# Asymmetry functions of joint angles in the human gait

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## ABSTRACT

The idea of this project is to study the asymmetry during human walking on some important angles. For this purpose, asymmetry functions have been developed. Until this moment, the asymmetry on these angles has been studied like something global with the asymmetry coefficients (for example, just taking the best value of asymmetry for every angle). With the asymmetry functions it is possible to study this asymmetry along the whole. Knowing this information, it could be possible to determine different anomalies depending on the angle and on the moment of the asymmetry. The ultimate goal is to obtain a computer program to perform the asymmetry functions at different angles from data obtained from patients.

**Keywords:** Asymmetry, asymmetry functions, asymmetry coefficients, joint angle, middle double step.

## 1. INTRODUCTION

At first sight, the walking process seems to be periodical and symmetrical, but neither of these are true. However, the differences between following gait periods and the difference between the right and left step are so insignificant, that gait is assumed as quasi-periodical and quasi-symmetrical. On the other hand, if someone has huge walking asymmetry or deviation of periodicity of the gait, it usually means that he is suffering from a disease. For a thorough analysis of gait asymmetry, it is worth to develop two of its symmetric models, one based on the left step and the second model, based on the right step.

### 1.1 Data capture:

The study of the asymmetry functions will be conducted using Matlab[1]. First, it is necessary to obtain patient data while he is walking. To do this, the patient is walking on a treadmill with infrared reflectors placed on the body at the points shown in the Figure 1. Data capture is carried out using infrared cameras. Location of the markers is recorded with 4 cameras and then 3D reconstruction is performed. There is thus obtained a signal matrix where each column describes the corresponding coordinate for the selected marker.

### 1.2 Double half-step models:

Once data are captured, they are adapted to the double half step model[2]. Using the techniques of double half step model makes it possible to control and characterize the kinematics of the subject's body by comparing the data obtained with the data of a normal step in each time step.

Once data are normalized, the separation of the data concerning the right and the left legs is performed. Having done that, two models that simulate the complete walking based on each of the legs are created. These models are nothing but arrays of the same dimension data, so that any point can be compared in each of the legs at the same instant of time. These are the data which are split for the study of the asymmetry. The program that allows us to obtain these models was created by Asier Sancho Hidalgo[3].

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Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2014, edited by Ryszard S. Romaniuk, Proc. of SPIE Vol. 9290, 92901R

doi: 10.1117/12.2075156

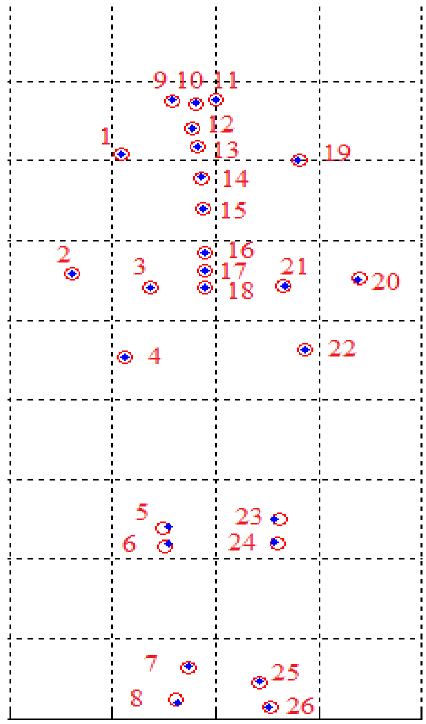


Figure 1. Location of markers on the human body in frontal plane.

## 2. JOINT ANGLES

For this project we have chosen three angles that are of great importance for the study of asymmetry in human walking. These angles are shown in the Figure 2:

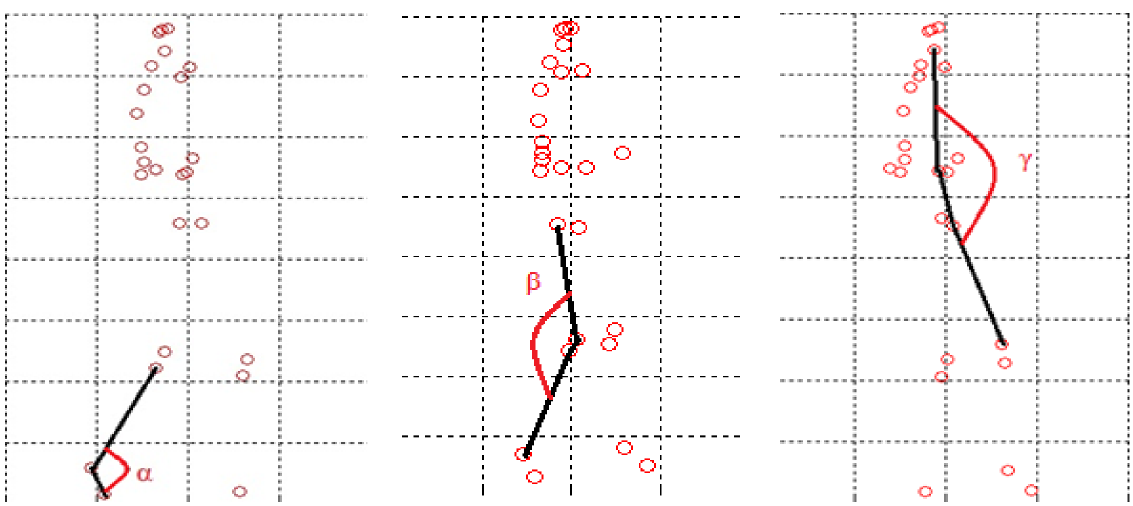


Figure 2. Presentation of the joint angles in the ankle, knee and hip

From data of left and right step models, it is possible to calculate the vectors that define the different angles and from them the own angles. The program will allow selecting between these angles and calculating the different asymmetry functions.

## 3. ASYMMETRY FUNCTIONS

After selecting one angle, the temporal function that represents the value of this angle along the time is created for both models (right step and left step). Given these functions, it is possible to compute a new function that compares the asymmetry between the two models for each of the time instants.

In the case of this program, it is possible to calculate up to six different asymmetry functions, with different properties. Definitions of asymmetry functions are presented below.

$$AF_1(i) = LeftAng(i) - RightAng(i)\,[º] \quad (1)$$

$$AF_2(i) = \frac{LeftAngq(i) - RightAng(i)}{LeftAng(i) + RightAng(i)}\,[\%] \quad (2)$$

$$AF_3(i) = \left|\frac{RightAng(i)}{LeftAng(i)} - \frac{LeftAngq(i)}{RightAng(i)}\right|\,[\%] \quad (3)$$

$$AF_4(i) = \left(\frac{RightAng(i)}{LeftAng(i)} + \frac{LeftAng(i)}{RightAng(i)} - 2\right)\,[\%] \quad (4)$$

$$AF_5(i) = \frac{RightAng(i) - LeftAng(i)}{\max(RightAng(i), LeftAng(i))}\,[\%] \quad (5)$$

$$AF_6(i) = \left|\frac{RightAng(i) - LeftAng(i)}{\max(RightAng(i), LeftAng(i))}\right|\,[\%] \quad (6)$$

Where $AF_n$ is asymmetry function, RightAng(i) and LeftAng(i) are respective angles defined for the i-th image.

From the asymmetry function, it is possible to obtain the value of the asymmetry coefficient, which measures the degree of asymmetry of the distribution with respect to the arithmetic mean of the values obtained in different moments of time in the asymmetry function.

$$AC = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

## 4. OPERATION OF THE PROGRAM

When the program is executed, the operation is given in the form of menus to interact with. To boot, the data concerning the right step and left step models are needed. The choices are represented in the Figure 3.

