Project R2D2

BRAC UNIVERSITY

Inspiring Excellence

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DECLARATION

This is to declare that the thesis entitled “Project R2D2” is submitted by our group members in partial fulfillment of the requirements for the award of Bachelor of Science in Computer Science and Engineering and Electrical and Electronics Engineering during Spring semester in 2017 at BRAC University under the guidance and supervision of DR.MD.KHALILUR RHAMAN. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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Abstract

This project presents, in detail, an electrically operated mechanical robotic system based on the fictional AI character “Artoo-Detoo” or “R2D2” from the movie saga “Star Wars” by Lucasfilm Ltd. It played a critical supporting role in the movie and is heavily revered by the ‘Star Wars’ fan. So, it was a great experience to build a copy of R2D2. The project “R2D2” will definitely catch everyone’s eyes as it will bring back all those nostalgic memories most of us had debating, arguing and yet enjoying the Star Wars saga.

The main objective of this project is for entertainment purpose but we will also add some extra features to add some spice to the mix. R2D2 head is internally fitted with a camera to stream live feed to our controlling device. A laptop is used instead of a traditional controller, with the assistance of medium ranged router to control the movement of the R2D2. R2D2 can detect faces and also take photos for now.

Future prospects of this project is vast, as functions such as voice recognition and face recognition can alter the role of R2D2 from being just entertainment to a robot who can identify and track any individual. Thus we can also make R2D2 fully autonomous with collision detection and path tracking. Voice recognition is a must have nowadays. This will be used for motion control as well as communicating with any person.

Contents

Introduction

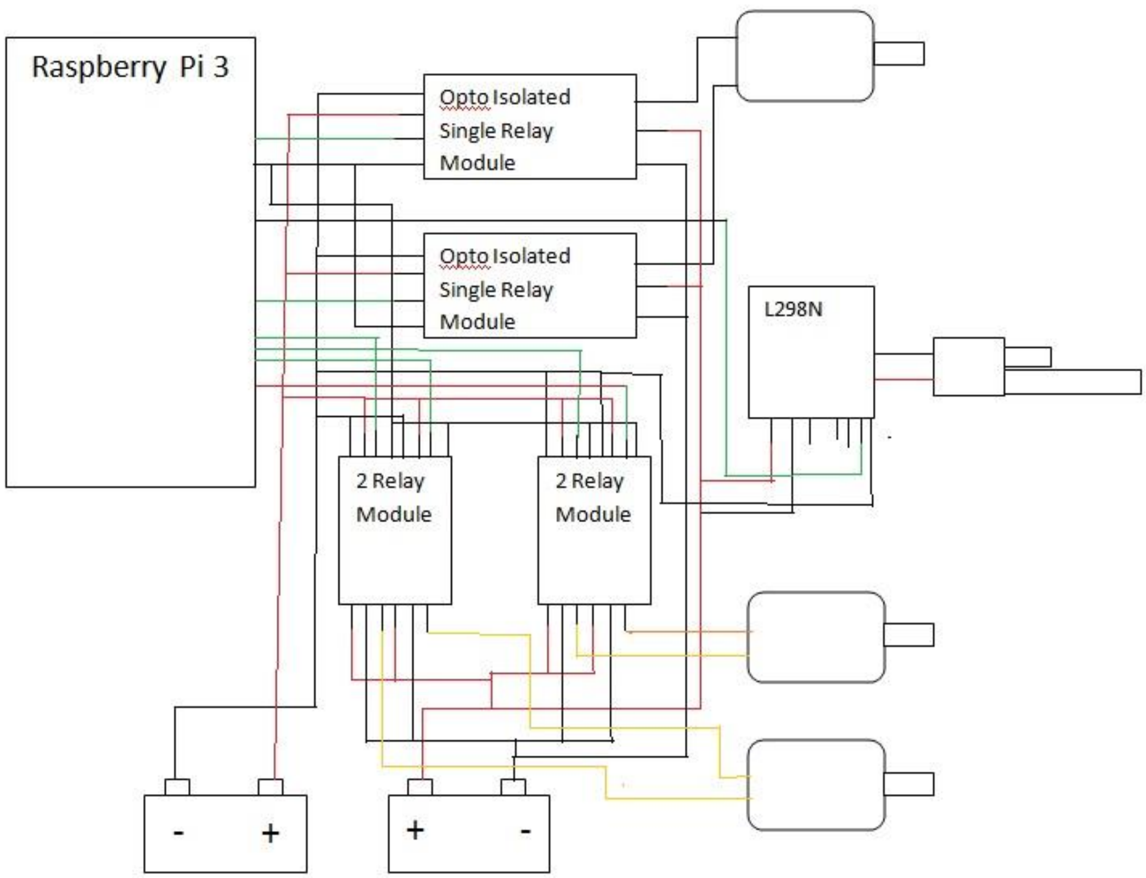
For many people a robot is just a machine that imitates a human—like the androids in Star Wars, Terminator or Wall-E. The types of robots that we encounter most frequently are robots that do work that are too dangerous, boring, onerous, or just plain nasty. Most of the robots in the world are of this type. They can be found in auto, medical, manufacturing and space industries. In fact, there are over a million of these types of robots working for us and alongside us today.

