NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

PROJECT TITLE GOES HERE

YOUR NAME
Matriculation number

Supervisor: XXXXX
Co-supervisor: XXXXX

A Final Year Report submitted to Asian School of the Environment, Nanyang Technological University in partial fulfilment of the requirements for the Degree of

BACHELOR OF SCIENCE WITH HONOURS IN ENVIRONMENTAL EARTH SYSTEMS SCIENCE

2020/2021 Semester 1

Abstract

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Keywords: Blind source separation, Independent component analysis, Independent vector analysis, Sparse component analysis, Automatic speech recognition, Android application development.

Graphical Abstract

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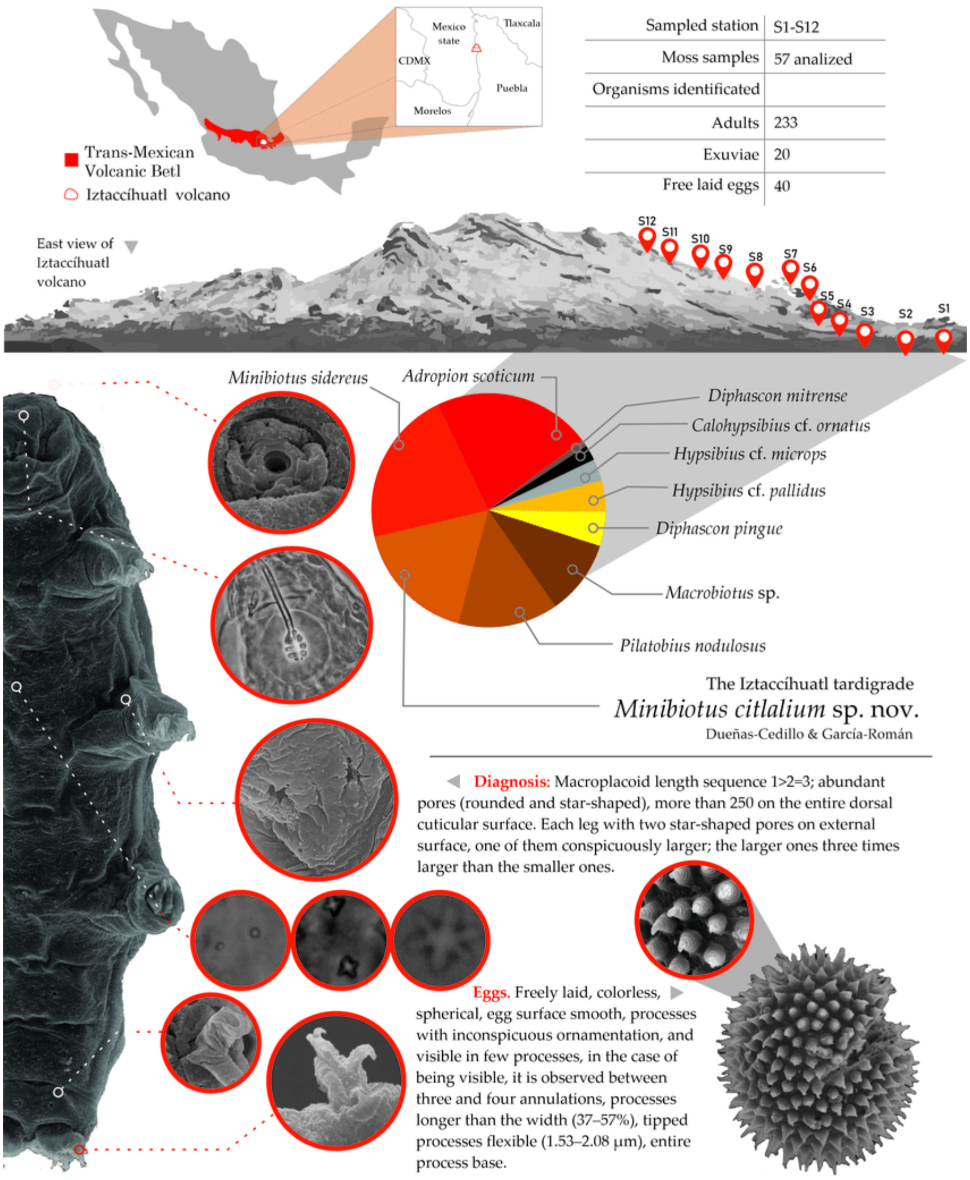

Acknowledgement

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1. Introduction

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This project aims to develop an Android application, implementing blind source separation to improve the performance of automatic speech recognition for recordings with multiple speech sources.