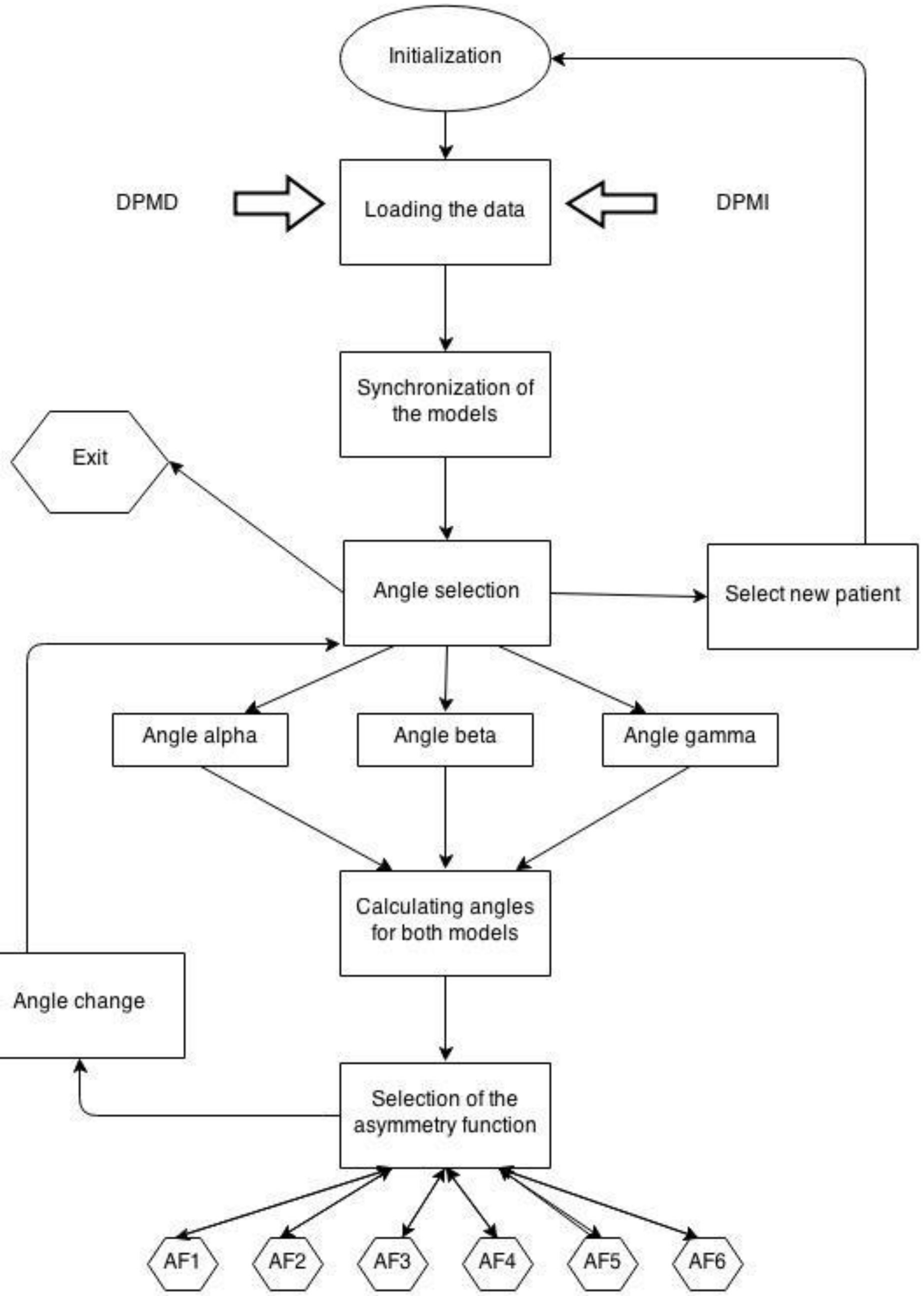


Figure 3. flow diagram of presented program

## 5. RESULTS

Below, it is presented the result of the execution of the program selecting one angle (in this case, alpha angle).

Representation of the angle: The first image shows the representation of the alpha angle for both legs in the right step model. The second image shows the representation of the same angle in the left step model. The third image shows the representation of the comparison of one leg in both models. The last picture shows the comparison of the other leg in both models.

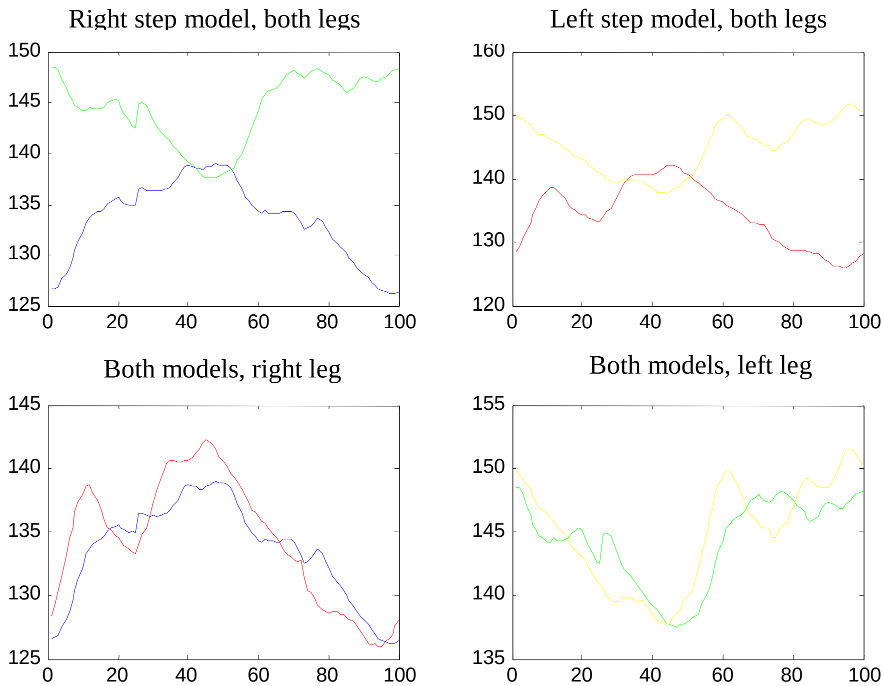


Figure 4. First asymmetry function where it is simply shown the difference in degrees between the two models for each of the time intervals.

