Machine Learning Applications

Time Series Prediction with Convolutional Neural Networks and Keras

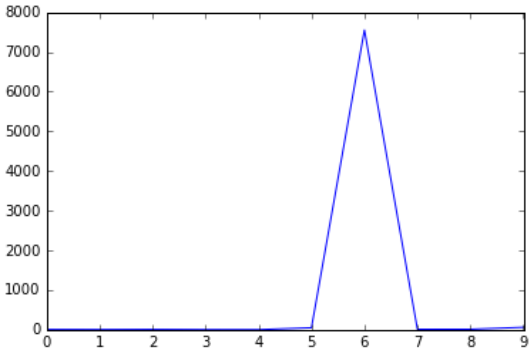
June 17, 2017 by owygs156

A convolutional neural network (CNNs) is a type of network that has recently

gained popularity due to its success in classification problems (e.g. image recognition
or time series classification) [1]. One of the working examples how to use Keras CNN for time series can be found at this link[2]. This example allows to predict for single time series and multivariate time series.

Running the code from this link, it was noticed that sometimes the prediction error has very high value, may be because optimizer gets stuck in local minimum. (See Fig1. The error is on axis Y and is very high for run 6) So I updated the script to run several times and then remove results with high error. (See Fig2 The Y axis showing small error values). Here is the summary of all changes:

- Created multiple runs that can allow to filter bad results based on error. Training CNN is running 10 times and for each run error data and some other associated data is saved. Error is calculated as square root of sum if squared errors for last 10 predictions during the training.
- Added also plot to see error over multiple runs.
- In the end of script added one plot that showing errors for each run (See Fig1.) , and another plot showing errors only for runs that did not have high error (See Fig2.).
- Added saving keras model to file for each run and then loading it from file for model that showed best results (min error). See [3] for more information on saving and loading keras models.
- Added ability to load time series from csv file.



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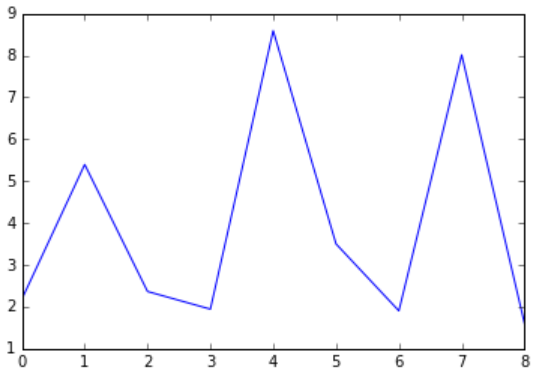
Error for all runs

Fig 1.



Error chart after removing runs with high value error

Fig 2.

Below is the full code

```
#!/usr/bin/env python
"""
This code is based on convolutional neural network
model from below link
gist.github.com/jkleint/1d878d0401b28b281eb75016ed2
9f2ee
"""

from __future__ import print_function, division

import numpy as np
from keras.layers import Convolution1D, Dense, MaxP
ooling1D, Flatten
from keras.models import Sequential
from keras.models import model_from_json

import matplotlib.pyplot as plt
import csv
```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```
__date__ = '2017-06-22'

error_total =[]
result=[]
i=0

def make_timeseries_regressor(window_size, filter_l
ength, nb_input_series=1, nb_outputs=1, nb_filter=4
):
    """:Return: a Keras Model for predicting the next

    The model can handle multiple input timeseries (`n

    :param int window_size: The number of previous tim
    :param int nb_input_series: The number of input ti
      The `X` input to ``fit()`` should be an array of
      a 2D array of shape ``(window_size, nb_input_ser
      single timeseries), one instance could be ``[[0]
    :param int nb_outputs: The output dimension, often
      For each input instance (array with shape ``(win
      usually the value(s) predicted to come after the
      in the sequence. The `y` input to ``fit()`` shou
    :param int filter_length: the size (along the `win
      each position along each instance. The differenc
      to the number of input timeseries (its "width" b
      dimension.  This is useful as generally the inpu
      meaningful to look for patterns that are invaria
    :param int nb_filter: The number of different filt
    """
    model = Sequential((
        # The first conv layer learns `nb_filter` filt
        # Its output will have shape (None, window_siz
        # the input timeseries, the activation of each
        Convolution1D(nb_filter=nb_filter, filter_leng
        MaxPooling1D(),     # Downsample the output of
        Convolution1D(nb_filter=nb_filter, filter_leng
        MaxPooling1D(),
        Flatten(),
        Dense(nb_outputs, activation='linear'),     #
    ))
    model.compile(loss='mse', optimizer='adam', metric
```

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```
    # To perform (binary) classification instead:
    # model.compile(loss='binary_crossentropy', optimi
    return model


def make_timeseries_instances(timeseries, window_si
ze):
    """Make input features and prediction targets from

    :return: A tuple of `(X, y, q)`.  `X` are the inpu
      ``(timeseries.shape[0] - window_size, window_siz
      corresponding row of `y` is the next value in th
      to predict a hypothetical next (unprovided) valu
    :param ndarray timeseries: Either a simple vector,
      row) and the series is axis 1 (the column).
    :param int window_size: The number of samples to u
    """
    timeseries = np.asarray(timeseries)
    assert 0 < window_size < timeseries.shape[0]
    X = np.atleast_3d(np.array([timeseries[start:start
    y = timeseries[window_size:]
    q = np.atleast_3d([timeseries[-window_size:]])
    return X, y, q


def evaluate_timeseries(timeseries, window_size):
    """Create a 1D CNN regressor to predict the next v
    as input features and evaluate its performance.

    :param ndarray timeseries: Timeseries data with ti
    :param int window_size: The number of previous tim
    """
    filter_length = 5
    nb_filter = 4
    timeseries = np.atleast_2d(timeseries)
    if timeseries.shape[0] == 1:
        timeseries = timeseries.T       # Convert 1D v

    nb_samples, nb_series = timeseries.shape
    print('\n\nTimeseries ({} samples by {} series)
:\n'.format(nb_samples, nb_series), timeseries)
```


