Research on Multi-terrain Adaptable Post Disaster Rescue Navigation Vehicle

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1.1Abstract

As natural disasters increase, earthquakes have become a major threat to many people's lives. Therefore, post-earthquake rescue operations are particularly important. Rescue robots are mechanical devices that can assist rescue personnel in rescuing and assisting in the search for victims. Good rescue robots can greatly enhance the speed of rescue operations and save many lives. Through my understanding of rescue robots, I have found that most existing rescue robots use a tracked chassis for movement. However, I also found that the maneuverability of small rescue robots in rubble needs to be improved. Therefore, I thought of enhancing the obstacle-crossing ability of the chassis by proposing a rotating mechanism for the tracks. This optimization aims to improve the vertical obstacle-crossing performance of existing rescue robots, increase rescue efficiency, and save rescue time After mechanical and electronic design, I manufactured a physical prototype for experimental testing. Compared to traditional chassis without a rotating mechanism, the obstacle-crossing ability was found to increase by 80%. Due to the limitations of servo motor torque, the actual improvement could be even greater, theoretically up to 190%. At the same time, the stability of its movement is ensured. Experimental results showed a lateral displacement of 2mm on flat ground and 4cm on rough terrain, indicating excellent stability during movement.

2.1Background and Purpose

Severe earthquakes unleash chaos, disrupting lives and landscapes. Infrastructure crumbles, leaving cities paralyzed. Tsunamis, if triggered, inundate coastal regions. On average, there are approximately 20,000 earthquakes worldwide each year, with about 16 of them being of magnitude 7.0 or higher. The number of deaths in 2023 stood at 59259, and it is still rising rapidly. These earthquakes result in significant destruction and loss of life, making rapid and efficient disaster response essential. Navigating earthquake ruins is challenging due to the extensive damage caused by collapsed structures, debris, and unstable terrain. Firefighters must risk their lives to explore unknown regions. The advent of a multi-terrain adaptive multi-functional robot is crucial to support one to rescue or pick up forgotten object in the ruins or places that human beings are unable to reach.

Due to the difficulty of the missions and the harshness of the environment, the possibility of ending up with a damaged machine is extremely high. Firefighters may join the rescue in person, but there’s a high chance that they may sacrifice themselves too. Thus, a cheap, lightweight but solid, and efficient multi-terrain adaptive automobile would be very helpful to accurately locate the position of the victims, and the firefighters then can rescue them as quick as possible after confirming the location and risk. This method substitutes the traditional way of letting firefighters exploring debris by themselves, which put their lives at a lower risk. This article aims to explain the design and benefits of such a machine that I designed.

2.2 Current Status of Research

The field of rescue robotics was created by researchers in Japan and the U.S. in response to the dire events of 1995: the Hanshin earthquake and Oklahoma City bombing. These disasters came at a time when robots were becoming mobile − no longer fixed to the factory floor. Notable early examples include the use of robots in the aftermath of the 1986 Chernobyl nuclear disaster and the 1985 Mexico City earthquake. These early robots were often primitive in design and limited in their capabilities.

Figure.1 Chernobyl Rescue Bot

Murphy's team from the University of South Florida was the only academic institution among the teams coordinated by the Texas A&M Center for Robot-Assisted Search and Rescue (CRASAR) that responded to the World Trade Center attacks on Sept. 11, 2001. It was the first recorded use of a rescue robot at a disaster site. The operational challenges at disaster sites, including uneven terrain, debris, confined spaces, and potential communication interferences, could have posed significant hurdles for the robots, impacting their ability to perform effectively. In the modern days, corporations such as Boston Dynamics invented a wide range of robots that could adapt to different terrains along with diverse capabilities. For example, "Atlas," a bipedal humanoid robot capable of performing complex movements and tasks, and "Stretch," a robot designed for material handling and warehouse automation.

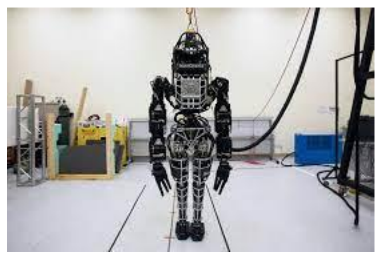


Figure.2 Bost Dynamics Rescue Robot

However, even though these machines are extremely advanced, but they unlikely to be used in real life scenarios due to the instability and the considerable amount of cost of mass production.

The European research project TRADR has allowed scientists and firefighters to use ground robots and drones to assist in post-disaster rehabilitation. It provided inspiration for me. This is a very successful example of an automobile that I want to create. This remote-controlled robot's mission is to search and explore the accident site. It has a rotational camera in the front that can create a 3-d dimensional graph of the environment, enabling people to understand the terrain even faster. The automobile itself has a unique design of the wheels, allowing the robot to maneuver over intricate terrains. Here is a picture of the automobile:

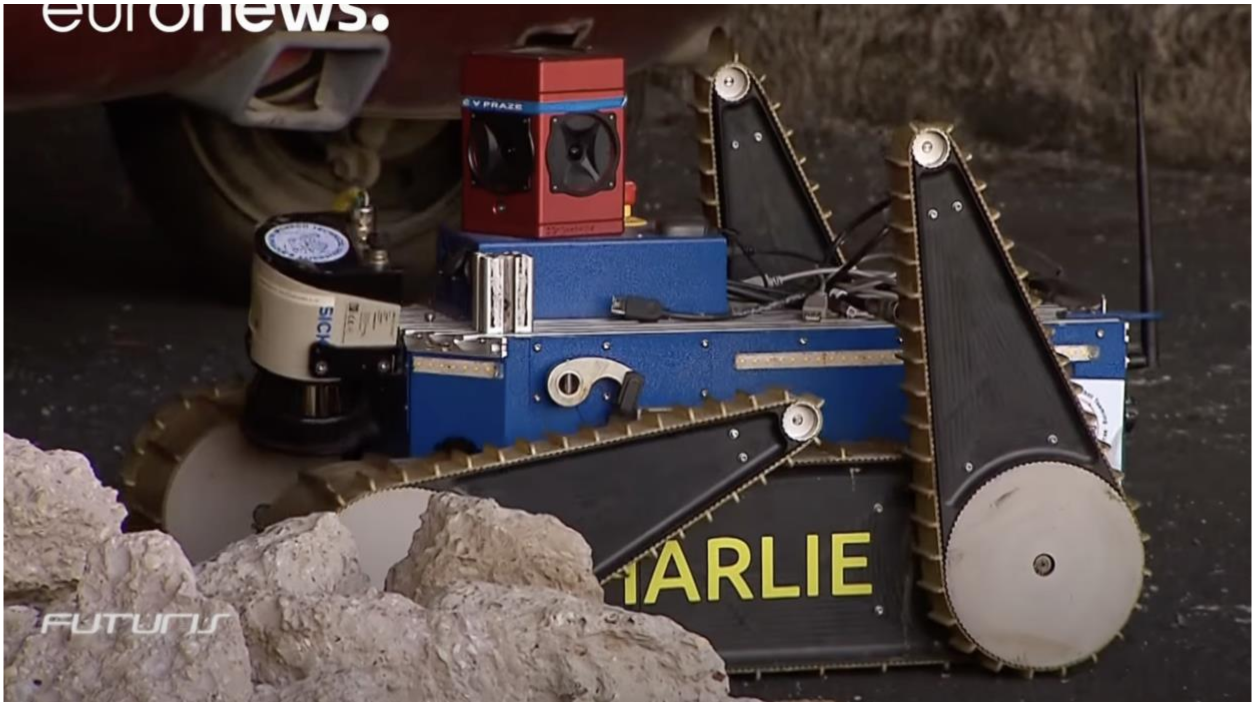


Figure.3TRADR Post-Disaster Bot.

The goal is to assess the risks and protect the lives of the rescuers. These robots usually work together with firefighters. The research team brought the robot to a collapsed 14th century church debris, and the robot had to cooperate with a drone to film the entire environment to create a 3-d environment. The result was ideal. However, the robot requires a lot of energy to move. The main part of the robot is steel, which makes the robot relatively clumsy, but such design is a very great inspiration for me. I must make my design more light-weighted if I can't succeed their technology.

Design Goal and Theory

I designed a light-weighted automobile with a claw that can do advanced movements in complex terrains to some extents to reach places that are steep, aiming to provide supports for the people in disasters and needs. The technology could be broken into two parts: coding and engineering. Arduino is the main software and platform to code. It is the "Big Brain" that controls all the motions of the mechanic claw and the base wheels (caterpillar bands). Engineering is also a huge part of this project, including 3d and 2d modeling. Fusion(3D-modeling) and AutoCAD(2D-modeling) are the software involved.

My robot will mainly be dealing with harsh terrains, such as steep slopes or slippery and uneven grounds. The machine should be able to move quickly when facing obstacles. The robot will be able to satisfy the following movements:

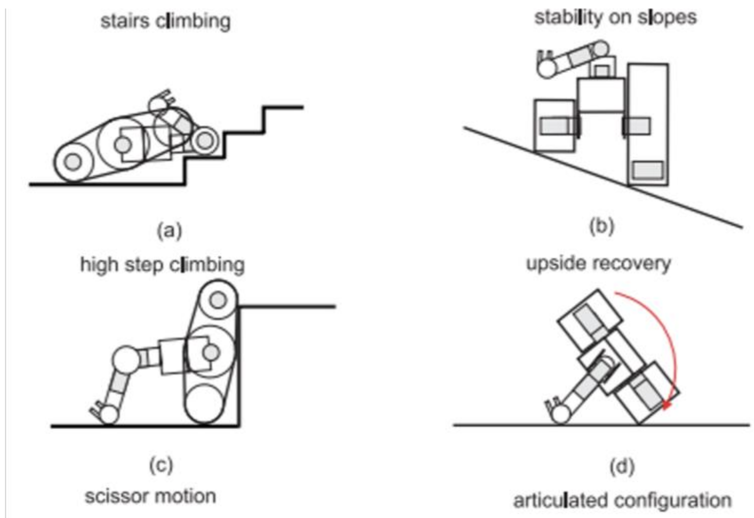


Figure.4 Goal of my vehicle

3. Structural Design

3.1 Design Requirement Analysis

Since the robot must function in post-disaster environments, it is very harsh and full of different types of obstacles that would. There are important requirements for the chassis and the ability to pass through hard terrains of the robot. A mechanic claw would also be needed. According to my research on precedents, similar robots are equipped with caterpillar bands. Caterpillar bands provide superior traction and stability, allowing robots to navigate challenging terrain. They also enable robots to distribute their weight evenly over a larger surface area so that it keeps a better balance. In addition, they also enable the machine to carry heavier objects. Because of these advantages, I want to add caterpillar bands to my own machine.

Traditional caterpillar bands chassis of the robots are not immaculate. The traditional chassis design with caterpillar bands are fixed. There are still some flaws that would hinder them from navigating through harsh environments. For example, when crossing a stair-like slope with high inclination, a fixed-caterpillar track would be stuck and unable to pass through. Due to the relatively high height difference between stair-like obstacles, exceeding the height of the tracks themselves, this causes traditional fixed-track caterpillars to easily get stuck at the front end when crossing such obstacles, unable to move forward due to being wedged on steep slopes.

Therefore, the robot would have to find a new route and that wastes the precious time to rescue. Thus, a rotational caterpillar that could pass stair-like slope efficiently would be required.

The multi-terrain adaptive machine of mine has a base, a rotational claw and two 360-degree rotational caterpillar track. The two bases are connected to the base with screws and bearings, thus allowing the bases to spin and perform advanced movements. The bases are 300mm long, 100mm wide and 60mm high. Such size can grasp the ground tightly while not losing maneuverability.

3.2 Base of Caterpillar track Design

Based on my design goal analysis in 3.1, I designed a dismountable and 360-degree caterpillar track structure. The picture shown below is my installed caterpillar track:

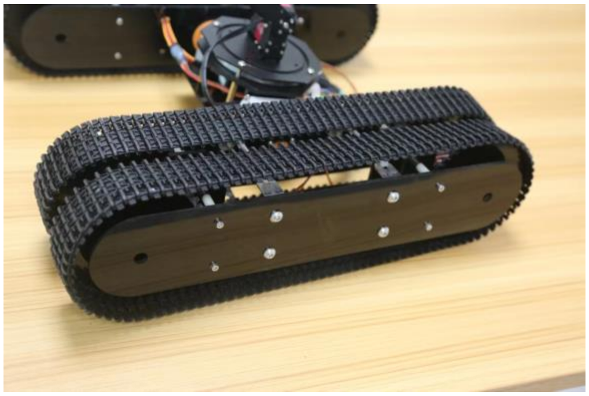


Figure.5 Version 1 Caterpillar Tracker and Base

The track chassis I designed is composed of two tracks, two drives. Its drive energy is the use of 20 kg per cm of two-shaft steering gear. In this way, it is easy to achieve the common speed of the track when the double steering gear drives the double track to ensure the stability of the chassis. I designed the track chassis using the two-dimensional software AutoCAD for plane design, as shown in the following figure (the outline of the parts of the chassis), most of which are cut and assembled by plates.

