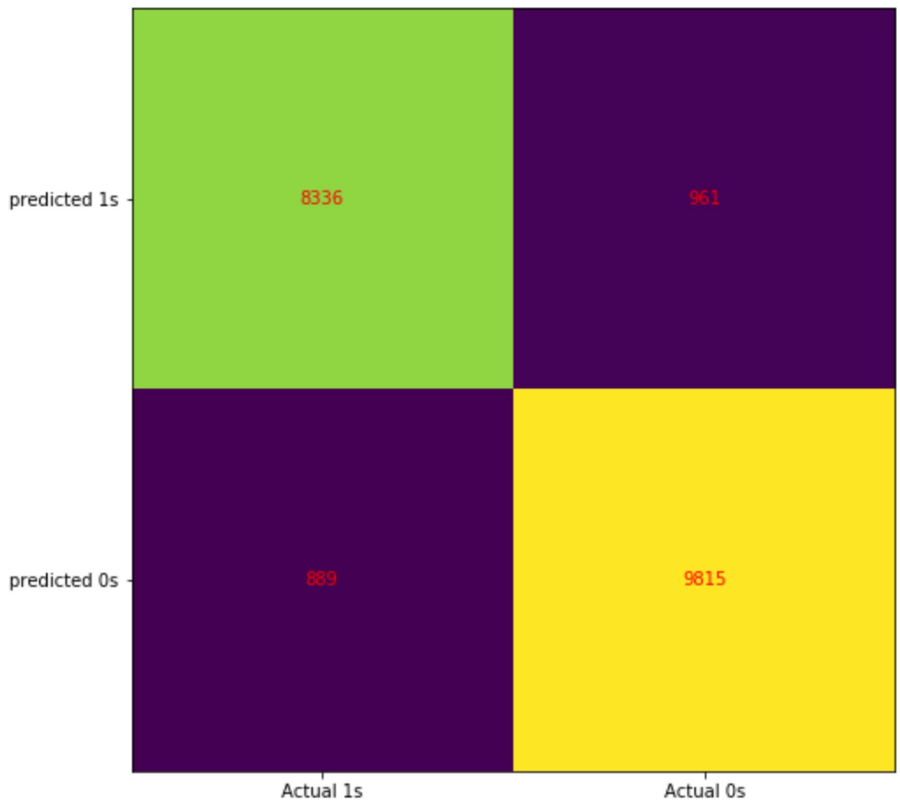
In [23]:
```
##plot our training accuracy and validation accuracy
plt.plot(CNN_MODEL.history['accuracy'])
plt.plot(CNN_MODEL.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='lower right')
plt.show()
```



In [24]:
```
## Predicting using CNN
CNN_MODEL_pred = model.predict(x_test, batch_size=32, verbose=1)
CNN_MODEL_predicted = np.argmax(CNN_MODEL_pred, axis=1)
```

```
626/626 [==============================] - 1s 1ms/step
```

In [25]:
```
## Confusion matrix for the CNN
CNN_MODEL_cm = confusion_matrix(np.argmax(y_test, axis=1), CNN_MODEL_predicted)
fig, ax = plt.subplots(figsize = (8, 8))
ax.imshow(CNN_MODEL_cm)
ax.grid(False)
ax.xaxis.set(ticks=(0,1), ticklabels=('Actual 1s', 'Actual 0s'))
ax.yaxis.set(ticks=(0,1), ticklabels=('predicted 1s', 'predicted 0s'))
ax.set_ylim(1.5, -0.5)
for i in range(2):
    for j in range(2):
        ax.text(j, i, CNN_MODEL_cm[i, j], ha= 'center', va= 'center', color= 'red')
plt.show()
```



In [26]:
```
test_cm = CNN_MODEL_cm
```

In [27]:
```
## Sensitivity Analysis
test_sens = test_cm[1, 1]/(test_cm[1, 1] + test_cm[0, 1])
print(test_sens)
```

```
0.9108203414996288
```

In [28]:
```
## Specificity Analysis
test_spec = test_cm[0, 0]/(test_cm[0, 0]+test_cm[1, 0])
print(test_spec)
```

```
0.9036314363143632
```

In [29]:
```
## PPV Analysis
test_npv = test_cm[1, 1]/(test_cm[1, 1] + test_cm[1, 0])
print(test_npv)
```

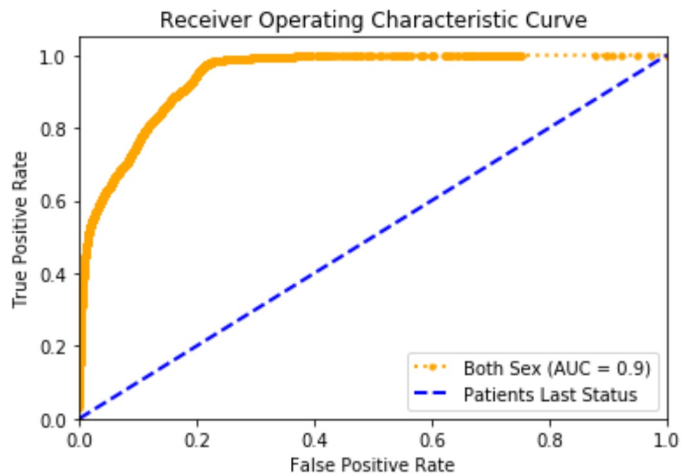
```
0.9169469357249627
```

In [30]:
```
## NPV Analysis
test_npv = test_cm[0, 0]/(test_cm[0, 0]+test_cm[0, 1])
print(test_npv)
```

```
0.8966333225771754
```

