Vehicle with Transformable

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2.Abstract

a. Backgrounds

In daily occasions, the vehicle need to pass through different types of fields because the real occasions are very complex compared to simulations. Thus, exquisite mechanical designs are necessary for vehicles. Also, this technique can be applied to aerospace robots, automatic-driving vehicles.

b. Objectives

(1) Can climb onto a stair (6cm in height).
The wheels need sharp teeth that can help the car climb up the steps. The size of the wheels should be big enough to make the car climb the steps easily.

(2) Can drive on sand
The contact area of the wheel and the sand should be large enough to prevent the car from sinking into the sand.

(3) Can drive fast on a flat surface.
The size of the wheel should correspond to the output power of the driving motor. The total weight of the car should be light enough.

(4) Can go through a door that is 60 centimeters wide and 10 centimeters high.
The size of the car needs to be controlled in a proper range. The size limitation of this project is 30cm×30cm×10cm. The wheels can change its diameter to less than 10cm to make the car go through the gate.

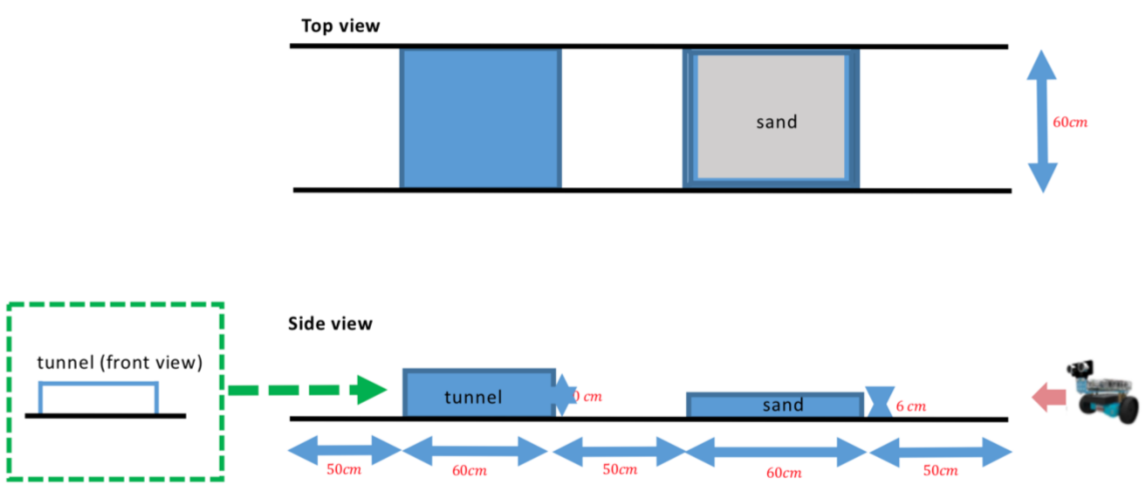
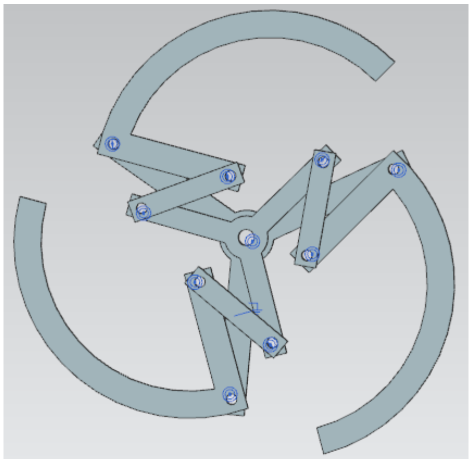
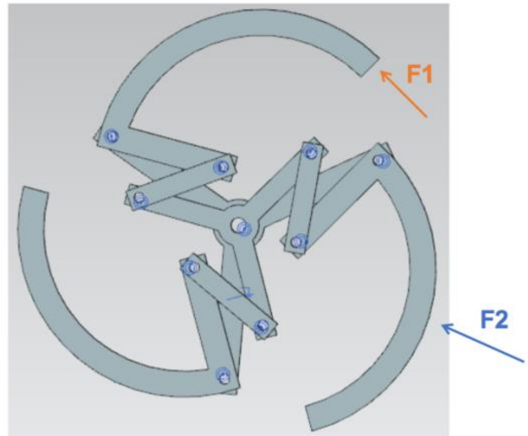


Figure 1. Game Field

c. Methods

We used the method of linkage transformation to realize this function.





(1) Basics design

(a)Automatically expanded when facing obstacle

(b)Transform without using extra servo or motor

(c)Simple linkage structure to avoid instability

(2) Functionality

(a)When facing vertical obstacle, the force is F1, which cause the wheel to expand

(b)When running on the ground, the force is F2, which keep the wheel at the shrink mode

d. Main results and conclusions

The linkage transformation methods enable the vehicle's wheels to expand when experiencing the resistance forces from the obstacles. After passing through the sand field, turning the wheels reversely can shrink the wheels.

3.Introduction

a. To determine different types of the fields and transform the wheels to the corresponding shapes.

b. Our group applied the method of linkage transformation. It enables wheels to transform between two shapes freely.

4. Synthesis (Design)

a. Describe your originality (creativity) of your linkage design compared with other designs published.

Our linkage design is different from most other designs published. For most of the transformable wheel vehicle design, 'active deformation' is used, while in our design, we apply 'passive deformation'. In our design, the transformation of wheels does not require extra motor or servo to drive. With the help of our linkage design, when the wheels meet the step, the main driving motor can provide the power to transform the wheels. When the wheels are expanded, it can form a structure with three long ‘claws’, which is can help the vehicle climb the steps or run on the sand land easily. And since we only use two motors in total on our vehicle, the structure is simple and the weight of the vehicle is low, making it light, flexible and stable.

b. Graphical linkage synthesis

i. The linkage synthesis in our design is a two position synthesis.

ii. Justification of linkage size for both expansion and shrink modes

The linkage size: Expansion mode size R_e=76mm

Shrink mode size R_s=32mm

For the expansion mode dimension, the following figure provides a graphical justification of size design. From the figure, we can see that the expansion mode size is appropriate for climbing the stair with height of 60mm.

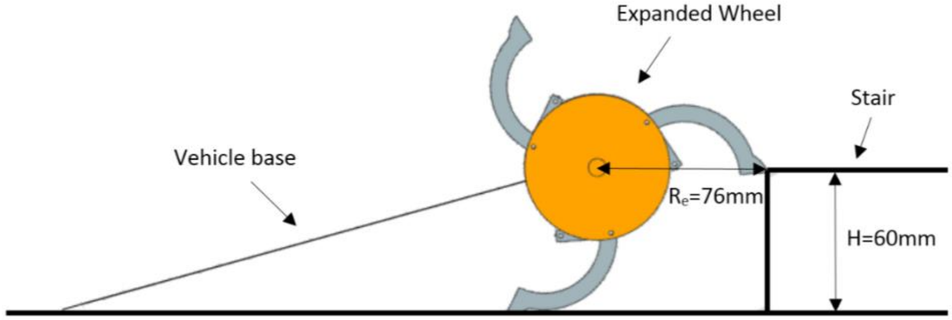


Figure 2. Side view of the vehicle when climbing the stair

For the shrink mode case, the shrink mode size is 32mm, which indicates that the vehicle can run through the tunnel with height of 10mm when it is in shrink mode.

