David António Freire Moura

Bachelor in Computer Science

Exploratory Analysis of Individual Metrics in Team Sports Using *IoT* Sensors

Dissertation plan submitted in partial fulfillment
of the requirements for the degree of

Master of Science in
Computer Science and Informatics Engineering

Adviser: Carmen Pires Morgado, Profª. Auxiliar,
NOVA University of Lisbon

Co-adviser: Ruben Duarte Dias da Costa, Director,
Knowledge Biz Consulting

FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

DRAFT: 2019-07-01

Abstract

The dissertation must contain two versions of the abstract, one in the same language as the main text, another in a different language. The package assumes that the two languages under consideration are always Portuguese and English.

The package will sort the abstracts in the appropriate order. This means that the first abstract will be in the same language as the main text, followed by the abstract in the other language, and then followed by the main text. For example, if the dissertation is written in Portuguese, first will come the summary in Portuguese and then in English, followed by the main text in Portuguese. If the dissertation is written in English, first will come the summary in English and then in Portuguese, followed by the main text in English.

The abstract shoul not exceed one page and should answer the following questions:

- What's the problem?
- Why is it interesting?
- What's the solution?
- What follows from the solution?

Keywords: Keywords (in English) . . .

Resumo

Independentemente da língua em que está escrita a dissertação, é necessário um resumo na língua do texto principal e um resumo noutra língua. Assume-se que as duas línguas em questão serão sempre o Português e o Inglês.

O *template* colocará automaticamente em primeiro lugar o resumo na língua do texto principal e depois o resumo na outra língua. Por exemplo, se a dissertação está escrita em Português, primeiro aparecerá o resumo em Português, depois em Inglês, seguido do texto principal em Português. Se a dissertação está escrita em Inglês, primeiro aparecerá o resumo em Inglês, depois em Português, seguido do texto principal em Inglês.

O resumo não deve exceder uma página e deve responder às seguintes questões:

- Qual é o problema?
- Porque é que ele é interessante?
- Qual é a solução?
- O que resulta (implicações) da solução?

E agora vamos fazer um teste com uma quebra de linha no hífen a ver se a LaTeX duplica o hífen na linha seguinte...

zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz zzz zzzz comentar-
-lhe zzz zzzz zzz zzzz

Sim! Funciona! :)

Palavras-chave: Palavras-chave (em Português) ...

Contents

List of Figures

List of Tables

Listings

Glossary

computer An electronic device which is capable of receiving information (data) in a particular form and of performing a sequence of operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals.

Acronyms

GPS	Global Positioning system
IoT	Internet of Things
KBZ	Knowledgebiz Consulting
NBA	National Basketball Association

Symbols

*

Chapter 1

Introduction

This chapter focuses on introducing the preparation phase of this thesis. It starts by describing the motivation and the context of the problem and describing the problem itself. Afterwards, the goals are set, and the expected contributions to the company *Knowledgebiz Consulting* (KBZ) and to the field of study are explained. Finishing this chapter, the structure of the rest of the document is presented.

1.1 Motivation and Context

In an era where information drives our world and big data analytics are a common interest in every academic and industrial field, the sports industry is starting to use data in their behalf. Huge amounts of data are produced per game and per training session, and techniques like data mining and machine learning give coaches and players more insightful information and statistics. This rich data can also help the business side of sports, like the NBA Drafts or the football transfer market.

Countless tracking systems exist for different sports, and even for different activities in each sport, but many of them are either very expensive, resource-intensive or attached to the field. There are two widely systems to track the position and collect metrics from the players: GPS sensors attached to each player, some of them have included an inertial measuring unit (accelerometer, gyroscope and magnetometer), and an array of cameras placed around the field of the game (e.g. SportVU and recently Second Spectrum used in NBA).

These systems have various concerns:

- The GPS signal can accurately measure the position, the speed and the displacement of a player. But it can't measure metrics like jumps, shoots and passes or falls.

- When in a closed court (like most of basketball courts), there is no GPS signal. The tracking is made using cameras around the court. This visual system can accurately track the position of the players and gather advanced metrics. The downside of this system is the need of high processing power, and that the cameras are attached to the court.
- The issue of the cameras being attached to the court is that every court needs to have this expensive system installed to be able to track the players performance.

The problem I am addressing is the necessity to use multiple devices to simultaneously track a player position in-game and get advanced metrics about the individual performance of a player, as well as the performance of the entire team.

1.2 Objectives

The proposed objective of this thesis is to develop an easy to use, portable and low-cost system using inertial sensors to accurately track the position and gather individual and collective player metrics in real-time, focusing the improvement of the game, the training sessions and the recovery of the player and the team. The sport chosen to implement this system was basket, because it is often played indoors, constraining the use of GPS, the number of players per team is 5 (small when compared to 7 players in a handball team or 11 players in a soccer team), and it's one of the sports that invests more in new technologies, like IoT to track players and teams.

