ME 470 / ECE 445: Senior Design Laboratory

Project Proposal

Supernumerary Robotic Limbs

Group Number: 27

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1. Introduction

1.1 Problem and Background

Supernumerary limbs can be helpful in daily activities or specific workplace tasks, which are additional appendages attached to the human body to enhance physical capabilities, such as providing extra arms for multitasking or aiding in rehabilitation after injury. The advantages of Supernumerary limbs are numerous. They can not only act as physical arms to complete some daily tasks, but can also help with some works which requires high precision. Overall, the integration of supernumerary limbs holds the potential to revolutionize human-machine interaction and expand the possibilities for human augmentation and assistance [1].

The primary goal of designing supernumerary limbs is to integrate them with the human body while enhancing functionality and usability. Some components, including the mechanism of limbs, electronics for actuation and control interface, are vital to the success to the product. In dangerous environment or some postures that are uncomfortable and arduous, a type of supernumerary robotic limbs is designed to attach to a human body that can support the human by acting as additional legs.

According to the US Bureau of Labor Statistics, in 2014 there were over 190,000 workplace injuries in manufacturing sectors and 50,000 injuries in agriculture [2]. Overall, the cost of workplace injury amounted to over $190 billion and resulted in over 1.1 million lost days of work [3]. Out of all workplace injuries in 2014, approximately one in three was a musculoskeletal disorder [4].

In our investigation, we found that when workers work in narrow and low places, such as underground pipelines, workers often need to kneel on the ground and usually need a hand to support the ground to maintain stability. In this case, workers only have one hand to use for construction, which is not only more tiring, but also very inconvenient. We wanted to have an object that would help workers support and move around in confined Spaces while freeing up their hands to work more easily.

1.2 Solution

A new type of supernumerary robotic limbs is proposed to provide support and enhance the safety of workers working in dangerous environment. This supernumerary robotic limbs for human body support is designed to be worn like a backpack. Two robotic limbs can coordinate their position according to the user’s need. At the bottom of limbs, wheels are installed so that the system can move with the human. For example, when he finishes the task in one location and want to move to another spot, he doesn’t need to take off the system. What he needs to do is to walk as usual. Also, some sensors are also included in the design to detect motion tendency of the human to provide extra help for him to stand up and sit down. Since the system is independent from human body and the robotic limbs work as additional legs, the worker’s hands are totally free while the stability of his body is enhanced. In addition, we also hope to add accessories for MR Glasses, so that users do not need a remote control to manipulate the movement and shape of the robot arm in a narrow space, but simply operate through the screen presented on the MR.

