Chapter 2

Investigation of Human Locomotion With a Powered Lower Limb Exoskeleton

Sergey Fedorovich Jatsun
Southwest State University, Russia

Andrey Yatsun
Southwest State University, Russia

Sergei Savin
Southwest State University, Russia

ABSTRACT

In this chapter, the lower limb exoskeleton is studied. The roles of the exoskeleton both as a measurement device for studying human locomotion and as an assistive device that restores the human ability to walk are discussed. Particular attention is given to the investigation of the role of the pressure sensors and other devices that allow us to measure normal reactions at the contact points with the supporting surface and also detect these contacts. The way the geometry of the supporting surface affects the sensors system of the robot is considered, and new designs for feet sensor system are proposed. These include elastic foot, a foot with actuated sensors, and a foot with spring-damper systems.

INTRODUCTION

Nowadays there are tens of millions of people who live with the injuries of the musculoskeletal system. It is often, but not always, possible to restore the function of musculoskeletal system with special training devices (Bogue, 2009; Mikołajewska & Mikołajewski, 2011; Tung 2013). One of the ways to restore walking ability to the patient is based on the use of lower limb exoskeleton, which allow the user to perform complicated motions, such as verticalization, walking and others (Bogue, 2015; Ferrati et al., 2013; Pons, 2008; Carpino et al., 2013).

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The development of devices that allow the user who is suffering from a dysfunction of musculoskeletal system to move is being done in USA, Japan, South Korea, Germany, Russia and other countries. While the attempts to create exoskeletons had been made for a long time only relatively recently there had been a progress in creating vertically stable prototypes. One of the main design issues is ensuring the vertical balance of the system (Barbareschi et al., 2015; Wang et al., 2013; Jatsun et al., 2016a, 2016b; Panovko et al., 2016). Because of this issue the development of lower limb exoskeletons needs to be based on theoretical studies of the vertical balancing problem and on walking simulation results.

At the moment there are two different types of exoskeletons that gain prominence. First type represents combined motion scheme, where the vertical balance is achieved using crutches help by the exoskeleton’s user. Examples of such devices are Ekso Bionics, ReWalk, and ExoAtlet (Esquenazi et al., 2012; Gwynne, 2013), developed and produced by laboratories and commercial companies.

This motion type requires the user to be well trained, having developed shoulder and arm muscles, thus limiting the number of patients who are capable of using it. It also impedes the walking comfort.

The second type of exoskeletons is different as there the exoskeleton itself allows the system to remain vertically balanced, without requirement for the user to play any active role in the motion. Therefore this type of exoskeleton does not require the use of crutches. Such devices have been developed by company Rex Bionics, shown in Figure 1 on the left (Viteckova et al., 2013; Contreras-Vidal & Grossman, 2013), and at the Robotics and Mechatronics lab at Southwest State University, where ExoLite lower limb exoskeleton had been developed, shown in figure 1 on the right (Jatsun et al., 2015, 2016c, 2016d). These two devices allow the user to walk comfortably without crutches.

These exoskeletons can be used to perform verticalization, walking straight forward and backwards, walking upstairs and performing other types of motions while leaving the hands free (Jatsun et al., 2016e, 2016f, 2016g). Development of this type of exoskeletons is a difficult task as their development is based on the study of human walking biomechanics.

**Figure 1. General view of Rex and ExoLite exoskeletons**