Human Activity Recognition:

Business Problem:

This project is to build a model that predicts the human activities such as Walking, Walking_Upstairs, Walking_Downstairs, Sitting, Standing or Laying.

Data :

The experiments have been carried out with a group of 30 volunteers within an age bracket of 19-48 years. Each person performed six activities (WALKING, WALKING_UPSTAIRS, WALKING_DOWNSTAIRS, SITTING, STANDING, LAYING) wearing a smartphone (Samsung Galaxy S II) on the waist. Using its embedded accelerometer and gyroscope, we captured 3-axial linear acceleration and 3-axial angular velocity at a constant rate of 50Hz. The experiments have been video-recorded to label the data manually. The obtained dataset has been randomly partitioned into two sets, where 70% of the volunteers was selected for generating the training data and 30% the test data.

The sensor signals (accelerometer and gyroscope) were pre-processed by applying noise filters and then sampled in fixed-width sliding windows of 2.56 sec and 50% overlap (128 readings/window). The sensor acceleration signal, which has gravitational and body motion components, was separated using a Butterworth low-pass filter into body acceleration and gravity. The gravitational force is assumed to have only low frequency components, therefore a filter with 0.3 Hz cutoff frequency was used. From each window, a vector of features was obtained by calculating variables from the time and frequency domain.

Feature Information :

For each record in the dataset it is provided:

- Triaxial acceleration from the accelerometer (total acceleration) and the estimated body acceleration.
- Triaxial Angular velocity from the gyroscope.
- A 561-feature vector with time and frequency domain variables.
- Its activity label.
- An identifier of the subject who carried out the experiment.

Class Labels:

In the dataset, Y_labels are represented as numbers from 1 to 6 as their identifiers.

1. WALKING as 1
2. WALKING_UPSTAIRS as 2
3. WALKING_DOWNSTAIRS as 3
4. SITTING as 4
5. STANDING as 5
6. LAYING as 6

Machine Learning Problem :

It is a Multi-class classification.

Load Data :

In [1]:

```
import pandas as pd
import numpy as np
from matplotlib import pyplot as plt
import seaborn as sns
```

In [2]:

```
SIGNALS = [
    "body_acc_x",
    "body_acc_y",
    "body_acc_z",
    "body_gyro_x",
    "body_gyro_y",
    "body_gyro_z",
    "total_acc_x",
    "total_acc_y",
    "total_acc_z"
]

def _read_csv(filename):
    return pd.read_csv(filename, delim_whitespace=True, header=None)


def load_signals(subset):
    signals_data = []

    for signal in SIGNALS:
        filename = f'C:/Users/Friend/AI/AI_datasets/HumanActivityRecognition/{subset}/Inertial Signals/
{signal}_{subset}.txt'
        signals_data.append(
            _read_csv(filename).as_matrix()
        )
    return np.transpose(signals_data, (1, 2, 0))



def load_y(subset):
    filename = f'C:/Users/Friend/AI/AI_datasets/HumanActivityRecognition/{subset}/y_{subset}.txt'
    y = _read_csv(filename)[0]

    return pd.get_dummies(y).as_matrix()


def load_data():
    X_train, X_test = load_signals('train'), load_signals('test')
    y_train, y_test = load_y('train'), load_y('test')

    return X_train, X_test, y_train, y_test

X_train, X_test, Y_train, Y_test = load_data()
```

```
C:\Users\Friend\Anaconda3\lib\site-packages\ipykernel_launcher.py:23: FutureWarning: Method .as_matrix
will be removed in a future version. Use .values instead.
C:\Users\Friend\Anaconda3\lib\site-packages\ipykernel_launcher.py:33: FutureWarning: Method .as_matrix
will be removed in a future version. Use .values instead.
```

In [3]:

```
timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = len(set([tuple(category) for category in Y_train]))

print(timesteps)
print(input_dim)
print(len(X_train))
```

```
128
9
7352
```

Deep Learning Models:

In [5]:

```
ACTIVITIES = {
    0: 'WALKING',
    1: 'WALKING_UPSTAIRS',
```

```
    2: 'WALKING_DOWNSTAIRS',
    3: 'SITTING',
    4: 'STANDING',
    5: 'LAYING',
}
```

In [6]:

```
def confusion_matrix(Y_true, Y_pred):
    Y_true = pd.Series([ACTIVITIES[y] for y in np.argmax(Y_true, axis=1)])
    Y_pred = pd.Series([ACTIVITIES[y] for y in np.argmax(Y_pred, axis=1)])

    return pd.crosstab(Y_true, Y_pred, rownames=['True'], colnames=['Pred'])
```

In [7]:

```
np.random.seed(42)
import tensorflow as tf
tf.set_random_seed(42)
```

```
C:\Users\Friend\Anaconda3\lib\site-packages\h5py\__init__.py:36: FutureWarning: Conversion of the secon
d argument of issubdtype from `float` to `np.floating` is deprecated. In future, it will be treated as
`np.float64 == np.dtype(float).type`.
  from ._conv import register_converters as _register_converters
```

In [8]:

```
session_conf = tf.ConfigProto(
    intra_op_parallelism_threads=1,
    inter_op_parallelism_threads=1
)

from keras import backend as K
sess = tf.Session(graph=tf.get_default_graph(), config=session_conf)
K.set_session(sess)
```

```
Using TensorFlow backend.
```

In [9]:

```
from keras.models import Sequential
from keras.layers import LSTM
from keras.layers.core import Dense, Dropout
```

LSTM with 1 hidden Layer:

In [15]:

```
def plt_dynamic(x, vy, ty, ax, colors=['b']):
    ax.plot(x, vy, 'b', label="Validation Loss")
    ax.plot(x, ty, 'r', label="Train Loss")
    plt.legend()
    plt.grid()
    fig.canvas.draw()
```

