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# Speech Recognition

- With Artificial Neural Networks -

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Project Report  
ED5-1-E17

Aalborg University  
Electronics and IT

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**Electronics and IT**  
Aalborg University  
<http://www.aau.dk>

## **AALBORG UNIVERSITY**

### STUDENT REPORT

**Title:**

Speech Recognition

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**Participant(s):**

Stefan Bîrs

Tiberiu-Ioan Szatmari

Kamran Thomas Alimagham

**Supervisor(s):**

Daniel Ortiz-Arroyo

D. M. Akbar Hussain

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**Abstract:**

This report goes into detail about the implementation of distributed speech recognition systems, information retrieval and machine learning. The main objective of the speech recognition system is to provide a handsfree human-computer interface experience, where the system is also able to handle noise.

*The content of this report is freely available, but publication (with reference) may only be pursued due to agreement with the author.*



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# Preface

The project entitled Speech Recognition with Focus on information retrieval and command prompt was made by three students from the Electronics and Computer Engineering programme at Aalborg University Esbjerg, for the P5 project during the fifth semester.

Aalborg University, November 14, 2017

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Stefan Birs

<sbars15@student.aau.dk>

---

Tiberiu-Ioan Szatmari

<tsz atm15@student.aau.dk>

---

Kamran Thomas Alimaghani

<kalima15@student.aau.dk>



# Chapter 1

## Introduction

The focus of this project will be on implementing speech recognition system...

The main focus is to design and implement an different artifitial neural networks (ANN) and try different regulation techniques to get the best performing speech recognition system we can achieve...

The particular software platform is the open source TensorFlow [1] software library released by Google, where it allows non-AI (Artificial Intellegent) experts to design, build, and train deep learning models. In order to create a control solution for the said speech recognizer it is necessary to create a artifitial neural network...

Speech is probably the most important forms of communication. Because its the most natural and efficient way to communicate with each other. Humans learn all the relevant skills during early childhood, without any instruction, and they continue to rely on speech communication throughout their life [2]. Humans also want to have a similar natural, easy and efficient form of communication with machines. Until recently, the idea of holding a conversation with a computer seemed pure science fiction.

But things are changing, and quickly. A growing number of people now talk to their mobile smart phones, asking them to set reminders, search for directions, or send email and text messages. Chief technology officer of © Nuance Communications Vlad Sejnoha stated, "We're at a transition point where voice and natural-language understanding are suddenly at the forefront".

[2]



## Chapter 2

# Problem Description

### 2.1 Problem Description

List to write about here:

- Main Objective/Goal
- What will be required
- How are we going to solve the Objective?

### 2.2 Problem Delimitation

To ensure that the project meets the desired scope, specific success criteria are formed which will be evaluated during the final stages of the report. The following list of requirements are the desired success criteria, where the focus will be on reaching the given goals.

- Detect human speech
- Design a deep neural network
- Compare different regularization techniques (drop out, batch normalization...)
- Design a filter
- Create a network infrastructure for Client/Server Model (Distribution)
- Implement a speech recognition system with information retrieval

Brief summary on how are we going to obtain all of these bullet points.



## Chapter 3

# Speech Processing

Speech is an effortless and highly efficient form of communication. Continuous speech recognition software is readily available from stores and it allows the user to interact with its surrounding without the need of written commands [3, p. 396]. Amazon's Alexa [4] and Microsoft's Cortana [5] are perfect examples of home companions that are able to perform basic tasks received via voice commands. As speech recognition increases in accuracy to the high nineties, reaching a performance of 99% means that this technology will make the leap from being annoying to use to becoming the main way we interact with computers. This idea is further backed up by the fact that people tend to speak much faster than they are able to type [6]. In some cases, speech can be three times faster in conveying information than typing and for professional debaters, speaking can be even six times faster.

Words are carried as sound waves, which are analog signals. In order for the speech to be processed, it needs to be run through a signal processor that selects the frequencies and amplitude of the signal. Further on, the signal is mapped to individual sound units called phones. These phones need to be identified and grouped in such a way to ensure that each word has a different phonetic structure, otherwise, words would be impossible to distinguish from one another.

