Mobile-controlled wireless rover with IR sensors

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Abstract

Wireless, sensor-driven robotics is a discipline with ready applications in military, factory and civilian uses. While they initially lacked robustness due to the inherent problems associated with wireless technology such as fluctuating signal strength and difficulty in debugging, the technology has now matured such that several critical services and mechanisms now operate wirelessly. Coupled with the ubiquity of Wireless LAN technology and the Internet, we find that there are some interesting use cases for remotely-controllable vehicles.

In this paper we both provide the specifications for and build a movable robot which may be controlled from any device connected to the same Wireless LAN, via a Web 2.0 interface. IR sensors feed information back to the controlling human, allowing them to maneuver accordingly based on the terrian.

While not suitable for industry or military grade applications, this setup was found to be robust from an experimental and academic viewpoint.

1 Introduction

- Rovers have been widely employed by military and research community (space research) to explore unknown terrains. However rovers have also been in use for simpler applications such as monitoring of different zones on the factory floor. Be it simple or complex rover, they present two major challenges:

  1. Interaction with the environment
  2. Wireless control

- In comparison with the scientific Mars rovers which are voluminous beasts of the order of a few hundred kilograms [1], our rover is a simple three-wheeled bot weighing slightly more than a 1500 grams. The motors power the back wheels and the front wheel is simply a ball-bearing with a low coefficient of friction, allowing the rover to move quickly over smooth surfaces.

A block-diagram of the overall hardware system is as follows:

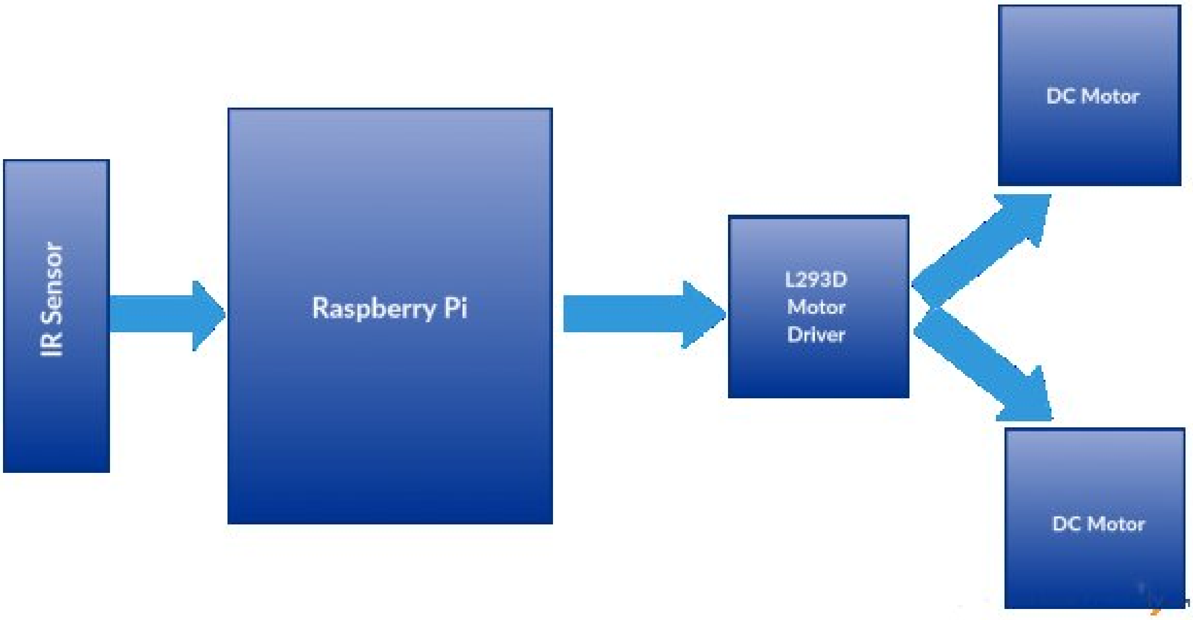

Figure 1: System diagram of the rover

- The microcontroller used is the Raspberry Pi 3, a popular and well-supported hobbyist board. It comes bundled with an onboard Wireless chip and 40 General Purpose Input/Output pins for interfacing with the motors and IR sensors. Power is supplied via a pair of 9v batteries (to the motors) and a 5600 mAh powerbank (to the Pi). The controlling GUI is served by a Python Django server running on Raspbian, a Linux-based distribution installed on the Raspberry Pis external memory.
- The DC motors that move the rover around are standard 300 rpm high-torque motors [3] (low torque motors were unsuccessful in moving the rover on even flat surfaces). The power is delivered via 9v batteries, and controlled via a L293D motor driver.
- An important module of the rover is the trio of IR sensors on the bottom panel, around one inch above the ground. They are used to detect the terrain (black or white) and can be used for line-following even in dim environment. While sufficient for our current purposes, it is possible to replace them with complex, application-specific sensors if required e.g. landmine-detection apparatus for military use cases.