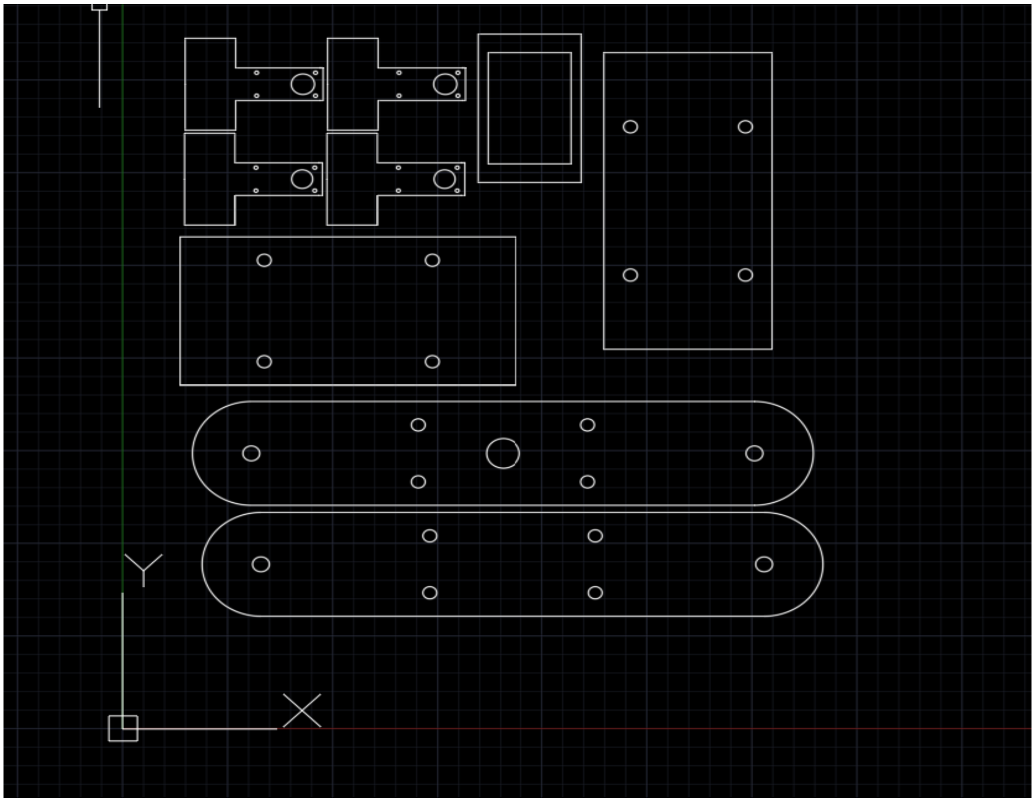


Figure.6 Overall 2-d graph of version one base and caterpillar tracker components

Our three-dimensional structure is isolated spatially between the panels using nylon spacers. Assembly is done using three-millimeter bolts, and servos are fixed with T-shaped plates. The power from the servos is then transmitted to the drive gear of the panel-cutting conveyor belt. Two side panels prevent roadside sand and gravel from entering and affecting the meshing of gears and conveyor belts. Below is the diagram of my panel-cutting gear. The gear pitch is determined by measuring the spacing between the holes of the conveyor belt. The number of teeth on the gear is used to determine the radius of the driving gear. This dimension also determines the width of our conveyor belt. We have selected 40 teeth for the gear, with a gear module of 2.5, because our gear material is 5-millimeter acrylic. Due to the lower strength of acrylic, it is necessary to ensure that the gear has sufficient root strength when meshing with the conveyor belt to prevent breakage during meshing. Moreover, a gear module of 2.5 facilitates the laser cutting of our gears. Using a gear module of 1 would result in severe root cutting due to the inherent errors in laser cutting, leading to a decrease in gear strength.

According to the formula, p=pi*m, the pitch of the teeth at this time also applies to the transmission of our gears and tracks.

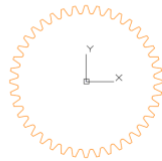


Figure.7 2-d graph of gear

This is a standard gear with 40 teeth and a module of 2.5. Since I am using 5-millimeter acrylic for cutting, the thickness of the gear is greater than the gap of the conveyor belt, so grinding is required to ensure smooth insertion. The image below shows the ground gear.

The rotating part of our first-generation chassis adopts a structure where the servo is directly connected to the servo disc. The servo selected has a torque of 60 kg·cm, and after testing, this servo meets the requirements. However, the direct connection between the servo and the servo disc will cause excessive stress on the servo disc during the rotation of the entire chassis, leading to severe wear on the servo disc. This may result in loosening issues after prolonged use.

Besides these advantages, there are still parts of the robot that could be improved. The connection between the caterpillar bands and the mechanic claw base. Such a fragile design cannot prevent the caterpillar bands from shaking vertically. The caterpillar bands may even fall apart when encountering extreme terrains. Thus, I will strengthen the connection here in version 2.

Figure.8 Connection before ver.2

To solve this problem, we optimized the site. The following is the optimized structure of the second generation site

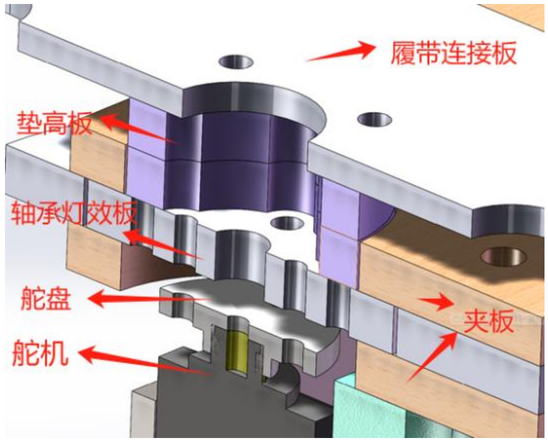


Figure.9 3-d graph of ver.2 connection

The main structure of my design (show above) is primarily responsible for connecting the track propulsion section with the main control board and providing rotational freedom and power to the mechanical arm's main body. Due to the substantial weight of the tracks, the strength of the connections in this area needs to be sufficiently high to meet the demands of track obstacle traversal.