iii. CAD figures

1. On the linkages

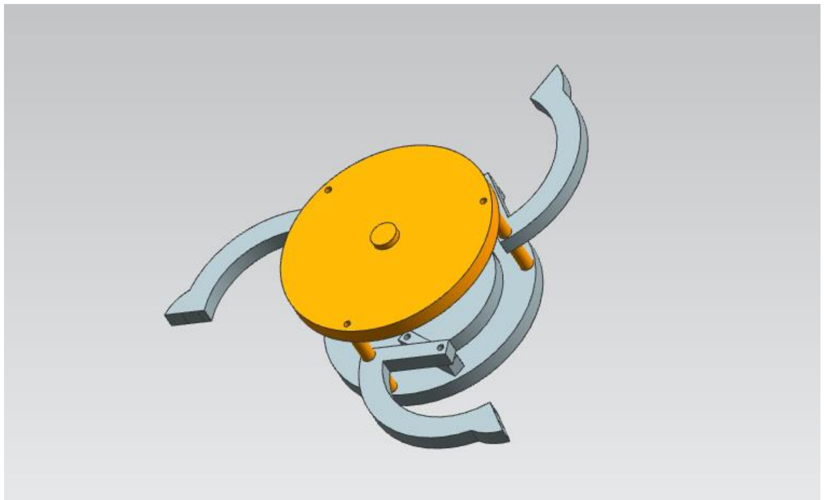


Figure 3. CAD of linkages

2. The whole vehicle

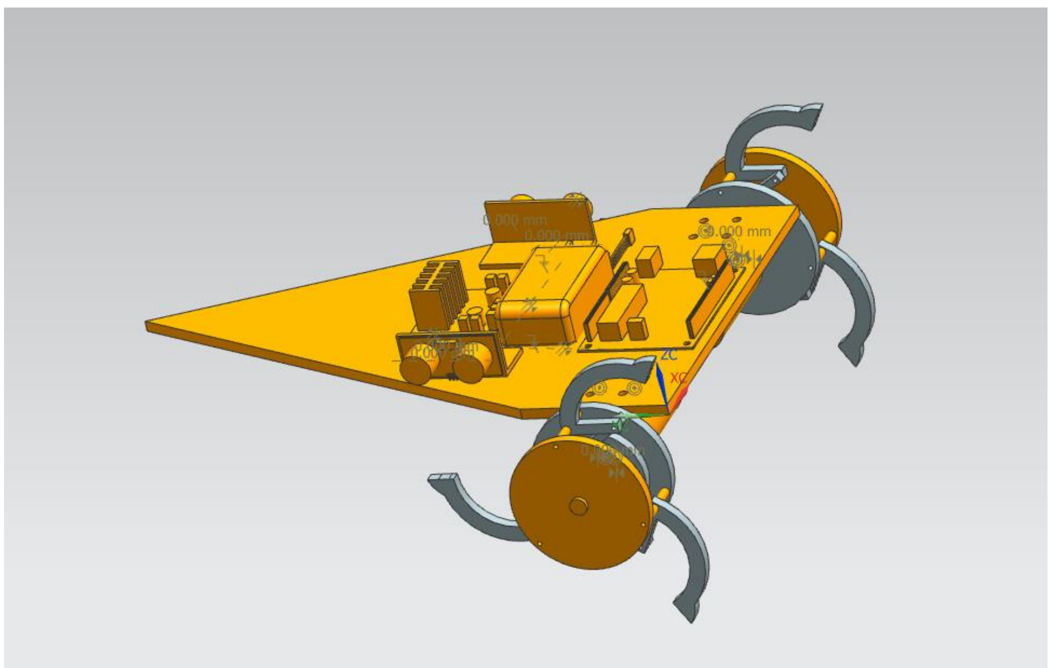
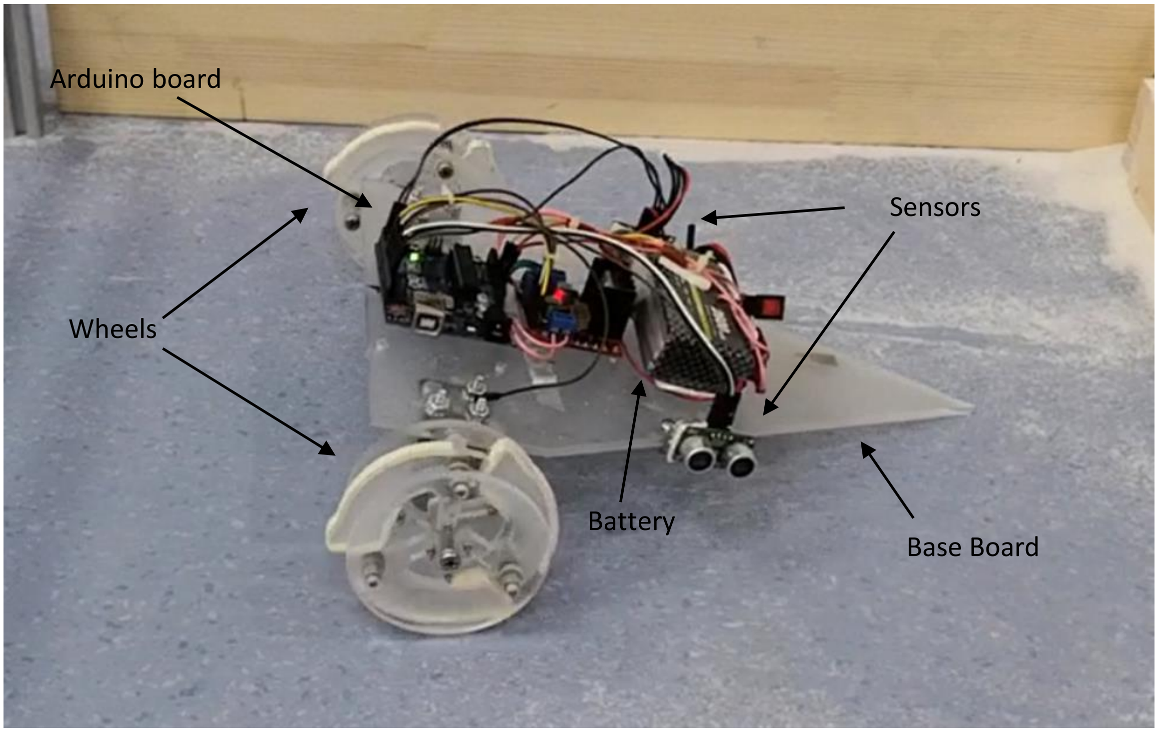


