



**Escola Tècnica Superior d'Enginyeria
de Telecomunicació de Barcelona**

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Improvement of algorithms to identify transportation modes for MobilitApp, an Android Application to anonymously track citizens in Barcelona

Author: Gerard Marrugat
Director: Mónica Aguilar
Co-Director: Silvia Puglisi

26/05/2016

Index

1. Introduction
2. MobilitApp
3. Transport Mode Detection
 - 3.1 APIs
 - 3.2 Accelerometer Sensor Listener
4. Analyzing Mobility Data
 - 4.1 Collecting Data
 - 4.2 Analyzing Data
 - 4.3 Mobility Patterns
5. Extra Features
6. Conclusions and Future Work

Index

1. Introduction

2. MobilitApp

3. Transport Mode Detection

1. APIs
2. Accelerometer Sensor Listener

4. Analyzing Mobility Data

1. Collecting Data
2. Analyzing Data
3. Mobility Patterns

5. Extra Features

6. Conclusions and Future Work

Introduction

Smart City

Urban and technological development focused on sustainability and able to satisfy citizens' needs

Smart City Areas

- Public Services
- Socio-Cultural Environment
- Medicine & Health
- Sustainability



Image source: <http://www.kikusui.co.jp/en/company-info>

Introduction

Smart Mobility

Citizens Environment



Image source: http://www.arup.com/smart_mobility

Smart Parking

Car Sharing

E-Mobility

Non Fossil Fuels

Index

1. Introduction
- 2. MobilitApp**
3. Transport Mode Detection
 1. APIs
 2. Accelerometer Sensor Listener
4. Analyzing Mobility Data
 1. Collecting Data
 2. Analyzing Data
 3. Mobility Patterns
5. Extra Features
6. Conclusions and Future Work

MobilitApp



Image source: http://www.arup.com/smart_mobility

IMPROVE
TRANSPORTATION
INFRASTRUCTURES

MobilitApp

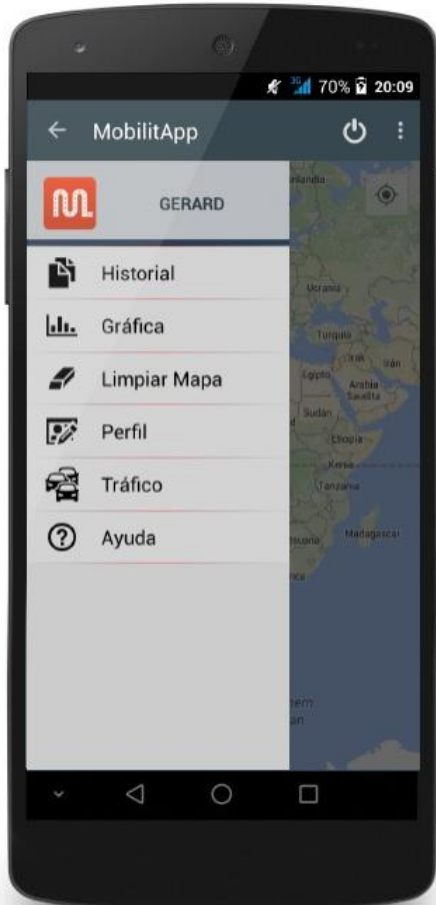


Image source: MobilitApp Project

Functionalities

- Anonymously Citizens Tracking
- Transportation Mode Detection
- Real-Time Traffic Information

Google
APIs

Open Data

MobilitApp

Requirements

- **Minimum OS version:**
 - Android 3.0 (Honeycomb)
- **Location Mode:**
 - High Accuracy (GPS+WPS)
 - Battery Saving (WPS)
- **Wi-Fi enabled**



Image source: www.elcomercio.es

GPS (Global Positioning System)

WPS (Wi-Fi Positioning System)

Index

1. Introduction
2. MobilitApp
- 3. Transport Mode Detection**
 1. APIs
 2. Accelerometer Sensor Listener
4. Analyzing Mobility Data
 1. Collecting Data
 2. Analyzing Data
 3. Mobility Patterns
5. Extra Features
6. Conclusions and Future Work

Transport Mode Detection

- APIs

Activity Recognition

Places

Directions

Google™



Image source: <http://apievangelist.com/2011/05/21/google-apis-console/>

Problems

- Not distinguish among motorized transports
- Network connection
- External Service
- Providing Information

Transport Mode Detection



Image Source: shutterstock

LISTENING
MOBILE
SENSORS

MOBILITY
PATTERNS

Transport Mode Detection

Mobile Accelerometer

Local Data

Acceleration value along axis

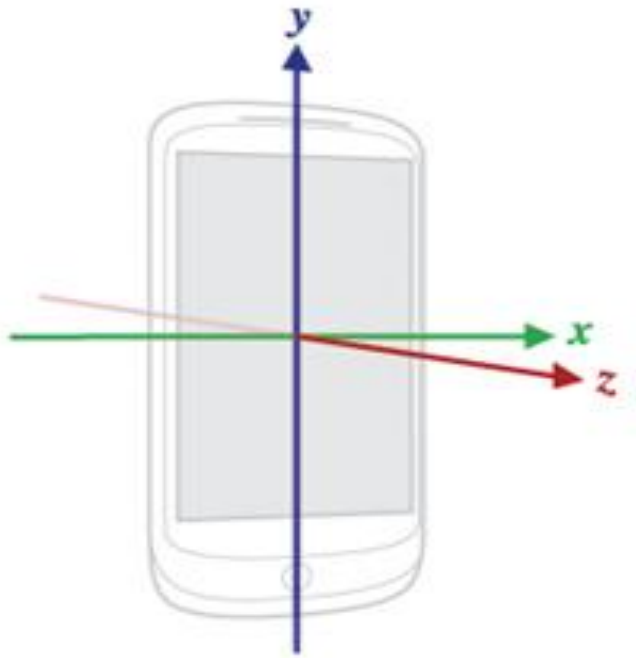


Image Source: <https://developer.android.com/>

Low Power Consumption

Sensor/Feature	Consumption
Accelerometer	0.23 mA
Magnetic Field	6.8 mA
Gyroscope	6.1 mA
WiFi	330 mA
GPS	145 mA