In [31]:
```
from sklearn.datasets import make_classification
from sklearn.preprocessing import label_binarize
from scipy import interp
from itertools import cycle

n_classes = 1

from sklearn.metrics import roc_curve, auc

# Plot linewidth.
lw = 8

# Compute ROC curve and ROC area for each class
fpr = dict()
tpr = dict()
roc_auc = dict()
for i in range(n_classes):
    fpr[i], tpr[i], _ = roc_curve(y_test[:, i], CNN_MODEL_pred[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Compute micro-average ROC curve and ROC area
fpr["micro"], tpr["micro"], _ = roc_curve(y_test.ravel(), CNN_MODEL_pred.ravel())
roc_auc["micro"] = auc(fpr["micro"], tpr["micro"])

# Compute macro-average ROC curve and ROC area

# First aggregate all false positive rates
all_fpr = np.unique(np.concatenate([fpr[i] for i in range(n_classes)]))

# Then interpolate all ROC curves at this points
mean_tpr = np.zeros_like(all_fpr)
for i in range(n_classes):
    mean_tpr += interp(all_fpr, fpr[i], tpr[i])

# Finally average it and compute AUC
mean_tpr /= n_classes

fpr["macro"] = all_fpr
tpr["macro"] = mean_tpr
roc_auc["macro"] = auc(fpr["macro"], tpr["macro"])

# Plot all ROC curves
plt.figure(1)
plt.plot(fpr["micro"], tpr["micro"],
         label='Both Sex (AUC = {0:0.1f})'
               ''.format(roc_auc["micro"]),marker = '.',
         color='orange', linestyle=':', linewidth=2)

plt.plot([0, 1], [0, 1], 'b--', label = 'Patients Last Status',linewidth=2, lw=lw)
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver Operating Characteristic Curve')
plt.legend(loc="lower right")
plt.show()
```

```
C:\Users\eagye\anaconda1\lib\site-packages\ipykernel_launcher.py:33: Deprecation
Warning: scipy.interp is deprecated and will be removed in SciPy 2.0.0, use nump
y.interp instead
C:\Users\eagye\anaconda1\lib\site-packages\ipykernel_launcher.py:49: MatplotlibD
eprecationWarning: Saw kwargs ['lw', 'linewidth'] which are all aliases for 'lin
ewidth'.  Kept value from 'linewidth'.  Passing multiple aliases for the same pr
operty will raise a TypeError in 3.3.
```



In [ ]:

In [ ]:

In [ ]:

In [1]:
```
## CONSIDER THE CONVOLUTIONAL NEURAL NETWORK FOR EACH GENDER SEPARATELY
```

In [2]:
```
## Modules required
import pandas as pd
import numpy as np
from scipy import misc
from PIL import Image
import glob
from matplotlib.pyplot import imshow
import seaborn as sn
import pickle
from keras.preprocessing import image
from keras.preprocessing.image import load_img
from keras.preprocessing.image import img_to_array
from keras.applications.imagenet_utils import decode_predictions
from keras.utils import layer_utils, np_utils
from keras.utils.data_utils import get_file
from keras.applications.imagenet_utils import preprocess_input
from keras.utils.vis_utils import model_to_dot
from keras.utils import plot_model
from keras.initializers import glorot_uniform
from keras import losses
import keras.backend as K
from keras.callbacks import ModelCheckpoint
from sklearn.metrics import confusion_matrix, classification_report
from keras import layers
from IPython.display import SVG
import matplotlib.pyplot as plt
%matplotlib inline
import keras
import tensorflow as tf
from tensorflow.keras.models import Sequential, Model, load_model
from tensorflow.keras.layers import Dense,Dropout, Activation, Flatten, Input, Add,
ZeroPadding2D, Conv2D, MaxPooling2D
from hyperopt import Trials, STATUS_OK, tpe
from hyperas import optim
from hyperas.distributions import choice, uniform
```

In [3]:
```
# Code
MBC = (pd.read_excel('MBC.xlsx'))
```

In [4]:
```
#Import 'train_test_split' from 'sklearn.model_selection'
from sklearn.model_selection import train_test_split
#Import numpy#
import numpy as np
```

In [5]:
```
## CONSIDER FITTING CONVOLUTIONAL NEURAL NETWORK FOR THE MALE GENDER
```

In [6]:
```
MBC.head()
```

Out[6]:

	PatStatus	Race	MarST	Gender	AgeDiag	Grade	Stability	No.Visits	Lstay	Laterality	...	LyNode	Amorp
0	1	3	0	1	61	3	0	9	1	4	...	1	
1	1	3	1	1	63	2	0	3	5	6	...	1	
2	1	3	0	1	67	3	0	8	4	1	...	1	
3	1	3	1	1	51	3	1	9	4	8	...	0	
4	1	3	0	1	56	1	0	9	1	8	...	1	

5 rows × 25 columns

In [7]:
```
## Reshaping into array
MBC.iloc[3,1:].values.reshape(6,4).astype('int8')
```

Out[7]:
```
array([[ 3,  1,  1, 51],
       [ 3,  1,  9,  4],
       [ 8,  1,  1,  0],
       [ 1,  1,  0,  1],
       [ 9,  1,  0,  1],
       [ 0,  1,  0,  0]], dtype=int8)
```

In [8]:
```
## Preprocessing the data
```

In [9]:
```
## Storing the independent variables array in form length, width, height into df_x
df_x = MBC.iloc[:,1:].values.reshape(len(MBC), 6, 4, 1)

## Storing the dependent variables in y
y = MBC.iloc[:,0].values
```

In [10]:
```
# converting y to categorical
df_y = keras.utils.to_categorical(y, num_classes = 2)
```

In [11]:
```
df_x =np.array(df_x)
df_y = np.array(df_y)
```

In [12]:
```
df_y
```

Out[12]:
```
array([[0., 1.],
       [0., 1.],
       [0., 1.],
       ...,
       [1., 0.],
       [1., 0.],
       [1., 0.]], dtype=float32)
```

