# Project Proposal For
# Movable Robotic Arm Platform for Laboratory

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By

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# Context

# 1. Introduction

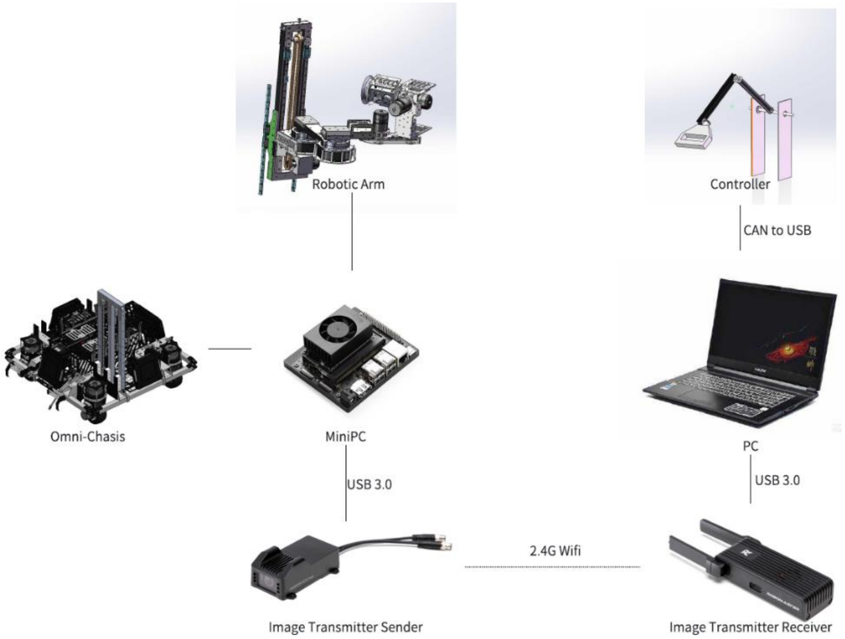
## 1.1 Problem

In today's rapidly advancing technological landscape, there is a growing need for solutions that can perform tasks in environments that are either hazardous or inaccessible to humans. This encompasses a wide array of scenarios, from executing precise maneuvers in dangerous industrial settings to conducting rescue operations in disaster-struck areas where human responders are at risk of injury or are physically unable to perform the necessary tasks. Traditional methods, such as direct human intervention or the use of cumbersome machinery, often fall short due to safety concerns, physical limitations, or the inability to execute the fine motor skills required in many such situations. Moreover, existing robotic solutions that mimic human dexterity often require the operator to wear specialized equipment, which may not fit all users comfortably or be quickly deployable in emergency situations.

## 1.2 Solution

Our project proposes a versatile robotic arm system equipped with a camera to capture and analyze human hand movements, enabling it to replicate these actions with high precision. This robotic arm is mounted on a wheeled base, allowing for autonomous or remote-controlled navigation across various terrains and environments. Our innovative approach circumvents the limitations of direct human involvement and the need for wearing potentially cumbersome control gear. The system's design focuses on flexibility and ease of use, making it adaptable to a wide range of operators and scenarios, from intricate tasks in unsafe industrial environments to swift response in post-disaster rescue missions. By combining delicate and powerful operations, our solution addresses the apparent contradiction of requiring both finesse and strength in critical tasks, such as removing heavy debris to rescue earthquake victims. The robotic arm's design emphasizes user-friendly interaction, with the potential for operators to switch control seamlessly, enhancing its utility across diverse applications.