Gyroscope is also listened -> Rate of rotation around axis

Transport Mode Detection

• Accelerometer Sensor Listener

The State of Art

- Hemminki, S., Nurmi, P., Tarkoma, S.: Accelerometer-based transportation mode detection on smartphones. In: Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems. p. 13. ACM (2013) ref: <https://goo.gl/dpl59q>
- Phan, T.: Improving activity recognition via automatic decision tree pruning. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing. pp. 827 ACM (2014) ref: <http://goo.gl/Lp7Nru>

Independent Application

Tool to Collect Data

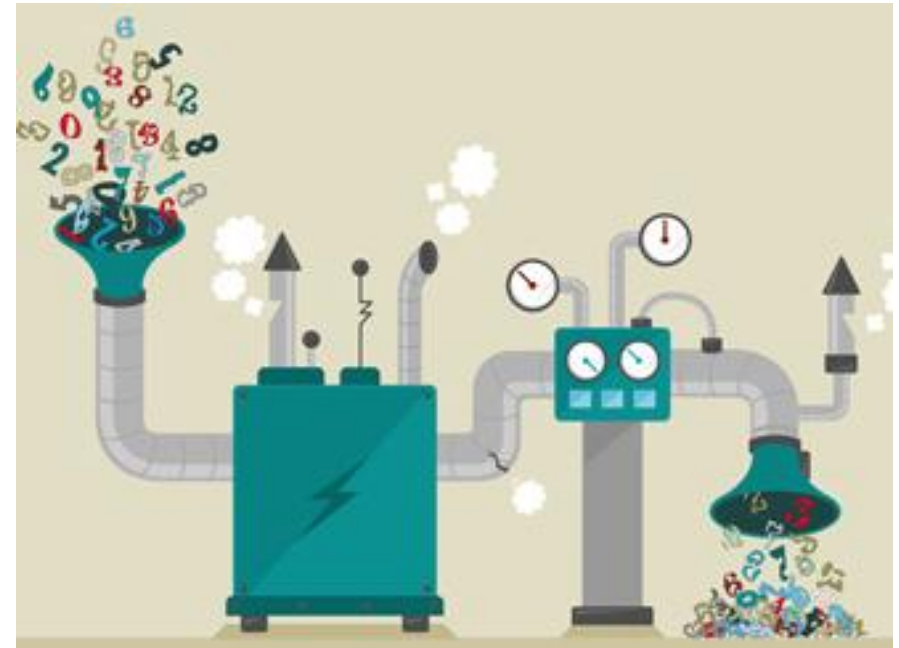


Image Source: <http://flightsafety.org/aerosafety-world-magazine/october-2013/data-delirium>

ASL Application Interface

Acceleration Data

Time	X-Axis	Y-Axis	Z-Axis
00:01:238	-0,565	3,380	7,843
00:01:357	-0,795	4,958	6,549
00:01:476	-1,162	6,347	5,562
00:01:664	-0,347	5,237	6,000
00:01:711	0,827	4,235	9,934
00:01:763	0,640	4,264	8,184
00:01:830	0,917	3,672	9,474
00:01:899	0,574	3,346	9,970
00:02:021	-0,030	3,872	7,863
00:02:138	-0,350	4,712	7,472
00:02:311	0,121	4,306	8,949
00:02:372	0,659	3,895	9,298
00:02:445	0,147	3,928	8,226
00:03:211	-0,115	3,551	8,648
00:03:687	0,053	3,583	8,303
00:04:842	-0,479	3,551	7,637
00:05:266			
Start		Stop	
Exit			

Data Collected

Timestamp

X-Acceleration

Y-Acceleration

Z-Acceleration

Image source: MobilitApp Project

Transport Mode Detection

Once process collection is finished...

Saved in a File



Sent to the Server



Deleted from Mobile



Transport Mode Detection

Including ASL in MobilitApp

Which Transport?

Users Collaboration

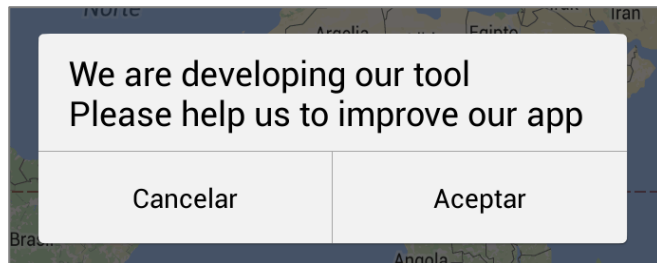
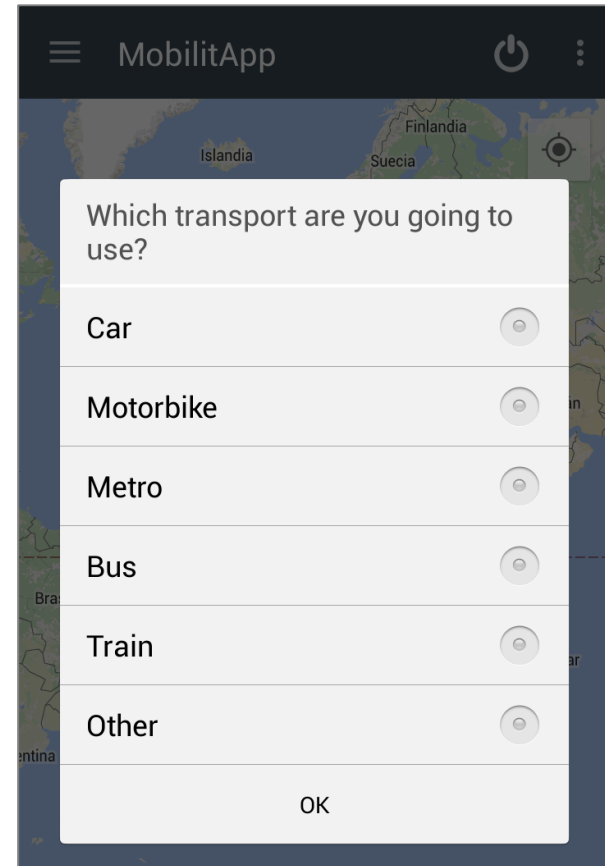


Image source: MobilitApp Project



Transport Mode Detection

How Data is Collected?

