Development of Extremity-Exoskeleton System with EEG signals with Mechatronics Approach

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Abstract

Lower limb rehabilitation robots (lower back exoskeleton) are one of the robotics fields where research is still ongoing to find solutions to the problems of paralysis and movement restriction caused after an accident as a result of various reasons. Hemiplegia, commonly known as stroke, causes loss of movement or restriction of movement in patients with the right and left parts of the body being affected as a result of blockage in the cerebral vessels. Physical therapy and rehabilitation are very important in such disease situations. For hemiplegic patients, the rehabilitation applications applied include exercises for strengthening of muscles, occupational therapy, treatment determined according to the patient, such as hip and knee joints, physical therapy such as exercise methods and speech therapy, rehabilitation methods and devices used in applications. When evaluated from this point of view, it is important to use walking robots in the treatment methods we mentioned above. In this thesis project, Walking robot (Rehabilitation Robot or Exoskeleton Robot) is used for individuals with congenital joint disorders, for individuals with disabilities, for individuals who have difficulty in movement and walking as a result of subsequent hemiplegia, fall, slip, injury, for occupational diseases related to lower extremities in workers working in the business sector, for individuals with lower skeletal system in the construction industry, paint industry and heavy-work industry. It is a robot model that can also be used for occupational diseases related to lower extremities in workers working in the business sector, for individuals with lower skeletal system disorders due to natural disasters such as work accidents and earthquakes, and for individuals with walking and movement restrictions. For this reason, walking robot (Rehabilitation Robot or Exoskeleton Robot) will be studied in the research. By creating walking robot design, simulation and prototype, it is aimed to create products and be useful to the sector.

Keywords: lower limb-exoskeleton, rehabilitation robot, engineering design, manipulator, EEG reader

1. Layout

The lower extremity of the human being is separated into three parts: the thigh, the shins and the foot. In healthy individuals, the lower extremity section has the dexterity to act the joints comfortably with natural freedom. For individuals with confined mobility, natural freedom of motion and joint spacing may alter depending on the injuries exposed. For this reason, these robots, which we specify as exoskeletons, come into prominence when manpower support is required in rehabilitation practices. Especially in recent years, it has been noticed that the functionality of the legged robots, which we have started to see in various media, can be increased according to the difficulties encountered, and it has revealed the fact that the determined targets can be achieved. However, these robots are still being researched and studies are being conducted in experimental settings.

Originally thought of as the bionic skeleton, which began with drawings, this structure has been the subject of many science fiction or fantasy fiction books and films [5] in the past, and continues to be the subject of research in many respects for researchers working in the fields of Mechatronics, Electrical-Electronics, computer and Biomedical Engineering. When it came to the agenda for the first time, this robotic model which resembles an exoskeleton was a running aid made by Yagn and patented in 1890 [6]. This model, which consists of a simple spring, has emerged as a model that aims to run and jump by working similar to the legs.

The manufacturing industry has commenced to work on wearable robots on the basis of the machines coming in sight with the progress of automation systems [7,8]. They have worked on biped robots comprising of unbreakable rigid materials bearing resemble to a skeleton with mechanical parts, designs and metal connections. Between 1965 and 1971, General Electric attempted to put forward a structure planned as an outer skeleton called "Hardiman". This model, which was contemplated to handle a load of 680 kg, flamed out [9]. From this point of view, studies have begun on the upper extremities, that is, the arms.

After half a century, with the development of control systems, electronic systems and power systems [10], technological advances have commenced studies on Exoskeleton Robots (EXR). It has been observed in a limited number of studies that Exoskeleton or Walking Robots (EXR or WR), which are used by patients who have little or almost lost mobility in the lower limbs due to various reasons, increase mobility in patients. Although breakthrough has been made, exploratory is still kept going in laboratory settings and these robots are only used in a small number of overpriced clinics for rehabilitation trials or treatments.

