NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF MECHANICAL AND AEROSPACE ENGINEERING

MP4006 – Project Report

TRI-ARM ROTATING AUTO-BOT

Submit to

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By

Robotics Group H

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Abstract

This report shows the design of a three-legged robot that can climb stairs. It includes detail studies of current robotics mechanism to climb stairs. All the advantages of the different climbing mechanism are noted and incorporated into our robot design. It shows the motion planning, synchronization, programming and fabrication to assemble a three-legged robot.

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Group Members

Figure 1 Group photo

FU CHAO, DENG LIXI, PANG SIN LOONG, HO SWEE TIM,

LEONG KOK HOU, JOSEPH LIM KOK KEONG, TRAN LE DUNG

(FROM LEFT TO RIGHT)

GROUP LEADER: TRAN LE DUNG

1. Introduction

There are many robots that can maneuver on the ground. But, there are not many robots that can climb stairs. Maneuvering through this obstacle is crucial for the advancement of robotics field. There are various mechanisms to climb stairs. Below are few examples of climbing stair robot:

Figure 3 Intelligent mobility platform with active spoke system

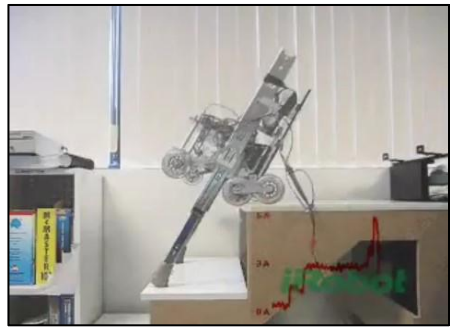

Figure 2 Rack and pinion climbing mechanism

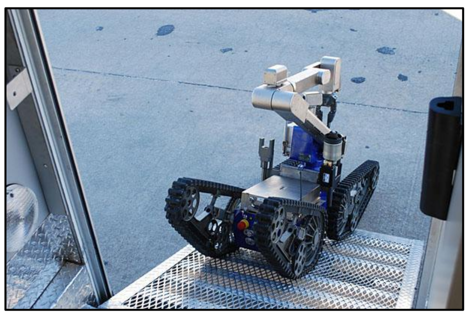

Figure 4 Dynamic wheel rotator robot

Each of the robots shown in the pictures above has their own unique mechanism to climb stairs. In Figure 2, it shows a genius way of dynamically adjusting the height of the sprockets to allow the robot to climb over the obstacles. In addition, in Figure 3 the robot uses rack and pinion method to move the robot upwards before it falls on to the stair. Furthermore, in Figure 4 it shows a robot that has rotatable chain wheels, these wheels provide the force to push the robot upwards to climb stair.

We studied the designs and mechanisms of all these 3 robots and we came out with our own unique mechanism. We designed a three-legged robot to climb stair. Climbing stairs using a three-legged robot requires quasi-static motion to keep the stability of the robot. Besides that, it requires synchronization of the three legs and an optimized climbing motion. Motion planning of the robot to climb stairs is essential to ensure that the robot is always in a stable condition.

In addition, this robotic mechanism helps robot to maneuver through any obstacles. Besides that, it is capable to climb stairs swiftly and to walk around. This could lead to a possibility of creating a new platform for domestic robot.

2. Methodology

2.1 Materials

The following materials and equipment are used in our project:

Item	Qty
Servo, Futaba S5801	4
Servo, JR DSR 8801	1
Servo, JR DSR 581	1
Multi-Speed motor	1
Arduino Duemilanove Microcontroller	2
Prototype board for circuit	2
Ultrasonic range finder	1
Material (Aluminum bars) for robot structure / linkages	1 Set
Others (Fuses, PCB headers, 5V regulator, M2 screws and nuts)	1 Set
SPS-3610 Power Supply	1 Set
Switch	1
Extension wire for Servo motor	3
Wheels	3
Miscellaneous Materials	1 Set

Table 1 Material list for this project

2.2 Design

Our robot is carefully designed in the early stage of the project. The following 2 sections are the detailed designs of the robot.