The field of robotics has excelled so far that we can now bring our wildest of imagination into reality. Comparably robotics is no far behind on par with other sectors of technological revolution. The depth of study in this field is only ever growing as more of the companies and organizations of the world are advancing towards robotic automation; decreasing human labor. While animation movies play a role in expanding and expressing our imagination, projects like the NASA's Mars Rover "Sojourner"" and the "Mars Exploration Rover" have solidified a belief and excitement in the youth that impossible is achievable.

Motivation

From early years of boyhood we were bombarded with fictional characters and/in movies; Stars Wars was one of them. Back inside our heart we felt the urge to bring some fictional characters to life, just as a mean to entertain ourselves. A few things hampered our ability to be of any success here. One, the correct infrastructure and second the right motivator. Luckily, we were blessed with both here at BRAC University. Projects such as “Chondrobot”, “Mars rover” and other robotics projects helped us to take a bold step forward into building up our own entertainment robot “R2-D2”. As much we have taken pride and confidence from the former projects, wewant to inspire and motivate the future great minds with our little effort.

Mechanical



Raspberry Pi 3
Opto Isolated
Single Relay
Module
Opto Isolated
Single Relay
Module
L298N
2 Relay
Module
2 Relay
Module
-
+
+
-

Head

A ring rod has been used to as the base upon which SS rod was welded to be used as the skeleton. SS metal sheet was cut into thin pieces and using high amount of heat the pieces were fused together on the skeleton. As a result of the uneven heat distribution the head is slightly tilted on one side. Then the head was hammered to produce the half oval shape of the head. The head has been attached to a metal gear wheel via a small rod in the center. Few pieces are cut out and connected with hinges. Three servo motors (micro servo 9g) has been used to flip the hinged pieces. There is a small hole that has the pi camera stuck with glue on the other side. Every circuitry including the relays, raspberry pi and the router are placed inside the head.

<u>Body</u>

Three ring rods at equal distance has been welded with vertical rods to produce the skeleton. Then SS metal sheet was wrapped around the skeleton. 3 bearings are situated on the top, left and right side of the body. The left and right bearing are passed through by a metal rod that connects the two side legs together. The top bearing houses the gear that holds the head with it and allows the head to rotate freely. Near the top bearing a motor is attached to rotate the head gear.

Side legs

SS metal sheet has been used to make the side legs. They were cut according to design and then the pieces were welded together. A metal rod connects the two legs though left and right bearing housed in the body. On bottom of each legs a motor is attached with two trolley wheels that are run by a timing chain with the help of two chain sprockets.

Center leg

The center leg has the same base and wheels of the side legs but has a rectangular hollow box as a body which houses an actuator. The body is connected to the rod that connects the two side legs. The actuator pushes the base of the leg forward and back and the body tilts with its movements accordingly.

