Sequential Data Modelling

Blanca Florentino Liano (Start of PhD: Oct. 2015 Part-Time)
Supervisors: Ken Brown, Barry O'Sullivan
Industrial Supervisor: Michael Giering

United Technologies Research Center
Insight Centre for Data Analytics

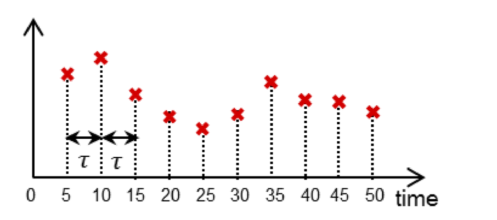
Objective

Develop deep learning methods for event prediction

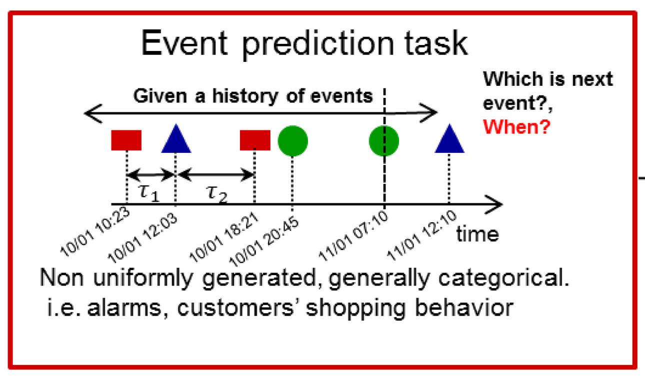
Problem

Event sequence data are time-stamped **categorical** data collected over time at **no particular frequency.**

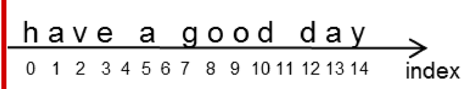
Time Series data vs **Event/Transactional data** vs **Sequential data**



Uniformly sampled data, generally numerical. i.e. temperature, number of calls per hour



Non uniformly generated, generally categorical. i.e. alarms, customers' shopping behavior

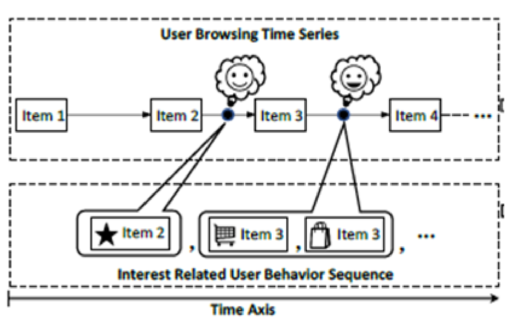


Examples of event sequential data

Artificial Event Sensor Data
Threshold-based alarm events

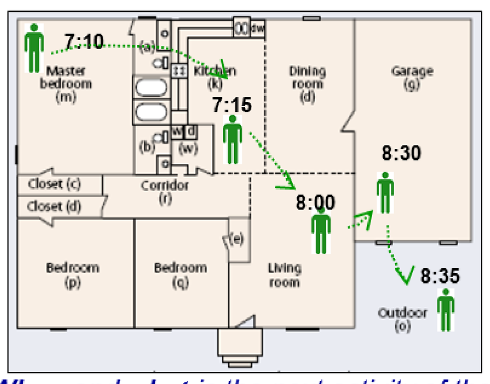
Which alarm will happened next and when?

Transactional data
E-commerce data, medical records



Which item will be purchased next and when?

Behaviour user data
User Activity/location data

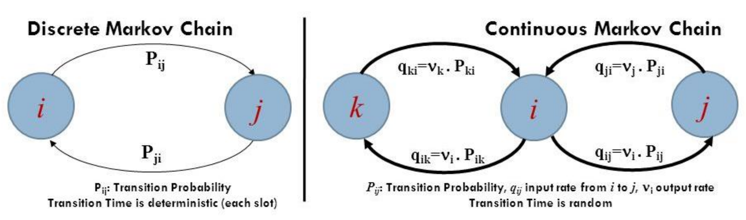


When and what is the next activity of the user?