The first generation used a direct connection structure with servos, resulting in severe wear on the steering wheel and significant track movement. Therefore, a bearing clamp structure was adopted, using a 5mm thick acrylic plate instead of a rotating bearing. The gaps generated by laser cutting serve as the rotational pair. The apertures in the front and rear clamp plates are smaller than the diameter of the intermediate bearing replacement plate, achieving similar effects to bearings while ensuring higher strength. The intermediate rotating plate needs four connecting holes to link with the steering wheel. The intermediate bearing equivalent plate acts as a spacer, and the track connection plate is rigidly connected. The clamp plates are connected to the servo mounting parts.

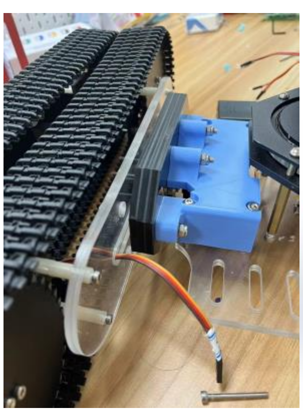
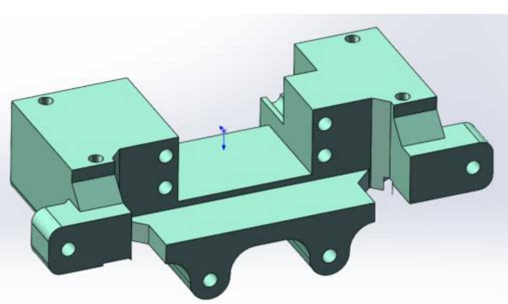
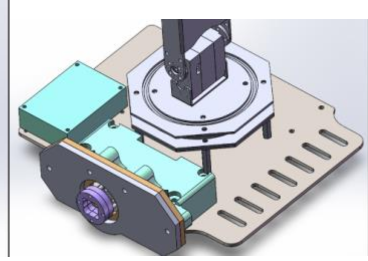




Figure.10 Ver.2 connection Figure.11 3-d ver.2 component. Figure.12: 3-d overall installation

(a) (b) (c)

I designed some new structures to reinforce this part. In figure (a), blue part is identical with the 3-d model in figure (b), and there is a 360-degree servo right under the blue structure. It is obvious in figure (a) that there is one transparent and three other smaller black acrylic plate between the caterpillar bands and the servo. These serve as connectors: The transparent plate connects the caterpillar band, so the horizontal force acted on the caterpillar band will not shift it anymore. For the three black acrylic plates as shown in figure(a), two plates on the outside covers the other one in the middle, and they have different structures. The two outer plates, shown in figure(d), each has a large hole for the screws from the other side to come through. These reinforce the connection between the servo and the caterpillar bands. The plate in the middle has a smaller hole that allows bearing to come through, as shown in figure(e). In figure (c), the purple part is used to maintain a proper distance between caterpillar bands and the base so that the bands will no collide with the screws going from outside to inside.

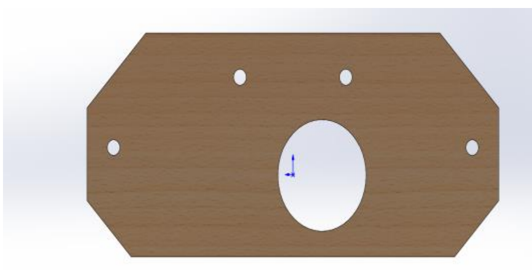


Figure.13 New connection Plate
(d)

Figure.14 New Connection Plate
(e)

Another Problem that I faced was that the caterpillar band easily gets stuck. That was because I was using 4 separate laser-cutter gears on each side, so that any horizontal shaking would make the caterpillar bands deviate from originate position, which then stopes moving. This is crucial, so I designed a new type of gear show in the picture below. Instead of using 4 separate gears separately, I combined two of them together using a 3-d printer shown below. To be more specific, it is no longer a gear, but a very similar device called the belt wheel. This perfectly solves the problem of shaking. I tried to test the shake that the robot experiences during when moving, and the result was ideal with just a few millimeters of shaking.

Figure.15 ver.2 Belt Wheel

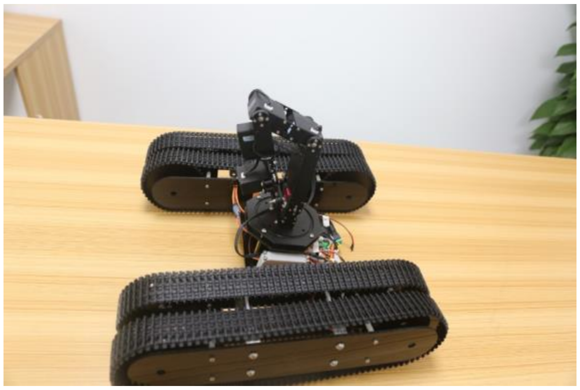
3.3 Grasping structure design

Since we will encounter a lot of obstacles in the rescue mission, this time may delay a lot of rescue time because of the long way around. Therefore, the handling of obstacles is the most efficient method, so we use a 6-free robotic arm to complete this operation. The three-dimensional picture of the robot arm is shown in the figure below

Figure.16 3-d graph of mechanic claw

The robotic arm is powered by six servos. Among them, the servo with a larger load at the bottom has a torque of 30 kg·cm, while the servo with a smaller load at the top is 15 kg·cm. The length of the robotic arm is 381 millimeters. When installed on the chassis, it can grasp obstacles beyond the chassis, meeting our requirement for obstacle removal.

