In [1]:

```
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras import optimizers
from tensorflow.keras.models import Sequential, Model
from tensorflow.keras.layers import Convolution2D, ZeroPadding2D, MaxPooling2D, Dropout, Flatte
n, Activation
from tensorflow.keras.callbacks import ModelCheckpoint
from tensorflow.keras.preprocessing.image import ImageDataGenerator
import tensorflow.keras.backend as K
import skimage as skimage
```

Clear the Keras session

In [2]:

```
K.clear_session()
```

Load data

All the data we used is from [https://data.vision.ee.ethz.ch/cvl/rrothe/imdb-wiki/ (https://data.vision.ee.ethz.ch/cvl/rrothe/imdb-wiki/)](https://data.vision.ee.ethz.ch/cvl/rrothe/imdb-wiki/). we only used WIKI face only dataset with about 22000+ face images. Before we started, we get rid off some invalid images such as images without face and images of people whose ages are over 100 or below 0. In addition we split data into training and test with rate 2 to 1 and read them with ImageDataGenerator. More detail is on another notebook.

In [3]:

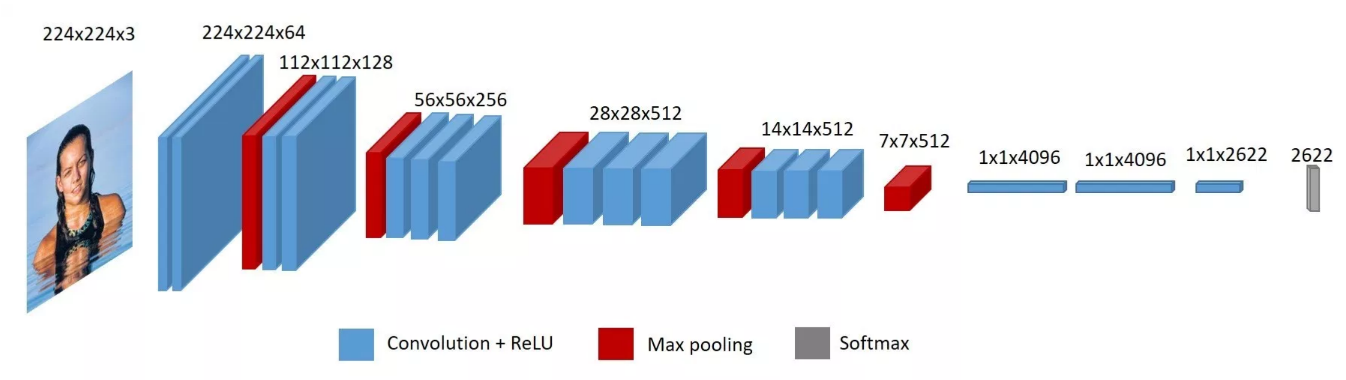
```
#Load train data
train_data_dir = './train'
batch_size = 256
train_datagen = ImageDataGenerator(rescale=1./255)
train_generator = train_datagen.flow_from_directory(
    train_data_dir,
    target_size=(224,224),
    batch_size=batch_size)

#Load test data
test_data_dir = './test'
test_datagen = ImageDataGenerator(rescale=1./255)
test_generator = test_datagen.flow_from_directory(
    test_data_dir,
    target_size=(224,224),
    batch_size=batch_size)
```

```
Found 16606 images belonging to 101 classes.
Found 5534 images belonging to 101 classes.
```

Construct model

The model we used is VGG-Face which created by Omkar M. Parkhi, Andrea Vedaldi and Andrew Zisserman in *Deep Face Recognition*. The structure of the model is as following:



To use the model, first we should construct the model manually.

In [4]:

```
#print(Xts.shape, yts.shape, Xtr.shape, ytr.shape)

model = Sequential()
model.add(ZeroPadding2D((1,1),input_shape=(224,224, 3)))
model.add(Convolution2D(64, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2,2), strides=(2,2)))

model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(128, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D((2,2), strides=(2,2)))

model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(256, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(256, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(256, (3, 3), activation='relu'))
model.add(MaxPooling2D((2,2), strides=(2,2)))

model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(512, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(512, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(512, (3, 3), activation='relu'))
model.add(MaxPooling2D((2,2), strides=(2,2)))

model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(512, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(512, (3, 3), activation='relu'))
model.add(ZeroPadding2D((1,1)))
model.add(Convolution2D(512, (3, 3), activation='relu'))
model.add(MaxPooling2D((2,2), strides=(2,2)))

model.add(Convolution2D(4096, (7, 7), activation='relu'))
model.add(Dropout(0.5))
model.add(Convolution2D(4096, (1, 1), activation='relu'))
model.add(Dropout(0.5))
model.add(Convolution2D(2622, (1, 1)))
model.add(Flatten())
model.add(Activation('softmax'))
```

```
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tensorflow/python/o
ps/resource_variable_ops.py:435: colocate_with (from tensorflow.python.framework.o
ps) is deprecated and will be removed in a future version.
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tensorflow/python/k
eras/layers/core.py:143: calling dropout (from tensorflow.python.ops.nn_ops) with
keep_prob is deprecated and will be removed in a future version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_p
rob`.
```