In [13]:
```
df_x.shape
```

Out[13]:
```
(15599, 6, 4, 1)
```

In [14]:
```
df_y.shape
```

Out[14]:
```
(15599, 2)
```

In [15]:
```
#Import 'train_test_split' from 'sklearn.model_selection'
from sklearn.model_selection import train_test_split

#Import numpy#
import numpy as np
#Split the data into train and test sets #
x_train, x_test, y_train, y_test=train_test_split(df_x,df_y, test_size=0.2, random_
state=123)
```

In [16]:
```
x_test.shape
```

Out[16]:
```
(3120, 6, 4, 1)
```

In [17]:
```
y_test.shape
```

Out[17]:
```
(3120, 2)
```

In [18]:
```
### CNN Model
model = Sequential()
model.add(Conv2D(64, (3,3), input_shape = (6, 4, 1)))
model.add(Activation("relu"))
model.add(MaxPooling2D(pool_size=(1,1)))
model.add(Dropout(0.25))

model.add(Flatten())
model.add(Dense(64))
model.add(Dropout(0.25))

model.add(Dense(2))
model.add(Activation('sigmoid'))
model.compile(loss="categorical_crossentropy", optimizer="adam", metrics=['accuracy
'])
```

In [19]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 4, 2, 64)          640
_________________________________________________________________
activation (Activation)      (None, 4, 2, 64)          0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 4, 2, 64)          0
_________________________________________________________________
dropout (Dropout)            (None, 4, 2, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 512)               0
_________________________________________________________________
dense (Dense)                (None, 64)                32832
_________________________________________________________________
dropout_1 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 130
_________________________________________________________________
activation_1 (Activation)    (None, 2)                 0
=================================================================
Total params: 33,602
Trainable params: 33,602
Non-trainable params: 0
_________________________________________________________________
```

In [20]:
```
## fitting the model with
CNN_MODEL = model.fit(x_train, y_train, batch_size=40, epochs=10, validation_data=
(x_test, y_test))
```

```
Epoch 1/10
312/312 [==============================] - 1s 4ms/step - loss: 0.5219 - accurac
y: 0.7045 - val_loss: 0.3930 - val_accuracy: 0.8240
Epoch 2/10
312/312 [==============================] - 1s 3ms/step - loss: 0.2359 - accurac
y: 0.9140 - val_loss: 0.1334 - val_accuracy: 0.9526
Epoch 3/10
312/312 [==============================] - 1s 4ms/step - loss: 0.1407 - accurac
y: 0.9507 - val_loss: 0.1234 - val_accuracy: 0.9548
Epoch 4/10
312/312 [==============================] - 2s 7ms/step - loss: 0.1234 - accurac
y: 0.9548 - val_loss: 0.1206 - val_accuracy: 0.9497
Epoch 5/10
312/312 [==============================] - 1s 3ms/step - loss: 0.1168 - accurac
y: 0.9578 - val_loss: 0.1221 - val_accuracy: 0.9545
Epoch 6/10
312/312 [==============================] - 1s 3ms/step - loss: 0.1119 - accurac
y: 0.9574 - val_loss: 0.1098 - val_accuracy: 0.9548
Epoch 7/10
312/312 [==============================] - 2s 7ms/step - loss: 0.1063 - accurac
y: 0.9607 - val_loss: 0.1035 - val_accuracy: 0.9564
Epoch 8/10
312/312 [==============================] - 1s 3ms/step - loss: 0.1053 - accurac
y: 0.9594 - val_loss: 0.1070 - val_accuracy: 0.9548
Epoch 9/10
312/312 [==============================] - 2s 7ms/step - loss: 0.1009 - accurac
y: 0.9606 - val_loss: 0.0941 - val_accuracy: 0.9599
Epoch 10/10
312/312 [==============================] - 1s 3ms/step - loss: 0.1017 - accurac
y: 0.9606 - val_loss: 0.0966 - val_accuracy: 0.9599
```

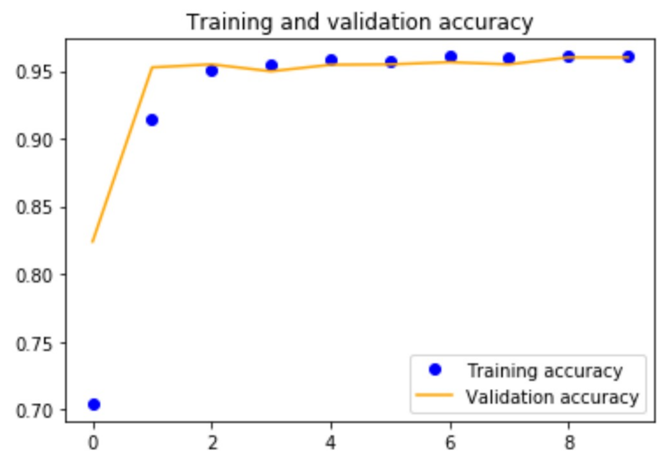
In [21]:
```
## MODEL EVALUATION
```

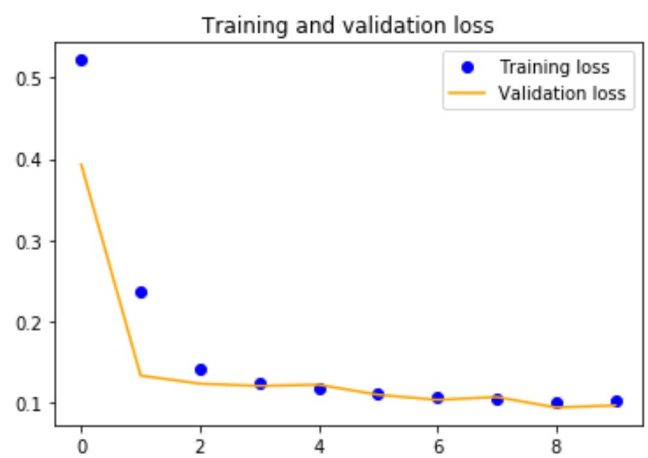
In [22]:
```
## Prediction loss and accuracy
test_eval = model.evaluate(x_test, y_test, verbose=0)[1]
```

In [23]:
```
print('Test accuracy:', test_eval)
```

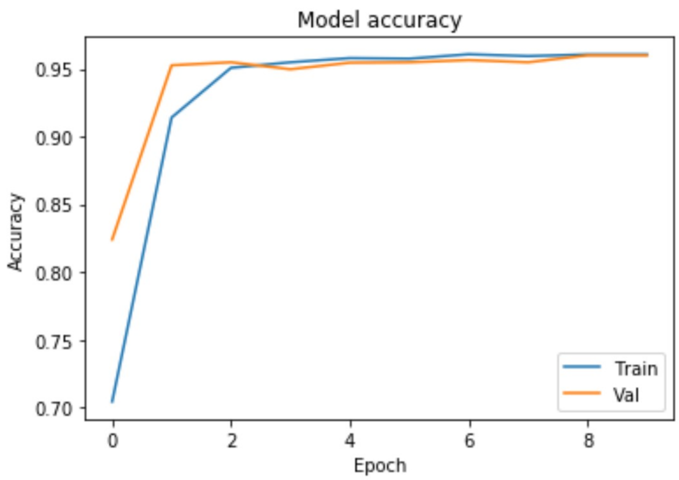
```
Test accuracy: 0.9599359035491943
```

In [24]:
```
##plot the accuracy and loss plots between training and validation data to check fo
r over-fitting