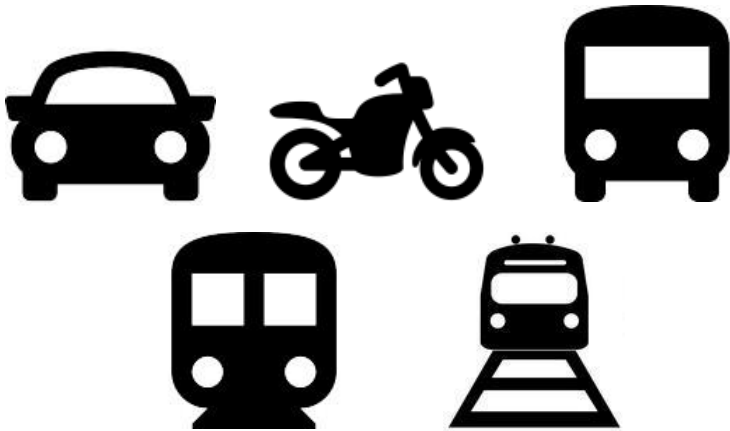
- ASL -> Background Service
- 20 seconds every 2 minutes
- Storage and Upload

Index

1. Introduction
2. MobilitApp
3. Transport Mode Detection
 1. APIs
 2. Accelerometer Sensor Listener
- 4. Analyzing Mobility Data**
 1. Collecting Data
 2. Analyzing Data
 3. Mobility Patterns
5. Extra Features
6. Conclusions and Future Work

Analyzing Mobility Data

• Collecting Data



Total Downloads: 25

Observed Users: 7

Transportation Modes: 5

Spent Time: 30 h 15 min

Note

- Execution Times
- Mobile Phone Location

Analyzing Mobility Data

- Analyzing Data

Different Transports -> Different Behaviours

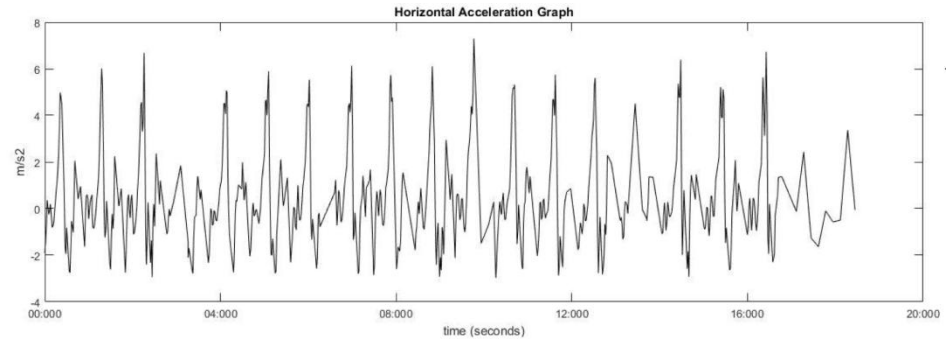
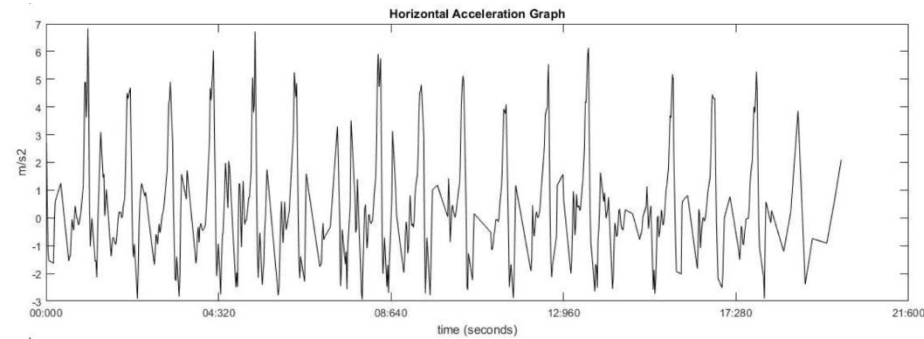
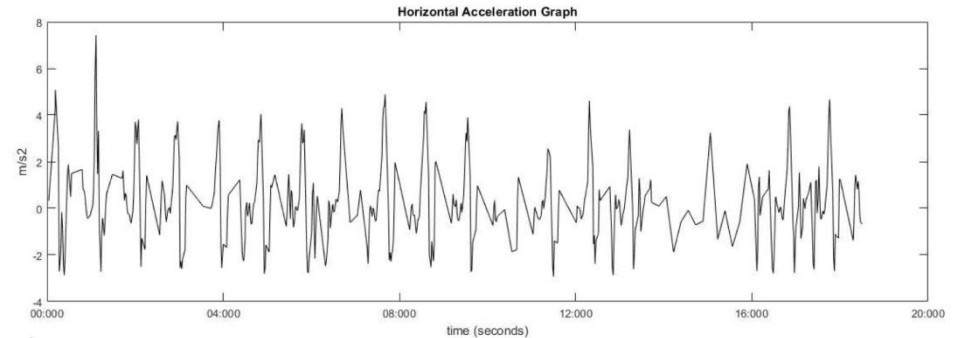
Horizontal Acceleration