Figure 4. CAD of the whole vehicle

iv. Picture of your prototypes and components



Picture of the prototype and the components

5. Fabrication and Assembly (Manufacturing)

a. Justification of materials selection

i. Base and wheel component materials: Acrylic board

1. Applicable for 2D fabrication
2. Light weight
3. Sufficient material strength

ii. Motor type selection: 12V DC motor

1. Sufficient output torque for climbing the stair
2. Easy to manipulate
3. Low cost

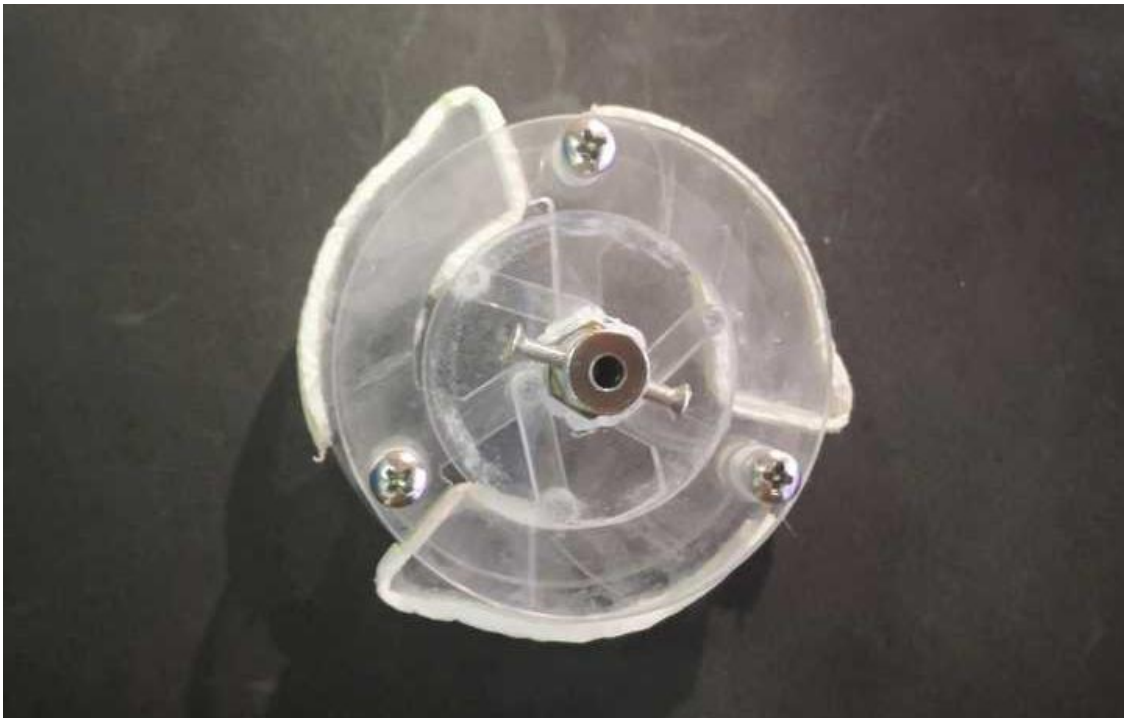
iii. Sensors: Ultrasonic distance sensor

We select ultrasonic distance sensor in our design, because the main task we tried to achieve with sensors in this project is to detect the direction that the vehicle is heading so that we can turn the direction of the vehicle and prevents collision with the walls. We install two ultrasonic distance sensors at the back of vehicle, making them point to the walls on two sides of the vehicle. The accuracy of the ultrasonic distance sensor is sufficient for our objective and they are easy to manipulate.

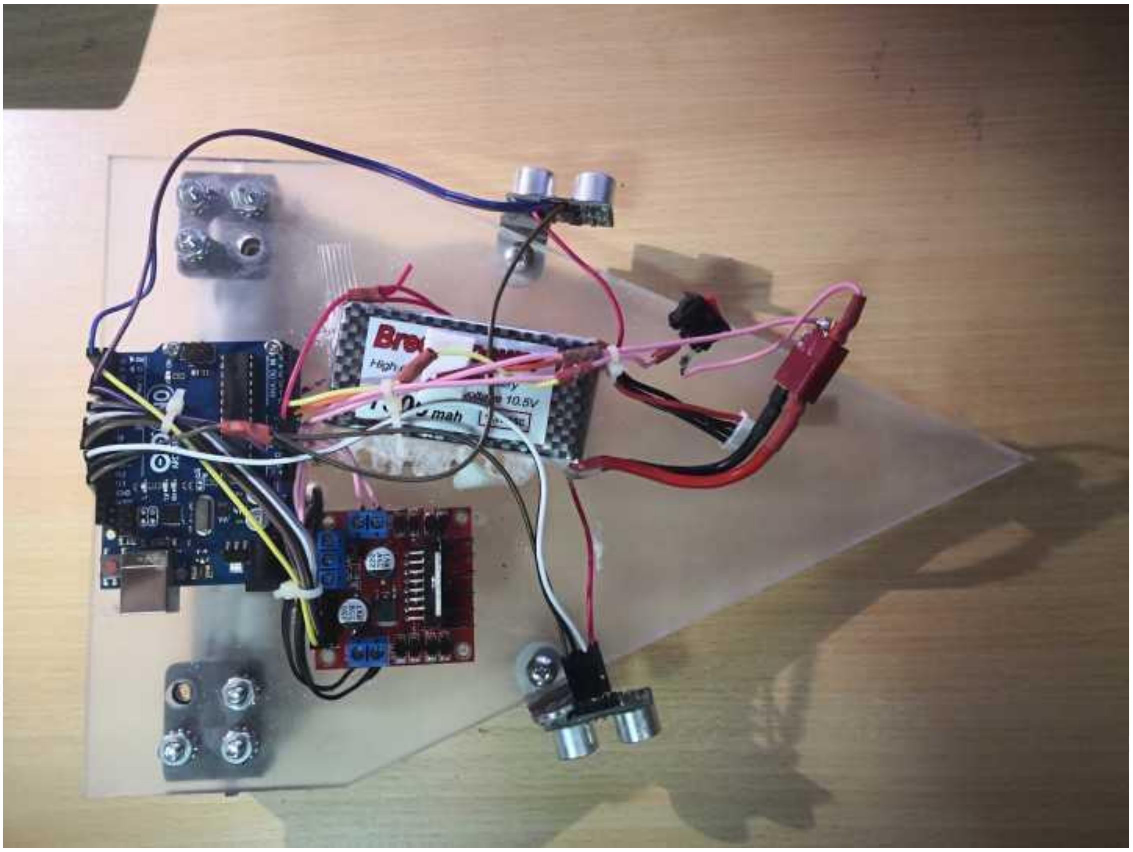
b. Describe the procedure of manufacturing

Use AutoCAD to draw design the 2D feature of the base board and the wheels. Use laser cutting device to cut the acrylic board.