import numpy as np
from keras.utils import to_categorical
import matplotlib.pyplot as plt
%matplotlib inline

accuracy = CNN_MODEL.history['accuracy']
val_accuracy = CNN_MODEL.history['val_accuracy']
loss = CNN_MODEL.history['loss']
val_loss = CNN_MODEL.history['val_loss']
epochs = range(len(accuracy))
plt.plot(epochs, accuracy, 'bo', label='Training accuracy')
plt.plot(epochs, val_accuracy, 'orange', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'orange', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```





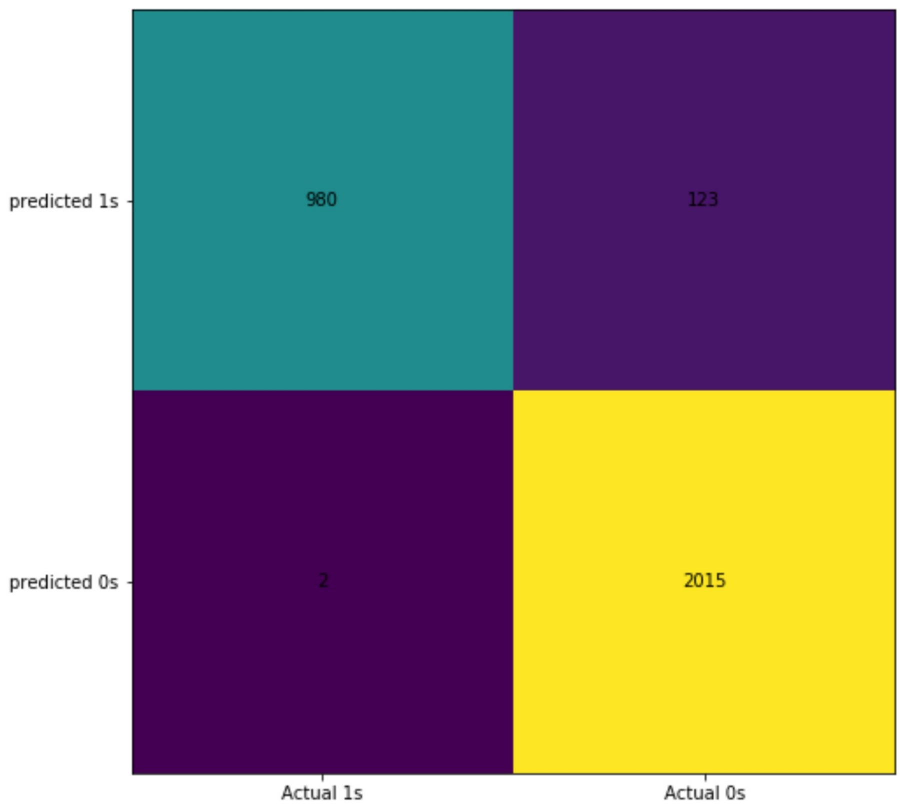
In [25]:
```
##plot our training accuracy and validation accuracy
plt.plot(CNN_MODEL.history['accuracy'])
plt.plot(CNN_MODEL.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='lower right')
plt.show()
```



In [26]:
```
## Predicting using CNN
CNN_MODEL_pred = model.predict(x_test, batch_size=32, verbose=1)
CNN_MODEL_predicted = np.argmax(CNN_MODEL_pred, axis=1)
```

```
98/98 [==============================] - 0s 1ms/step
```

In [27]:
```
## Confusion matrix for the CNN
CNN_MODEL_cm = confusion_matrix(np.argmax(y_test, axis=1), CNN_MODEL_predicted)
fig, ax = plt.subplots(figsize = (8, 8))
ax.imshow(CNN_MODEL_cm)
ax.grid(False)
ax.xaxis.set(ticks=(0,1), ticklabels=('Actual 1s', 'Actual 0s'))
ax.yaxis.set(ticks=(0,1), ticklabels=('predicted 1s', 'predicted 0s'))
ax.set_ylim(1.5, -0.5)
for i in range(2):
    for j in range(2):
        ax.text(j, i, CNN_MODEL_cm[i, j], ha= 'center', va= 'center', color= 'k')
plt.show()
```



In [28]:
```
test_cm = CNN_MODEL_cm
```

In [29]:
```
## Sensitivity Analysis
test_sens = test_cm[1, 1]/(test_cm[1, 1] + test_cm[0, 1])
print(test_sens)
```

```
0.9424695977549111
```

In [30]:
```
## Specificity Analysis
test_spec = test_cm[0, 0]/(test_cm[0, 0]+test_cm[1, 0])
print(test_spec)
```

```
0.9979633401221996
```