In [10]:

```
epochs = 30
batch_size = 16
n_hidden = 32
```

In [11]:

```
model1 = Sequential()
model1.add(LSTM(n_hidden, input_shape=(timesteps, input_dim)))
model1.add(Dropout(0.5))
```

```
model1.add(Dense(n_classes, activation='sigmoid'))
model1.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_1 (LSTM)                (None, 32)                5376
_________________________________________________________________
dropout_1 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_1 (Dense)              (None, 6)                 198
=================================================================
Total params: 5,574
Trainable params: 5,574
Non-trainable params: 0
_________________________________________________________________
```

In [12]:

```
model1.compile(loss='categorical_crossentropy',optimizer='rmsprop',metrics=['accuracy'])
history = model1.fit(X_train,Y_train,batch_size=batch_size,validation_data=(X_test, Y_test),epochs=epoc
hs)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 59s 8ms/step - loss: 1.3139 - acc: 0.4358 - val_loss: 1.13
52 - val_acc: 0.4700
Epoch 2/30
7352/7352 [==============================] - 59s 8ms/step - loss: 0.9788 - acc: 0.5773 - val_loss: 0.95
13 - val_acc: 0.5884
Epoch 3/30
7352/7352 [==============================] - 59s 8ms/step - loss: 0.7977 - acc: 0.6457 - val_loss: 0.83
43 - val_acc: 0.6013
Epoch 4/30
7352/7352 [==============================] - 59s 8ms/step - loss: 0.6989 - acc: 0.6582 - val_loss: 0.75
32 - val_acc: 0.6098
Epoch 5/30
7352/7352 [==============================] - 59s 8ms/step - loss: 0.6359 - acc: 0.6797 - val_loss: 0.73
35 - val_acc: 0.6183
Epoch 6/30
7352/7352 [==============================] - 58s 8ms/step - loss: 0.5819 - acc: 0.6865 - val_loss: 0.87
86 - val_acc: 0.6098
Epoch 7/30
7352/7352 [==============================] - 58s 8ms/step - loss: 0.5676 - acc: 0.7058 - val_loss: 0.81
91 - val_acc: 0.6132
Epoch 8/30
7352/7352 [==============================] - 58s 8ms/step - loss: 0.5583 - acc: 0.7217 - val_loss: 0.66
39 - val_acc: 0.7190
Epoch 9/30
7352/7352 [==============================] - 57s 8ms/step - loss: 0.5386 - acc: 0.7557 - val_loss: 0.63
88 - val_acc: 0.7167
Epoch 10/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.4804 - acc: 0.7911 - val_loss: 0.50
77 - val_acc: 0.7509
Epoch 11/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.4320 - acc: 0.8052 - val_loss: 0.51
43 - val_acc: 0.7418
Epoch 12/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.4279 - acc: 0.8062 - val_loss: 0.49
51 - val_acc: 0.7472
Epoch 13/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.3911 - acc: 0.8130 - val_loss: 0.56
06 - val_acc: 0.7516
Epoch 14/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.3898 - acc: 0.8313 - val_loss: 0.45
18 - val_acc: 0.8137
Epoch 15/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.3308 - acc: 0.8942 - val_loss: 0.47
32 - val_acc: 0.8633
Epoch 16/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2891 - acc: 0.9176 - val_loss: 0.37
94 - val_acc: 0.8765
Epoch 17/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2660 - acc: 0.9246 - val_loss: 0.50
82 - val_acc: 0.8660
```

```
Epoch 18/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2538 - acc: 0.9251 - val_loss: 0.47
72 - val_acc: 0.8806
Epoch 19/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2502 - acc: 0.9312 - val_loss: 0.70
13 - val_acc: 0.8307
Epoch 20/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.1980 - acc: 0.9382 - val_loss: 0.39
88 - val_acc: 0.8890
Epoch 21/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2018 - acc: 0.9372 - val_loss: 1.76
82 - val_acc: 0.7075
Epoch 22/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2455 - acc: 0.9310 - val_loss: 0.58
12 - val_acc: 0.8687
Epoch 23/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2194 - acc: 0.9329 - val_loss: 0.64
68 - val_acc: 0.8744
Epoch 24/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2282 - acc: 0.9304 - val_loss: 0.47
21 - val_acc: 0.8741
Epoch 25/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2166 - acc: 0.9359 - val_loss: 0.41
31 - val_acc: 0.8938
Epoch 26/30
7352/7352 [==============================] - 32s 4ms/step - loss: 0.2173 - acc: 0.9350 - val_loss: 0.48
41 - val_acc: 0.8887
Epoch 27/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.2224 - acc: 0.9353 - val_loss: 0.35
90 - val_acc: 0.8935
Epoch 28/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.1961 - acc: 0.9385 - val_loss: 0.52
97 - val_acc: 0.8802
Epoch 29/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.1876 - acc: 0.9416 - val_loss: 0.43
24 - val_acc: 0.8924
Epoch 30/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.1999 - acc: 0.9411 - val_loss: 0.48
83 - val_acc: 0.8829
```

In [13]:

```
print(confusion_matrix(Y_test, model1.predict(X_test)))
```

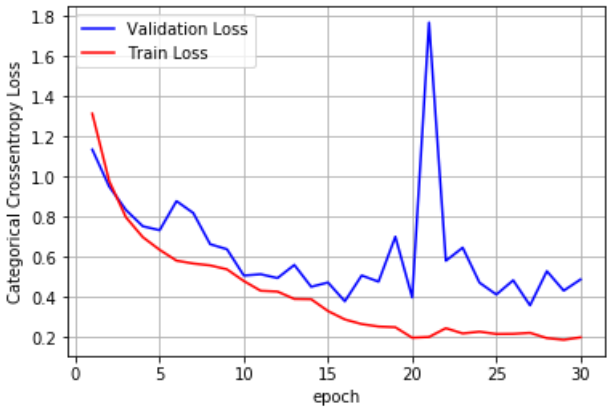
```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 537        0         0        0                   0
SITTING                  0      383       108        0                   0
STANDING                 0       99       432        1                   0
WALKING                  0        0         0      472                  23
WALKING_DOWNSTAIRS       0        0         0       27                 381
WALKING_UPSTAIRS         0        0         1       61                  12

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            0
STANDING                           0
WALKING                            1
WALKING_DOWNSTAIRS                12
WALKING_UPSTAIRS                 397
```

