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Footstrike pattern determination

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Report submitted in partial fulfilment of the requirements of the module Project (E) 448 for the degree Baccalaureus in Engineering in the Department of Electrical and Electronic Engineering at Stellenbosch University.

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I would like to thank my dog, Muffin. I also would like to thank the inventor of the incubator; without him/her, I would not be here. Finally, I would like to thank Dr Herman Kamper for this amazing report template.

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Abstract

English

The English abstract.

Contents

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Nomenclature

Variables and functions

$p(x)$	Probability density function with respect to variable x.
$P(A)$	Probability of event A occurring.
ε	The Bayes error.
ε_u	The Bhattacharyya bound.
B	The Bhattacharyya distance.
s	An HMM state. A subscript is used to refer to a particular state, e.g. s_i refers to the i^{th} state of an HMM.
$\mathbf{S}$	A set of HMM states.
$\mathbf{F}$	A set of frames.
$\mathbf{o}_f$	Observation (feature) vector associated with frame f.
$\gamma_s(\mathbf{o}_f)$	A posteriori probability of the observation vector $\mathbf{o}_f$ being generated by HMM state s.
μ	Statistical mean vector.
Σ	Statistical covariance matrix.
$L(\mathbf{S})$	Log likelihood of the set of HMM states $\mathbf{S}$ generating the training set observation vectors assigned to the states in that set.
$\mathcal{N}(\mathbf{x}\|\mu, \Sigma)$	Multivariate Gaussian PDF with mean μ and covariance matrix Σ.
a_{ij}	The probability of a transition from HMM state s_i to state s_j.
N	Total number of frames or number of tokens, depending on the context.
D	Number of deletion errors.
I	Number of insertion errors.
S	Number of substitution errors.

Acronyms and abbreviations

AE	Afrikaans English
AID	accent identification
ASR	automatic speech recognition
AST	African Speech Technology
CE	Cape Flats English
DCD	dialect-context-dependent
DNN	deep neural network
G2P	grapheme-to-phoneme
GMM	Gaussian mixture model
HMM	hidden Markov model
HTK	Hidden Markov Model Toolkit
IE	Indian South African English
IPA	International Phonetic Alphabet
LM	language model
LMS	language model scaling factor
MFCC	Mel-frequency cepstral coefficient
MLLR	maximum likelihood linear regression
OOV	out-of-vocabulary
PD	pronunciation dictionary
PDF	probability density function
SAE	South African English
SAMPA	Speech Assessment Methods Phonetic Alphabet

Chapter 1

Introduction

1.1. Background and Motivation

In the modern day, jogging is one of the most popular physical activities. People all over the world partake in this physical activity. One would think that jogging is a simple exercise and there are no major injury or health concerns. However, there are some major concerns as jogging has a high injury rate. Over the past few years, there has been an increasing interest in this subject and many studies have been conducted on how these injuries can be analyzed. Strike patterns during running has been acknowledged as potential way of identifying injuries or risk of injury.

1.2. Problem Statement

There are not many commercial devices that can determine a user's foot strike patterns. T

1.3. Objectives

The objective of this project is to use a prototype wearable device that captures the pressure applied to a grid of pressure sensing resistors. The prototype has been build by a previous student and is capable of capturing the data. The device has capabilities of transmitting the data wirelessly to a mobile phone. The main object is then to use the data captured and transmit it to a smartphone. An android application will then be designed and development that can process and display this data in a useful manner. The application can then be used by medical experts to assist in medical assessments like the Gait analysis.

1.4. Scope and Limitations

1.5. Overview of the report

1.6. Section heading

This is some section with two table in it: Table 1.1 and Table 1.2.

Table 1.1: Performance of the unconstrained segmental Bayesian model on TIDigits1 over iterations in which the reference set is refined.

Metric	1	2	3	4	5
WER (%)	35.4	23.5	21.5	21.2	22.9
Average cluster purity (%)	86.5	89.7	89.2	88.5	86.6
Word boundary F-score (%)	70.6	72.2	71.8	70.9	69.4
Clusters covering 90% of data	20	13	13	13	13

Table 1.2: A table with an example of using multiple columns.

	Accuracy (%)		
Model	Intermediate	Output	Bitrate
Baseline	27.5	26.4	116
VQ-VAE	26.0	22.1	190
CatVAE	28.7	24.3	215