In [31]:
```
## PPV Analysis
test_npv = test_cm[1, 1]/(test_cm[1, 1] + test_cm[1, 0])
print(test_npv)
```

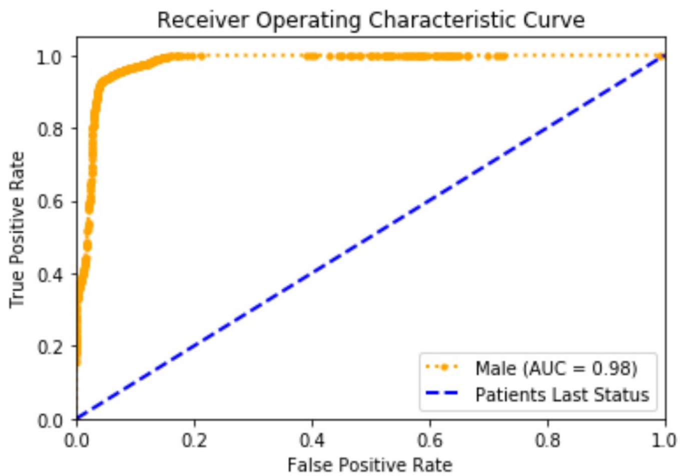
```
0.999008428358949
```

In [32]:
```
## NPV Analysis
test_npv = test_cm[0, 0]/(test_cm[0, 0]+test_cm[0, 1])
print(test_npv)
```

```
0.8884859474161378
```

In [33]:
```
from sklearn.datasets import make_classification
from sklearn.preprocessing import label_binarize
from scipy import interp
from itertools import cycle

n_classes = 1

from sklearn.metrics import roc_curve, auc

# Plot linewidth.
lw = 8

# Compute ROC curve and ROC area for each class
fpr = dict()
tpr = dict()
roc_auc = dict()
for i in range(n_classes):
    fpr[i], tpr[i], _ = roc_curve(y_test[:, i], CNN_MODEL_pred[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Compute micro-average ROC curve and ROC area
fpr["micro"], tpr["micro"], _ = roc_curve(y_test.ravel(), CNN_MODEL_pred.ravel())
roc_auc["micro"] = auc(fpr["micro"], tpr["micro"])

# Compute macro-average ROC curve and ROC area

# First aggregate all false positive rates
all_fpr = np.unique(np.concatenate([fpr[i] for i in range(n_classes)]))

# Then interpolate all ROC curves at this points
mean_tpr = np.zeros_like(all_fpr)
for i in range(n_classes):
    mean_tpr += interp(all_fpr, fpr[i], tpr[i])

# Finally average it and compute AUC
mean_tpr /= n_classes

fpr["macro"] = all_fpr
tpr["macro"] = mean_tpr
roc_auc["macro"] = auc(fpr["macro"], tpr["macro"])

# Plot all ROC curves
plt.figure(1)
plt.plot(fpr["micro"], tpr["micro"],
         label='Male (AUC = {0:0.2f})'
               ''.format(roc_auc["micro"]),marker = '.',
         color='orange', linestyle=':', linewidth=2)

plt.plot([0, 1], [0, 1], 'b--', label = 'Patients Last Status',linewidth=2, lw=lw)
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver Operating Characteristic Curve')
plt.legend(loc="lower right")
plt.show()
```

```
C:\Users\eagye\anaconda1\lib\site-packages\ipykernel_launcher.py:33: Deprecation
Warning: scipy.interp is deprecated and will be removed in SciPy 2.0.0, use nump
y.interp instead
C:\Users\eagye\anaconda1\lib\site-packages\ipykernel_launcher.py:49: MatplotlibD
eprecationWarning: Saw kwargs ['lw', 'linewidth'] which are all aliases for 'lin
ewidth'.  Kept value from 'linewidth'.  Passing multiple aliases for the same pr
operty will raise a TypeError in 3.3.
```



In [ ]:

In [ ]:

In [ ]:

In [1]:
```
## CONSIDERING THE FEMALE DATA SEPARATELY FOR THE ANALYSIS
```

In [2]:
```
## Modules required
import pandas as pd
import numpy as np
from scipy import misc
from PIL import Image
import glob
from matplotlib.pyplot import imshow
import seaborn as sn
import pickle
from keras.preprocessing import image
from keras.preprocessing.image import load_img
from keras.preprocessing.image import img_to_array
from keras.applications.imagenet_utils import decode_predictions
from keras.utils import layer_utils, np_utils
from keras.utils.data_utils import get_file
from keras.applications.imagenet_utils import preprocess_input
from keras.utils.vis_utils import model_to_dot
from keras.utils import plot_model
from keras.initializers import glorot_uniform
from keras import losses
import keras.backend as K
from keras.callbacks import ModelCheckpoint
from sklearn.metrics import confusion_matrix, classification_report
from keras import layers
from IPython.display import SVG
import matplotlib.pyplot as plt
%matplotlib inline
import keras
import tensorflow as tf
from tensorflow.keras.models import Sequential, Model, load_model
from tensorflow.keras.layers import Dense,Dropout, Activation, Flatten, Input, Add,
ZeroPadding2D, Conv2D, MaxPooling2D
from hyperopt import Trials, STATUS_OK, tpe
from hyperas import optim
from hyperas.distributions import choice, uniform
```

In [3]:
```
# Code
FBC = (pd.read_excel('FBC.xlsx'))
```

In [4]:
```
## CONSIDERING THE FEMALE DATA SEPARATELY FOR THE ANALYSIS
FBC.head()
```

Out[4]:

	PatStatus	Race	MarST	Gender	AgeDiag	Grade	Stability	No.Visits	Lstay	Laterality	...	LyNode	Amorp
0	1	3	1	0	52	3	0	5	1	4	...	1	
1	1	3	1	0	48	3	0	4	3	5	...	1	
2	0	3	0	0	69	2	0	7	9	8	...	1	
3	1	3	0	0	47	2	0	15	9	9	...	1	
4	1	3	0	0	66	3	0	9	5	4	...	1	

