ME 470 / ECE 445: Senior Design Laboratory

Design Document

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've discovered that workers tasked with soldering beneath the hull of a boat often face significant challenges. Working in such confined spaces requires them to lie on their backs, which not only strains their posture but also limits their ability to maneuver and work effectively. In this position, workers typically struggle to maintain stability and control over their soldering tools, as they require at least one hand to support themselves. To address these issues, we propose the development of a specialized support system that allows workers to comfortably and securely position themselves beneath the boat while freeing up their hands for soldering work. This system could include a combination of ergonomic padding, adjustable harnesses, and stabilizing mechanisms to enhance worker comfort, safety, and efficiency in this demanding environment.

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 wearer. 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. Instead, He can sit on the floor and utilize the traction between his shoes and the surface to glide seamlessly from one spot to another, ensuring continuous workflow without the hassle of removing the support system. 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

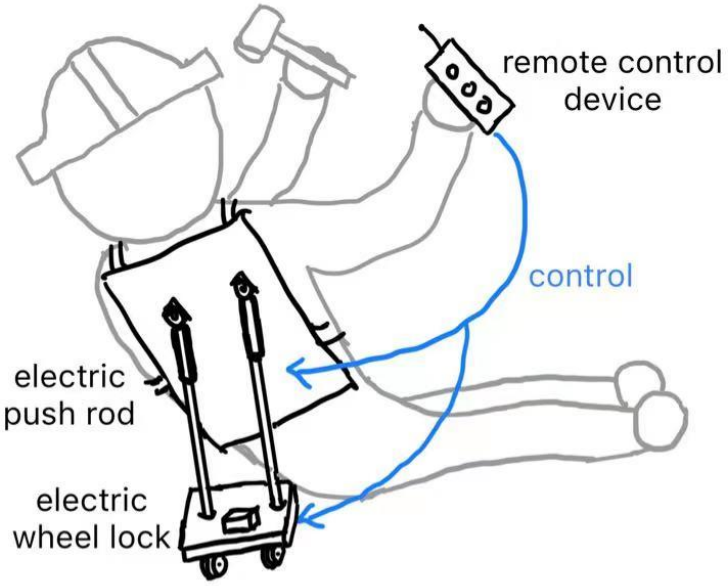

Figure 1: Visual Aid of the Project

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 acute angle between the wearer's back and the ground is small. According to our measurements and estimates, the maximum gravity of the electric push rod supporting a person is about 0.4 of the weight of a person. That is to say, when the load capacity of each rod is about 235, our machine can support 120 kilograms of people.
- Because we don't need a fast electric push speed, we just need to keep the user more comfortable to move to the position he wants to reach. So we need a smaller putting speed. Compared to this, it is more important that we need two rods that can be pushed in sync so that the user can not tilt because of the length of the electric push rod.
- 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