2.2.1 Structure

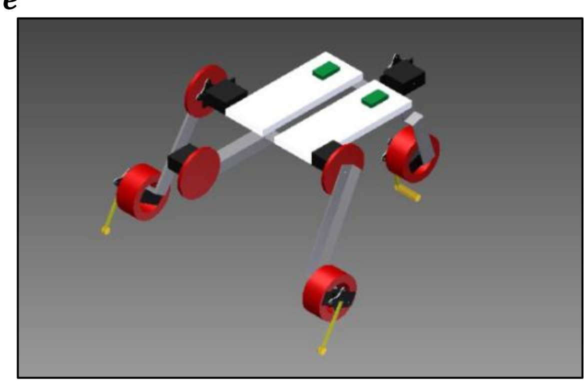

Figure 5 Structure design

The layout of the robot is basically a 'Tri-leg' vehicle. As shown in the figure 5, the main body of the robot is made of 2 control board; 3 legs are attached to the main body, each is driven by 2 motors. There are 2 legs in the front side of the robot, 1 other leg is put at the back. Each leg is designed similar to a human leg; it is with upper thigh and lower shank. Under the main body, 3 wheels are installed; in which 1 wheel is driven by motor to propel the whole robot to move forward.

With a total number of 7 motors, the robot has a total of 7 degrees of freedom. The robot is able to make some complicated movements, such as standing up, lying down, moving forward, and climbing.

The dimensions of the robot are:

Folding position: 60cm (L) x 24cm (W) x 28cm (H)

Extension position: 23cm (L) x 24cm (W) x 16cm (H)

The electrical power used to drive the robot is SPS-3610 Power Supply, 7.2 Volt.

2.2.2 Mechanics

The main objective of the robot is to climb stairs automatically. The climbing mechanics are illustrated with the following pictures.

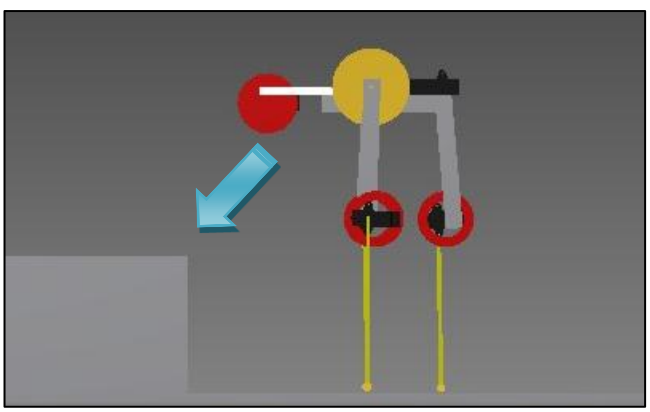

Figure 6 Mechanics A

a) Meeting the stair: Firstly, before moving forward to the stairs in front, the robot is adjusted to the standard standing position, as shown in figure 6. The 3 legs are extended to the longest to support the robot and get ready for the next movement.

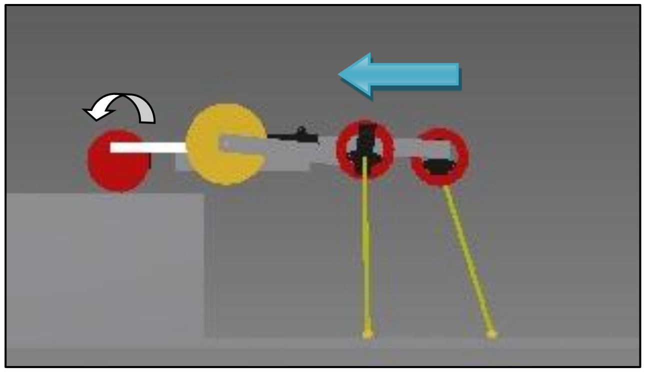

Figure 7 Mechanics B

b) Approaching to the stair: Secondly, the robot will bend forward to put some part of it onto the staircase. The front wheel and part of the main body lay on the staircase, while the 3 legs are still on the ground to maintain the balance of the robot. Then, the front wheel is driven by a motor causing it to turn, and consequencely pull the whole robot forward onto the staircase.