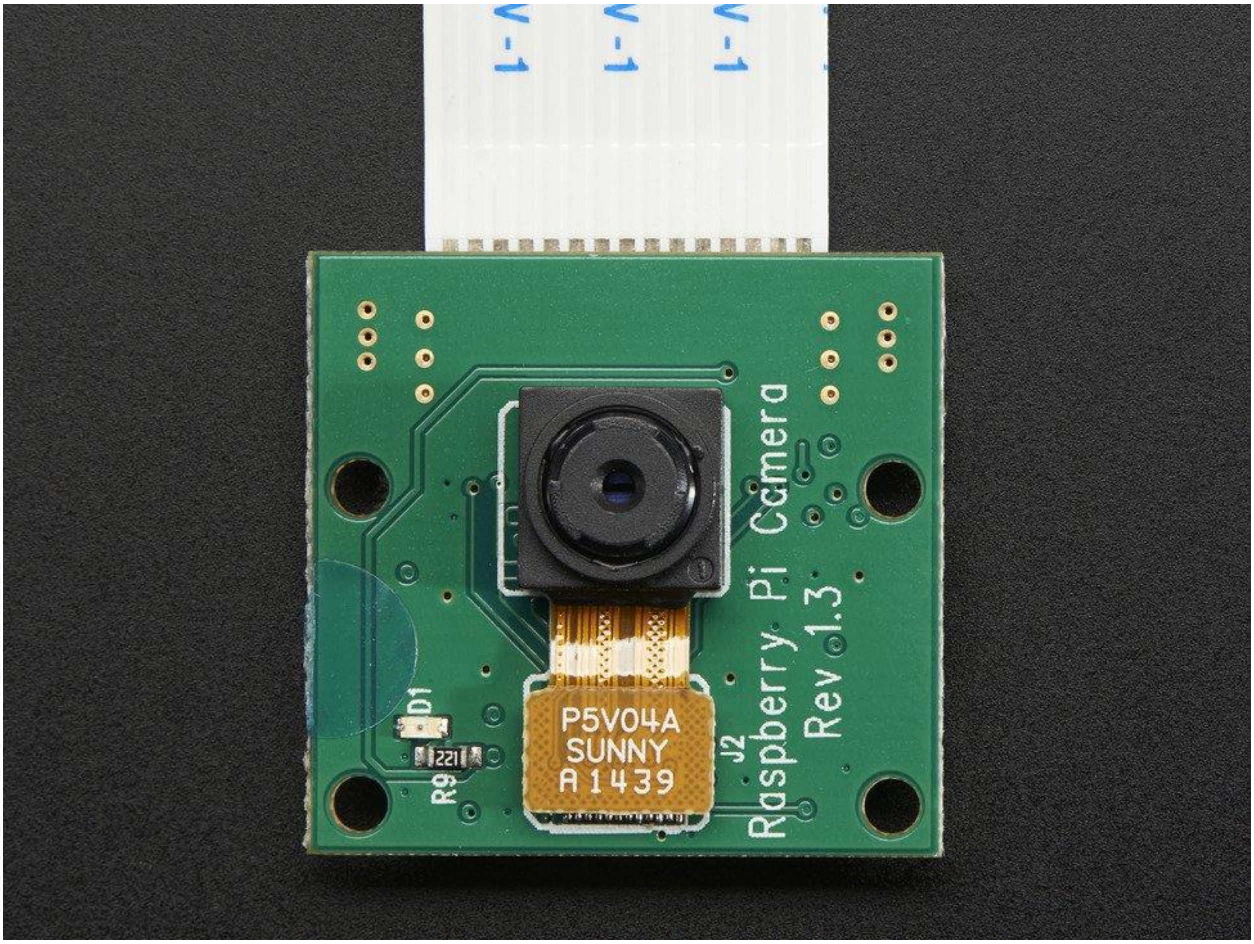
Components

1. Raspberry Pi 3 Model B

Specifications

SoC: Broadcom BCM2837
CPU: 4× ARM Cortex-A53, 1.2GHz
GPU: Broadcom VideoCore IV
RAM: 1GB LPDDR2 (900 MHz)
Networking: 10/100 Ethernet, 2.4GHz 802.11n wireless
Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy
Storage:microSD
GPIO: 40-pin header, populated
Ports: HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)

The Raspberry Pi 3 Model B is the primary embedded system chosen to control the R2D2. It can



be called the brain of our robot. It is powered by power bank via the Micro USB cable and will operate completely wirelessly through the connection of a router.

2. Raspberry Pi Camera Board

Specifications

- Small board size: 25mm x 20mm x 9mm
- A 5MP (2592×1944 pixels) Omnivision 5647 sensor in a fixed focus module
    - Support 1080p30, 720p60 and 640x480p60/90 video record

The Raspberry Pi Camera Module is used to record and watch live stream from the environment. It is connected directly with the Raspberry Pi 3 via the provided cable.

