Measurement of Human Walking on Sagittal Plane for Exoskeleton Walking Pattern Generation

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Abstract

Researchers have been worked on exoskeletons and active orthoses since 1960s. There are many competitions on these searches area. One of them is Human Exoskeleton Assistance System Prototype (HEASP) that is developed at Dokuz Eylül University. HEASP's goal is to assist one leg extremity persons. In this paper, the capturing of human walking parameters on sagittal plane is introduced. These parameters used for walking pattern generation and making pattern decision control strategies on HEASP.

1. Introduction

Human exoskeletons development was began for military purpose. Especially, United States Defense Advanced Research Agency (DARPA) has sponsored many of projects [1, 2]. At the same time, other programs have introduced different purposed exoskeleton systems [3-5]. These entire projects, exoskeleton devices are body wear systems by operated healthy person. Some researchers, different from others, are interested in the term active orthoses is used to help a leg pathology persons [6, 7]. In other words, these exoskeleton devices are assistive devices for especially lower limp extremities [8].

Human Exoskeleton Assistance System Prototype (HEASP) is an exoskeleton device that is developed at Dokuz Eylül University (Fig.1).

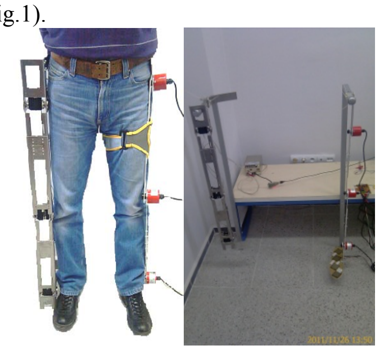

Fig. 1. Human Exoskeleton Assistance System Prototype (HEASP)

HEASP is built to assist a person has one leg extremities. Prototype basically consists of two parts. First part is a powered robotic leg that is worn on extremity leg; second part is a joint angle and foot force measurement system that is mounted on healthy leg.

Walking pattern generation is an important issue of exoskeletons. Generally, Exoskeleton walking pattern parameters were obtained by measuring during human walking. In this study, a joint angle and foot force measurement system is evaluated.

This paper presents human walking on sagittal plane and the joint angle and foot force measurement system in Section 2. Measurements of human walking parameter are given in Section 3. Using of walking data and conclusion are given Section 4 and Section 5 respectively.

2. Human Walking on Sagittal Plane

Human body is very complicated skeleton structure. Creating dynamic model like a human is not easy. Therefore a simplified model is used for measuring walking parameters and running robotic leg [9]. Human motion is examined on three planes (Fig.2). Human upper body has 12 degrees of freedom (DOF). For each leg, there are 3 DOF in the hip joint, 1 DOF in the knee joint, and 2 in the ankle joint. If one inspect on sagittal plane each joint has a one DOF.

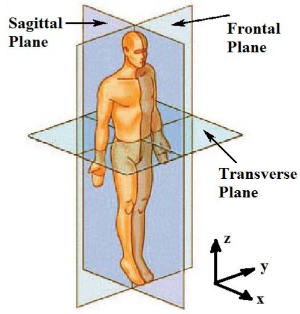

Fig. 2. Human body planes
(www.training.seer.cancer.gov/anatomy/body/terminology.html)

Travers and frontal plane movement can be ignored due to a big joint changing on sagittal plane. With these simplifications, human walking is only interested and measured on sagittal plane.

For this purpose, the joint angle and foot force measurement system was built seen in Fig.3. It has a magnetic encoder for each joint and force sensors on each foot. While magnetic encoders are collecting joint angels changing, foot sensors are determining ground reaction forces instantaneously. Collecting data cannot be used for the HEASP because its kinematic structure is not the same as human anatomy. Therefore, data was analyzed and mapped for generating final walking pattern.

Fig. 3. The joint angle and foot force measurement system.

3. Measurement of Walking Data

Qiang Huang et al. [9] worked to biped walking on sagittal plane at their research. They showed that foot and hip trajectories determines the walking characteristic. Also kinematic solution of joint angles can be solved by invers kinematic with using these trajectories. Therefore, foot and hip trajectory parameters are focused on, when measuring human walking data.