**Table 3.1:** Phones

[ay]	<u>i</u> ris
[b]	<u>b</u> in
[er]	<u>b</u> ir <u>d</u>
[l]	<u>l</u> ip
[p]	<u>p</u> in
[th]	<u>t</u> h <u>i</u> n

Phones can have different sounds depending on the context. For example, the phone *th* in the word *three* has a different sound to *th* in *then*. To overcome these different variations of the same phones, it is better to abstract the phones into a generalized grouping called a **phoneme**. Phonemes are written in-between forward slashes (*/th/*) and they will have a specific pronunciation for each sound, depending on the context. These phonemes are used as a transitional layer when trying to convert speech to text and vice versa, when speech needs to be synthesized.

### 3.1 Signal processing

Sound waves that carry human speech are variations in air pressure. The key components of a sound wave are its **amplitude**, which measure the intensity of the sound and the **frequency**, which describes the rate at which the amplitude varies over time. When speaking in a microphone, the change in air pressure causes the diaphragm to oscillate. The size of the oscillations is directly proportional to the amplitude of the signal, while the rate at which the diaphragm oscillates gives represents the rate at which the air pressure changes. At specific time intervals, the signal can be sampled and the data can be used in a wide array of digital signal processing tools. For example, the digital signal can be plotted as an x-y plot, where the y-axis defines the amplitude and the x-axis shows the time. The frequency can be easily be determined from the plot as we find the number of cycles that the signal does per second.

Although a visual difference can be seen when plotting vowels and consonants, a visual inspection of the waveform will not reveal any critical information, making it impossible to see all the phonemes.

To feed this information to the neural network, some preprocessing and signal manipulation is required so the input can be understood and passed through the neurons. These steps are expanded upon in the following subsections.

#### Preprocessing

No matter how powerful and how advanced a computer is, it still works in discrete time. In order to represent an analogue signal on the computer we have to sample it according to the Nyquist–Shannon sampling theorem, which states that the sampling frequency has to be at least double the frequency of the original signal in order to replicate the original signal without aliasing. For a better understanding of the process, a visual representation of the word "Hello" as it is formed for the



input of the neural network is shown in figure?? where it is sampled at 8000 Hz.

### Fourier transform

To analyse a discrete signal we use the Fourier transform. This allows us to convert the signal in the frequency domain and deconstruct it in a series of simple sine waves. These sine waves have specific amplitudes and frequencies and while plotting the FFT of the signal, the dominant waves can be identified by the intensity of the amplitude.

In Figure ??, a visual representation of the FFT is shown. It can be seen that there are a lot of frequencies that make up the word "Hello". The dominant ones are in the range of 500Hz. Considering that this recording has a minimum amount of noise, we have to consider the full range of the frequencies, from zero and up to 3500Hz.

### Spectrogram

The spectrogram of the signal was computed from the FFT and it shows a visual representation of the spectrum of frequencies marked by the intensity of the color. After the spectrogram is sliced into 25 ms chunks, it is feed as the input to the network. A neural network can find patterns in this data more easily than raw sound waves because audio data and patterns can be seen in the graph.

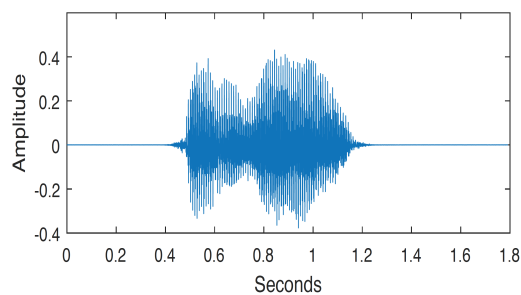


Figure 3.1: Left caption.

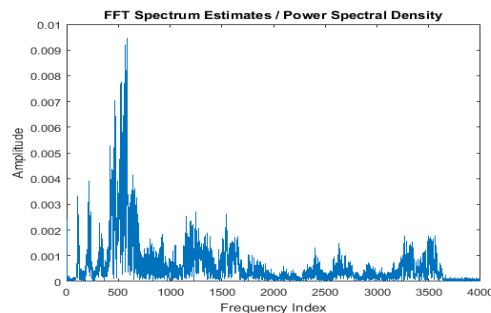


Figure 3.2: Right caption.