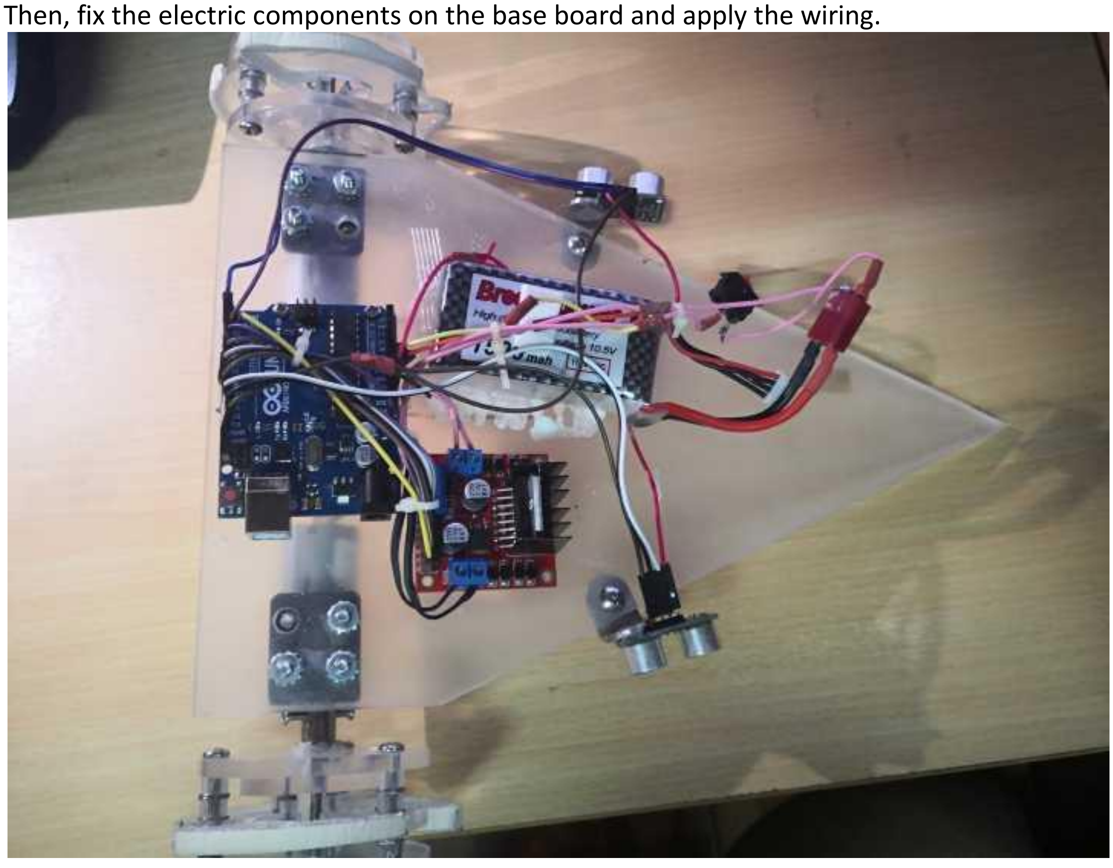
c. Describe the procedure of assembly of components, motors, sensors, etc.



First, assemble the wheel with acrylic board components with screws and nuts.



Then, fix the electric components on the base board and apply the wiring.



Finally, assemble the wheel onto the body of vehicle.

6. Algorithm

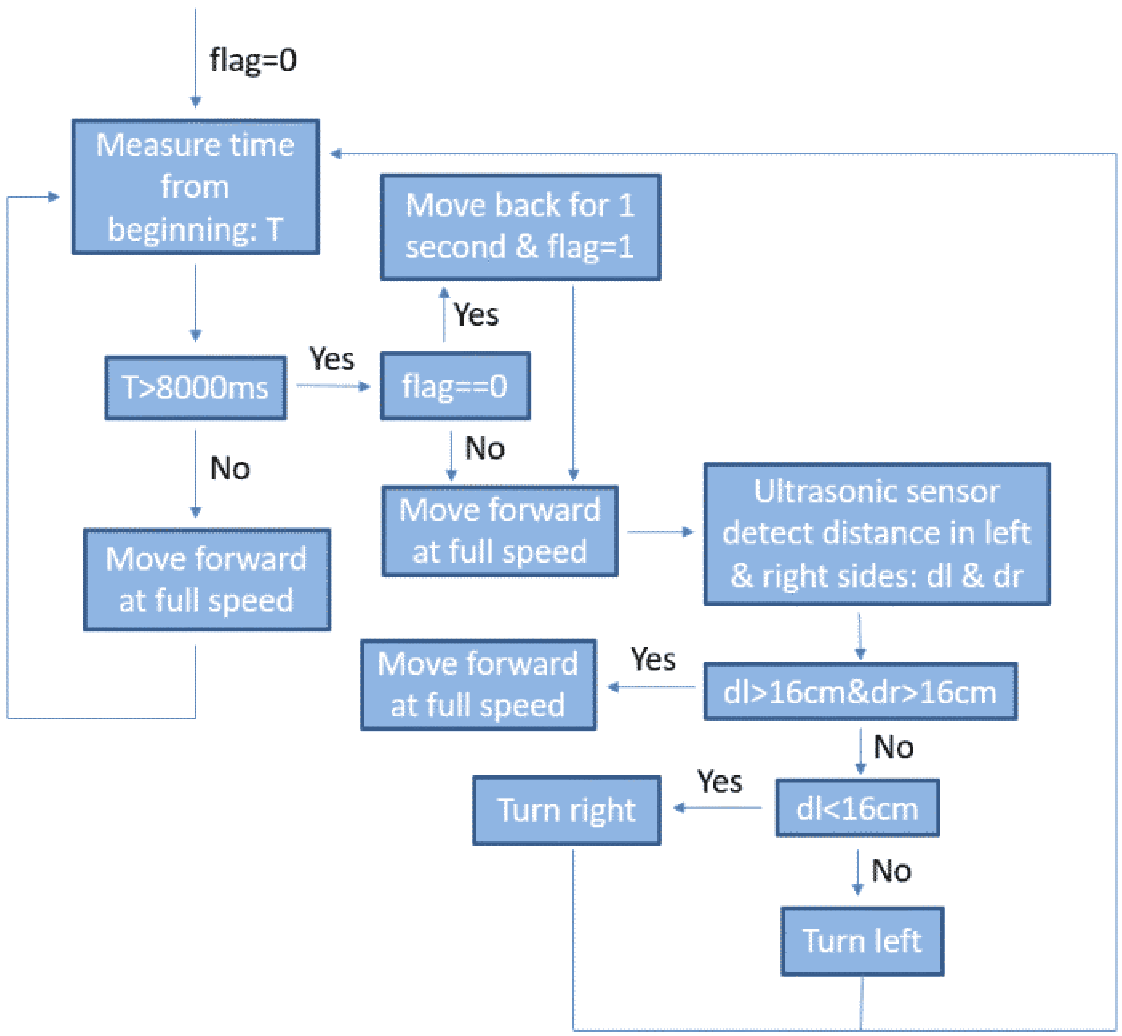
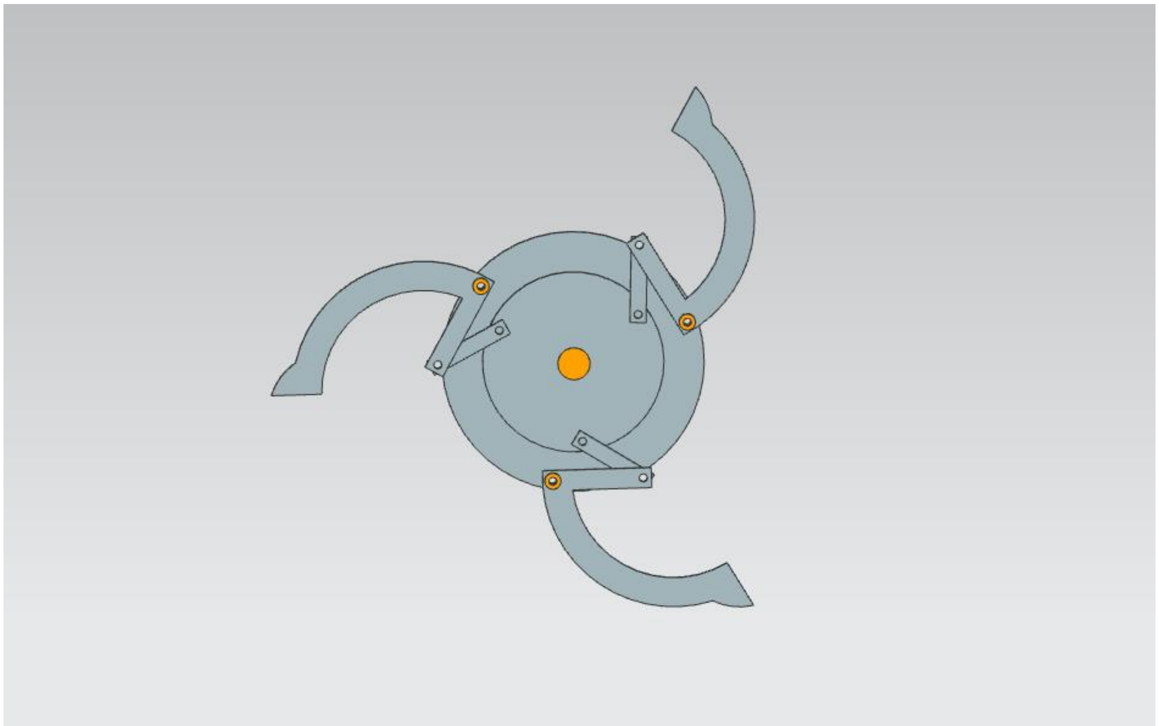