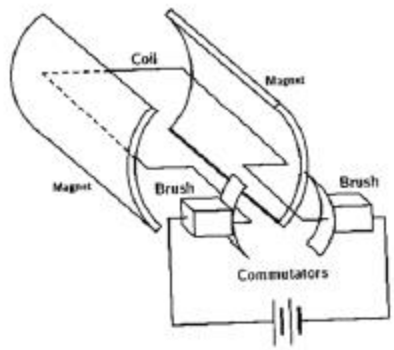
214 series gearhead motors

Specifications

- 14Nm stall torque DC motor
- 12V reversible
- Water resistant
- For use with sprockets and drives
- Weight 1.6 pounds

The 214 series gearhead DC motor is the main driving mechanism behind the two side legs and the head. Two motors were used on each side of the leg that will be used for motion and another has been used on the head with which the head will rotate.

working principle of DC motor



3. Linear Actuator

Screw type	ACME
Weight*	2.95kg
Protection	IP54
Compatible controller	Compatible with all controllers (*Notice the type of connector: Audio/DIN 4pin)
Working temp.	+5°C~40°C

* Stroke length 200mm

* Option: (1) IP66

(2) Safety Nut (RL■S+183, S≤300/RL■S+233, S>300)

(3) Back fixture turned 90°

4. Micro servo 9g

Specifications:
Size : **21x12x22 mm / 0.74x0.42x0.78 in**
Voltage : **3v ~ 6v**
Weight: **9g / 0.39oz**
Speed : **0.12 sec/60(4.8V)**
Torque : **1.6kg-cm**
Working Temp : **-30C~60C**
Gears: **Nylon White type**

Three small servos are used to open the small hatches on top of the head.

1. Relays are simple switches which are operated both electrically and mechanically. Relays consist

of a n electromagnet and also a set of contacts. The switching mechanism is carried out with the
help of the electromagnet. There are also other operating principles for its working. But they differ according to their applications. Most of the devices have the application of relays.

Why is a relay used?

The main operation of a relay comes in places where only a low-power signal can be used to
control a circuit. It is also used in places where only one signal can be used to control a lot of
circuits. The high end applications of relays require high power to be driven by electric motors
and so on. Such relays are called contactors.

Relay Design

There are only four main parts in a relay. They are

- Electromagnet
- Movable Armature
- Switch point contacts
- Spring

How relay works?

The working of a relay can be better understood by explaining the following diagram given below.

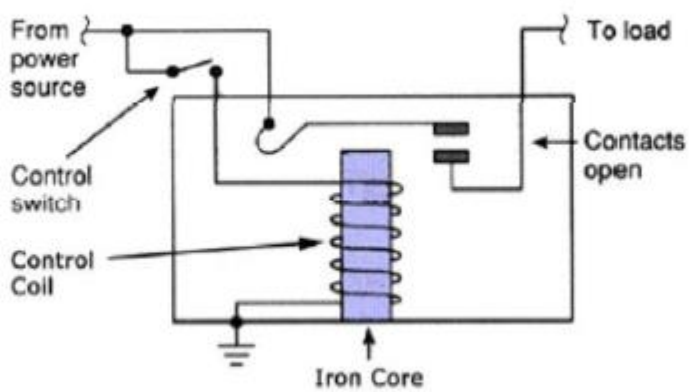


Figure-3.11: Working Principle of a Relay

Relays are mainly made for two basic operations. One is low voltage application and the other is
high voltage. For low voltage applications, more preference will be given to reduce the noise of
the whole circuit. For high voltage applications, they are mainly designed to reduce a phenomenon called arcing.

2. Opto Isolated 2 Relay Module

Specifications

- High current relay, AC250V 10A, DC30V 10A
- 2 LEDs to indicate when relays are on
- Works with logic level signals from 3.3V or 5V devices
- Opto isolation circuitry
- PCB size: 50x45 mm