The figures are on  
GitHub, need to figure  
out how they work in La-  
TeX



## Chapter 4

# Machine Learning for Speech

### 4.1 Artificial Neural Networks

#### 4.1.1 What is an Artificial Neural Network?

Artificial Neural Networks are nothing but a computerized representation of the human brain. The human brain learns from its experiences, creating new neural pathways. These neural pathways are connected chains of neurons. Some neural connections are stronger than others and can be modulated, or changed, following learning or during behavioral modifications. The strength of the neural connections is defined by weights.

[continue here](#)

This brain modeling approach is a less technical way to develop machine learning solutions, but it is known to be more efficient and accurate than previous traditional approaches, such as the Hidden Markov Model (HMM).

#### 4.1.2 Artificial Neuron

The term "Neural" is derived from the basic functional unit "Neuron" which typically comprises of these four parts:

1. Dendrites: Accept inputs
2. Soma: Process the inputs
3. Axon: Turn the processed inputs into outputs
4. Synapses: The electrochemical connections between neurons

The connections can be inhibitory (decreasing strength) or excitatory (increasing strength) in nature.

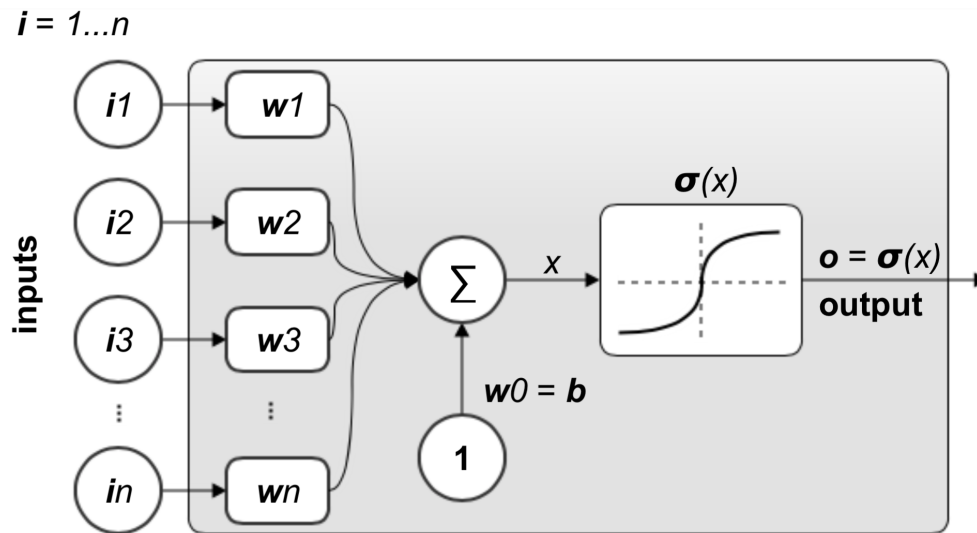


Figure 4.1: Basic Artificial Neuron.

## 4.2 Types of Artificial Neural Networks

### 4.2.1 Feedforward Network

### 4.2.2 Recurrent Neural Network

### 4.2.3 Modular Neural Network

### 4.2.4 Kohonen Self Organizing Maps

### 4.2.5 Convolutional Neural Network

## 4.3 TensorFlow

TensorFlow provides multiple Application Programming Interfaces (APIs) for machine learning. The lowest level API "TensorFlow Core" provides complete programming control [1]. For those who require fine levels of control over their models, TensorFlow Core is a well-suited tool for the job. There are higher level APIs that are built on top of TensorFlow Core. These higher level APIs are typically easier to learn and use than Tensorflow Core [1]. In addition, the higher level APIs such as "tf.estimator" helps with managing data sets, estimators, training and inferences (testing your trained network), as well as, making repetitive tasks easier and more consistent [1].

The subsection below will start with TensorFlow Core. In order to gain an understanding of the basic principles that TensorFlow has to offer, a model shall be made. In the subsection after that, the same model will be implemented with `tf.estimator`. Knowing TensorFlow Core principles will give us a great mental model of how things are working internally when we use the more compact higher level API.

