Analysis of a person of walk through their movement

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***Abstract*— An application was developed for the Android operating system that makes use of the accelerometer of a cell phone in order to measure the amount of movement of feet of people when walking, as well as symmetry and homogeneity. The results obtained from one person are shown; although the system was applied to 24 actors. The mathematical operations demonstrate their worth and simplicity for mediation of the signals, without being intrusive and with the advantage of being able to apply to different fields of research or medicine.**

Keywords—* *Android, Accelerometer, Authentication, Amount of Movement

I. Introduction

The gait of a person can be analyzed by biometrics [1]. Therefore it is important where the sensor is placed. In this case, the cell phone was placed in the ankles of the people [2].

As in [3] a computer application for mobile was developed; where, the gait analysis was implemented using statistical techniques [4]; and methods such as Markov models or chains [5], which in the present case consisted of the application of a particular case known as DTW (Dynamic Time Warping); In addition, this article takes advantage of the three-dimensional characteristics of the acceleration signal of the march [6] [7] measured with the accelerometer of cell phone. You can opt for the use of Wavelets [8], but it would overload the cell phone; So it was preferred to divide the signal into cycles and perform the low algorithm in the Android operating system. Thus the technique consumes fewer resources and uses the amount of movement, homogeneity and symmetry.

Some techniques for gait recognition employ computer vision [9]; but for this analysis, the use of a conveniently located camera is needed, which may be invasive to the space surrounding the individual. The use of a cell phone only requires the use of a bra placed on the ankle and can be used practically for hours, without causing inconvenience to the user.

The work developed can generate future techniques for human identification as in [10] [11]; Regardless of whether the march is slow or fast [12] [13].

The sensors of a cell phone were used; with which, the amount of movement and some other characteristics of the walking style of people, or the state of stress of a population or workplace [15] [16] is measured.

II. Development

In the case of foot movement, the following characteristics must be observed [15,16]:

- Kinetic Energy: The global energy spent by the user during the movement of his legs.
- Smoothness and Fluency: Smooth movements are characterized by the generation of large circles in the movement, medium speed and without sudden changes in acceleration
- Direction: The direction of the velocity or acceleration vector can be determined. A direct movement is characterized by almost rectilinear trajectories.
- Periodicity. The repetition of metrics in time intervals.
- Impulsivity. Unexpected reaction and therefore a sharp increase in acceleration.

Homogeneity, symmetry and amount of movement of legs of a person were obtained [17], by measuring the acceleration using a cell phone:

The accelerometer and the linear acceleration sensor are used to detect movement; These have some differences between them, which make it preferable to use any of them depending on the situation. The accelerometer provides data in m / s^2, that are received by the sensor for the X, Y, and Z axes. There is also linear acceleration through a synthetic sensor that performs data processing to deliver them to the application. See figures 1 and 2.

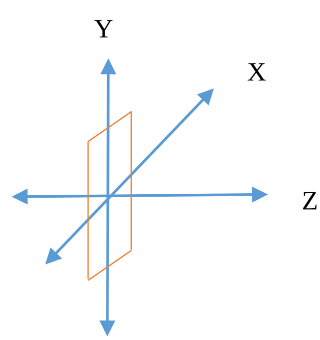

Fig. 1. Fig. 1. Cartesian system for cell movement registration.

A. Mobile app

The interface of Figure 2, has the option to select which of the two acceleration sensors will be used to make the measurements; there is a checkbox that enables or disables the use of the high pass filter, which is used to reduce the noise generated by the constant of the force of gravity, which is exerted on the device and that affects the measurements. Both sensors provide the acceleration data on the X, Y and Z axes, both the magnitude and the direction.

There is a graphic area that allows visual display of the data generated from motion detection, although it is worth mentioning that it does not affect the measurement of the data in any way.

The information received from the sensors (the data of the X, Y, Z axes) is stored in a CSV file (comma-separated values) in the application cache.