In [16]:

```
score1 = model1.evaluate(X_test, Y_test)

print('Test score:', score1[0])
print('Test accuracy:', score1[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch')
ax.set_ylabel('Categorical Crossentropy Loss')

x = list(range(1,epochs+1))
```

```
vy = history.history['val_loss']
ty = history.history['loss']

plt_dynamic(x, vy, ty, ax)
```

```
2947/2947 [==============================] - 1s 420us/step
Test score: 0.48826993001486146
Test accuracy: 0.8829317950458093
```



LSTM with 2 hidden Layers:

In [17]:

```
epochs = 30
batch_size = 16
```

Hidden Layers = 32,Drop-out = 0.6

In [18]:

```
n_hidden = 32
model2 = Sequential()
model2.add(LSTM(n_hidden,return_sequences=True,input_shape=(timesteps, input_dim)))
model2.add(Dropout(0.6))
model2.add(LSTM(n_hidden))
model2.add(Dropout(0.6))
model2.add(Dense(n_classes, activation='sigmoid'))
model2.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_2 (LSTM)                (None, 128, 32)           5376
_________________________________________________________________
dropout_2 (Dropout)          (None, 128, 32)           0
_________________________________________________________________
lstm_3 (LSTM)                (None, 32)                8320
_________________________________________________________________
dropout_3 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_2 (Dense)              (None, 6)                 198
=================================================================
Total params: 13,894
Trainable params: 13,894
Non-trainable params: 0
_________________________________________________________________
```

In [19]:

```
model2.compile(loss='categorical_crossentropy',optimizer='rmsprop',metrics=['accuracy'])
history = model2.fit(X_train,Y_train,batch_size=batch_size,validation_data=(X_test, Y_test),epochs=epoc
hs)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 71s 10ms/step - loss: 1.1998 - acc: 0.5178 - val_loss: 0.8
683 - val_acc: 0.6440
Epoch 2/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.8431 - acc: 0.6272 - val_loss: 0.80
84 - val_acc: 0.6152
Epoch 3/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.7142 - acc: 0.6974 - val_loss: 0.74
53 - val_acc: 0.7017
Epoch 4/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.6332 - acc: 0.7550 - val_loss: 0.76
67 - val_acc: 0.7133
Epoch 5/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.5030 - acc: 0.8192 - val_loss: 0.69
05 - val_acc: 0.8083
Epoch 6/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.3889 - acc: 0.8886 - val_loss: 0.51
45 - val_acc: 0.8375
Epoch 7/30
7352/7352 [==============================] - 70s 9ms/step - loss: 0.3122 - acc: 0.9140 - val_loss: 0.39
79 - val_acc: 0.8738
Epoch 8/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.2692 - acc: 0.9210 - val_loss: 0.43
23 - val_acc: 0.8548
Epoch 9/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.2410 - acc: 0.9270 - val_loss: 0.39
13 - val_acc: 0.8856
Epoch 10/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.2277 - acc: 0.9319 - val_loss: 0.41
48 - val_acc: 0.8812
Epoch 11/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.2177 - acc: 0.9361 - val_loss: 0.34
36 - val_acc: 0.8996
Epoch 12/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.2141 - acc: 0.9354 - val_loss: 0.33
92 - val_acc: 0.8958
Epoch 13/30
7352/7352 [==============================] - 73s 10ms/step - loss: 0.1982 - acc: 0.9374 - val_loss: 0.3
516 - val_acc: 0.8935
Epoch 14/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1896 - acc: 0.9366 - val_loss: 0.3
772 - val_acc: 0.9009
Epoch 15/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.1810 - acc: 0.9387 - val_loss: 0.45
02 - val_acc: 0.8928
Epoch 16/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.1759 - acc: 0.9404 - val_loss: 0.41
50 - val_acc: 0.8856
Epoch 17/30
7352/7352 [==============================] - 72s 10ms/step - loss: 0.1610 - acc: 0.9446 - val_loss: 0.4
530 - val_acc: 0.8955
Epoch 18/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.1798 - acc: 0.9422 - val_loss: 0.41
35 - val_acc: 0.9046
Epoch 19/30
7352/7352 [==============================] - 73s 10ms/step - loss: 0.1635 - acc: 0.9426 - val_loss: 0.4
349 - val_acc: 0.8962
Epoch 20/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.1551 - acc: 0.9448 - val_loss: 0.4
900 - val_acc: 0.9036
Epoch 21/30
7352/7352 [==============================] - 72s 10ms/step - loss: 0.1634 - acc: 0.9465 - val_loss: 0.4
723 - val_acc: 0.8968
Epoch 22/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1568 - acc: 0.9467 - val_loss: 0.4
645 - val_acc: 0.9019
Epoch 23/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1626 - acc: 0.9450 - val_loss: 0.4
054 - val_acc: 0.9111
Epoch 24/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.1697 - acc: 0.9460 - val_loss: 0.37
71 - val_acc: 0.9121
Epoch 25/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.1607 - acc: 0.9480 - val_loss: 0.39
```

```
94 - val_acc: 0.9036
Epoch 26/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.1528 - acc: 0.9478 - val_loss: 0.53
50 - val_acc: 0.8996
Epoch 27/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.1558 - acc: 0.9459 - val_loss: 0.68
54 - val_acc: 0.8877
Epoch 28/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.1622 - acc: 0.9491 - val_loss: 0.5
923 - val_acc: 0.8996
Epoch 29/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.1595 - acc: 0.9484 - val_loss: 0.66
90 - val_acc: 0.8999
Epoch 30/30
7352/7352 [==============================] - 68s 9ms/step - loss: 0.1739 - acc: 0.9408 - val_loss: 0.59
48 - val_acc: 0.8992
```