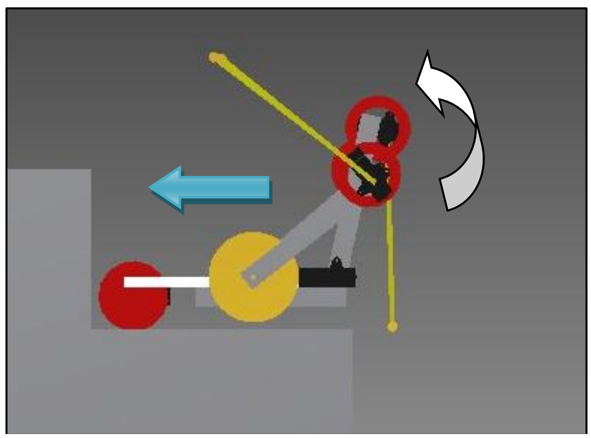

Figure 8 Mechanics C

c) Laying on the stair: In the third step, the 3 legs return to the folded position, meanwhile the whole robot is pulled forward by the front wheel.

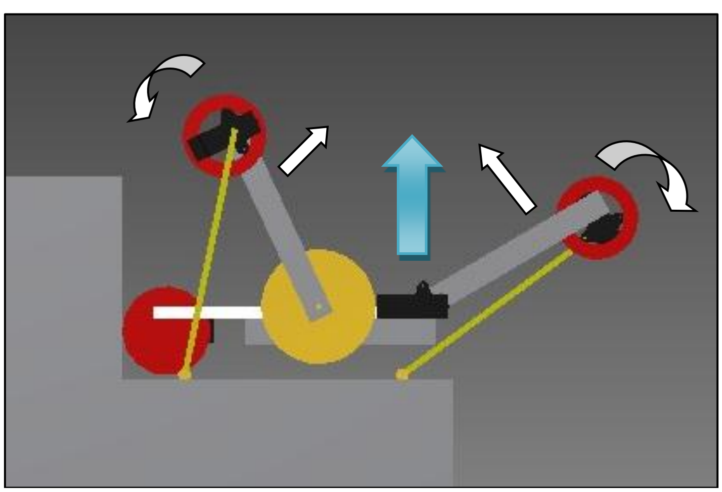

Figure 9 Mechanics D

d) Standing up on the stair: In the next step, the 3 legs stand on the ground, and all the 6 motors turn together to support the whole robot, providing enough torque and force for the robot to stand up on the first staircase, and retain the same position as shown in figure 6.

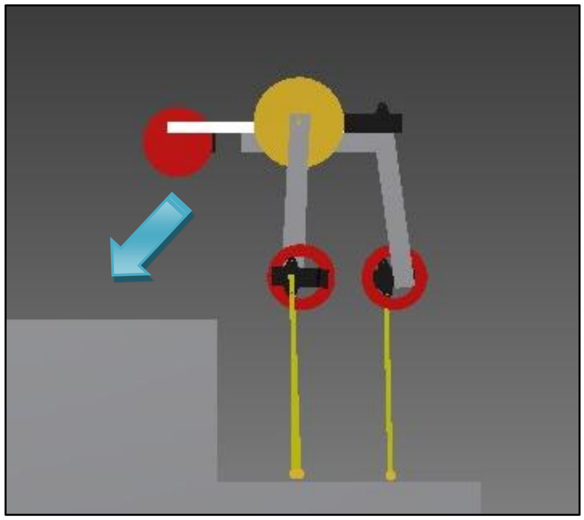

Figure 10 Mechanics E

e) Continue climbing: the same position of step a) is achieved here; the robot goes on to climb the next staircase.

3. Execution

3.1 Fabrication

3.1.1 Material

Aluminum is used to fabricate the legs and body of the robot. Aluminum, which is both strong and lightweight, satisfies our design requirements. We need to have a light and durable body for the robot, which makes it more agile. Moreover, aluminum is easier to fabricate because it is relatively softer compare to steel.

3.1.2 Dimensioning

After drawing the robot in CAD and obtaining all the links dimensions, we started to fabricate all the parts. However, there is a tolerance of $\pm$1cm for each link. Furthermore, after completing the fabrication, all the lengths of the 3 legs are compared again to ensure it has the same length for the three legs.

