# James Dyson Foundation Undergraduate Bursary 2020/2021

## Outreach activity report

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# 1 Plan

My project investigated using conformal geometric algebra for the kinematics of robot manipulators. Although conformal geometric algebra is interesting, it is a more niche subject, so decided to focus my outreach activity on robot kinematics.

Additionally, to make the topic more accessible, I decided to look at mobile robots instead of robot manipulators, a topic which although still challenging, is more accessible than robot manipulators which is very mathematical.

The outreach activity was split into three parts:

1. A qualitative overview of mobile robots: A discussion of different components of a mobile robot, to give some general ideas about the topic.
2. A brief look at the kinematics of a differential drive robot: Presenting the maths required to control a differential drive robot, and intuition behind it, without going into too much detail.
3. Designing and simulating a robot that can avoid obstacles.

## 1.1 A qualitative overview of mobile robots

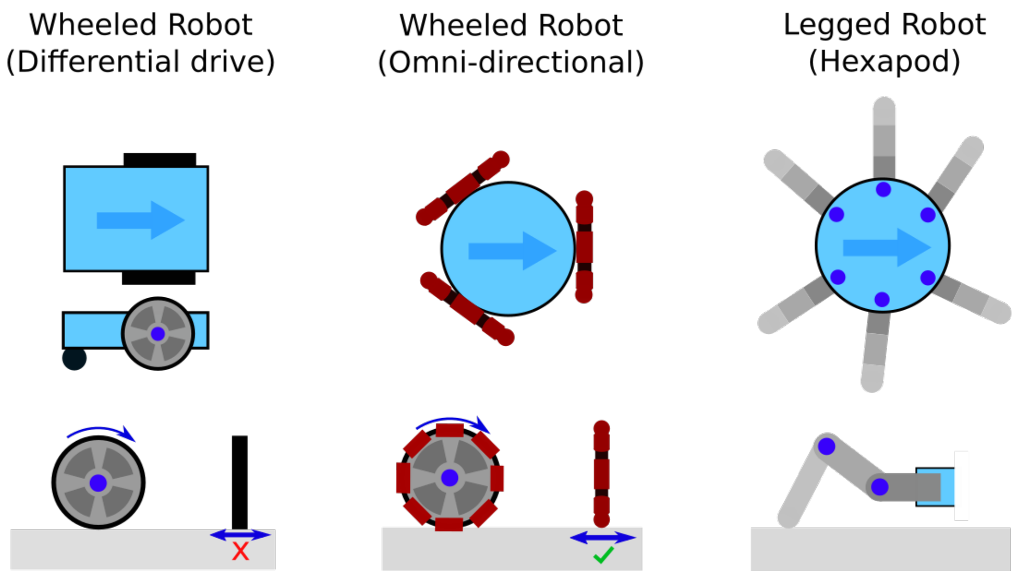
In this section, I would follow a presentation, covering:

- What a mobile robot is.
- What the different components of a mobile robot are.
- The types of locomotion method used by a mobile robot.
- Examples of some sensors used by mobile robots.

To make it more interactive, I avoided talking for too long initially, giving a brief description, followed by an opportunity for students to discuss between themselves.

Following this, I would listen to feedback from the students and expand on whatever thoughts they had.

As an example, the slide on robot locomotion presented the following figure:




This presented two types of wheeled locomotion (differential drive and omni-directional) as well as a type of legged locomotion (a hexapod).

After describing how each type of robot moved, the students then discussed the advantages and disadvantages of the different locomotion methods, and when you might use one over another.

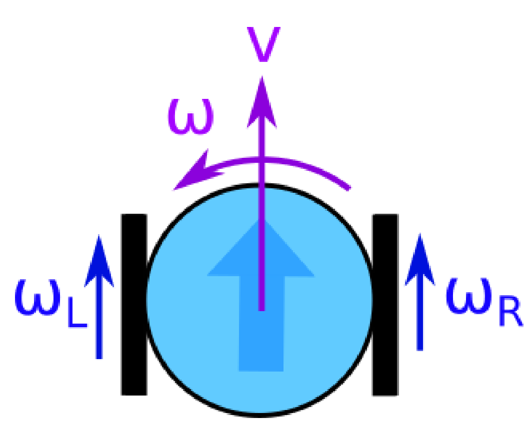
When listening to the students feedback after, I used videos to expand on a few key points, and make things clearer. For example, showing that the omni-directional robot is able to move freely in any direction, while the differential drive robot can only move forwards/backwards and rotate.

## 1.2 A brief look at the kinematics of a differential drive robot

A differential drive robot is controlled by two wheels, with wheel speeds $\boldsymbol{\omega_R}$ and $\boldsymbol{\omega_L}$ which drive the robot forwards with speed $\boldsymbol{v}$ and rotate with angular speed $\boldsymbol{\omega}$.

