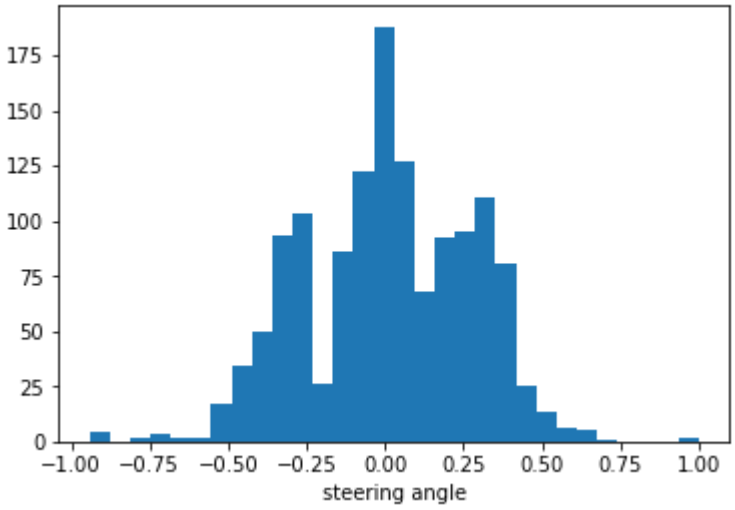
In [1]:
```
import csv
import cv2
import keras
import numpy as np
import sklearn

from keras.models import Sequential
from keras.layers import Flatten, Dense, Input, Lambda, Conv2D, MaxPooling2D, Dro
from keras.callbacks import History


k_prob =0.25
EPOCHS = 2
BATCH_SIZE = 16
VALID_SIZE_RATIO = 0.1
TEST = 0
LOAD = 0
LOAD_MODEL = 'model_nvidia_lin_e2.h5'
SAVE_MODEL = 'model_nvidia_prep_lin_test1.h5'


history = History()

samples_00 = []  # samples of steering angle         n == 0
samples_02 = []  # samples of steering angle     0 < n <= 0.25
samples_12 = []  # samples of steering angle -0.25 < n <= 0
samples_99 = []  # samples of steering angle outside of the above
steer      = []  #
with open('data/driving_log.csv') as csvfile:
    reader = csv.reader(csvfile)
    for line in reader:
        if(line[0] == 'center'):
            print("skipping line:", line)
        else:
            if(float(line[3]) == 0):
                samples_00.append(line)
            elif(float(line[3]) > 0 and float(line[3]) <= 0.25):
                samples_02.append(line)
            elif(float(line[3]) < 0 and float(line[3]) >= -0.25):
                samples_12.append(line)
            else:
                samples_99.append(line)
            steer.append(float(line[3]))

u_steer, u_cnt = np.unique(steer, return_counts=True)
print("len steer", len(steer))
print(*(map('{}: {}'.format, u_steer, u_cnt)), sep="\n")

import matplotlib.pyplot as plt
import numpy as np
%matplotlib inline
plt.hist(steer, normed=True, bins=30)
plt.xlabel('steering angle');

print("len samples_00", len(samples_00))
print("len samples_02", len(samples_02))
```

```
print("len samples_12", len(samples_12))
print("len samples_99", len(samples_99))
```

In [2]:
```
import random
from random import shuffle

def down_sample_size(samples, target_size):
    random.shuffle(samples)
    return samples[0:target_size]

DROP_ZERO_RATIO = 0.97  #0.98
DROP_PT_2_RATIO = 0.80  #0.75
DROP_PTN2_RATIO = 0.81  #0.76

bal_samples_00 = down_sample_size(samples_00, int(len(samples_00)*(1-DROP_ZERO_RA
bal_samples_02 = down_sample_size(samples_02, int(len(samples_02)*(1-DROP_PT_2_RA
bal_samples_12 = down_sample_size(samples_12, int(len(samples_12)*(1-DROP_PTN2_RA

print("len bal_samples_00", len(bal_samples_00))
print("len bal_samples_02", len(bal_samples_02))
print("len bal_samples_12", len(bal_samples_12))
print("len     samples_99", len(samples_99))

samples = []
for sam in bal_samples_00:
    samples.append(sam)
for sam in bal_samples_02:
    samples.append(sam)
for sam in bal_samples_12:
    samples.append(sam)
for sam in samples_99:
    samples.append(sam)

random.shuffle(samples)
print("len samples", len(samples))

steer = []
for line in samples:
    steer.append(float(line[3]))

plt.hist(steer, normed=False, bins=30)
plt.xlabel('steering angle');
```

```
len bal_samples_00 130
len bal_samples_02 313
len bal_samples_12 279
len     samples_99 636
len samples 1358
```


175
150
125
100
75
50
25
0
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
steering angle

