Device Validation to Monitor Speed in High Performance Roller Skaters Through the Internet of Things (IoT)

Paula-Andrea Wilches-Castellanos[1,2],
Daniel-Alejandro Quiroga-Torres[1](✉),
Pedro-Antonio Aya-Parra[1], and Jefferson Sarmiento-Rojas[1]

[1] School of Medicine and Health Sciences, Universidad del Rosario, GiBiome Research Group, Bogotá, Colombia
Daniel.quiroga@urosario.edu.co
[2] Biomedical Engineering Department, Escuela Colombiana de Ingeniería Julio Garavito, Bogotá, Colombia

Abstract. Internet of things technology has grown in recent years. One of the sectors where it has had the greatest reception is sports. In Colombia, for every 61 high-performance athletes there is, on average, one coach. For this reason, the purpose of this work was to validate an intelligent device that enables remote monitoring of the speed of high-performance roller skaters using the Internet of things. The authors equipped professional Luigino skates with electronic instrumentation, with which it was possible to measure a high-performance skater's linear speed and distance traveled of by means of Hall effect sensors and a magnet. To eliminate false measurements, a distance sensor was also installed in the skate skids to determine when the skate was in contact with the ground. This information was sent to the Internet through the MQTT protocol to a main broker that was responsible for the processing and visualization of the data. The linear velocity was validated at four speeds (0.8, 5, 8 and 10 km/h) using a treadmill. The error of the measurements was between 1% and 5%.

Keywords: Internet of Things · Monitoring · Roller skater · Sports

1 Introduction

Currently, the application area of Internet of things (IoT) technology has expanded to include different sectors, such as the industrial sector and the health sector. The technology has been implemented at different scales, for example, the implementation of IoT in cities, smart homes and portable devices [1]. According to a GSMA report, by 2025 about 25.2 billion devices worldwide are expected to be interconnected via the IoT [2]. On the other hand, according to Frost & Sullivan, in Colombia it is expected that between 2017 and 2022 the annual income rate of IoT technologies will grow by 20.8% and will reach $523.7 million dollars; the growth opportunity focuses on improving productivity and innovation [3].

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In recent years, one of the areas that has implemented IoT has been sports. Countries such as China have experienced an 84% increase in this industry between 2009 and 2014 [4]. At the global level in sports, IoT has focused on monitoring vital signs, recordings about electrical activity at the body and physiological variables such as pulse, temperature, blood pressure, electrocardiogram, electromyogram, oxygen saturation and intensity and duration of activities. These IoT advances have focused on professional and non-professional athletes [5].

According to data from the observatory of Coldeportes (Colombia), in 2016 a total of 94,020 athletes and 1,533 sports trainers were affiliated with different federations, resulting in a ratio of approximately 61 athletes to one coach [6]. This difference can negatively affect the performance of athletes, since the athlete is not in constant supervision. For this reason, one of the biggest problems in Colombian sport is the relationship between athletes and coaches. Other issue is the lack of optimal training monitoring. Today there are devices that allow for the measurement and monitoring of physical parameters such as heart rate, respiratory rate, calories burned et cetera, but these devices have high costs.

On the other hand, in the field of biomedical engineering, sports-related technologies are being developed. These technologies can be used to record physical variables, such as heart rate [7]; analyze sports gestures [8–10]; and provide support in monitoring and training the athlete [11, 12]. Different investigations have also been carried out on the speed of skaters and the importance of this variable to his or her sport [13–15]. In view of the foregoing, the aim of this research was to build and validate a device that enables one to monitor the speed of a high-performance roller skater remotely using IoT.

2 Materials and Methods

The solution had two stages. First, the instrumentation of the roller skates was carried out to calculate the speed and distance traveled by the professional roller skater (see Fig. 1A). The second stage was the visualization of the data acquired from the athlete on a web page (see Fig. 1B). The coach could use this data visualization to monitor the athlete from anywhere in the world.