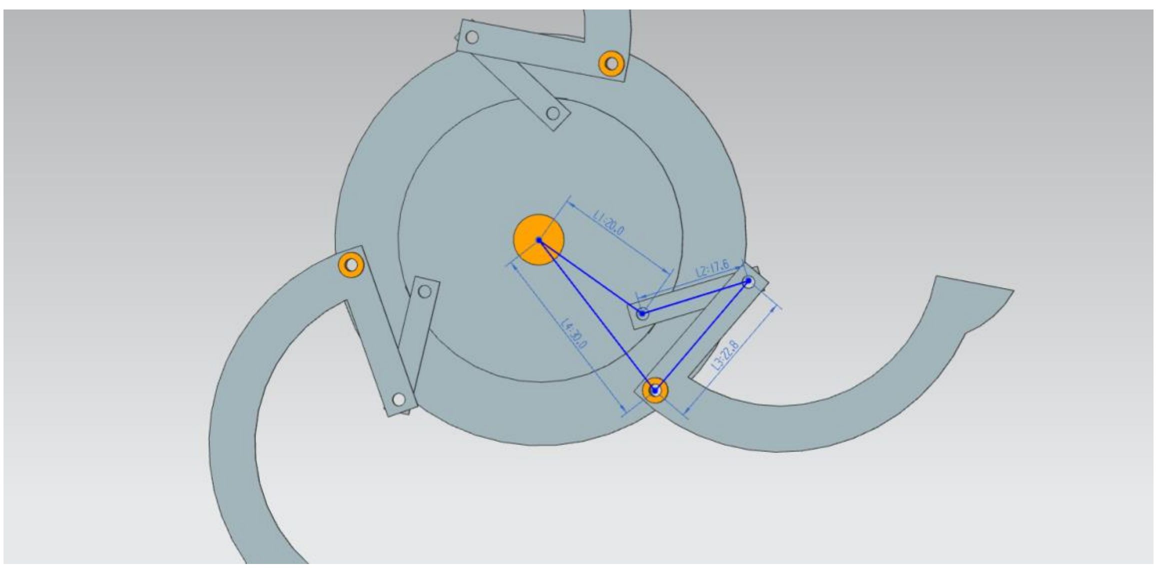
Figure x. Flow chart of the vehicle

7. Analysis

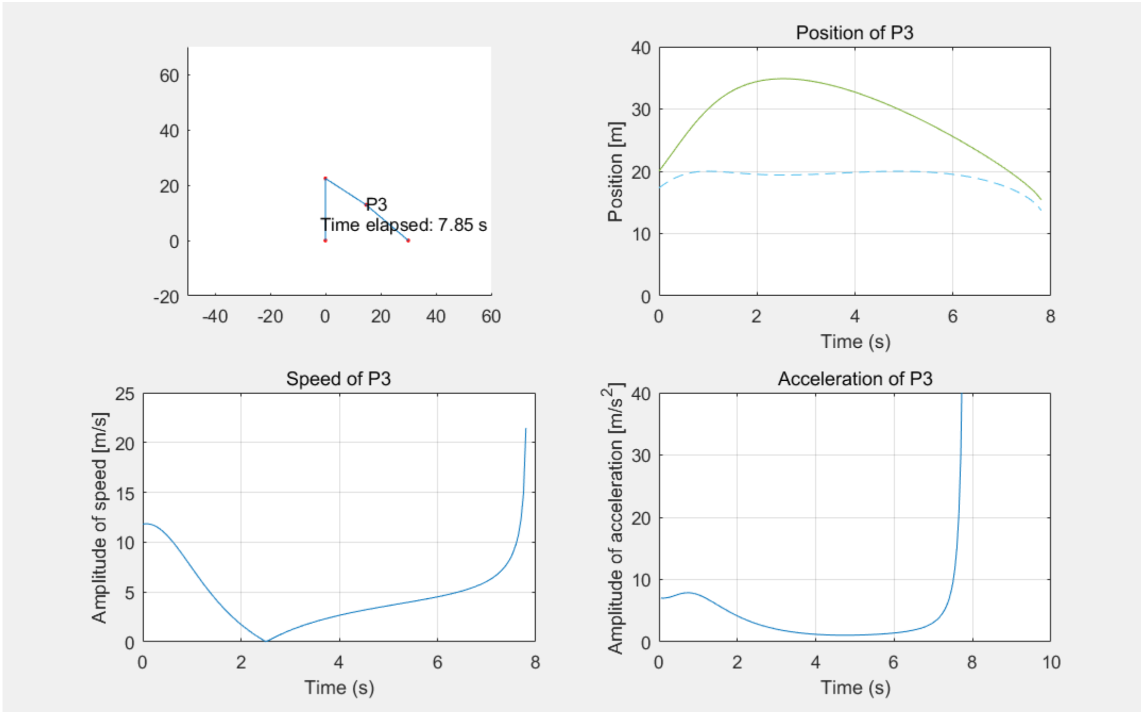
a. Classification of the designed linkage