2. Material and Methods

2.1 Data Collection

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Figure 2-1:

Adapted from Sapp, 2004

2.2 Maecenas lobortis

The summary of speaker information for the evaluation sources and analyses of **pulse code modulation (PCM)** used in this report is presented in Table A-1.

2.2.1 Frequency-domain ipsum dolor

The various types of window functions and their properties are reviewed in Harrris et al.(1978). For this project, we use the periodic Hamming window defined by

$$w(\tau) = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi\tau}{R}\right) & 0 \leq \tau < R, \\ 0, & \text{otherwise,} \end{cases} \tag{2.1}$$

with 75% overlap.

2.3 Vestibulum tempus

A set of N source signals $\boldsymbol{s}(\tau) = [s_0(\tau), \ldots, s_{N-1}(\tau)]^T \in \mathbb{R}^{N \times T_t}$ over the samples $0 \leq \tau < T_t$, such that $s_n = [s_n(\tau = 0), s_n(1), \ldots, s_n(T_t - 1)]$ for $0 \leq n < N$, undergoes mixing whose result is observed by an array of M sensors (in this project's context, microphones). The observed signals are represented by $\boldsymbol{x}(\tau) = [x_0(\tau), \ldots, x_{M-1}(\tau)]^T$, such that $x_m = [x_m(\tau = 0), x_m(1), \ldots, x_m(T_t - 1)] \in \mathbb{R}^{M \times T}$ for $0 \leq m < M$. The sources are mixed convolutively such that

$$\boldsymbol{x}(\tau) = \sum_{k=0}^{K-1} \boldsymbol{A}_k \boldsymbol{s}(\tau - k) \tag{2.2}$$

where $\boldsymbol{A}_k \in \mathbb{R}^{M \times N}$ with K often assumed, in practice, to be some finite positive integer. This means that $\boldsymbol{x}(\tau)$ can be thought of as the output signal of a finite impulse response filter with input $\boldsymbol{s}(\tau)$ and $\boldsymbol{A}_k$ representing the coefficients of the kth-order filter.

However, solving a convolutive system in the time domain is difficult and requires significant computational power. To simplify the problem, BSS problems are often transformed into the frequency domain such that

$$\boldsymbol{X}(\omega, t) = \boldsymbol{A}(\omega) \boldsymbol{S}(\omega, t) \tag{2.3}$$

where $\boldsymbol{X}(\omega, t) \in \mathbb{C}^{M \times T_f}$ and $\boldsymbol{S}(\omega, t) \in \mathbb{C}^{N \times T_f}$ are the frequency-domain representation of the observed signals and the source signals respectively (Smaragdis, 1998).

The configuration of 2 sources used is detailed in Figures A-2 to A-5.

3. Results and Discussion

3.1 Main Activity

A crucial part of an Android application comprises of ‘activities’. A set of transcript evaluation were assumed in this project and are summarized at Table A-2

Table 3-1 shows the summary of the performance for each algorithm by acoustic environment (Env.) and the average runtimes (Rt.) for two-source separation.

	Algorithm	Rt. (s)	Env.	SDR	SIR	SAR	STOI	ESTOI	WER
Raw	AuxIVA	358.2	LTH	7.218	8.883	**13.310**	0.675	0.503	0.392
			OFC	**8.240**	10.302	**13.316**	0.705	0.544	0.310
			OTD	**14.357**	17.246	**18.263**	0.780	0.611	0.161
	FastICA	135.2	LTH	**9.564**	**15.960**	10.961	0.778	**0.609**	**0.155**
			OFC	7.873	**13.206**	10.001	**0.760**	**0.599**	**0.207**
			OTD	10.421	**18.700**	11.281	0.781	0.615	**0.146**
	SCA-DSF	**96.1**	LTH	9.425	15.675	10.917	**0.779**	0.606	0.167
			OFC	7.300	12.221	9.805	0.754	0.595	0.224
			OTD	9.705	17.472	10.852	**0.785**	**0.622**	0.162
Improvement	AuxIVA		LTH	16.959	8.838	19.726	0.423	0.330	-0.587
			OFC	16.471	10.258	16.212	0.394	0.315	-0.690
			OTD	23.727	17.041	24.701	0.483	0.440	-0.820
	FastICA		LTH	19.304	15.915	17.377	0.527	0.436	-0.824
			OFC	16.104	13.161	12.897	0.448	0.370	-0.793
			OTD	19.791	18.495	17.719	0.484	0.444	-0.836
	SCA-DSF		LTH	19.166	15.630	17.333	0.528	0.433	-0.812
			OFC	15.530	12.176	12.700	0.442	0.365	-0.776
			OTD	19.075	17.267	17.290	0.488	0.451	-0.819
	Input Mixture		LTH	-9.741	0.045	-6.416	0.251	0.173	0.979
			OFC	-8.231	0.045	-2.895	0.311	0.229	1.000
			OTD	-9.370	0.205	-6.438	0.297	0.171	0.982

