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DESIGN OF ROBOTIC EXOSUIT FOR GAIT ASSISTANCE IN PARAPLEGICS

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ABSTRACT

This project is to design and develop a robotic exosuit intended to assist over ground gait for paraplegic the person who have suffered from spinal cord injury. This robotic suit is giving wheelchair users the chance to walk. Almost fully encasing the bottom half, they hold the legs in place while they walk from place to place, controlled by a small joystick at waist height. Compared to previous soft exoskeleton suit, this device is a very powerful tool which resulting in high mechanical efficiency for steady walk and even it enables the navigation of stairs and slopes safely. This device is a bipedal exoskeleton suit with eight degrees of freedom which can give acceleration to the patient's hip, knee and ankle. It is designed to implement different control strategies like walk forward, turn left and turn right. The interface between the user and the device can be controlled through mems sensor or joystick. It does not require crutches or a walking frame to provide stability, leaving the hands free.

Keywords: robotic exosuit, GAIT.

1. INTRODUCTION

Humanoid robot research is a popular research topic in the robotics field for engineers. Humanoid robots give higher mobility and flexibility than other conventional wheeled robots. Robots have to be able to adapt to the complicated environments, such as rugged terrain, sloped surfaces, and steep stairs. The humanoid robot control systems will be providing high performance mobility, behavioural robustness, behavioural complexity, and control of high degrees of freedom (DOFs) systems [5].

This robotic suit is giving wheelchair users the chance to walk. Almost fully encasing the bottom half, they hold the legs in place while they walk from place to place, controlled by a small joystick at waist height. "-First hands-free, self supporting, independently controlled robotic walking device- designed from concept to finished product with mobility impaired users in mind". It does not require crutches or a walking frame to provide stability, leaving the hands free. Can be used by people with a complete spinal cord injury (c 4/5 level). Even it enables the navigation of stairs and slopes safely.

A number of exoskeletons has been developed for tasks ranging from heavy lifting to helping the wearer by providing robotic rehabilitation in a hospital setting. Recently, with improvements in the actuator and sensor technology we had seen these systems become portable, and begin to start transition from academic to commercial applications. Several categories of exoskeletons and exosuit exist, including those that provide the ability to reproduce human movements that have been completely lost by accident, e.g. in the case of a patient paralyzed below the waist of their body. To achieve this process, the device must provide sufficient control to ensure the user's full stability walk, making high speed and agility secondary concerns to balance and safety. In effect, these devices can be thought of wheelchair users the replacement of chairs and offer an elegant and potentially life changing suit. Another type of exoskeleton is designed to assist the able-bodied users to perform the tasks more easily or for longer duration. In particular, considerable work has been conducted in the area of active exoskeletons for augmenting load carriage capacity. For all these kind of devices, a key challenge is minimizing the body weight and power requirements and to this end some groups have been proposed passive architectures in an effort to reduce the exoskeleton's energy consumption [8].

These previous exoskeletons all rely on the rigid frameworks of linkages, mounted to the human body at the selected locations via pads, straps, or other interface techniques used. As the wearer flexes orextends their biological joints of the body, these rigid links considerably added inertia to movement which will be overcome by the motors or by the users. Though great effort has been made to minimize these effects, considerable impedance still added to the natural gait dynamics and kinematics. Also, usual static misalignment of the biological and exoskeleton's joints can result in dynamic misalignments of up to 10 cm during normal body movement, causing pain and even minor injury to the users [8]. The design model of degrees of freedom (dof) used in this project is shown in the below figure, which has totally eight degrees of freedom in each leg it will be four degrees of freedom. The hip has two dof, the knee have one, and the ankle have one dof placed as per the below diagram.

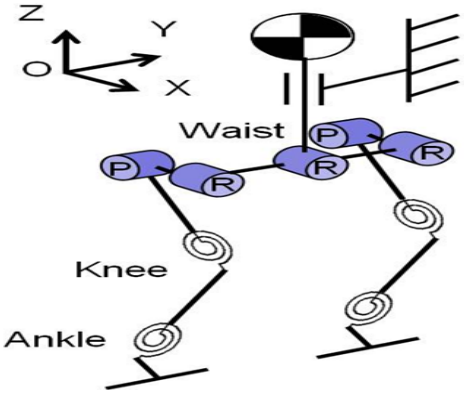

Figure-1. Degrees Of Freedom (DOF) system model used in project.

One solution have been included in redundancy, active degrees of freedom to accommodate these misalignments; however, this adds further weight ratio to the system. It is partly added for the reasons that these systems do not typically reduce the metabolic power required for locomotion. In order to address these issues there has been recently working on developing active suit that shows great promise in reducing the impedance experienced by the suit wearer and allowing more natural movement to the motion. As an alternative to rigid exoskeletons, we present the design and evaluation of a robotic wearable device, we call an "exosuit". This device was designed to augment the immovable muscle work of the user's or patient by applying assistive torques at the wearer's joints with the goal of making the wheel chair person chance to walk in any surface.

