NPFL116 Compendium of Neural Machine Translation

Notes on Deep Learning

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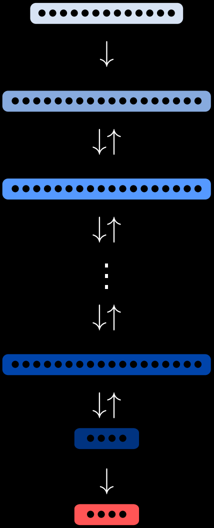
Deep Learning

- machine learning that hierarchically infers suitable data representation with the increasing level of complexity and abstraction (Goodfellow et al.)
- formulating end-to-end relation of a problems’ raw inputs and raw outputs as parameterizable real-valued functions and finding good parameters for the functions (me)
- industrial/marketing buzzword for machine learning with neural networks (backpropaganda, ha, ha)

Neural Network



$$x$$

$$\downarrow$$

$$h_1 = f(W_1 x + b_1)$$

$$\downarrow$$

$$h_2 = f(W_2 h_1 + b_2)$$

$$\downarrow$$

$$\vdots$$

$$\downarrow$$

$$h_n = f(W_n h_{n-1} + b_n)$$

$$\downarrow$$

$$o = g(W_o h_n + b_o)$$

$$\downarrow$$

$$E = e(o, t) \quad \rightarrow \quad \frac{\partial E}{\partial o}$$

$$\vdots$$

$$\uparrow$$

$$\vdots$$

$$\uparrow$$

$$\vdots$$

$$\uparrow$$

$$\vdots$$

$$\uparrow$$

$$\frac{\partial E}{\partial W_o} = \frac{\partial E}{\partial o} \cdot \frac{\partial o}{\partial W_o}$$

$$\uparrow$$

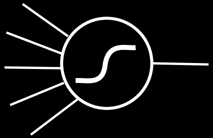
$$\frac{\partial E}{\partial o}$$

Building Blocks (1)

- individual neurons / more complex units like recurrent cells *(allows innovations like inventing LSTM cells, ReLU activation)*
- libraries like Keras, Lasagne, TFSlim conceptualize on layer-level *(allows innovations like batch normalization, dropout)*
- sometimes higher-level conceptualization, similar to functional programming concepts *(allows innovations like attention)*

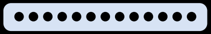
Building Blocks (2)

Single Neuron



- computational model from 1940’s
- adds weighted inputs and transforms to input

Layer



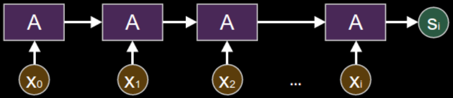
$$f(Wx + b)$$

...*f* nonlinearity, *W* ...weight matrix, *b* ...bias

- having the network in layers allows using matrix multiplication
- allows GPU acceleration
- vector space interpretations

Encoder & Decoder

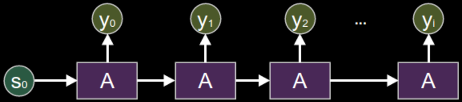
Encoder:



Functional fold (reduce) with function

`foldl a s xs`

Decoder:



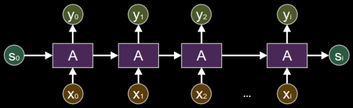
Inverse operation – functional unfold

`unfoldr a s`

Source: Colah's blog (http://colah.github.io/posts/2015-09-NN-Types-FP/)

RNNs & Convolutions

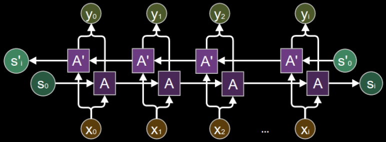
General RNN:



Map with accumulator

`mapAccumR a s xs`

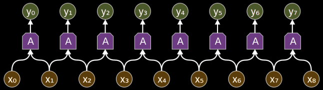
Bidirectional RNN:



Zip left and right accumulating map

```
zip (mapAccumR a s xs)
(mapAccumL a' s' xs)
```

Convolution:



Zip neighbors and apply function

`zipWith a xs (tail xs)`

Source: Colah’s blog (http://colah.github.io/posts/2015-09-NN-Types-FP/)

Optimization

- data is constant, treat the network as function of parameters
- the differentiable error is function of parameters as well
- clever variants of gradient descent algorithm

Deep Learning as Alchemy

- there no rigorous manual how to develop a good deep learning model – just rules of thumb
- we don’t know how to interpret the weights the network has learned
- there is no theory that is able to predict results of experiments (as in physics), there are only experiments

Recoding in mathematics

Algebraic equations

$$\begin{aligned} 10x^2 - x - 60 &= 0 \\ 0.2x^3 - 2x^2 - 10x + 4 &= 0 \\ -2x^2 - 10 &= 0 \end{aligned}$$

...became planar curves

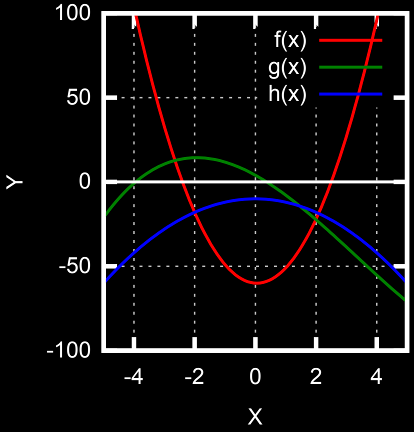
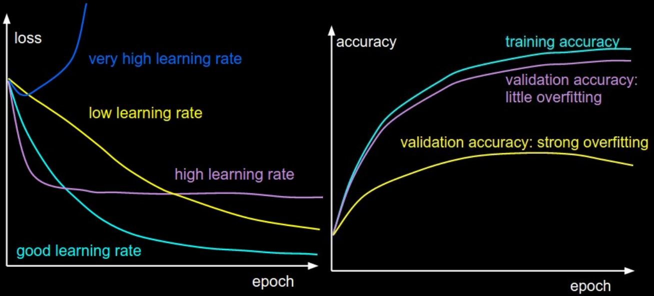


Image: Existential comics (`http://existentialcomics.com/`)

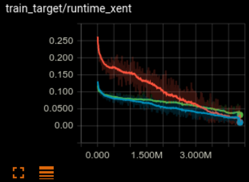
Watching Learning Curves

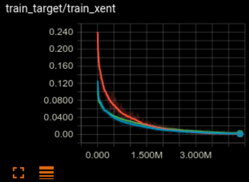


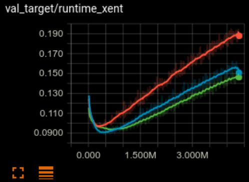
Source: Convolutional Neural Networks for Visual Recognition at Stanford University
(`http://cs231n.github.io/neural-networks-3/`)

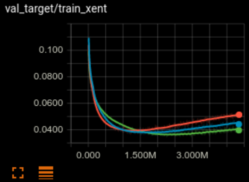
Other Things to Watch During Training

- train and validation loss

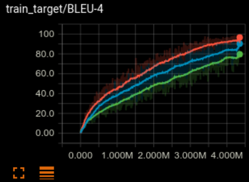


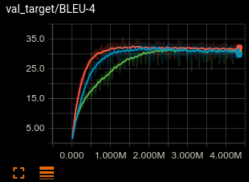






- target metric on training and validation data





MT is hard

- language are not word-by-word equivalent
- there is not better way of expressing the sentence than the language itself
- even if we have a system, it’s hard to evaluate it

What’s Strange on Neural MT

- we naturally think of translation in terms of manipulating with symbols
- neural network represents everything as real-space vectors

Reading for the Next Week

Sutskever, Ilya, Oriol Vinyals, and Quoc V. Le. "Sequence to sequence learning with neural networks." *Advances in neural information processing systems*. 2014.
`https://papers.nips.cc/paper/5346-sequence-to-sequence-learning-with-neural-networks.pdf`

Question:
What are the problems of the presented architecture? How do you think the neural MT continued after publishing this paper?