3.1.3 Securing Servo Motor to the Link

The servo motor is secured to the link using 2 screws and nuts. An opening is cut through the link to allow the servo motor to slot into the link and the side of the motor (screw hole) is secured using the screws. This design of securing the servo motor is very strong and secure.

3.1.4 Securing Link to the Servo Motor

The link is attached to the servo motor using a horn. The horn will be attached to the servo motor and the link. Holes will be drilled to allow the screws to be tightened between the links and the horn.

3.2 Hardware

Servo motors, ultrasonic range detector and microcontrollers are connected together in a circuit board using wire.

3.2.1 Wire Connection

There are many wires tangling around the robot (7 servo motors and 1 ultrasonic range detector). Therefore, arranging the wire properly is important to prevent the wire from impeding the movements of the robot. To solve the problem, tape is used to tie the wire together and stick to the frame of the robot.

However, there is still a problem that the robot faces when the 2 legs of the robot are rotating. It will entangle the wire because the wire is protruding outward and not going through the shaft of the motor.

3.2.2 Safety Measure

Fuse is always connected to ensure that there is no sudden power surge or over supply of power to the electronic circuit which could cause severe damage to the microcontroller and other electronic components.

3.3 Software

The motion of the robot is programmed into to the microcontroller. Then, the microcontroller will send out signal to the servo motors and receive signal from the sensor. In addition, the microcontroller will make logical decision when it detects obstacles so that it can maneuver through it.

3.3.1 Converting from BASIC Stamps to Arduino

At first, BASIC Stamps was used as the microcontroller for our robotics project. However, various problems arose when BASIC Stamps was used. The problems are:

a) Programming in BASIC Stamp has limited capability
b) Servo motors draw too much current when connected to BASIC Stamp
c) Constant jerking of the servo motor at certain angle

As a result, we decided to use Arduino to replace BASIC Stamp as the microcontroller for our robot.

3.3.2 Communication

This robot requires 2 Arduino microcontrollers. The first Arduino microcontroller is used to connect 6 servo motors and the second Arduino microcontroller is used to connect one multispeed motor and an ultrasonic range detector. Using 2 Arduino microcontrollers require communication between each microcontroller to ensure that all links are moving at the same time.

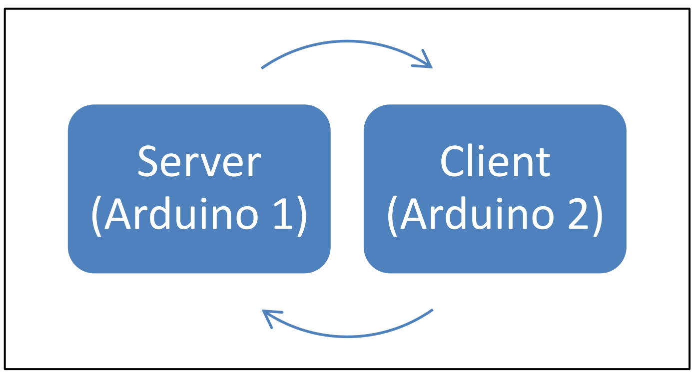

Figure 11 Server and client communication

Synchronization is crucial for a robotics motion. Therefore, a server and client is established between the 2 Arduino microcontrollers (as shown above) to allow data being sent to each microcontroller. A channel is setup afterwards to allow data being sent and received by the microcontroller. Semaphore technique is used to ensure that there is no data lost sent/received by the Arduino microcontroller.

3.3.3 Calibration

The rotation of servo motor is controlled using pulse-width modulation. Each servo motor has to be calibrated with the Arduino microcontroller to determine the exact rotation angle needed for the robotic motion. Manual calibration on the servo motor is done by sending a pulse to the servo motor and then views the servo motor rotation and record the absolute angle (view from the ground – as seen on the robot). A rotation system is established as shown below, counter clockwise rotation will give a positive angle and the 0 degree is set on the x-axis. The figure shown below is just a representation of one servo motor.