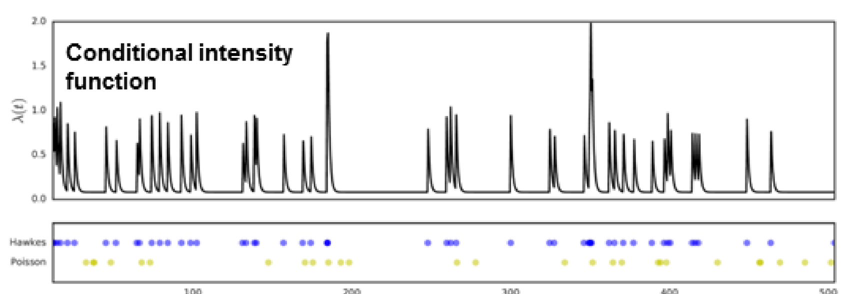
Related work

Event modelling approaches

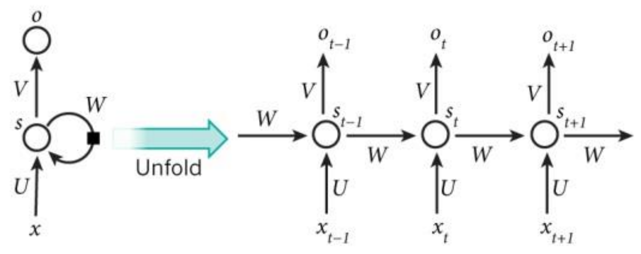
Markov Chain Models



Point Processes

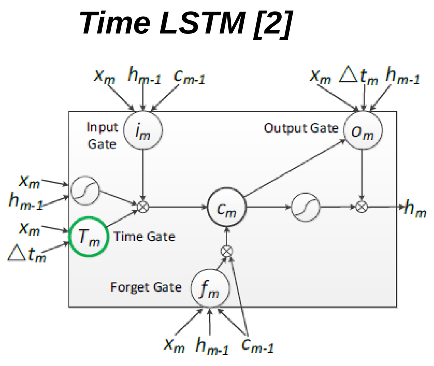


Recurrent Neural Networks

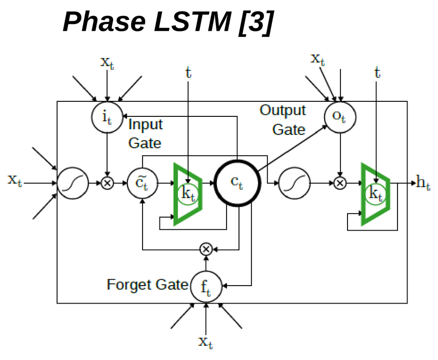


New RNN Architectures

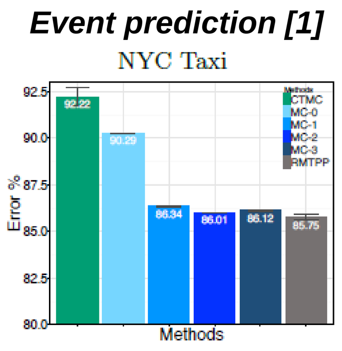
Time LSTM [2]



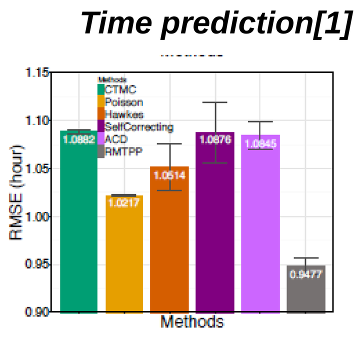
Phase LSTM [3]



Event prediction [1]



Time prediction[1]

