Monitoring Children and Elderly Using a WBAN

Felipe Thamay
State University of Paraíba
Nucleus of Strategic Technology in Health – NUTES
Campina Grande, Brazil
Email: felipethamay [AT] hotmail.com

Misael Elias de Morais
State University of Paraíba
Nucleus of Strategic Technology in Health – NUTES
Campina Grande, Brazil

Abstract - **Technologies using wireless data transmission are becoming increasingly popular, and the wireless body area network, allied directly to the wireless sensor network, has been studied and implemented by many researchers and industry. Monitoring of children and the elderly has been one of the main focuses in studies related to the injuries suffered by them, in the home environment. In this perspective, the system assists the person in charge of monitoring the child from 0 to 6 years old and the elderly, showing, through an application installed in the smartphone of the responsible, eventual falls in the elderly, excessive distances of the child and the ambient temperature, as well as other configurations application and sensors used. Therefore, the smartphone application will be notified, assisting in the decision making of the parents or guardians.**

Keywords-Embedded Device; Fall detection and prediction; Minimally Invasive Sensors; Vigilance.

I. INTRODUCTION

The development of Science and Technology (electronics and computer science) in the twentieth century contributed to an accelerated evolution of medical equipment. As stated [1], the evolution of sensors for medical applications paved the way for dozens of health-related devices applied to patient monitoring.

The research in the field of wireless sensor networks led the IEEE to form a working group specifically for this area of technology, the IEEE 802.15.6 standard, specifically aimed at the Wireless Body Area Network, aiming to provide a standard international low-power, short-range, and extremely reliable wireless communication within or outside the human body [2].

Wireless sensor networks consist of one or more distributed nodes, implemented to collect information about parameters of interest using the respective sensors (eg temperature, acceleration, light, humidity). According to [3], a sensor node can be formed by a radio transmitter, a battery and a processor.

Researches [4] show that the advancement of these technologies is directly related to IOT. This trend can be defined as the communication between electronic devices, that is, it allows sensors to collect and exchange data through an existing network infrastructure.

In the business area, remote monitoring by means of embedded devices increases efficiency, saving time and consequently reducing expenses, making a full-time professional available. One of its features is the ability to send an alert at any time of the day, with relevant information such as intrusion alert or even turning off an equipment.

In the health segment, it can assist in the monitoring of the vital signs of the human body, that is, it monitors the physiological parameters, regardless of where the person is, whether in the hospital, at home or on the street [5].

These sensors can also be wearable, that is, they can be attached to an individual's clothing or accessory. MetaDetector was developed by Mbientlab, to be fixed on any clothing / fabric and thus be programmed to interact with the user's movements or the surrounding environment [6].

A study of [7], performed with the elderly, aged from 60 years, presented a number of reports of femoral fractures and their consequences: number of hospitalizations; proportion of hospitalizations and hospitalization rate, in the city of João Pessoa - PB, from 2008 to 2012. The study pointed out that 1,200 fracture procedures were performed by the SUS, of which 687 were in the elderly.

Data such as this are alarming, given that the elderly who have suffered traumatic injury, have mostly loss of autonomy and increased dependency, thereby increasing the care of family members while hospitalized [8].

In this perspective, we propose the development of a prototype of a monitoring system for children and the elderly, called "Weartool". His proposal is to monitor the movement of the child and the elderly, in order to identify falls in the elderly, possible places that could endanger the child, monitor the distance of the child and the ambient temperature.

This work will be divided as follows: 1. Introduction, 2. Overview, 3. System prototype architecture, 4. Partial results, 5. Acknowledgments and finally References.

II. OVERVIEW

A. Health field

An injury is described as an impact (physical force) that is transferred to an individual. Every injury is characterized as Injury Mechanism. Recent research by [9] describes that the circumstances that caused a certain injury, fractures and injuries of internal organs, is considered an injury.

The fall can be defined as an unintentional action of the body at a lower level in initial relation, where it is unable to correct its initial position in a timely manner, thus compromising its stability [10].

[11] states that falling in the elderly is a frequent situation with considerable physical, psychological and social consequences. One of the main consequences of falls is the fracture, where it causes the elderly greater vulnerability and new situations, leaving the same fragile and insecure due to the trauma that occurred.

Fracture of the Proximal Femur in the elderly causes a great functional incapacity, impairing the quality of life of the same. In studies [12], it shows that only 25% of the patients who have undergone FFP recover completely and the others may present symptoms resulting from the fracture, such as pain, swelling, difficulty climbing stairs, difficulty in walking. In the period from October 2005 to October 2006, there were 27,647 FFP cases, according to the survey.