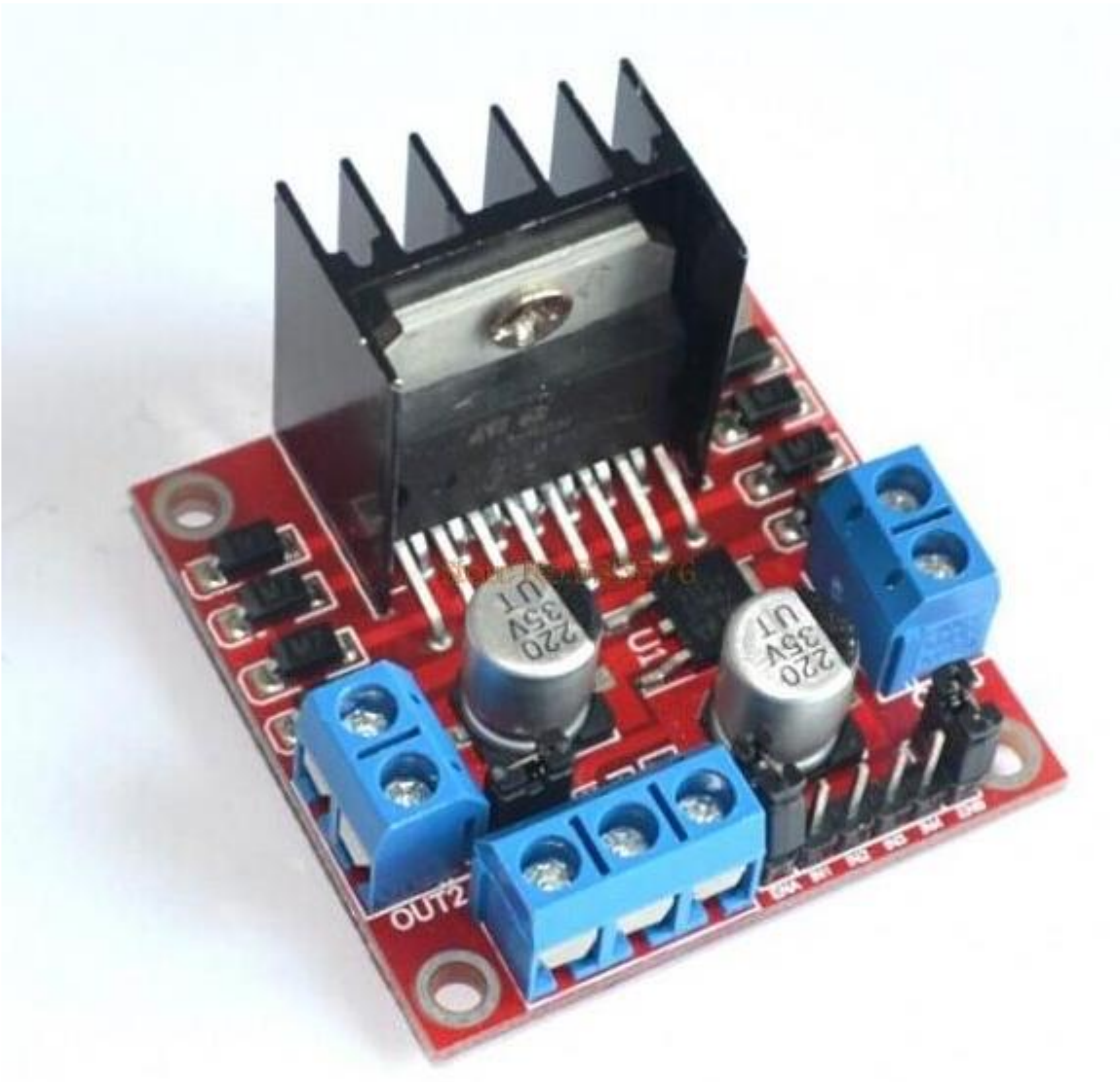
These 2 Relay modules have been used to control the side legs gearhead motors.

3. Opto Isolated Relay Modules

Specifications

- High current relay, AC250V 10A, DC30V 10A
- 2 LEDs to indicate when relays are on
- Works with logic level signals from 3.3V or 5V devices
- Opto isolation circuitry

4. Motor shield L298N



Specification

- Logic Control Voltage：5V (From Arduino)
- Motor Driven Voltage：4.8～35V (From Arduino or External Power Source)
- Logic supply current Iss：≤36mA
- Motor Driven current Io：≤2A
- Maximum power consumption：25W（T=75℃）
- PWM、PLL Speed control mode
- Control signal level:
    - High：2.3V≤Vin≤5V
    - Low：-0.3V≤Vin≤1.5V

- The L298N motor driver has been used to control the middle leg actuator.

5. TP Link TL-WR720N Wireless Router

HARDWARE FEATURES

Interface	2 10/100Mbps LAN Ports 1 10/100Mbps WAN Port
Button	WPS/Reset
Antenna	5dBi Fixed Omni Directional
External Power Supply	5VDC / 0.6A
Dimensions (W x D x H)	6.2 x 4.8 x 1.3 in.(158 x 122 x 32 mm)

WIRELESS FEATURES

Wireless Standards	IEEE 802.11b, IEEE 802.11g, IEEE 802.11n
Frequency	2.4-2.4835GHz
Signal Rate	Up to 150Mbps
Reception Sensitivity	130M: -68dBm@10% PER 108M: -68dBm@10% PER 54M: -68dBm@10% PER 11M: -85dBm@8% PER 6M: -88dBm@10% PER 1M: -90dBm@8% PER