3.4 Overall design



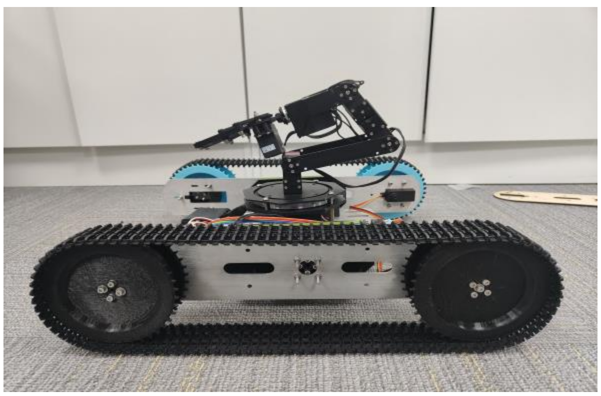


Figure.17 Version 1 Vehicle Figure.18 Version 2 vehicle

Overall Improvements：

1. 1. The double track is simplified into a single track: reduce the torque of the rotating steering gear, so that the whole can have a better obstacle crossing height and faster traveling speed, strengthen the track connecting plate, reduce the deformation of the track part by using steel plate to increase the overall stiffness, and the connection part also has better strength, and can resist great deformation in the process of climbing over obstacles.2.
2. Power management optimization: The integrated power supply of the first generation will lead to the increase of the current of the steering gear, which will affect the power supply of the steering gear control board and the current stability of other steering gear and mechanical arm, which will easily lead to the chip in the steering gear main control

board being burned. The second generation is optimized by separating the power supply of the mechanical arm from the power supply of the chassis.

3. Optimization of the structure of the rotating parts of the track: the first generation of the rotating part of the track, while directly connecting the steering wheel and the steering gear in the rotation, also must resist the reverse torque required by the gravity support of the robot, which will lead to insufficient strength of the connected part and serious wear and shaking. The second generation through the thick transmission shaft structure, only through the steering gear transmission resistance to the light through the structure to bear.

4. Track belt meshing: the first generation uses the plate for meshing, which requires grinding gears and lacks the axial limit. The second generation uses the printed parts of the gear teeth for meshing. The double-row meshing makes the track not produce axial displacement, which greatly improves the stability of the track and optimizes the phenomenon of clamping teeth.

4. Hardware

4.1 Overall Control Logic

Our chassis and robotic arm sections are divided into two control systems, each with its own power management. This means there are two separate power modules for supplying power. This is because the two servos responsible for rotation consume more power and have a higher current. If they were to share one power source, it could lead to excessive current, potentially causing the circuit board to burn out. The chassis section is controlled via a mobile phone, while the robotic arm section is operated using a PS2 game controller. The control interface on the mobile phone is shown in the figure below.

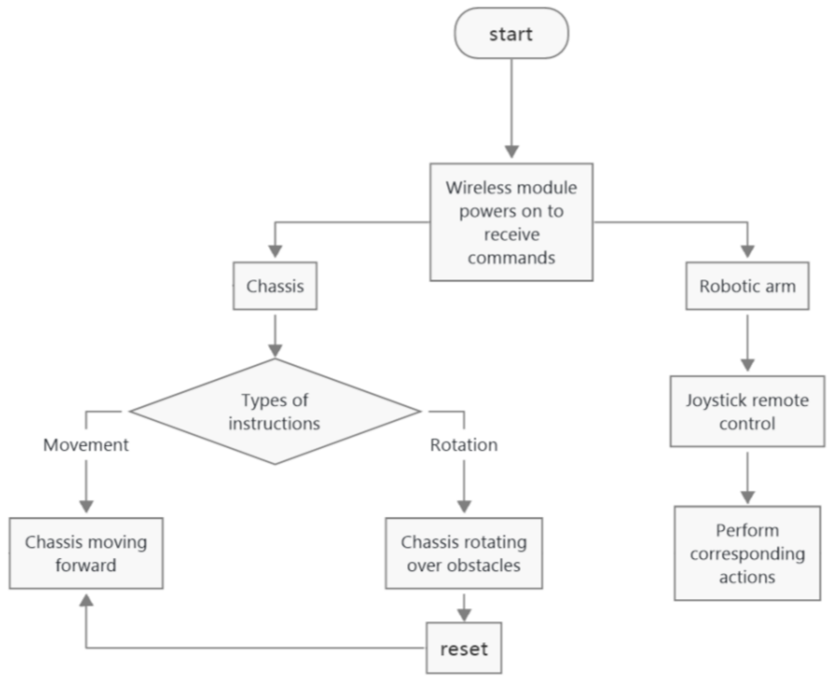
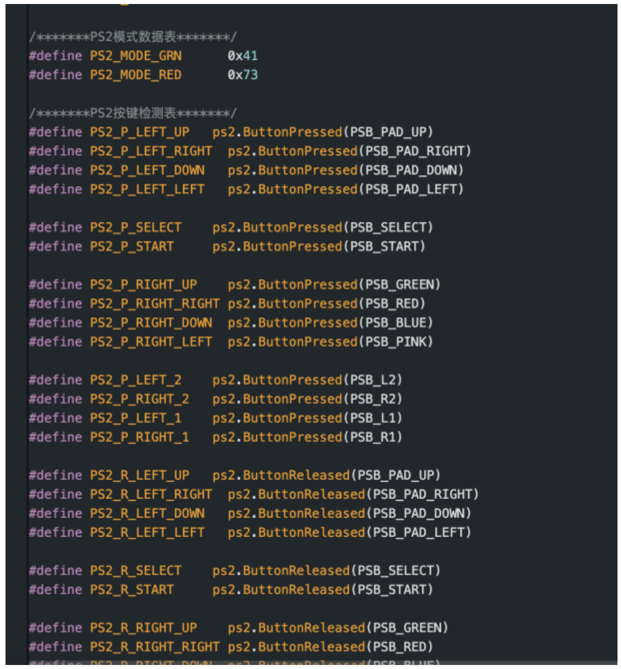