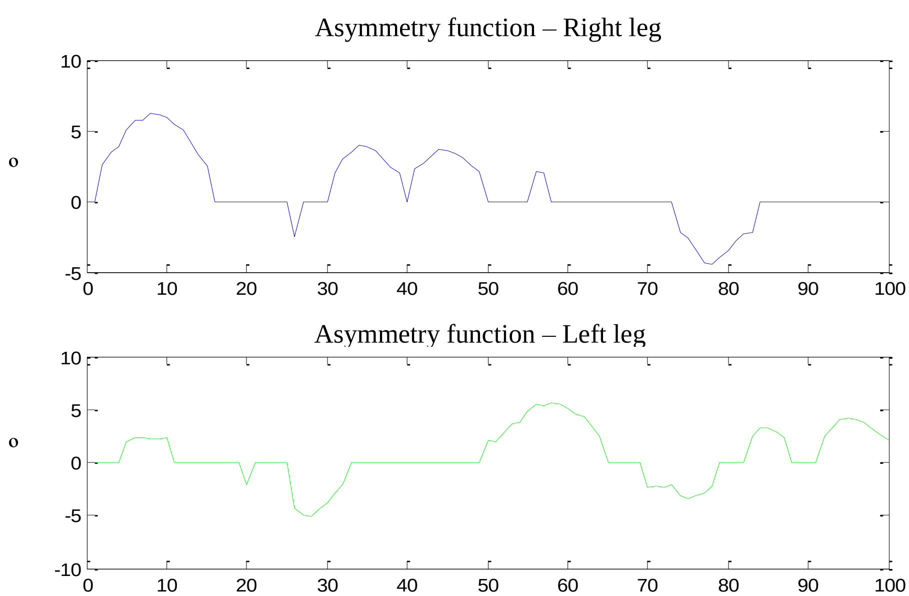


Figure 5. First asymmetry function where it is simply shown the difference in degrees between the two models for each of the time intervals.

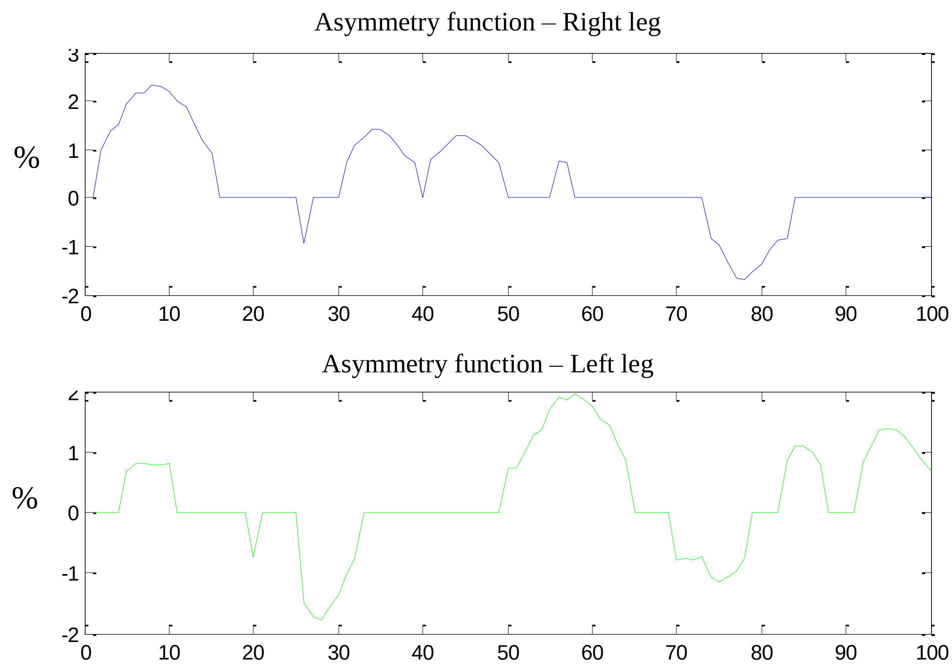


Figure 6. Second asymmetry function. This function seems similar to the previous function, but given percentage.