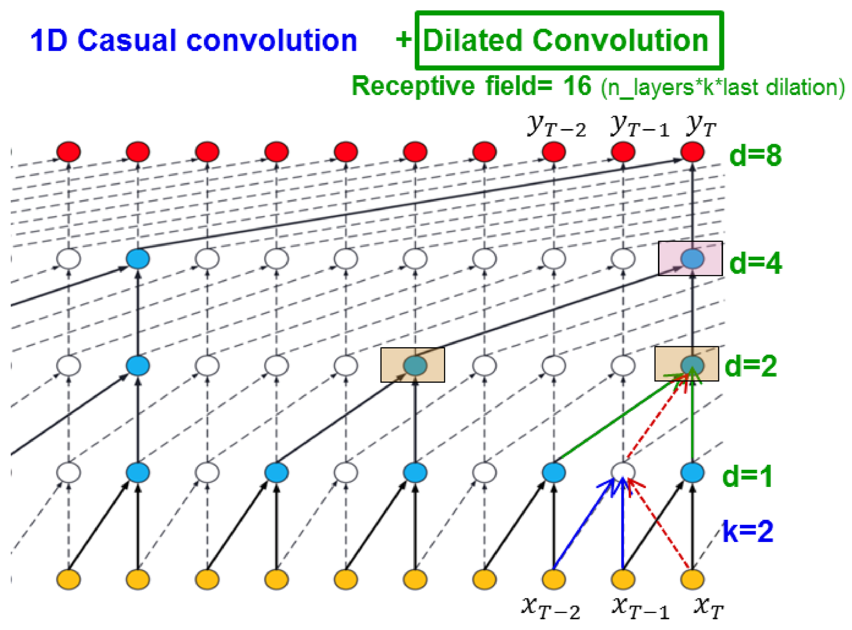


	Precision@20
LSTM	0.68
Phase-LSTM	0.61
Time-LSTM	0.74

✓RNN and point process combination is SOA in event prediction

SOA in sequence modelling

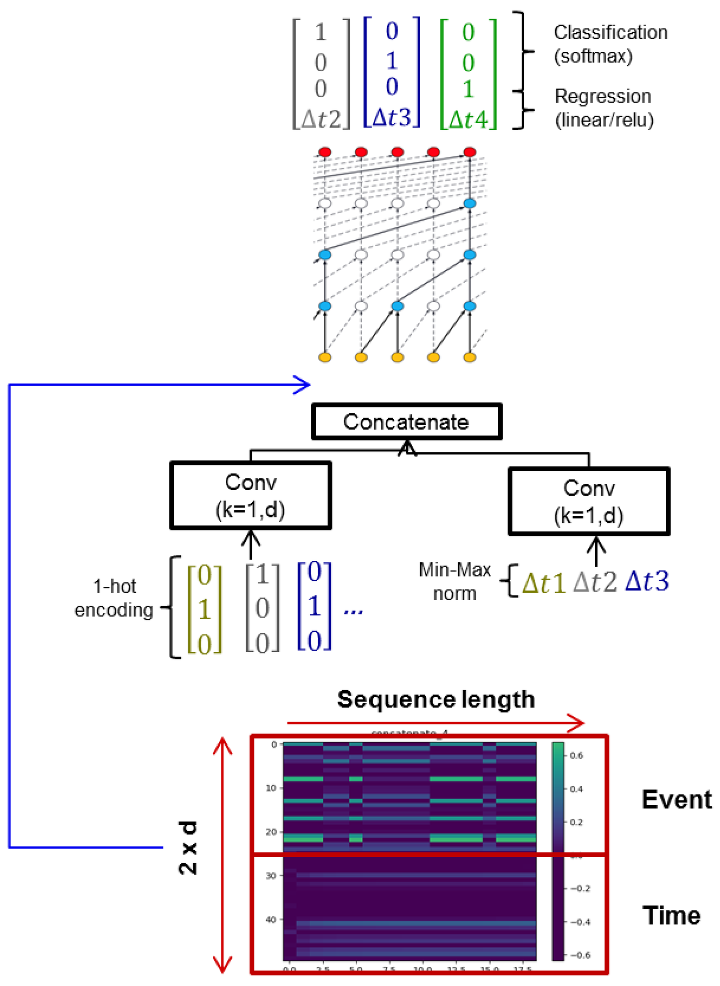
Temporal Convolutional Neural Networks (TCNs) [5]