Figure.17 Control Logic

Figure. 18 Bluetooth Control On Iphone

4.2Codes

For the coding part, I used Arduino. The main principle is like this: When the key of the PS2 controller is pressed, the signal is sent by the ps2 controller transmitter. The Arduino control board is connected with a signal receiver, which converts physical signals into electrical signals and receives them through the serial port of the main control board.



```
/*******PS2模式数据表*******/
#define PS2_MODE_GRN      0x41
#define PS2_MODE_RED      0x73

/*******PS2按键检测表*******/
#define PS2_P_LEFT_UP   ps2.ButtonPressed(PSB_PAD_UP)
#define PS2_P_LEFT_RIGHT  ps2.ButtonPressed(PSB_PAD_RIGHT)
#define PS2_P_LEFT_DOWN   ps2.ButtonPressed(PSB_PAD_DOWN)
#define PS2_P_LEFT_LEFT   ps2.ButtonPressed(PSB_PAD_LEFT)

#define PS2_P_SELECT    ps2.ButtonPressed(PSB_SELECT)
#define PS2_P_START     ps2.ButtonPressed(PSB_START)

#define PS2_P_RIGHT_UP    ps2.ButtonPressed(PSB_GREEN)
#define PS2_P_RIGHT_RIGHT ps2.ButtonPressed(PSB_RED)
#define PS2_P_RIGHT_DOWN  ps2.ButtonPressed(PSB_BLUE)
#define PS2_P_RIGHT_LEFT  ps2.ButtonPressed(PSB_PINK)

#define PS2_P_LEFT_2    ps2.ButtonPressed(PSB_L2)
#define PS2_P_RIGHT_2   ps2.ButtonPressed(PSB_R2)
#define PS2_P_LEFT_1    ps2.ButtonPressed(PSB_L1)
#define PS2_P_RIGHT_1   ps2.ButtonPressed(PSB_R1)

#define PS2_R_LEFT_UP   ps2.ButtonReleased(PSB_PAD_UP)
#define PS2_R_LEFT_RIGHT  ps2.ButtonReleased(PSB_PAD_RIGHT)
#define PS2_R_LEFT_DOWN   ps2.ButtonReleased(PSB_PAD_DOWN)
#define PS2_R_LEFT_LEFT   ps2.ButtonReleased(PSB_PAD_LEFT)

#define PS2_R_SELECT    ps2.ButtonReleased(PSB_SELECT)
#define PS2_R_START     ps2.ButtonReleased(PSB_START)

#define PS2_R_RIGHT_UP    ps2.ButtonReleased(PSB_GREEN)
#define PS2_R_RIGHT_RIGHT ps2.ButtonReleased(PSB_RED)
```

Figure.19 Code for Controller

To put it simple, when a button is pressed, it is recorded as 1, while if it is released, it is recorded as 0. The signals are then sent to the main Arduino control board through a USB connector.

I also programmed for the steering engines, and the following are my codes:

```
  返回值:     无
 **************************************************/
void onTimer(){
  sevro0_pwm += last_left_x/2;
  if(sevro0_pwm < 500){
    sevro0_pwm = 500;
  }
  else if(sevro0_pwm > 2500){
    sevro0_pwm = 2500;
  }
  sprintf(cmd_return, "#001P%04dT0200!\n", sevro0_pwm);
  Serial.print(cmd_return);

  if (lu == 1) {
    angle1 +=40;
  }
  else if (ld == 1) {
    angle1 -= 40;
  }

  if(angle1< 500){
    angle1 = 500;
  }
  if( angle1 > 2500){
    angle1 = 2500;
  }

  sprintf(cmd_return, "#002P%04dT0200!\n", angle1);
  Serial.print(cmd_return);
}
```

Figure.20 Code for Servo

Then the main control board writes corresponding processing programs according to the communication protocol of the remote control to analyze the signals. At this point, the main control board has been informed which button is pressed, the program according to the classification processing, control the corresponding steering gear rotation.

The function of Loop function is to determine the corresponding state of each key by analyzing the signal after the connection, and change the variable corresponding to each key:

```
int lu = 0;
int ld = 0;
int l1 = 0;
int l2 = 0;
int r1 = 0;
int r2 = 0;
int ll = 0;
int lr = 0;
int ru = 0;
int rd = 0;
int rr = 0;
int rl = 0;
int se = 0;
int st = 0;
```

Figure.21 Initial value for controller

Here is my timer interrupt callback function, in the timer.ino file:

After detecting the state of the key, the defined variable is directly changed (see the figure above). At the same time, the interrupt function is entered, and the corresponding variable changes the pwm value of different steering gear to realize the rotation of the steering gear.

An example: The steering gear driver that drives the base rotation is as follows:

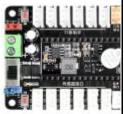
```
void onTimer(){
  // 底座旋转
  sevro0_pwm += last_left_x/4;
  if(sevro0_pwm < 500){
    sevro0_pwm = 500;
  }
  else if(sevro0_pwm > 2500){
    sevro0_pwm = 2500;
  }
  sprintf(cmd_return, "#001P%04dT0200!\n", sevro0_pwm);
  Serial.print(cmd_return);
```

Figure.22 Timer

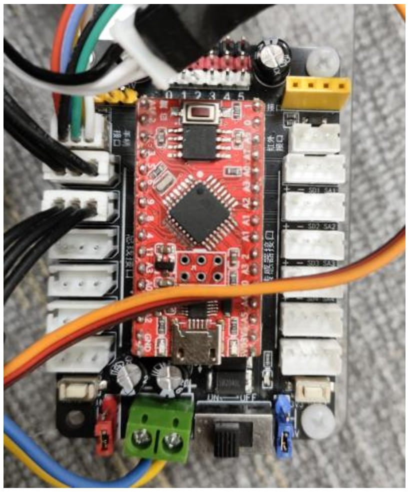
Here it indicates that the pwm of servo0 specifies 500-2500, which corresponds to the 0-180 Angle of the 180 steering gear. Our initialization defines the pwm as 1500, which is to achieve the median of 500-2500 to achieve the alignment of the steering gear.

In addition, the steering gear 3456 is controlled by directly writing the steering gear Angle. This is because the steering gear 3456 is operated by the joystick of SP2 handle, and the output corresponding to the joystick operation is a virtual quantity. Here, the data returned by the joystick is calculated by the following function to define the rotation Angle of the steering gear.

4.3 Hardware

Name	Picture	Detail
Steering Gear Control Panel		DC:6-8.4v 76mm-66mm Pwm:6 Iic:1
Single Shaft Steering Gear		30 kg.cm 8.4V
Nano Board ATmega328P		5V 16M Micro-Controller Board Compatible with Arduino IDE
Buck Power Module		9-30v --- 5V
Rechargeable Lithium-ion Battery		12V 2200mAh