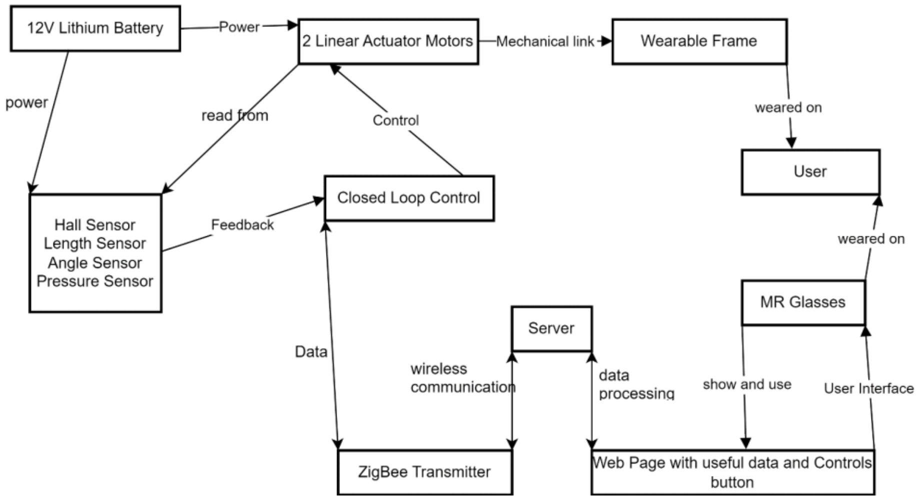

Figure 2: Block Diagram

2.2 Physical Design

On the left side of the horizontal plate, there is a cuboid housing the battery, while four universal wheels are positioned beneath the plate to enhance stability and provide a horizontal force component. The inclined plate serves as the backpack, housing a PCB (Printed Circuit Board) internally. The PCB's primary function is to regulate the two vertical rods, designed to function as linear actuators. During operation, the length of the linear actuators can be adjusted to accommodate varying requirements in diverse working environments. The backpack is secured to the user's body using shoulder-strap-like belts.

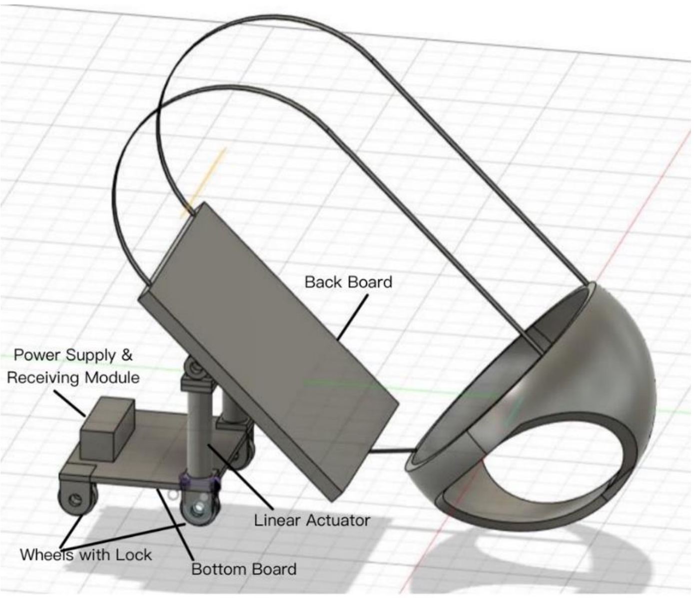

Figure 3: Physical Design

2.3 Subsystem requirements

2.3.1 Motion system

We divide the motion system into two parts: the electric push rod responsible for pushing the worker's back, and the wheels responsible for overall movement.

First, we will discuss electric push rods.

The linear actuators plays a pivotal role in supporting the limbs. The length of the linear actuators 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 linear actuators 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 linear actuator to respond swiftly to these signals to ensure seamless support for the user's movements.

Based on the above, and in conjunction with market research, we have decided to opt for an electric push rod with a working voltage of 12V. Our rationale for selecting this voltage should be elaborated within the respective section of the functional system.

Next, we will talk about mobile 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 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.

Requirements	Verification
1. Should be able to withstand the weight of a person lying on it. In our expectation, we consider the maximum weight of the worker to be 120kg. According to the drawing analysis, 40 percent of the human weight is pressed on the backboard and acted on the electric push rod.	1. We will choose stainless steel or cast iron to ensure the structure of the wheels to enhance their strength. We will also increase the diameter and width of the wheels to improve their load-bearing capacity. If necessary, we will select wheels

2. The wheels can be locked without rolling, either by a manual lock or an electric lock mechanism. 3. The locked wheel will not slip when the user is resting on the tool .	with ball bearings to enhance their stability performance. 2. By installing electromagnetic locking devices on the caster wheels, the locking mechanism can be electronically controlled to open or close. When the electromagnetic lock is in the closed state, the caster wheels can freely rotate; whereas when the electromagnetic lock is in the open state, it prevents the caster wheels from rotating, thereby locking the wheels. We will implement control of the caster wheels through a microcontroller. 3. We will choose materials such as rubber or polyurethane to achieve better slip resistance. Additionally, we will add appropriate patterns and textures to the surface of the wheels. 4. We calculate an electric push rod that is suitable for our use by using the required push rod speed and torque as well as power. 5. For the wheel to be purchased, ask for its coefficient of friction and calculate the maximum friction it can provide based on its mature human gravity of 0.4. At the same time, when the wheels are received, we will also test a variety of sites.

