

Learning Idioms and Slang using a Deep Learning approach with Speech Recognition

Davide Berdin
`{davide.berdin.0110}@student.uu.se`

Master Thesis
Department of Information Technology

September 15, 2015

Abstract

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

To my family that never stopped believing in me

Acknowledgements

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Contents

1	Introduction	2
2	Artificial Neural Networks	4
2.1	Artificial Neuron	4
2.2	Network Function	4
2.3	Learning	5
2.4	Multilayer Perceptron	6
3	Deep Learning	7
3.1	Introduction	7
3.2	Deep Learning in Artificial Neural Networks	7
3.2.1	Architectures	7
3.3	Deep Belief Networks	7
3.4	Deep Boltzmann Machines	8
4	Implementation	9

Chapter 1

Introduction

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo

Chapter 2

Artificial Neural Networks

2.1 Artificial Neuron

Our brain is composed by biological neurons and an artificial neuron (or AN) is a representation of it. Every AN can gather signals from other neurons or from the environment, and after an elaboration it transmits another signal to all the other ANs that are connected to it [1]. A representation of AN is depicted in 2.1.

Each connection to the artificial neuron has a numerical weight associated to it in which the input signal is hold back. The value of the weight can be either positive or negative. In most cases, the sums of each node are weighted and then given as input to a *non-linear* function called **transfer function** or **activation function** [2]. The activate function defines the output value of the node and typically, the *Step Function*, *Sigmoid Function* and a *Softmax Function* are the most used.

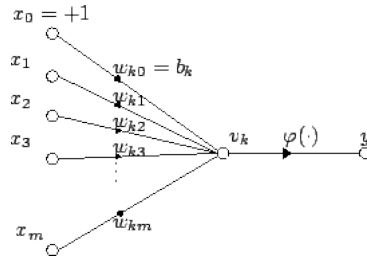


Figure 2.1: Representation of an Artificial Neuron [2]

From the mathematical point of view, we can define an artificial neuron as follow:

given $m + 1$ inputs with signals from x_1 to x_m and weights values from w_0 to w_m . The *bias* is then defined by the input x_0 in which a value of 1 will be assigned. The bias value allows us to *shift* the curve of the activation function to a certain direction and it is defined with $w_{k0} = b_k$ [2].

The output of the AN is:

$$y_k = \varphi \left(\sum_{j=0}^m w_{kj} x_j \right)$$

2.2 Network Function

When there are many artificial neurons interconnected between each other in the different layers, we form a *network*. 2.2 shows an example of ANN where the **inputs** are represented by the first layer in which they send data through the connection to the second group of neuron. The connection between two neurons is called *synapses* where the **weight** is stored. The second layer is connected to the third one that represents the **output** of the network. There can be multiple stratum between the inputs and the outputs and these are called *hidden layers*.

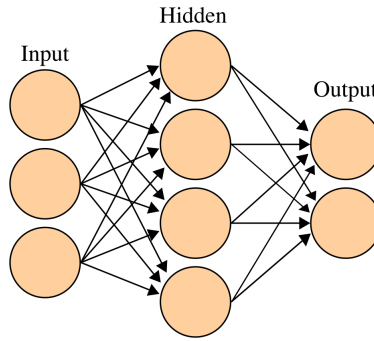


Figure 2.2: Example of ANN [3]

Typically, a neural network is defined by three factors:

- 1 How the different layers are interconnected
- 2 How the the weights are updated (learning process)
- 3 How the neuron's input value is converted to its output activation (activation function)

2.3 Learning

For every application the design of a neural network is different and after it has structured, the NN is ready to be trained. The first step is the initialization of the weighth. Normally they are initialized with random values, although, in [4] they developed a method to “*determining the optimal initial weights of feedforward neural networks based on the Cauchy's inequality and a linear algebraic method*”. More, in [5] they tested seven different weights' initialization for twelve different problems. Thus, even the initialization of the connections values is application-dependant.

The learning paradigms can be grouped in three major categories: **supervised**, **unsupervised** and **reinforcement learning**.

Supervised Learning

This learning technique is the task of inferring a function from labeled training data [6] [7]. The set responsible for training the model is composed by *training examples* in which every sample consists of an *input object* and a **desidered** *output value*. What the algorithms does is to analyze the train dataset and produce an inferred function that will be used to map the new examples [6]. Basically, the algorithm can be seen as *learning* with a *teacher*, in the sense that the there is costantly a feedback on the status of the application.

Unsupervised Learning

While in supervised learning, the system has a desidered output given from the training dataset, in the unsupervised paradigm, the system has to learn to estimate the right output given a new input [8]. In *classification*, this output is a class label whereas in *regression* is a real number. There are several ways to model this kind of learning system. *Clustering*, using *Self-Organizing Maps*, *K-means* or *hierachical clustering* are among the most famous approaches.