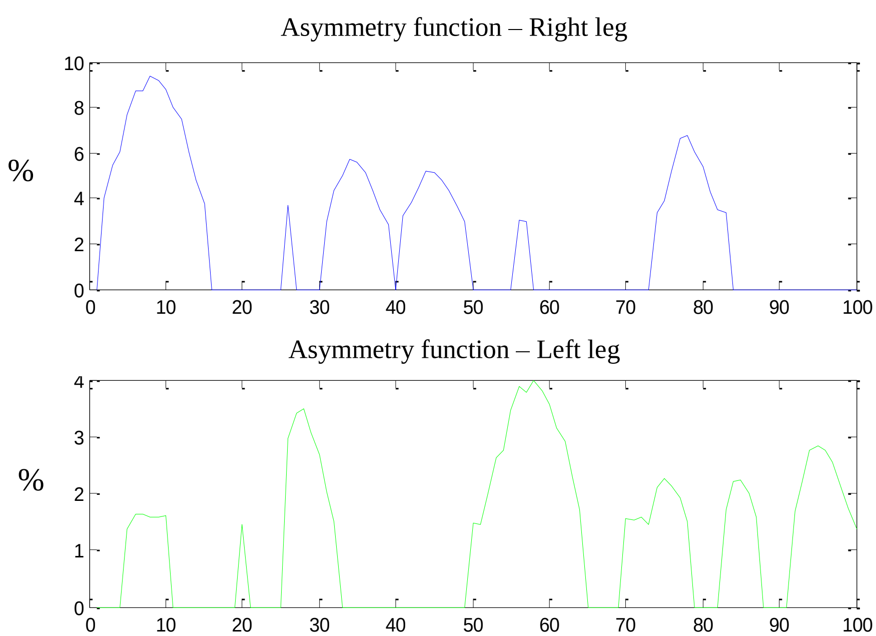


Figure 7. Third asymmetry function is very sensitive to changes. It has large leaps as differences in different time instants are larger.

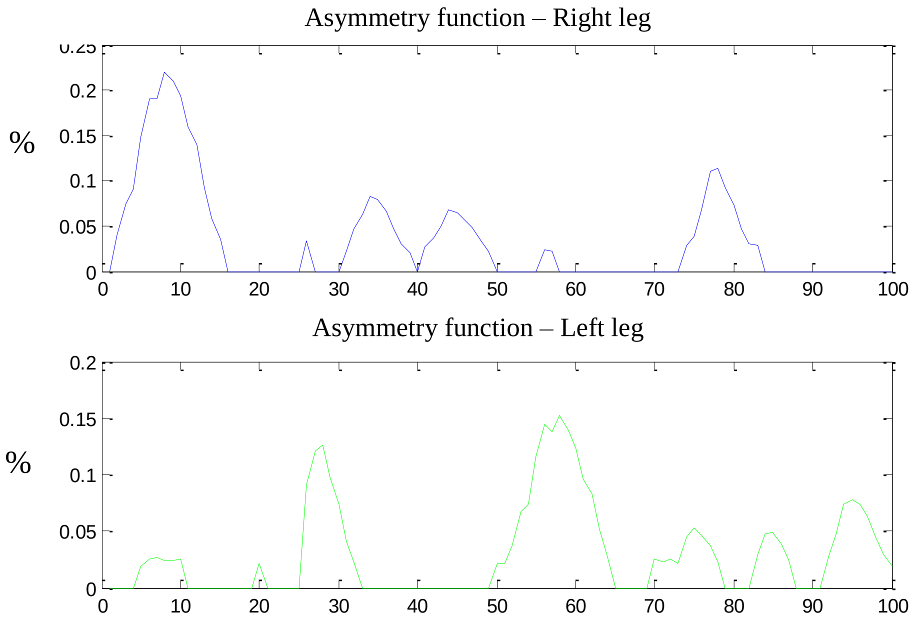


Figure 8. Fourth asymmetry function: Like the one above, it is also very sensitive to changes, but represents a much smaller scale (0 to 1%).