Statistical Analysis

Peak Analysis

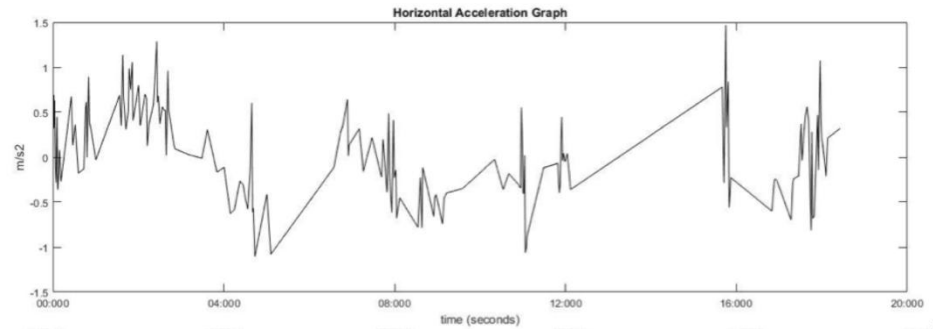
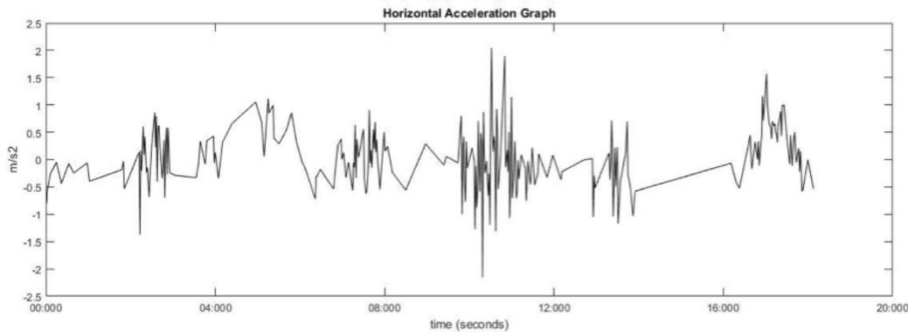
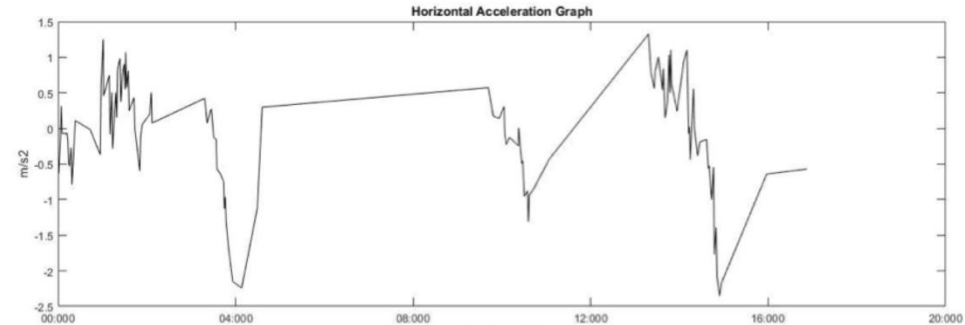
Analyzing Mobility Data

Bus Horizontal Acceleration



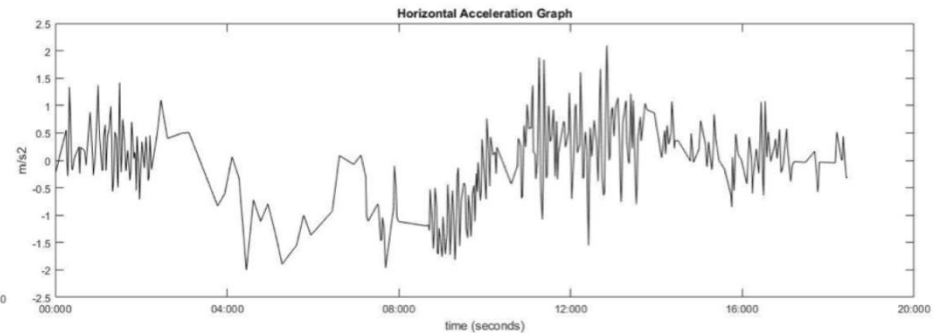
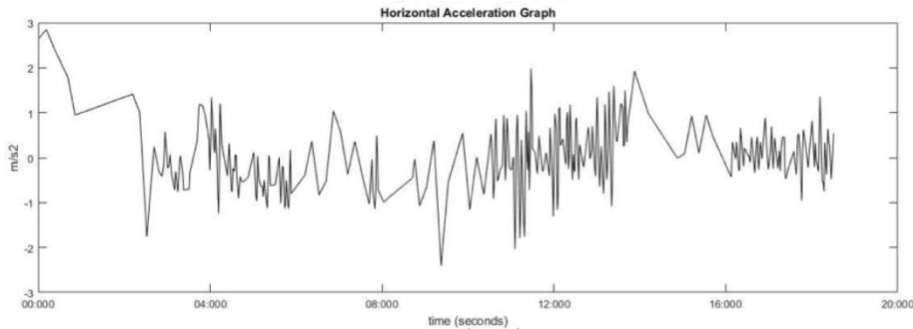
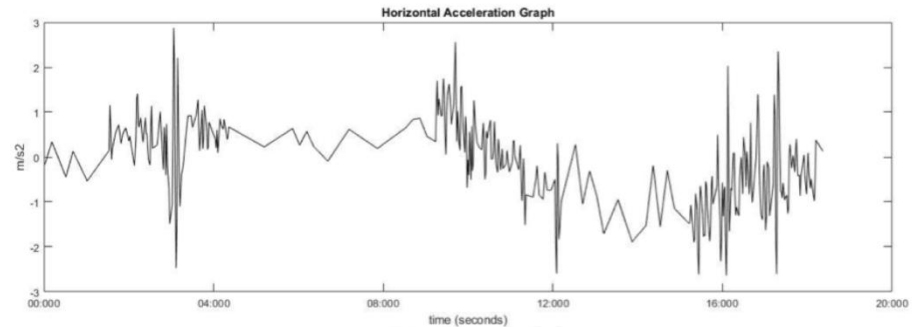
Analyzing Mobility Data