2.1 Skates Instrumentation

In this study, the Hall effect sensor A1302 was used to calculate the linear velocity of the skater (see Eq. 1). To obtain this measurement, a neodymium magnet was installed on the rear wheel of the skate with its south pole pointing up towards the sensor. The sensor was located on the chassis with its front face facing the rim (see Fig. 2A).

$$Velocity = 2\,\pi\,frequency\;radius \tag{1}$$

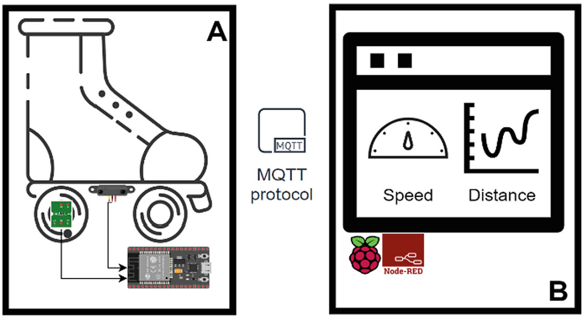

Fig. 1. Block diagram of the solution

A distance measurement was necessary, since analysis of the skater's movement demonstrated that the athlete does not keep his or her foot on the floor surface at all times. When the foot is lifted, the wheel is still rotating, but this rotation no longer represents the speed of the athlete. A distance sensor was used to identify the moment at which the skate was no longer in contact with the floor; the Hall effect sensor data was disregarded at this time. The sensor used for the measurement was the Sharp GP2Y0A21YK0F, which was located on the inner part of the skate on the upper part of the chassis, as displayed in Fig. 2B. Each time the distance sensor indicated less than the determined threshold, the rotation was recorded as 0 revolutions per minute by the algorithm.

Fig. 2. Mount sensors on the skate.

The Fire-Beetle ESP32 card from DFROBOT was used to send the information acquired by the sensors and enabled the transmission of the data via a Wi-Fi connection and the Message Queuing Telemetry Transport (MQTT) protocol.

2.2 Data Visualization

The visualization and data treatment were developed using the Node-RED platform developed by IBM to connect hardware devices, Application Programming Interfaces (APIs) and online services graphically by means of flows and nodes. This platform was installed on a Raspberry Pi B, which received the data using the MQTT protocol and graphed the information on a web page in real time.

2.3 Solution Validation

For the linear speed data validation, a Life Fitness Flexdeck treadmill was used. The validation test consisted of placing the skate on the treadmill without inclination at a constant speed for a period of 10 min (see Fig. 3). The data was sent every time a change in the Hall effect sensor was detected. Four different speeds were programmed on the treadmill (0.8 km/h, 5 km/h, 8 km/h and 10 km/h). After the measurements, the descriptive statistics were determined and the average error of the data was calculated. Statistical tests were performed with the IBM SPSS Statics V 25 software.

Fig. 3. Experimental setup for speed validation

3 Results

Table 1 presents the descriptive statistics for each of the speeds programmed on the treadmill and found in each of the data packages acquired in the Raspberry Pi B+.

Table 1. Descriptive Statistics Programmed Speeds

Programmed speed (km/h)	n	Mean (km/h)	Median (km/h)	Standard deviation (km/h)	Kolmogorov Smirnov pValue
0.8	240	0.7765	0.7752	0.0311	0.00
5	1468	4.8378	4.7752	0.1675	0.00
8	2528	7.7546	7.9002	0.3023	0.00
10	1428	8.829	9.4248	2.0160	0.00

From these data, the average error percentage of each of the measurements was found. The value programmed on the treadmill was taken as the real value, and the median value recorded at each of the speeds was taken as the experimental value. The results are displayed in Table 2.

Table 2. Error in measurements

Real speed (km/h)	Speed measure (km/h)	Error rate (%)
0.8	0.7752	3.1
5	4.7752	4.5
8	7.9002	1.2
10	9.4248	5.8

4 Conclusions

It can be seen that the errors are less than 6% for all of the programmed speeds; this may be due to the speed response of the Hall effect sensor chosen for this prototype. The median was the measure that best described the data, since the set of records was not normal, as can be seen in the results of the Kolmogorov-Smirnov statistical test.

It was found that the implemented device facilitated the remote monitoring of the linear speed of a high-performance skater using the Internet of things. This type of application was proven to be an alternative for coaches because it reliably enables remote monitoring of activities and exercises of athletes.

Conflict of interest. The authors report no conflicts of interest.

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