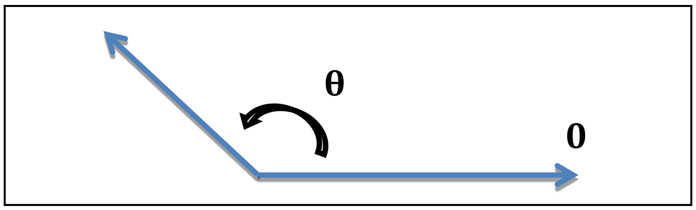

Figure 12 Rotation coordinate system

Arduino Pulsing Out Angle Signal	Absolute Angle of Servo motor
88	0
98	10
108	20
118	30
128	40
138	50

Table 2 Arduino pulse width and the absolute angle of servo motor

After establishing the relationship between the Arduino pulse width and the absolute angle of servo motor, the climbing motion could be programmed.

4. Motions

We have made a staircase with height of 9cm, length of 49 cm and width of 46 cm for the robot to climb. In this section, the actual motions of our robot are elaborated and comparison with our design is analyzed.

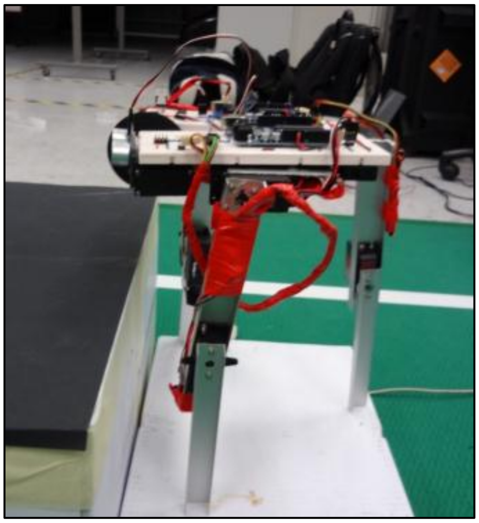

Figure 13 Motion A

a) Encountering the stair: The robot stands in front of the staircase and get ready to climb. The stability of the robot is well maintained.

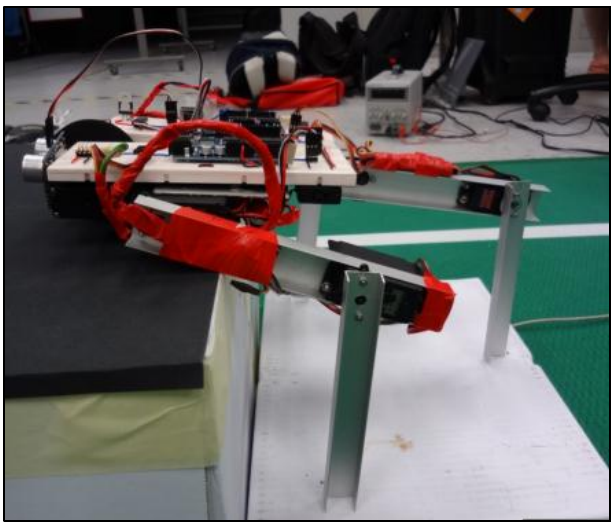

Figure 14 Motion B

b) Approaching the stair: by turning the 6 motors, the robot quickly approach the stairs, and the main body is laid on the stair. All the three legs are still standing on the ground. Slightly different from our design, almost the whole main body (control boards) are laid on the stair in this step. This new motion is safer and more stable than the original design.

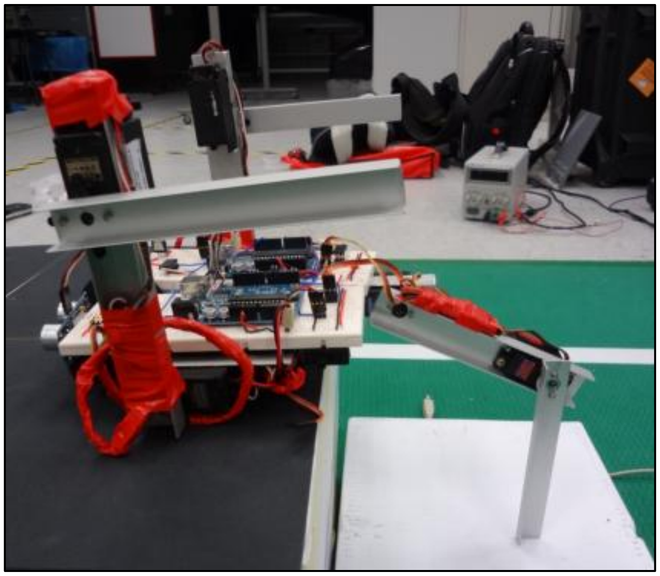

Figure 15 Motion B2

Approaching the stair continued: The 2 front legs rotate up and stay above the stair, while the back leg is still on the ground supporting the robot.