1.3 Visual aid

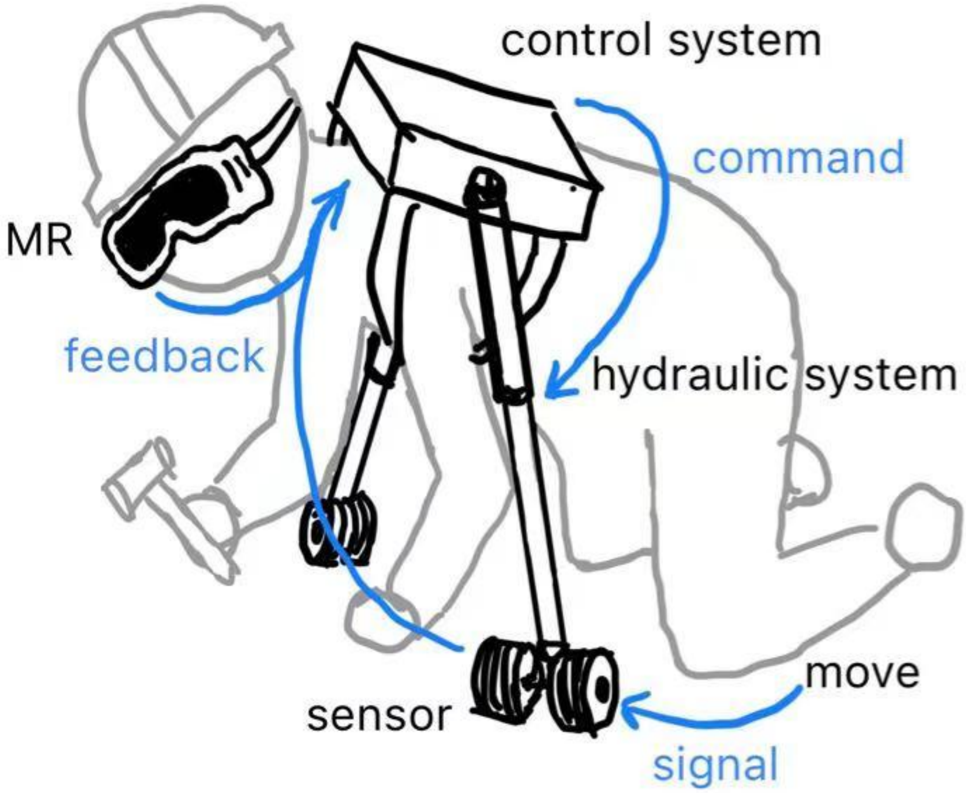

Figure 1: Visual Aid of the Project

1.4 High-level requirements list

- The maximum force that the system can provide must be high enough so that the limbs can support human body when the angle is small.
- The identification of motion tendency has to be accurate, stable and response fast enough in order to make the system easy and reliable to use.
- Since the supernumerary robotic limbs are worn as backpack on the back of a human, it has to be adjustable and comfortable for different people of different size and back characteristics to use.

2. Design

2.1 Block diagram

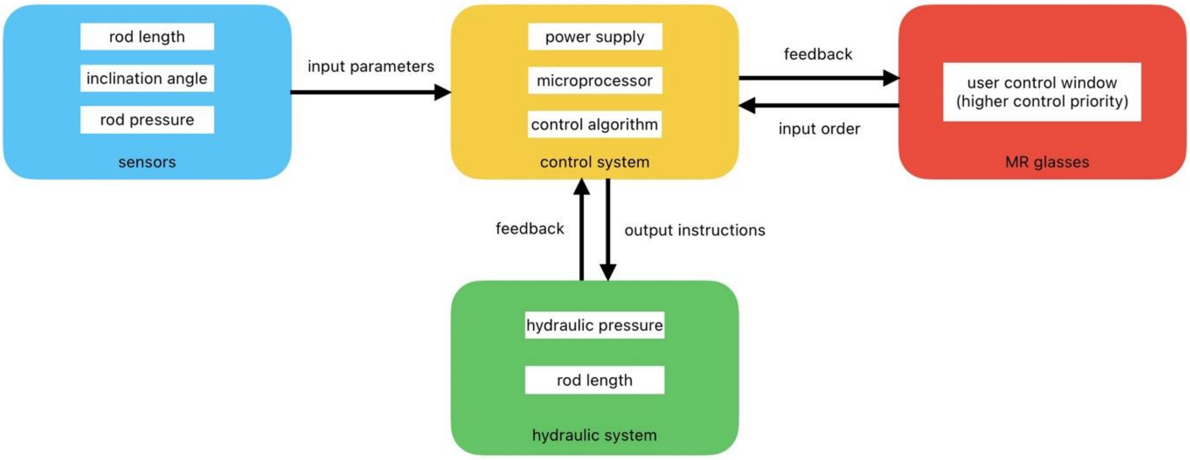

Figure 2: Block Diagram

2.2 Subsystem overview

Our design comprises three primary components: the backpack housing the entire control system and chips, two symmetrically designed limbs, and MR glasses. Each limb is equipped with a wheel at its base, facilitating rotation to ensure contact with the ground as the user moves. This innovative feature significantly alleviates the weight burden on the user's shoulders compared to non-wheeled supernumerary robotic limbs. In the absence of wheels, users must manually support the entire product while in motion, resulting in increased physical strain due to the product's weight distribution. When utilizing our design, the wheels located at the base of each limb remain locked, while sensors embedded within the limbs continuously monitor force changes. Based on these sensor inputs, the control system determines whether additional force should be applied to the limbs to assist the user in sitting down or standing up. This added force enhances the usability of the design, simplifying the user experience and facilitating effortless transitions between seated and standing positions. Additionally, a pre-programmed learning algorithm is integrated into the control system to adapt to the unique usage habits of different individuals. This algorithm continually learns from user interactions, enabling the design to accommodate a wider range of users and expand its applicability across diverse populations. By capturing and analyzing user-specific data, the system optimizes its performance over time, ensuring a personalized and intuitive experience for all users. MR Glasses can put the robotic arm operation interface in front of the user, so that the user can control the movement of the robotic arm without unnecessary manipulators and actions. Moreover, compared to the instability of the sensor, the control window of MR Glasses controls the control system with a higher priority.

