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RECOGNITION OF CHARACTERISTIC PATTERNS IN HUMAN GAIT THROUGH COMPUTER VISION TECHNIQUES

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Abstract: The analysis of the human gait is of great importance for the diagnosis and the choice of the type of treatment that the patient must obtain. In this work, we report a proposal of the capture of the movement and an interpretation of the signal obtained by means of artificial intelligence and computer vision. Results were obtained by means of the acquisition of quantitative parameters characteristic of a gait pattern, in order to be able to group patients according to their characteristics by applying clustering with the use of the k-means algorithm. Markers were placed on the knee of the patient and through them the acquisition of the data was performed in real time. These data are plotted in 2D and 3D for a better understanding of the analysis. The main objective of this article is to propose a technique of pre-diagnosis by grouping and recognition of patterns so that, in turn, this can be used to make decisions about professional intervention in the patient.

Keywords: Human Gait, Pattern Recognition, Grouping, K-means Algorithm, Computer Vision.

I. INTRODUCTION

The analysis of the human movement, and more concretely of the human march, has attracted a scientific interest from remote times taking this interest to the development of different methods for its study. Currently, a complete analysis of the progress of a patient allows identifying the specific problems that affect it and starting from these it is possible to perform a surgical prescription, therapeutic, pharmacological or technical aids to help the patient [1]. There are several models that describe quantitatively the human march with approximations to the dynamics of movement, inspired by the morphophysiology of the locomotor system; models are found from a simple inverted pendulum to complex computational algorithms [2].

To coordinate the work of a large number of skeletal muscles and due to the large number of degrees of freedom throughout the locomotor system, each step varies slightly from the previous one. Therefore, the human march is not perfectly repetitive, even on a very uniform surface. The slight asymmetry may reflect functional differences in the contribution of each member to propulsion and control during walking and this is often used as a strong indicator in the rehabilitation and clinical setting [3].

It is necessary for the analysis of the march to have a standardized protocol that allows obtaining the parameters of interest in a reliable and efficient way. This protocol depends on the type of patient, laboratory configuration, parameters to be obtained, as well as the placement of markers, among other aspects [1]. Doctors take considerable time to evaluate movement patterns either through visual observation or video graphic analysis [4].

Generally, descriptor extraction strategies are used, for example, adjustment of polynomials in biological signals since, by means of computational ways, it is easy to mathematically characteristic a biological time series for a later reproduction for modeling purposes [5].

There are different models and techniques for gait analysis, among them, the camera space management method is a computer vision technique that does not require calibration. An important feature of this method is that the manual objectives are defined and pursued in the 2D reference frame. Images for each of the participating cameras, in this case two cameras. These objectives are used using the "six vision parameters", which are determined by a non-linear classification process called "least squares differential correction" [6] according to a model of free solutions that work directly in the sequences of the March. A very interesting class of holistic techniques only uses binary maps (silhouettes) of walking humans. Such techniques are really suitable for most practical applications and where the color or texture information may not be available or removable. The outline of the silhouette is probably the most reasonable feature in this class. It can be used directly or to extract the Fourier descriptors [7]. Another technique "Restores the background and Reconstruction of the silhouette". First, the background of the current frames is restored, and then the threshold is applied to the segmented portion. The subtraction of the current frame in the known frame is less than the value of the threshold that is called background or in the foreground. After the background subtraction, the silhouettes have some discontinuities and noises. This can be easily eliminated by the morphological operation. By using continuous erosion and dilation operations, discontinuities and noise are eliminated [8].

Another way is through model-based approaches that obtain a series of static or dynamic body parameters via the modeling of components such as the hip, knees, legs, arms and muscles. Gait signals derived from these models are used for the identification and recognition of an individual. It is evident that model-based models are invariable in view and independent of escalation. These advantages are important for practical applications since reference sequences and test sequences are unlikely to be taken from the same point of view [9].

Of all the previously mentioned research works, it is important to mention that it is not observed, that with the proposed methods or techniques, a pre-diagnostic is reached, and they are only used for the identification of individuals.

In this article, we initially show a simulation of signals of various characteristics with the aim of applying the k-means algorithm and derived from this, verify its functionality. Subsequently, a number of patients were tested using computer vision techniques to evaluate physical phenomena during a walking task on a fixed treadmill. Markers of different colors placed on the knee of the patients were used to evaluate the march in real time by means of the detection of colors and follow-up of them to generate the data. Finally, the k-means algorithm was applied with software developed in Python and with the use of conventional web cameras.

