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GAF-CNN-LSTM

for Multivariate Time-Series Images Forecasting

Edson F. Luque Mamani, Cristian Lopez del Alamo • 10-jun-2019

Abstract

Forecasting multivariate time series is challenging for a whole host of reasons not limited to problem features such as having multiple input variables, time series preparation, and the need to perform the same type of prediction for multiple physical sites. Although the literature on time series forecasting is focused on 1D signals. We use the Gramian Angular Fields (GAFs) to encode time series into 2D texture images, later take advantage of the deep CNN-LSTM architecture where LSTM uses a CNN as front end. Thus, we propose a novel unified framework for forecasting multivariate time series using a way to encode time series as images. Preliminary experimental results on the UEA multivariate time series forecasting archive, demonstrate competitive forecast accuracy (RMSE and MAPE) of the proposed approach, compared to the existing deep approaches as LSTM, CRNN, 1D-MTCNN.

Keywords: CNN, Multivariate Time-Series, Forecasting, Images.

GAF-CNN-LSTM Network

We use CNNs to extract distinctive features of time series images, and then to apply LSTM to predict near future values of the target value. We call this model **GAF-CNN-LSTM**, which is presented in Fig. 1.

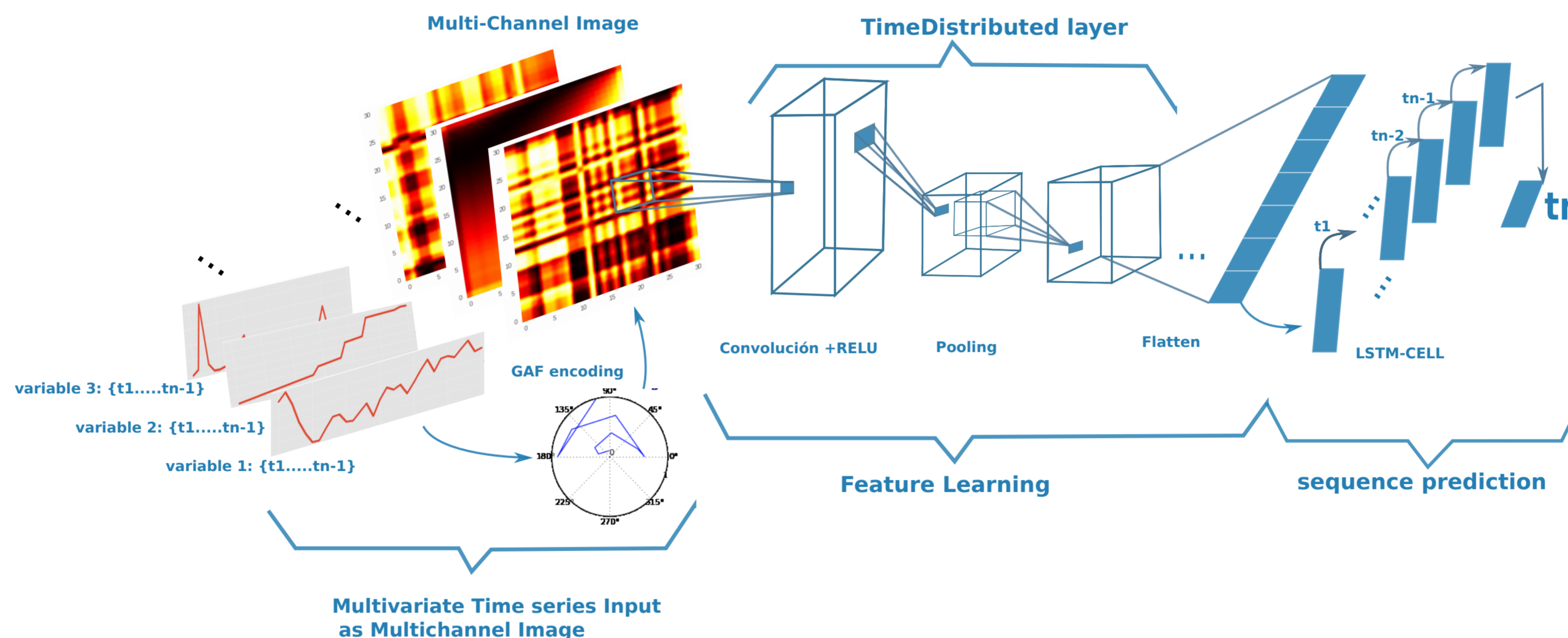


Figure: GAF-CNN-LSTM model, where inputs are multi-channel images (each variable represent one channel in multivariate time series context). Finally, we used a time-distributed approach in order to applying the same layer or layers multiple times, providing a sequence of “image interpretations” or “image features” to the LSTM model to work on.

