Using Recurrent Neural Networks to Predict Future Events in a Case with Application to Cyber Security

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Overview

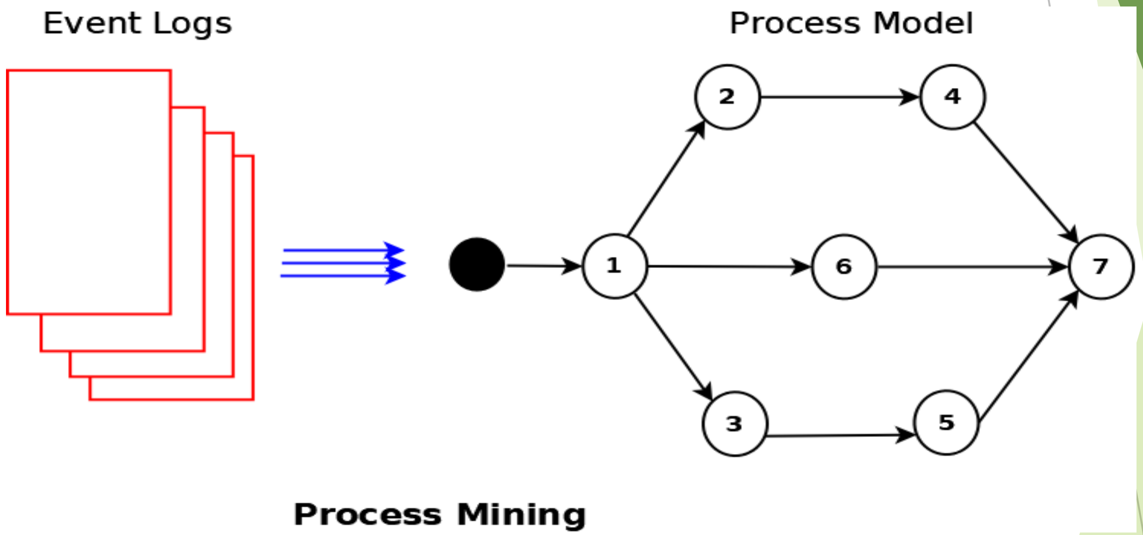
- Cyber attacks target business organizations every day
- Large numbers of security alerts detected
- Cyber security personnel require software support for prioritizing these alerts
  - Predict future events in currently executing business processes
  - Identify critical software services and infrastructure required to enable these events
  - Prioritize security alerts that target these software services
- Primary question: *"Can the application of deep learning to process mining be used to predict future events in an ongoing process?"*

Paper Overview

- State-of-the-art descriptions for:
  - Process Mining
  - Deep Learning
- Train deep learning networks, specifically LSTM models as an alternative to conventional process mining
- Outline two methods to train LSTMs to predict future events
- Evaluate both methods in terms of accuracy

Process Mining

- The discovery, analysis and modelling of information from logged data.
- Data is comprised of events
- Process model can be extracted from data
- Cases are sequences of events found in model
- ProM is an open-source process mining tool used to generate process models

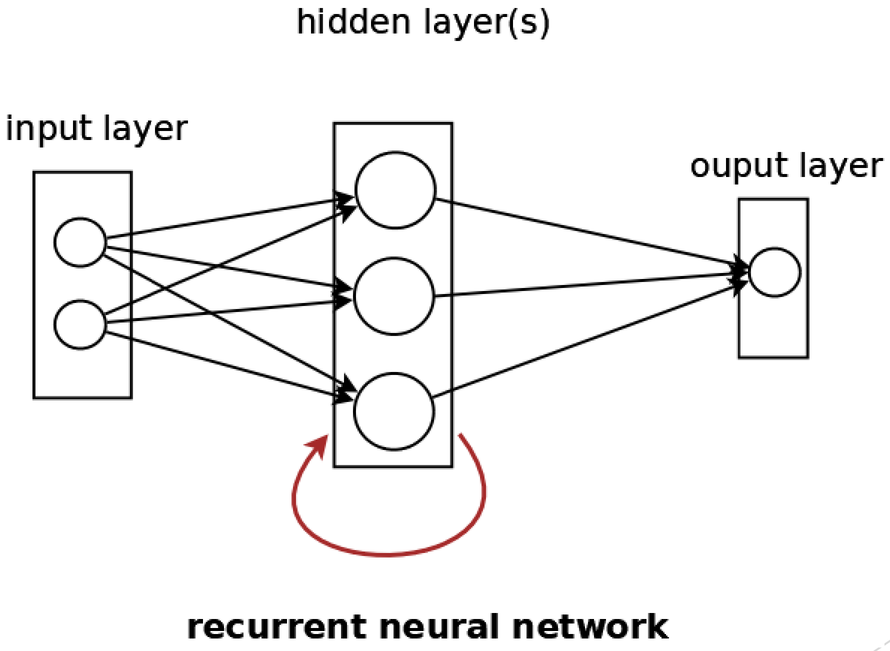


Deep Learning/Neural networks

- An alternate form of conventional process mining is to
  - train a deep learning neural network model to learn the typical behaviour of cases
  - use model to make predictions about future events
- Neural networks are software systems comprised of a number of layers which output data in response to input received at an input layer
- The neural network used is a **Recurrent Neural Network** (RNN).