Traumatic Brain Injury occurs when an external force strikes the head due to sudden acceleration or deceleration or sudden impact resulting in fracture of the skull, internal bleeding, loss of consciousness for more than an hour, or a combination of these factors. With this, affecting some aspects of the individual's life, such as personality. Because the brain lesions do not heal like other lesions, their recovery is functionally [13].

Studies [14] treat traumatic brain injury as a lesion around the scalp, skull and brain, caused after a closed or penetrating injury to the brain structures, causing cranial fractures and damage to the brain tissue.

B. Field of technology

The Internet of Things is a new built paradigm in which it demonstrates the ability to communicate electronic devices over the internet through specific protocols. With this, IoT provides a broad vision where a network of smart things, uniquely identified with devices such as sensors attached, anywhere, on any device, working together to deliver a variety of on-demand services to customers (FORTINO, TRUNFI, 2014). In the medical field, specific sensors can also be equipped within environments to monitor the health and well-being of patients, or even be wearable, also ensuring that appropriate treatment is being administered correctly [15].

With the evolution of this paradigm, allied directly to the development of connected wireless sensors, the IEEE has established a working standard called IEEE 802.15.6 for WBAN standardization. With this, creating an international standard for low power devices with maximum reliability.

One of the technologies of data transfer used by the sensors is Bluetooth. It allows the exchange of data quickly and safely, between equipment that has the same technology. This in turn has been evolving since its inception, to meet the demands of the market. Bluetooth 4.0 is one of the most recent and most used technologies, starting its commercialization from the year 2010 [16]. Some of the characteristics of this new technology is the high speed, and can reach up to 1MB per second; low battery consumption, increasing even more when the device is idle; high security, with the new 128-bit encryption protocol and the range extension, which went from 9 to 61 meters.

Mbientlab [6] is a company offering low-power Bluetooth wireless sensor solutions. These sensors are ideal for eHealth, fitness, commercial, industrial, educational and portable applications. They are focused on prototyping, product research and development and include measurement of heart rate, temperature and galvanic response of the skin.

Research conducted [17] indicates that 89.5% of smartphone users in Brazil use the Android operating system. Later comes Windows Phone with 5.9% and iOS with only 3.5%. So, Android becomes a national trend.

A wireless body area network requires that the data collected have high reliability and security, since most are private data and confidences. For this, cryptographic mechanisms must be adopted to guarantee the integrity and reliability of the information, since this information will travel through a wireless medium until reaching its destination [18].

The MD5 hash function is used as a means of data security in software. It is unidirectional, that is, once encrypted it can not be transformed back into the initial text. It works with 128-bit encryption, where it is widely used in software that uses peer-to-peer (P2P) communication, file integrity checking, and user input. It was developed by the company RSA Data Security in 1991, where the name derives from its founders, Ron Rive-st, Adi Shamir and Len Adleman. The MD5 function succeeded the MD4 because it had some security problems [19].

The inertial measurement unit is a device that measures and reports the specific force and angular rate that in a body. They are widely used in equipment requiring knowledge of their exact position. It is implemented using one or more accelerometers for detection of linear acceleration and one or more gyroscopes for measuring the rate of rotation [20].

III. SYSTEM ARCHITECTURE

The main system architecture is generic. Our prototype is implemented as shown in Figure 1 and Figure 2, which shows the system architecture with the main interfaces. The sensors can be coupled to the clothing and environment, providing the sensors with the need.

MetaDetector (Figure 3) is the embedded device used, where the various sensors are available. It is a low power technology where it uses a CR2032 battery, Bluetooth 4.0 (2.4Ghz), an ARM® Cortex®-M0 MCU processor, 256kB flash memory, 32kB RAM, a temperature sensor, a light sensor, a proximity sensor and motion sensor (accelerometer and 3-axis gyroscope).