Lokomat, a commercially built exoskeleton robot, is an exoskeleton robot created for patients who have suffered spinal cord injury, brain injury, neurological diseases, traumatic injuries or stroke-stroke [11]. In this robot, there is a harness extending from the top of the head, and this harness supports the patients. This wiring harness is similar to a suspended seat belt, or parachute system, which lightens the body and allows the patient to walk with the help of a robot. It moves the lower extremity parts of the body up and down at each step of the patient. It creates torque for the hip and knee joints to move. In this robot model, since the exoskeleton system is in the foreground, the force control mechanism has been created, and the extension movement for the ankle is passive in this model [11,12].

In accordance with the literature review, more than 200 robot studies have been conducted. According to the strategies and results procured the walking, jumping and movement flexibility of four-legged robots, studies have been initiated on Exoskeleton Robots or Walking Robots (EXR or WR) for the use of people with mobility limitations, and these studies carry forward unabated today [13]. Asimo, one of the humanoid robot series launched by Honda Motor in 1986 [14], has two legs and can perform human-specific walking and running characteristics, so many patients who have lower limb problems and currently have to live in a wheelchair can be reminded of both human-specific physical and physiological characteristics that have been forgotten or are about to be forgotten with exoskeleton robots, that is, walking robots, and these patients can gradually regain their life activities.

Fig. 1. Humanoid Robot Asimo [14].

EXRWR is a robot model that can be used in many fields from healthcare, painting and heavy duty to the business sector [3]. While research and experimental experiments have been augmented on these robots, called EXRWR, on both upper limbs (arms) and lower limbs (legs) in recent years, it has been seen that walking, jumping, running movements in the lower extremities are possible in trials conducted on level surface. Our thesis project aims to design a EXRWR to help patients with movement restrictions due to various reasons, hemiplegia, work accidents, traffic accidents, and diseases, brain, spinal cord injury, earthquakes, loss of sensation in the lower extremities of the body, or damage to the legs, hips, and knee joints during rehabilitation, and to contribute to the industry by demonstrating its accuracy with both kinematic and dynamic models [2] and simulation. Our goal here is to provide flexibility by reducing the force carried by the legs by transferring the weight of the body and the weight caused by gravity to the ground in a balanced way, and to help individuals of all age groups who have difficulty in standing up, taking steps, climbing stairs due to problems in their lower extremities, and to support them to participate in social life. In particular, EXRWR will be very useful for individuals who use wheelchairs, because starting to use a wheelchair due to problems encountered later or as they get older will have a negative impact on the physical and physiological characteristics of the human body over time. Just as characteristics such as standing, walking and moving will cause the slowing down or limitation of characteristics in the lower extremities (legs, hips and knees, joints), it will also lead to a decrease in the quality of life of individuals psychologically. With EXRWR, individuals who use wheelchairs and have mobility restrictions for various reasons can be helped to carry out activities such as moving, walking, sitting and standing by applying the exercises recommended both in rehabilitation centers [15] and at home in order to overcome such problems, and they maintain a life that is not normal but close to normal.

Humanoid robots are designed to mimic human body structure and abilities. Structure and connection points and kinematics, mass distribution and moment and dynamics have been studied because it is important to maintain dynamic equilibrium while taking into account the basic structures and movements of human beings. Health problems seen in dangerous and very dangerous jobs return to factories or companies as a cost. In a competition sponsored by the US Department of Defense, projects were created on humanoid robot applications involving search and rescue. Considering the earthquake experienced in our country as the “Catastrophe of the Century”, it is necessary to bring to the agenda the importance of robots that will be designed based on humanoid features to work in dangerous, narrow and collapsed scattered environments, structures and buildings that are man-made.