5 rows × 25 columns

In [5]:
```
## The new fitted logistic regression model with selected variables
## Modules required
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import keras
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense,Dropout, Activation, Flatten, Conv2D, Max
Pooling2D
from hyperopt import Trials, STATUS_OK, tpe
from hyperas import optim
from hyperas.distributions import choice, uniform

## Reshaping into array
FBC.iloc[3,1:].values.reshape(6,4).astype('int8')
```

Out[5]:
```
array([[ 3,  0,  0, 47],
       [ 2,  0, 15,  9],
       [ 9,  1,  1,  0],
       [ 3,  1,  1,  1],
       [ 2,  0,  1,  1],
       [ 0,  1,  0,  1]], dtype=int8)
```

In [6]:
```
## Preprocessing the data
```

In [7]:
```
## Storing the independent variables array in form length, width, height into df_x
df_x = FBC.iloc[:,1:].values.reshape(len(FBC), 6, 4, 1)

## Storing the dependent variables in y
y = FBC.iloc[:,0].values
```

In [8]:
```
# converting y to categorical
df_y = keras.utils.to_categorical(y, num_classes = 2)
```

In [9]:
```
df_x =np.array(df_x)
df_y = np.array(df_y)
```

In [10]:
```
df_y
```

Out[10]:
```
array([[0., 1.],
       [0., 1.],
       [1., 0.],
       ...,
       [0., 1.],
       [0., 1.],
       [0., 1.]], dtype=float32)
```

In [11]:
```
df_x.shape
```

Out[11]:
```
(84403, 6, 4, 1)
```

In [12]:
```
df_y.shape
```

Out[12]:
```
(84403, 2)
```

In [13]:
```
#Import 'train_test_split' from 'sklearn.model_selection'
from sklearn.model_selection import train_test_split

#Import numpy#
import numpy as np
#Split the data into train and test sets #
x_train, x_test, y_train, y_test=train_test_split(df_x,df_y, test_size=0.2, random_
state=123)
```

In [14]:
```
x_test.shape
```

Out[14]:
```
(16881, 6, 4, 1)
```

In [15]:
```
y_test.shape
```

Out[15]:
```
(16881, 2)
```

In [16]:
```
### CNN Model
model = Sequential()
model.add(Conv2D(64, (2,3), input_shape = (6, 4, 1)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(1,1)))
model.add(Dropout(0.25))

model.add(Flatten())
model.add(Dense(64))
model.add(Dropout(0.25))

model.add(Dense(2))
model.add(Activation('sigmoid'))
model.compile(loss="categorical_crossentropy", optimizer="adam", metrics=['accuracy
'])
```

In [17]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 5, 2, 64)          448
_________________________________________________________________
activation (Activation)      (None, 5, 2, 64)          0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 5, 2, 64)          0
_________________________________________________________________
dropout (Dropout)            (None, 5, 2, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 640)               0
_________________________________________________________________
dense (Dense)                (None, 64)                41024
_________________________________________________________________
dropout_1 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 130
_________________________________________________________________
activation_1 (Activation)    (None, 2)                 0
=================================================================
Total params: 41,602
Trainable params: 41,602
Non-trainable params: 0
_________________________________________________________________
```

In [18]:
```
## fitting the model with
CNN_MODEL = model.fit(x_train, y_train, batch_size=30, epochs=10, validation_data=
(x_test, y_test))
```