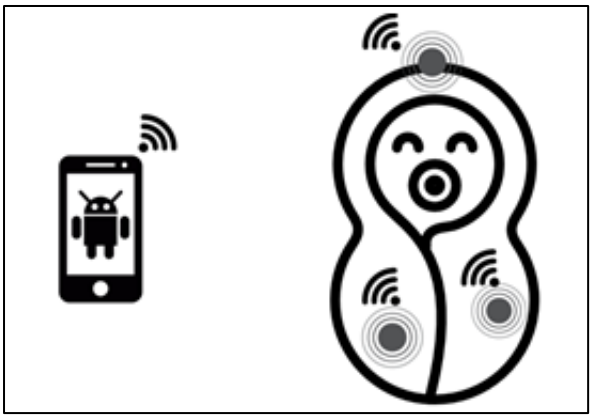


Figure 1. Generic scheme of the system

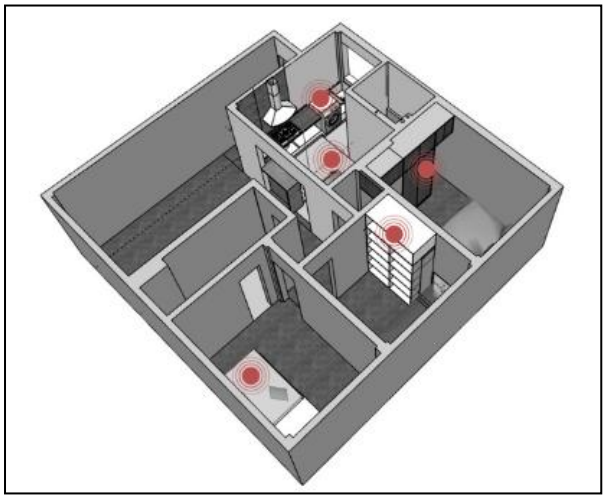


Figure 2. Disposition of devices in domestic environment.

Figure 3. Embedded device MetaDetector.

A. *Application*

The "WEARTOOL" application (Figure 4) will make full control of the sensors where they have sent information about the movement of the child and the elderly, ambient temperature, approximate location and other functions relevant to the configuration of the application and sensors.

Figure 4. Application WEARTOOL

Diagram 1 shows, through the use case, how the sensors connected to the application will be used. The responsible for the child or the elderly, will monitor the fall and distance, through notifications generated on the smartphone and can also be checked at room temperature in real time. The sensor will be attached to the laundry, where the sensor, if you feel a dangerous situation, can press the button of the sensor, where it will issue a notification.

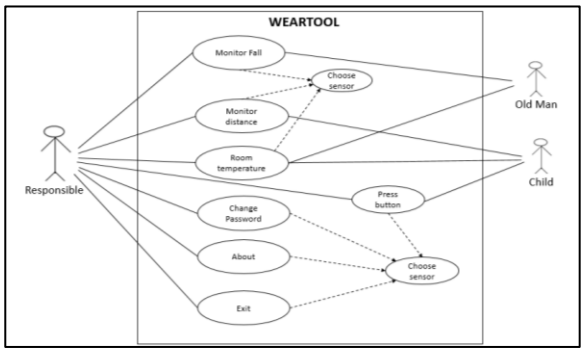


Diagram 1. Use case.

A.1 Monitor Fall

In the first situation, when a de facto fall occurs, the application will immediately send a notification. Fall monitoring will evaluate the behavior of the elderly, where the app will decide in which situations a notification will be issued.

This will be done through the accelerometer and gyro sensors, where the orientation of the segments of the human body is measured by an inertial measurement unit.

A.2 Track Distance

The distance monitoring feature will be done by iBeacon, returning the approximate distance between the sensor and the smartphone. In the application screen, it will indicate the distance in meters and the signal strength.

Another feature is the monitoring button. This button is attached to the sensor, where the child, upon feeling need, will press the button, generating a notification in the application, alerting those responsible that the child is needing to be located.

A.3 Room temperature

The ambient temperature gauging function, ie, local temperature, is used to check the temperature at which the sensor is located, serving in cases where a constant temperature has to be checked and maintained for the child's comfort and well-being or old man.

In this case, the sensor will be arranged in the environment in which the calibration will be done.

A.4 Settings

In the application settings screen we will have information about the sensor: Manufacturer, Model, Serial Number, Firmware, Hardware and MAC. We will have the option to update the sensor firmware, check the sensor led, where it is available in red, green and blue. We can also check RSSI. that is, the strength of the received signal in relation to the sensor and the application. And we can also check the battery level of the sensor.

A.5 Security

MD5 is a 128-bit unidirectional cryptographic hash function developed by RSA Data Security, Inc. The Algorithm works as follows: It receives a String variable and calculates the MD5 Hash (MessageDigest.getInstance ("MD5")). After that, we will have an encrypted 32-bit array, which will be stored in the database. When the user writes the password to connect to the sensors, it will be compared to the resultant hash recorded in the database, and then the connection will be made between the app and the sensor.