2.3.2 Sensor system

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

1. Length sensor: Sensors are needed to measure the length of the linear actuators, allowing for dynamic adjustments based on the user's motion.
   Here we would like to use photoelectric sensors. We will be putting it on a linear motor. What we envisage is to make the length sensor similar in structure to an actuator, consisting of two sleeves, one thick and one thin. The two of them together can move up and down freely, allowing the photoelectric sensor inside to sense the distance and preventing splashes from the outside, such as sludge, from affecting the operation of the photoelectric sensor.
   We will place this sensor on the side of the linear motor as a way to stabilize and synchronize its motion with that of the motor.
2. Pressure sensor: We can detect the approximate posture of the worker when using the equipment by using pressure sensors distributed at various positions on the backplate.

We will measure the pressure exerted on different parts of the backplate when the worker is working normally and set a threshold. If the pressure is too high or too low, the propulsion system will automatically stop working and return to its initial state.
We plan to use two piezoelectric pressure sensors. It is characterised by rapid response. We will punch holes in the backplate and place it in the corresponding area where the pressure of the backplate is most visible when the person's back is in contact with it (we will measure this in the lab). The data will then be transmitted to the main control board for analysis and corresponding motor attitude adjustment.

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.

We think it's important to note that the main purpose of both sensors is to prevent the motor or wearer from having an abnormal posture while in use. For example, the user hitting their head or being crushed by a heavy object, a failure in the control of one of the motors causing the user to tip over, etc. So when making this part we will focus on how fast it reacts to abnormal situations. Of course, we will also measure the human body data in the laboratory. We will confirm the range of fluctuation of the data in different parts of the body when the wearer is working normally and the threshold of abnormal situations.

Requirements	Verification
1. The length sensor must provide accurate displacement measurements of the linear actuators within ±0.5 mm accuracy to ensure precise control over the actuator's extension and retraction. 2. The pressure sensors must respond to changes in pressure with a response time of less than 100 milliseconds, and be able to differentiate between normal operational pressures and those indicative of dangerous postures with a sensitivity of ±2 Newtons.	1. Calibration: Compare the length sensor's readings with a known high-precision measurement instrument across the full range of actuator motion. Adjust the sensor's readings to match the standard if necessary. Encase the sensor setup in a mock-up actuator sleeve and expose it to simulated environmental conditions including splashing with substances like sludge. Assess sensor function post-exposure to ensure no degradation in performance. Integration Test: Install the sensor on the linear motor and test the synchronization of the motor's motion with the length sensor's measurements under various speed and load conditions. 2. Response Time Test: Measure the time taken for the sensor to respond to a sudden pressure change using a fast-acting mechanical actuator. Sensitivity

	Test: Apply a series of controlled pressures on the sensor, both within and outside the normal operating range, to ensure it accurately detects and measures the force applied. Threshold Determination: In the laboratory, simulate various normal and abnormal postures the worker might assume. Measure the pressures on the backplate to establish a baseline and threshold. Then, in actual operation, if the pressure readings are beyond these thresholds, the system should trigger a stop and return to the initial state. Placement Test: Drill holes and place the sensors in the backplate at points of highest pressure contact as determined in preliminary lab tests. Assess whether the chosen locations provide the best representation of the wearer's posture by comparing sensor data against visual observations of the posture.