```
Epoch 1/10
2251/2251 [==============================] - 11s 5ms/step - loss: 0.3300 - accur
acy: 0.8355 - val_loss: 0.2250 - val_accuracy: 0.8900
Epoch 2/10
2251/2251 [==============================] - 12s 5ms/step - loss: 0.2363 - accur
acy: 0.8785 - val_loss: 0.2042 - val_accuracy: 0.8833
Epoch 3/10
2251/2251 [==============================] - 12s 5ms/step - loss: 0.2270 - accur
acy: 0.8755 - val_loss: 0.2016 - val_accuracy: 0.8850
Epoch 4/10
2251/2251 [==============================] - 11s 5ms/step - loss: 0.2207 - accur
acy: 0.8771 - val_loss: 0.1945 - val_accuracy: 0.8856
Epoch 5/10
2251/2251 [==============================] - 12s 5ms/step - loss: 0.2167 - accur
acy: 0.8775 - val_loss: 0.1924 - val_accuracy: 0.8865
Epoch 6/10
2251/2251 [==============================] - 12s 5ms/step - loss: 0.2132 - accur
acy: 0.8797 - val_loss: 0.1938 - val_accuracy: 0.8849
Epoch 7/10
2251/2251 [==============================] - 13s 6ms/step - loss: 0.2108 - accur
acy: 0.8802 - val_loss: 0.1892 - val_accuracy: 0.8867
Epoch 8/10
2251/2251 [==============================] - 13s 6ms/step - loss: 0.2091 - accur
acy: 0.8803 - val_loss: 0.1935 - val_accuracy: 0.8873
Epoch 9/10
2251/2251 [==============================] - 13s 6ms/step - loss: 0.2083 - accur
acy: 0.8809 - val_loss: 0.1885 - val_accuracy: 0.8861
Epoch 10/10
2251/2251 [==============================] - 12s 5ms/step - loss: 0.2059 - accur
acy: 0.8813 - val_loss: 0.1941 - val_accuracy: 0.8878
```

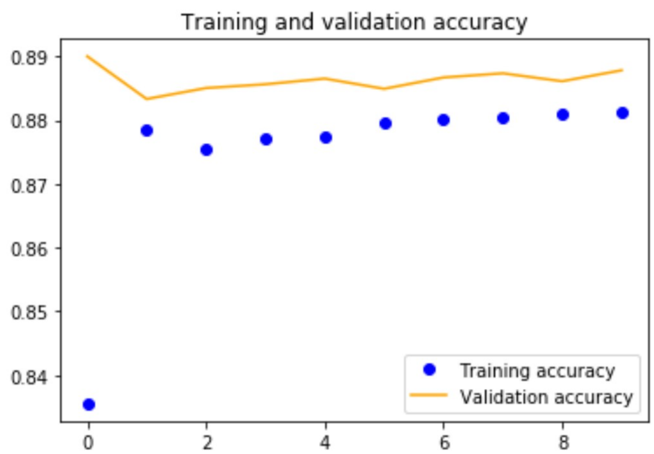
In [19]:
```
## MODEL EVALUATION
```

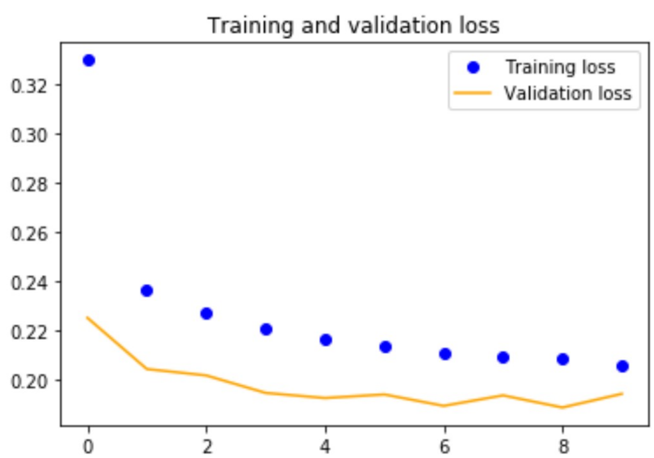
In [20]:
```
## Prediction loss and accuracy
test_eval = model.evaluate(x_test, y_test, verbose=0)[1]
```

In [21]:
```
print('Test accuracy:', test_eval)
```

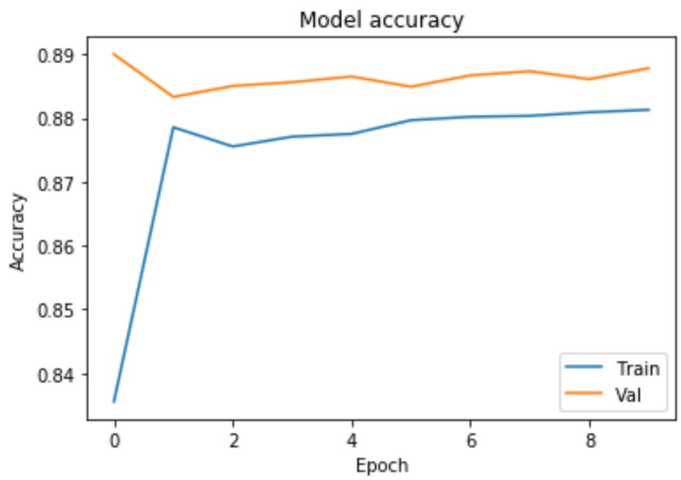
```
Test accuracy: 0.8878028392791748
```

In [22]:
```
##plot the accuracy and loss plots between training and validation data to check fo
r over-fitting

import numpy as np
from keras.utils import to_categorical
import matplotlib.pyplot as plt
%matplotlib inline

accuracy = CNN_MODEL.history['accuracy']
val_accuracy = CNN_MODEL.history['val_accuracy']
loss = CNN_MODEL.history['loss']
val_loss = CNN_MODEL.history['val_loss']
epochs = range(len(accuracy))
plt.plot(epochs, accuracy, 'bo', label='Training accuracy')
plt.plot(epochs, val_accuracy, 'orange', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'orange', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```





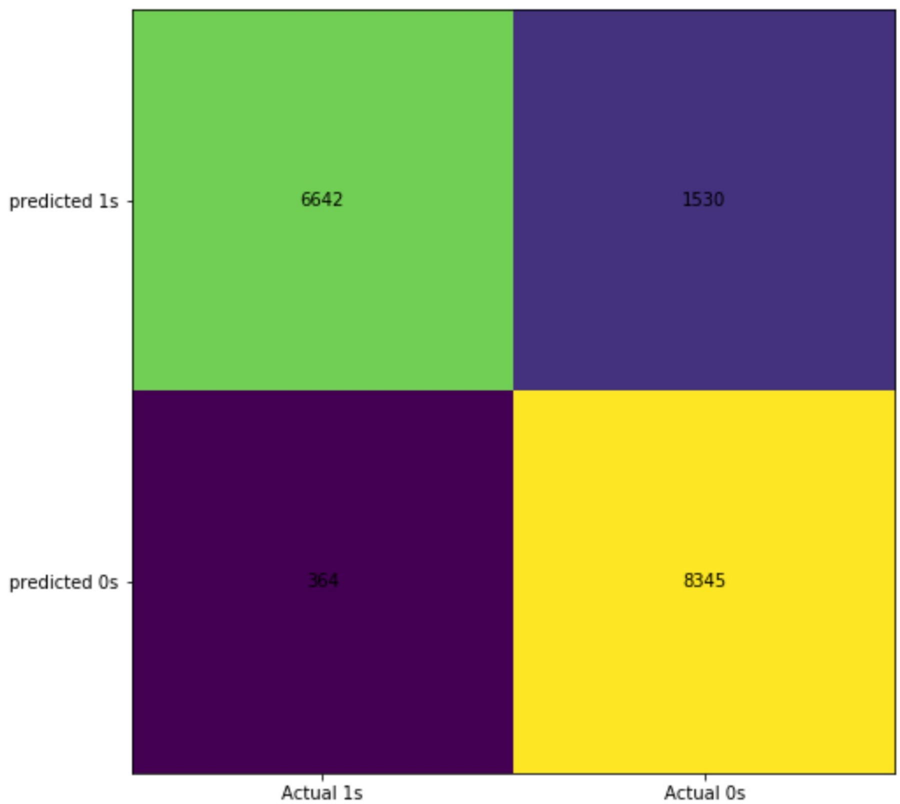
In [23]:
```
##plot our training accuracy and validation accuracy
plt.plot(CNN_MODEL.history['accuracy'])
plt.plot(CNN_MODEL.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='lower right')
plt.show()
```