## 1.3 Visual Aid



**Visual Aid**

## 1.4 High-level requirements list

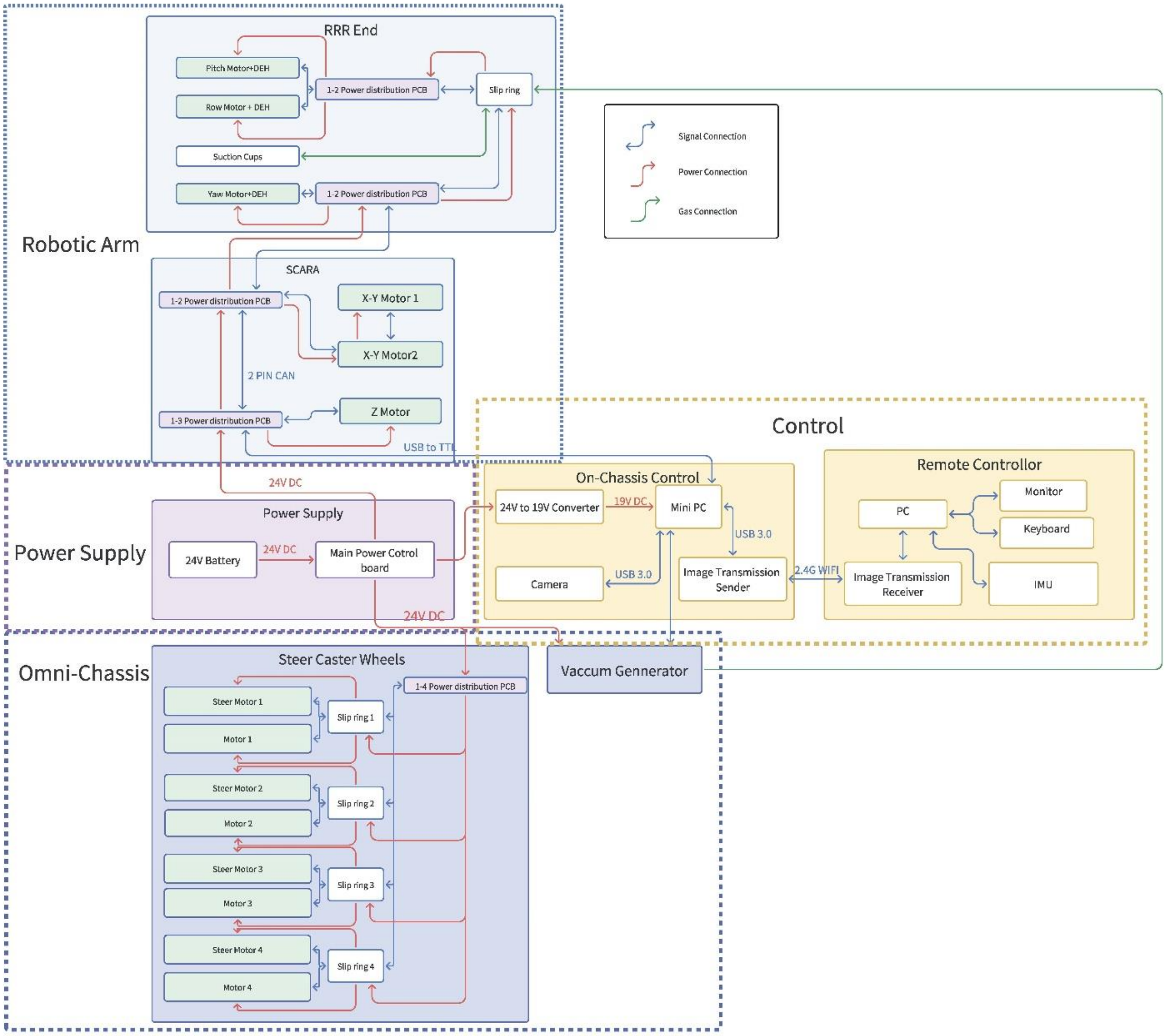
- The robotic arm must accurately replicate human hand movements, the error between operator's hand coordinate and transformed coordinate of robotic arm end should be smaller than 10%, ensuring precise manipulation of objects or tools as captured by the camera system.

- The wheeled base must be capable of navigating diverse terrains with stability and agility, achieving a mobility efficiency that allows for operation in varied environments, including industrial sites and disaster zones.

- The system must provide an intuitive control interface that can be adapted for use by different operators without the need for specialized fitting or extensive training, ensuring rapid deployment and versatility in emergency and routine scenarios.