Car Horizontal Acceleration



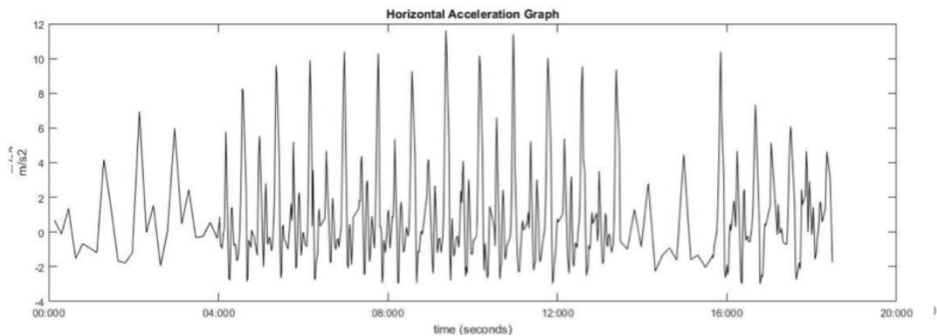
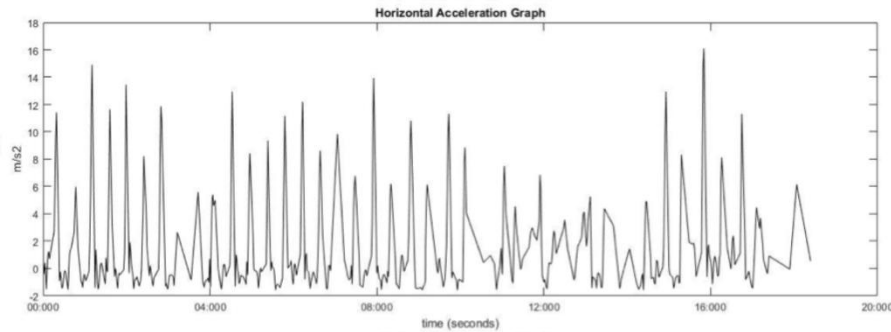
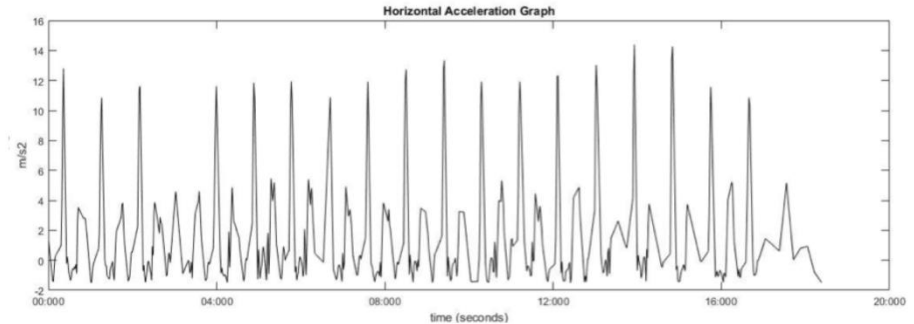
Analyzing Mobility Data

Motorbike Horizontal Acceleration



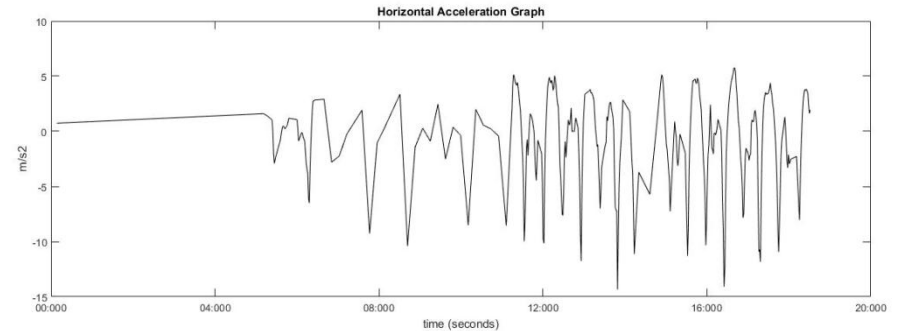
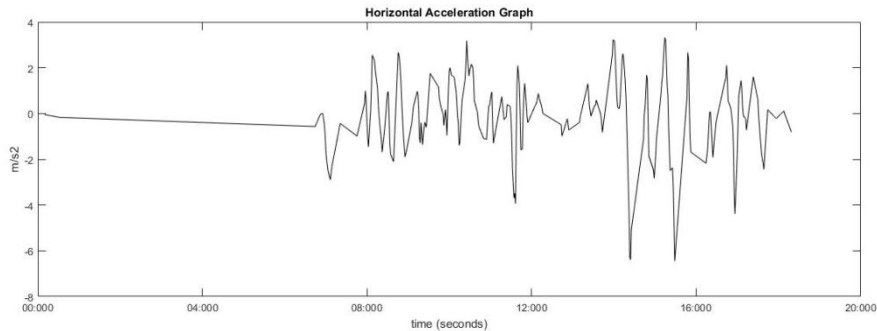
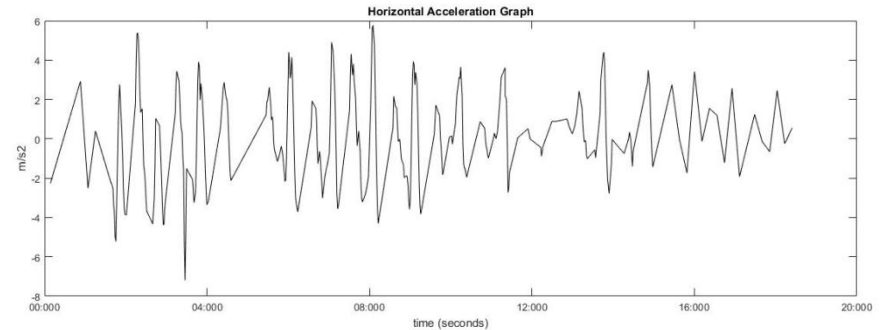
Analyzing Mobility Data