✓**Outperform** RNNs
✓Exhibit **longer memory**
✓**Training and evaluation faster (parallelism)**
✓Has **stables gradients**
→ Not used for event prediction tasks

Convolutional Architecture for event prediction

TCNs architecture for event prediction



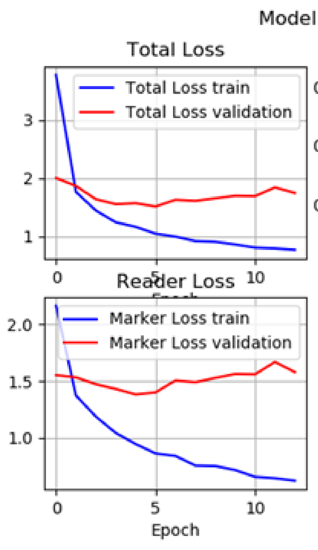
➢ Modelling time explicitly as an input (time interval)

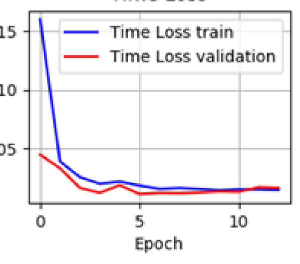
Combined loss function

$$-\frac{1}{N}\sum_{t\in T}\sum_{c=1}^{M} y_c^t \log(\hat{y}_c^t) + \frac{1}{N}\sum_{t\in T}(i_t - \hat{i}_t)^2$$

Classification (Cross entropy) — Regression (MSE)