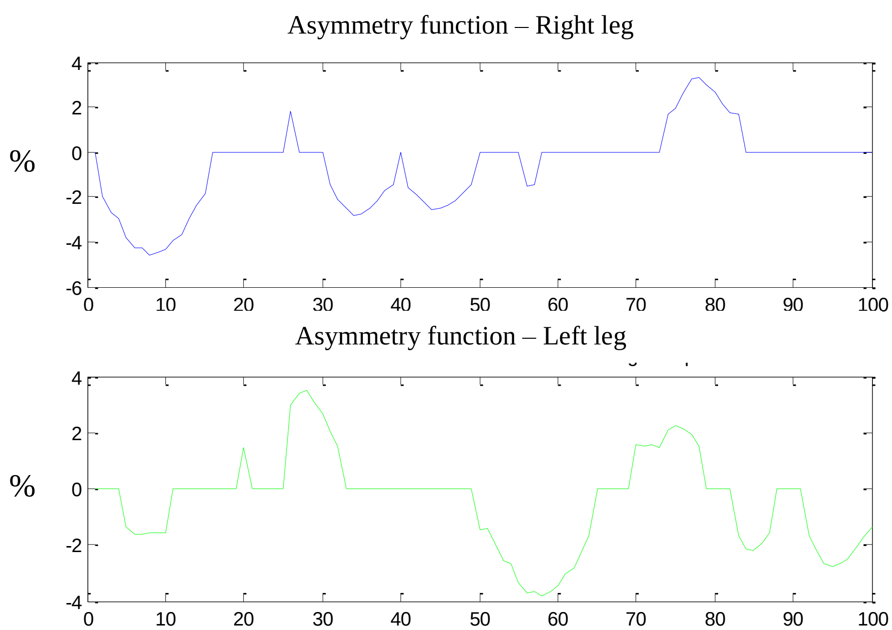


Figure 9. Fifth asymmetry function: This function is more sensitive in each of the time intervals to the angle that presents a greater value in each case.

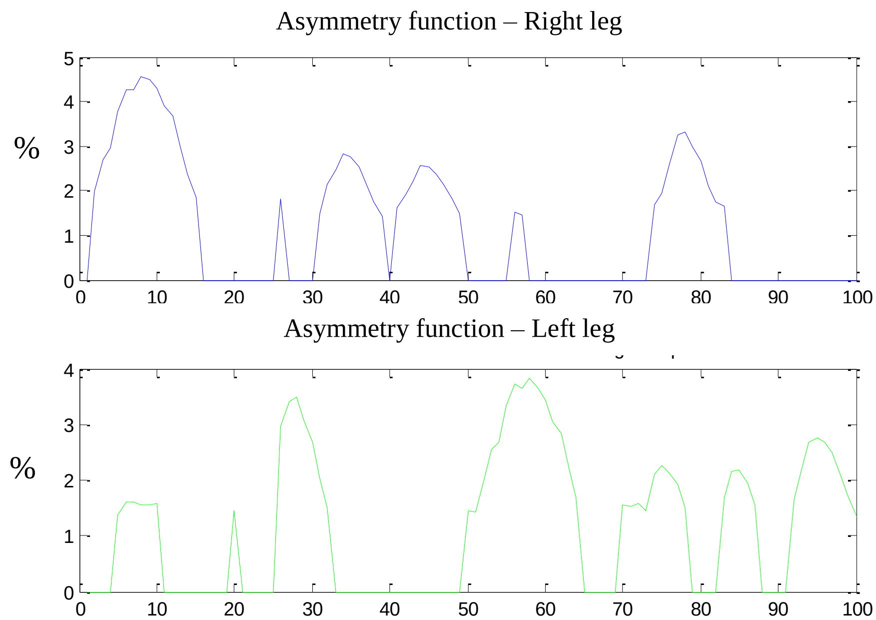


Figure 10. Sixth asymmetry function: Very similar to the function mentioned above, but only in a positive range due to the absolute value. It does not take into account which leg has a higher value of the angle at each time instant

## 6. CONCLUSIONS

### 6.1 Categorize a patient:

If a study about asymmetry coefficients is performed, it may be the case that a patient would show a large asymmetry in any angle, but after observing the asymmetry function of the patient in that angle it does not present large asymmetries. This may be because the function at any instant of time presents a great leap, which would increase the asymmetry coefficient. Thus, we arrive at the conclusion that the most optimal way to classify a patient is studying the asymmetry function.

Thus, it should be done a division in phases for the full walking, to study the asymmetry in each of the angles during different phases. Then, some levels could be created, so that they could differentiate different pathologies depending on the asymmetry value, the phase at which they occur and the angle at which they occur.

