Quantum Robot

Learning about Quantum Circuits Using Qiskit
and about a basic Quantum Robot

Prepared By: Aritra Mukhopadhyay
under the supervision of Prof. Prasanta K Panigrahi

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Abstract

Qiskit is an open-source software development kit widely used for learning quantum computation and working on related topics. It is used to run quantum algorithms both on simulation of quantum computers and on real quantum computers. It translates common programming languages like Python into quantum machine language.

Just like classical computers, quantum computers are also based on gates. They are called Quantum Gates. We can do all sorts of operations with those gates. But the working of those gates is quite different from that of the classical logic gates.

Braitenberg Vehicles are very simple devices, yet the resulting behaviour may appear complex or even intelligent. With the aid of Quantum Computers an excellent future application of Quantum Roots can be at our hands. As a practical example, quantum-controlled Braitenberg vehicles is a mobile quantum system and hence acts as a quantum robot.

I read a paper and tried to simplify the quantum circuits and algorithms. The aforementioned quantum circuit is designed with the help of IBM quantum experience.

Keywords: *Braitenberg Vehicles, Quantum Circuit, Quantum Gates, Quantum Robot, Qiskit, IBM Quantum Experience.*

Acknowledgement

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1 Introduction

The project primarily focused on learning and understanding quantum circuits. I thoroughly played around with IBM Quantum Experience and Qiskit to build intuitions about Quantum Gates and their uses in Quantum Circuits.

I read some papers which were provided to me by Prof. Panigrahi. Soon I came across the paper [Mahanti et al., 2019]. While reading the paper, I came up with two easier solutions to the problem addressed in the paper. My report talks about those very solutions.

2 Braitenberg Vehicles

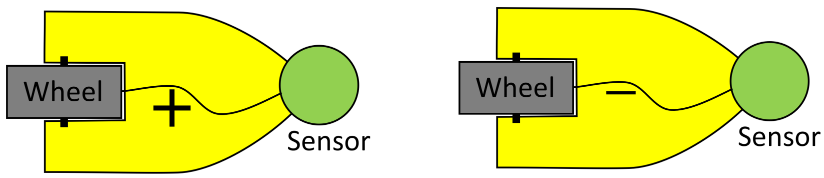
Valentino Braitenberg (1926-2011) was an Italian neuroscientist and a synthetic psychologist. He spent most of his life doing experiments to understand how the animal nervous system works. He was also interested in building synthetic models of human or animal behaviour. He is well known for his book [Braitenberg, 1986]. This book consists of a series of thought experiments about behaviours which can be expected of simple devices. All these thought experiments were inspired by animals and their nervous systems. He said "when we analyse a mechanism, we tend to over-estimate its complexity".

2.1 Working of a Basic Braitenberg Vehicle

These are simple vehicles consisting of actively driven wheels and sensors. The sensors are stimulated by some stimulus (light, temperature, sound, presence of certain chemicals etc). The rotation speed of the wheels is directly controlled by the two sensor data. Depending upon how many sensors and wheels are there and how the sensor data influences the wheel speed (either excitatory or inhibitor), Braitenberg vehicles have been divided into the following categories:

2.1.1 Vehicle 1

These vehicles (in Fig 1) consist of a single sensor and a single wheel. These devices cannot change their directions. They move in a straight line.



(a) Excitatory Signal (b) Inhibitory Signal

Figure 1: Braitenberg Vehicle Model 1

Now the sensor can either give an excitatory or an inhibitory signal to the wheel:

- **Excitatory Signal from Sensor:** Here, wheel speed is directly proportional to the strength of the stimulus. As the sensor senses more stimulus, (the stimulus is near) the wheel rotates faster; the vehicle gains speed. Thus, the speed of the vehicle is more when the vehicle is near the stimulus and the vehicle moves slowly when it is away from the stimulus. As a result, it spends less time near the source of stimulus and more time roaming away from it.

- **Inhibitory Signal from Sensor:** Here, wheel speed is inversely proportional to the strength of the stimulus. As the sensor senses more stimulus, the vehicle slows down. Thus, the devices gather around the source of stimulus.

2.1.2 Vehicle 2

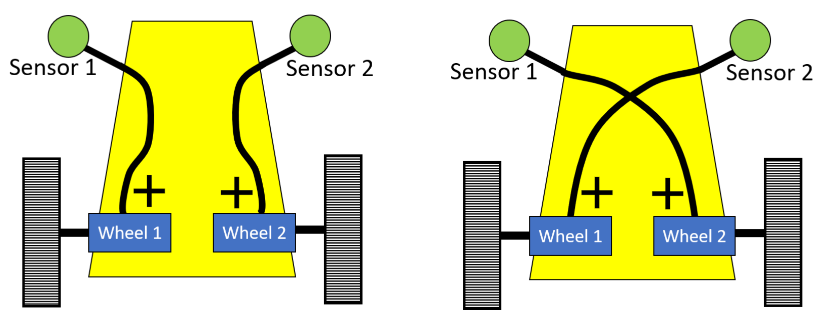
These vehicles (in Fig 2) consist of two sensors and two wheels. Unlike Vehicle 1, they can move freely on a 2D plane. But here, the sensors can always give an excitatory signal to the wheels. They have been divided into three categories depending upon their connections:

- **Uncrossed connections (2a):** Here, the left sensor is attached to the left wheel and the right sensor is attached to the right wheel. Now, suppose a source of stimulus is present on the right side of the vehicle, the right sensor is stimulated more than the left one. Hence the right wheel rotates faster than the left wheel. Thus the vehicle turns left and goes away from the stimulus.
  Inference: The vehicle expresses **fear** from the cause of the stimulus.