# 2. Design

## 2.1 Block Diagram



# 3. Subsystem

## 3.1 Robotic Arm

### 3.1.1 Overview

The robotic arm subsystem consists of two main components: the RRR(Articulated) end and the SCARA（Selective Compliance Assembly Robot Arm) subsystem, connected by two 1-2 power distribution PCB boards.

The first three axles of the robotic arm adopt a non-traditional SCARA configuration, while the rest three axes adopt the classic orthogonal spherical wrist configuration (RRR) because using SCARA configuration instead of the traditional RRR configuration can reduce the maximum torque of the joint.

Additionally, the dead weight of the arm can be supported by the frame instead of the motor, which needs to continuously output torque and can lead to unnecessary energy consumption.

This hybrid design allows for the RRR end to be used for heavy lifting and the SCARA end to be used for precise manipulation.

### 3.1.2 Requirement

The robotic arm subsystem requires the following:

•The robotic arm must be able to lift the payload of 5 kg.

•The robotic arm must be able to move the payload to a position within 1 mm of the target position.

### 3.1.3 Tolerance Analysis

The robotic arm subsystem can be inaccurate due to the precision of the actuators(360°/8192), the mechanical components, and vibrations during operations. Furthermore, the robotic arm subsystem may fail to lift the payload due to the payload being too far from the center of mass.

To be more detailed, the encoder resolution of joint motor in robotic arm is 8192 per round, which means the smallest angle we can read is 0.044 degree. Since length of link 1 and link 2 is 20cm, the minimum resolution of each link position is more than 0.15mm, which means the resolution of the end position of robotic arm will be more than 0.9mm.

## 3.2 Power supply

### 3.2.1 Overview

The Power Supply (PS) system is crucial for the operational efficacy of the movable robotic arm, featuring a simplistic yet highly efficient design composed of a battery and a power control board. The system's primary component, the battery, ensures a steady supply of 24V DC power. This pivotal system not only energizes the robotic arm but also seamlessly integrates with and powers the three other major subsystems: the Robotic Arm system, the Control System, and the Omni-Chassis system, guaranteeing a continuous 24V DC power supply to these systems.

### 3.2.2 Requirement

Central to the PS system are two key components: a 24V battery and a Main Power Control board. The Main Power Control board functions as the intermediary between the battery and the subsystems, facilitating the distribution of power necessary for their uninterrupted function.

### 3.2.3 Tolerance Analysis

The PS system is engineered to support a variety of critical components to ensure the robotic arm's high performance and reliability. It must efficiently power at least 3 STM32F04 chips located in the handle, each paired with an acceleration sensor for enhanced precision and control. Additionally, the system powers a main control chip (STM32F04) that orchestrates the operation of the arm, and three servos on the robotic arm side, crucial for the arm's movement and functionality. This requirement highlights the PS system's integral role in sustaining the arm's responsiveness and operational integrity across a range of tasks.

## 3.3 Control

### 3.3.1 Overview

The main function of the control system is to control the action of the robotic arm. The system recognizes the hand movement of the manipulator through the camera and then controls the robotic arm to simulate the hand movement.

The control system consists of two subsystems: On-Chassis Control System and Remote System.

The On-Chassis Control System is mainly responsible for capturing images with the camera and transmitting them to the Remote System. The system is controlled by a mini PC and the camera captures the image and transmits the image to the remote system through the Image Transmission Sender.

The Remote system is mainly responsible for controlling the whole robot arm's action through the PC. The system uses an Image Transmission Receiver to receive image signals from the On-Chassis Control system, and the two are connected via 2.4g WIFI. the Receiver will transmit the image signals to the PC after receiving the image signals, and the manipulator will use the signals received by the PC to manipulate the robot arm.

### 3.3.2 Requirement

On-Chassis Control System: The system requires a CONVERT to convert the 24V DC supplied by the power system to 19V DC. A camera is used to capture the images and a mini PC is used for control. Image Transmission sender is used to transmit the image signal.

Remote System: The system has an image transmission receiver to receive image signals. It is controlled by a PC, which is connected to a keyboard and a monitor. And an IMC, which is IMU: BMI088. The BMI088 is a high-performance 6-axis inertial sensor that allows for highly accurate measurement of orientation and detection of motion along three orthogonal axes.