Mechanic Claw Control Hardware：



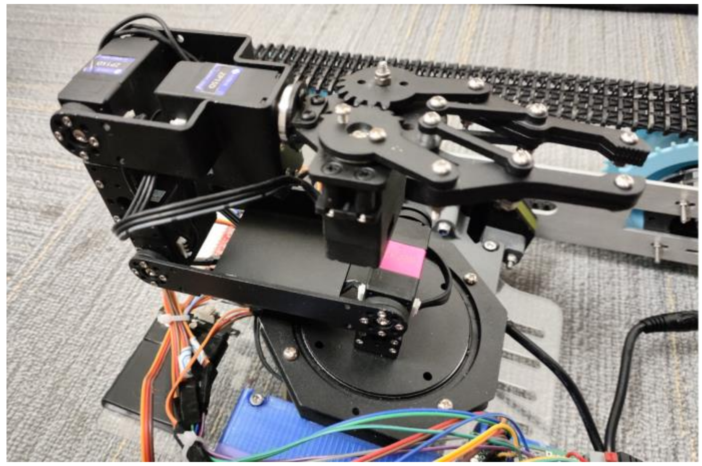


Figure.23 Mechanic Claw Control Plate   Figure.24 Mechanic Claw

Base Control Hardware：

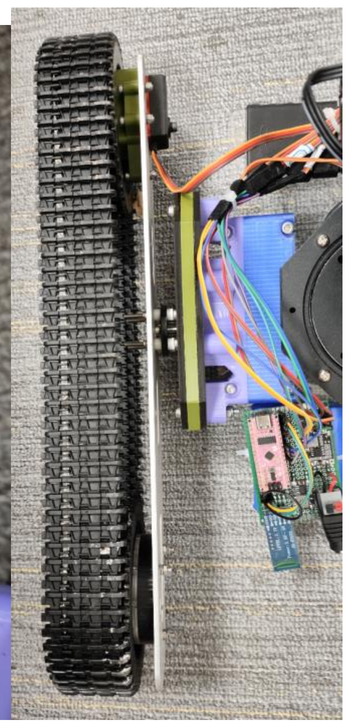


Figure.25(left)&26(right) Base control plate and base

5. Experiments

5.1 Chassis Mobility Test

High stability is required for the robot to navigate through complex terrain, making testing of the chassis mobility essential. My experiment was made by driving the same distance on flat ground and rough ground respectively, recording video at the same Angle, and analyzing through tracker, a physics experiment analysis software. We separately analyzed the acceleration of the trolley situation in the video and the movement of the center of gravity in the vertical direction to analyze whether the motion ability of the trolley on the rough ground would be greatly weakened.

The following is the test process of the experiment on a flat ground. I first conducted the test on a flat ground and recorded the experiment video, as shown in the figure on the left, for analysis through the tracker. Then the process of running the same test on the rough road is shown in the figure on the right.