### 6.2 Division of the asymmetry function in phases:

A possible division into phases is suggested by Jacquelin Perry[4]. This can be seen in the Figure 11. Thus, taking this division, the different phases on angle representation and function asymmetry:

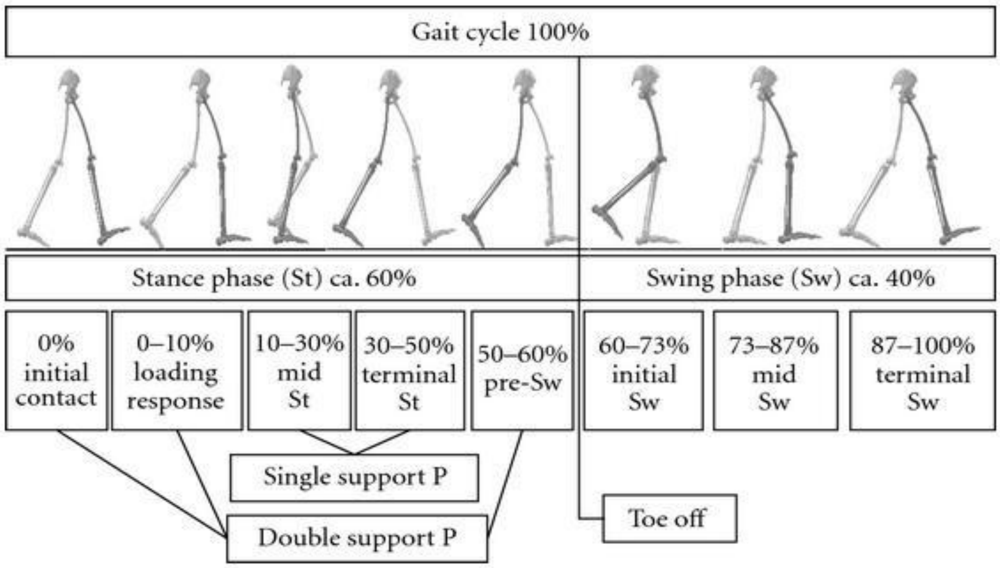


Figure 11. Gait phases suggested by Jacquelin Perry.