Then we load the pretrained weights (also offered by those reseachers). We locked the model's layer weights except last 7 layers because early layers could detect some patterns. Then we cut the last convolution layer to replace it with 101 units (ages from 0 to 100) but not 2622 units.

In [5]:

```
#Load weights for VGG-model
model.load_weights('vgg_face_weights.h5')
#Make the VGG-model layers untrainable except last 7 layers
for layer in model.layers[:-7]:
    layer.trainable = False
#Change the last Convolution layer into 101 output(from age 0 to 100)

model_output = Sequential()
model_output = Convolution2D(101, (1, 1), name='predictions')(model.layers[-4].output)
model_output = Flatten()(model_output)
model_output = Activation('softmax')(model_output)

age_model = Model(inputs=model.input, outputs=model_output)
age_model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
zero_padding2d_input (InputL (None, 224, 224, 3)       0         
_________________________________________________________________
zero_padding2d (ZeroPadding2 (None, 226, 226, 3)       0         
_________________________________________________________________
conv2d (Conv2D)              (None, 224, 224, 64)      1792      
_________________________________________________________________
zero_padding2d_1 (ZeroPaddin (None, 226, 226, 64)      0         
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 224, 224, 64)      36928     
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 112, 112, 64)      0         
_________________________________________________________________
zero_padding2d_2 (ZeroPaddin (None, 114, 114, 64)      0         
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 112, 112, 128)     73856     
_________________________________________________________________
zero_padding2d_3 (ZeroPaddin (None, 114, 114, 128)     0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 112, 112, 128)     147584    
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 56, 56, 128)       0         
_________________________________________________________________
zero_padding2d_4 (ZeroPaddin (None, 58, 58, 128)       0         
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 56, 56, 256)       295168    
_________________________________________________________________
zero_padding2d_5 (ZeroPaddin (None, 58, 58, 256)       0         
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 56, 56, 256)       590080    
_________________________________________________________________
zero_padding2d_6 (ZeroPaddin (None, 58, 58, 256)       0         
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 56, 56, 256)       590080    
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 28, 28, 256)       0         
_________________________________________________________________
zero_padding2d_7 (ZeroPaddin (None, 30, 30, 256)       0         
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 28, 28, 512)       1180160   
_________________________________________________________________
zero_padding2d_8 (ZeroPaddin (None, 30, 30, 512)       0         
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 28, 28, 512)       2359808   
_________________________________________________________________
zero_padding2d_9 (ZeroPaddin (None, 30, 30, 512)       0         
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 28, 28, 512)       2359808   
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 14, 14, 512)       0         
_________________________________________________________________
zero_padding2d_10 (ZeroPaddi (None, 16, 16, 512)       0         
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 14, 14, 512)       2359808   
_________________________________________________________________
zero_padding2d_11 (ZeroPaddi (None, 16, 16, 512)       0         
_________________________________________________________________
conv2d_11 (Conv2D)           (None, 14, 14, 512)       2359808   
_________________________________________________________________
```

```
zero_padding2d_12 (ZeroPaddi (None, 16, 16, 512)       0
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 14, 14, 512)       2359808
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 7, 7, 512)         0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 1, 1, 4096)        102764544
_________________________________________________________________
dropout (Dropout)            (None, 1, 1, 4096)        0
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 1, 1, 4096)        16781312
_________________________________________________________________
dropout_1 (Dropout)          (None, 1, 1, 4096)        0
_________________________________________________________________
predictions (Conv2D)         (None, 1, 1, 101)         413797
_________________________________________________________________
flatten_1 (Flatten)          (None, 101)               0
_________________________________________________________________
activation_1 (Activation)    (None, 101)               0
=================================================================
Total params: 134,674,341
Trainable params: 119,959,653
Non-trainable params: 14,714,688
_________________________________________________________________
```

Fit model

Because the data is little, so we only need 3 epochs to train the model (more epochs will cause overfit), and each epoch we go through all the data we have.

