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Bachelor in Computer Science

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

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Exploratory Analysis of Individual Metrics in Team Sports Using Inertial Sensors

Lorem ipsum.

Acknowledgements

The acknowledgements. You are free to write this section at your own will. However, usually it starts with the institutional acknowledgements (adviser, institution, grants, workmates, . . .) and then comes the personal acknowledgements (friends, family, . . .).

Abstract

Team Sports like basketball, football and baseball rely on data insights to improve player and team performance, practice scheduling and injury recovery. Recent improvements in data mining and machine learning techniques have encouraged the research of better ways to collect player data.

There are different approaches currently available, using video tracking systems or wearable sensors. The latter systems can be very precise in tracking position outdoors using GPS or indoors using Ultra-Wideband or RFID positioning, they fall short in the analysis of game related metrics, like accelerations and jumps or passes and shoots in the case of Basketball.

This work proposes a solution that can track both position and metrics of players and teams in real-time using inertial sensors, providing the users (e.g. players, coaches) an application with insightful information in order to improve the performance of the individual player and the whole team.

Resumo

Desportos colectivos tais como o basquetebol, futebol ou basebol usam dados para melhorar o desempenho em jogo, o planeamento de treinos e a recuperação de lesões de jogadores e da equipa. O aperfeiçoamento de técnicas como *data mining* e *machine learning* têm levado à pesquisa de formas de recolher mais e melhores dados dos jogadores.

Hoje em dia há várias abordagens diferentes: usando sistemas de captura de video ou utilizando sensores. Esta última abordagem pode ser bastante precisa no posicionamento em exteriores, utilizando sistemas como o GPS, ou em interiores, utilizando sistemas de posicionamento como Ultra-Wideband ou RFID. No entanto, estes sistemas não efetuam o reconhecimento de métricas de jogo como acelerações ou saltos, ou passes e lançamentos no basquetebol

Este trabalho propõe uma solução que visa medir em tempo real o posicionamento de jogadores e da equipa no campo, assim como recolher métricas de jogo, utilizando sensores de inércia. Deste modo, pretende-se fornecer aos utilizadores (e.g. jogadores, treinadores) uma aplicação com informações úteis e detalhadas sobre o desempenho dos jogadores individualmente, e da sua equipa como um todo.

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Listings

Acronyms

BLE	BLuetooth Low Energy
BR/EDR	Basic Rate/Enhanced Data Rate
ECG	Electrocardiography
FIFA	Fédération Internationale de Football Association
GLONASS	GLObal NAvigation Satellite System
GNSS	Global NAvigation Satellite system
GPS	Global Positioning system
IMU	Inertial Measurement Unit
IoT	Internet of Things
KBZ	Knowledgebiz Consulting
MEMS	Micro-electromechanical systems
NBA	National Basketball Association
NFC	Near Field Communication
NFL	National Footbal League
PPG	Photoplethysmogram
RFID	Radio-frequency identification
UWB	Ultra-wideband

Symbols

Introduction

1. Big picture dos desportos e tracking em desportos

2. Falar da monitorização de jogadores com câmaras e sensores

3. Problemas dessas abordagens.

4. Objetivos:

   - Maior precisão em métricas individuais usando wearables

   - Abordagem low-cost com IMUs

   - Solução wearable com processamento local e central, com vários sensores por jogador

   - Métricas a medir

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Related Work

Trabalho relacionado sobre:

1. Algoritmos de tracking de posição usando IMUs

   - Analysis of NBN23 system:
   - Madgwick
   - Carl Fischer

2. Algoritmos de métricas

   - 9 movement recognition with neural networks:

3. Outros trabalhos de métricas de performance (em equipa?)

4. ???Rede de Sensores???

System Proposal

To achieve the goals set in Chapter 1, a system that collects and processes the raw data from the IMU sensors and transforms it into meaningful metrics, storing it, and then presents it in a clear way to the user has to be built.

The proposed architecture is shown in Figure 3.1, and it is comprised of three segments:

1. Edge - Data Collection and Processing

2. Server - Data Storing and Application Server

3. Client - Frontend Application

3.1 Edge

The Edge segment is composed of at least one IMU Sensor and one Raspberry Pi, connected via Bluetooth.