2.3.3 Power system

The energy system is straightforward. In essence, it comprises batteries and wiring that connect the batteries to the remaining modules to supply power. We have opted for 12V batteries. Initially, our research revealed that the majority of linear motors available in the market operate at voltages of 12V, 24V, and 36V. However, those operating at 24V and 36V typically deliver thrust exceeding 500N, surpassing our requirements and budget constraints. Moreover, selecting a lower voltage enhances the safety of our device and helps alleviate heating issues. The batteries will be positioned centrally between the two electric push rods on the backplate. This placement shields them from the surrounding rigid structures, effectively preventing any potential crushing of the batteries.

Taking into account our goal of enabling the worker to operate the device for a minimum of three hours while wearing it, and considering our research findings indicating a motor power consumption range of 36-60W, we need to perform some calculations. Moreover, linear motors typically utilize an internal screw-type structure that, when stationary, can automatically lock through mechanical means, resulting in minimal power consumption. Consequently, we will base our calculations on a scenario where one-third of the working time involves the electric push rod in operation.

Given these factors, we can determine the necessary battery size. Let's consider the worst-case scenario: continuous operation of the motor at its maximum power consumption of 60W for one-third of the time, equating to one hour.

Energy consumption for one hour of operation = Power × Time. To cover a three-hour work period, the total energy required would be:

Total energy = Energy consumption per hour × Total working hours = 60Wh × 1 hours = 60Wh

Thus, the battery capacity should be at least 60 watt-hours (Wh) to ensure the device operates for three hours under the specified conditions.

What needs to be added is that, considering weight and portability, we have opted for lithium batteries.

We've chosen the most standard copper-core cables for the wiring to balance practicality and convenience. These cables will be easily accessible to us, whether we procure them externally or seek assistance from the school.

Requirements	Verification
1. It should be safe and maintain its safe state under compression and high temperatures. 2. The volume and weight should not be too large, because it should be worn on the body. 3. The battery capacity should be larger, so that the entire system can be used for a longer time. 4. The system should operate continuously for 8 hours on a single charge under typical usage conditions.	1. According to the requirements, our batteries have the following characteristics: high voltage, large energy ratio, long storage life, good high and low temperature performance, and good safety. Currently we plan to use lithium batteries to meet our design needs. 2. Conduct a battery drain test under controlled usage cycles to measure operational time until the battery is depleted.

2.3.4 Control system

Our control system comprises two main modules: a remote controller and a control chip.

The remote controller will feature three buttons, allowing control over the electric push rod's ascent, descent, and halt. For convenience, we plan for the remote controller to be wired and securely fastened to the worker's chest using the safety harness. The wires connecting to the computation unit fixed on the backplate will be neatly integrated into the safety harness, minimizing any disruption to the surroundings. We will endeavor to design the PCB board inside the remote controller and employ 3D printing technology to create an enclosure.

The control chip consists of two computation units: an Arduino development board and a motor control board. The motor control board facilitates the connection between Arduino and the motors, where we will program instructions. Our strategy involves leveraging distance and angle sensors to monitor the device's orientation. For instance, if sensor feedback indicates a tilt to the left, we'll command the left motor to lift and stabilize the posture. Should the left motor reach its maximum extension, instructions will be relayed to retract the right motor. This automatic posture correction feature will activate 2 seconds after receiving instructions from the remote controller. Additionally, an emergency braking mechanism will be implemented based on data from the previously mentioned pressure sensors.

As for the remote controller, the two linear actuator we bought was attached with two wired controllers. Our plan is to use a wireless controller, that means we need to re-design a controller, starting from the PCB circuits. Therefore, we will take apart one of the remotes given to learn about the circuit of the controller. Next, we will connect the PCB board to our Bluetooth module, which we will use nRF8532 series of Nordic Semiconductor (As shown below).