In [6]:

```
#Using Loss funtion 'categorial crossentropy' and Optimization algorithm 'Adam'
age_model.compile(loss='categorical_crossentropy', optimizer=optimizers.Adam(), metrics=['accura
cy'])
#Make a checkpoint in case it goes wrong
checkpointer = ModelCheckpoint(
    filepath='age_model.hdf5',
    monitor='val_loss',
    verbose=1,
    save_best_only=True,
    mode='auto')
#Training the model
epochs = 3
steps_per_epoch = train_generator.n//batch_size
validation_steps = test_generator.n//batch_size
#Call the fit_generator function
hist = age_model.fit_generator(
    train_generator,
    steps_per_epoch=steps_per_epoch,
    epochs=epochs,
    validation_data=test_generator,
    validation_steps=validation_steps,
    callbacks=[checkpointer])

'''
scores = []
for i in range(epochs):
    print("epoch", i)

    iXtr = np.random.choice(Xtr.shape[0], size=batch_size)

    score = age_model.fit(Xtr[iXtr], ytr[iXtr], epochs=1, validation_data=(Xts, yts))

    scores.append(score)
'''
```

```
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tensorflow/python/o
ps/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 1/3
22/22 [==============================] - 27s 1s/step - loss: 3.4742 - acc: 0.0589

Epoch 00001: val_loss improved from inf to 3.47419, saving model to age_model.hdf5
65/65 [==============================] - 97s 1s/step - loss: 3.7652 - acc: 0.0479
- val_loss: 3.4742 - val_acc: 0.0589
Epoch 2/3
22/22 [==============================] - 24s 1s/step - loss: 3.4063 - acc: 0.0631

Epoch 00002: val_loss improved from 3.47419 to 3.40632, saving model to age_model.
hdf5
65/65 [==============================] - 94s 1s/step - loss: 3.4271 - acc: 0.0702
- val_loss: 3.4063 - val_acc: 0.0631
Epoch 3/3
22/22 [==============================] - 24s 1s/step - loss: 3.4028 - acc: 0.0605

Epoch 00003: val_loss improved from 3.40632 to 3.40284, saving model to age_model.
hdf5
65/65 [==============================] - 93s 1s/step - loss: 3.2730 - acc: 0.0927
- val_loss: 3.4028 - val_acc: 0.0605
```

Out[6]:

```
'\nscores = []\nfor i in range(epochs):\n    print("epoch", i)\n    \n    iXtr = n
p.random.choice(Xtr.shape[0], size=batch_size)\n    \n    score = age_model.fit(Xt
r[iXtr], ytr[iXtr], epochs=1, validation_data=(Xts, yts))\n    \n    scores.append
(score)\n'
```

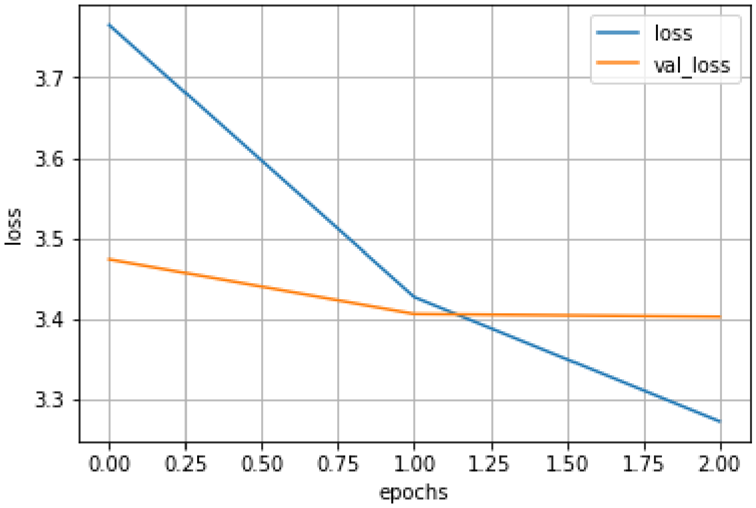
Result

We can find out the accuracy is 6% which seems very low. However, it is actually not. We all know that guess the exact right age is very hard and all we need is a range of possible ages, so we need some processes to get the right prediction. But first, we should plot the training loss and validation loss vs. epoch.

In [7]:

```
loss = hist.history['loss']
val_loss = hist.history['val_loss']

plt.plot(loss)
plt.plot(val_loss)
plt.grid()
plt.xlabel('epochs')
plt.ylabel('loss')
plt.legend(['loss','val_loss'])
plt.show()
```



Reseachers developed a way to convert classifcation into regression. They proposed that we should multiply each softmax out with its corresponded label. Summing this multiplications, which we knew is the math expectation, will be the apparent age prediction.