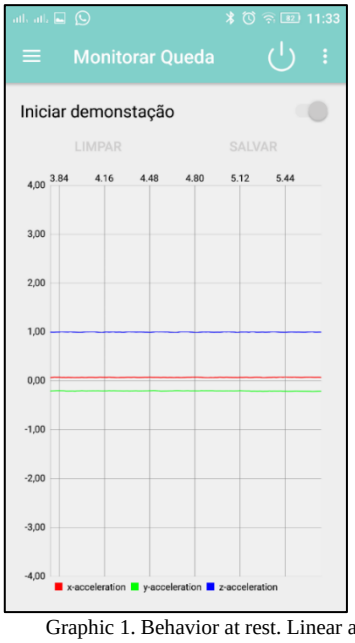
IV. PARCIAL RESULTS

Tests were performed simulating a fall using the device. In accelerometer graphs for falling in the elderly, it is expected that there will be a variation of the acceleration in the form of a peak, followed by a decrease that tends to zero, since after the fall, the tendency is for the elderly person to stay for a few moments on the ground (rest , a = 0 m / s 2).

In a 3-dimensional accelerometer, the X, Y, and Z curves must obey a degree of synchrony, since an elderly body is not an ideal mass object, which can be neglected in a rotational / vibrational motion. Regardless of the type of fall, there are variations in the 3 axes. Therefore, where the highest harmony of the three axes can be observed, it is the greatest possibility of the fall register.

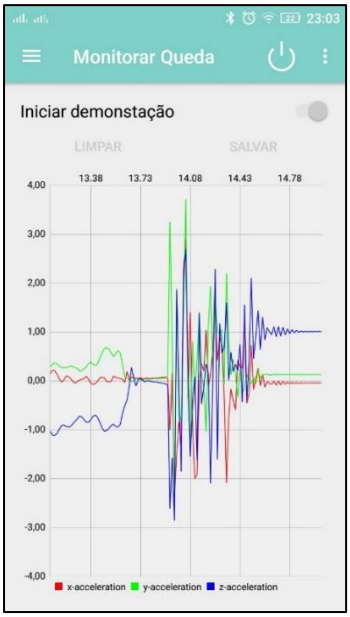
Physically, when it comes to gravity, the acceleration varies on the y-axis, but if the elderly falls, necessarily, the acceleration variation has to be more intense on the axis of gravity. In the preliminary graphs, the z axis behaves like axis of gravity, since the most intense variation (peak) is in z.

Graph 1 shows the child's resting behavior, showing a linearity between the x, y and z axes. This graphic can be taken as a reference in the identification of the movement.



Graphic 1. Behavior at rest. Linear axes.

Graph 2 shows the drop down where it is observed that from the beginning of the graph up to the interval of 13.73s, there are slight variations of acceleration, when the child was in random motion (walking). Then, from 13.73s to approximately 14s, there is a variation of this movement, it is the one that precedes / causes the fall.



Graphic 2. Fall down.

From 14s to 14.43s, there is a large variation in the x, y and z axes followed by a tendency to rest (from 14.5s onwards). These central points of the graph where there is the greatest variation of acceleration in the 3 axes, configure the fall.

Regarding the monitoring of the distance of the child, tests of the signal range were done, having an efficiency up to 50m in free field and 15m with barrier, thus covering relatively considerable areas for monitoring. Figure 5 represents the maximum distance of 50m, where it had -93 dBm, the equivalent of 19% RSSI. The minimum observed distance was 50cm with -46dBm, equivalent to 61% of RSSI.

In figure 3, it shows the temperature of the location where the sensor is located. It is possible to see the linearity of the graph, since the test was done in an air-conditioned environment, with an exact temperature of 23ºc, figure 7, to verify the efficiency of the temperature sensor used.

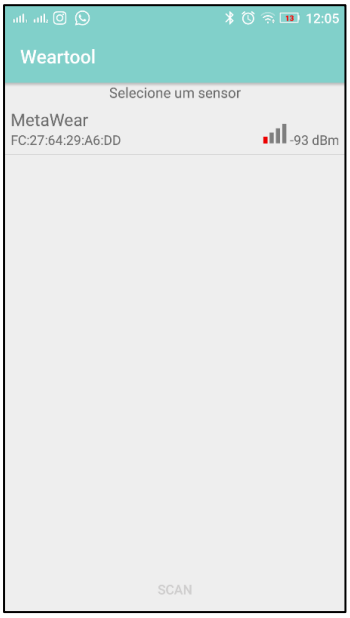


Figure 5. Maximum distance from sensor to smartphone.