As the number of sensors can grow, and due to the limitation of the number of connections to a Bluetooth receiver, the number of Raspberry Pi's can also grow, in order to establish connection with all the IMU Sensors. This also helps to share the computation of the game metrics between the Raspberry Pi's.

3.1.1 IMU Sensors

The IMU sensors are attached to the players, and their only job is to send accelerometer and gyroscope raw data to the Raspberry Pi they are connected, over Bluetooth.
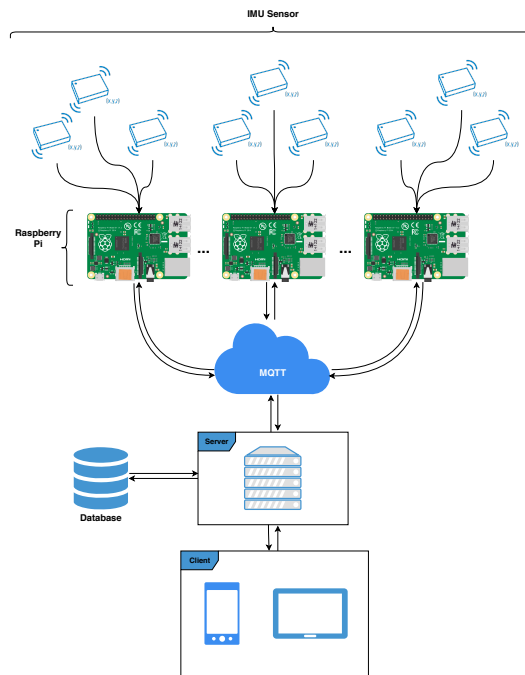
Figure 3.1: Proposed Architecture

3.1.2 Raspberry Pi

In the Raspberry Pi is where the "hard"work is done. Besides connecting and controlling the IMU Sensors, this unit has two main jobs: to collect the raw data sent by the IMU Sensors several times per second, and perform calculations with the gathered data to measure in-game metrics, which are then broadcasted to the server, to be stored and shown to the User.

3.2 Server

The Server is the main piece of the architecture, allowing the interaction between the User and the IMU Sensors.

The Server can broadcast instructions to the Raspberry Pi, controlling the IMU Sensors. When data is received from the Raspberry Pi's, the Server stores it, so that it can be shown to the User.

The Server also hosts the Client Application, where it receives the instructions to be sent to the Edge, and it shows the received data to the User.

3.3 Client

The Client Application provides the User an interface in which he can control the IMU Sensors, and displays the edge-computed in-game metrics.

SYSTEM IMPLEMENTATION

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1. Raspberry Pi

   a) quais os algoritmos

      i. Dribbles

      ii. Saltos

      iii. Passos/Distância/Posição

      iv. Tempo parado/andar/correr

   b) operações sensores

   c) como se controlam os sensores

   d) como são enviados os dados (mqtt)

   e) feito em node

2. Server

   a) REST API feita em Node

   b) DB em mySQL, explicar modelo

   c) como troca mensagens com o rPi

3. Cliente

   a) Feito em React

   b) Permite gerir equipas, jogadores e jogos

   c) métricas por jogo, vários sensores por jogador

aaa ——//——

The description of the System Implementation according to the proposed architecture will be separated in the three segments: Edge, Server and Client.

4.1 Edge

4.1.1 IMU Sensor Control and Communication

The IMU Sensors used in the implementation were developed by AITEX. They communicate through Bluetooth Low Energy and have 3 sensors built-in: 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer.

The following operations are supported by IMU Sensors:

- State control

    - Start Raw Data Collection

    - Stop Raw Data Collection

    - Shutdown

- Sample Rate

- MPU Configuration

The IMU Sensors must pair with a Raspberry Pi, which is searching for the known sensors. After being paired, the operations can be communicated to the IMU Sensors through Bluetooth Notifications.

Before starting the data collection, it is necessary to set the sample rate to 50 Hz (necessary for the metrics algorithms), and to activate the gyroscope and the magnetometer sensor by changing the MPU Configuration. By default only the accelerometer sensor is active.

