Data Acquisition from the Integration of Kinect Quaternions and Myo Armband EMG Sensors to Aid Equinus Foot Treatment

Francisco M. A. Araújo[1][a], N. M. Fonseca Ferreira[2,3][b], Salviano F. S. P. Soares[4,5][c], António Valente[6][d] and Gilson L. S. Junior[1][e]

[1]*Federal Institute of Education, Science, and Technology of Piauí, Teresina, Brazil*
[2]*Institute of Engineering of Coimbra Polytechnic of Coimbra, Coimbra, Portugal*
[3]*INESC TEC-INESC Technology and Science and Knowledge Engineering and Decision-Support Research Center (GECAD) of the Institute of Engineering, Polytechnic Institute of Porto, Portugal*
[4]*IEETA – UA, Aveiro, Portugal*
[5]*University of Trás-os-Montes and Alto Douro, Vila Real, Portugal*
[6]*INESC TEC-INESC Technology and Science and University of Trás-os-Montes and Alto Douro, Vila Real, Portugal*

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Abstract: This paper shows the advantage of using different sensors such the Microsoft Kinect and Myo Armband to acquire movement description of the plantarflexion and dorsiflexion of the foot with the help of the quaternions and the EMG Myo sensor. For the integration of these devices, it was chosen Python to develop the algorithm and create an interface to aid the signal acquisition. This integration, enabling an accurate motion description as well as a scale of EMG signal, allow the possibility of quantifying the treatment of the people with equinus foot.

1 INTRODUCTION

Equinus foot is a condition that is characterized by the limitation of the dorsiflexion movement of the foot, in normal circumstances, the foot has the ROM (Range of motion) of 36º to the action of plantarflexion and 7º to dorsiflexion, according to (NASA, 2014). Because of the lack of necessary flexibility thus leaving the foot in an extended position. This condition may be either congenital or acquired, caused by tensions in the Achilles tendon or the calf muscles (Soleus, lateral gastrocnemius and medial gastrocnemius), and according to (Schmid et al., 2016), equinus foot is the most common issue regarding the human gait motility affecting patients with hemiplegic cerebral palsy, causing deviation of the pelvis, hence creating inconsistency in the gait.

The Equinus foot implies the lack of mobility of the patient. It is of extreme importance, to improve methods of treatment, considering gains in movement is linked to reduction of the incidence of adjacent problems, such as infections and osteoporosis, improvement of cardiac functions and even reducing the dependency of an accompanying person, besides positive psychological impacts in the process of rehabilitation (Costa et al., 2005) and (Vital et al., 2003; 2017 and 2018).

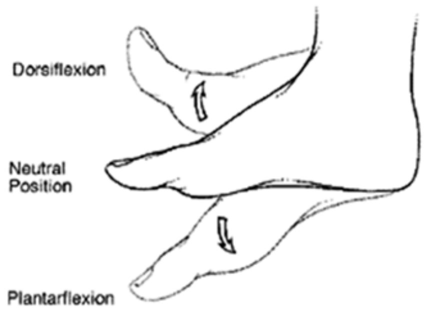

Figure 1: Movements of the foot - Rage of motion in the Dorsiflexion 7º and Plantarflexion 36º.

This paper proposes to create a way of quantifying the status of the patient as well as their improvement along the treatment.

[a] https://orcid.org/0000-0001-8928-0077
[b] https://orcid.org/0000-0002-2204-6339
[c] https://orcid.org/0000-0001-5862-5706
[d] https://orcid.org/0000-0002-5798-1298
[e] https://orcid.org/0000-0002-5177-2065

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1.1 Rotation and Translation Methods

There are many methods of describing the translation and rotation of a rigid body, among those, we shall briefly explain some of them as well as the reason we chose quaternions over the others. According to (Kenwright, 2012), the most used method of representations is the Euler-Angles, used to representing the orientation and translation through three angels possessing orthogonal axes (x, y, and z) we can achieve twelve combinations of sets of angles, and to work with angles we have to convert them into matrices. And while they are of easy comprehension, they suffer from the disadvantage of the angles changing by up to 2π radians, another problem is the Euler coordinates are not precise when interpolating near the Gimbal's Lock, which occurs when two sets of axes are aligned, turning them, in that moment in the same axis.

In the case of matrices, even though it is a more straightforward subject that students have early contact with, we have as the main problem the time to processes the amount of data, and the difficulty in visualizing in which axis, the rotation, and the angle.

1.2 Quaternions

Quaternions are hypercomplex numbers belonging to the numerical set $\mathbb{H}$, isomorphic to numbers in the numerical set $\mathbb{R}^4$. Such as complex number quaternions are defined by possessing both real and imaginary part, wherein real coefficients multiplied by components form the imaginary part: $\hat{\imath}, \hat{\jmath}, \hat{k}$. They are represented by the equation:

$$\hat{q} = q_0 + q_1\hat{\imath} + q_2\hat{\jmath} + q_3\hat{k} \tag{1}$$

Another representation is $\hat{q} = (S + \vec{V})$, where S represents the real part and V represents the imaginary part, when q_0 equals to zero we will call it pure quaternion, since it has just imaginary parts.

The operations of quaternions are responsible for rotation and translation. To rotate a pure quaternion $\hat{v}$ to an also pure quaternion $\hat{w}$ that have to use operator $|\hat{q}|$. And we also have to know the concept of a conjugate of a quaternion (Adorno, 2017):

Conjugate of a quaternion is defined as its real part minus the imaginary part.

$$\widehat{|q|} = \mathrm{Re}(\hat{q}) - \mathrm{Im}(\hat{q}) \tag{2}$$

So, the rotation will be represented by:

$$\mathrm{T} = \hat{v} \rightarrow \widehat{|q|} \rightarrow \hat{w} \tag{3}$$

$$\hat{v} = \begin{bmatrix}0\\1\\1\end{bmatrix}, \quad \hat{v} = \hat{\jmath} + \hat{k} \quad |\hat{q}| = \hat{k} = 1 \tag{4}$$

$$\hat{w} = \hat{q}\hat{v}\hat{q}^* = \hat{k}(\hat{\jmath} + \hat{\jmath})(-\hat{k}) = -\hat{\jmath} + \hat{k} \tag{5}$$

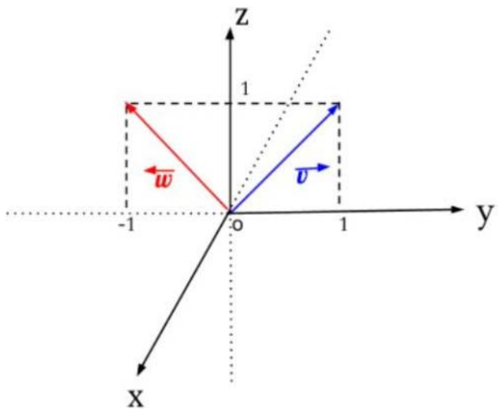

Figure 2: Quaternion rotation, rotation the quaternion v to the quaternion w.

2 MATERIALS AND METHODS

2.1 The Myo Armband

The Myo armband is a wearables gesture and motion control (Żorski and Pałys, 2016) that enables the user to control device such as computer, tablets and phones and it composed by nice axis-IMU with three-axis gyroscope, three-axis accelerometer, three-axis magnetometer, and eight EMG sensors, those sensor allow the Myo Armband to track gestures of the user through electrical signal.

Figure 3: Myo armband - EMG sensors numbered from 1 to 8.

2.1.1 EMG Signals

In this experiment, the Myo is used in the leg, and we are using the EMG sensors to record data from the muscles responsible for the plantar and dorsiflexion movement.

The EMG sensors measure electromyographic signals, and this method consists of a non-evasive technique that measures the electrical signals produced by the muscles during their contraction and relaxation, this technique was chosen because it performs the measurement directly in the muscles to be studied, both voluntary and will be recognized.

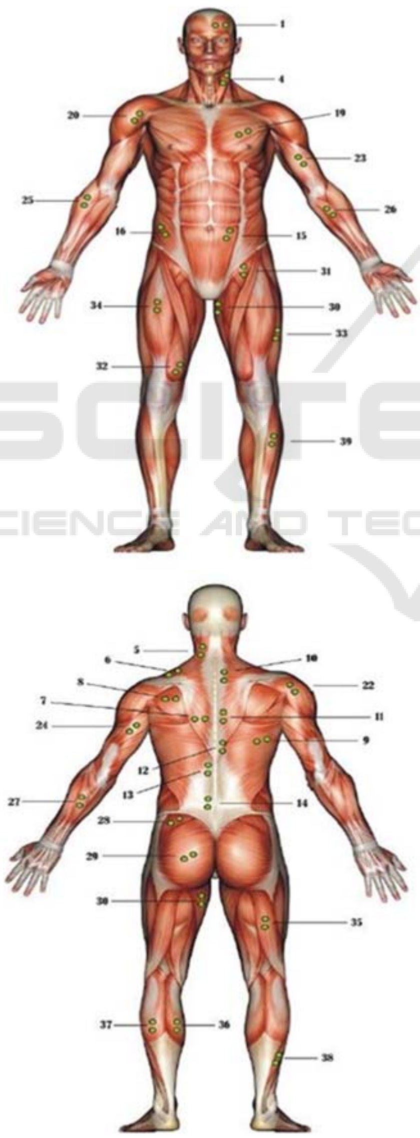

Figure 4: Optimal placement of the EMG sensors – 36-medial gastrocnemius, 37-lateral gastrocnemius, 38-Soleus and 39-Tibialis anterior.

Regarding the placement of the Myo Armband, according to (Florimond, 2010) the best position to place the sensors are in the muscles tibialis anterior, soleus, medial gastrocnemius and lateral gastrocnemius (Figure 4).

To control the test using Myo, we created an interface to simplify the acquisition of data stipulation a time of 1 minute, 30 seconds or 5 seconds, in the analysis done in this paper we used the time of 5 seconds. (Micael et al., 2013) and (Dias et al., 2014).

2.2 Microsoft Kinect

The Microsoft Kinect was firstly launched in 2011, and it brought a new way of playing video games, the user is now able to play without having to hold any peripherical device. According to (Pagliari et al., 2014), Kinect is a device that enables motion capture, among one of the advantages that Kinect brigs are official libraries and SDKs (Software Development Kit) which allow researchers to contribute to this technology. In this paper, we are using the SDK 2.0 published at 10/21/2014.

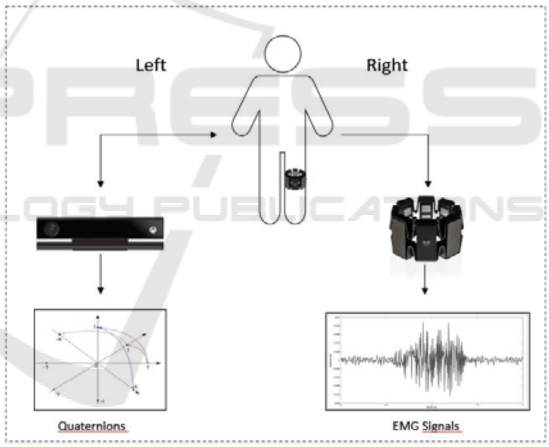

Figure 5: Representation of the interface Myo-Kinect.

The motion analysis nowadays is a field of interest among a variety of areas, and for medical application as well. The Microsoft Kinect, according to (Kalkbrenner et al., 2014) can be used in the evaluation of patient activity, posture as well as gesture recognition. Including 3D depth sensor and an optical camera, can be used to analyse angles and movement, enabling the acquisition of depth and even of quaternions in any given joint, the sequences of joints captured by the Kinect are shown in Figure 5.

Initially, we researched ways to extract data from Kinect and found some applications developed in Python, C # and C ++ languages. It was decided to use python using the library PyKinect2 due to its easy manipulation and quick configuration.

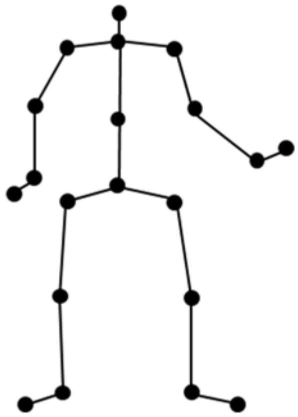

Figure 6: Sequences of joints captured by the Kinect.

After choosing the language and the application for Kinect, it was studied its operation of to extract data of position and rotation of each joint of the body read by Kinect along with the results of Myo (Figure 6).

3 RESULTS AND DISCUSSIONS

The capture of the quaternions is obtained by the motion capture of the Microsoft Kinect, while the subject, starting of the total plantarflexion (Figure 6) going to the total dorsiflexion., it is important to emphasize that the foot must be positioned as perpendicular as possible to the Kinect, the quaternions response is a 3D graphic and the unit used by the library we are using is in meters. And aiming integration with Myo armband, it is essential to set a correct position of the EMG sensor, sensor enumerated from 1 to 8.

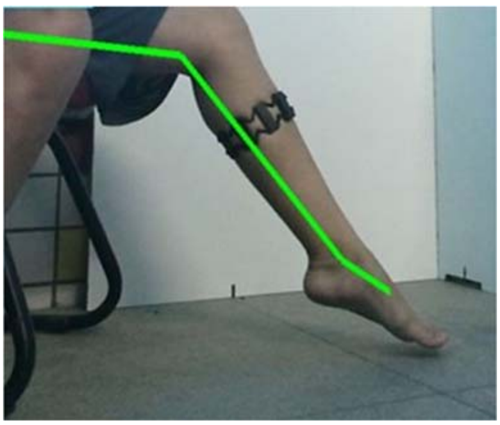

Figure 7: Motion capture of Kinect.

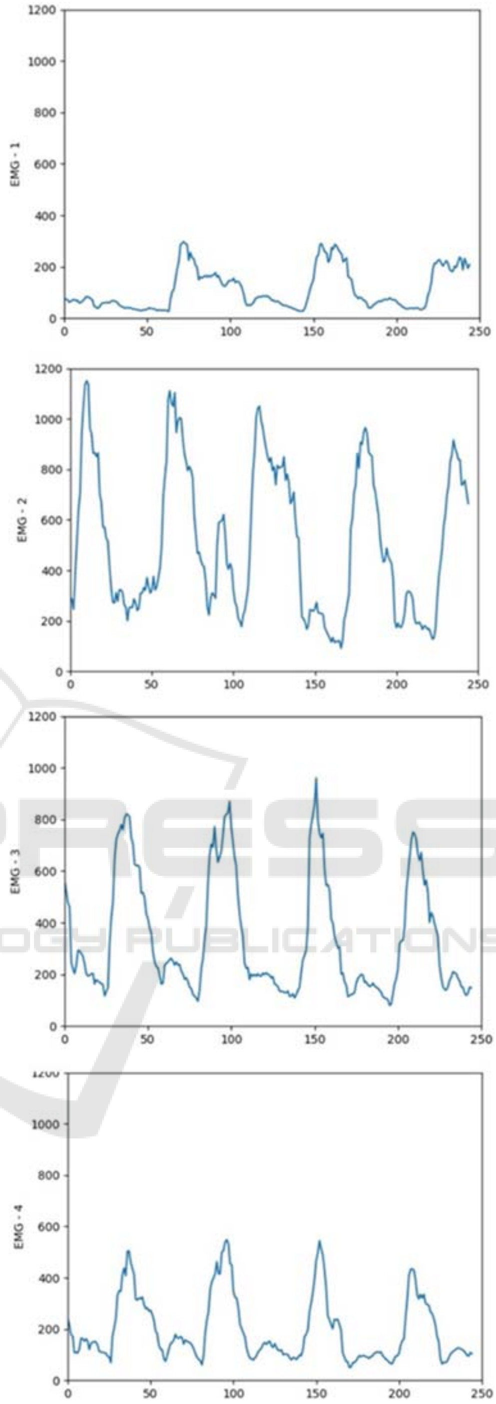

Figure 8: Representation of data – 3: soleus, 1 and 2: lateral gastrocnemius and 4: Tibialis anterior.

The EMG sensor 4 is representing data from the muscle tibialis anterior, sensor 5 serves the muscle soleus, sensor 3 and 4 are representing the medial gastrocnemius while the sensor 1 and 2 the lateral gastrocnemius. And for the results of the Kinect, we find this- graphic (Figure 10) representing the movement of the right foot joint, with the frequency of 30 Hz and 30fps and full HD camera. And we have the graphic of the motion in the axes X, Y, and Z showing in Figure 8.

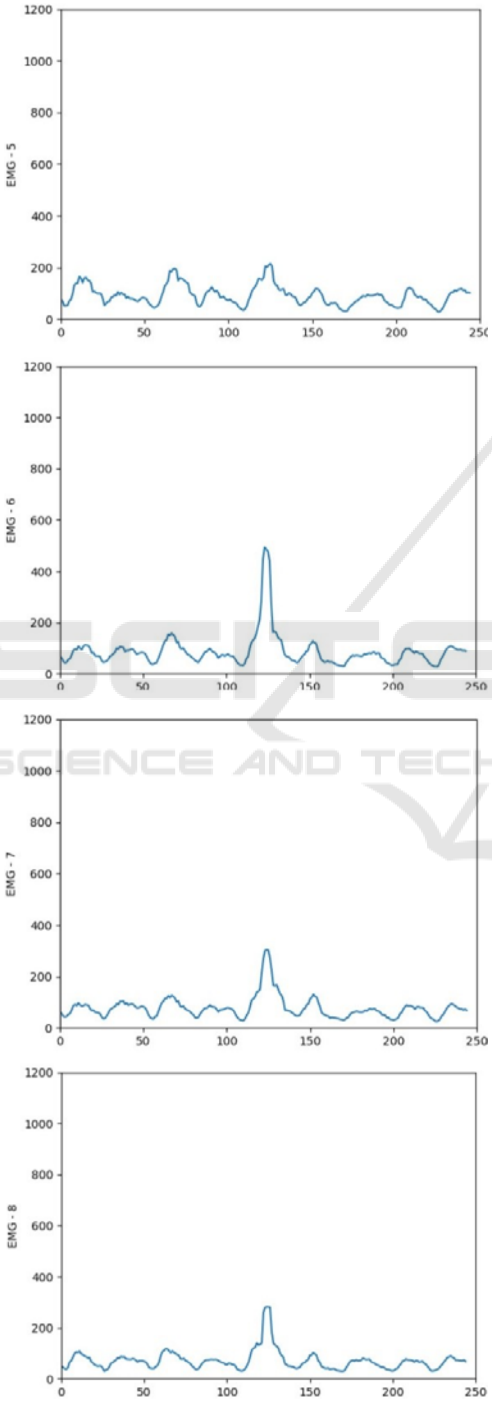

Figure 9: Representation of data –7 and 8 medial gastrocnemius.

Since quaternions can be generated both using kinect or using third part sensor such as IMU sensors, Żorski and Pałys, (2016) prove that the quaternions generate by the Kinect and IMU sensors in the Myo armband are similar, however they notice limitation in the IMU sensor resulting in a range of 70 – 80% of recognition of the gestures.

The IMU sensor were not used in this work because the gesture recognition it is built just for arms, however the EMG signal is possible to read even if it is not assigned to any gesture, and since the equinus foot has the characteristic of decreasing the intensity of the electromyographic signal, the improvement of the patient can be quantified by the increase of the read signal.

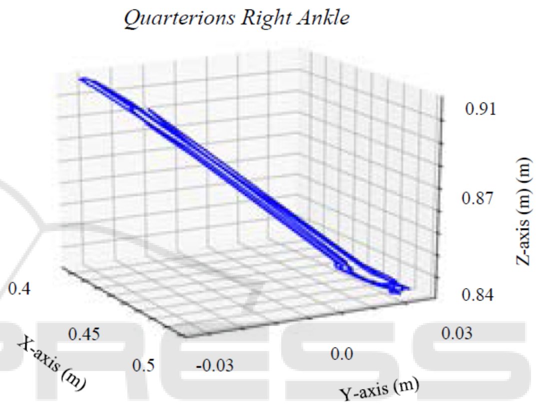

Figure 10: The trajectory of the right foot using the motion capture features of the Microsoft Kinect.

4 CONCLUSION

This paper proposed to integrate the motion capture features of Microsoft Kinect and the EMG sensors of the Myo Armband, and even though the Myo was not designed to be used in the leg and nonetheless this device is not primarily used to capture motion of the leg, the EMG sensor proved useful to bring a satisfactory accuracy, but in one hand there is the quality of the signal of the Myo EMG in the other hand there is the difficulty to apply any unit to its meseuramnets, so even though they show what occurs during the movement and it is possible to compere the results among them it was not possible to assign any unit.

Regarding the treatment of equinus foot with the integration of this two devices, thanks to the smoothness of the results of quaternions and the scale that we can acquire from the EMG sensor we can both describe the movement with accuracy and quantify the improvement of the patient.

In order to improve the data acquisition and aplication this process can be enhanced by using precise EMG sensors that allow unit readings and studying a more precise way of image caputure.

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