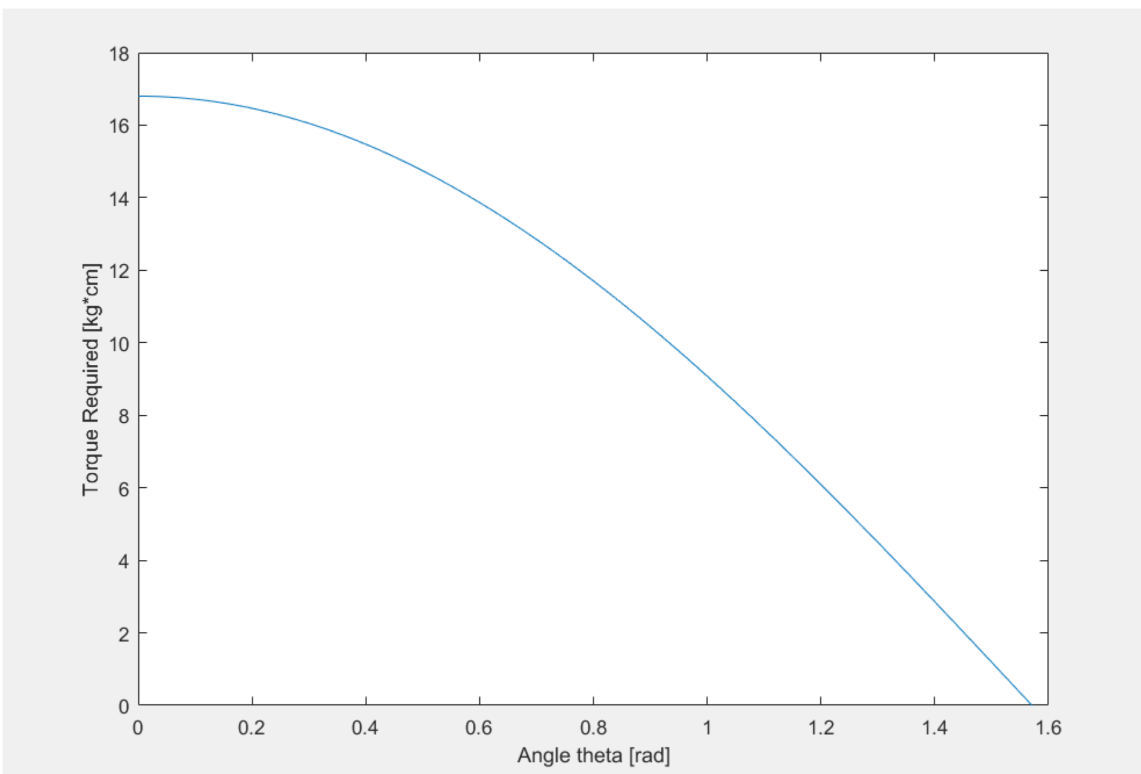
The wheel of our vehicle is composed with three sets of four-bar linkage. The DOF of the linkage is 1. The linkages are all non-grashof linkage. The linkages could be classified as triple-rocker linkage.



b. Position analysis for transformation



c. force analysis



According to the result of force analysis, the maximum output torque required is around $16.8\text{kg} \cdot \text{cm}$. So accordingly, we select two motors that can produce a maximum torque around $9\text{kg} \cdot \text{cm}$ when working under voltage 12V.

d. Rolling speed analysis

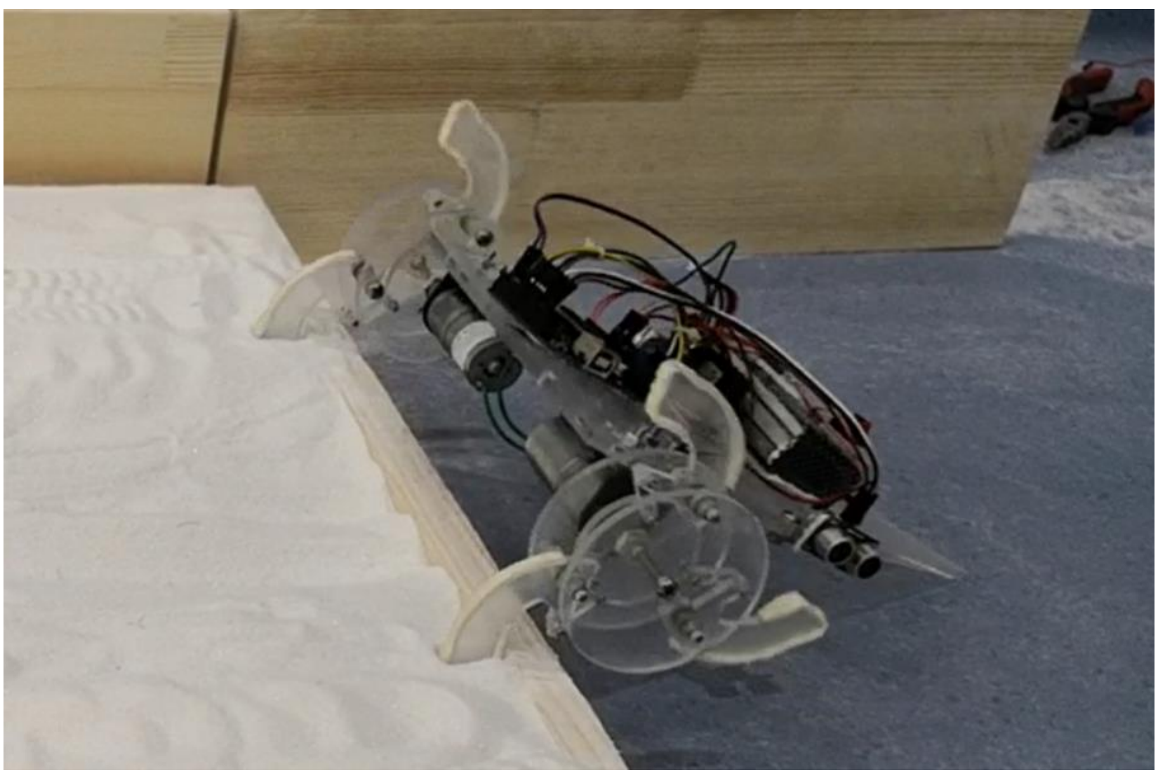
Because of the simple structure and low weight of the vehicle, we expected the rolling speed of our vehicle to be close to the motors' rated speed, which is 130rpm. Since the rough surface of the sand land may cause extra frictional drag. Accordingly, we expected the rolling speed on the smooth surface to be 120rpm, and the rolling speed on the sand surface to be 110rpm.