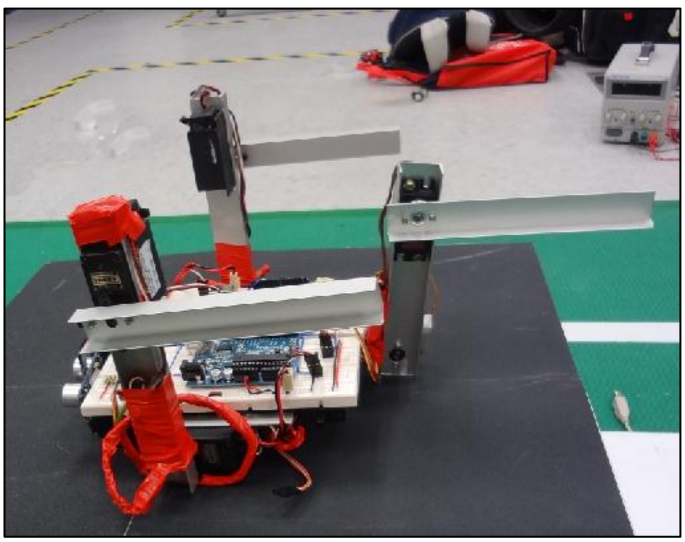

Figure 16 Motion C

c) Laying on the stair: In this step, the back leg is rotated up, the front whell rolls to pull the whole robot forward on the staircase. The motion is fast and smooth.

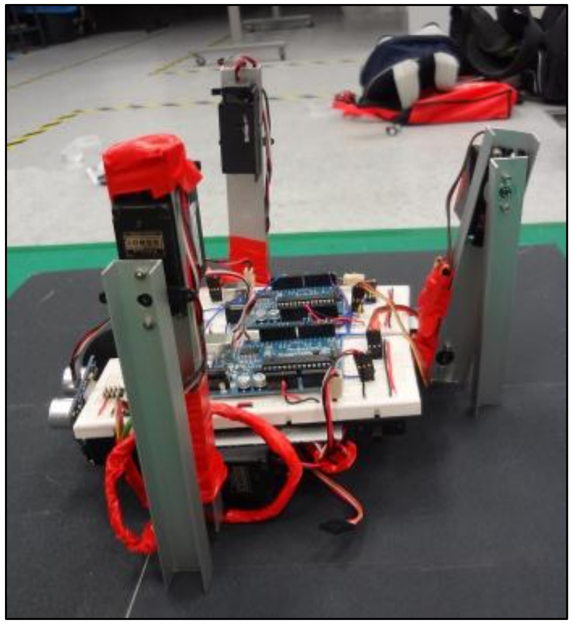

Figure 17 Motion D1

d) Standing up on the stair: Once the whole robot is on the staircase, the 3 legs are folded to the standby position, just like the pre-jumping pose of a grasshopper. The lower shank touch the stair, and the 3 legs are all vertically arranged.