In [24]:
```
## Predicting using CNN
CNN_MODEL_pred = model.predict(x_test, batch_size=32, verbose=1)
CNN_MODEL_predicted = np.argmax(CNN_MODEL_pred, axis=1)
```

```
528/528 [==============================] - 1s 1ms/step
```

In [25]:
```
## Confusion matrix for the CNN
CNN_MODEL_cm = confusion_matrix(np.argmax(y_test, axis=1), CNN_MODEL_predicted)
fig, ax = plt.subplots(figsize = (8, 8))
ax.imshow(CNN_MODEL_cm)
ax.grid(False)
ax.xaxis.set(ticks=(0,1), ticklabels=('Actual 1s', 'Actual 0s'))
ax.yaxis.set(ticks=(0,1), ticklabels=('predicted 1s', 'predicted 0s'))
ax.set_ylim(1.5, -0.5)
for i in range(2):
    for j in range(2):
        ax.text(j, i, CNN_MODEL_cm[i, j], ha= 'center', va= 'center', color= 'k')
plt.show()
```



In [26]:
```
test_cm = CNN_MODEL_cm
```

In [27]:
```
## Sensitivity Analysis
test_sens = test_cm[1, 1]/(test_cm[1, 1] + test_cm[0, 1])
print(test_sens)
```

```
0.8450632911392405
```

In [28]:
```
## Specificity Analysis
test_spec = test_cm[0, 0]/(test_cm[0, 0]+test_cm[1, 0])
print(test_spec)
```

```
0.948044533257208
```

In [29]:
```
## PPV Analysis
test_npv = test_cm[1, 1]/(test_cm[1, 1] + test_cm[1, 0])
print(test_npv)
```

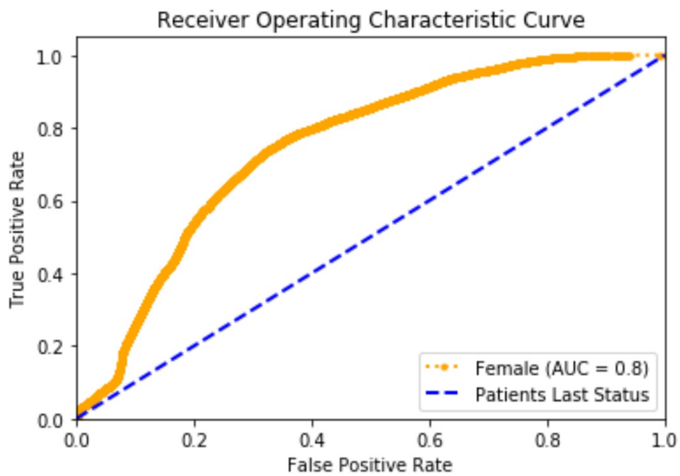
```
0.9582041566195889
```

In [30]:
```
## NPV Analysis
test_npv = test_cm[0, 0]/(test_cm[0, 0]+test_cm[0, 1])
print(test_npv)
```

```
0.8127753303964758
```

In [32]:
```
from sklearn.datasets import make_classification
from sklearn.preprocessing import label_binarize
from scipy import interp
from itertools import cycle

n_classes = 1

from sklearn.metrics import roc_curve, auc

# Plot linewidth.
lw = 8

# Compute ROC curve and ROC area for each class
fpr = dict()
tpr = dict()
roc_auc = dict()
for i in range(n_classes):
    fpr[i], tpr[i], _ = roc_curve(y_test[:, i], CNN_MODEL_pred[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Compute micro-average ROC curve and ROC area
fpr["micro"], tpr["micro"], _ = roc_curve(y_test.ravel(), CNN_MODEL_pred.ravel())
roc_auc["micro"] = auc(fpr["micro"], tpr["micro"])

# Compute macro-average ROC curve and ROC area

# First aggregate all false positive rates
all_fpr = np.unique(np.concatenate([fpr[i] for i in range(n_classes)]))

# Then interpolate all ROC curves at this points
mean_tpr = np.zeros_like(all_fpr)
for i in range(n_classes):
    mean_tpr += interp(all_fpr, fpr[i], tpr[i])

# Finally average it and compute AUC
mean_tpr /= n_classes

fpr["macro"] = all_fpr
tpr["macro"] = mean_tpr
roc_auc["macro"] = auc(fpr["macro"], tpr["macro"])

# Plot all ROC curves
plt.figure(1)
plt.plot(fpr["micro"], tpr["micro"],
         label='Female (AUC = {0:0.1f})'
               ''.format(roc_auc["micro"]),marker = '.',
         color='orange', linestyle=':', linewidth=2)

plt.plot([0, 1], [0, 1], 'b--', label = 'Patients Last Status',linewidth=2, lw=lw)
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver Operating Characteristic Curve')
plt.legend(loc="lower right")
plt.show()
```

```
C:\Users\eagye\anaconda1\lib\site-packages\ipykernel_launcher.py:33: Deprecation
Warning: scipy.interp is deprecated and will be removed in SciPy 2.0.0, use nump
y.interp instead
C:\Users\eagye\anaconda1\lib\site-packages\ipykernel_launcher.py:49: MatplotlibD
eprecationWarning: Saw kwargs ['lw', 'linewidth'] which are all aliases for 'lin
ewidth'.  Kept value from 'linewidth'.  Passing multiple aliases for the same pr
operty will raise a TypeError in 3.3.
```



In [ ]:

In [ ]:

In [ ]:

In [ ]:

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In [ ]: