Experimental Approaches Regarding a Children Rehabilitation Test Bed

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Abstract. Through this paper there are presented some approaches regarding the experimental research of a walking test bed especially designed for children with ages between 4 to 6 years old. The proposed test bed consists of an exoskeleton and a treadmill. The exoskeleton has six actuation units for motion assistance through chain transmissions of the entire locomotion system. Thus there will be performed experimental tests in specific laboratory conditions, by having in sight reference motions of healthy subjects during walking activities. The obtained experimental results will validate the proposed prototype design, based on comparative analyses.

Keywords: human lower limb · mechatronics · exoskeleton

1 Introduction

In present many rehabilitation systems were designed especially for human locomotion rehabilitation processes and these addresses to adults and elderly persons. In case of children locomotion rehabilitation processes, these systems are limited due to the fact that these are in a continuous growth process. Thus, specific companies have to design parameterized rehabilitation systems which will be adapted for any child's age and anthropomorphic data. By referring at these, it can be mentioned appropriate research work in this field like [1–3]. In general, the designed children rehabilitation systems need to have in their structure modular devices in order to adapt and to improve the locomotion system for satisfying the ability to walk in case of children with ages between 4 to 6 years. By having in sight the analyzed models mentioned as a state-of-the-art process, it can be remarked that it is necessary to develop and perform experimental analyses of a child locomotion system. Thus the designed experimental test bed was developed by having in sight rehabilitation systems presented in [4, 5] according with the anthropometric parameters of human locomotion system [6].

By having in sight the purpose of this proposed research work, it is necessary to start with an experimental analysis of children locomotion system which this will be presented in second section of this comparative analysis. This will give access to a database which serves as input data for the rehabilitation walking test bed presented in third section. It is well known that the proposed research work is a complex one, thus the aim is to achieve

I. Dumitru et al. (Eds.): ICOME 2022, AHE 15, pp. 197–204, 2023.
https://doi.org/10.2991/978-94-6463-152-4_23

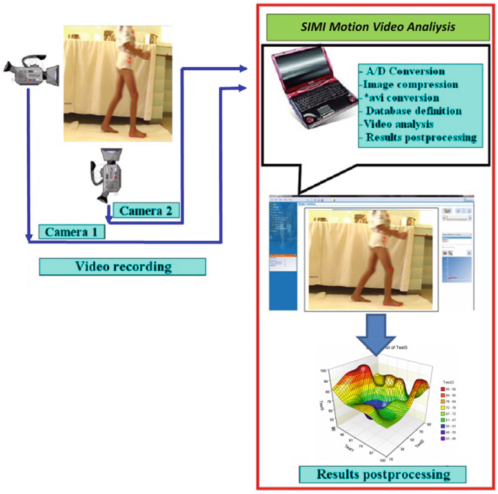

Fig. 1. SIMI Motion workflow [7].

a comparative analysis between a healthy subject and the proposed children walking rehabilitation test bed for a case study and only for the right child lower limb. These are described in the fourth section of this research. Finally it can be conclude that the designed rehabilitation test bed can be used for a four years old child which was born with congenital disorders on the right human lower limb.

2 Child Lower Limb Experimental Analysis

For the experimental analysis, a video-analysis equipment was used. This equipment called SIMI Motion can be found in one of the University of Craiova laboratories namely Faculty of Physics and Sports [7].

The performed experimental test was done according with a literature overview from [6, 8, 9]. The children locomotion system experimental analysis was performed on a number of 10 children with the age between 4 to 6 years old. The aim of this analysis was to obtain a database which consists on angular amplitudes from hip, knee and ankle joints during walking activity. Thus, in this research frame only essential data were extracted especially for a child of 5 years old and it was considered as a case study. These data consists of right hip, knee and ankle angular amplitudes laws and it serves for a comparative analysis of the designed exoskeleton test bed performed in laboratory conditions.

The experimental analysis principle consists on attaching of a three reflective markers for each child lower limb. These markers are centered on the interest joints and it will represent the equipment target for tracking them during walking activity. The experimental analysis workflow is shown in Fig. 1. A snapshot during walking activity, performed by the proposed child is represented in Fig. 2, where it can be identified the attached markers.

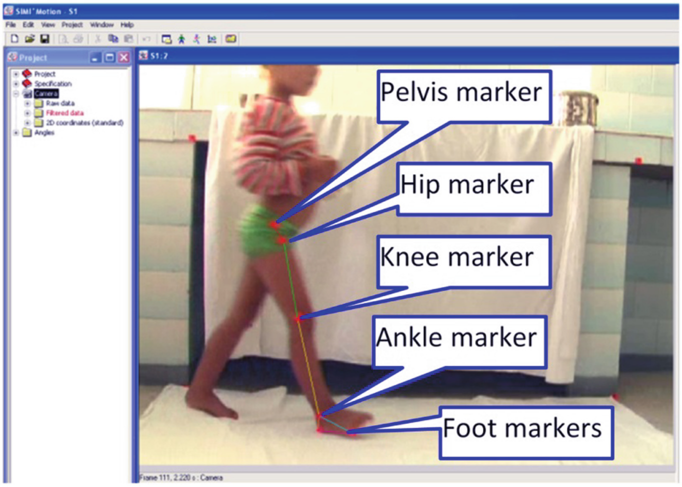

Fig. 2. Snapshot during experimental analysis

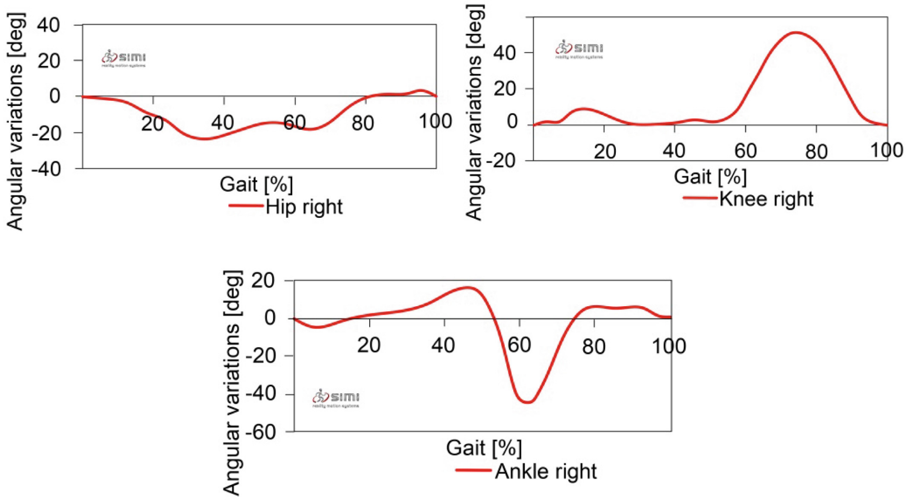

Fig. 3. Acquired angular amplitudes for right hip, knee and ankle [degrees] vs. Gait [%] during a test

During experimental analysis, the proposed child was made 4 steps during walking activity in a time interval between 0 to 2.4 s. The SIMI Motion software records the entire vide sequence and in this case will be retained only a single gait which was performed in 0.8 s. Thus a complete gait was made between 1.6 to 2.4 s. This time period is important for walking rehabilitation test bed setup and also the joints angular amplitudes developed by the targeted joints. Thus in Fig. 3 are represented the angular joints variation laws which are helpful for the comparative analysis.

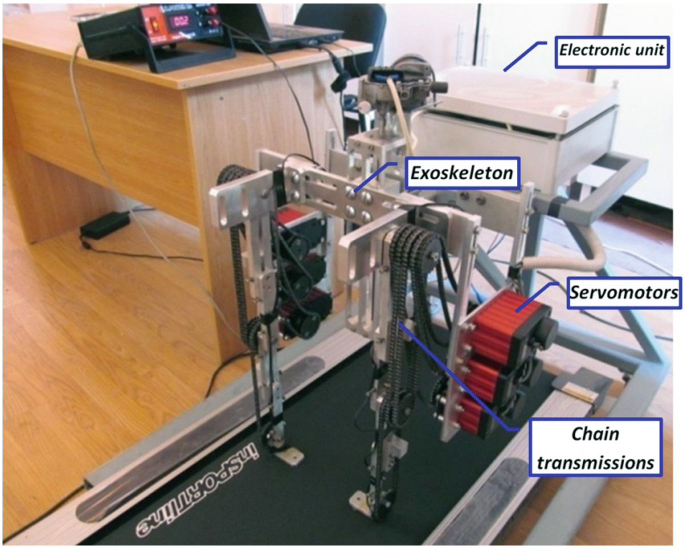

Fig. 4. Children walking rehabilitation test bed prototype – view no.1.

By having in sight the reported diagrams in Fig. 3, it can be remarked that there were obtained angular amplitudes represented through smooth curvature for the right child lower limb, namely hip, knee and ankle joints during one gait. Thus, for hip it can be observed that this has an interval between 0 to -20 degrees. As for the knee this is between 0 to 45 degrees and in case of ankle joint the reported values can be found between -42.5 degrees and 17.5 degrees.

After this experimental test it can be conclude that the hip motion law must have the same cure path for programming the proper servomotor and this should have a value of 20 degrees. In case of knee the servomotor should work with a maximum of 45 degrees and in case of ankle servomotor, this will have a value of 25 degrees during walking by keeping the same curve paths as the ones reported in Fig. 3.

3 Children Locomotion Rehabilitation Test Bed

The designed walking rehabilitation system dedicated to children between 4 to 6 years old was designed in University of Craiova, Faculty of Mechanics laboratories. Several components were manufactured from lightweight materials like aluminum alloys and plastic, in order to minimize the entire structure weight for having smooth motions with small inertia momentums during functionality. The designed prototype it is presented in Fig. 4, respectively Fig. 5 and it can be remarked that this has four main subsystems namely a proper rehabilitation exoskeleton, an actuation system based on chain transmissions, the command and control unit and a threadmill.

The exoskeleton and actuation system are mounted on a rigid frame which will guide the child subject in the pelvis zone. It can be remarked that this is a complex test bed and it has the ability to adapt its dimensional parameters to any anthropometric parameters

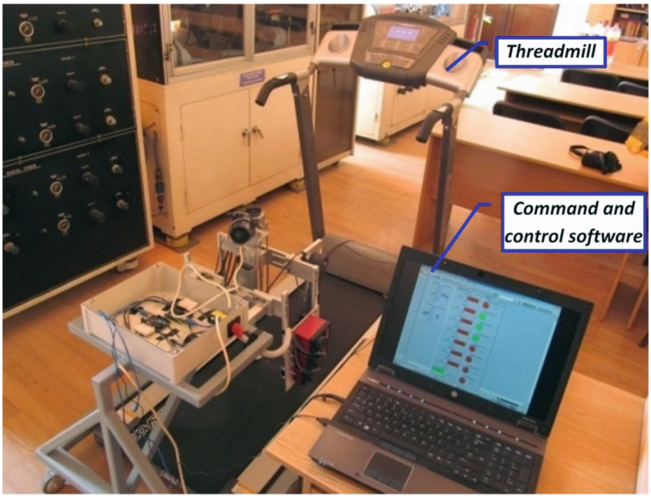

Fig. 5. Children walking rehabilitation test bed prototype – view no. 2.

specific to children between 4 to 6 years old. The actuation system has in its structure six TORXIS servomotors which can develop a nominal torque of 30Nm. These can support any angular motion laws implemented through a controller type Orangutan SVP. The motion was transmitted from each servomotor to a chain transmission type SKF.

The walking rehabilitation test bed has at each foot level pressure sensors for monitoring in a continuous mode the ground contact between exoskeleton and the threadmill.

By having in sight the developed prototype, this was designed by considering the following initial conditions: to be simple and lightweight; to offer the possibility for adapting this at any anthropometric parameters of a child with an age between 4 to 6 years; to have the possibility for adapting specific therapeutically procedures at the child locomotion system level; to perform motion almost appropriate with the natural ones during child gait; to extend the programming algorithms in case of the servomotors for different motion laws based on user friendly interface; to have flexible systems for fixing the exoskeleton legs on the child lower limbs; to suspend the entire structure and the exoskeleton weight should not be transmitted to patient during walking; continuous patient monitoring and also for the kinetotherapy specific exercises; using a minimum number of therapeutic personnel during functional recovery locomotion system exercises.

4 Experimental Comparative Analysis

The experimental analysis was performed in laboratory conditions without involving any human subject. The aim of these experimental tests was to validate the conceptual solution of the proposed experimental walking test bed with the future child subject which has congenital disorders on the right lower limb. The controller in this case was uploaded with angular variation motion laws obtained in experimental way, by converting them

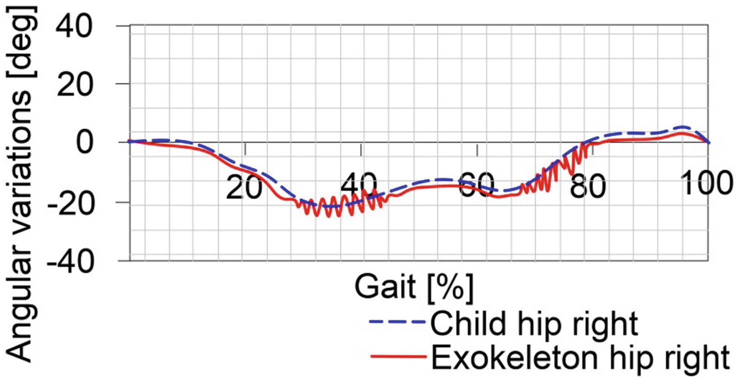

Fig. 6. Hip angular amplitude comparative case (child vs. exoskeleton) for a complete gait

into polynomial forms. The experimental analysis was done by having in sight a similar procedure like the one presented at the healthy child experimental analysis. Thus, it was used the same video-motion equipment namely SIMI Motion, at it was respected the time interval during a single gait. This time interval was from 0 to 0.8 s and actuation sequence was done for a 4 complete steps and after this the entire cycle was reloaded. Another important aspect is the fact that each exoskeleton leg enters in contact with the treadmill.

After analyzing the recorded video sequences important data were obtained for each joint from exoskeleton right leg. The diagrams obtained in a comparative mode with the ones from a healthy subject are shown in Figs. 6, 7 and Fig. 8.

By having in sight the reported diagram from Fig. 6, it can be remarked that the obtained motion laws are very similar. The exoskeleton right leg has similar behavior like the child right lower limb and also the obtained values are the same like the obtained ones when it was completed an experimental analysis of a case study. A major remark is the one of identifying two areas where on the reported diagram can be seen an abnormal trajectory for the exoskeleton right leg. The present spikes on these zones are produced by a smaller stiffness of the exoskeleton components when contact between foot and threadmill occurs. First one can be found between 26 to 42% from a complete gait. Other one is between 64 and 79% due to the limitation of the exoskeleton leg when the foot is in the air.

In case of the reported diagram from Fig. 7 the angular knee amplitude has a similar behavior like in the hip case. Thus the remarks are valid also for this joint.

By having in sight the ankle joint behavior it can be remarked that the identified zones with spikes are much larger than the ones reported in Fig. 6 and Fig. 7. Respectively first zone is between 21% to 52% and the second zone is between 67% and 79.5%.

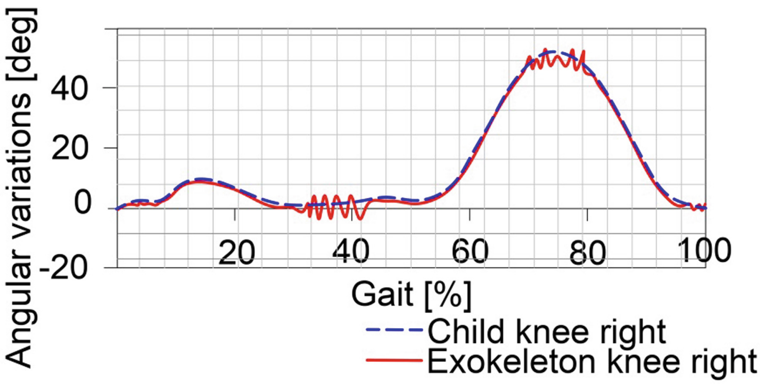

Fig. 7. Knee angular amplitude comparative case (child vs. exoskeleton) for a complete gait

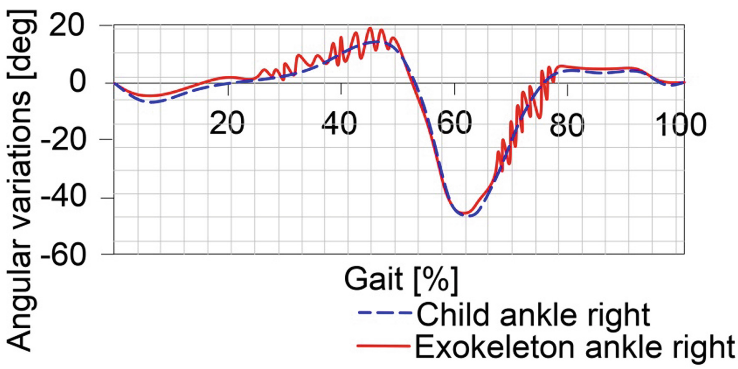

Fig. 8. Ankle angular amplitude comparative case (child vs. exoskeleton) for a complete gait

5 Conclusions

In this paper, the characteristics and functioning of an anthropomorphic rehabilitation system for walking activities is analyzed through an experimental experience for an application in assisting disable children during walking. The robotic system has actuators for each human lower limb joints, from which the motion is transmitted to joints with the help of chain transmissions. Tests have proved the movement of this robotic system as suitable for locomotion rehabilitation actions, because it behaves like child locomotion during walking in terms of trajectory and acceleration.

Therefore a prototype was tested and validated for a case study of a four years old child with congenital disorders. The comparative analysis demonstrates through this case study, that the obtained prototype can be implemented in other case studies which involves rehabilitation procedures in case of children locomotion system.

In a near future, this system can be modified in order to be autonomous one and to assist disable children. Also its functionality can be modified and can perform specific therapeutically procedures dedicated to human lower limbs rehabilitation.

Acknowledgement. This work was supported by the European Social Fund within the Sectorial Operational Program Human Capital 2014–2020 and by the grant of the Romanian Ministry of Education and Research, CCCDI – UEFISCDI, project number PN-III-P2-2.1-PED-2019-0937, within PNCDI.

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