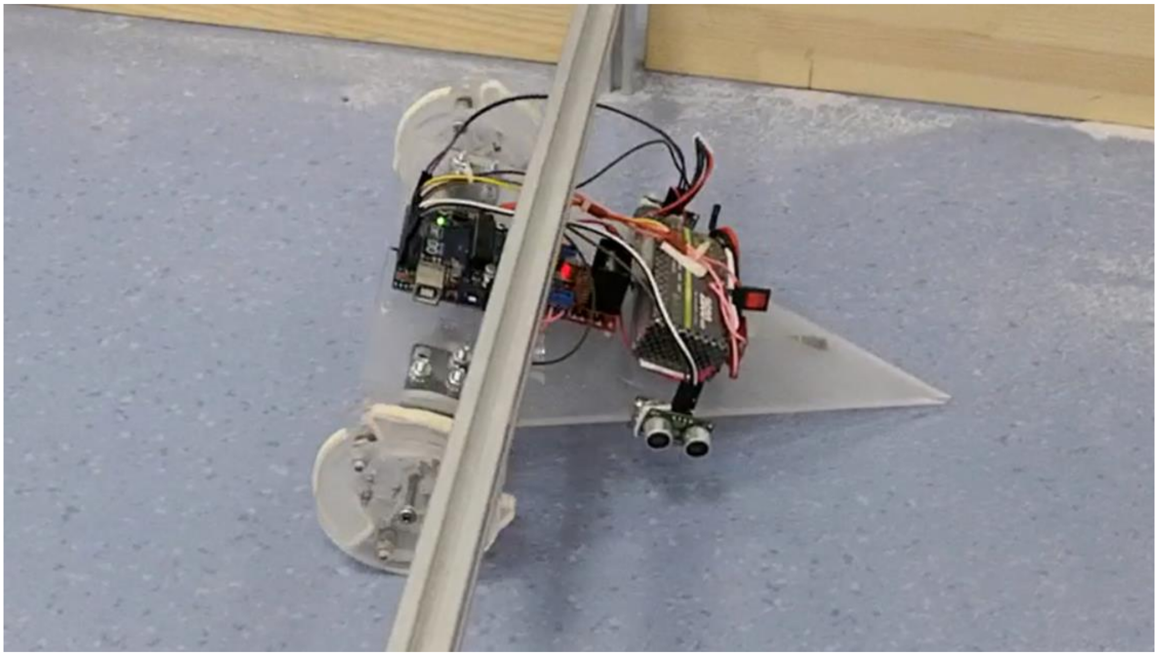
8. Experiment

a. Demonstration of load caring capacity

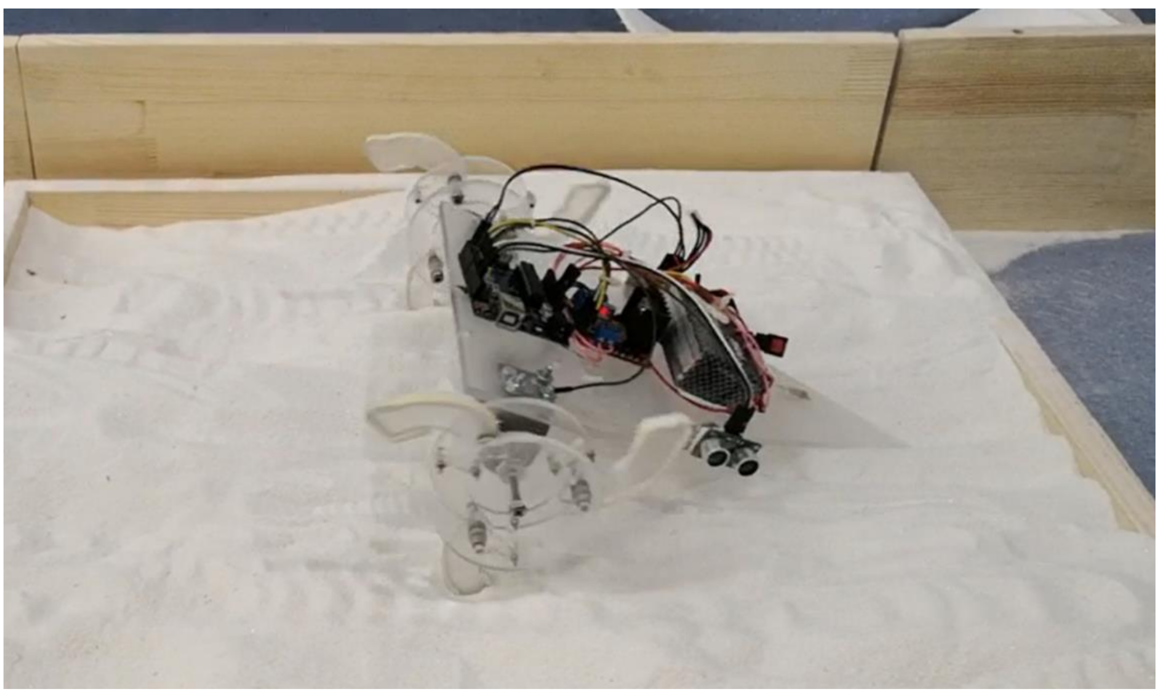
According to theoretical estimation, the load that the vehicle can carry is 3kg. Then we measure the load that the vehicle can carry by examination. We apply the measurement for five times and the final test result (average of five values) is 3.2kg. The result is quite close to our estimation, mainly because the structure of our vehicle is simple and thus comparative easy to analysis and predict.

b. Demonstration of climbing onto the sand box and running through the tunnel

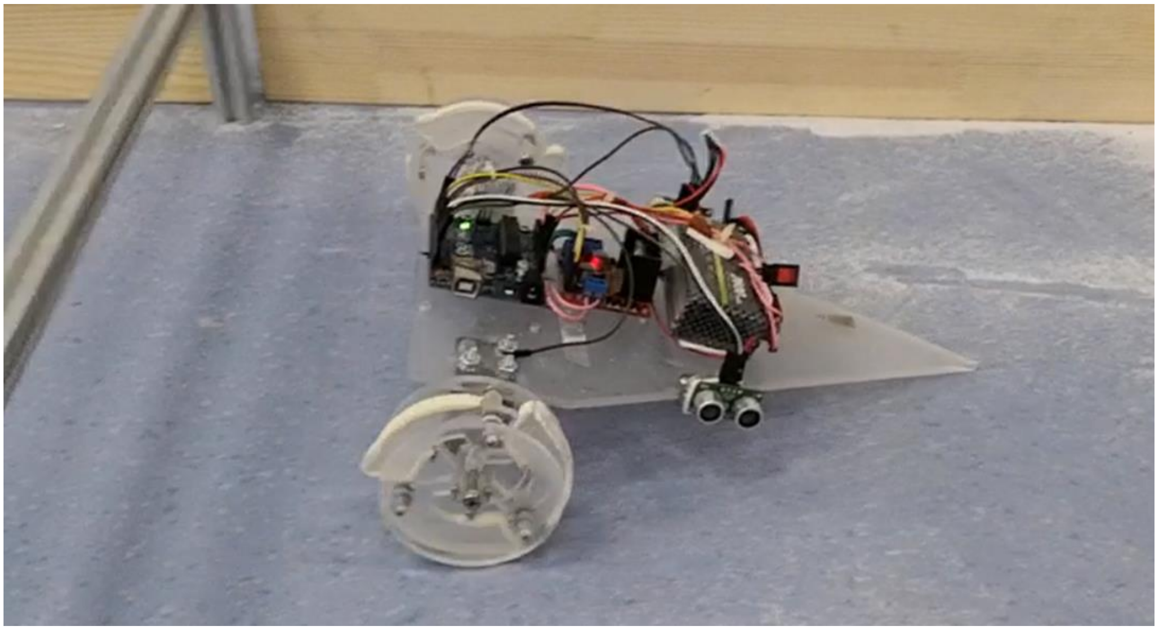




c. Demonstration of rolling on sand and smooth surface



The rolling speed on sand is measured to be around 100rpm.



The rolling speed on the smooth ground is measured to be around 120rpm.

9. Discussion

Compared to the designed cases, our prototype did not work well with more powerful motors. Thus, our prototype is limited to certain output power.

However, the advantage of our design is that we have less weight, smaller size and more flexible structures.

10.Conclusion

By linkage transformation, our group managed to climb onto the steps, expand the wheels to go across the sand field and transform back to pass through the door.