In [20]:

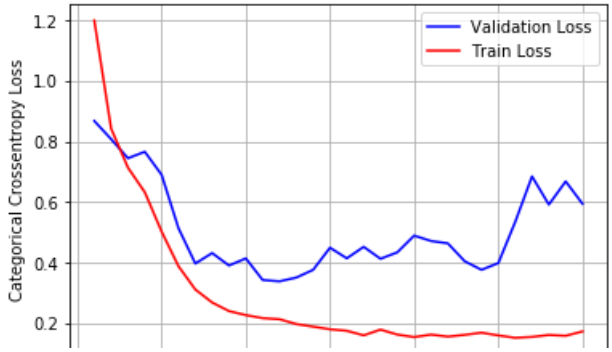
```
print(confusion_matrix(Y_test, model2.predict(X_test)))
```

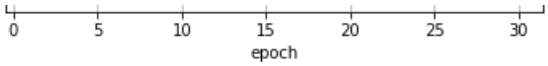
```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0         0        0                   0
SITTING                  0      409        73        6                   0
STANDING                 0       94       437        1                   0
WALKING                  0        0         0      467                   2
WALKING_DOWNSTAIRS       0        0         0       12                 371
WALKING_UPSTAIRS         0        0         0       15                   0

Pred                WALKING_UPSTAIRS
True
LAYING                            27
SITTING                            3
STANDING                           0
WALKING                           27
WALKING_DOWNSTAIRS                37
WALKING_UPSTAIRS                 456
```

In [21]:

```
score2 = model2.evaluate(X_test, Y_test)

print('Test score:', score2[0])
print('Test accuracy:', score2[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch')
ax.set_ylabel('Categorical Crossentropy Loss')

x = list(range(1,epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']

plt_dynamic(x, vy, ty, ax)
```

```
2947/2947 [==============================] - 3s 967us/step
Test score: 0.5947882716293358
Test accuracy: 0.8992195453003053
```





Hidden Layers = 64,Drop-out = 0.6

In [22]:

```
n_hidden = 64
drop_out = 0.6
model3 = Sequential()
model3.add(LSTM(n_hidden,return_sequences=True,input_shape=(timesteps, input_dim)))
model3.add(Dropout(drop_out))
model3.add(LSTM(n_hidden))
model3.add(Dropout(drop_out))
model3.add(Dense(n_classes, activation='sigmoid'))
model3.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_4 (LSTM)                (None, 128, 64)           18944
_________________________________________________________________
dropout_4 (Dropout)          (None, 128, 64)           0
_________________________________________________________________
lstm_5 (LSTM)                (None, 64)                33024
_________________________________________________________________
dropout_5 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_3 (Dense)              (None, 6)                 390
=================================================================
Total params: 52,358
Trainable params: 52,358
Non-trainable params: 0
_________________________________________________________________
```