	WIRELESS FEATURES
Transmit Power	CE: <20dBm(2.4GHz) FCC: <30dBm
Wireless Functions	Enable/Disable Wireless Radio, WDS Bridge, WMM, Wireless Statistics
Wireless Security	64/128/152-bit WEP / WPA / WPA2,WPA-PSK / WPA2-PSK
	SOFTWARE FEATURES
Quality of Service	WMM, Bandwidth Control
WAN Type	Dynamic IP/Static IP/PPPoE/ PPTP/L2TP/BigPond
Management	Access Control Local Management Remote Management
DHCP	Server, Client, DHCP Client List, Address Reservation
Port Forwarding	Virtual Server, Port Triggering, UPnP, DMZ
Dynamic DNS	DynDns, Comexe, NO-IP
VPN Pass-Through	PPTP, L2TP, IPSec (ESP Head)
Access Control	Parental Control, Local Management Control, Host List, Access Schedule, Rule Management
Firewall Security	DoS, SPI Firewall IP Address Filter/MAC Address Filter/Domain Filter IP and MAC Address Binding
	OTHERS
Certification	CE, FCC, RoHS
Package Contents	TL-WR720N Power Supply Unit Resource CD RJ-45 Ethernet Cable Quick Installation Guide
System Requirements	Microsoft® Windows® 2000, XP, Vista™ or Windows 7, Windows8/ 8.1/10 MAC® OS, NetWare®, UNIX® or Linux
Environment	Operating Temperature: 0℃~40℃ (32°F~104°F) Storage Temperature: -40℃~70℃ (-40°F~158°F) Operating Humidity: 10%~90% non-condensing Storage Humidity: 5%~95% non-condensing

6. LED Light Strips

7. Samsung MicroSD 8GB Memory Card

8. Power bank

9. Laptop

10. Connectors

11. Male-Male/Male-Female/Female-Female Wires

12. SS sheet

13. Gear

14. Chain sprockets

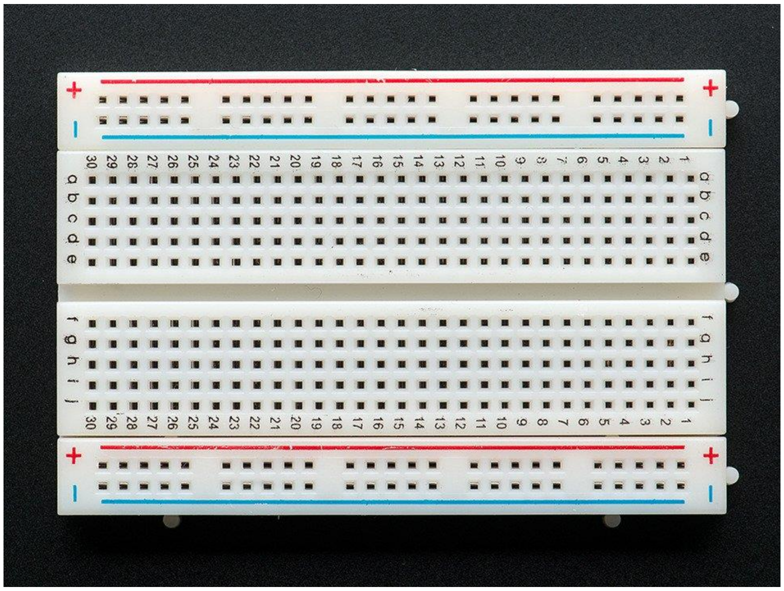
15. Timing chain

16. 12V Sealed Rechargeable Battery

17. Base Bearing

18. UCF200 Bearing

19. Bread Board



20. Hose Pipe

21. Trolley Wheels

22. Switch

Communication and control

We control our R2D2 wirelessly. By router we gave an IP address to raspberry pi. Then we connect our laptop with router which provide IP address to pi. Connection established through Putty software. By putty we make laptop screen, keyboard, mouse as raspberry pi screen, keyboard and mouse. Our signal pass through WiFi. We can control our robot from 150 meter of distance.