Methodology

Imaging Time Series

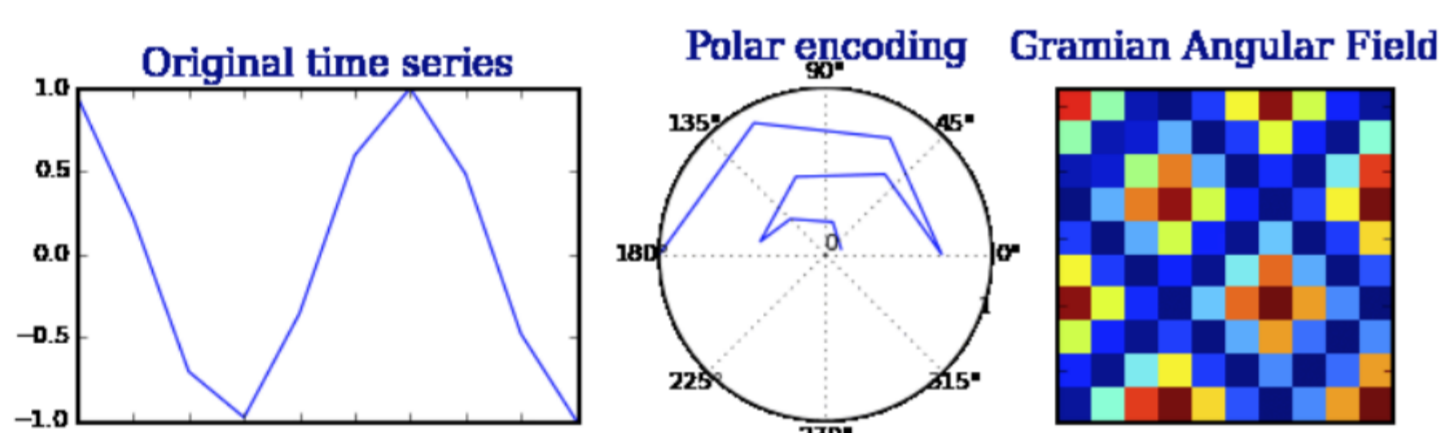


Figure: A Gramian Angular Field (GAF) [5], in which we represent time series in a polar coordinate system instead of the typical Cartesian coordinates.

$$X = \{x_1, x_2, \dots, x_n\}, \begin{cases} \phi = \arccos(\bar{x}_i), -1 \leq \bar{x}_i \leq 1, \bar{x}_i \in \bar{X} \\ r = \frac{t_i}{N}, t_i \in \mathbb{N} \end{cases} \quad (1)$$