Forward kinematics gives the equation for $\boldsymbol{v}$ and $\boldsymbol{\omega}$ in terms of the control inputs (the wheel speeds):

$$\boldsymbol{v} = \frac{r}{2}(\boldsymbol{\omega_R} + \boldsymbol{\omega_L}) \qquad \boldsymbol{\omega} = \frac{r}{2L}(\boldsymbol{\omega_R} - \boldsymbol{\omega_L})$$



Inverse kinematics is the inverse relationship, giving the required control inputs for desired linear and angular speeds.

$$\boldsymbol{\omega_R} = \frac{1}{r}(\boldsymbol{v} + \boldsymbol{\omega} L) \qquad \boldsymbol{\omega_L} = \frac{1}{r}(\boldsymbol{v} - \boldsymbol{\omega} L)$$

The maths required to derive the forward kinematics is too high level for the students (requiring knowledge of angular velocity), so instead I just gave the equation and some intuition behind it. For example, if both wheels move at the same speed, the term $(\boldsymbol{\omega_R} - \boldsymbol{\omega_L})$ is zero, so the robot doesn't rotate and moves straight forward.

The students were given the opportunity to try and derive the inverse kinematics equations from the forward kinematics equations.

After finishing the section, I showed a couple of robots I had built myself which used these exact inverse kinematics equations, to demonstrate an interesting application.

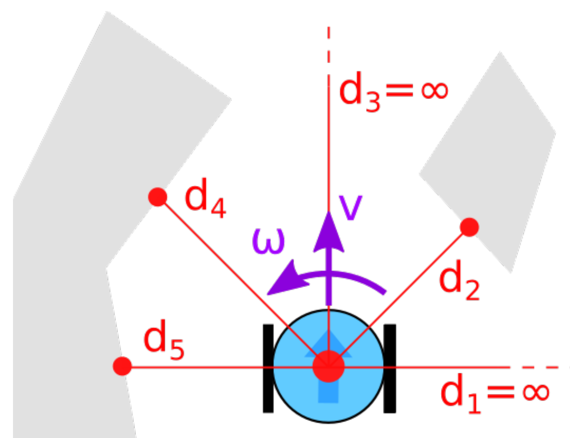
## 1.3 Designing and simulating a robot that can avoid obstacles

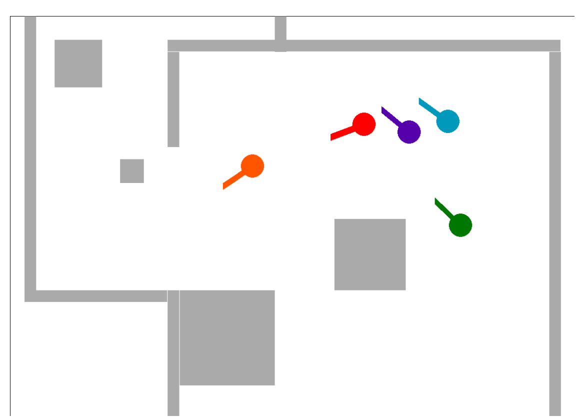
Finally, as a more interesting activity, the students would be introduced to a simple method for controlling a mobile robot to avoid obstacles (similar to a Braitenberg vehicle). This would then be demonstrated in simulation.

This method involved setting the linear and angular speeds using readings from a set of five distance sensors.

Essentially, this involved transforming the inputs $d_i$ to inputs $x_i$, which gave a value $x_i = 0$ when an obstacle was far away and $x_i = 1$ when an obstacle is close. With this, you could control the robot to rotate away from obstacles.

The simulation was done using a Python program I wrote, shown on the right.



# 2 Evaluation

## 2.1 Engagement

Early in the activity, I received good feedback from the discussion sessions. The students were able to come up with a number of points I had in mind, and responded well when I asked follow up questions.

When looking at the differential drive kinematics, engagement dropped off since it was just me presenting some maths, which was probably difficult to manage on a Friday afternoon especially. The students weren't able to give the inverse kinematics equations for the differential drive robot, although one student gave an answer that was close.

When getting onto the last section, due to time constraints, I wasn't able to follow through with the plan of having the students design their own robots: this would have involved them choosing a team colour, and a set of control parameters. Instead, I used some randomly generated values and demonstrated the algorithm in use, which ended up working out okay.

## 2.2 Level of difficulty

Although the maths presented should have been manageable, it may have been out of the students' comfort zone. This perhaps wasn't well suited to an outreach activity. Instead I could have just presented the equations to give a taste of what maths was used, but not focus on it.