II. Theoretical Description and Simulation

A. *Human Gait*

Corresponds to a sequence of coordinated and alternating movements that allow us to move. It is a complex process that requires the proper functioning and interaction of different structures such as a control system in charge of the central nervous system, levers that provide the corresponding movement to the bones and forces to move the levers in charge of the muscular system. Alterations at any of these levels can determine changes in gait [6].

B. *Human gaitphases*

The human march is composed of steps that in turn form strides. Stride is also called the gait cycle. [7]

- Steps

The Sequence of events that takes place between successive points of contact of alternate feet with the ground includes a bipedal and a monopedal support interval.

- Stride

Its beginning is considered at the moment in which the foot touches the ground and the end in which the same foot touches the ground again. It is comprised of two intervals of bipedal support and two monopedal supports one for each foot.

The process is described in figure 1. It is established that the stride begins with the support of the foot closest to the observer, called the ipsilateral foot. At the farthest foot, we refer to as a contralateral foot.

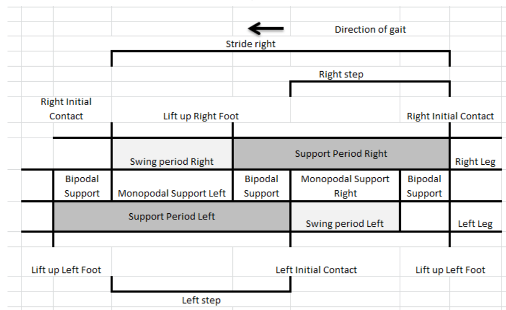


Figure 1: Phases of the human gait

C. Computer2952isión

Also called artificial vision, machine vision, robot vision, image analysis or scene interpretation, is the process of extracting the real world from images using a computer as a tool [8].

D. Tracking objects

Object tracking is defined as a problem of estimating the trajectory of an object in a flat image as it moves through the scene. That is, an algorithm whose purpose is to follow objects to show which is the situation of the object that is following in a video frame [9].

For the development of this work, it was decided to use the center of mass of the indicators as a central point to follow, in addition, the functionality of showing the coordinates of each central point in the object was added. With this an effective follow-up is made thanks to the tracking of the geometric center of the indicator and not of this completely.

Using the OpenCV library, more specifically its function "moments", it returns the moments of area of up to third order of a polygon in a structure, this structure stores all the moments calculated by means of the following formula [9]:

$$m_{ij} = \sum_{x,y}^{i,j} \left(array(x,y) \cdot x^i \cdot y^j \right) \qquad \text{eq. (1)}$$

E. Human gait pattern recognition

The human gait is a quasi-periodic process with peculiarities that allow identifying a specific person. We used three characteristics to distinguish among different human gait styles:

- Symmetry: The degree with which the movement of a leg is similar to the other one.
- Homogeneity: The degree with which the whole gait profile repeats in time.
- The estimated proportion between legs length and weight [10].

F. Clustering techniques

Clustering techniques are a set of data as input, which is grouped according to common characteristics that they possess. These clustering methods are very useful if you don't have with a result expected, that is believed to be training or unsupervised learning. Although these methods of clustering solutions that show satisfactory results are a comprehensive task to find the number of optimal clusters or groups that offer better results than another number of k values. [11].

G. K-means

It is an unsupervised classification algorithm that groups objects into "k" groups based on their characteristics. Said algorithm consists of 3 steps:

1. Initialization: once the number of "k" groups has been chosen, "k" centroids are established in the data space, chosen randomly.

2. Assignment of objects to the centroids: each object of the data is assigned to its nearest centroid.

3. Update of centroids: the position of the centroid of each group is updated taking as the new centroid the position of the average of the objects belonging to said group.

Repeat step 2 and 3 until the centroids do not move, or move below a threshold distance in each step [11].

Simulating functions such as sine, cosine and sine by cosine, to which the amplitude and period of each function are randomly modified, each one is represented by different color and figure, obtaining the points of figure 2.