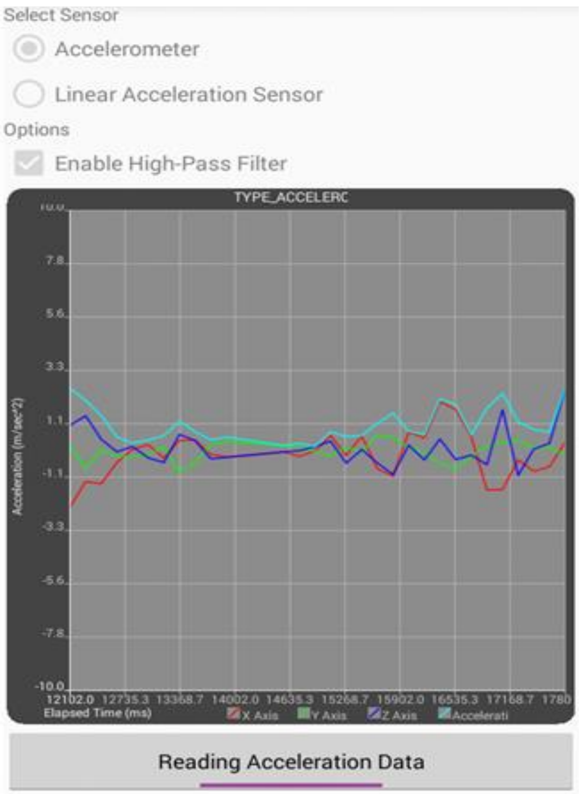

Fig. 2. Motion Sensor Application Interface.

Once the button was pressed to finish reading the data, a menu opens that allows saving the information generated in the file with CSV extension. The default name that appears to save the file is made up of a prefix that represents the selected sensor (Acc "Accelerometer" and LAcc "Linear Accelerometer") corresponding to the accelerometer and linear accelerometer; The date and time at which the test was recorded and carried out are also stored.

B. Position

The position of the accelerometer is essential to obtain a good measurement; so it can be placed in the pants pocket as in [18]; but it complicates the measurement since the magnitude is significantly affected, as its intensity decreases, which complicates an analysis; for example, when climbing or descending stairs as explained in [19]; Another option is to place it on the waist [20]; however, the results are not good [21]. Thus, as in [22], it was decided to use it on the ankle, obtaining data with greater magnitude for its analysis.

C. Input Data

The acceleration of the three orthogonal axes X, Y, Z is measured, using the accelerometer as a sensor.

Each record in the file stores by columns the data a_X, a_Y, and a_Z, the date and the moment in which the values were obtained.

Where [5]:

- the a_X is the horizontal acceleration (X-axis) with positive values to the right.
- a_Y is the vertical acceleration (Y-axis) with positive values up.
- a_Z is the acceleration on the Z-axis with positive values in front of the screen.

The data of the X and Y axes are the most used since they are more related to walking cycles; Two files were generated, one for each foot of the people tested.

D. Relevant Features

Fundamentally important characteristics to observe in the gait of the people are homogeneity and symmetry [23].

To calculate each of the characteristics, the signal obtained in cycles is separated and the value of the highest peaks in each cycle is taken to reference the calculation of the characteristics.

E. Homogeneity

Homogeneity ($\mathcal{H}$) indicates how similar or different a step is to another; $\mathcal{H}$ can take values between 0 and 1. For the present case, homogeneity was measured by calculating "Dynamic time warping (DTW)" with 0 being an identical homogeneity. This is calculated on each foot (left and right) and for each of the axes before (X, Y, Z).

$$\mathcal{H} = DTW\ (X+1, X)\ ) \tag{1}$$

Where:

$\mathcal{H}$ is the homogeneity

DTW is the algorithm "Dynamic Time Warping that is applied to a sample with respect to a previous or later one.

F. Movement Amount

The amount of movement (QoM) refers to the activity of the body or a part of it, and to calculate it a sum of the displacements of each point between two instants of time is made, in this case, the peak of each cycle to each axis [24].

$$QoM_J = \sum abs(v_i - v_{i-1}) \tag{2}$$

Where:

i It is the index of the peak captured per cycle.

v_i It is the value of the peak in the ith moment.

J It is a Cartesian axis (X, Y or Z).

G. *Symmetry*

The symmetry (S) is obtained by comparing the movement between both feet, for this purpose the amount of movement obtained for the "x, y, z" axis per foot is used. The closer to 1 the value of S is the more symmetrical the movement between the two feet.