Due to the ethical considerations, a limited number of persons tested for trials. Fig.4 shows that the right joint angle changes on sagittal plane. Also the foot contact forces with joint angles are shown in Fig.5.

Force data shows that when the foot heel touches the ground and the foot toe leaves from the ground. In other words, it represents walking step cycles. Needed parameters, such as, the period for walking step, the period of the double-support phase, step length can be calculated. For this purpose, every step is sort out and mapped shown in Fig.6.

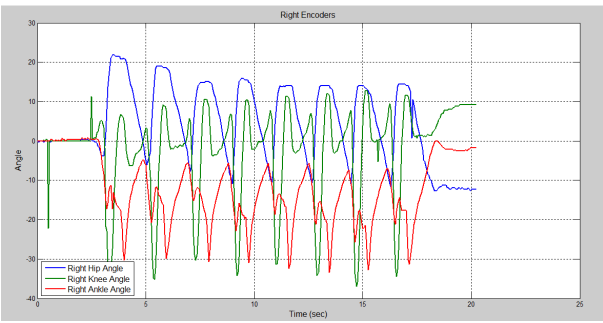

Fig. 4. The right joint angle changes on sagittal plane.

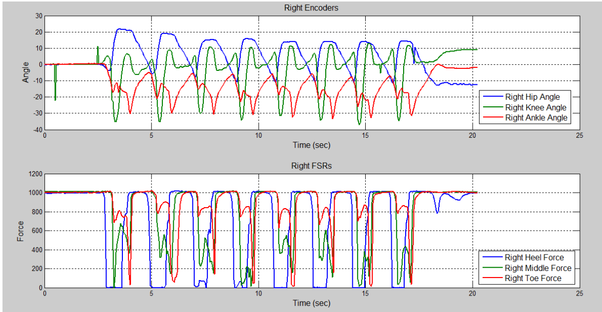

Fig. 5. The foot contact forces with joint angles.

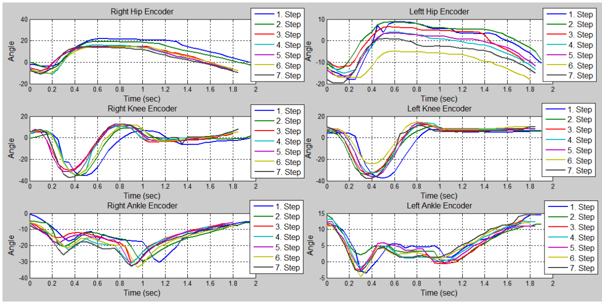

Fig. 6. The foot contact forces with joint angles.

The parameters shown in Table.1 are reached by analyzing walking data and finding average value.

Table 1. Some walking parameters of one step

Ds	Tc	Td	Ho	Lo	Hmax-Hmim
40 cm	0,8 s	0,15 s	1,5 cm	16 cm	60 cm

Where, Ds is the length of one step. The period for one walking step is Tc. Td is the interval of the double-support phase. Lo and Ho are the position of the highest point of the swing foot ankle that is important if there are obstacles in environments. Hmax-Hmin demonstrates to differences between hips maximum and minimum position when walking.

4. Using of Walking Data

Measurements of walking data are in use two purposes. First, it is used for identifying the characteristic of walking who wears the HEASP. It is called a preparation of walking and determinates the walking patterns generations for a powered robotic leg. Second is called the real time decision-maker which is used for choosing which walking pattern will be use at next step. In other words, the joint angle and foot force measurement system on healthy leg says the powered robotic leg which pattern should be used.

5. Conclusions

In this paper, measurement of human walking parameters and usage of these parameters on exoskeleton system HEASP have been presented. The joint angle and foot force measurement system was built for capturing human walking characteristics. Walking data captured from a limited number of persons were mapping and processed for HEASP by neural network based real time decision-maker which synchronizes simulated patterns to human motion. Results also are used for a preparation of the walking patterns generations successfully.

Although the walking is a little bit mechanics, this method prevents unbalanced conditions, especially with inertial balance control support in whole system. Active inertial balance feedback and control option may not require extra support stick equipment need in the next studies.

As a future work, new smaller and more effective wireless data capturing system will be developed at second phase of project in order to develop ergonomic to the user.

6. Acknowledgment

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7. References

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