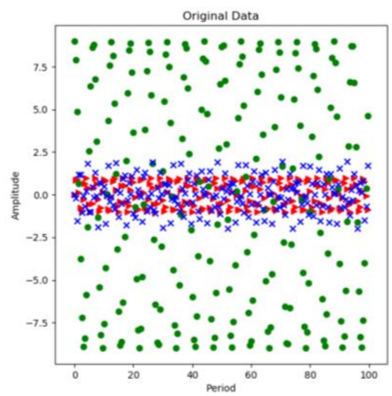


Figure 2: Simulation of functions sine, cosine and sine by cosine with a random modification of period and amplitude.

After the simulation of the raw data acquisition we apply the k-means algorithm to generate 3 groups in this case, obtaining the result shown in figure 3.

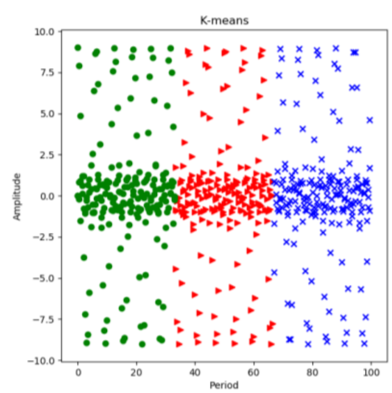


Figure 3: Application of the K-means algorithm in the simulated functions.

III. EXPERIMENTAL SETUP AND RESULTS

The acquisition of the data was done in the way shown in Figure 4.

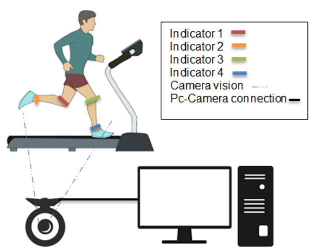


Figure 4: System Model for human gait recording.

As a test, the comparison of the right knee is made in two test subjects, one with no problem in his knee and the second with a considerable deviation of the knee. This experiment was carried out with a frontal view that is shown in figure 5. In this test a characteristic vector obtained with the generated signal of the individual was taken into account, as well as the magnitude, maximum and minimum amplitude in the "x" axis and maximum and minimum amplitude in axis "and" as well as other parameters such as age, weight and height.

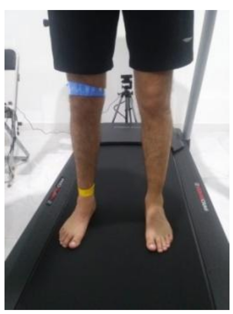
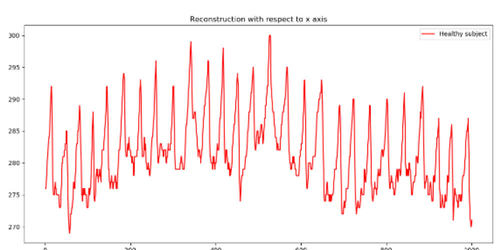
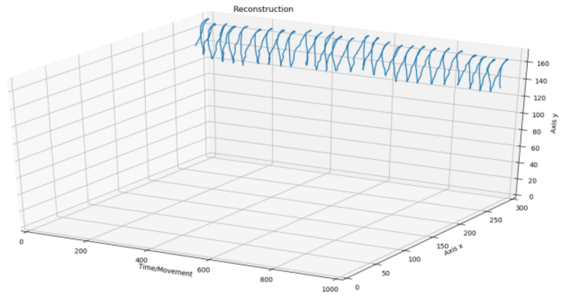


Figure 5: Front view in the data acquisition.

We obtain different graphs for the evaluation as a result of the analysis of the march. First, figures 6 and 7 that show a graph generated by the healthy patient are observed. Figure 6 represents the record of knee movement behavior of a healthy patient with respect to time and figure 7 records the behavior on the y-axis with respect to time.



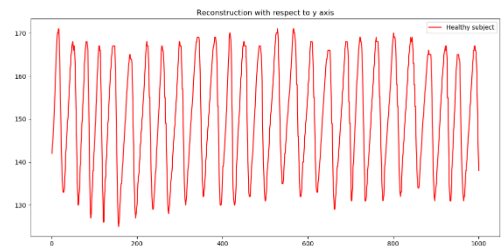
(a)



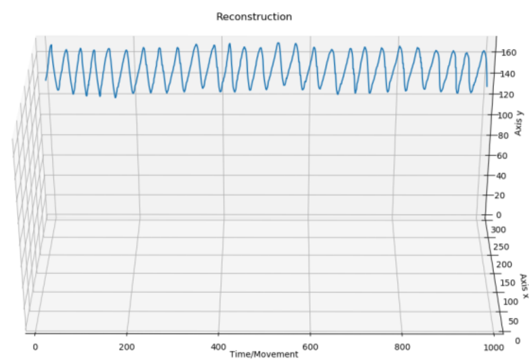
(b)

Figure 6: Signal obtained by the x-displacement of the knee along the time for a healthy subject. (a) 2D, (b) 3D.