In [23]:

```
model3.compile(loss='categorical_crossentropy',optimizer='rmsprop',metrics=['accuracy'])
model3.fit(X_train,Y_train,batch_size=batch_size,validation_data=(X_test, Y_test),epochs=epochs)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 99s 13ms/step - loss: 1.1031 - acc: 0.5199 - val_loss: 1.0
280 - val_acc: 0.5667
Epoch 2/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.7983 - acc: 0.6495 - val_loss: 0.7
187 - val_acc: 0.6932
Epoch 3/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.6560 - acc: 0.7171 - val_loss: 0.6
754 - val_acc: 0.7177
Epoch 4/30
7352/7352 [==============================] - 98s 13ms/step - loss: 0.5287 - acc: 0.7643 - val_loss: 0.5
936 - val_acc: 0.7472
Epoch 5/30
7352/7352 [==============================] - 98s 13ms/step - loss: 0.4408 - acc: 0.8017 - val_loss: 0.5
514 - val_acc: 0.7947
Epoch 6/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.3725 - acc: 0.8645 - val_loss: 0.4
454 - val_acc: 0.8395
Epoch 7/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.2395 - acc: 0.9232 - val_loss: 0.6
714 - val_acc: 0.8191
Epoch 8/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.1972 - acc: 0.9391 - val_loss: 0.4
554 - val_acc: 0.8931
Epoch 9/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.1826 - acc: 0.9418 - val_loss: 0.4
027 - val_acc: 0.8968
Epoch 10/30
7352/7352 [==============================] - 100s 14ms/step - loss: 0.1937 - acc: 0.9336 - val_loss: 0.
3139 - val_acc: 0.90570s  - ETA: 4s - l
```

```
Epoch 11/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.1687 - acc: 0.9406 - val_loss: 0.3
432 - val_acc: 0.9165
Epoch 12/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.1517 - acc: 0.9486 - val_loss: 0.3
941 - val_acc: 0.912513s - loss: 0.148 - E
Epoch 13/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.1387 - acc: 0.9490 - val_loss: 0.5
433 - val_acc: 0.9111o - ETA: 1s - loss: 0.1400 - acc: 0. - ETA: 0s - loss: 0.1393 - acc: 0
Epoch 14/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.1552 - acc: 0.9475 - val_loss: 0.7
033 - val_acc: 0.8935
Epoch 15/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.1694 - acc: 0.9455 - val_loss: 0.5
474 - val_acc: 0.90601s - loss: 0.1698 - acc
Epoch 16/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.1610 - acc: 0.9455 - val_loss: 0.5
640 - val_acc: 0.9030
Epoch 17/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.1451 - acc: 0.9498 - val_loss: 0.7
351 - val_acc: 0.8785
Epoch 18/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.1484 - acc: 0.9484 - val_loss: 0.5
413 - val_acc: 0.8904TA: 10 - ETA: 5s - loss: 0.1 - ETA: 2s - loss: 0.14
Epoch 19/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.1435 - acc: 0.9474 - val_loss: 0.5
694 - val_acc: 0.9172: 0.1417 - - ETA: 13s - loss - ETA: 11s - loss: 0.14 - ETA: 2s - loss: 0.1426 -
Epoch 20/30
7352/7352 [==============================] - 101s 14ms/step - loss: 0.1375 - acc: 0.9478 - val_loss: 0.
5936 - val_acc: 0.9087
Epoch 21/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.1374 - acc: 0.9487 - val_loss: 0.5
314 - val_acc: 0.9016
Epoch 22/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.1420 - acc: 0.9459 - val_loss: 0.5
950 - val_acc: 0.9002
Epoch 23/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.1491 - acc: 0.9453 - val_loss: 0.7
254 - val_acc: 0.8904
Epoch 24/30
7352/7352 [==============================] - 97s 13ms/step - loss: 0.1488 - acc: 0.9455 - val_loss: 0.5
331 - val_acc: 0.9019
Epoch 25/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.1391 - acc: 0.9516 - val_loss: 0.7
242 - val_acc: 0.8802
Epoch 26/30
7352/7352 [==============================] - 87s 12ms/step - loss: 0.1359 - acc: 0.9471 - val_loss: 0.5
849 - val_acc: 0.9155
Epoch 27/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.2542 - acc: 0.9325 - val_loss: 0.5
843 - val_acc: 0.90530.2582
Epoch 28/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.1272 - acc: 0.9532 - val_loss: 0.6
856 - val_acc: 0.9026 - ETA: 0s - loss: 0.1273 - acc: 0.953
Epoch 29/30
7352/7352 [==============================] - 136s 19ms/step - loss: 0.1242 - acc: 0.9557 - val_loss: 0.
6369 - val_acc: 0.9006
Epoch 30/30
7352/7352 [==============================] - 168s 23ms/step - loss: 0.1446 - acc: 0.9490 - val_loss: 0.
6064 - val_acc: 0.9002
```

Out[23]:

```
<keras.callbacks.History at 0x2b412ae4d30>
```

In [24]:

```
print(confusion_matrix(Y_test, model3.predict(X_test)))
```

Pred	LAYING	SITTING	STANDING	WALKING	WALKING_DOWNSTAIRS	\
True						
LAYING	497	0	27	0	12	
SITTING	2	354	135	0	0	
STANDING	0	54	478	0	0	
WALKING	0	1	1	460	14	
WALKING_DOWNSTAIRS	0	0	0	0	410	

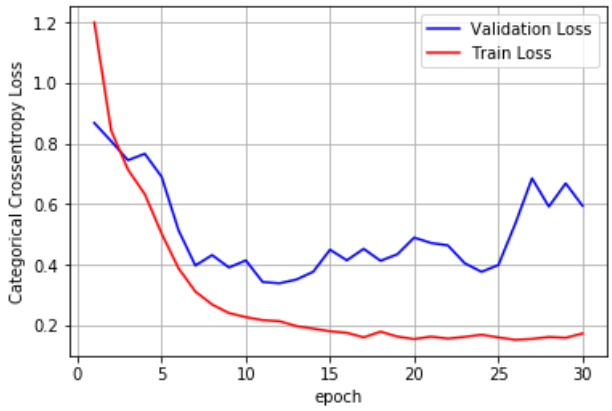
```
WALKING_DOWNSTAIRS        0        0          0         0                 419
WALKING_UPSTAIRS          0       12          0         4                  10
```

```
Pred                 WALKING_UPSTAIRS
True
LAYING                              1
SITTING                             0
STANDING                            0
WALKING                            20
WALKING_DOWNSTAIRS                  1
WALKING_UPSTAIRS                  445
```

In [27]:

```
score3 = model3.evaluate(X_test, Y_test)

print('Test score:', score3[0])
print('Test accuracy:', score3[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch')
ax.set_ylabel('Categorical Crossentropy Loss')

x = list(range(1,epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']

plt_dynamic(x, vy, ty, ax)
```

```
2947/2947 [==============================] - 9s 3ms/step
Test score: 0.6063831242102351
Test accuracy: 0.9002375296912114
```



Hidden Layers = 32,Drop-out = 0.8

In [28]:

```
n_hidden = 32
drop_out = 0.8
model4 = Sequential()
model4.add(LSTM(n_hidden,return_sequences=True,input_shape=(timesteps, input_dim)))
model4.add(Dropout(drop_out))
model4.add(LSTM(n_hidden))
model4.add(Dropout(drop_out))
model4.add(Dense(n_classes, activation='sigmoid'))
model4.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_6 (LSTM)                (None, 128, 32)           5376
_________________________________________________________________
dropout_6 (Dropout)          (None, 128, 32)           0
_________________________________________________________________
lstm_7 (LSTM)                (None, 32)                8320
```

```
_________________________________________________________________
dropout_7 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_4 (Dense)              (None, 6)                 198
=================================================================
Total params: 13,894
Trainable params: 13,894
Non-trainable params: 0
_________________________________________________________________
```