Model Losses



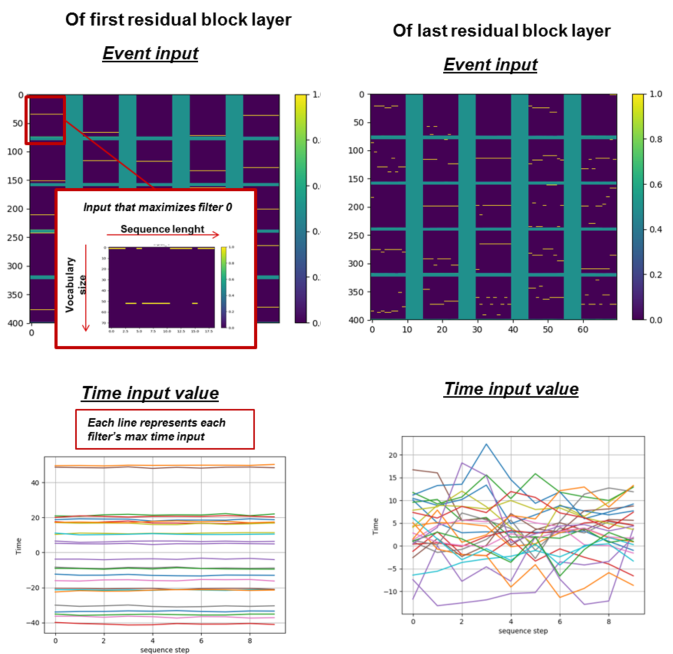


We can use weighed loss function

$$Total\ Loss = W_c(classLoss) + W_r(regLoss)$$

Results

DB	MIMIC Max Len=33 #Seq= 650 Voc Siz =75	Financial Max Len=3319 #Seq= 200 Voc Siz =2	SO Max Len=736 #Seq= 6633 Voc Siz =22	Location Prediction Max Len=3200 #Seq= 182 Voc Siz =54
Baselines Most Frequent y(t)=x(t) Mean time	Acc=30.5% Acc=**64.8**% RMSE(day)= 1.3	Acc=51% Acc=**61.9**% RMSE(s)= 1.6	**Acc=43%** Acc=30.9% RMSE(day)= 12	Acc=23.3% **Acc=57.6%** RMSE(hr)=1.5
SOA with RNNs				
RMTPP[1]	Acc=82.51% RMSE(day)=5.7	Acc=62.3% RMSE(s)=1.4	Acc=**48.6**% RMSE(day)=**10**	Acc=61% RMSE(hr)=2.1
My TCN				
TCN for events	Acc= **87%** RMSE(day)=**0.9**	Acc= **62.7**% RMSE(s)=**0.9**	Acc= 45.5% RMSE(day)=11.8	Acc=**66.7**% RMSE(hr)=**0.6**

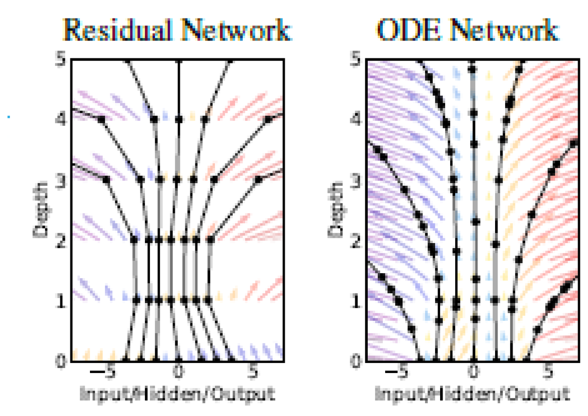


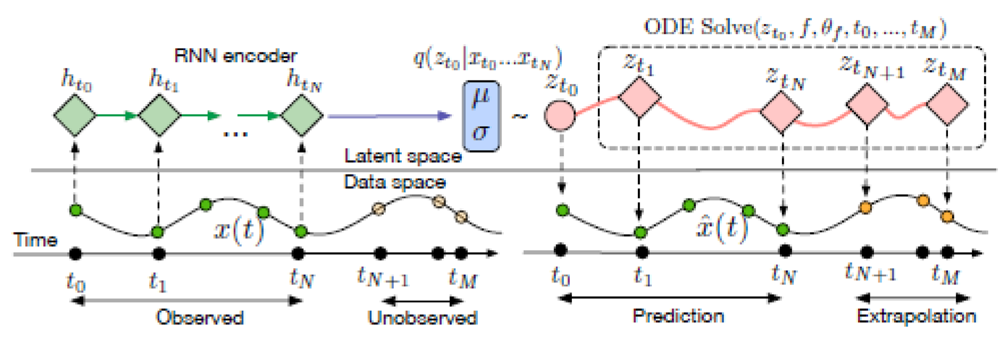
➢ TCNs improves event prediction compared with RNN SOA approach
➢ Time prediction also improves but still error is high compared with baselines
➢ Lower convolutional layers learn low frequency patterns and higher layers high frequency patterns

Next steps

- Fine tune TCN for event prediction
- Investigate Differential Neural networks for event prediction to leverage ODEs properties and solvers

Neural ordinary Differential Equations [4]





References

[1] Du, Nan, et al.. "Recurrent marked temporal point processes: Embedding event history to vector." KDD 2016
[2] "What to Do Next: Modeling User Behaviors by Time-LSTM" JCAI 2017
[3] Phased LSTM: Accelerating Recurrent Network Training for Long or Event-based Sequences
[4] Chen, Tian Qi and Rubanova, et al. "Neural Ordinary Differential Equations" NIPS (2016)
[5] Bai, Shaojie, J. Zico Kolter, and Vladlen Koltun. "An empirical evaluation of generic convolutional and recurrent networks for sequence modeling." (2018).

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