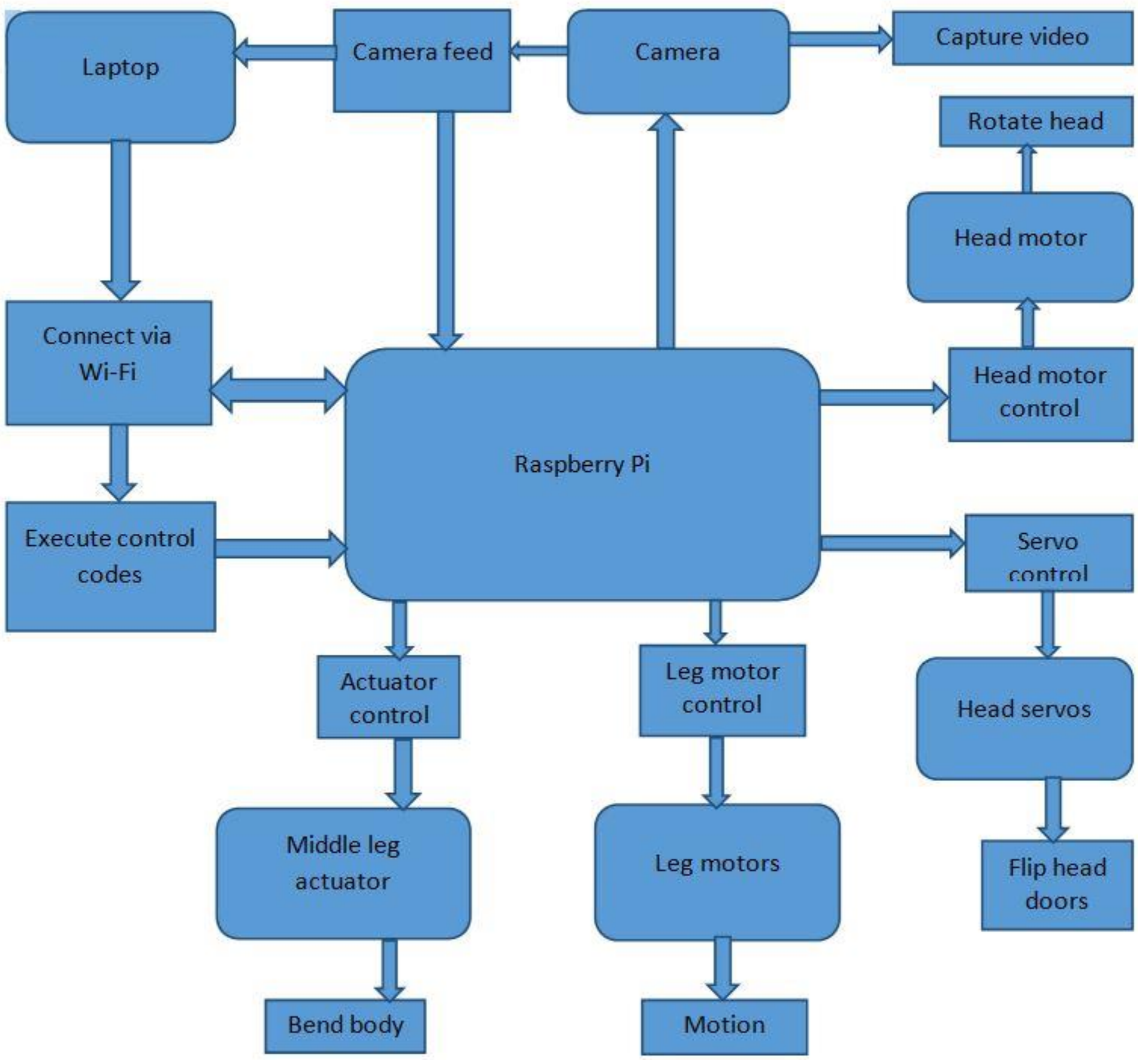
Doing GPIO pins high and low pi pass signal to relay and motor driver.

For DC motors control we send signal from pi to 12V relay.

Our actuator is getting signal from L298N then starts to move.

For live streaming it takes continuous picture by pi camera and send to laptop screen. Quality of the video is really high.

Flow Chart


Laptop
Camera feed
Camera
Capture video
Rotate head
Head motor
Connect via Wi-Fi
Head motor control
Raspberry Pi
Execute control codes
Servo control
Actuator control
Leg motor control
Head servos
Middle leg actuator
Leg motors
Flip head doors
Bend body
Motion

Experimental Result

We exhibited the head and noted that the three servos fitted there each requires in about 5V to power. The external 5V was provided by a motor driver's always 5V output pin. We had assigned just one pin from Raspberry Pi to control all the three servos through the use of a miniature breadboard. Earlier, a lot of the pins of our Raspberry Pi got burned as we were experimenting with larger loads directly connected to the Pi without any use of motor driver or relay. As one pin from the Raspberry Pi was assigned to the three servos, the signal sent was weak. In theory, all the servos were connected in parallel; the voltage must be equal to them all. But in reality the voltage to each of them varied.

Servo 1 got 1.2V

Servo 2 got 1.2V

Servo 3 got 1.5V

So, we tested them out individually connecting them to Raspberry Pi one at a time. The signal sent was 4.7-4.9V for all of them.