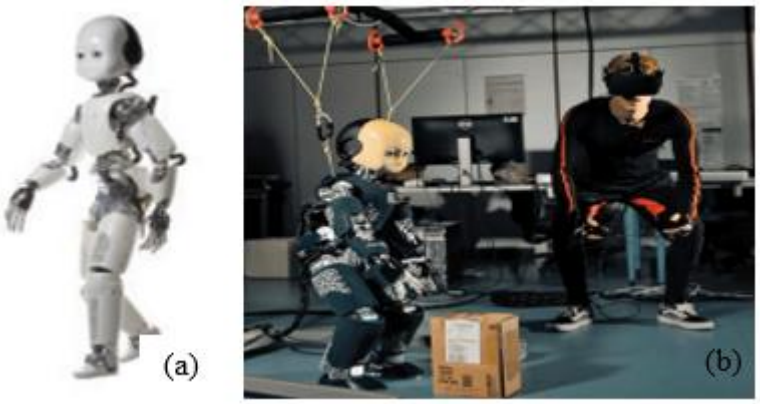

Fig. 2. [a]. iCub humanoid robot [b] Load lifting operation with humanoid robot [16]

In this study, based on the idea we mentioned above, we will work on EXRWR robots that can be used both for rehabilitation purposes and in the dangerous and heavy-duty sector.

2. Method

In this study, pathological findings will be studied based on science of kinesiology, which is known as the examination and investigation of anatomical and mechanical principles related to human movements. In this context, functional human movements will be examined with the help of kinesiology, physiology, biomechanics and anatomy.

Based on walking bipedal humanoid robots, a study will be carried out on the Lower Extremity, i.e. Bipedal Rehabilitation Robot, which can help individuals with restricted or reduced mobility in the lower extremities (knees, feet, ankles and bones) due to various reasons such as earthquakes, paralysis or heavy work, and which has been focused on in recent years. By determining the physical and biological principles of the human during walking with 3D simulation, both control and operational analysis will be obtained for the Two-Legged Rehabilitation Robot. Figure 3. Illustrates the movement structure of the human Lower Limb Section during walking. Height: 1.70 m and Weight: 63.5 kg.

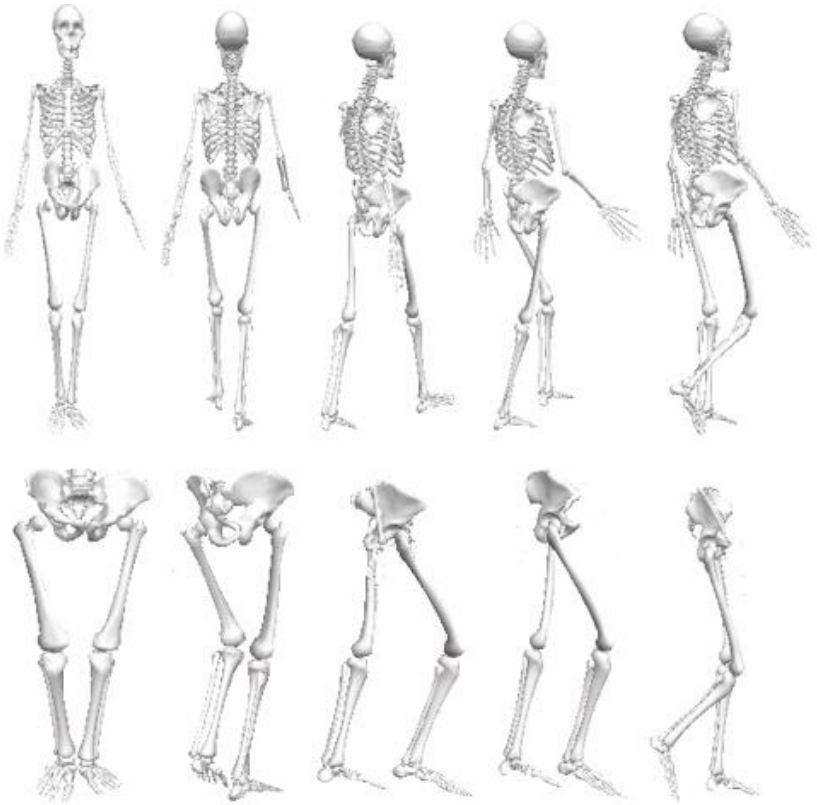

Fig. 3. Lower Extremity Movements at the Moment of Walking with Visual3D Educational Version.