Through the 3D graphic, the obtained results can be analyzed from different strategic points.



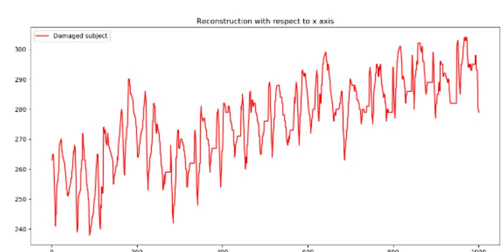
(a)



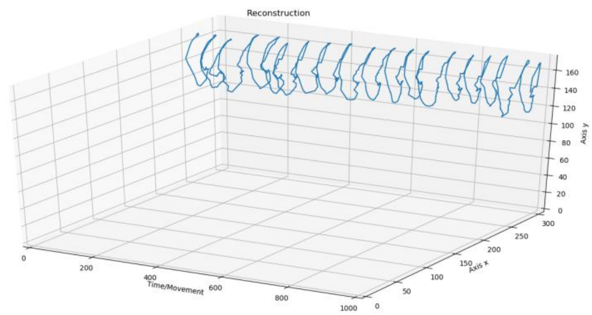
(b)

Figure 7: Signal obtained by the y-displacement of the knee along the time for a healthy subject. (a) 2D, (b) 3D.

Below is shown in figures 8 and 9 the result of the test subject with problems in the right knee.



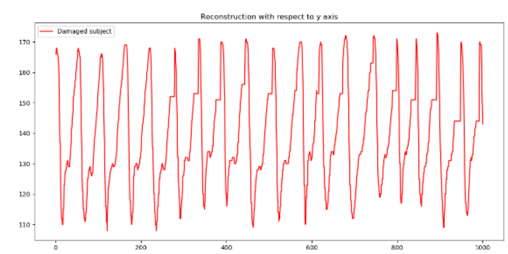
(a)



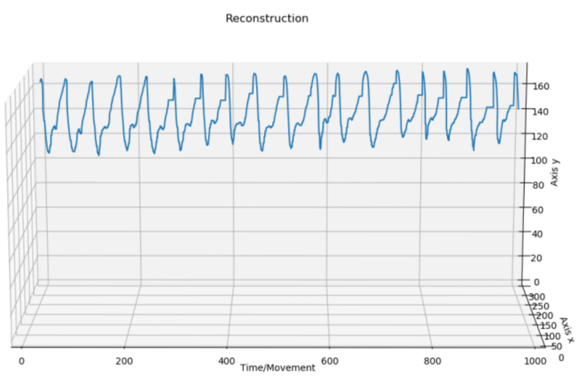
(b)

Figure 8: Signal obtained by the x-displacement of the knee along the time for a subject with problems on the right knee. (a) 2D, (b) 3D

It is worth mentioning that both data sets are of the same length for later evaluation.



(a)



(b)

Figure 9: Signal obtained by the y-displacement of the knee along the time for a subject with problems on the right knee. (a) 2D, (b) 3D

As can be seen in figures 7 and 9, the knee abnormality is evident in the patient with problems unlike the healthy patient. To have a better comparison, they were united in a single 3D graphic with different views and the comparison is shown in figure 10.