In [29]:

```
model4.compile(loss='categorical_crossentropy',optimizer='rmsprop',metrics=['accuracy'])
history = model4.fit(X_train,Y_train,batch_size=batch_size,validation_data=(X_test, Y_test),epochs=epoc
hs)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 131s 18ms/step - loss: 1.4410 - acc: 0.4217 - val_loss: 1.
1411 - val_acc: 0.4656
Epoch 2/30
7352/7352 [==============================] - 130s 18ms/step - loss: 1.0816 - acc: 0.5394 - val_loss: 0.
9022 - val_acc: 0.5898
Epoch 3/30
7352/7352 [==============================] - 134s 18ms/step - loss: 0.9246 - acc: 0.5894 - val_loss: 0.
8111 - val_acc: 0.6193
Epoch 4/30
7352/7352 [==============================] - 133s 18ms/step - loss: 0.8749 - acc: 0.6028 - val_loss: 0.
8078 - val_acc: 0.6196
Epoch 5/30
7352/7352 [==============================] - 129s 18ms/step - loss: 0.8385 - acc: 0.6171 - val_loss: 0.
7979 - val_acc: 0.6084
Epoch 6/30
7352/7352 [==============================] - 138s 19ms/step - loss: 0.8010 - acc: 0.6226 - val_loss: 0.
7752 - val_acc: 0.6162
Epoch 7/30
7352/7352 [==============================] - 139s 19ms/step - loss: 0.7849 - acc: 0.6319 - val_loss: 0.
7464 - val_acc: 0.6155
Epoch 8/30
7352/7352 [==============================] - 136s 19ms/step - loss: 0.7805 - acc: 0.6318 - val_loss: 0.
7245 - val_acc: 0.6200
Epoch 9/30
7352/7352 [==============================] - 140s 19ms/step - loss: 0.7763 - acc: 0.6329 - val_loss: 0.
7554 - val_acc: 0.6162
Epoch 10/30
7352/7352 [==============================] - 135s 18ms/step - loss: 0.7753 - acc: 0.6367 - val_loss: 0.
7512 - val_acc: 0.6200
Epoch 11/30
7352/7352 [==============================] - 137s 19ms/step - loss: 0.7431 - acc: 0.6397 - val_loss: 0.
7782 - val_acc: 0.6196
Epoch 12/30
7352/7352 [==============================] - 142s 19ms/step - loss: 0.7458 - acc: 0.6394 - val_loss: 0.
7855 - val_acc: 0.6128
Epoch 13/30
7352/7352 [==============================] - 133s 18ms/step - loss: 0.7271 - acc: 0.6517 - val_loss: 0.
8045 - val_acc: 0.6101
Epoch 14/30
7352/7352 [==============================] - 73s 10ms/step - loss: 0.7055 - acc: 0.6536 - val_loss: 0.6
471 - val_acc: 0.6166
Epoch 15/30
7352/7352 [==============================] - 72s 10ms/step - loss: 0.6801 - acc: 0.6579 - val_loss: 0.6
003 - val_acc: 0.6261
Epoch 16/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.6359 - acc: 0.6695 - val_loss: 0.6
034 - val_acc: 0.6335
Epoch 17/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.6099 - acc: 0.6914 - val_loss: 0.6
670 - val_acc: 0.6254
Epoch 18/30
7352/7352 [==============================] - 72s 10ms/step - loss: 0.5994 - acc: 0.6982 - val_loss: 0.6
284 - val_acc: 0.6257
Epoch 19/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5728 - acc: 0.7100 - val_loss: 0.68
21 - val_acc: 0.7414
Epoch 20/30
```

```
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5686 - acc: 0.7179 - val_loss: 0.59
38 - val_acc: 0.7679
Epoch 21/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5992 - acc: 0.7233 - val_loss: 1.21
94 - val_acc: 0.7272
Epoch 22/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5778 - acc: 0.7273 - val_loss: 0.80
56 - val_acc: 0.7503
Epoch 23/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5524 - acc: 0.7339 - val_loss: 0.56
08 - val_acc: 0.7577
Epoch 24/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5281 - acc: 0.7403 - val_loss: 0.56
39 - val_acc: 0.7659
Epoch 25/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5296 - acc: 0.7410 - val_loss: 0.52
68 - val_acc: 0.7672
Epoch 26/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5179 - acc: 0.7444 - val_loss: 0.52
53 - val_acc: 0.7737
Epoch 27/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5260 - acc: 0.7493 - val_loss: 0.51
69 - val_acc: 0.7706
Epoch 28/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.4890 - acc: 0.7678 - val_loss: 0.58
22 - val_acc: 0.7703
Epoch 29/30
7352/7352 [==============================] - 67s 9ms/step - loss: 0.5277 - acc: 0.7731 - val_loss: 0.63
34 - val_acc: 0.7699
Epoch 30/30
7352/7352 [==============================] - 68s 9ms/step - loss: 0.4735 - acc: 0.7787 - val_loss: 0.53
64 - val_acc: 0.7611
```

In [30]:

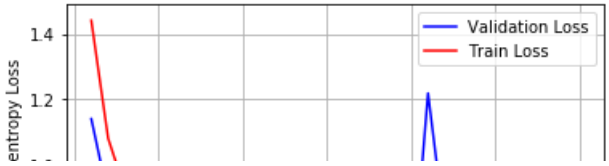
```
print(confusion_matrix(Y_test, model4.predict(X_test)))
```

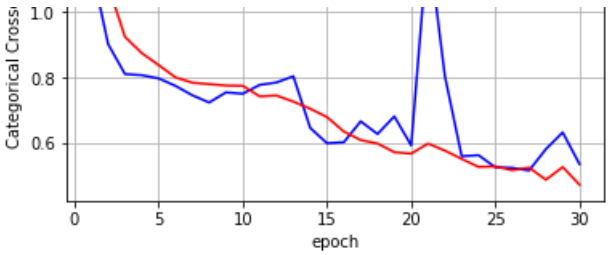
Pred	LAYING	SITTING	STANDING	WALKING	WALKING_UPSTAIRS
True					
LAYING	537	0	0	0	0
SITTING	9	430	50	2	0
STANDING	0	141	390	1	0
WALKING	1	0	0	467	28
WALKING_DOWNSTAIRS	0	0	0	2	418
WALKING_UPSTAIRS	11	1	0	40	419