The symmetry is formulated as follows:

$$S_J = \frac{QoM_{izqJ}}{QoM_{derJ}} \; Si \; QoM_{derJ} \geq QoM_{izqJ} \quad (3)$$

Or

$$S_J = \frac{QoM_{derJ}}{QoM_{izqJ}} \; Si \; QoM_{derJ} < QoM_{izqJ} \quad (4)$$

Where:

QoM_{izqJ} Amount of movement in the left foot.

QoM_{derJ} Amount of movement in the right foot.

J It is a Cartesian axis (X or Y).

III. Analysis and Results

With the calculation of the characteristics of Homogeneity, Amount of movement and Symmetry, three vectors are generated for the analysis of gait of the people. Table 1 shows the vectors for the right and left foot; containing the homogeneity $\mathcal{H}$, the amount of movement QoM and the symmetry S.

Table 1. Resulting vectors

Pie Izquierdo	Pie Derecho	Total
$\mathcal{H}$x	$\mathcal{H}$x	$\mathcal{H}$x
$\mathcal{H}$y	$\mathcal{H}$y	$\mathcal{H}$y
$\mathcal{H}$z	$\mathcal{H}$z	
QoMx	QoMx	QoMx
QoMy	QoMy	QoMy
QoMz	QoMz	QoMz
		Sx
		Sy

The graph in Figure 3 shows the walking of a person for the right foot, 6 cycles are observed. Indicates the acceleration when moving the foot forward or backward the foot.

Table 2 shows the basic statistics of Figure 3. There is a maximum speed of 38.61 m / s2 and a minimum of - 30.02 m / s2. Fort he Mode the value is 0.

Table 2. Basic acceleration statistics on the X-axis

Statistical Metric	Magnitude (m/s^2)
Min	-30.02
Max	38.61
Mean	0.001355
Median	0.03764
Mode	0
Std	4.393
Range	68.63

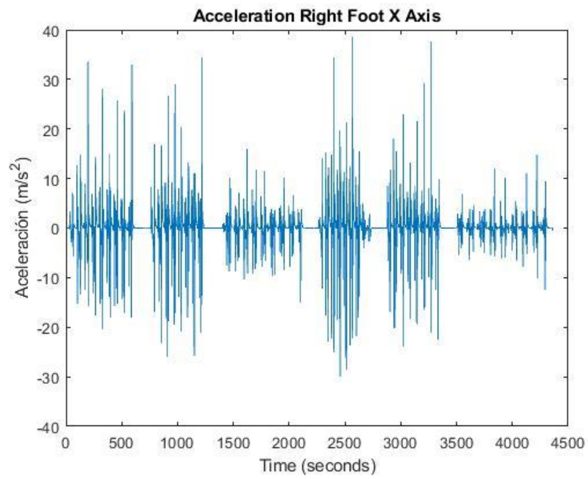

Fig. 3. Acceleration of the right foot on the X-axis

The "y" axis indicates the acceleration when the foot is raised or lowered. In this case, the acceleration is lower compared to when the foot is moved on the X-axis. See graphs 3 and 4.

The fact that there is greater acceleration on the X-axis does not indicate that the individual uses less speed to lift the foot than to move it. This may indicate that the person was not running but has a hurried pace.

Table 3 shows the basic statistics of the test subject in terms of measuring the acceleration for the Y-axis of the cell phone. As in the X-axis, Mode turned out to be zero. The maximum acceleration reaches almost half that of the X-axis.

Table 3. Basic acceleration statistics on the Y-axis

Statistical Metric	Magnitude (m/s^2)
Min	-24.8
Max	16.27
Mean	0.00097
Median	-0.002181
Mode	0
Std	2.882
Range	41.08

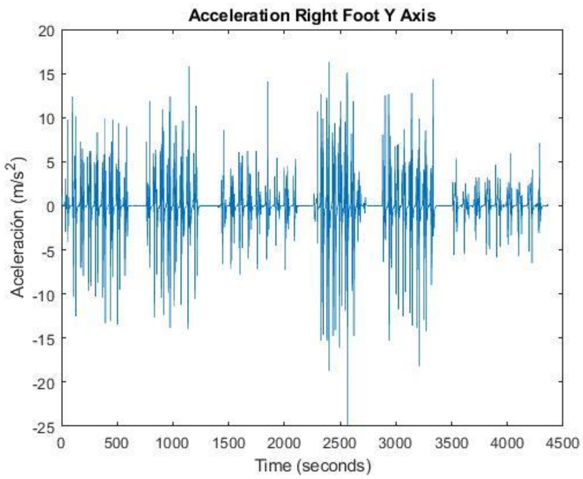

Fig. 4. Graph of the axes of the walking of the right foot.