- **Crossed connections (2b):** In this case, the left sensor is attached to the right wheel and the right sensor is attached to the left wheel. Now, to a stimulus on the right, the system responds by rotating the left wheel faster. It moves towards the stimulus. As it moves closer to the stimulus, its speed increases. Soon, the vehicle collides with the stimulus at great speed.
  Inference: The vehicle expresses **aggression/hate** towards the cause of the stimulus.

- **Double connections (2c):** Here, both the sensors are connected to both the wheels. As both the wheels symultaneously recieve the same signal, this vehicle cannot turn (turning is achieved by different speed of the wheels). Thus, inspite of having a more complex connection, the vehicle is inferior to both 2a and 2b vehicles.
  Inference: More complex connections do not always give us to more complex functionality.

Braitenberg talked about a lot of other sorts of vehicles which show love, hatered, and many other behaviours. But this much discussion is enough for the purpose of this report.



(a) Uncrossed Connection (b) Crossed Connection

Figure 2: Braitenberg Vehicle Model 2

3 The Problem and Modified Design

3.1 The Problem

We know that the 2b vehicle discussed above crashes into the stimulus with great speed. It shows aggression. That is not a very desirable thing to happen. Our main goal is to fix that and come up with a solution using quantum phenomena. To achieve this we modify the vehicle a bit. Till now, our vehicle was moving on a 2D plane. To avoid the collision we tried to get help from the 3rd dimension.

3.2 Proposed Modified Design

We have seen that the Vehicle 1 has a single wheel and it only moves along a straight line (1 wheel can only give us 1-dimensional motion). As we add another wheel in Vehicle 2 we get full access over the plane (2D). So, it is clear that to enable another degree of freedom, we have to add another actuator of some kind to make our vehicle fly above the stimulus (acts as an obstacle here).

Now, *'flying'* in the real world is a problem in itself. So we won't go into the details of how the vehicle achieves this flying motion. For the scope of this report, we assume that we have done the required arrangements for the vehicle to fly. We say for simplicity that we have attached a propeller on top of the vehicle. It makes the vehicle fly, like a helicopter. Here, we won't discuss problems like the vehicle itself rotating in the opposite direction as a result of the reaction force of the rotating propellers. Let that be a problem for another day.

So, finally, we are left with a vehicle which looks like Fig 3.

3.3 Robot Configurations

- **Sensors:** 2 sensors are attached on two sides of the vehicle for detecting the stimulus.

- **Actuators:** 2 wheels on two sides and 1 propeller on top for taking off the ground.

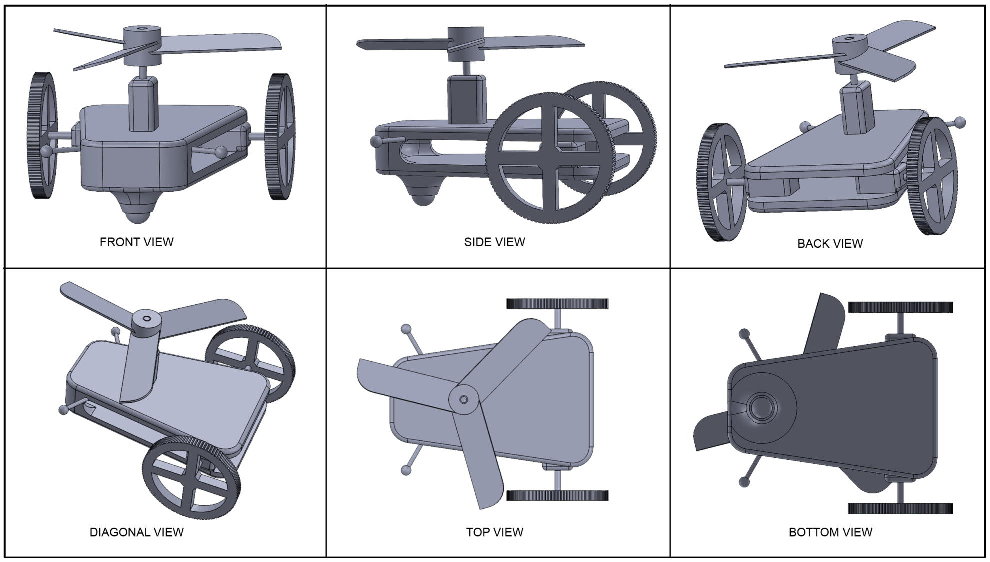


Figure 3: 3D model of the proposed design

4 Behaviour of the Vehicle

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