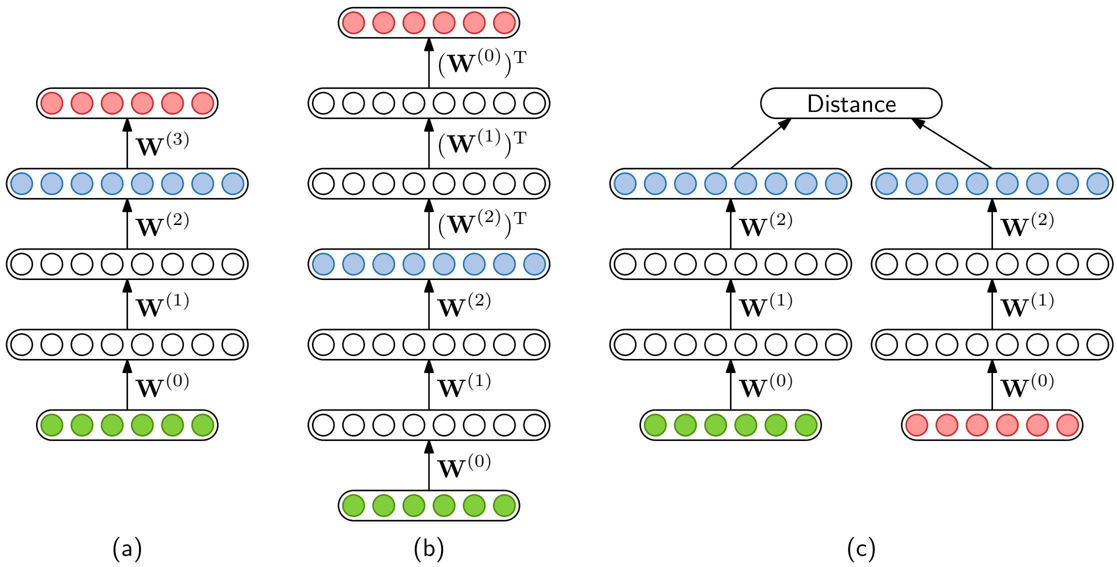

Figure 1.1: (a) The cAE as used in this chapter. The encoding layer (blue) is chosen based on performance on a development set. (b) The cAE with symmetrical tied weights. The encoding from the middle layer (blue) is always used. (c) The siamese DNN. The cosine distance between aligned frames (green and red) is either minimized or maximized depending on whether the frames belong to the same (discovered) word or not. A cAE can be seen as a type of DNN [1].

This is a new page, showing what the page headings looks like, and showing how to refer to a figure like Figure 1.1.

The following is an example of an equation:

$$P(\mathbf{z}|\boldsymbol{\alpha}) = \int_{\boldsymbol{\pi}} P(\mathbf{z}|\boldsymbol{\pi})\, p(\boldsymbol{\pi}|\boldsymbol{\alpha})\, \mathrm{d}\boldsymbol{\pi} = \int_{\boldsymbol{\pi}} \prod_{k=1}^{K} \pi_k^{N_k} \frac{1}{B(\boldsymbol{\alpha})} \prod_{k=1}^{K} \pi_k^{\alpha_k - 1}\, \mathrm{d}\boldsymbol{\pi} \tag{1.1}$$

which you can subsequently refer to as (1.1) or Equation 1.1. But make sure to consistently use the one or the other (and not mix the two ways of referring to equations).

Chapter 2

Literature Review

2.1. Foot strike patterns and Gait analysis

2.2. Bluetooth Low Energy BLE

2.2.1. How Does BLE Work?

When using Bluetooth Low Energy it is important to know the roles of each device. In all BLE application there are two roles which are the **central** and the **peripheral** devices. The peripheral device will be the device that broadcasts or advertises information and the central device will be scanning for information. A good visual representation of how BLE works is to think of an advertising board where the peripheral device keeps pinning new info onto the board and the central device scans the board and uses the information available. These two devices have their own unique addresses. The peripheral will be advertising information to any near devices while the central will for any device or devices that are advertising information. When the central device finds the advertised information a connection attempt is made. Once a connection is established, the central device can start read and writing information from and to the peripheral device.

2.2.2. Services, Characteristics and Descriptor

The information transfer system for BLE can be seen in the following hierarchical order. A service is a collection of characteristics and each characteristic has a descriptor that describes the characteristic. See the basic illustration below 2.1.

Service		
Characteristic 1	Characteristic 2	Characteristic 3
Descriptor	Descriptor	Descriptor

Figure 2.1: Basic hierarchy of BLE

Each **service** has its own unique identifying code called a UUID. This is to allow one peripheral device to have multiple services. This code can be 128-bit long for each service. A service can also be seen as a group of capabilities. For example, a smartwatch that can measure hart rate, temperature and track your GPS location. These three capabilities can be grouped under one service and can be called the activity service. This method of grouping information allows the central device to better understand and use the information that the peripheral is advertising.

The capabilities mentioned in the above example are better known as **characteristics**. Each characteristic has its own unique identifying code called a UUID. This is to allow one service to have multiple characteristics. A characteristic can be seen as a single capability. For example, the characteristic of measuring heart rate. This characteristic can be seen as a single capability of the activity service.

Each characteristic can have a **descriptor** that describes the characteristic. A descriptor can be seen as a single piece of information about the characteristic. For example, the descriptor of the characteristic of measuring heart rate can be the range of the heart rate measurement. This descriptor can be seen as a single piece of information about the characteristic of measuring heart rate.

2.3. Android application

Chapter 3

System Design

3.1. System overview

3.2. Device components

3.2.1. Arduino Nano 33 BLE

3.2.2. LiFePO4 Battery

3.2.3. IEE Smart Footwear Sensor

3.3. App components

Chapter 4

Summary and Conclusion

Bibliography

[1] G. E. Dahl, D. Yu, L. Deng, and A. Acero, "Context-dependent pre-trained deep neural networks for large-vocabulary speech recognition," *IEEE Trans. Audio, Speech, Language Process.*, vol. 20, no. 1, pp. 30–42, 2012.

Appendix A

Project Planning Schedule

This is an appendix.

Appendix B

Outcomes Compliance

This is another appendix.