Table 3-1: Performance summary for two-source separation
LTH - lecture theatre; OFC - office; OTD - outdoor.

The permissions to perform any process with such functionalities must be declared in the manifest as shown in Figure 3-1.

```xml
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    <!-- Package declaration...  -->

    <uses-permission android:name="android.permission.RECORD_AUDIO" />
    <uses-permission android:name="android.permission.WRITE_EXTERNAL_STORAGE" />
    <uses-permission android:name="android.permission.INTERNET" />
    <uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" />

    <!-- The rest of the manifest... -->
</manifest>
```

Figure 3-1: Declaration of the permissions required in the Android manifest

3.1.1 Recording of the Observed Mixture

As the user presses the record button (A), the method `startRecording()` is invoked and the record button's icon changes to a stop symbol as shown in Figure 3-2.

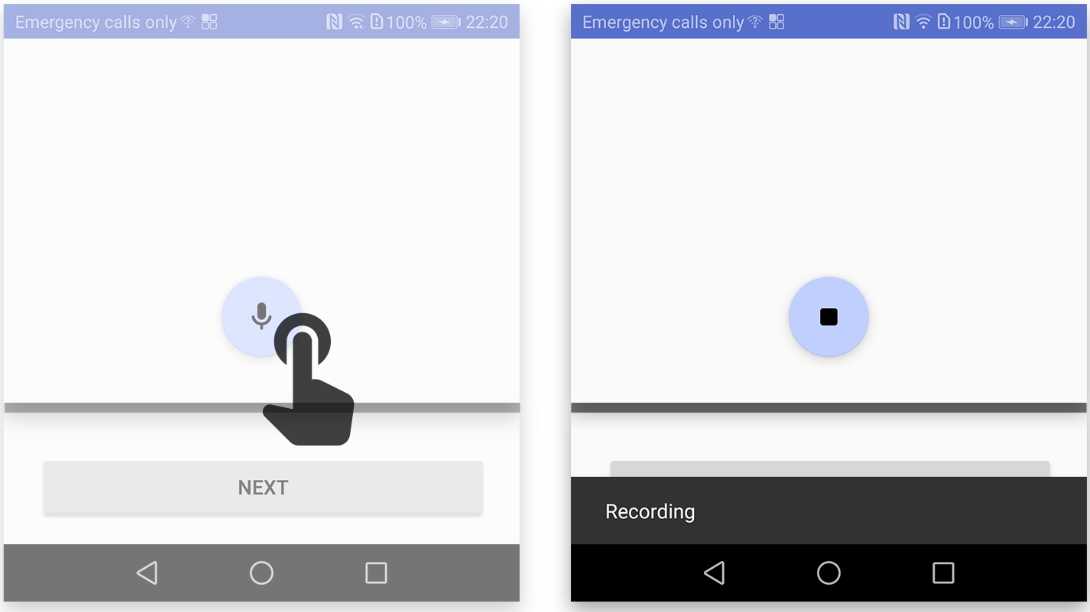

Figure 3-2: Record button icon changes from a microphone to a stop symbol

4. Conclusion and Future Work

4.1 Project Summary

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4.2 Areas of Improvement

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4.3 Future Works

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Appendix Tables and Figures

Table A-1

Table A-1 shows the speaker initials (ID), sex, dialect region number (DR), and the sentences used for each of the sources. Sentences that are trimmed are denoted with asterisks.

Source	Speaker ID	Sex	DR	Sentences			
1	JWT0	M	1	SI1291	SI751	SI1381*	
2	AEM0	F	2	SA1	SA2	SI762	SI1392*
3	SLS0	F	3	SI1056	SI1686	SI2316	
4	BAS0	F	4	SI1387	SI1472	SI2066*	
5	DWH0	M	5	SI1168	SI1925	SX35	
6	JRK0	M	6	SI1662	SI2130	SI880	SX160*

Table A-1: Speaker information for the evaluation sources
M - male; F - female. DR1 - New England; DR2 - Northern; DR3 - North Midland; DR4 - South Midland; DR5 - Southern; DR6 - New York City.