11.Reference

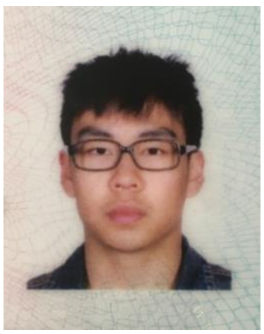
1Jaehyung "Joshua" Ju, "L22 Project Report (II)," URL: https://umji.famousedu.com/courses/76/files/folder/Lecture?preview=30019 [cited 31 July 2017].

2Online datasheet resource ," 25GA370 DC motor", URL: https://item.taobao.com/item.htm?spm=a230r.1.14.20.176c6651SSqekX&id=551307517331&ns=1&abbucket=11#detail

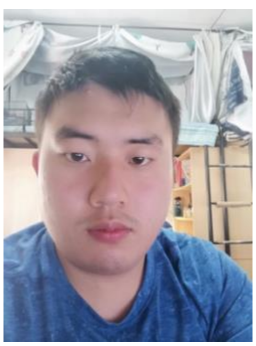
12.Appendix

a. Personal Contribution

Contribution: Arduino coding



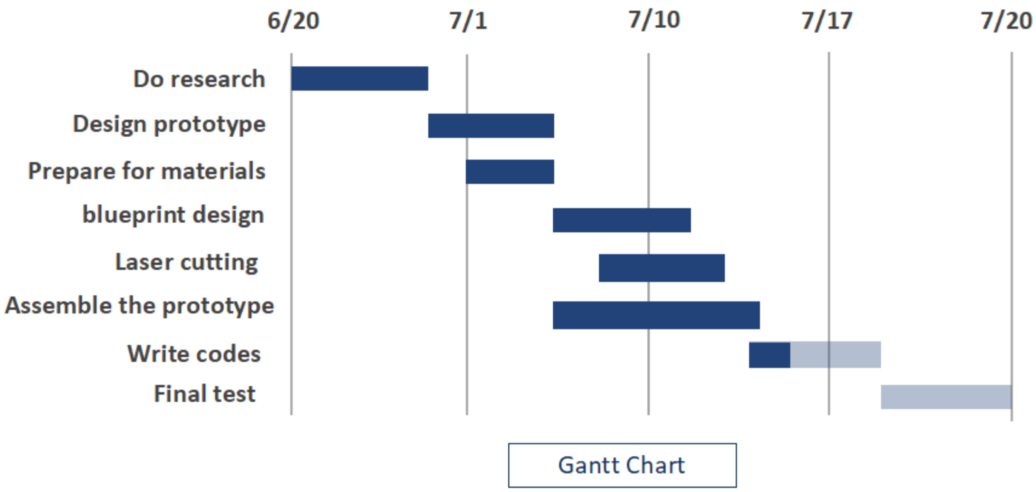
Contribution: Section 4-7



Contribution: wheel design and manufacture part

Contribution: Section 1,2,3,9,10,12

b. Gantt Chart



c. Budget

Name	Cost (RMB)
Acrylic Board *2	48
25GA370 Motor (130 rpm) *2	35
Ultrasonic Sensor*2	20
L298N	7.7
Battery (11.1V)	49
Electric Wire	4
Angle iron*2	4
Heat Shrink Tubing	2
Gasket (M2&M4)	3
Screw (M2&M4)	4
Nut (M2&M4)	4
Total	180.7

d. Arduino Programming Code

```
long times;

int flag=0;


int TrigPinl = 12;
```

```
int EchoPinl= 13;
float distancel;
int TrigPinr = 2;
int EchoPinr = 4;
float distancer;
//int TrigPinf = 11;
//int EchoPinf = 4;
//float distancef;


//left
int ENA1=3;
int input1=9;
int input2=10;
//right
int ENA2=5;
int input3=8;
int input4=7;
void setup() {
  Serial.begin(9600);
  pinMode(TrigPinr, OUTPUT);
  pinMode(EchoPinr, INPUT);
  pinMode(TrigPinl, OUTPUT);
  pinMode(EchoPinl, INPUT);
 // pinMode(TrigPinf, OUTPUT);
 // pinMode(EchoPinf, INPUT);

  pinMode(input1, OUTPUT);
  pinMode(input2, OUTPUT);
  pinMode(input3, OUTPUT);
```

```
  pinMode(input4, OUTPUT);

}



void loop() {
  times=millis();
  Serial.println(times);
if(times<=7500)
    {
        digitalWrite(input1,HIGH);
        digitalWrite(input2,LOW);
        digitalWrite(input3,HIGH);
        digitalWrite(input4,LOW);
        analogWrite(ENA1,255);
        analogWrite(ENA2,255);
    }
else if(times>7500)
 {
    if(flag==0)
    {

        digitalWrite(input1,LOW);
        digitalWrite(input2,LOW);
        digitalWrite(input3,LOW);
        digitalWrite(input4,LOW);
        analogWrite(ENA1,0);
        analogWrite(ENA2,0);
        flag=2;
```

```
    Serial.println("!!!!!!!!!!!!!!!!!!!!");
    delay(1000);
  }
  else if(flag==2)
   {
    digitalWrite(input1,LOW);
    digitalWrite(input2,HIGH);
    digitalWrite(input3,LOW);
    digitalWrite(input4,HIGH);
    analogWrite(ENA1,255);
    analogWrite(ENA2,255);
    flag=1;
    delay(700);
   }
  else if(flag==1)
   {
/*****************ULTRAsonic********************/
/***************left*******************/
    digitalWrite(TrigPinl, LOW);
    delayMicroseconds(2);
    digitalWrite(TrigPinl, HIGH);
    delayMicroseconds(10);
    digitalWrite(TrigPinl, LOW);

    distancel = pulseIn(EchoPinl, HIGH) / 58.00;
    Serial.print(distancel);
    Serial.print("cml    ");
 /***************right******************/
    digitalWrite(TrigPinr, LOW);
```

```
    delayMicroseconds(2);
    digitalWrite(TrigPinr, HIGH);
    delayMicroseconds(10);
    digitalWrite(TrigPinr, LOW);

    distancer = pulseIn(EchoPinr, HIGH) / 58.00;
    Serial.print(distancer);
    Serial.print("cmr");
    Serial.println();

/**************************motor***************************/
if(distancer>=16.0&&distancel>=16.0)
 {
   digitalWrite(input1,HIGH);
   digitalWrite(input2,LOW);
   digitalWrite(input3,HIGH);
   digitalWrite(input4,LOW);
   analogWrite(ENA1,255);
   analogWrite(ENA2,255);
 }
else
  {
   if(distancel<16.0)
     {
      digitalWrite(input1,HIGH);
      digitalWrite(input2,LOW);
      digitalWrite(input3,HIGH);
      digitalWrite(input4,LOW);
      analogWrite(ENA1,255);
```

```
        analogWrite(ENA2,150);
        delay(50);
       }
      else if(distancer<16.0)
       {
        digitalWrite(input1,HIGH);
        digitalWrite(input2,LOW);
        digitalWrite(input3,HIGH);
        digitalWrite(input4,LOW);
        analogWrite(ENA1,150);
        analogWrite(ENA2,255);
        delay(50);
       }


    }
  flag=1;}
 }
}
```