1.3 Expected Contribuitions

blablablablabla.

1.4 Document Structure

The rest of the document is organized as follows: Chapter 2 presents the state of the art: what are the approaches currently used by professional teams regarding player tracking and data collection, what sensors are used commonly used for this application, which communication protocols are more suitable for the goals set and the related works in the field. Chapter 3 will describe the developed work so far, and Chapter 4 proposes this thesis elaboration plan.

Chapter 2

State of the art and related work

A sensor is a device that detects or measures a physical property, and converts that value to an electric signal, which is usually transmitted to a processing unit.

2.1 Different Approaches

blablablablabla.

2.1.1 Video Tracking System Approach

blablablablabla.

2.1.2 Sensor Tracking System Approach

blablablablabla.

2.2 Sensors

blablablablabla.

2.2.1 Data Acquisition Sensors in Sports

blablablablabla.

2.2.2 Motion Sensors

blablablablabla.

2.3 Communication Protocols

blablablablabla.

2.3.1 Protocols

2.3.1.1 Cellular

Cellular technology is meant to use cases where the need of data throughput is high, there is a big distance to cover and there are low restraints on power consumption. Using GSM/3G/4G (and soon 5G), peak data rates can reach up to 20Gbps [1]. Cellular communication protocol is meant to applications in mobile devices.

2.3.1.2 SigFox

SigFox builds wireless networks to connect low power objects and devices, which are continuously turned on and send small amounts of data. SigFox uses Ultra Narrow Band modulation and communicates at 100 or 600 bits per second [2]. SigFox is complementary with other technologies, like Bluetooth, GPS, Cellular and WiFi, unleashing the applications of this technology.

2.3.1.3 6LoWPAN

6LoWPAN comes from the combination of IPv6 and Low Power Wireless Personal Area Network and aims to define the IPv6 to low data rates, low power and small footprint applications, providing an adaptation layer between the MAC and the network layer (IPv6). It supports different types of topologies, like star and mesh [3].

2.3.1.4 NFC

Near Field Communication is a very short-range (0-10cm) wireless protocol, establishing wireless connections between network appliances and consumer electronic, carrying very low amounts of data (424 Kbits/second). Some examples are touching the pay terminal with the NFC-enabled phone to authorize the payment, or connecting electronic devices, like a smartphone and a headset [4].

2.3.1.5 ZigBee

ZigBee is a widely used IoT protocol with different applications in the areas of home automation, offices and healthcare systems. The networks can be configured in multiple topologies, like star, mesh and cluster tree, and consists in three types of devices: end device, router and coordinator [5].

- The coordinator is the most capable device, responsible for starting and maintaining the network, store security keys and connect with other networks.

- Router devices can run applications just like de end devices, but additionally can pass information from other devices and extend the network.
- End devices are the simplest and less expensive devices, can only talk to another device, but are able to sleep and to save more power than router or coordinator devices.

2.3.1.6 Z-Wave

2.3.1.7 WiFi

2.3.1.8 Bluetooth

...

Bluetooth network topologies can be of different types, as shown in Figure 2.1:

- **Point-to-point (1:1) -** Point-to-point network topology is used for connecting devices one-to-one. In BR/EDR this type of communication is optimized for audio streaming, like headsets, speakers or free-hands systems. In BLE, this topology is optimized for data transfer with devices like fitness trackers and PC peripherals.
- **Broadcast (1:m) -** Broadcast establishes one-to-many connections and is only available in BLE. This topology is optimized for local information sharing, like point-of-interest information, indoor navigation and asset tracking.
- **Mesh (m:n) -** Mesh establishes many-to-many device connections and is only available in BLE. This type of topology is useful when a large number of devices are present and need a trustworthy and safe connection network, like a building with automatic lighting functions or a sensor network. Mesh networks can span a very large physical area. This is particularly useful when a device relies on data from another device that is not in his direct range.

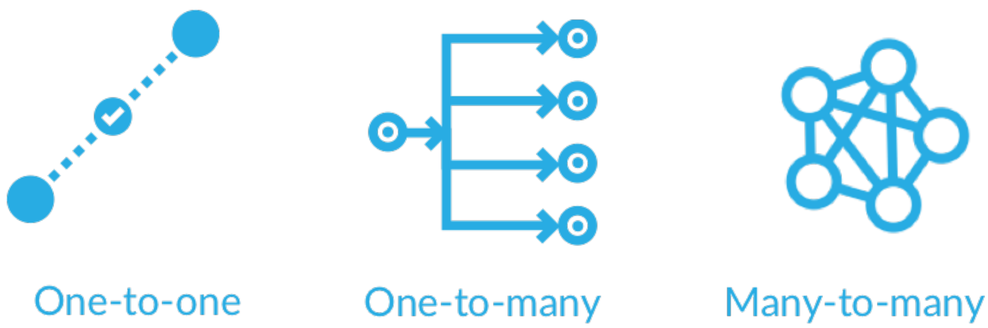

Figure 2.1: BLE Topologies [6]