Table A-2

Source	Transcript
1	they should live in modest circumstances avoiding all conspicuous consumption serve in frankfurter buns or as a meat dish but briefly the topping
2	she had your dark suit in greasy wash water all year don't ask me to carry an oily rag like that fill small hole in bowl with clay assume for
3	can thermonuclear war be set off by accident it latches when you close it so stay as long as you like Davy Mathews it's disgusting the way you're always eating
4	several factors contributed to this change she greeted her husband's colleagues with smiling politeness offering nothing He saw a pint-sized man
5	it takes a great deal of sophisticated thought to get the impact of this fact so what's this all about help celebrate your brother's success
6	did anyone see my cab See you in about an hour the revolution now under way in materials handling makes this much easier as co-authors we presented our new book

Table A-2: Transcript of the evaluation sources

Figure A-1

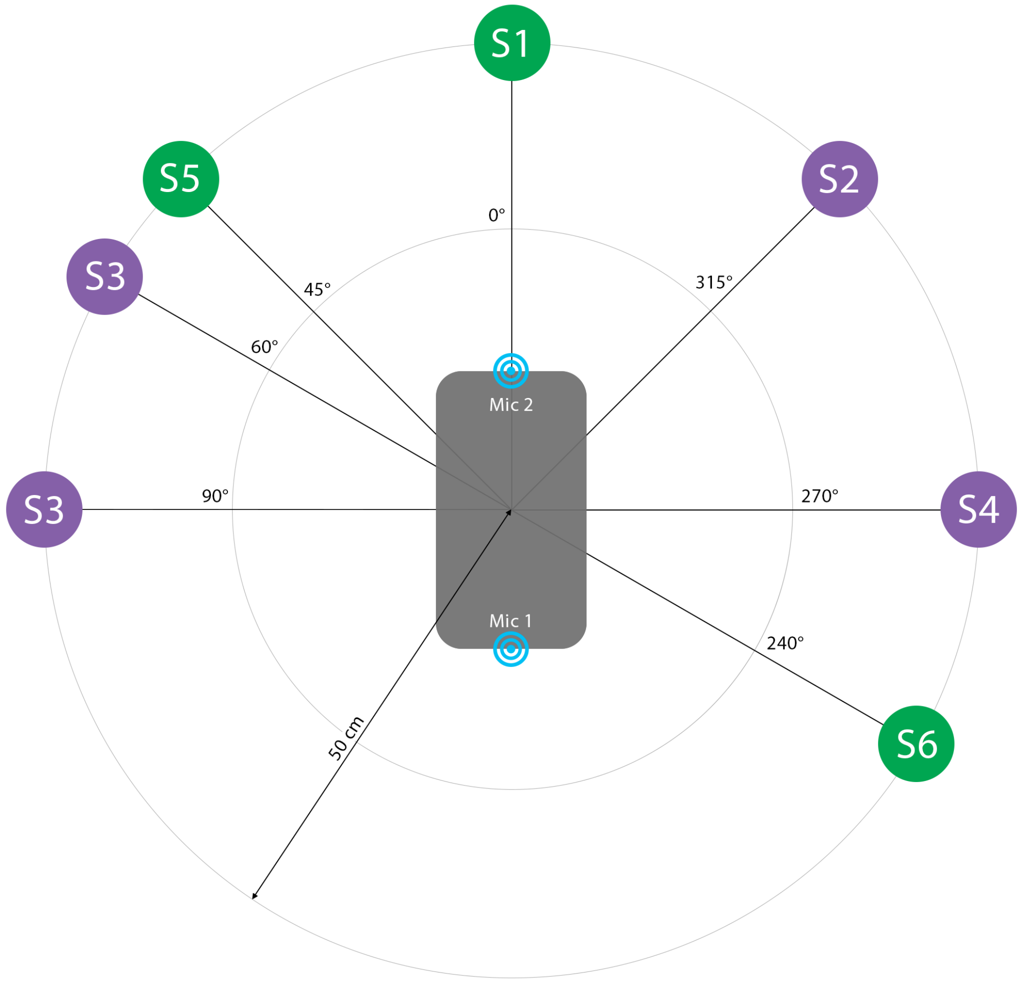

Figure A-1: Positions of the loudspeaker for each source speaker
A green circle denotes a male speaker. A purple circle denotes a female speaker. The angle is measured with respect to the line passing through the microphones in a counterclockwise manner, starting from the top of the phone where Microphone 2 is located. Note that Speaker 3 was recorded at two different positions. The figure is not to scale.