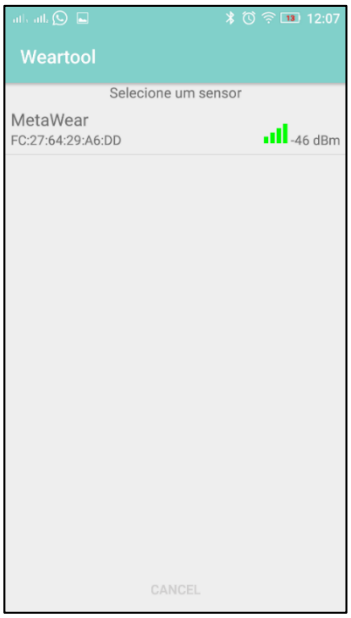
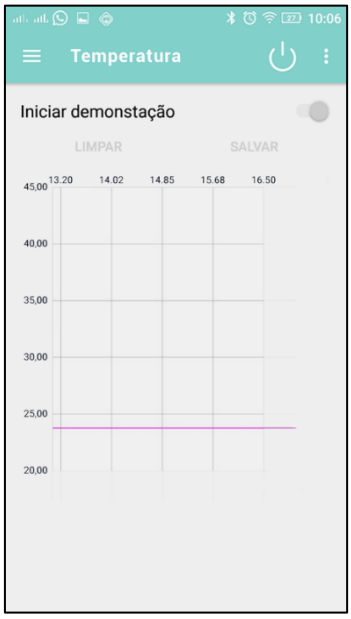


Figure 6. Minimum distance from sensor to smartphone.

Figure 7. Local temperature indicator.



Graphic 3. Room temperature.

V. CONCLUSIONS AND FUTURE WORK

Different fall patterns were characterized and modeled using the accelerometer and gyroscope sensors of 3 axes, based on IMU, where the signals obtained from the movements were processed and analyzed by a SoC.

Analyzing the data by means of the graphs obtained from the possible falls, we can see the variation of the graph in the x, y and z axes. With this we evaluate the falls as intermediate level those that were between -3 and 3 in the z axis of gravity, and serious to very serious ones that are above this range.

Regarding the monitoring of the child's distance, signal range tests were performed, having an efficiency of up to 50 meters in free field and 15 meters with a barrier, thus covering relatively considerable areas for monitoring.

The verification of the ambient temperature was also verified because the tests were done in air conditioned environments, thus being able to verify the effectiveness of the sensor.

Subsequently, in the definitive results, it will be necessary to take reference graphs, with larger intervals, established parameters and definition of axes. It is necessary to identify how the graphs of random movements manifest themselves with none, little or much variation of acceleration to have a greater security in the analysis of the data.

VI. ACKNOWLEDGE

This article is the result of the WBAN Networks project for health and wellness. We would like to thank the State University of Paraíba - UEPB and the Nucleus of strategic technologies in health - NUTES.

REFERENCES

[1] AMEEN, Moshaddique Al; KWAK, Kyung-sup. Social Issues in Wireless Sensor Networks with Healthcare Perspective. The International Arab Journal Of Information Technology, Jordânia, v. 8, n. 1, p.52-58, jan. 2011.

[2] KWAK, Kyung Sup; ULLAH, Sana; ULLAH, Niamat. An overview of IEEE 802.15.6 standard. 2010 3rd International Symposium On Applied Sciences In Biomedical And Communication Technologies (isabel 2010), [s.l.], p.1-6, nov. 2010. IEEE. http://dx.doi.org/10.1109/isabel.2010.5702867.

[3] CHEN, Meng; LI, Zhi; ZHANG, Guanglie. A cooperative software-hardware approach for wireless body area network implementation. The 4th Annual Ieee International Conference On Cyber Technology In Automation, Control And Intelligent, [s.l.], p.214-218, jun. 2014. IEEE. http://dx.doi.org/10.1109/cyber.2014.6917463.

[4] FORTINO, Giancarlo; TRUNFIO, Paolo. Internet of Things Based on Smart Objects: Technology, Middleware and Applications. Switzerland: Springer Science & Business Media, 2014. 198 p.