In [31]:

```
score4 = model4.evaluate(X_test, Y_test)

print('Test score:', score4[0])
print('Test accuracy:', score4[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch')
ax.set_ylabel('Categorical Crossentropy Loss')

x = list(range(1,epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']

plt_dynamic(x, vy, ty, ax)
```

```
2947/2947 [==============================] - 3s 1ms/step
Test score: 0.536436351557261
Test accuracy: 0.7611129962673906
```





Hidden Layers = 64,Drop-out = 0.8

In [32]:

```
n_hidden = 64
drop_out = 0.8
model5 = Sequential()
model5.add(LSTM(n_hidden,return_sequences=True,input_shape=(timesteps, input_dim)))
model5.add(Dropout(drop_out))
model5.add(LSTM(n_hidden))
model5.add(Dropout(drop_out))
model5.add(Dense(n_classes, activation='sigmoid'))
model5.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_8 (LSTM)                (None, 128, 64)           18944
_________________________________________________________________
dropout_8 (Dropout)          (None, 128, 64)           0
_________________________________________________________________
lstm_9 (LSTM)                (None, 64)                33024
_________________________________________________________________
dropout_9 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_5 (Dense)              (None, 6)                 390
=================================================================
Total params: 52,358
Trainable params: 52,358
Non-trainable params: 0
_________________________________________________________________
```

In [33]:

```
model5.compile(loss='categorical_crossentropy',optimizer='rmsprop',metrics=['accuracy'])
history = model5.fit(X_train,Y_train,batch_size=batch_size,validation_data=(X_test, Y_test),epochs=epoc
hs)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 92s 13ms/step - loss: 1.2349 - acc: 0.4819 - val_loss: 0.8
841 - val_acc: 0.5643
Epoch 2/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.8676 - acc: 0.6099 - val_loss: 0.8
622 - val_acc: 0.5830
Epoch 3/30
7352/7352 [==============================] - 98s 13ms/step - loss: 0.8102 - acc: 0.6296 - val_loss: 0.8
227 - val_acc: 0.6023 - loss: 0.8111 - acc: 0.6
Epoch 4/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.6975 - acc: 0.6737 - val_loss: 0.7
357 - val_acc: 0.6230
Epoch 5/30
7352/7352 [==============================] - 102s 14ms/step - loss: 0.6466 - acc: 0.6972 - val_loss: 0.
6956 - val_acc: 0.7279
Epoch 6/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.6378 - acc: 0.7223 - val_loss: 0.6
277 - val_acc: 0.7336
Epoch 7/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.5218 - acc: 0.7764 - val_loss: 0.5
251 - val_acc: 0.7574
Epoch 8/30
```

```
7352/7352 [==============================] - 91s 12ms/step - loss: 0.4651 - acc: 0.7824 - val_loss: 0.6
482 - val_acc: 0.7452
Epoch 9/30
7352/7352 [==============================] - 101s 14ms/step - loss: 0.4685 - acc: 0.7893 - val_loss: 0.
5819 - val_acc: 0.7411s - loss:
Epoch 10/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.4139 - acc: 0.8137 - val_loss: 0.4
824 - val_acc: 0.8487
Epoch 11/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.3956 - acc: 0.8610 - val_loss: 0.3
859 - val_acc: 0.8605
Epoch 12/30
7352/7352 [==============================] - 157s 21ms/step - loss: 0.3221 - acc: 0.9071 - val_loss: 0.
5192 - val_acc: 0.8649
Epoch 13/30
7352/7352 [==============================] - 169s 23ms/step - loss: 0.2891 - acc: 0.9200 - val_loss: 0.
4769 - val_acc: 0.8643
Epoch 14/30
7352/7352 [==============================] - 172s 23ms/step - loss: 0.2329 - acc: 0.9313 - val_loss: 0.
4497 - val_acc: 0.8948
Epoch 15/30
7352/7352 [==============================] - 170s 23ms/step - loss: 0.2402 - acc: 0.9289 - val_loss: 0.
4965 - val_acc: 0.8904
Epoch 16/30
7352/7352 [==============================] - 171s 23ms/step - loss: 0.2317 - acc: 0.9344 - val_loss: 0.
2846 - val_acc: 0.9077
Epoch 17/30
7352/7352 [==============================] - 169s 23ms/step - loss: 0.2374 - acc: 0.9306 - val_loss: 0.
4899 - val_acc: 0.8958
Epoch 18/30
7352/7352 [==============================] - 173s 24ms/step - loss: 0.2277 - acc: 0.9329 - val_loss: 0.
4238 - val_acc: 0.9077
Epoch 19/30
7352/7352 [==============================] - 172s 23ms/step - loss: 0.1975 - acc: 0.9382 - val_loss: 0.
4375 - val_acc: 0.9016
Epoch 20/30
7352/7352 [==============================] - 168s 23ms/step - loss: 0.1949 - acc: 0.9380 - val_loss: 0.
5025 - val_acc: 0.9060
Epoch 21/30
7352/7352 [==============================] - 168s 23ms/step - loss: 0.1839 - acc: 0.9414 - val_loss: 0.
5706 - val_acc: 0.9070
Epoch 22/30
7352/7352 [==============================] - 169s 23ms/step - loss: 0.2133 - acc: 0.9374 - val_loss: 0.
4284 - val_acc: 0.9118
Epoch 23/30
7352/7352 [==============================] - 173s 23ms/step - loss: 0.1853 - acc: 0.9393 - val_loss: 0.
4336 - val_acc: 0.9046
Epoch 24/30
7352/7352 [==============================] - 178s 24ms/step - loss: 0.2485 - acc: 0.9221 - val_loss: 0.
3684 - val_acc: 0.9128
Epoch 25/30
7352/7352 [==============================] - 176s 24ms/step - loss: 0.1761 - acc: 0.9427 - val_loss: 0.
5995 - val_acc: 0.9002
Epoch 26/30
7352/7352 [==============================] - 177s 24ms/step - loss: 0.2156 - acc: 0.9373 - val_loss: 0.
4492 - val_acc: 0.9264
Epoch 27/30
7352/7352 [==============================] - 169s 23ms/step - loss: 0.1926 - acc: 0.9395 - val_loss: 0.
5274 - val_acc: 0.9169
Epoch 28/30
7352/7352 [==============================] - 166s 23ms/step - loss: 0.1738 - acc: 0.9403 - val_loss: 0.
5740 - val_acc: 0.9013
Epoch 29/30
7352/7352 [==============================] - 167s 23ms/step - loss: 0.1919 - acc: 0.9376 - val_loss: 0.
7271 - val_acc: 0.8880
Epoch 30/30
7352/7352 [==============================] - 161s 22ms/step - loss: 0.1727 - acc: 0.9440 - val_loss: 0.
4763 - val_acc: 0.9063
```