Figures A-2 - A5

The configurations of the mixtures are shown, not to scale, in Figures A-2 to A-5. The source configuration for each mixture is the same across all acoustic environments.

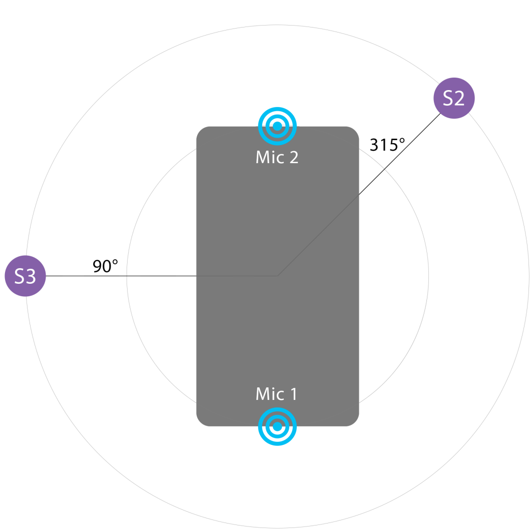

Figure A-2: Configuration 1 for two-source mixture

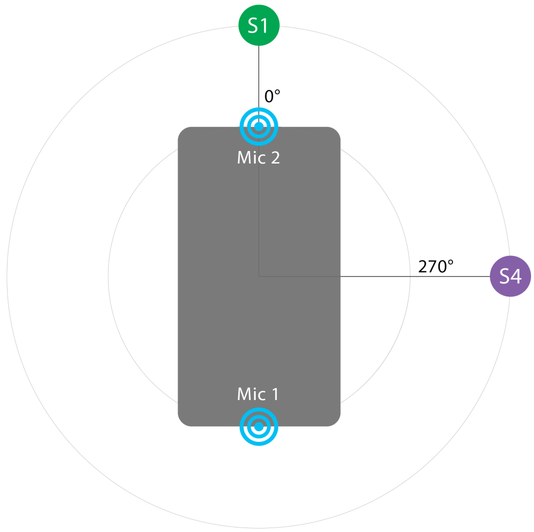

Figure A-4: Configuration 1 for three-source mixture

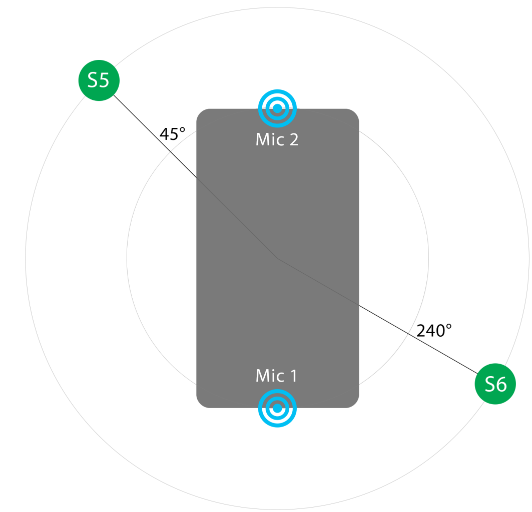

Figure A-3: Configuration 2 for two-source mixture

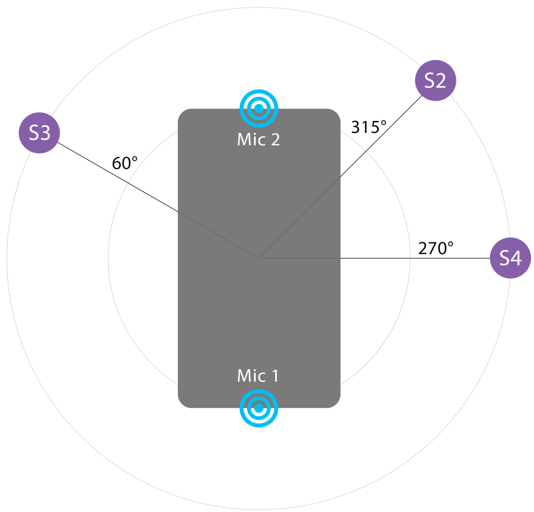

Figure A-5: Configuration 2 for three-source mixture