In order to start collecting data from an IMU Sensor, it is needed to provide information like the MAC Address of the sensor, an identification of the game being played and the player wearing the sensor (because the sensors can be changed from game to game between the players). It is also needed to send the position of the sensor in the player's body, to calculate the metrics, as each algorithm uses data collected from a different part of the body. When the metrics are calculated, they are sent to the server via mqtt, to be stored there. The Raspberry Pi's don't store data, they only server as a vehicle of instructions and data between the server and the sensors.

A single Raspberry Pi is then responsible by maintaining the connection with several IMU Sensors; communicate instructions; receive accelerometer, gyroscope and magnetometer data, and stores it temporarly; depending on the position of the sensor, calculate the according metrics algorithms with the received data; send the calculated metrics to the

4.1.2 Metrics Algorithms

4.1.3 Steps

4.1.4 Dribbles

4.1.5 Jumps

4.2 Server

4.3 Client

The client application was developed in React, with the goal of controlling the IMU Sensors, and manage teams, players and games. It should also display Player and Team game-related metrics.

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Table 5.1: Percentage of data loss (Raspberry Pi 3b+).

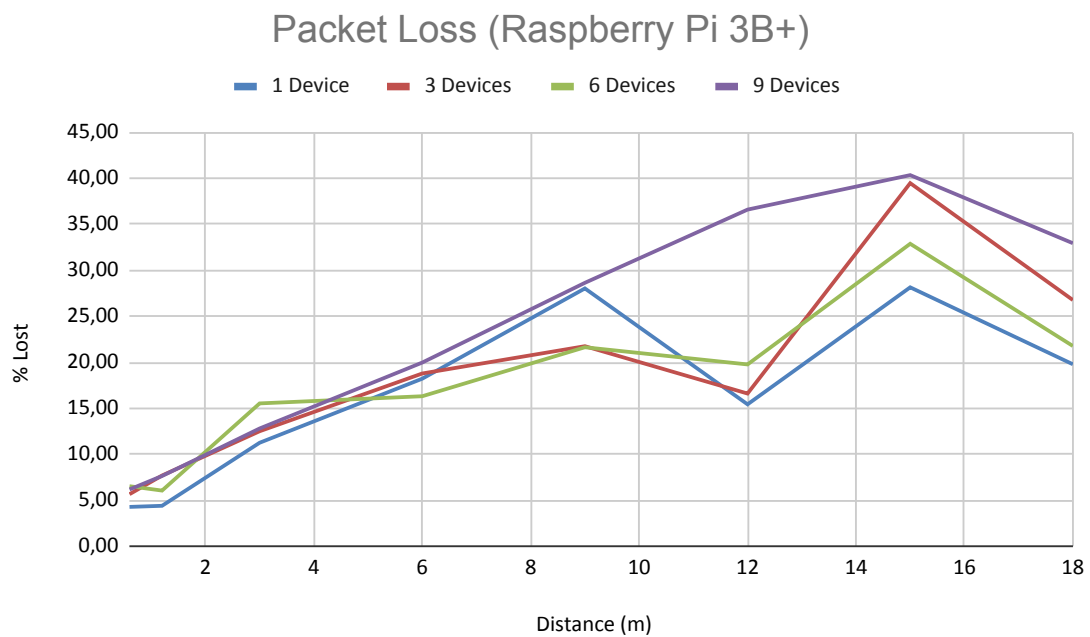|	0,6m	1,2m	3m	6m	9m	12m	15m	18m
1 Device	4,27	4,39	11,25	18,22	28,04	15,43	28,16	19,79
3 Devices	5,65	7,68	12,50	18,79	21,76	16,60	39,50	26,78
6 Devices	6,52	6,05	15,53	16,31	21,64	19,77	32,90	21,78
9 Devices	6,17	7,63	12,80	19,98	28,65	36,62	40,37	32,96

Figure 5.1: Percentage of data loss (Raspberry Pi 3b+)

1. Comunicação - Perda de pacotes IMU -> rPi

   a) raspberry Pi 3b+

   b) raspberry Pi 4

2. Fiabilidade dos algoritmos

   a) Dribbles

   b) Saltos

   c) Passos/Distância

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FUTURE WORK

CONCLUSIONS