### 3.3.3 Tolerance Analysis

The control system's recognition of hand movements is not always accurate, which may result in the robotic arm not moving in the way the manipulator wants it to, causing the task to fail. Also, the timing of signal transmission is an issue to be considered. This may cause the robotic arm to move much slower than the manipulator.

## 3.4 Omni-Chassis

### 3.4.1 Overview

The core component of the omni-chassis subsystem consists of four omni-wheels driven by four motors and slip rings. The omni-wheels are designed to allow the robot to move in any direction without changing the orientation of the robot, allowing swift omnidirectional movement. The power is distributed to the motors through a 1-4 power distribution PCB connect to the power supply subsystem.

### 3.4.2 Requirement

The omni-chassis subsystem requires the following:

•The omni-chassis must be able to move the robot in any direction without changing the orientation of the robot.

•The omni-chassis must be able to move the robot at a speed of 1 m/s.

### 3.4.3 Tolerance Analysis

The omni-chassis subsystem fail to move the robot in any direction due to the omni-wheels being misaligned or the motors being unbalanced. Additionally, the omni-chassis subsystem may fail to move the robot at the desired speed due to the motors being underpowered.

# 4. Ethics and Safety

## 4.1 Ethical Considerations

The development and deployment of our robotic arm system, designed to replicate human hand movements and operate in hazardous environments, raise significant ethical considerations. In alignment with the IEEE Code of Ethics and ACM Code of Ethics, our project commits to prioritizing the safety, health, and welfare of the public, ensuring that our technology enhances the quality of life, fairness, and dignity of all stakeholders involved.

Privacy and Surveillance: Given the system's reliance on camera technology to capture human movements, there is a potential risk of privacy invasion. To mitigate this, our project will implement strict data handling protocols, ensuring that all captured data are anonymized and securely stored, with access restricted to authorized personnel only.

Autonomy and Misuse: The potential for the robotic arm to be repurposed for unintended or harmful activities, such as surveillance or in military applications, necessitates a robust ethical framework. We will incorporate failsafe mechanisms and operational limits to prevent misuse, ensuring the system's use remains within the scope of humanitarian and industrial assistance.

Accessibility and Inclusivity: Aligning with the principles of fairness and avoiding discrimination, our project aims to ensure that the robotic arm system is accessible and adaptable to a wide range of users, regardless of their physical abilities. This commitment extends to providing equitable access to the benefits of our technology, fostering inclusivity in its application.

## 4.2 Safety Concerns and Regulatory Compliance

Our project's design and operational framework will be developed in strict compliance with relevant safety and regulatory standards to mitigate potential risks associated with its functionality and deployment in various environments.

Operational Safety: The robotic arm will be engineered with built-in safety features, including emergency stop functions, collision avoidance systems, and adaptive response mechanisms to unexpected obstacles or failures. This approach ensures the protection of both the operator and bystanders during its operation.

Regulatory Standards: Compliance with state and federal regulations, industry standards, and campus policies will be rigorously pursued. This includes adhering to the Occupational Safety and Health Administration (OSHA) guidelines for robotic equipment and the American National Standards Institute (ANSI) safety standards for industrial robots and robot systems.

Risk of Injury: To address the potential for injury from mechanical failure or operational error, our system will undergo extensive testing and validation to meet high reliability and safety metrics. Training protocols will be developed to educate operators on safe handling and operation procedures, minimizing the risk of accidents.

Environmental Impact: Consideration will be given to the environmental impact of our system, ensuring that materials and processes used in the construction and operation of the robotic arm are sustainable and minimize ecological footprints. This includes evaluating the lifecycle of the system and implementing recycling or disposal protocols for end-of-life units.

## 4.3 Conclusion

In conclusion, our project team is committed to upholding the highest ethical standards and safety protocols, ensuring that the development and deployment of our robotic arm system contribute positively to society. By adhering to the IEEE and ACM Code of Ethics, incorporating safety and regulatory standards, and addressing potential ethical and safety issues proactively, we aim to develop a technology that is not only innovative but also responsible and beneficial to humanity.