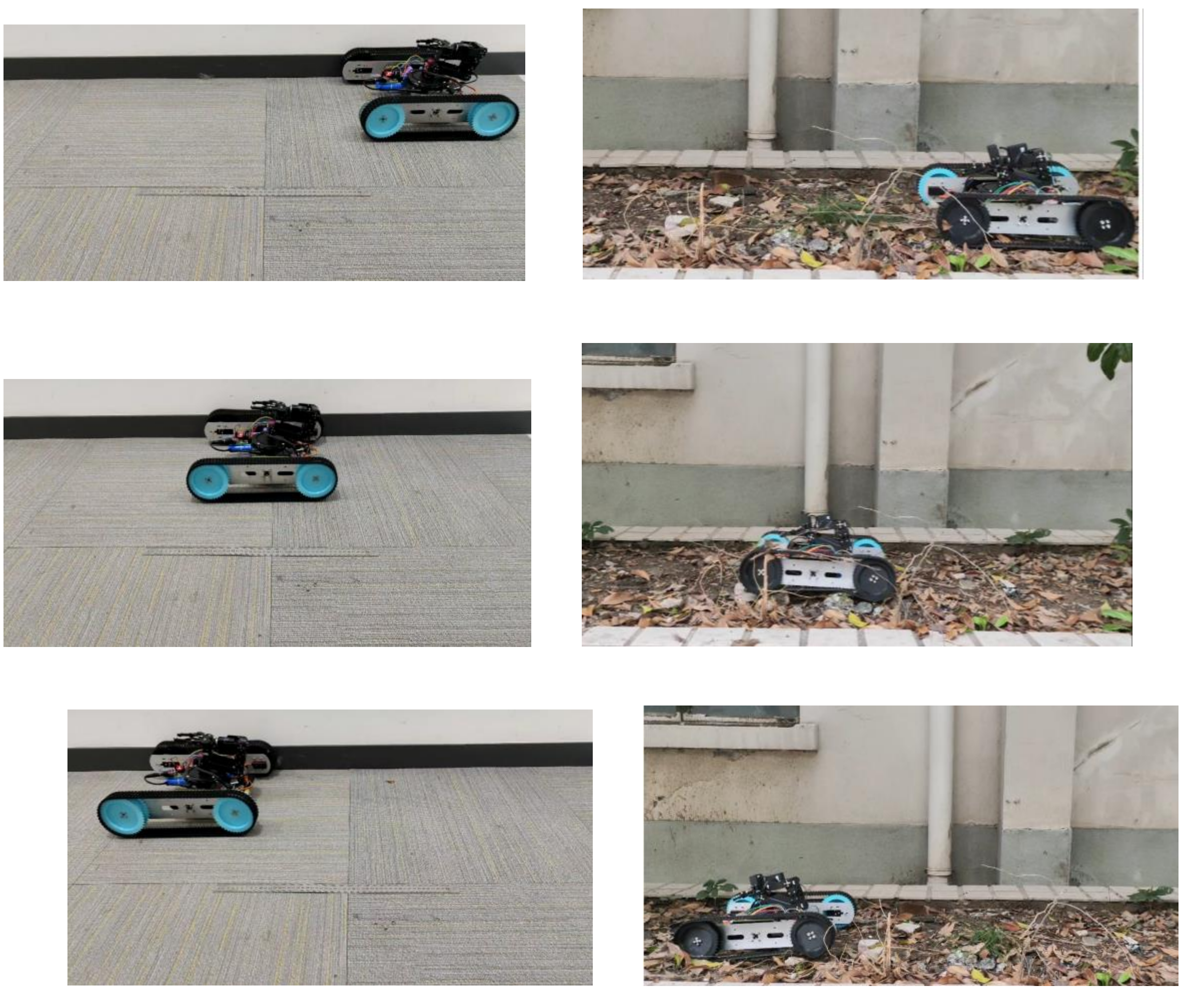


Figure 27-32 Experimenting Vehicle on two different roads

Figure.33 The displacement of the Y-axis of the robot on flat ground

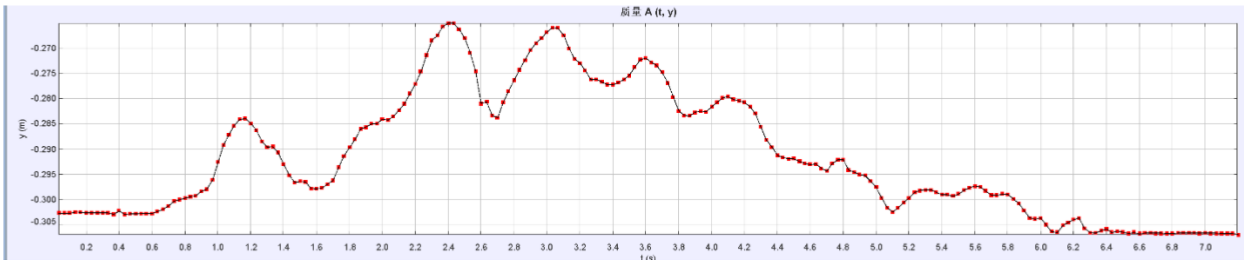


Figure.34 The displacement of the Y-axis of the robot on rough ground

From the analysis above, it can be seen that the movement of the robot on flat ground is stable. Due to a parallel error between the camera and the ground, the distance on the Y-axis is 0.002m, which is only 2mm. The nearly straight line on the neat undulating surface indicates the good stability of the robot's movement. Furthermore, analyzing the movement on rough terrain shows an error distance of 0.04m, with a 4cm error. Since the roughness of the ground itself can reach 4cm, the robot demonstrates good stability when crossing such rugged terrain.

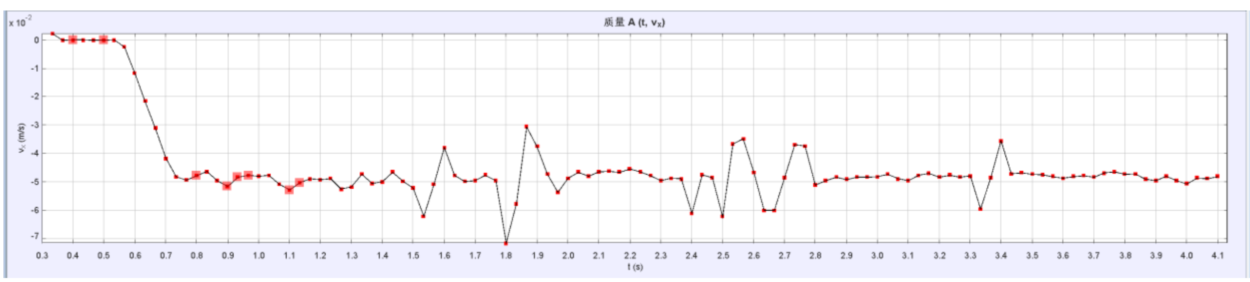


Figure.35 The X-axis velocity of the robot on flat ground

Figure.36 the X-axis velocity of the robot on rough ground

From the speed analysis of the robot crossing obstacles in the above figure, it can be observed that the speed on flat ground is approximately 5cm/s, while the speed on rough terrain stabilizes at 2.5cm/s. This indicates that the robot experiences a speed loss of around

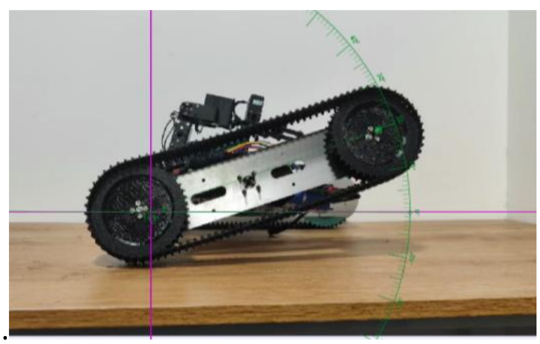
50% on rough terrain. However, the good thing is that the speed on rough terrain remains relatively stable, enabling the robot to effectively carry out rescue operations.

5.2 Obstacle-crossing Ability of The Base

The ability of the rescue robot to cross obstacles is an innovative feature that sets it apart from other rescue robots. By adding a rotating degree of freedom on its tracks, it significantly increases the height it can cross over obstacles. This gives it the capability to handle step-like obstacles that are higher than half of its track height. Therefore, the experiment of crossing obstacles serves as a demonstration of its obstacle-crossing ability.

Experiment process: The experiment aims to explore how much the addition of the rotating degree of freedom enhances the obstacle-crossing capability by testing its performance in crossing obstacles of various heights. The process involves measuring the height of different platforms and conducting obstacle-crossing experiments.

Below is the process of our tested vertical lift:



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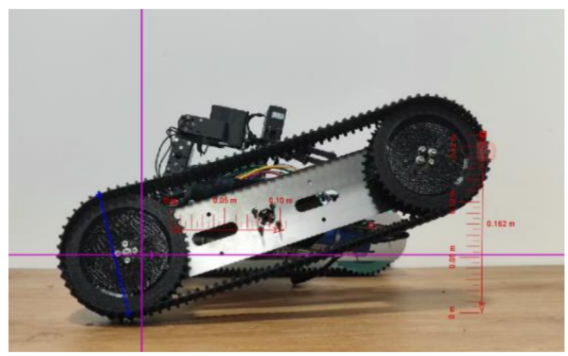

Figure. 37 Angle of the tracker

Fiigure. 38 Height of the tracker

According to the tracker analysis, the vertical lift angle can reach 20 degrees. Based on the height of the lift from the ground to half the height of the track, it can be determined that the theoretical maximum height for crossing obstacles is 162mm, with the track height being 110mm. The theoretical crossing height without the rotating joint is 55mm. Theoretically, the ability to cross obstacles can be increased by 194%.

Below is the process of our rescue robot crossing obstacles during both simulated and actual tests:

Figure.39-43: Entire process of vehicle crossing obstacle.

According to the above diagram, the robot successfully crossed the obstacle as shown. Through measurements, it was determined that the height of crossing the obstacle is 100mm, which is 45mm higher than the theoretical crossing height. This indicates an 81% improvement in obstacle-crossing capability compared to before. The significant deviation from the theoretical value is due to the excessive climbing height, where the servo motor cannot support the entire body to lift into the plane. Therefore, the torque of the servo motor needs to be further increased to achieve the theoretical level of obstacle-crossing. This experiment also demonstrates that the added rotating structure has significantly enhanced the obstacle-crossing capability compared to a regular rescue robot

The vehicle is still a prototype, and a lot of other sensors such as thermal sensor could be added to the top of the mechanic arm. There could also some improvements such as adding wheels. There is a lot of potential and it also makes a constructive contribution to earthquake rescue missions.

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