Metro Horizontal Acceleration



Analyzing Mobility Data

Train Horizontal Acceleration



Analyzing Mobility Data

Statistical Analysis

Parameters

Mean
Standard Deviation
Variance
Root Mean Square Error
Maximum Value
Minimum Value

Peak Analysis

Parameters

Peak Area
Peak Interval

Analyzing Mobility Data

- Mobility Patterns

Statistical Analysis

	Mean (m/s ²)	Standard Deviation (m/s ²)	Maximum (m/s ²)	Minimum (m/s ²)
Bus	5,17	0,72	8,2	0,015
Car	5,26	0,63	6,14	2,45
Motorbike	3,03	0,7	5,55	1,26
Metro	3,32	2,52	13,7	0,004
Train	4,13	2,41	12,36	0,097

Analyzing Mobility Data

Road Vehicles

	Mean (m/s ²)	Standard Deviation (m/s ²)	Maximum (m/s ²)	Minimum (m/s ²)
Bus	5,17	0,72	8,2	0,015
Car	5,26	0,63	6,14	2,45
Motorbike	3,03	0,7	5,55	1,26

Rail Vehicles

Metro	3,32	2,52	13,7	0,004
Train	4,13	2,41	12,36	0,097

Analyzing Mobility Data

Peak Analysis

Road Vehicles

	Interval Length (s)	Peak Area (m/s)
Bus	0,5	1,1
Car	1,37	0,78
Motorbike	0,52	0,66

Rail Vehicles

Metro	0,6	1,57
Train	0,67	1,65

Analyzing Mobility Data

Road Vehicles

	Interval Length (s)	Peak Area (m/s)
Bus	0,5	1,1
Car	1,37	0,78
Motorbike	0,52	0,66