In [8]:

```
#Predict ages on a batch of test data
Xts, yts = test_generator.next()
#Multiply each softmax out with its label.
#Summing this multiplications will get a apparent age prediction
predictions = age_model.predict(Xts)
output_indexes = np.array([i for i in range(0, 101)])
apparent_predictions = np.around(np.sum(predictions*output_indexes, axis=1))

yts_actual = np.empty(yts.shape[0], dtype=int)
for i in range(0, yts.shape[0]):
    yts_actual[i] = np.argmax(yts[i])

#Compute the mean absolute error
error = np.mean(np.abs(apparent_predictions - yts_actual))
print("The mean absolute error is: {0:0.1f}".format(error))
```

```
The mean absolute error is: 5.7
```

The mean absolute error of a batch of test data is 6, which is somehow acceptable. To get a more accurate result, you simple need more data.

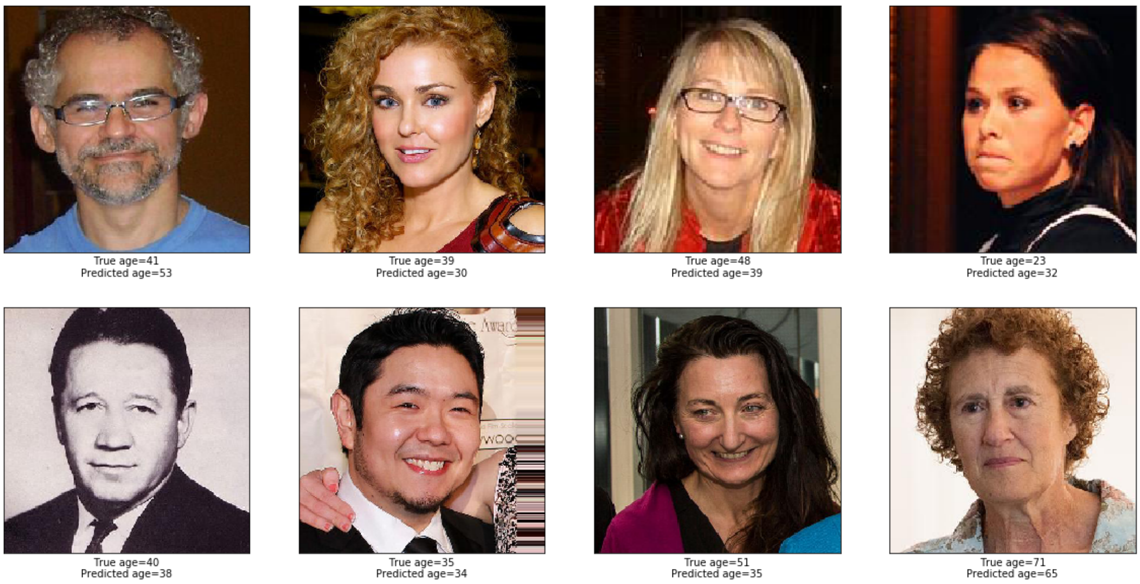
We plot some test images below, so you can see the result visually.

In [9]:

```
# Display the image
def disp_image(im):
    if (len(im.shape) == 2):
        # Gray scale image
        plt.imshow(im)
    else:
        # Color image.
        im1 = (im-np.min(im))/(np.max(im)-np.min(im))*255
        im1 = im1.astype(np.uint8)
        plt.imshow(im1)

    # Remove axis ticks
    plt.xticks([])
    plt.yticks([])

plt.figure(figsize=(20,10))
nplot = 8
for i in range(nplot):
    plt.subplot(2, 4, i+1)
    disp_image(Xts[i])
    plt.xlabel('True age={0:d}\nPredicted age={1:.0f}'.format(yts_actual[i], apparent_predictio
ns[i]))
plt.show()
```



Then we use the picture of Kit Harington, the actor of Jon Snow in the *Game of Thrones*, to make a prediction. The picture is taken in 2019 when he is 32 years old.

In [10]:

```
myImage = skimage.io.imread('jon_snow.jpg')
myImage_r = skimage.transform.resize(myImage, (224,224), anti_aliasing=True)
y = age_model.predict(myImage_r[None,:,:,:])
apparent_y = np.around(np.sum(y*output_indexes, axis=1))
disp_image(myImage_r)
plt.xlabel('True age={0:d}\nPredicted age={1:.0f}'.format(32, apparent_y[0]))
```

Out[10]:

```
Text(0.5, 0, 'True age=32\nPredicted age=31')
```

True age=32
Predicted age=31

The result is pretty good.