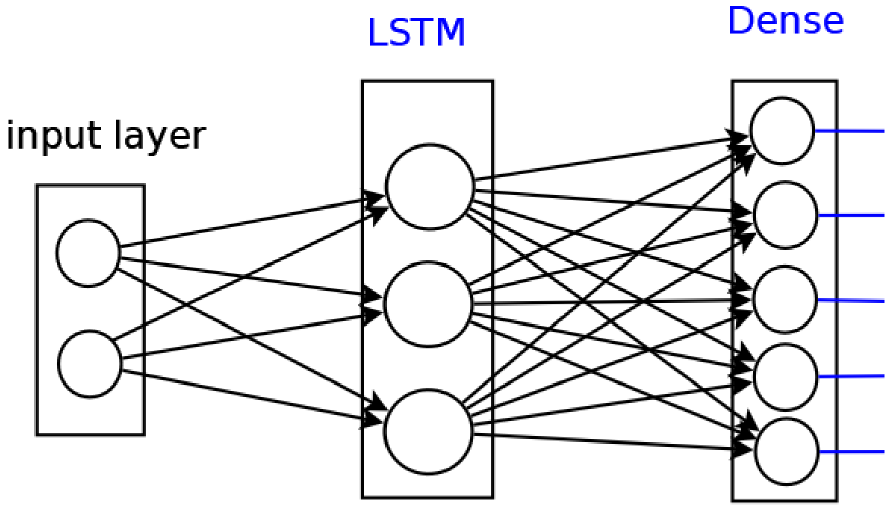
Recurrent Neural Networks (RNN)

- Neural network is required to process sequential data
- Events at a single time step of a sequence can affect subsequent events
- RNN model is a neural network where the output is fed back into the model over a number of time steps
- RNNs can be trained on cases



LSTM Model

- Long Short Term Memory (LSTM) is a type of RNN
- Advantages
  - Models noisy, sequential data
  - Processes data with time based fields
  - Detects long-term dependencies
- LSTM network is the hidden layer(s) of our model
- The output layer is a Dense layer where each node outputs a numeric value.
- The actual output is a probability distribution over a number of different event types
- The highest probability value and its corresponding event type is the predicted future event.



LSTM RNN Model

LSTM Model Training Methods

Teacher Forcing Method

Table I

X (input)	Y (output)
[1, 2, 3, 4, 5]	[2, 3, 4, 5, !]

- Uses the output from the previous time step as input
- For example, along the sequence when predicting the value 2, the input is 1 and so on.
- This method uses a Keras TimeDistributed layer to apply a Dense layer at every time step and output values at every time step

Prefix Method

Table II

X (Input)	Y(Output)
[1, 2]	[3]
[1, 2, 3]	[4]
[1, 2, 3, 4]	[5]
[1, 2, 3, 4, 5]	[!]

- Generates a set of all possible prefixes with a length greater than 1
- Predicts a single suffix event following the prefix

Case Study

- Four data sets were used to carry out the deep learning approaches
  - Three were event logs used for the Business Process Intelligence Challenges (BPIC) from 2012, 2013 and 2014
  - Fourth was a help desk event log for an Italian company's ticket management process
- Event log used for BPI 2012 is an application procedure for financial services
- BPI 2013 used VINST an incident management system for IT related incidents
- BPI 2014 is an event log for different ICT processes (interactions, incidents, changes) for Rabobank Group, a banking and financial services company

Case Study - Accuracy Results/Evaluation

Data Sets	Cases	Events	Prefix		Teacher Forcing	
			Time (Mins)	Accuracy	Time (Mins)	Accuracy
BPI 2012	7469	6	17.9	68.64%	0.5	68.18%
Help Desk	3803	9	2.7	81.16%	0.97	80.39%
BPI 2013	7553	13	32.1	65.66%	0.5	62.94%
BPI 2014	6000	69	42.5	48.28%	0.5	43.68%

Analysis

- The **Prefix** method is shown to have slightly greater accuracy than the **Teacher Forcing** methodology.
- However the **Teacher Forcing** approach takes a far shorter time to train
- The **Helpdesk** data set has the greatest accuracy due to having the smallest vocabulary of events and set of cases
- To the best of our knowledge, LSTM networks have not been previously applied to event prediction for the 2014 data set.

Thank you for watching

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