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Assessment of the laterality effects through forearm reaction forces in walker assisted gait

A. Abellanas[a]*, A. Frizera[a], R. Ceres[a], R. Raya[a]

[a]*Bioengineering Group, IAI-CSIC (Consejo Superior de Investigaciones Científicas), Ctra. Campo Real km 0.200 Arganda del Rey, Madrid, 28500 Spain*

Abstract

In this paper it is presented a study of the laterality components in walker assisted gait for elderly or disabled people. This work relies on the measurement of forearm reaction forces in the SIMBIOSIS platform and their relation with the lateral movement of Centre of Gravity (*CoG*) of the user body during gait with the walker.
The discussion presented shows that the reaction forces of the forearm have a strong correlation with the lateral movement of *CoG*, and suggests that *CoG* and *FRF* have proportional relationship particular for each subject and for each gait speed gait.

Keywords: 3D system force sensors; displacement of CoG; partial body weight support.

1. Introduction

The present work has been developed in the framework of the SIMBIOSIS project [1] in which the interaction between user and rolling walker (wheeled walker) during assisted gait is studied. The SIMBIOSIS platform is a walker based on a modified commercial rollator (Fig. 1.a) for gait modeling and evaluation. The main mechanical modification introduced is the addition of a structure for partial body weight support and the autobrake motor system to control the movement of the walker. These modifications were designed to increase the amount of weight that can be supported by the rollator improving, at same time, the dynamic stability during gait.

As it is found in the literature [2], rollators are the most appropriate walkers considering the maintenance of natural gait for subjects with pathological gait, such as elderly people. However, such devices are not so good respecting to stability and weight support. The stability and reduction of fall risk will be enlarge by motor traction and intelligent control, that is the next task to do in the project.

In the literature, there are some studies related with the reaction forces in the handles of the walker [3] that analyze forces and torques to estimate the main events of the gait cycle such as toe off, heel strike, step time, etc [4]. However, the relationship between reaction forces due to weight support and displacement of CoG of the user body has not been yet well studied.

* Corresponding author. Tel.: +34-91-817-19-00;
E-mail address: andres@iai.csic.es

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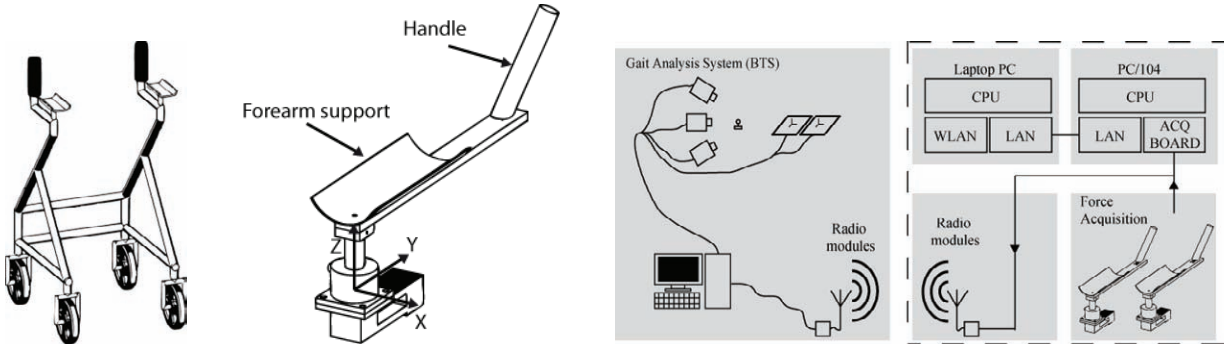

Fig. 1. (a) The modified structure of the rollator with the new armrests; (b) Detail of the armrest placed with the 3D system force sensors; (c) Diagram of SIMBIOSIS architecture.

This assistive solution is proposed to improve three important factors of human gait: the (gait) pattern, the stability and the support of partial body weight [5-6]. In particular, in this paper, it is studied the lateral movement of the *CoG*, that is closely related to stability and gait pattern.

2. Method

2.1. Experiments

To study these effects, twenty experiments have been analyzed. The experiments were made walking in straight line through the laboratory of gait analysis walking with the instrumentalized walker. The laboratory is 7x1.5 meters. In this space in each experiment the user can be made seven or eight steps.

2.2. Architecture

In order to study the interaction force between user and walker one 3D system force sensors, Fig. 1.b, for each armrest has been included for measuring the human-machine interaction forces. The 3D force sensors consist of one MBA400-200Lb biaxial sensor [7] and one TPP-3/75 load cell [8] with their respective amplifiers for each forearm. The biaxial sensors are used for measure the X (lateral component) and Y (advance component) components. The load cells measure the Z component. These force sensors are integrated in a real-time architecture based on the Matlab® Real-Time xPC Target Toolbox. The sensorial configuration has been developed taking into account the amplitude of the forces applied on the walker's structure through the forearm and the natural frequency of human gait.

In addition to recording the data of the forearm reaction forces, the *CoG* has been determinated by Movement Analysis Systems of BTS Bioengineering (six infrared cameras) [9] along with the protocol of Davis [10].

In Fig. 1.c it is shown a diagram of the architecture of the SIMBIOSIS project. To complete the system description, it must be commented the synchronous system that consists of in two radio modules. The module embedded in walker work like emitter and the other is connected to I/O port of Gait Analysis System.

2.3. Procedure

The signals obtained by the force sensors are sampled at 100Hz, however, the frequencies of the cyclic parameters during normal gait have frequencies less than 2 Hz. Due to this, that signals are passed through band pass filter, that filtering frequencies below 0.5 Hz and greater than 2Hz, by zero-phase digital filtering. Low frequencies are filtered to avoid e.g. constants effects of discharges more weight in one armrest than the other. The filtering of high frequencies is due to the vibrations of the architecture and electrical noise.

Fig. 2 shows the raw signals for each arm (continuous line) and the results of the filtering (line with circles).

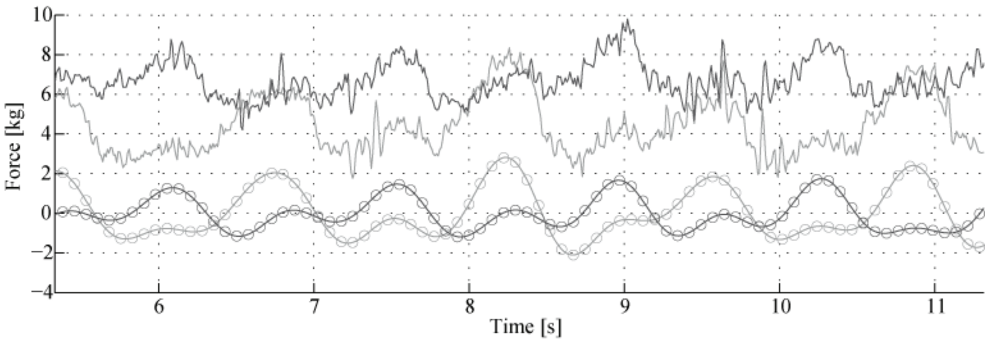

Fig. 2: Raw signals for each arm (continuous line) and the results of the filtering (line with circles). Black and grey lines correspond with left and right forearm force respectively.

3. Discussion

In Fig. 3 it is shown an example of the one of the experiments. As can be seen there are a strong temporal correlation between Total Forearm Reaction Force (*FRF_T*, black line) and lateral *CoG* (grey line). Note that the footprints represent the time when left and right foot (black and grey respectively) are contacting.

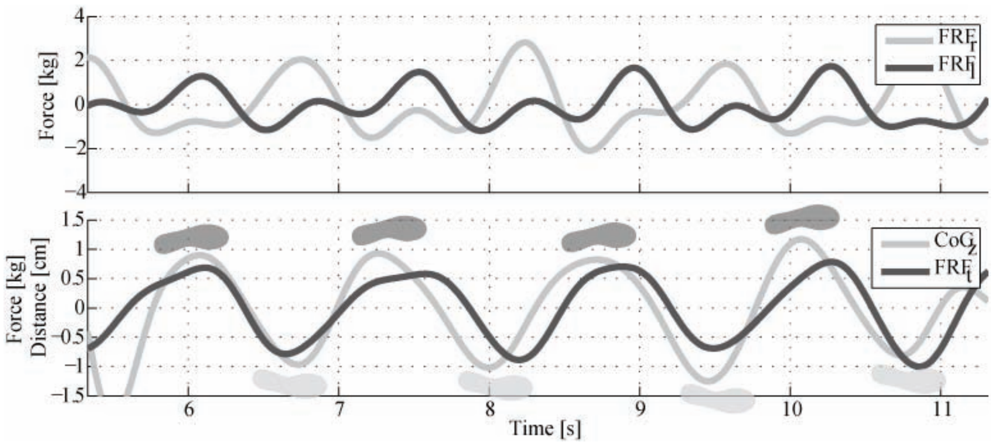

Fig. 3: FRF_r and FRF_r and CoG lateral evolution and FRF_T.

The temporal shift between both signals is due to the forearm reaction forces have two main components (a) the component relative to the body weight discharged into armrest and (b) the component relative to acceleration of the user body, these accelerations become their maxima later that the *CoG* become its maxima, this is the main reason of exists this shift. In the literature there are several researches that studies by inverse dynamic of the lower limbs during gait, but there are very few of they, that study the inverse dynamic of the upper limb.

These results are interesting because from the natural interaction between user and the walker (to push it with their arm and hands) it is possible to know the qualitatively the laterality of the *CoG*.

4. Conclusions

During gait, the *CoG* of the user's body presents an oscillatory vertical [11] and lateral movement [12]. Both movements are related and decrease when a walker is used. The measurement of the movement of *CoG* of the user during gait is correlated with the laterality component and is strongly related with gait stability. The knowledge o position of *CoG* is vital to control the stability of the gait assisted devices.

For the study of the displacement of the *CoG* in gait analysis, usually photogrammetry is employed. Nevertheless, such technique of measurement is not ambulatory and not suitable for a continuous analysis in wide environments.

In this work it is shown that there is strong relation between the lateral displacement of the *CoG* and the forearm reaction forces measured by a 3D sensor. The knowledge of this lateral displacement offers relevant information about asymmetries, postures, etc. that are important in order to define the normal or pathological patterns of gait and to set up rehabilitation tasks.

Further to this qualitative estimation, partial results have been obtained (only five experiments for the same subject has been studied) which suggest that *CoG* and *FRF* have proportional relationship particular for each subject and for each gait speed gait.

Acknowledgements

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