To identify the problem we tested what the cause was. The test was to not use the breadboard and also measure the current flow when the servos were in parallel. It turns out the current was not enough when in parallel. Also breadboard increased resistance slightly.

The second and more severe problem we faced involved the whole set of wire used to connect. The relays were switching properly and were powered by a different battery. But after switching the "Com" terminal was showing a huge drop in voltage from 0-2 V, whereas we provided 12V from another battery. Due to risk of speedy discharge and less torque generation by the motor we used two separate 12V batteries- one to power up the relay board and motor driver circuit. The other was to power the motors and actuators. So, after nervous breakdown and some serious counseling we decided to change the whole set of wire and in place used a sturdier one. That did the trick.

The reason we identified was that load required for the motor was too high for the low grade wire. And it may have burnt somewhere inside so the connection was quite loose. Also, the wire cross-sectional was small and as resistance is inversely proportional to cross-sectional area the voltage drop was within the wire itself.

Conclusion

Bangladesh is a country which does not yet have a vibrant community for robotics. Few of us who challenge ourselves to go down this path often face certain hindrance and at times the end goal seems quite far away. We were no different from this scenario.

Limitation

The head or dome is oval shaped with a vertical height of 11 inches and diameter of 18 inches. Due to the lack of cost effective CNC machines we had to modify the design. The body and the head was manually cut and welded through a trial and error process. So, there lies our first problem; the proper alignment of the body and the head. The head is a bit more bent so when it turns a full 360 degrees, it has some parts of it outside the edge of the body.

We planned and adapted as the project progressed. This took its toll on us financially.

We had to use two different batteries making the body much heavier.

Many cheap buck, motor driver and relays were bought which after two to three trials burned out or just died, increasing the financial strain on us.

Future plan

Due to some missing library bug, face recognition was excluded but in the future this can be made fully autonomous robot through inclusion of facial recognition. Inclusion of certain gadget in its structure such as laser or a long hand like stick would increase the interaction and entertainment. R2D2 can also be assigned on security tasks when facial recognition and image processing is implemented.

Reference

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[2]http://www.r2-d2builder.com/r2d2builderpartsshoulders.html

[3] http://www.numpy.org/

[4] http://www.starwars.com/databank/r2-d2

[5]http://www.r2d2builder.com/r2d2builderpartsdome.html

[6] https://www.python.org/

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[9]https://grabcad.com/library/r2d2

[10]https://groups.yahoo.com/neo/groups/r2builders/info

Annex

i) Control Code

```
import curses
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BOARD)
GPIO.setup(7,GPIO.OUT)
GPIO.setup(11,GPIO.OUT)
GPIO.setup(13,GPIO.OUT)
GPIO.setup(15,GPIO.OUT)
GPIO.setup(16,GPIO.OUT)
GPIO.setup(18,GPIO.OUT)
GPIO.output(7,True)
GPIO.output(11,True)
GPIO.output(13,True)
GPIO.output(15,True)
GPIO.output(16,False)
GPIO.output(18,False)
screen = curses.initscr()
curses.noecho()
curses.cbreak()
screen.keypad(True)

try:
    while True:
```

```
char = screen.getch()
if char == ord('q'):
    break
elif char == curses.KEY_RIGHT:
    GPIO.output(7,False)
    GPIO.output(11,True)
    GPIO.output(13,False)
    GPIO.output(15,True)
elif char == curses.KEY_LEFT:
    GPIO.output(7,True)
    GPIO.output(11,False)
    GPIO.output(13,True)
    GPIO.output(15,False)
elif char == curses.KEY_UP:
    GPIO.output(7,True)
    GPIO.output(11,False)
    GPIO.output(13,False)
    GPIO.output(15,True)
elif char == curses.KEY_DOWN:
    GPIO.output(7,False)
    GPIO.output(11,True)
    GPIO.output(13,True)
    GPIO.output(15,False)
            elif char == ord(','):
                GPIO.output(16,True)
                GPIO.output(18,False)
elif char == ord('.'):
                GPIO.output(18,True)
```

```
                GPIO.output(16,False)
            elif char == 10:
                GPIO.output(7,True)
                GPIO.output(11,True)
                GPIO.output(13,True)
                GPIO.output(15,True)
                GPIO.output(16,False)
                GPIO.output(18,False)

finally:
    #Close down curses properly, inc turn echo back on!
    curses.nocbreak(); screen.keypad(0); curses.echo()
    curses.endwin()
    GPIO.cleanup()
```