While not nearly state-of-the-art, this setup is sufficient for the proof-of-concept which we build.

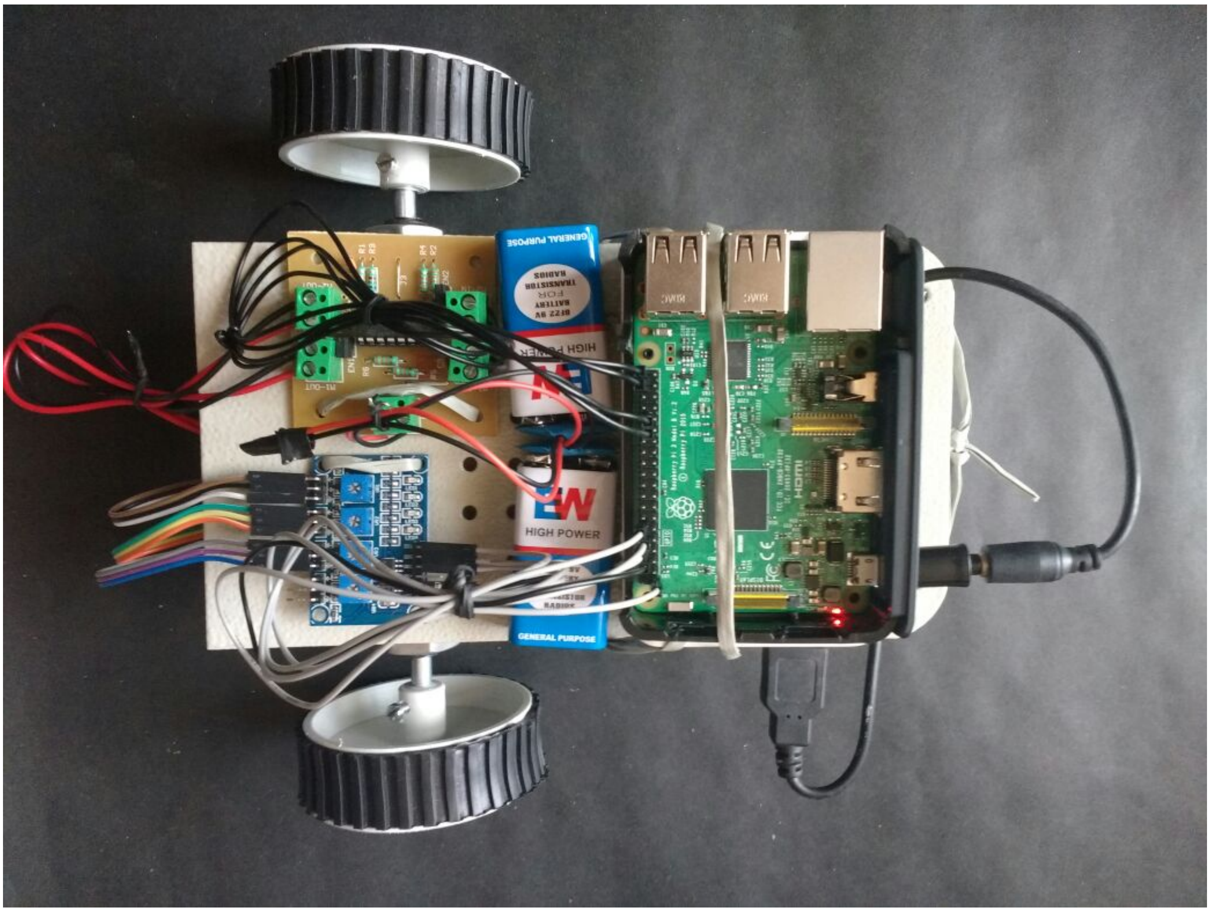

Figure 2: A photograph of the assembled rover

2 Motivation

The main aim of the project is to learn about embedded systems as a whole, and along the way display the applicability and robustness of wireless technology in robotics. We do so using a movable, proof-of-concept rover which we then control using a GUI interface accessible through either a mobile phone or laptop, anywhere in the vicinity. A simple extension of this notion would allow the control of robots in other countries or even on other planets.

3 Problem Definition

1. To construct a movable robot, with a 15x8 chassis, two wheels and three IR sensors attached to a makeshift cardboard bottom, and a Raspberry Pi 3B and DSG powerbank secured to the top. The IR sensor board and motor drivers are secured to the chassis with electrical tape or plastic cords to prevent movement.

