Recurrent Neural Networks in Theano

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Recurrent Neural Networks

Neural networks that can process sequences of inputs

- Used to process speech, language, music,. . .
- Recurrent Neural Networks are very powerful:
  - Non-linear
  - Distributed representations
  - No Markov assumptions
- However:
  - Optimization can be challenging
  - Learning *long-term dependencies* is difficult
  - Computations are not as easy to *parallelize*

Standard Architecture

$$h_t = q(W_{xh}x_t + W_{hh}h_{t-1} + b_h)$$
$$y_t = r(W_{hy}h_t + b_y)$$

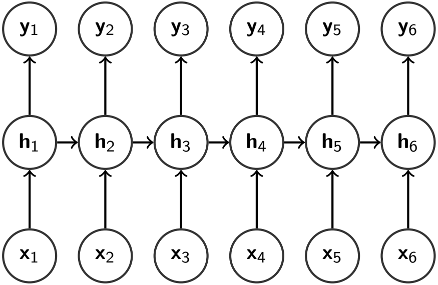

Figure : A simple Recurrent Neural Network

Long Short-Term Memory (LSTM)

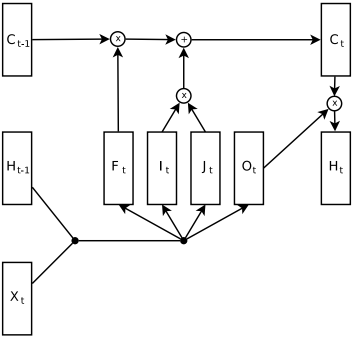

Figure : LSTM: Learn long term dependencies by asserting control over what goes in and out of *memory cells*.[2]

[2] Figure Taken from Jozefowicz et al. (2015)

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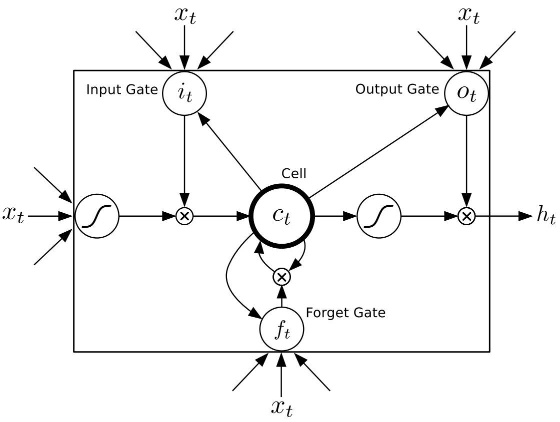


Figure : Another LSTM[3]

[3]Figure from Graves et al. (2013)

Update Equations

$$
\begin{aligned}
i_t &= \tanh(W_{xi}x_t + W_{hi}h_{t-1} + b_i)\\
j_t &= \sigma(W_{xj}x_t + W_{hj}h_{t-1} + b_j)\\
f_t &= \sigma(W_{xf}x_t + W_{hf}h_{t-1} + b_f)\\
o_t &= \sigma(W_{xo}x_t + W_{ho}h_{t-1} + b_o)\\
c_t &= f_t \otimes c_{t-1} + i_t \otimes j_t\\
h_t &= \tanh(c_t) \otimes o_t
\end{aligned}
$$

RNNs can be Stacked

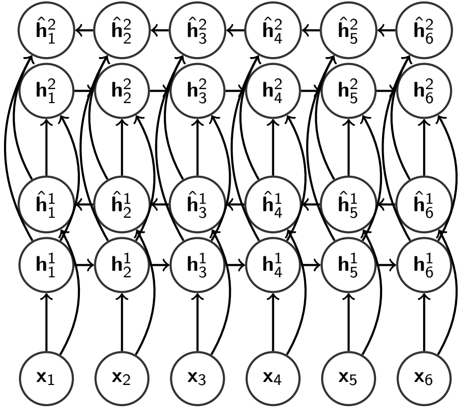
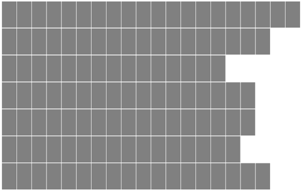


Figure : Two Bidirectional Recurrent Neural Networks stacked on top of each other.

Parallelizing RNN computations

Apply RNNs to *batches* of sequences

Present the data as a 3D tensor of $(T \times B \times F)$. Each dynamic update will now be a matrix multiplication.



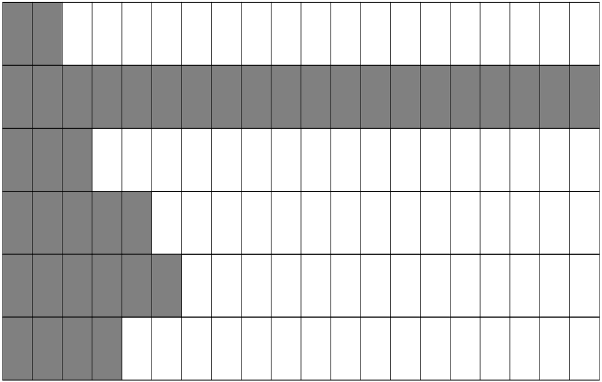
Binary Masks

A *mask* matrix may be used to aid with computations that ignore the padded zeros. In Theano this may be required to keep computations *differentiable*.

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0

Binary Masks

It may be necessary to (partially) sort your data.



Final Notes

- Fuel has a transformer that automatically padds a batch of sequences and adds a mask
- Since masks are often used for multiplication, their type should often be floating point
- Be careful that your implementation doesn't nest `scan` nodes

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- Be careful that your implementation doesn't nest `scan` nodes
- Have fun!