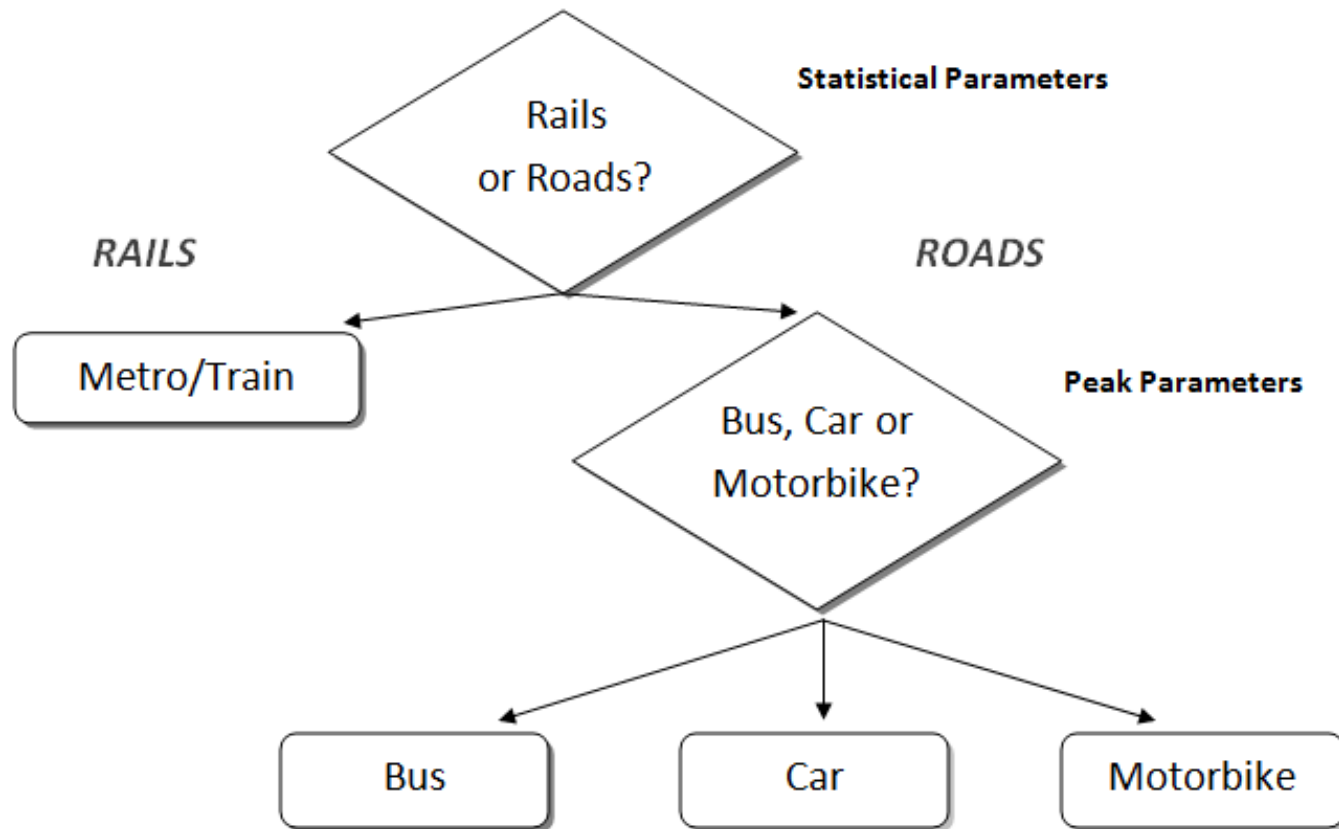
Rail Vehicles

Metro	0,6	1,57
Train	0,67	1,65

- No differences among Rail Vehicles
- Future Work

Analyzing Mobility Data

Classification Diagram



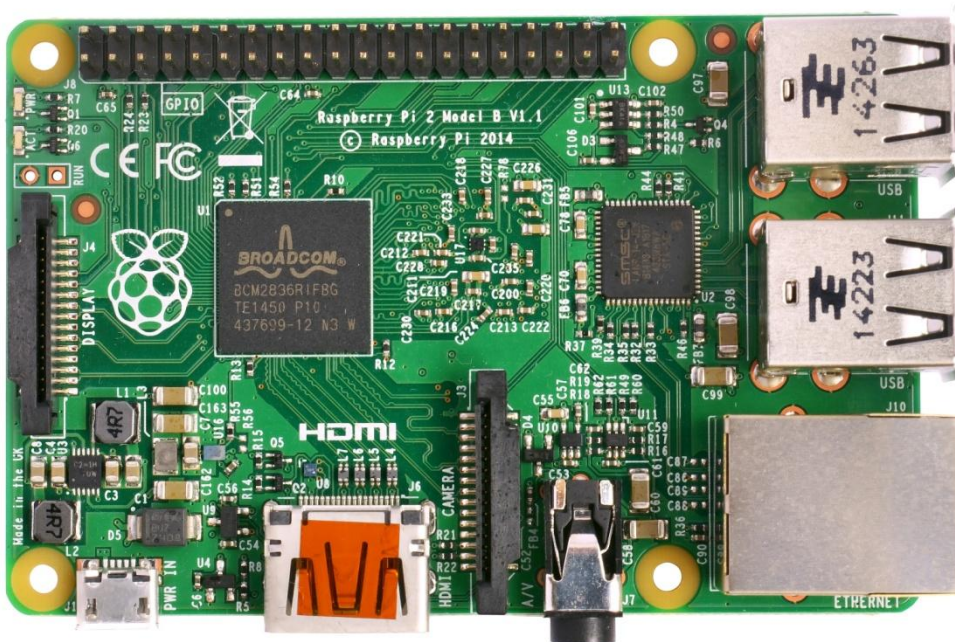
Index

1. Introduction
2. MobilitApp
3. Transport Mode Detection
 1. APIs
 2. Accelerometer Sensor Listener
4. Analyzing Mobility Data
 1. Collecting Data
 2. Analyzing Data
 3. Mobility Patterns
- 5. Extra Features**
6. Conclusions and Future Work

Extra Features

The Server

Raspberry Pi 2 Model B



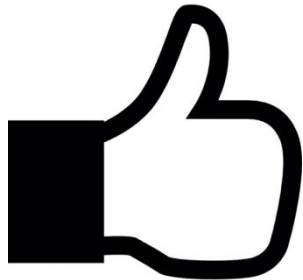
Services

- Web Page
- Data Storage

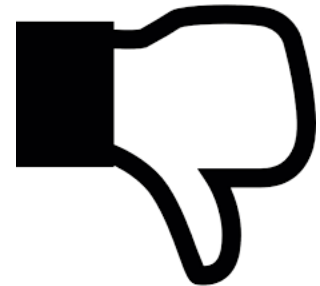
Features

- Broadcom BCM2835 system on a chip (SoC)
- 900MHz quad-core ARM Cortex-A7 CPU
- 1GB de RAM
- Debian Linux ARM

Extra Features



- Low Power Consumption: 3,5 W/h
- Reduced Price (45\$)
- Size (6cm x 9cm)



- Processor Capacity Limited
- RAM memory

Extra Features

Web Page

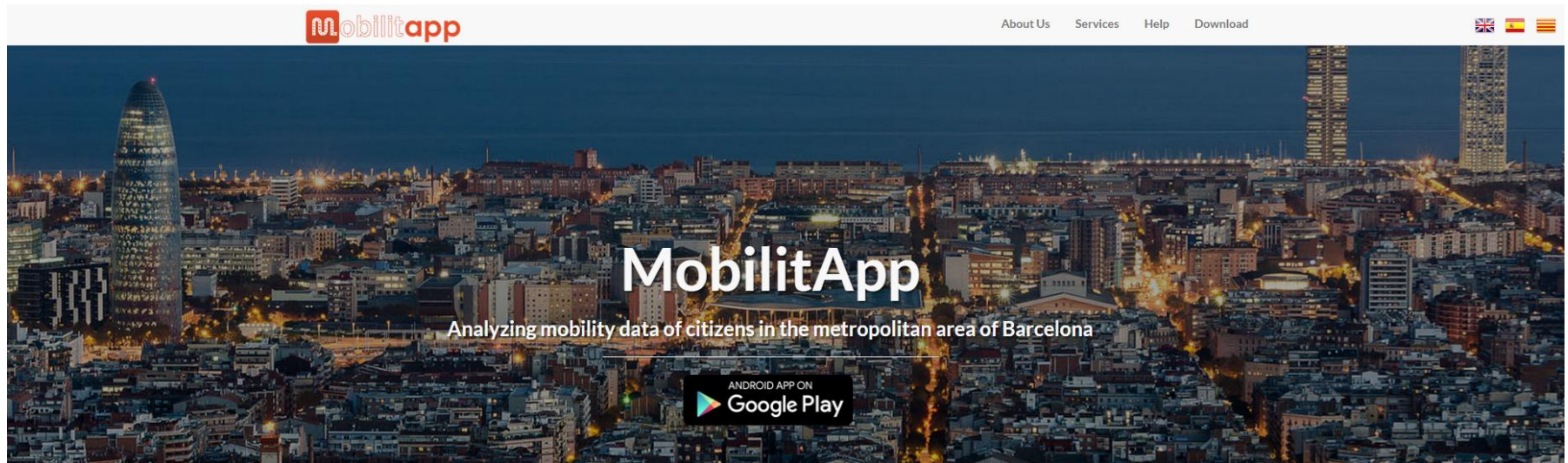


Image source: MobilitApp Project

mobilitapp.noip.me

Extra Features

Promotional Video

[MobilitApp Promotional Video](#)