Table 4 together with Figure 5 shows the analysis done for the acceleration of the right leg. The Z-axis shows lateral displacements of people. When the acceleration increases on this axis it indicates that the person is taking a turn; or that there is another person or object that displaces it. For this case again the Mode was zero but now the same is also true with the Median. The acceleration is less than for the Y and X-axis; So we can assume that the person walks in a straight line.

Table 4: Basic acceleration statistics on the Z-axis

Statistical Metric	Magnitude (m/s^2)
Min	-16.49
Max	18.02
Mean	0.0006864
Median	0
Mode	0
Std	2.081
Range	34.51

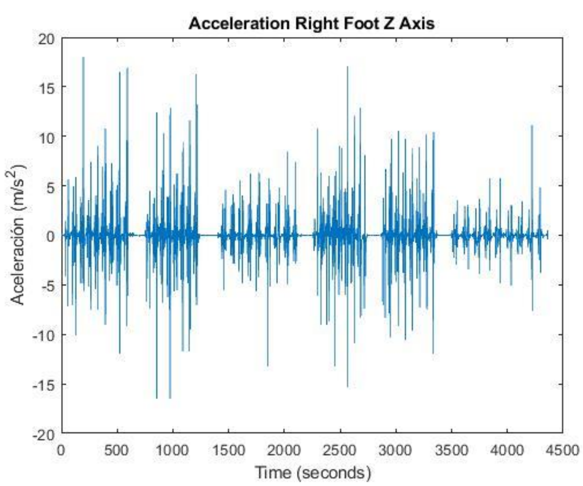

Fig. 5. The graph Z-axis of the walk of the right foot.

The same procedure is performed for the left leg; However, for some operations, it is better to measure the statistical parameters per cycle; as shown in figures 6,7 and 8. The basic statistics are summarized in table 5. The maximum acceleration is on the X-axis, for both legs. This is logical since it is the same person and the same instant of time; However, the movement of the left leg has lower maximum accelerations.

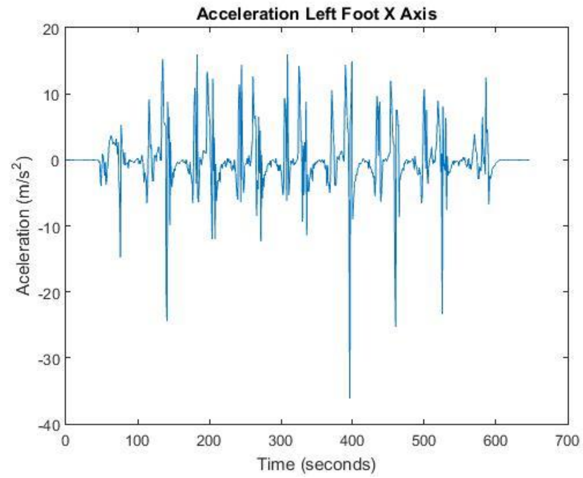

Fig. 6. Acceleration is the first cycle for the left foot on the X-axis

The graph in Figure 7 shows differences in the acceleration of the Y-axis; which is smaller than that of the X-axis of the left foot.

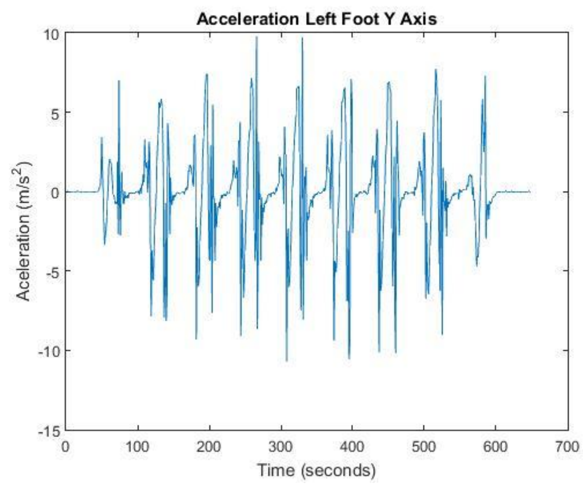

Fig. 7. Acceleration is the first cycle for the left foot on the Y-axis

Figure 8 shows the acceleration of the Z-axis with minor changes of speed with respect to the other axes.