In [3]:
```
from sklearn.utils import shuffle
from sklearn.model_selection import train_test_split
train_samples, validation_samples = train_test_split(samples, test_size=VALID_SIZ

def generator(samples, batch_size=32, validation=False):
    num_samples = len(samples)
    while 1: # Loop forever so the generator never terminates
        shuffle(samples)
        for offset in range(0, num_samples, batch_size):
            batch_samples = samples[offset:offset+batch_size]

            images = []
            angles = []
            for batch_sample in batch_samples:
                #processing center image
                name = 'data/IMG/'+batch_sample[0].split('/')[-1]
                center_image = cv2.imread(name)
                images.append(center_image)

                #processing steering angle
                center_angle = float(batch_sample[3])
                angles.append(center_angle)

                #processing flipped center image
                flip_image = cv2.flip(center_image, 1)
                #flip center image and invert steering angle by multiply by -1
                images.append(flip_image)
                angles.append(center_angle*-1.0)

                # if this is for validation data samples, don't include the manip
                if(validation == False):
                    #manipulate images to increase data sample for training
                    #processing lef image
                    name = 'data/IMG/'+batch_sample[1].split('/')[-1]
                    left_image = cv2.imread(name)
                    #add left image and add a random positive correction factor t
                    images.append(left_image)
                    angles.append(center_angle+0.25)
                    #angles.append(center_angle+((1-abs(center_angle))*0.25))

                    #processing right image
                    name = 'data/IMG/'+batch_sample[2].split('/')[-1]
                    right_image = cv2.imread(name)
                    #add right image and add a random negative correction factor
                    images.append(right_image)
                    angles.append(center_angle-0.25)
                    #angles.append(center_angle-((1-abs(center_angle))*0.25))

            X_data = np.array(images)
            y_data = np.array(angles)

            if(TEST==1):
                plt.hist(angles, normed=False, bins=30)
                plt.xlabel('steering angle');

                #print("X_data",X_data.shape)
```

```
                #print("y_data",y_data.shape)
                #print("X_data",X_data[:2])
                #print("y_data",y_data[:30])

            #return X and y dataset of batch size
            yield sklearn.utils.shuffle(X_data, y_data)

# compile and train the model using the generator function
train_generator = generator(train_samples, batch_size=BATCH_SIZE)
validation_generator = generator(validation_samples, batch_size=BATCH_SIZE)




print("Building a Keras Model")

#loading a previously trained model
if (LOAD==1):
    model = keras.models.load_model(LOAD_MODEL)

#starting a model for training
else:
    #instantiating a Keras Sequential Model
    model = Sequential()

    #crop out top and bottom pixels to reduce noise from sky and hood
    model.add(Cropping2D(cropping=((70,25), (0,0)), input_shape=(160,320,3)))

    #normalizing input data
    model.add(Lambda(lambda x: (x/255.0)-0.5))

    #for testing initial model bring up only
    if(TEST==1):
        #model.add(Flatten())  # size of 2496
        #model.add(Dense(1))
        print("skip model")
    else:
        model.add(Conv2D(16, kernel_size=(5,5), strides=(2,2), activation='relu')
        model.add(Conv2D(24, kernel_size=(5,5), strides=(2,2), activation='relu')
        model.add(Conv2D(36, kernel_size=(5,5), strides=(2,2), activation='relu')
        model.add(Dropout(k_prob))
        model.add(Conv2D(48, kernel_size=(3,3), activation='relu')) # 3x36x48   -
        model.add(Dropout(k_prob))
        model.add(Conv2D(64, kernel_size=(3,3), activation='relu')) #
        model.add(Dropout(k_prob))
        model.add(Flatten())  # size of 2496
        model.add(Dense(256))
        model.add(Dropout(k_prob))
        model.add(Dense(100))
        model.add(Dropout(k_prob))
        model.add(Dense(10))
        model.add(Dropout(k_prob))
        model.add(Dense(1)) #adding softmax activation at the last layer seems to

    model.compile(loss='mse',
                  optimizer='adam')
```

```
print("Fitting model with generators")
history_object = model.fit_generator(train_generator,
                                     steps_per_epoch=len(train_samples),
                                     validation_data=validation_generator,
                                     validation_steps=len(validation_samples),
                                     epochs=EPOCHS,
                                     callbacks=[history],
                                     verbose=1)

print("Save model")
model.save(SAVE_MODEL)
print("Written to ", SAVE_MODEL)
```

```
Building a Keras Model
Fitting model with generators
Epoch 1/2
1222/1222 [==============================] - 829s 679ms/step - loss: 0.0391 - v
al_loss: 0.0361
Epoch 2/2
1222/1222 [==============================] - 829s 678ms/step - loss: 0.0274 - v
al_loss: 0.0372
Save model
Written to  model_nvidia_prep_lin_test1.h5
```

In [4]:
```
### print the keys contained in the history object
print(history_object.history.keys())
print(history_object)

### plot the training and validation loss for each epoch
plt.plot(history_object.history['loss'])
plt.plot(history_object.history['val_loss'])
plt.title('model mean squared error loss')
plt.ylabel('mean squared error loss')
plt.xlabel('epoch')
plt.legend(['training set', 'validation set'], loc='upper right')
plt.show()
```

```
dict_keys(['loss', 'val_loss'])
<keras.callbacks.History object at 0x00000190844D06D8>
```