### 4.3.1 Tensors

The central unit of data in TensorFlow is the tensor. A tensor consists of a set of primitive values shaped into an array of any number of dimensions. A tensor's rank is its number of dimensions. Here are some examples of tensors:

```
3 # a rank 0 tensor; this is a scalar with shape []
[1., 2., 3.] # a rank 1 tensor; this is a vector with shape [3]
[[1., 2., 3.], [4., 5., 6.]] # a rank 2 tensor; a matrix with shape [2, 3]
[[[1., 2., 3.]], [[7., 8., 9.]]] # a rank 3 tensor with shape [2, 1, 3]
```

[customize colors](#)

### 4.3.2 TensorFlow Core

Getting Started With TensorFlow is done by using the import statement. This gives Python access to all of TensorFlow's classes, methods, and symbols and is called by the following statement:

```
import tensorflow as tf
```

All the programs written with the help of TensorFlow core are built around computational graphs. They are a series of operations arranged into a graph and connected by nodes. To see the outcome of a such a program, firstly the computational graph needs to be created and after that it needs to be run. This provides a contrast to normal code written in python and to display this, the print function for a tensorflow constant is called bellow.

```
node1 = tf.constant(3.0, dtype=tf.float32)
node2 = tf.constant(4.0) # also tf.float32 implicitly
print(node1, node2)
```

Output:

```
Tensor("Const:0", shape=(), dtype=float32)
Tensor("Const_1:0", shape=(), dtype=float32)
```

As seen above, printing an element does not show the value that it holds and it rather shows the technical details behind, such as the element being a constant of type float32. To investigate the contents of any element in tensorflow, an object of

type session needs to be defined. When the new object is run, a new session is generated and the content of the element can be seen. All code written is tensorflow core follows this basic principle.

```
sess = tf.Session()
print(sess.run([node1, node2]))
```

Output:  
[3.0]

Other basic elements in tensorflow are placeholders(`tf.placeholder`), they can be changed to accept external inputs and variables. Variables allow the system to change its outputs while keeping the same inputs, this allows the model to be trainable.

### 4.3.3 `tf.train` API

The `tf.train` API holds optimizers that change each variable to minimize the loss function. One of the simplest optimizers used to train neural networks is gradient descent. Each variable is modified by the magnitude of the derivative of loss with respect to that variable. Using a computer to gain these gradients is far less prone to error than doing it by hand. Each of the gradients will point towards the minimum of the loss function and when solving for the gradient a step needs to be determined as the rate of change. It is important to have a small step as to not jump over the valley where the function takes its minimum value, but in the beginning to reduce time and processing power a bigger step could be used. One solution to this problem is to use a variable step input that changes as the gradients are determined. TensorFlow can automatically produce derivatives given only a description of the model using the function `tf.gradients`. For simplicity, optimizers typically do this for us.

### 4.3.4 `tf.estimator` API

## 4.4 Deep neural network for speech

### 4.4.1 Deep Feed Forward (DFF)

The simplest of all neural networks, the feedforward neural network, moves information in one direction only. Data moves from the input nodes to the output nodes, passing through hidden nodes (if any). The feedforward neural network has no cycles or loops in its network.

reference this part with [https : //www.aller.in.com/blog/six-types-of-neural-networks](https://www.aller.in.com/blog/six-types-of-neural-networks)

#### 4.4.2 Recurrent Neural Network (RNN)

The recurrent neural network, unlike the feedforward neural network, is a neural network that allows for a bi-directional flow of data. The network between the connected units forms a directed cycle. Such a network allows for dynamic temporal behavior to be exhibited. The recurrent neural network is capable of using its internal memory to process arbitrary sequence of inputs. This neural network is a popular choice for tasks such as handwriting and speech recognition.

link this part with link above

#### Long/Short Term Memory (LSTM)





## **Chapter 5**

# **Distributed speech recognizer**

### **5.1 The DSR system**

### **5.2 Acoustic models**

### **5.3 Language model**



## **Chapter 6**

# **Knowledge-based IR system**

**6.1 The document retrieval system**

**6.2 The question answering system**



## **Chapter 7**

# **Discussion**



## Chapter 8

# Conclusion

In case you have questions, comments, suggestions or have found a bug, please do not hesitate to contact me. You can find my contact details below.

Jesper Kjær Nielsen  
jkn@es.aau.dk  
<http://kom.aau.dk/~jkn>  
Fredrik Bajers Vej 7  
9220 Aalborg Ø





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## **Appendix A**

### **Appendix A name**

Here is the first appendix