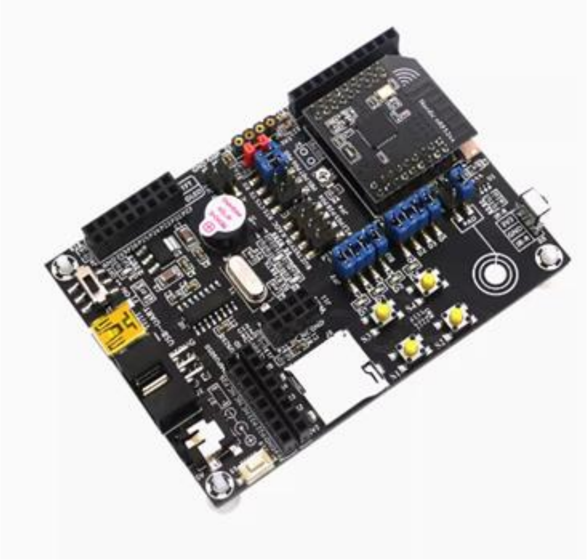

Figure 4: nRF8532 Bluetooth module

After completing the design of circuits, we will design and make an outer shell for the controller using 3D printers. As mentioned, the controller will have 3 buttons controlling the actuator to elongate, stop and curtail (draft shown below).

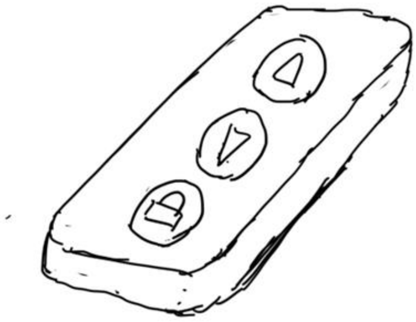

Figure 5: Draft of remote controller

After assembling the controller, we will be discussing which is the best spot to place the controller when trying to operate our device. In our image, the best place should be in front of the wearer, and placed on the left chest so that the wearer could operate without putting down the tool on the right hand considering most people are right-handed.

Remote Controller Requirements and Verification:

Requirements	Verification
1. The controller should be easily operable with one hand, specifically designed for left-hand use without looking. 2. The wiring must withstand regular flexing and exposure to environmental factors without failure for the product's intended lifespan. 3. The Bluetooth connection must maintain stability and performance within a range of 30 meters in an environment with potential electronic interference. 4. The controller housing must securely attach to a safety harness without risk of detachment under normal operational conditions.	1. Conduct user testing with a prototype to ensure users can comfortably reach and press all buttons. Record the ease of use and any discomfort reported by test subjects. 2. Perform a flex test on the wires by subjecting them to repeated bends and twists for a specified number of cycles. Test for environmental resistance by exposing the wires to moisture, dust, and extreme temperatures, then check for electrical and mechanical integrity. 3. Test the Bluetooth range and stability in various environments (like industrial settings with high electronic interference). Measure the signal strength and integrity across different distances and barriers. 4. Perform a mechanical stress test on the housing attachment by applying forces that mimic extreme operational movements. Evaluate the security of the attachment after the test.

Control Chip Requirements and Verification

Requirements	Verification
1. Distance and angle sensors must maintain an accuracy within ±2% under varying environmental conditions. 2. The motor control logic should respond to sensor inputs within 500 milliseconds, initiating corrective action as programmed.	1. Calibrate sensors in a controlled environment, then test in variable conditions (temperature, humidity, vibration). Compare sensor outputs with a known accurate reference to quantify accuracy. 2. Simulate sensor inputs and measure the response time and actions of the motors using high-speed cameras and data logging. Ensure actions meet the

	programmed criteria for various sensor input scenarios.

2.4 Tolerance analysis

2.4.1. Electric Push Rods

For the electric push rods in the supernumerary robotic limbs, tolerance analysis is crucial to ensure they operate within safe limits while providing the necessary support. Length tolerances are essential, as incorrect lengths could either prevent full extension and retraction or cause the rods to exert excessive force, leading to potential injury or damage to the device. Diameter tolerances must also be controlled to prevent the rods from jamming or wobbling, which would affect precision and stability. Additionally, force output tolerances need to be strictly managed to ensure the rods can support the intended loads without malfunctioning, ensuring both safety and functionality.