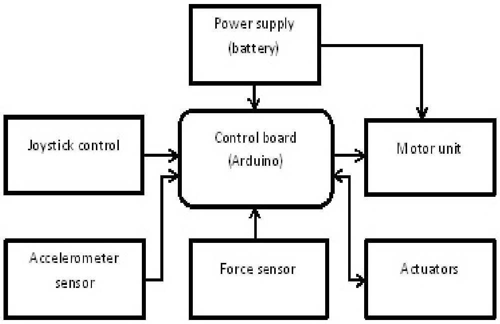

Figure-2. Functional diagram.

The functional diagrams which consist of xy joystick control, accelerometer sensor and force sensor are used as input control and then the motor and actuators are used as output. The xy joystick module is connected as input to arduino board to manually control the full robotic suit make walk forward, turn left and right. The accelerometer sensor is used to sense the robot body position at walking and for balance and steady walk. The force sensor will be placed in the robotic suit foot to sense the placing the leg on floor or any base to make sense like human leg also used in mean of climbing stairs and slopes. An actuator is a kind of motor that is responsible for moving or controlling a mechanism or system according to the surface. It is operated by a source of energy, typically electric current, pneumatic pressure, or hydraulic fluid pressure and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment.

2. REQUIREMENTS AND IMPLEMENTATION

Machine: Composites and various high grade metal alloys and plastics.

Motion generation: A combination of 10 high torque, high speed linear actuators designed and built to achieve maximum stability.

Exoskeletons are also called as wearable robots. A wearable robot is a mechatronic system that is designed according to the shape and function of the human body, with segments and joints corresponding to those of the patients it is externally mounted with. Teleoperation and power amplification were said to be the first applications, but after changes in recent technological advancement the range of application fields is said to have widened. Increasing recognition from the scientific community means that this technology is now employed in telemanipulation, man-amplification, neuromotor control research and rehabilitation, and to assist impaired human with robotic motor control (Wearable Robots: Biomechatronic Exoskeletons or exosuits).

Exoskeletons can also be applied in the area of rehabilitation for stroke or Spinal cord injury patients. Such exoskeletons are sometimes also called Step Rehabilitation Robots. The number of therapists needed for carrying the work can be replaced by an exoskeleton by allowing even the most impaired patient to be trained by one therapist, whereas several are currently needed. Also training will be more uniform, easier to analyze retrospectively and can be specifically customized for each patient. At this time there are several projects designing training aids for rehabilitation centers.

A. Joint flexibility

Flexibility of the human anatomy is another design issue, and which also affects the design of unpowered hard shell space suits. Several human joints such as the hip is ball and socket joint, with the centre of rotation inside the body. It is difficult for an exoskeleton to exactly match the motions of this ball and socket joint using a series of external single-axis hinge points, limiting flexibility of the wearer. A separate exterior ball joint can be used alongside the hip, but this then forms a series of parallel rods in combination with the wearer's bones. As the external ball and socket joint is rotated through its range of motion, the positional length of the knee/elbow joint will lengthen and shorten, causing all the joints misalignment with the wearer's body motion. This slip in suit alignment with the wearer can be permitted, or the suit limbs can be designed to shorten and lengthen under power assist as the wearer moves the body, to keep the knee/elbow joints in alignment.

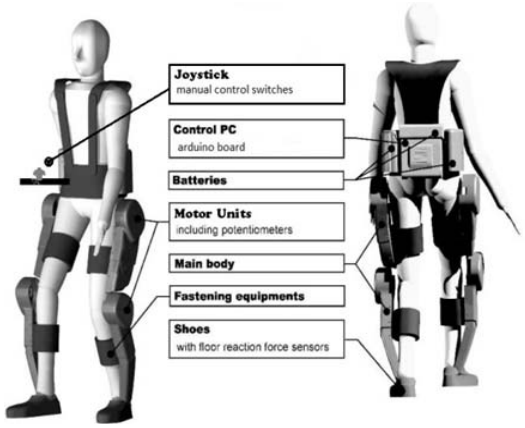

Figure-3. Final implementation of robotic exosuit.

A. Input control

A joystick is an input device which consisting of a stick that pivots on a base and reports its direction or angle to the device it is controlling, and usually have one or more push-buttons whose state can also be read by the controller.

B. Actuators

An actuator is a kind of motor that is responsible for moving or controlling a mechanism or system according to the surface. It is operated by a source of energy, typically electric current, pneumatic pressure, or hydraulic fluid pressure and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment.

C. Sensor unit

Accelerometer Sensor---An accelerometer is a device that measures proper acceleration ("g-force"). Proper acceleration is not as same as coordinate acceleration (rate of change of velocity). For example, an accelerometer at rest on the surface of the Earth will measure an acceleration $g = 9.81\ m/s^2$ straight upwards. By contrast, accelerometers in free fall orbiting and accelerating due to the gravity of Earth will measure zero.

These devices are called gravity gradiometers, as they measure gradients in the gravitational field. Such pairs of accelerometers in theory may also be able to detect gravitational waves.