In [34]:

```
print(confusion_matrix(Y_test, model5.predict(X_test)))
```

Pred	LAYING	SITTING	STANDING	WALKING	WALKING_DOWNSTAIRS	\
True						
LAYING	521	0	16	0	0	

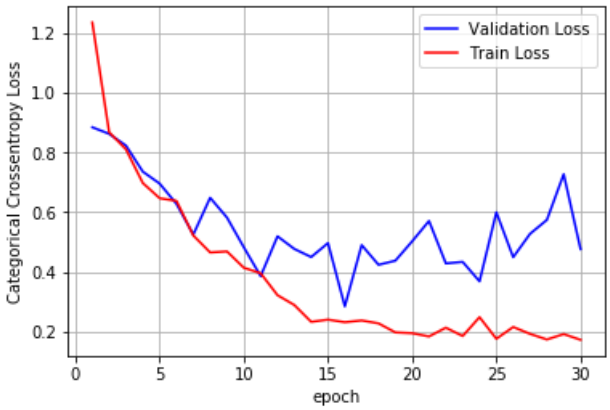
SITTING	6	375	91	1	0
STANDING	0	77	455	0	0
WALKING	0	0	0	473	14
WALKING_DOWNSTAIRS	3	0	0	0	411
WALKING_UPSTAIRS	5	5	1	5	19

Pred	WALKING_UPSTAIRS
True	
LAYING	0
SITTING	18
STANDING	0
WALKING	9
WALKING_DOWNSTAIRS	6
WALKING_UPSTAIRS	436

In [35]:

```
score5 = model5.evaluate(X_test, Y_test)

print('Test score:', score5[0])
print('Test accuracy:', score5[1])

fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch')
ax.set_ylabel('Categorical Crossentropy Loss')

x = list(range(1,epochs+1))
vy = history.history['val_loss']
ty = history.history['loss']

plt_dynamic(x, vy, ty, ax)
```

```
2947/2947 [==============================] - 10s 3ms/step
Test score: 0.47634486136884424
Test accuracy: 0.9063454360366474
```



Summary:

1. Data Pre-processing :For each window we have 561 features which on signal processed each window gives 128 time-steps.And at every time-step we have 9 time-series readings.Three gyroscope time-series data,three accelerometer time-series data for body and total accelerometer time-series data.
2. Load Data : taking all these values and get train and test to model.
3. Initialising : random seed,epochs,hidden Layer,drop-out
4. Import : Keras,Tensor Flow,Sequential,LSTM
5. Input data : (7352*1*28*9*);128 time steps,at every time step we have 9 time-series reading and 7352 time-series data(overlapped windows).
6. Training a model : Since the data input is very less,it is easy for the model to overfit if our model is complexly built.Hence choosing a simple LSTM architecture.
7. I have trained 5 models with different hidden and drop out values.The summary of the output is shown below.

Conclusion:

In [36]:

```
from prettytable import PrettyTable

Table = PrettyTable()

Table.field_names  = ["Model", "Nuerons", "Drop-out rate", "score"]

Table.add_row(["LSTM(Single Layer)", 32, 0.6,score1])
Table.add_row(["LSTM(Double Layer)", 32,0.6, score2])
Table.add_row(["LSTM(Double Layer)", 64, 0.6,score3])
Table.add_row(["LSTM(Double Layer)", 32, 0.8,score4])
Table.add_row(["LSTM(Double Layer)", 64, 0.8,score5])

print(Table)
```

```
+--------------------+---------+--------------+-----------------------------------------+
|       Model        | Nuerons | Drop-out rate |                  score                  |
+--------------------+---------+--------------+-----------------------------------------+
| LSTM(Single Layer) |    32   |      0.6      | [0.48826993001486146, 0.8829317950458093] |
| LSTM(Double Layer) |    32   |      0.6      |  [0.520119141131976, 0.8880217170003394]  |
| LSTM(Double Layer) |    64   |      0.6      |  [0.3858033237633154, 0.9284017645062775] |
| LSTM(Double Layer) |    32   |      0.8      |  [0.6408101797361757, 0.7441465897522904] |
| LSTM(Double Layer) |    64   |      0.8      |  [0.5258364012132946, 0.9026128266033254] |
+--------------------+---------+--------------+-----------------------------------------+
```