2. The Raspberry Pi automatically connects to a known Wireless LAN at bootup, thus allowing unsupervised bootups at regular intervals.

3. A Web 2.0 interface would be served via a Python Django server to a computer [1] connected to the same Wifi network as the Pi. This interface serves the controls *"Forwards"*, *"Backwards"*, *"Left"*, *"Right"* and *"Stop"*. The interface is served at an IP address known to the computer, removing the problem of reconfiguration.

4. The interface would additionally display the status of three IR sensors as binary values, e.g. 010, indicating the middle senor was triggered. This would be updated every few seconds without reloading the page. This is for reference of the human controller, similar to a video feed (which was infeasible due to bandwidth constraints).

5. On clicking one of the buttons, a request would be sent over the Wireless connection to the Django server, which would in turn send a message to the motor drivers, moving the rover in the desired direction (or stopping it).

Note that this is a proof-of-concept project. Every stage would require changes in hardware materials and electronics to build a workable rover system.

[1] Note that our only criterion for *computer* is a device with a JavaScript-enabled web browser that is able to communicate via HTTP requests. We may thus use mobile phones (Android, iOS etc.) or laptop or desktop computers to access this interface.

4 Methodology and Implementation

4.1 Hardware [1]

1. **Raspberry Pi 3 Model B:** The Raspberry Pi 3 is a hobbyist microcontroller board which can be used for a variety of embedded systems projects.

   It's specifications [5] include:

   - Broadcom BCM2837 64bit ARMv7 Quad Core Processor powered Single Board computer running at 1.2GHz
   - 1 GB RAM
   - BCM43143 WiFi on board
   - 4 USB 2.0 ports
   - 40 GPIO pins[3] (General Purpose Input Output)
   - Full HDMI port
   - Micro SD card slot (an 8Gb SanDisk MicroSD was used)

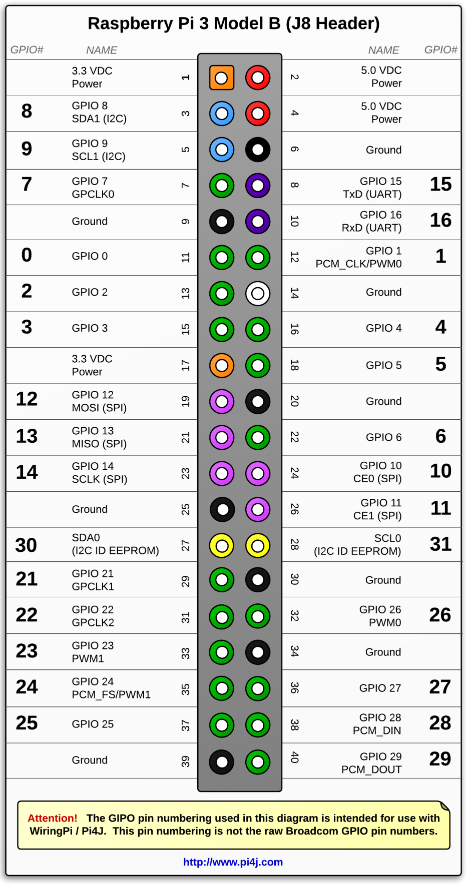

Figure 3: Raspberry Pi 3B pin diagram

[1] Most hardware for this project was obtained from specialty electronic stores around Mumbai. The Raspberry Pi 3B was borrowed from Prof. Bhole, Computers and Information Techonolgy Department, VJTI. We did our best not to alter his existing configurations.

2. **Wheels and motors:** the robot moves using two wheels each driven by a 300 RPM DC motor. These DC motors are connected with L293D IC which provides and H bridge to turn one motor and other off or both simultaneously in same direction or different direction.

3. **L293D Motor Driver:** a quadruple high-current half-H driver. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. This allows the wheels to move in both directions and also turn left and right. [4]

   We connect this driver[4] to the following pins of the Raspberry Pi:

Raspberry Pi 3B	L293D
GPIO 29 (pin 40)	VCC
GPIO 28 (pin 38)	GND
GPIO 26 (pin 32)	GND
Ground (pin 30)	GND

Table 1: Connections of Raspberry Pi to L293D Motor Driver

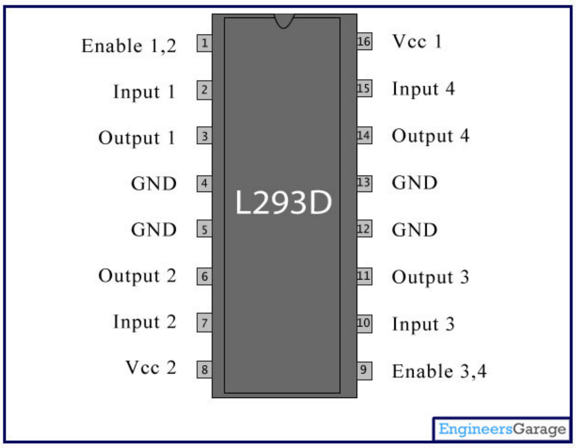

Figure 4: L293D Motor Driver pin diagram

4. **IR sensors:** In the rover, IR sensors are used to perform line-following on black or white striped lines.