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```
    model = make_timeseries_regressor(window_size=wind
    print('\n\nModel with input size {}, output siz
e {}, {} conv filters of length {}'.format(model.in
put_shape, model.output_shape, nb_filter, filter_le
ngth))
    model.summary()

    error=[]

    X, y, q = make_timeseries_instances(timeseries, wi
    print('\n\nInput features:', X, '\n\nOutput lab
els:', y, '\n\nQuery vector:', q, sep='\n')
    test_size = int(0.01 * nb_samples)           # In
    X_train, X_test, y_train, y_test = X[:-test_size],
    model.fit(X_train, y_train, nb_epoch=25, batch_siz

    # serialize model to JSON
    model_json = model.to_json()
    with open("model"+str(i)+".json", "w") as json_fil
          json_file.write(model_json)
    # serialize weights to HDF5
    model.save_weights("model"+str(i)+".h5")
    print("Saved model to disk")
    global i
    i=i+1

    pred = model.predict(X_test)
    print('\n\nactual', 'predicted', sep='\t')
    error_curr=0
    for actual, predicted in zip(y_test, pred.squeeze(
        print(actual.squeeze(), predicted, sep='\t'
)
        tmp = actual-predicted
        sum_squared = np.dot(tmp.T , tmp)
        error.append ( np.sqrt(sum_squared) )
        error_curr=error_curr+ np.sqrt(sum_squared)
    print('next', model.predict(q).squeeze(), sep='
\t')
    result.append  (model.predict(q).squeeze())
    error_total.append (error_curr)
    print (error)
```

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```
def read_file(fn):
    '''
    Reads the CSV file
    -----
    RETURNS:
        A matrix with the file contents
    '''

    vals = []
    with open(fn, 'r') as csvfile:
        tsdata = csv.reader(csvfile, delimiter=',')
        for row in tsdata:
             vals.append(row)

    # removing title row
    vals = vals[1:]
    y = np.array(vals).astype(np.float)
    return y
```

```
def main():
    """Prepare input data, build model, eval uate."""
    np.set_printoptions(threshold=25)
    ts_length = 1000
    window_size = 50
    number_of_runs=10
    error_max=200

    print('\nSimple single timeseries vector predic
tion')
    timeseries = np.arange(ts_length)
    # enable below line to run this time series
    #evaluate_timeseries(timeseries, window_size)

    print('\nMultiple-input, multiple-output predic
```

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Neural Networks with Python on the Web

Recently added many new links about neural nets for encoder - decoder, text translation, summarization , question answering , image recognition and other applications.

```
tion')
    timeseries = np.array([np.arange(ts_length), -np.a
    # enable below line to run this time series
    ##evaluate_timeseries(timeseries, window_size)

    print('\nMultiple-input, multiple-output predic
tion')
    timeseries = np.array([np.arange(ts_length), -np.a
    # enable below line to run this time series
    #evaluate_timeseries(timeseries, window_size)

    timeseries = read_file('ts_input.csv')
    print (timeseries)

    for i in range(number_of_runs):
        evaluate_timeseries(timeseries, window_size)

    error_total_new=[]
    for i in range(number_of_runs):
        if (error_total[i] < error_max):
            error_total_new.append (error_total[i])

    plt.plot(error_total)
    plt.show()
    print (result)

    plt.plot(error_total_new)
    plt.show()
    print (result)

    best_model=np.asarray(error_total).argmin(axis=0)
    print ("best_model="+str(best_model))




    json_file = open('model'+str(best_model)+'.json',
    loaded_model_json = json_file.read()
    json_file.close()
    loaded_model = model_from_json(loaded_model_json)
```

Archives

```
        # load weights into new model
        loaded_model.load_weights("model"+str(best_model)+
        print("Loaded model from disk")



if __name__ == '__main__':
    main()
```

References

1. Conditional Time Series Forecasting with Convolutional Neural Networks
2. Example of using Keras to implement a 1D convolutional neural network (CNN) for timeseries prediction
3. Save and Load Your Keras Deep Learning Models

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