By focusing on Kinematic and Dynamic Model and Control System Design, it is aimed to create a prototype after obtaining accurate results with the design and simulation of the movement and rotation of the hip and knee joints by examining the physical movements of the human lower extremity, such as walking, standing. With this prototype, it is planned to create a product for the human lower limb section by testing the External-Support skeleton in an experimental environment. The Lower Extremity Exoskeleton is a wearable product. After the design is created with 3D Dimensional drawing program for simulation, samples will be produced with 3D printer. Software will be created for the movements and rotations of the Hip and Knee Joints. In this design, sensors, motor, sensing module [1], PCP design, power supply, potentiometer, various mechanical elements and materials will be used. Although the theses on the lower extremity in our country are especially in the field of health, a limited number of studies have been carried out in the field of Engineering with the importance of robotic systems in the last few years.

Studies for the lower extremity in recent years have included two separate models, walking rehabilitation robots and a robot to aid human movement [17].

In recent years, studies for the lower limbs have centered upon two different models: gait rehabilitation robots and robots to assist human movement. The first model, walking robots, as shown in Figure 4, the patient is kept standing with the suspension-pulley system and walking movement is performed. Here, the necessary power for the muscle and skeleton is made available to motor control in the lower located extremity and the patient is made to walk. The suspension-pulley system attached from above is used to alleviate the weight of the body.

Fig. 4. Walking Robot with Suspension-Pulley System [18]

The second model is the exoskeleton robots, which assist in human movement without the use of a suspension-pulley system and are relevant to our Thesis Project. These robots are human movement assisting robots, which are being studied and experimented to be used in hemiplegic and paralyzed patients due to various reasons, as well as individuals who have subsequently lost their motor and sensory functions [17] due to accidents, earthquakes, and so on.

The communication between the brain and the computer is achieved by creating an interface between the brain and the computer [4]. The neural signals generated as a result of brain activity are transformed into commands and sent to the computer. Electroencephalography (EEG) measurement method has started to come to the fore in recent years in order to monitor brain activity with Brain-Computer Interface (BCI). Among the most important reasons for gaining popularity are its usefulness for applications, low risk and low cost, as well as its suitability for feasibility studies for analysis and evaluation [19]. EEG is a device that allows to be monitored using electrical method the activities produced by brain waves by placing the structure consisting of electrodes on the head [20].

3. Conclusions

In the study, it is thought to apply feasibility tests by measuring brain signals in order to design and program EXRWR movement close to human movements using EEG Reader. Our second point is to help to perform active and passive movements and exercises in a controlled manner for rehabilitation our patients who have movement restriction with a manipulator.

By measuring the electrical activity of the brain with the EEG method and analyzing it in computer environment [21,22], the relationship with the lower extremity part of the body will be investigated and the rehabilitation robot will be designed and implemented. It is seen in Figure 5

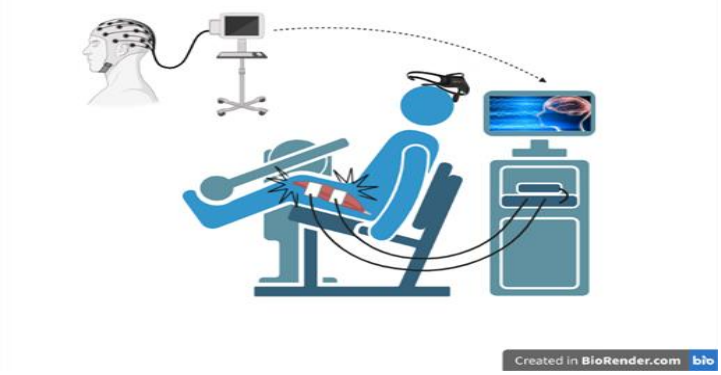

Fig. 5. Computerized environment analysis of the Lower Extremity section with EEG method.

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