2.3.2 Comparison

As shown in Table 2.1 blablabla

Table 2.1: Communication Protocol comparison

Technology	Frequency	Max Data Rate	Range	Power Usage	Cost
Cellular (4G)	Cellular Bands	100 Mbps	Several Km	High	High
SigFox	< 1 GHz	< 1 kbps	Several Km	Low	Medium
6LoWPAN	< 1 GHz	250 kbps	100 m	Low	Low
NFC	13.56 MHz	424 kbps	10 cm	Low	Low
ZigBee	2.4 GHz	250 kbps	100 m	Low	Medium
Z-Wave	< 1 GHz	100 kbps	30 m	Low	Medium
WiFi	2.4/5 GHz	54 Mbps	100 m	Medium	Low
BLE	2.4 - 2.48 GHz	2 Mbps	100 m	Low	Low

2.4 Related Work

blablablablabla.

Chapter 3

Developed Work

So far, the developed work has been focused on the player tracking. The extraction of metrics from wearable sensors hasn't been yet tackled.

To address this issue, the research was focused on Pedestrian Dead Reckoning, using Inertial Measurement Units. Dead reckoning is a technique used for estimating an object's position or its trajectory considering their current speed and direction. It is mainly used by marine or air navigation, but recently it has been applied to pedestrians.

Pedestrian Dead Reckoning is based on the usage of accelerometers to detect a step and estimate step-length, and gyroscopes to compute changes in direction. Magnetometers can be also used to determine the orientation according to Earth's North Pole, but this method might fail due to magnetic interferences, as described in Section 2.2.2.3.

There are several proposed algorithms to calculate a subject position using IMUs. Carl Fischer, Poorna Sukumar and Mike Hazas propose an approach to implement a tracker using a Kalman Filter and correcting the velocity using zero-velocity updates. Sebastian Madgwick presents a novel orientation algorithm, that claims to be more accurate than the Kalman based algorithm. Both approaches use a shoe-mounted sensor.

When this work started, the devices were only sending data of the accelerometer sensor. In order to retrieve data from the gyroscope and magnetometer, a special command had to be sent to the device to activate the sensors.

I started to implement the Madgwick algorithm, using the code available publicly in , gathering data from the available sensors. The results were poor, as the path calculated by the algorithm was off by thousands of meters. This could be because of the high frame rate needed by the algorithm (512 HZ = 2ms). At this rate, our sensor skips a high number of samples, loosing essential parts of the data set.

The following step was to try the Tutorial approach. Better results were achieved using this algorithm, but there were still some tweaks to make, and an error associated with the position of the sensor on the foot and its displacement while walking. Initially the sensor was placed below the shoe laces, but we found that the sensor moved while walking, and the position of the sensor was tilted, which introduced a deviation in the results.

Afterwards, the sensor was attached to the foot using 3 small rubber band. While walking, the sensor moved to front and to the right of the right foot. This caused a deviation in the route traced by the algorithm, as shown in the figure.

Chapter 4

Elaboration Proposal

4.1 Elaboration Phases

blablablablabla.

4.2 Elaboration Schedule

blablablablabla.

Bibliography

[1] ETSI. *5G, 5G Specs*. 2019. URL: https://www.etsi.org/technologies/5g (visited on 06/27/2019).

[2] SigFox. *SigFox Technology Overview*. 2019. URL: https://www.sigfox.com/en/sigfox-iot-technology-overview (visited on 06/27/2019).

[3] G. Mulligan. "The 6LowPAN architecture." In: *Proceedings of the 4th Workshop on Embedded Networked Sensors, EmNets 2007*. 2007, pp. 78–82. DOI: 10.1145/1278972.1278992.

[4] E. C. M. Association. *Near Field Communication White Paper*. 2004. URL: https://www.ecma-international.org/activities/Communications/tc32-tg19-2005-012.pdf.

[5] T. Salman and R. Jain. "A Survey of Protocols and Standards for Internet of Things." In: *Advanced Computing and Communications* 1 (2017).

[6] M. Afaneh. *The Ultimate Bluetooth Mesh Tutorial (Part 1)*. 2018. URL: https://www.novelbits.io/bluetooth-mesh-tutorial-part-1/ (visited on 06/27/2019).

2019 **Exploratory Analysis of Individual Metrics in Team Sports Using Inertial Sensors** **David Moura**