Reinforcement Learning

In reinforcement learning, the system takes actions to interact with its own environment. Each action will affect the state of the environment in which will produe a result in a form of either *reward* or *punishment*. The goal of this learning paradigm is to learn which is the best sequence of actions that maximises the rewards or minimises the punishments. There are quite a few approaches to find the best sequence of actions. The most famouse are *Monte Carlo methods*, *Temporal Difference methods* and *Direct Policy search methods*.

2.4 Multilayer Perceptron

The model created by the Multilayer perceptron (MLP) serves to map a set of inputs onto a group of outputs. The main feature of the MLP is that it is a *feedforward* artificial neural network. The MLP is formed by a defined number of layers in which every layer is *fully connected* to following one. Every neuron of the network has a nonlinear activation function, with the exception of the input nodes. The technique used in the MLP is of the kind of supervised and it uses the **backpropagation** for training the neurons [9]. Backpropagation is discussed more in details in 2.4.

Learning through Backpropagation

The learning phase in the neural network occurs in the moment that the connection weights change based on the error value in the output. The error is calculated comparing the result the network produced with the expected one. This is a typical example of supervised learning because the network compares the result it just obtained with the one that it was expecting. This process is done through **backpropagation**.

In backpropagation, the error output of the node j in the n th sample of the training dataset is given by

$$e_j(n) = d_j(n) - y_j(n) \quad (2.1)$$

where d is the expected output whereas y is the output value obtained from the neuron. The weights are then adjusted in such a way that the error is minimized. With 2.2 we are able to determine the corrections to apply given an output value produced by a perceptron.

$$\varepsilon(n) = \frac{1}{2} \sum_j e_j^2(n) \quad (2.2)$$

At this point using 2.3 we are able to determine the amount of change for each weight. This is done by **gradient descent** which is a first-order optimization algorithm. Gradient descent is used to find *local minima* of a function, where "it takes steps proportionally to the negative of the gradient of the function in that point"[10]. The opposite instead, it means that it is approaching to the *local maxima* of the function. Although, in this way, the process would be called *gradient ascent*[10].

$$\Delta w_{ji}(n) = -\eta \frac{\partial \varepsilon(n)}{\partial v_j(n)} y_j(n) \quad (2.3)$$

In 2.3, η represents the *learning rate* whereas y_i is the output of the previous neuron [9]. The learning rate parameter is one of the most important parameters when design a neural network. The reason is that, the value used for it ensures that the weights are converging as fast as possible avoiding waivings.

The calculation of the derivatives depends on the field v_j where this value changes itself. Continuing, 2.3 can be simplified to 2.4 where ϕ' represents the *derivate* of the activation function described before. Note that this does not changes itself.

$$\frac{\partial \varepsilon(n)}{\partial v_j(n)} = e_j(n) \phi'(v_j(n)) \quad (2.4)$$

Chapter 3

Deep Learning

3.1 Introduction

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

3.2 Deep Learning in Artificial Neural Networks

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

3.2.1 Architectures

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

3.3 Deep Belief Networks

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

3.4 Deep Boltzmann Machines

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Chapter 4

Implementation

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Bibliography

- [1] A. P. Engelbrecht, *Computational intelligence: an introduction*. John Wiley & Sons, 2007.
- [2] “Artificial neuron,” 2015. accessed 2015-09-08. Available: https://en.wikipedia.org/wiki/Artificial_neuron.
- [3] “Artificial neural network,” 2015. accessed 2015-09-08. Available: https://en.wikipedia.org/wiki/Artificial_neural_network.
- [4] J. Y. Yam and T. W. Chow, “A weight initialization method for improving training speed in feedforward neural network,” *Neurocomputing*, vol. 30, no. 1, pp. 219–232, 2000.
- [5] M. Fernandez-Redondo and C. Hernandez-Espinosa, “Weight initialization methods for multilayer feedforward,” in *ESANN*, pp. 119–124, 2001.
- [6] “Supervise learning,” 2015. accessed 2015-09-08. Available: https://en.wikipedia.org/wiki/Supervised_learning.
- [7] M. Mohri, A. Rostamizadeh, and A. Talwalkar, *Foundations of machine learning*. MIT press, 2012.
- [8] Z. Ghahramani, “Unsupervised learning,” in *Advanced Lectures on Machine Learning*, pp. 72–112, Springer, 2004.
- [9] “Multilayer perceptron (mlp),” 2015. accessed 2015-09-08. Available: https://en.wikipedia.org/wiki/Multilayer_perceptron.
- [10] “Gradient descent,” 2015. accessed 2015-09-08. Available: https://en.wikipedia.org/wiki/Gradient_descent.