2.4.2. Wheels

The wheels of the device must be designed with precise diameter tolerances to maintain the device's stability and proper ground clearance. Variations in wheel diameter could lead to uneven loading and potentially cause the device to tip or fail during operation. Material tolerances are also significant; the wheel material must consistently provide sufficient durability and wear resistance under the load and environmental conditions expected. The locking mechanism’s tolerances are particularly critical, as they must reliably engage and disengage to allow movement or provide stability when locked, without failing under stress.

2.4.3. Sensors

Sensor accuracy is paramount in the robotic limbs system, as they inform the control system's responses to user movements. Tolerances for sensor placement and alignment must be tight to ensure accurate readings of limb positioning and user intent. Sensitivity variability among sensors must be minimized to avoid discrepancies that could lead to inappropriate adjustments by the actuators, affecting the system's responsiveness and the user's comfort and safety. Ensuring that sensors deliver consistent outputs across various operational conditions is key to maintaining the effectiveness of the device.

2.4.4. Battery and Electrical Connections

The power system’s reliability depends on maintaining strict voltage and current tolerances within the batteries and electrical connections. Any deviation could result in insufficient power delivery or potentially hazardous overloads. Connector tolerances are also critical, as poor connections can lead to intermittent power supply, reducing the reliability and safety of the device. Ensuring robust, secure connections that can withstand the physical demands of the device's operational environment is essential for consistent performance.

2.4.5. Frame and Wearable Mounting System

The frame and mounting system must be designed with adjustable dimensional tolerances to accommodate various body types while ensuring the device remains secure and comfortable during use. Tolerances in material strength and flexibility are vital to withstand the stresses of operation without deforming or breaking. These tolerances must be carefully managed to ensure that the frame supports the device’s functionality without compromising user safety or comfort, particularly under dynamic loads and movements typical in a workplace environment.

3. Cost and Schedule

3.1 Cost Analysis

Our team have four members and the total project duration is ten weeks. Based on our estimation, this project can be completed eight hours per week. We set an hourly salary of $20:

$$4 * \$20/\text{hour} * 2.5 * 8 * 10 = \$16,000$$

The parts we need in this project are listed below:

Part	Manufacturer	Quantity	Cost (including process)	Description
steel frame	Shanghai Tingwan Metal	1	$5.4	The overall framework includes steel plates on the back and a wearable base.
filler material (cotton)	Yaoyang Packing Store	1	$3.2	Provide a buffer on the back to enhance the user experience.
electric pushing rod	Zhongshan Songli Electronic Technology Co., Ltd	2	$125.7	Control the rise and fall of the human body.
bearing	Shenzhen Dashan Bearing	2	$2.2	When the length of the push rod changes, the bearings are needed to adjust the angle between the back and the ground.
self-locking wheel	Zhejiang Linglang	4	$20.6	Change the position of the device on the ground.
12V battery	Shenzhen Sanrijing Electronic Technology Co., Ltd	2	$4.1	It can serve as a power source. One for driving push rods; another for the remote control.

PCB	PCBWay	1	$14.3	It is installed inside the remote control. The machine shop labor hours are approximately 48 hours.
Total	$175.5			

Thus, if we produce ten of this product, it would cost a total of $17755.

3.2 Schedule

This is the schedule from the week we wrote design document to the final demo week.