   IR sensors work on the principle of reflectance where there is one transmitter and one receiver. The transmitter transmits InfraRed rays which are received by the receiver to complete the circuit, due to which current flows through it. [6]

   Dark colors are good absorber of rays, and they reflect very few of the IR rays falling on it. [7] Due to this phenomenon, using a dark color as the background and white color as line allows to distinguish the path from the background as only white color will be detected by the sensors.

Pin No	Function	Name
1	Enable pin for Motor 1; active high	Enable 1,2
2	Input 1 for Motor 1	Input 1
3	Output 1 for Motor 1	Output 1
4	Ground (0V)	Ground
5	Ground (0V)	Ground
6	Output 2 for Motor 1	Output 2
7	Input 2 for Motor 1	Input 2
8	Supply voltage for Motors; 9-12V (up to 36V)	Vcc_2
9	Enable pin for Motor 2; active high	Enable 3,4
10	Input 1 for Motor 1	Input 3
11	Output 1 for Motor 1	Output 3
12	Ground (0V)	Ground
13	Ground (0V)	Ground
14	Output 2 for Motor 1	Output 4
15	Input2 for Motor 1	Input 4
16	Supply voltage; 5V (up to 36V)	Vcc_1

Figure 5: L293D pin description

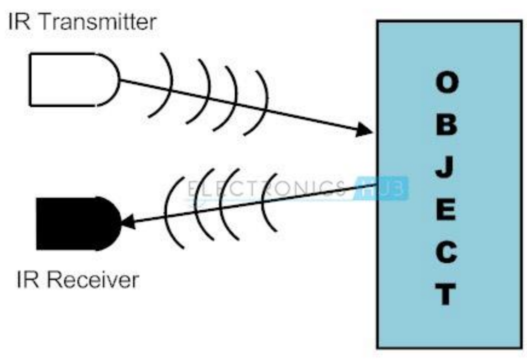

Figure 6: The working of IR sensors

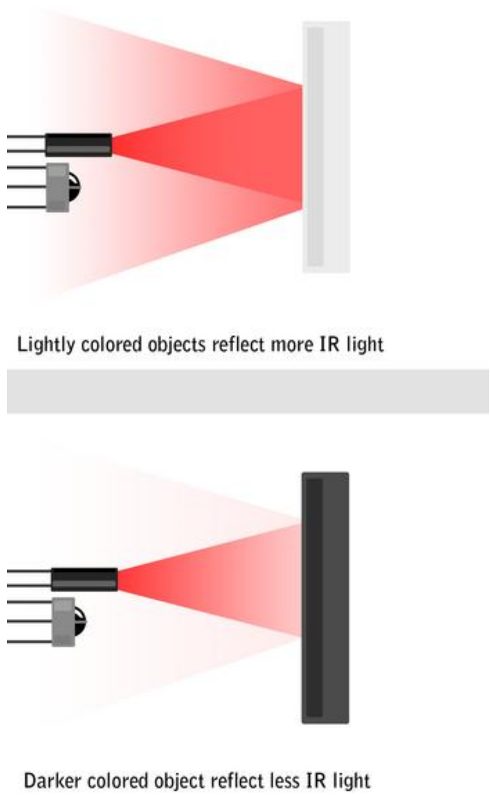

Figure 7: Dark colors absorb more light

References

[1] NASA, *Mars Science Laboratory Landing*, pg 34:
https://www.jpl.nasa.gov/news/press_kits/MSLLanding.pdf

[2] Raspberry Pi 3B pin diagram:
http://pi4j.com/pins/model-3b-rev1.html

[3] 300 RPM motors specification:
http://robokits.co.in/motors/high-torque-dc-geared-motor-300rpm

[4] L293D motor driver specification:
https://www.engineersgarage.com/sites/default/files/L293D.pdf

[5] Raspberry Bi 3 Model B specifications:
https://www.raspberrypi.org/documentation/hardware/computemodule/RPI-CM-DATASHEET-V1_0.pdf

[6] Graetzer George, *Math Into LaTeX*, Birkhuser Boston; 3 edition (June 22, 2000).