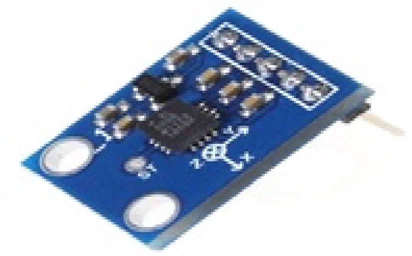

Figure-4. triple axis accelerometer - ADXL335.

Force Sensor---A force-sensing resistor is a material whose resistance changes when a physical force or pressure is applied on it. They are also known as "force-sensitive resistor" and are sometimes referred as "FSR“.

3. HUMAN WALKING MOTION

Human walking is accomplished with a strategy which is called the double pendulum. During forward walking motion, the leg that leaves the ground swings forward from the hip. This sweep is known as the first pendulum. Then the leg strikes the ground with the heel and rolls through to the toe in a motion described as an inverted pendulum. The motion of the two legs has been coordinated so that one foot or the other is always in contact with the ground. The process of walking recovers approximately sixty per cent of the energy used due to pendulum dynamics and ground reaction force.

Walking differs from a running gait in a number of ways. The most obvious is that during walking one leg always stays on the ground while the other is swinging. In running there is typically a ballistic phase where the runner is airborne with both feet in the air (for bipedals). Another difference term concerns the movement of the centre of mass of the body. In walking the body "vaults" over the leg on the ground, raising the centre of mass to its highest point as the leg passes the vertical, and dropping it to the lowest as the legs are spread apart. Essentially kinetic energy of forward motion is constantly being traded for a rise in potential energy. This is reversed in running where the centre of mass is at its lowest as the leg is vertical.

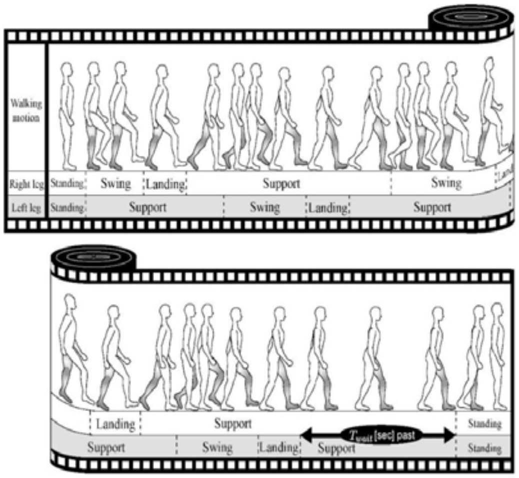

Figure-5. General human walking motion.

The general human walking motion strategy is shown in above fig. This is because the impact of landing from the ballistic phase is absorbed by bending the leg and the consequently storing energy in muscles and tendons. In running there is a conversion between kinetic energy, potential energy, and elastic energy.

4. PROTOTYPE IMPLEMENTATION

Based on the requirements outlined in Sections II and human walking motion design principles described in Section III, a prototype Exosuit was fabricated to demonstrate the concept.

Figure-6. Robot walk in flat surface.

The human interface for the robotic Exosuit is inherently flexible and is primarily made of hard components. The outer body frame is made of metal (Aluminium) and the motion is controlled my various servo motors. These robot is intended with human leg motion which consist of totally eight degree of freedom (dof)s, each leg has four motors in sequence. The motors and controller were housed in a metal frame; the suit was equipped with a force sensor at the robot foot which helps the sense of placing the foot on a surface.

The device can be manually controlled by the user through the dual-axis joystick as a input control. Walking motions like forward walk, left and right turn will be controlled through joystick. Foot placing in uneven surface can be identified by the sensor which is placed on the foot. The dynamic balance will be carried by the accelerometer sensor which is shown in Figure-4, hence the stabilization of the entire robotic suit is maintained by this kind of accelerometer sensor.

Figure-7. Robot walk in uneven surface.

5. CONCLUSIONS AND FUTURE ENHANCEMENT

We present here what we believe to be the first engineered robotic exosuit, which greatly improved mechanical impedance and inertia compared to previous soft exoskeletons and wearable assistive devices. Wearing this suit in a active powered mode will have great effect on hip, knee, and ankle joint kinematics as compared to other exosuits. We observed that when powered joint torque assistance is properly provided, it alters gait kinematics and andesirable increase in metabolic power occurs.

These wearable robotic suits that can work with various forms of human motion and related activities. Exosuit robotics is an emerging field that combines classical robotic design and control principles with active hard materials, enabling a new class of applications exemplified by the device presented. In this system, the symbiotic human-machine interaction is facilitated by the inherent weight and compliance of the device. The work in this paper is broadly applicable to awide variety of wearable robotic assistive devices and in particular can be applicable to the next generation Warrior Web suit being developed by DARPA.

Lastly, while we considered healthy gait during device development, other applications for this design methodology include assisting the elderly, rehabilitation for children and adults with disorders like Paraplegics the person with spinal cord injury. In these applications, rather than augment healthy performance, the system has the potential to provide assistance for limited function, where smaller forces have the potential to achieve greater changes in performance. Future work will also focus on statistically evaluating the efficacy of the exosuit with an increased number of human subjects. The input controls like joysticks might be replaced with Mind controlled robotic exoskeletons.

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