Week	Haotian Jiang	Xuekun Zhang	Yichi Zhang	Yushi Chen
Week 7 3/25/2024	**Determine the details of the design and purchase linear actuator and wheels**	**Research and discuss the possibilities of our current design and update our design**	**Research, purchase Bluetooth modules**	**Review basic knowledge of Arduino, assemble the framework with teammates**
Week 8 4/1/2024	**Design the connectors and find factories to process**	**Design our PCB board and preliminary test**	**Design PCB board**	**Learn the principle of remote control**
Week 9 4/8/2024	**Try to assemble the design and may redesign some parts**	**Complete the connection of the PCB board and the entire system and the preliminary test**	**Attempt to start modulating and demodulating Bluetooth signals.**	**Gain open-source documents and optimize the PCB design**
Week 10 4/15/2024	**Finish assemble**	**Perfect and complete testing of our control method.**	**Connect the components to the whole system.**	**Connect to motor control and finalize testing**
Week 11 4/22/2024	**Initial use testing, correction and redesign of its inadequacies.**			
Week 12 4/29/2024	**The final optimization and testing, the control of the motor, the adaptation of the remote control system, the comfort of wearing the final optimization.**			
Week 13 5/6/2024	**Mock demo and final demo!! Finished!**			

4. Discussion of Ethics and Safety

In the realm of developing supernumerary limbs, prioritizing ethical considerations is paramount, ensuring adherence to principles outlined in the IEEE and Code of Ethics [5] and ACM Code of Ethics and Professional Conduct [6]. 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. In terms of safety, we need to consider multiple factors:

Firstly, when working in narrow spaces, using linear motors with adjustable angles can greatly improve work efficiency. However, this also brings some potential safety hazards. If workers accidentally keep pressing the remote control, it may lead to head collisions, resulting in serious injuries. Therefore, in the design, consideration should be given to how to prevent such situations, such as setting up warning systems or automatic stop functions.

Secondly, the safety of the power source is also crucial. When working in high-temperature environments, the power source may continue to generate heat, causing discomfort or even danger to workers. In addition, poor power source design may cause electric leakage, increasing the risk of fire. Therefore, when selecting a power source, it must be ensured that it meets safety standards and takes into account the special requirements of the working environment. In our application scenario, because of the normal operation of the user, there is no high temperature environment that can overheat the battery. However, complex working environments may cause physical damage to the battery, such as severe deformation when the battery is impacted, punctured or compressed, which can cause danger. To this end, we plan to design a hard metal shell on the outside of the battery to protect the safety of the battery.

Furthermore, since working in narrow spaces such as sewers often encounters humid environments, the equipment must have good waterproof performance. Otherwise, the equipment may get damp, causing circuit shorts or even complete failure. To address this issue, waterproof materials or sealing techniques can be used in the design to ensure the reliability and stability of the equipment in humid environments.

Additionally, the responsiveness of the remote controller is also crucial. After operation, the remote controller should be able to respond promptly to ensure the accuracy and safety of the operation. Moreover, to cope with emergencies, consideration can be given to installing an emergency braking device in the equipment to stop the operation of the equipment promptly, ensuring the safety of workers.

Last but not least, when we enter an environment where motors are humming, drills are spinning, and cutting tools are cutting through material, every step counts and safety becomes your top priority. I always start with the essentials - personal protective equipment (PPE). When we worked on the project, no one operated the tools without wearing safety goggles to prevent accidental debris. Earmuffs or earplugs are necessary to protect our ears from the relentless hum of machinery and are crucial to preventing long-term hearing damage. Gloves are not in doubt; They protect our hands from scratches and severe cuts, and for anyone carrying heavy equipment, steel-toed boots are a must to protect their feet. Before we use the tool, we will seek the help of the tutor first, and try to do it in the presence of the tutor. It's vital that each of us knows the machine we're using inside out - not just how to boot it up, but its quirks, safety features, and what to do if things don't go according to plan. Of course, faced with different work tasks, we choose the right tools for the task, strictly follow the manufacturer's guidelines, and always ensure that safety protections are not only present, but properly protected - these are practices that we follow without compromise. Finally, before we actually start drilling or cutting, we make adequate emergency preparations. Everyone knows the quickest route to the nearest exit. We also know how to shut down equipment immediately in an emergency.

In summary, to ensure the safety of the working environment, we need to fully consider various potential risk factors in equipment design and power source selection, and take corresponding measures to reduce risks and ensure the safety of workers.

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