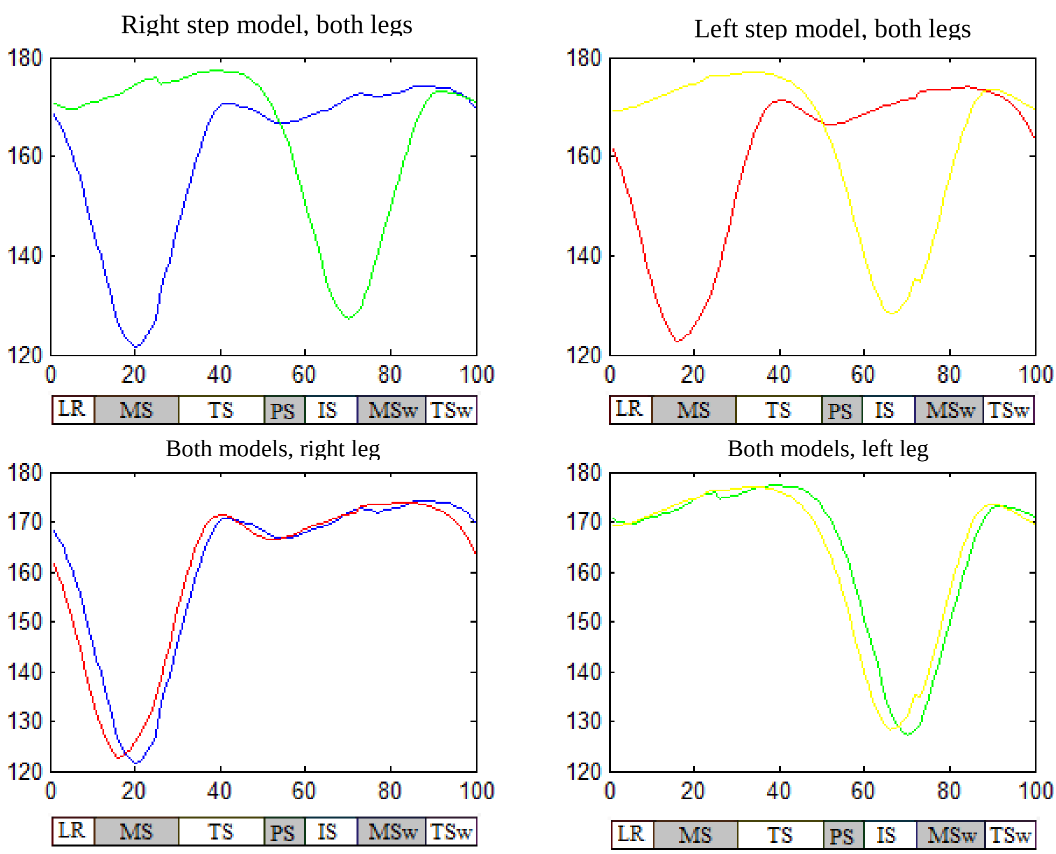


Figure 12. Joint angles correlated with gait phases

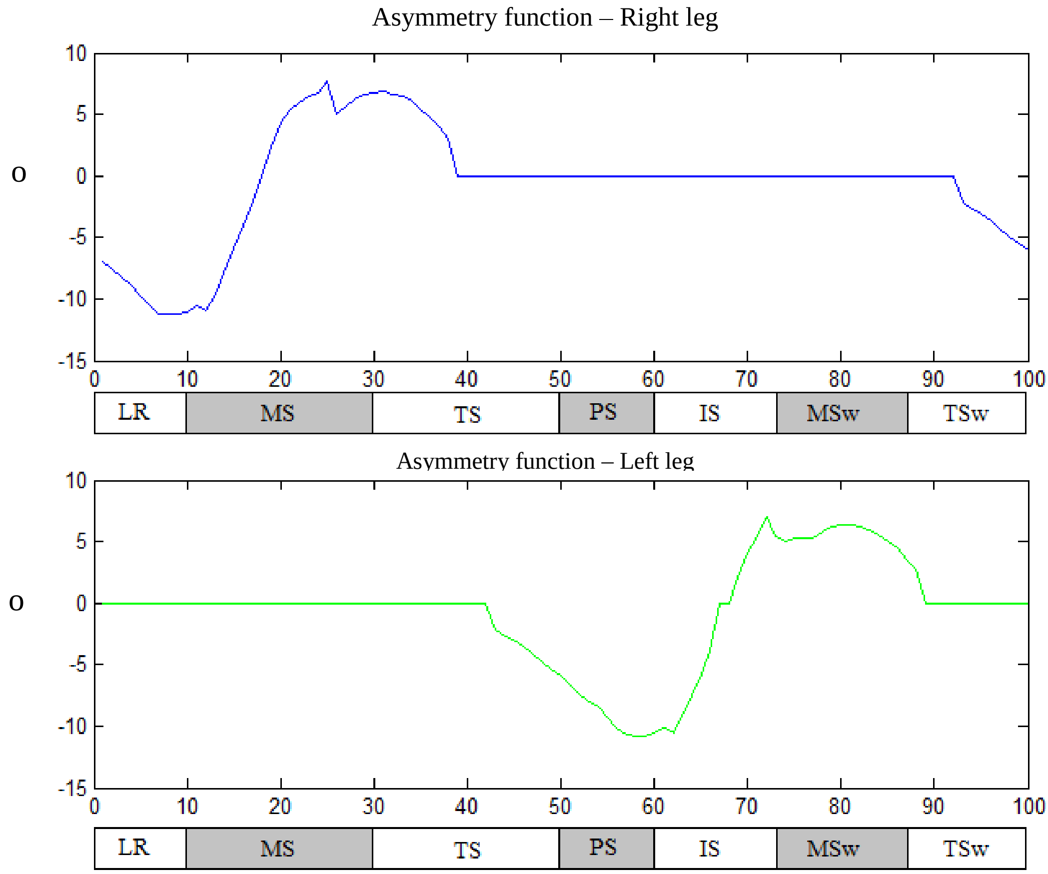


Figure 13. Changes of the asymmetry function in subsequent phases of the gait

In this specific example it is possible to observe that for the asymmetry function of the right leg there are big asymmetries in the "mid st" and "terminal st" phases. However, in the "pre-sw", "initial sw" and "mid sw" phases there are not asymmetries.

By studying the different phases is easier to differentiate between different pathologies according to the angle.

It is necessary to clarify that the existence of asymmetry in certain phases according to the angle does not imply the existence of one anomaly. It would be necessary to study different cases with a significant variety of patients to get conclusions about the current asymmetries.

## REFERENCES

[1] MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

[2] Dusza J. J, Wawrzyniak Z. M., Mugarra González C. F.,: Simplified model of mean double step (MDS) in human body movement, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments , edited by Ryszard S. Romaniuk, Proc. of SPIE Vol. 8454, 84541N · © 2012 SPIE CCC code: 0277-786/12/$18 · doi: 10.1117/12.200005 (2012)

[3] Sancho Hidalgo A.: “Modelos simetricos de la marcha humana” M.Sc. Thesis, Warsaw University of Technology, Institute of Electronics Systems (2013)

[4] Perry J: [Gait Analysis: Normal and Pathological Function] SLACK Incorporated, 6900 Grove Road, Thorofare, NJ 08086-9447(1992).