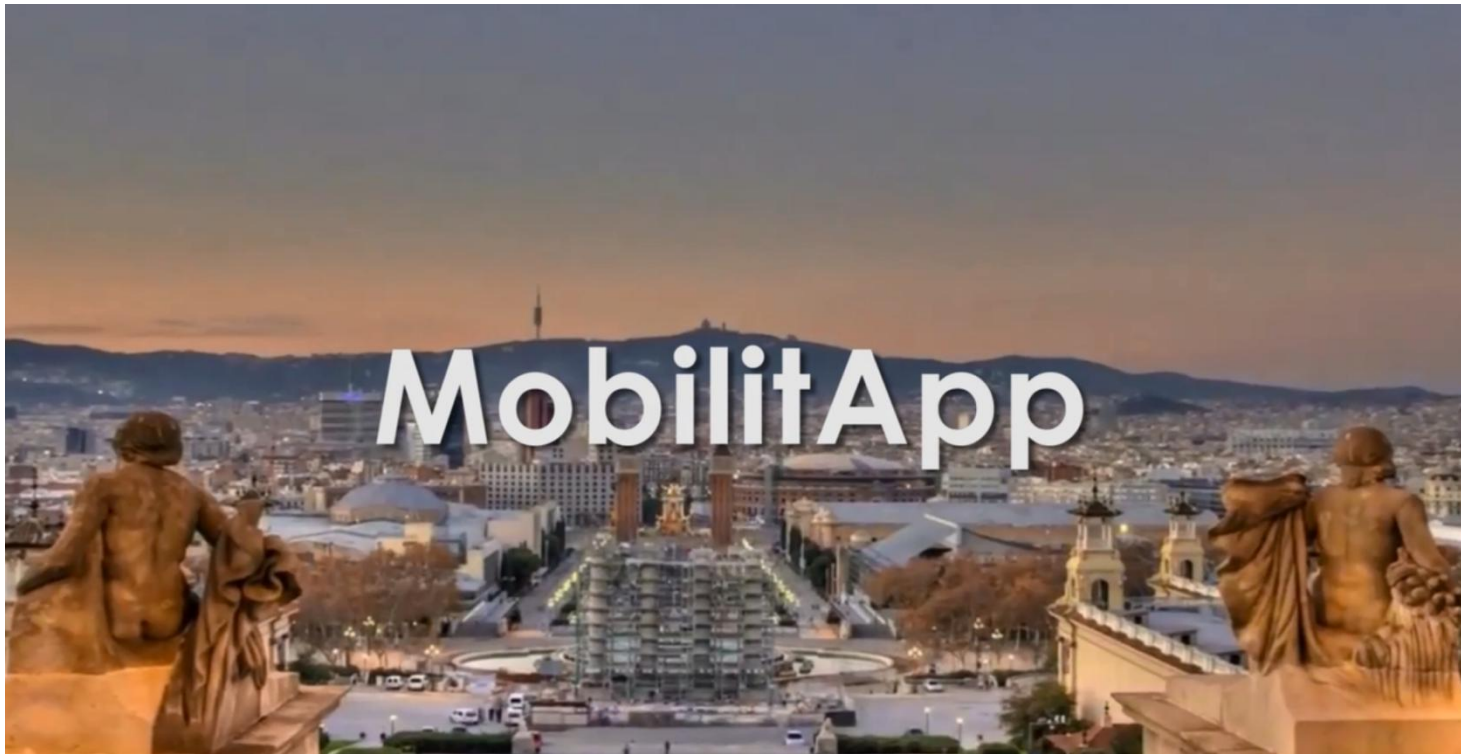


Image source: MobilitApp Project

Extra Features

Publications

- Silvia Puglisi, Ángel Torres Moreira, Gerard Marrugat Torregrosa, Mónica Aguilar Igartua and Jordi Forné. MobilitApp: Analysing mobility data of citizens in the metropolitan area of Barcelona. *EAI International Conference on Smart Objects and Technologies for Social Good*, October 2015

Ref: <https://arxiv.org/abs/1605.06536>

- Silvia Puglisi, Gerard Marrugat, Mónica Aguilar and Jordi Forné. How do you get there? Identifying means of transportation from mobile sensors patterns. *The 14th Annual IEEE Consumer Communications&Networking Conference* ,January 2017(in process)

Index

1. Introduction
2. MobilitApp
3. Transport Mode Detection
 1. APIs
 2. Accelerometer Sensor Listener
4. Analyzing Mobility Data
 1. Collecting Data
 2. Analyzing Data
 3. Mobility Patterns
5. Extra Features
- 6. Conclusions and Future Work**

Conclusions and Future Work

Conclusions

- Accelerometer Sensor Listener -> Scalable Solution
- Patterns -> Transport Detection Task
- Mobility Data



Image source: <https://www.traffic-masters.net>

Conclusions and Future Work

Future Work



- E-Call
- Transport Mode Detection Algorithm
- Attractive to users
- WiFi Metro Station
- Improve Infrastructure

Web Page

mobilitapp.noip.me

Promotional Video

[MobilitApp Promotional Video](#)



Escola Tècnica Superior d'Enginyeria
de Telecomunicació de Barcelona

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Improvement of algorithms to identify transportation modes for MobilitApp, an Android Application to anonymously track citizens in Barcelona

Thank you

Author: Gerard Marrugat
Director: Mónica Aguilar
Co-Director: Silvia Puglisi