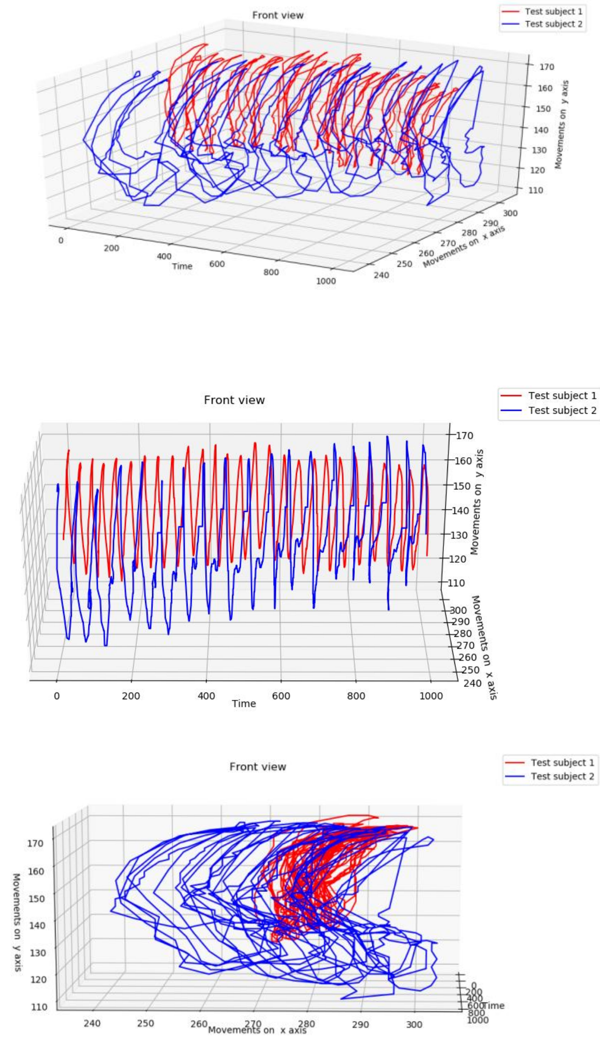


Figure 10: Different views of the comparison between the signals obtained from the right knee of subject 1 and subject 2

The main contribution of this work is the implementation of the k means clustering algorithm, where, to verify its functionality, it was applied under the same procedure, in a total population of 19 test subjects with a range of ages between 22 and 27 years, 7 of them have problems in the right knee and 12 are in healthy conditions on the same knee.

First we have figure 11 where the data of the population in an original state are shown that is without applying the k means. Figure 12 applies the clustering of the data.

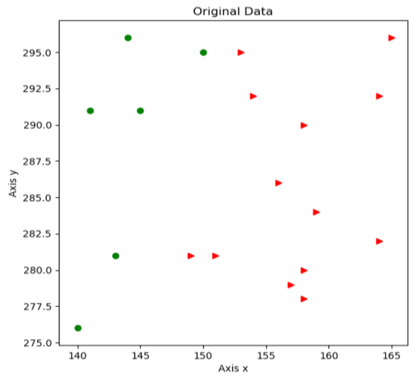


Figure 11: Original data used in the present tests.

Figure 11 depicts patients with abnormalities in the right knee with green circles and triangles in red representing healthy patients with the same knee.

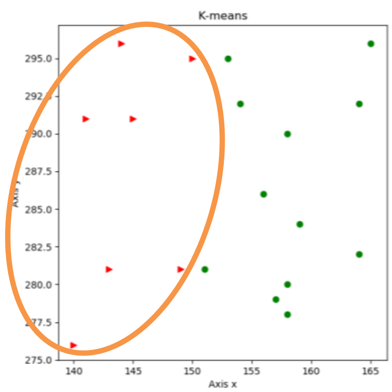


Figure 12: Application of the k-means algorithm in the test.

Figure 12 shows the result obtained by applying the k-means algorithm on the obtained samples. The generation of two groups is observed, where in this case, the elements represented by a red triangle inside the ellipse represent the subjects with problem or anomaly in the knee. In contrast, the green circles represent the subject with healthy knees. A classification of 94.93% is obtained, this means that a single subject of the 19 totals was classified in correctly.

IV. Conclusions

Through computer vision techniques it was possible to identify a knee abnormality in the march, which meant that the signals of human walking could be clustered, which means that we can generate groups depending on the severity of the problem of the people.

Greater descriptors are needed to obtain a better clustering of the data as long as they contain relevance on the characteristics of what is being evaluated.

It was possible to find a descriptive pattern in this gait analysis, which facilitated clustering.

If we put more indicators in both legs we will generate more data and therefore more descriptors in such a way, this will help us generate more clusters for the classification and allow us to be specific in a pre-diagnosis that supports the decision-making specialist.

As future work, a database will be implemented and a report of the analysis will be generated where it is shown as pre-diagnosis without the need for a specialist doctor to be present.

V. Acknowledgements

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