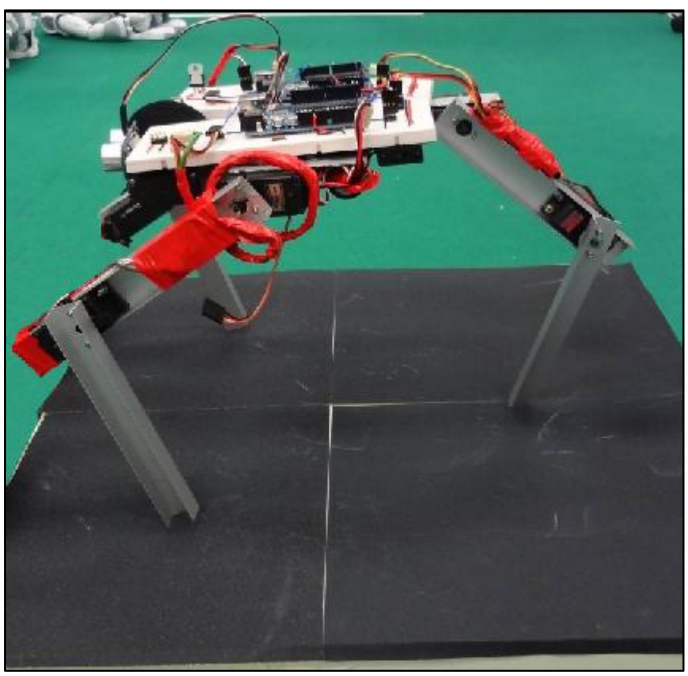

Figure 18 Motion D2

Standing up on the stair continued: Driven by the 6 motors, the 2 front legs unfold from front side and the back leg unfold from the back side. This motion is similar to human's movements when standing up from the squating position.

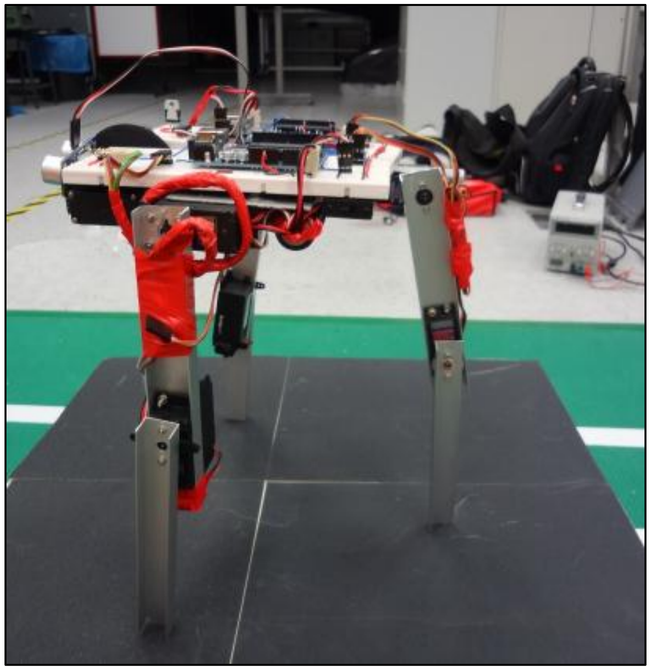

Figure 19 Motion E

e) Ready for continuous climbing: This is the final position of the robot after climbing the first stair. The robot has finished one round of all the motions, it can move to the second stair in the next step.

5. Conclusion

With creative design, fabrication and programming, our robot is able to achieve the climbing up the stairs, while maintaining stability and safety of the whole system. The followings are some conclusions we had for this project:

5.1 Advantages

- The robot is stable and reliable for the designed movements and functions
- The structure of the robot is relatively simple; it is convenient for maintenance works
- The control of the robot is precise, the program is robust and can be read easily
- Bionics concepts are incorporated to the motions of robot, which is innovative as well as effective.

5.2 Drawbacks

- The size of the stairs are restricted to the limit of the robot's height and length
- There is no feedback control system to reduce error of motion
- Landing of main body on stairs can be rough sometimes

5.3 Learning and Reflection

During this project, we have reviewed and used the knowledge of robotics and programming; each of us has various valuable learning points throughout the way. The followings are the reflections from our group members:

FU CHAO: Creative ideas always come from teamwork.

DENG LIXI: Teamwork is really powerful when we're working hard together.

PANG SIN LONG: Don't forget to enjoy the happiness and fun in the project.

HO SWEE TIM: I have learned how to coordinate the robot motion planning.

LEONG KOK HOU: Proper planning is essential for a project.

JOSEPH LIM KOK KEONG: We do not need a super structure to perform simple task.

TRAN LE DUNG: Practice is the best learning.

Although there are some drawbacks that we can improve in the future, we had done our best in applying our robotics and programming language from MP4006 Robotics and other courses to design and execute this project.

It has been a very enjoyable experience to work together with talented teammates on this enriching and innovative project. We hope to learn from this experience and have further developments in future robotics projects.

6. References

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Fundamentals of Robotics: Linking Perception to Action, World Scientific Pub., River Edge, NJ, 2003.

http://www.arduino.cc/