[5] SANGARI, A. Siva; LEO, J. Martin. Polynomial based light weight security in wireless body area network. 2015 Ieee 9th International Conference On Intelligent Systems And Control (isco), [s.l.], p.1-5, jan. 2015. IEEE. http://dx.doi.org/10.1109/isco.2015.7282331.

[6] MBIENTLAB. MBIENTLAB. 2016. Disponível em: <https://mbientlab.com/>. Access in: 05 nov. 2016.

[7] MOREIRA, Sérgio Augusto Paredes et al. Notifications of femur fractures in an elderly northeastern capital: in the years 2008 to 2012 Notificações de fraturas do fêmur em idosos de uma capital nordestina. Revista de Pesquisa: Cuidado é Fundamental Online, [s.l.], v. 7, n. 5, p.182-189, 30 dez. 2015. Universidade Federal do Estado do Rio de Janeiro UNIRIO. http://dx.doi.org/10.9789/2175-5361.2015.v7i5.182-188.

[8] LANDIM, Ana Caroline Fonseca et al. Assistência de enfermagem a idosos com traumas ósseos: uma revisão integrativa. Revista de Pesquisa: Cuidado é Fundamental Online, Rio de Janeiro, v. 1, n. 1, p.2083-2103, mar. 2015.

[9] SAMUEL, Nir et al. Falls in young children with minor head injury: A prospective analysis of injury mechanisms. Brain Injury, [s.l.], v. 29, n. 7-8, p.946-950, 8 maio 2015. Informa Healthcare. http://dx.doi.org/10.3109/02699052.2015.1017005.

[10] FREITAS, Ronaldo de et al. Cuidado de enfermagem para prevenção de quedas em idosos: proposta para ação. Revista Brasileira de Enfermagem: REBEN, Brasilia, p.478-485, jun. 2011.

[11] MAIA, Bruna Carla et al. Consequências das quedas em idosos vivendo na comunidade. Revista Brasileira de Geriatria e Gerontologia, [s.l.], v. 14, n. 2, p.381-393, jun. 2011. FapUNIFESP (SciELO). http://dx.doi.org/10.1590/s1809-98232011000200017.

[12] ARIYOSHI, Anne France. Características epidemiológicas das fraturas do fêmur proximal tratadas na Santa Casa de Misericórdia de Batatais - SP. 2013. 87 f. Dissertação (Mestrado) - Curso de Saúde na Comunidade, Faculdade de Medicina de Ribeirão Preto, Ribeirão Preto, 2013.

[13] CARLI, Pierre; ORLIAGUET, Gilles. Severe traumatic brain injury in children. The Lancet, [s.l.], v. 363, n. 9409, p.584-585, fev. 2004. Elsevier BV. http://dx.doi.org/10.1016/s0140-6736(04)15626-2.

[14] HUDDLESTON, Sandra Smith; FERGUSON, Sondra G.. Emergências Clínicas: Abordagens, Intervenções e Auto-Avaliação. Florianópolis: Guanabarra Koogan, 2006.

[15] ISTEPANIAN, R. S. H. et al. The potential of Internet of m-health Things "m-IoT" for non-invasive glucose level sensing. 2011 Annual International Conference Of The Ieee Engineering In Medicine And Biology Society, [s.l.], p.5264-5266, ago. 2011. IEEE. http://dx.doi.org/10.1109/iembs.2011.6091302.

[16] Bluetooth. Bluetooth Low Energy. Disponível em: <https://www.bluetooth.com/>. Access in: 19 may 2017.

[17] KANTAR. No Brasil há mais smartphones com sistema Windows do que iOS. 2015. Disponível em: <http://www.kantarworldpanel.com/br/Releases/Existem-mais-smartphones-com-Windows-do-que-iPhones-no-Brasi>. Access in: 10 oct. 2016.

[18] LÓPEZ, J. A. C.; PINO, F. Modelo para la evaluación en seguridad informática a productos de software, basado en el estándar ISO/IEC 15408 Common Criteria. Revista S&t, Cali, v. 19, n. 9, p.69-92, 2011.

[19] RIVEST, R. The MD5 Message-Digest Algorithm, Network Working Group, 1992.

[20] TESSENDORF, Bernd et al. An IMU-based sensor network to continuously monitor rowing technique on the water. 2011 Seventh International Conference On Intelligent Sensors, Sensor Networks And Information Processing, [s.l.], p.1-6, dez. 2011. IEEE.