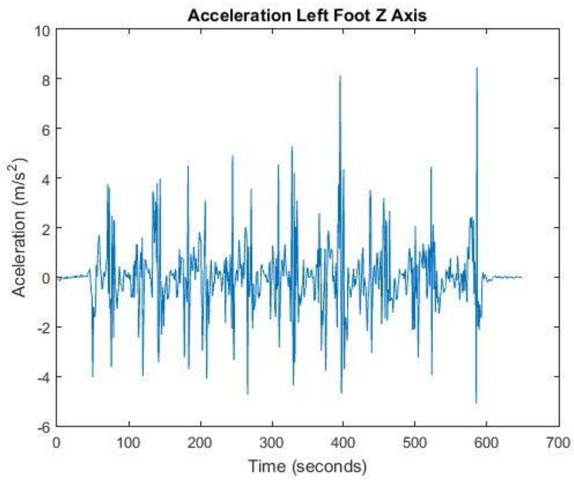

Fig. 8. Acceleration is the first cycle for the left foot on the Z-axis

Table 5. Statistics by cycle.

Métrica	Pie Derecho			Pie Izquierdo		
	X	Y	Z	X	Y	Z
Min	-20.4	-13.37	-11.94	-36.09	-10.66	-5.103
Max	33.6	12.33	18.02	15.97	9.795	8.455
Mean	0.0015	0.008	-0.0008	-0.0007	0.0001	-0.0018
Median	0.1447	-0.0196	0.0018	-0.1674	-0.0175	-0.0069
Mode	-20.4	-13.37	-11.94	-36.09	-10.66	-5.103
Std	5.042	3.114	2.556	4.576	2.931	1.374
Range	54	25.7	29.96	52.06	20.46	13.56

From the graphs in Figures 3 to 8, the three vectors shown in Table 6 are obtained, the first one representing the data of the left foot, the second one representing the right foot and the third the average considering both feet. Recall that the homogeneity indicates how similar or different a step is to another, in this case, $\mathcal{H}$ takes values far from 0; which may indicate that it is the same signal; However, we can say that walking has analogous cycles on the X, Y and Z axes, as observed in Figure 5; however, the value of $\mathcal{H}$ is far from the value of 0 that would indicate otherwise. This has an explanation since what DTW compares are continuous cycles in pairs. These continuous cycles give results close to 700, which corroborates what is seen in the graph in figure 5. As for the amount of movement QoM indicates that there is greater movement on the "x" axis compared to the "y" axis for the movement of this person. The step is more symmetrical in the "y" axis than in the "x" axis since its value is closer to 1, but the difference is really not very significant.

Right foot	Left foot	Average
$\mathcal{H}$x6c =1.209x10^3	$\mathcal{H}$x6c=1.234X10^3	$\mathcal{H}$x= 1.222 x10^3
$\mathcal{H}$y6c=686.05	$\mathcal{H}$y6c=715.95	$\mathcal{H}$y= 701
$\mathcal{H}$z6c=650.86	$\mathcal{H}$z6c=521.64	$\mathcal{H}$z= 586.25
QoMx= 7.51x10^2	*QoMx=7.22x10^2*	*QoMx= 7.365*
QoMy = 5.26x10^2	QoMy= 5.39x10^2	QoMy= 5.325
QoMz= 6.28x10^2	*QoMz= 5.17x10^2*	*QoMz= 5.725*
		Sx=0.961
		Sy= 0.975
		Sz=0.823

IV. CONCLUSIONS

The importance of recognizing relevant characteristics in the gait of the people is indisputable since by computerizing these characteristics it is possible to characterize the gait.

Twenty-four actors (with an equal number of left and right subjects) were registered using a motion capture system based on a cell phone placed at the ankles.

As work in the future, several factors that can intervene and affect the analysis of the gait remain, such as some type of pain, the use of different footwear or some deformation. So there is a very wide field of study for pattern recognition.

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