2.3 Subsystem requirements

2.3.1 Moving wheels

According to our design specifications, the mobile wheels located at the base of each limb should possess the capability to move in all 360-degree directions and also be lockable. When unlocked, these wheels serve to support the design and seamlessly accompany the user's movement from one location to another. However, when the user requires stability for tasks such as soldering in a crouched position, the wheels can be locked to prevent rotation, providing additional support to the user's body.

Upon researching, we found that universal wheels with locking mechanisms perfectly align with our requirements. Although Mecanum wheels also offer these features and precise motor-driven control, we opted for universal wheels due to budget constraints. Despite the precise motor control capability of Mecanum wheels, universal wheels fulfill our needs effectively while remaining cost-effective.

2.3.2 Hydraulic system

The hydraulic system plays a pivotal role in supporting the limbs. The length of the hydraulic rod adjusts dynamically based on the user's motion tendencies. For instance, when the user intends to stand up, sensors detect changes in force along the rod and transmit signals to the control system. Subsequently, the control system interprets these signals, discerns the user's motion tendencies, and generates a decision. Consequently, the control system outputs a command, prompting the hydraulic rod to provide the necessary force to assist the user in standing up.

According to our calculations, each rod must deliver a minimum force of 200 N to facilitate the user's standing motion comfortably, without exerting excessive pressure on the user's waist and knees. Additionally, it is imperative for the hydraulic system to respond swiftly to these signals to ensure seamless support for the user's movements.

2.3.3 Sensors

Several sensors are essential in our design to achieve our objectives effectively. Key parameters critical to the success of our design include:

1. Hydraulic Rod Length: Sensors are needed to measure the length of the hydraulic rod, allowing for dynamic adjustments based on the user's motion.
2. Pressure Along the Hydraulic Rod: Sensors will monitor the pressure along the hydraulic rod, providing vital feedback on the force exerted and ensuring safe and appropriate support for the user.
3. Angle Between Rod and the Ground: Sensors will determine the angle between the rod and the ground, aiding in the detection of the user's motion tendencies and facilitating adjustments in response to changes in position.

In addition to these parameters, other relevant parameters may be incorporated into the system based on our evolving needs and practical considerations in the future. These sensors collectively contribute to the functionality and adaptability of our design, enhancing user comfort and safety.

2.3.4 MR Glasses

We put a window on MR Glasses that was previously displayed on a computer to eliminate the need for a physical remote control in an innovative way of interaction, and this feature can make the operating system more intuitive and efficient in small Spaces. Initially, we will design the telescopic function of the hydraulic rod and the wheel's moving function, locking, steering and other functions integrated in the control window. In the future, we hope to be able to develop more features to use in the window.

2.4 Tolerance analysis

Since there is no wireless transmission in our design, we do not worry about the transmission speed and system response in our design. However, there are several other parts that do not have much tolerance and requires high accuracy.

Sensors:

Absolutely, the accuracy and sufficiency of sensor input parameters are crucial for the effectiveness of the algorithm in determining when and how to assist the user in maintaining a position, lowering down, or standing up. The reliability of the input directly influences the accuracy of the algorithm's output.

Having enough sensors to capture relevant data from different aspects of the user's motion and environment ensures that the algorithm receives comprehensive information to make informed decisions. Additionally, ensuring the accuracy of sensor measurements minimizes errors and enhances the algorithm's ability to provide precise assistance tailored to the user's needs.

Therefore, thorough consideration and testing of sensor selection, placement, and calibration are essential to establish a robust foundation for the algorithm's functionality and overall system performance.

3. Ethics and Safety

In the realm of developing supernumerary limbs, prioritizing ethical considerations is paramount, ensuring adherence to principles outlined in the IEEE and ACM Code of Ethics. The design and deployment of supernumerary limbs must uphold individual autonomy, privacy, and equity, while transparent communication fosters societal trust. Concurrently, strict adherence to safety standards and regulatory protocols is essential to mitigate potential risks associated with supernumerary limbs. Biomechanical compatibility, ergonomic design, and preemptive measures against unintended harm during operation are central to ensuring user safety.

References

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[2] Bureau of Labor Statistics, ”News Release,” US Department of Labor, USDL-15-2086, October, 2015

[3] J. Paul Leigh, ”Economic Burden of Occupational Injury and Illness in the United States”

[4] Bureau of Labor Statistics, ”Nonfatal Occupational Injuries and Ill nesses Requiring Days Away From Work, 2014”, US Dept of Labor, 2015.