Trinity College Dublin
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Learning for sensor-based, real-time fall detection for cyclists.

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A Final Year Project submitted in partial fulfilment
of the requirements for the degree of
B. A (Mod.) Computer Science

Declaration

I hereby declare that this project is entirely my own work and that it has not been submitted as an exercise for a degree at this or any other university.

I have read and I understand the plagiarism provisions in the General Regulations of the University Calendar for the current year, found at `http://www.tcd.ie/calendar`.

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Abstract

Like all extreme sports, mountain biking comes with the potential for serious injury to the rider in the event of an accident. Non fatal injuries can easily become fatal, when one is alone, far from help and potentially incapacitated. A study conducted by Paracelsus Medical University recorded injury rates as high as 16.8 injuries per 1000 hours of riding, with 22 being moderate and 16 being severe, with rider error being the leading cause (1). An automated crash detection system has the potential to be life saving in the worst of circumstances.

Existing discipline-specific solutions e.g., for road only or for mountain use only, on both hardware (Specialized's AnGi) and software (Strava Beacon,Garmin) have inflexible detection algorithms focusing on using thresholds for only one to two data points. For example AnGi records values from its inbuilt gyroscope and accelerometer, while Garmin's system uses only accelerometer values. Such threshold-based solutions pose issues in terms of high false detection rates and a single threshold value is unlikely to be suitable for different users at different skill levels.

This project expands on previous research done in the area of wearable fall detection devices for the elderly, focusing on the design of a software solution for real-time fall detection. Three data points are used: raw sensor data from both a tri-axial gyroscope and a tri-axial accelerometer as well as the rate of change of speed, calculated via GPS. The proposed system utilizes learning techniques to improve detection rates and over time generates a more personalized model. Based on pre-captured training data of both regular riding and crashes, data is classified using a multivariable logistic regression model in real-time to determine whether a crash has occurred. Raw sensor data is captured from the inbuilt sensors present on android smartphones.

This approach is implemented as an android application called "RideSafe" and was evaluated using a user study, comprising of X participants at local trail centres over a Y day period. Crash data was also collected, by means of intentional crashes in a controlled environment for verification. Results show that this system can successfully detect upwards of X crashes with a low rate of Y false positives. . . .

Acknowledgements

Thanks Mum!

You should acknowledge any help that you have received (for example from technical staff), or input provided by, for example, a company.

Contents

1 Introduction

1.1 Motivation

Personal experiences were the main driving factor in my motivation to pursue this study. As a mountain biker with 10 years of experience I have sustained my fair share of minor injuries, but witnessing injuries sustained by more venerable fellow riders are sometimes more impactful. Last summer on a seemingly normal spin with a friend, we discovered a woman lying injured off on the trail side, incapacitated and unable to call for help so I did on her behalf. Multiple phone calls later to aid the first responders in locating us they arrived - around 1 hour after impact. This experience made me realize how useless your mobile phone is to you in these situations when one is unable to even pick it up.

Currently there are 29,000 registered members of cycling Ireland and with mountain biking becoming ever more popular each year this number is set to grow.

1.2 Aims

The aim of this project was to develop an android application for real-time fall detection for cyclists, automating the process of requesting assistance, and to reduce response time in the event of an accident. Before development of the application I set myself strict aims to achieve.

Simplistic and Intuiative

After the initial set up process, to carry out the main use case: crash detection would be started and stopped with a single press of a button. Start the service, put your phone in your pocket and enjoy your time on you bike with piece of mind. Simple and convenient to use, removing the possibility of confusion for the end user, as the end users will be members of the general public. A simple user interface is important as the setting to which the app would be outdoors in potentially harsh weather conditions, external factors such as glare from the sun and the possibility of moisture on the screen make high detailed, small user interface elements unsuitable. Less is more in this scenario.

Diverse

Many existing systems are discipline specific, only working for one aspect of cycling i.e., for cross country usage only. I intend this app to have the potential to work for all disciplines of cycling. Targeting single disciplines would drastically reduce the number of potential users as well as producing highly undesirable, inaccurate results if used for the incorrect discipline.

Standalone

Utilizing android smartphones built in sensors removes the need for extraneous external equipment for ride monitoring. I intend the app to work as expected with one's phone placed in their pocket or bag, requiring no extra mounting equipment for either the rider or the bike.

Enjoyable user experience

Many existing solutions exhibit deal breaking issues which ultimately causes the end user to stop using the system, I aim to eradicate the pitfalls present in other systems leading to a better user experience.

Efficiency

Performance in terms of battery usage is of utmost importance, heavy battery usage would have the potential to kill the phone when one would need it most - in an emergency. Every possible optimization in terms of battery will be made where possible - without impacting performance.

1.3 Personal Goals

In addition to the aims of this project I had set some personal goals to achieve from undertaking this project.

Devolop a fully functional application.

Having had brief experience working with android studio before undertaking this project to develop simple applications, most of which were interfaces for arduino circuits connected via bluetooth, I had never developed such a large scale complex application prior to this project.

I was excited to broaden my skill set and develop an application ready to be published to the google play store.

Work with Embedded sensors.

Having experience working with microcontrollers and various sensors, I was excited to utilize the plethora of available sensors present in android smartphones today.

Collect and Analyse Real World Data.

Datasets for what a bike accident looks like in terms of sensor values are few and far between, I was excited to conduct my own research with many unknowns to which I would need to discover. Having very few similar documented studies available I was very interested to study this particular system in the domain of cycling.

Real world testing.

I was aware before undertaking this study that it would involve a lot of real world data collection, analysis and testing. Being a crash detection application testing could not be simulated sitting at a desk, which meant all my testing would need to be done in the real world which proved both challenging and exciting.

1.4 Readers Guide

2 - Background

This section will discuss the concept of fall/accident detection, exploring both the sport and medical applications. The two main approaches of fall detection will be discussed and the strong points as well as issues with each type of system will be discussed.

3 - Design

here about design

4 - Implementation

here about implementation

5 - Evaluation

evaluation goes here

6 - Conclusion

da CONCLUSION

2 Background

here is the background

2.1 The Concept

what fall detection is all about

2.2 Exsisting Solutions - Medical

much work has been done .....

2.2.1 Vision Based Approaches

expensive privacy issues

2.2.2 Sensor Based Approaches

2.3 Exsisting Solutions - Cycling

2.3.1 Garmin

2.3.2 Specilized's ANGI

2.4 Threshold based solutions

2.5 Supervised Machine Learning

3 Evaluation

4 Conclusion

Bibliography

[1] Johannes Becker. A prospective study of downhill mountain biking injuries. *British journal of sports medicine*, 47(458-462):1, 2013.

A1 Appendix

You may use appendices to include relevant background information, such as calibration certificates, derivations of key equations or presentation of a particular data reduction method. You should not use the appendices to dump large amounts of additional results or data which are not properly discussed. If these results are really relevant, then they should appear in the main body of the report.

A1.1 Appendix numbering

Appendices are numbered sequentially, A1, A2, A3... The sections, figures and tables within appendices are numbered in the same way as in the main text. For example, the first figure in Appendix A1 would be Figure A1.1. Equations continue the numbering from the main text.