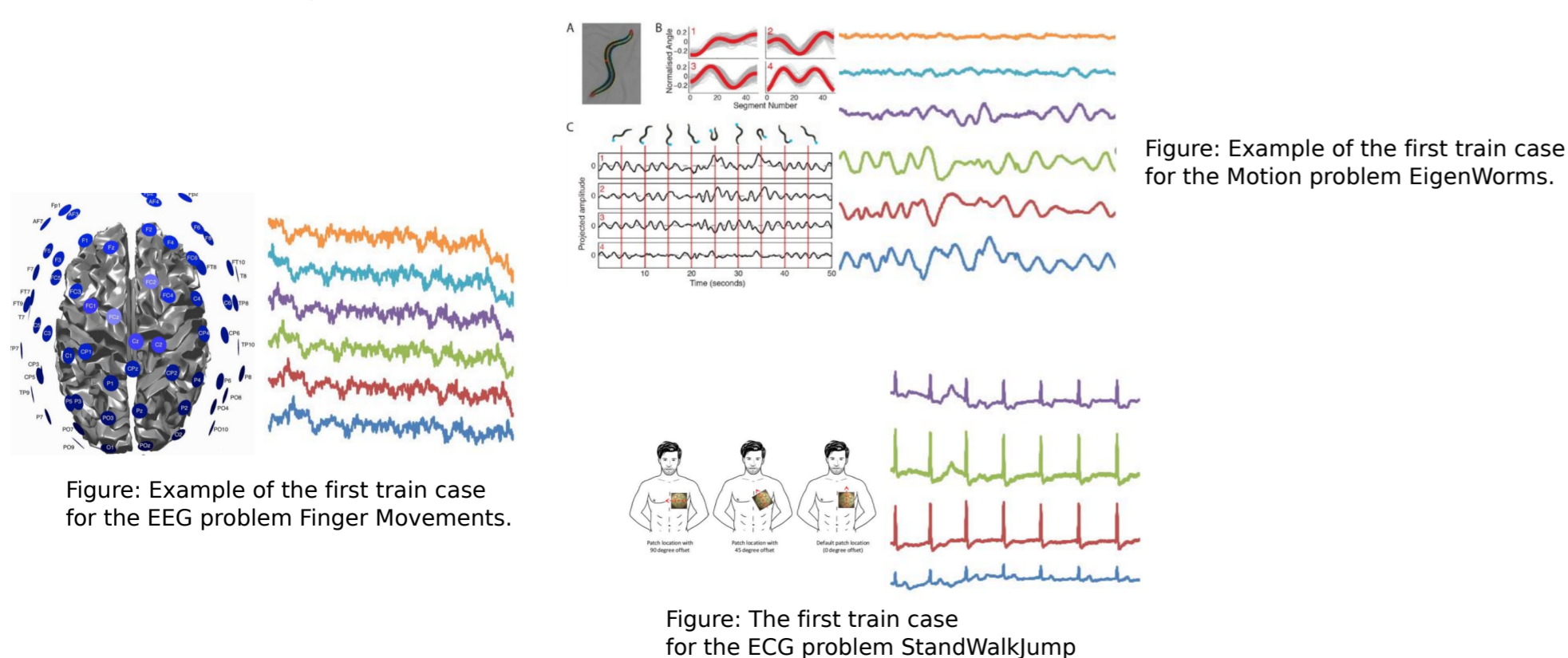
$$GAF_{matrix} = \begin{cases} \cos(\phi_1 + \phi_1) & \cos(\phi_1 + \phi_2) & \dots & \cos(\phi_1 + \phi_n) \\ \cos(\phi_2 + \phi_1) & \cos(\phi_2 + \phi_2) & \dots & \cos(\phi_2 + \phi_n) \\ \vdots & \vdots & \ddots & \vdots \\ \cos(\phi_n + \phi_1) & \cos(\phi_n + \phi_2) & \dots & \cos(\phi_n + \phi_n) \end{cases} \quad (2)$$

Preliminary Results

Table: RMSE and MAPE, 4 UEA multivariate data sets [1]

Dataset	LSTM		CRNN[2]		1D-MTCNN[4]		GAF-CNN-LSTM	
	RSME	MAPE	RSME	MAPE	RSME	MAPE	RSME	MAPE
MotorImagery	1.312	14.582	1.086	11.331	1.069	11.397	0.894	7.894
EigenWorms	0.741	9.178	0.945	8.256	0.845	8.569	0.736	8.984
EthanolConcentration	1.215	12.366	1.645	14.125	1.365	13.429	1.09	12.015
StandWalkJump	0.915	10.694	1.001	10.697	1.059	11.991	0.997	10.894

Figure: The UEA multivariate time series examples [1]



Conclusions

Based on the related works [2, 3, 4, 5, 6, 7, 8, 9], this is the first study that combines GAF encoding [5], CNN and LSTM in a unified framework to enable accurate forecasting in multivariate time series. The difference between related works and our framework is that they used a traditional forecasting and classification framework, with hand-crafted features and separated feature extraction and forecasting steps for univariate time series. While our proposed, automatically learns the texture features that are useful for the LSTM layer, avoiding preprocessing steps on multivariate time series forecasting. The GAF representation (polar coordinates) preserves absolute temporal relations. We propose a deep learning model, GAF-CNN-LSTM, to enable accurate multivariate time series forecasting. Experiments on 4 real world data sets show promising results. In the future, it is of interest to verify the proposed models on time series from different domains such as meteorological time series and to study the scalability of the proposed models for large time series data.

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