Australian National University

LAB REPORT COVER SHEET

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All assessment items submitted in hard copy are due at 5pm unless otherwise specified in the course outline.

Student ID For group assignments, list each student's ID	U 6366102		
Course Code	ENGN 6627		
Course Name	Robotics		
Assignment number			
Assignment Topic			
Lecturer	Dr. Viorella Ila / Dr. Rob Mahony		
Tutor			
Tutorial (day and time)			
Word count		Due Date	26/08/2018
Date Submitted	26/08/18	Extension Granted	

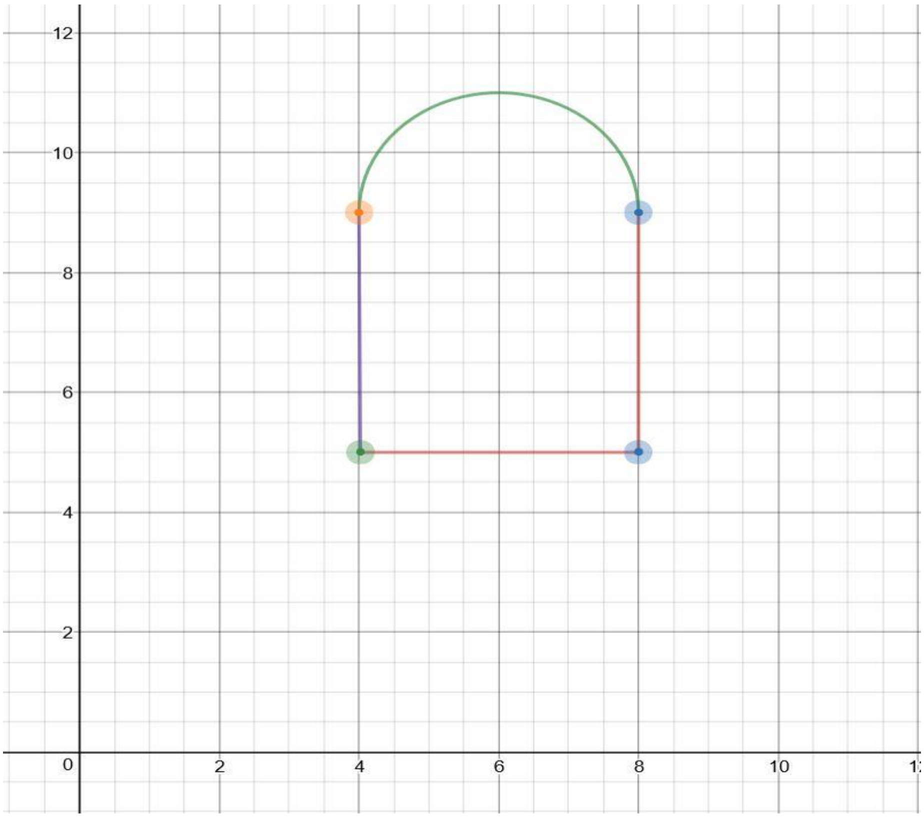
I declare that this work:

- ✓ upholds the principles of academic integrity, as defined in the ANU Policy: Code of Practice for Student Academic Integrity;
- ✓ is original, except where collaboration (for example group work) has been authorised in writing by the course convener in the course outline and/or Wattle site;
- ✓ is produced for the purposes of this assessment task and has not been submitted for assessment in any other context, except where authorised in writing by the course convener;
- ✓ gives appropriate acknowledgement of the ideas, scholarship and intellectual property of others insofar as these have been used;
- ✓ in no part involves copying, cheating, collusion, fabrication, plagiarism or recycling

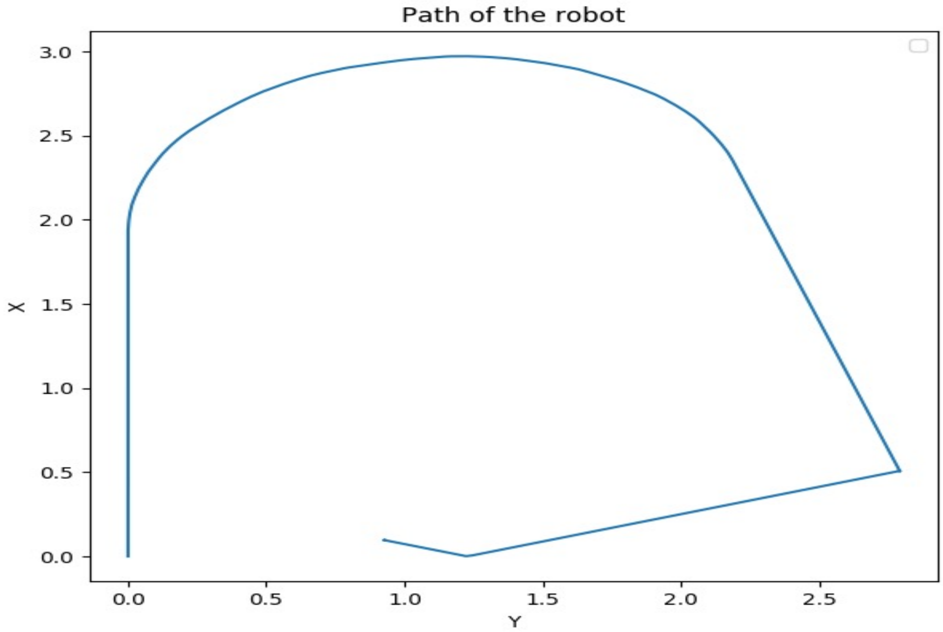
1. The primary source of errors which alters the robot from the desired path is sensor noise. Other errors may be caused due to floor, non-alignment of wheels, tyre slippage and many more.
   The problems we faced includes *under steering, over steering, drift errors, range errors.*
   The sources of these errors include *improper calibration*[1], *communication errors, software to hardware conversion/execution time, floor*
2. "*rosmsg*" shows the message type of a particular message. It also gives details about the datatype of the message. [2]
   For example, the datatype of the position parameters is float64 which is 64-bit IEEE float.
   Position x value was in constant rise when the robot moved in straight line and while taking turns orientation, x, y values changed continuously until the robot completed its turn and later x/y values was in rise with respect to the turn robot had taken.

```
harish@harish:~$ rosmsg show nav_msgs/Odometry
std_msgs/Header header
uint32 seq  #unsigned 32 bit
time stamp  #system time
string frame_id #string datatype
string child_frame_id
geometry_msgs/PoseWithCovariance pose
geometry_msgs/Pose pose
geometry_msgs/Point position # It gives the #position of
the robot
float64 x     #float 64 bit IEEE float
float64 y
float64 z
geometry_msgs/Quaternion orientation # It gives the
#orientation of the robot
float64 x
float64 y
float64 z
float64 w
float64[36] covariance
geometry_msgs/TwistWithCovariance twist
geometry_msgs/Twist twist # It contains linear and
#angular vectors
geometry_msgs/Vector3 linear #3-dimensional vector
float64 x
float64 y
float64 z
geometry_msgs/Vector3 angular #3-dimensional vector
float64 x
float64 y
float64 z
float64[36] covariance
```

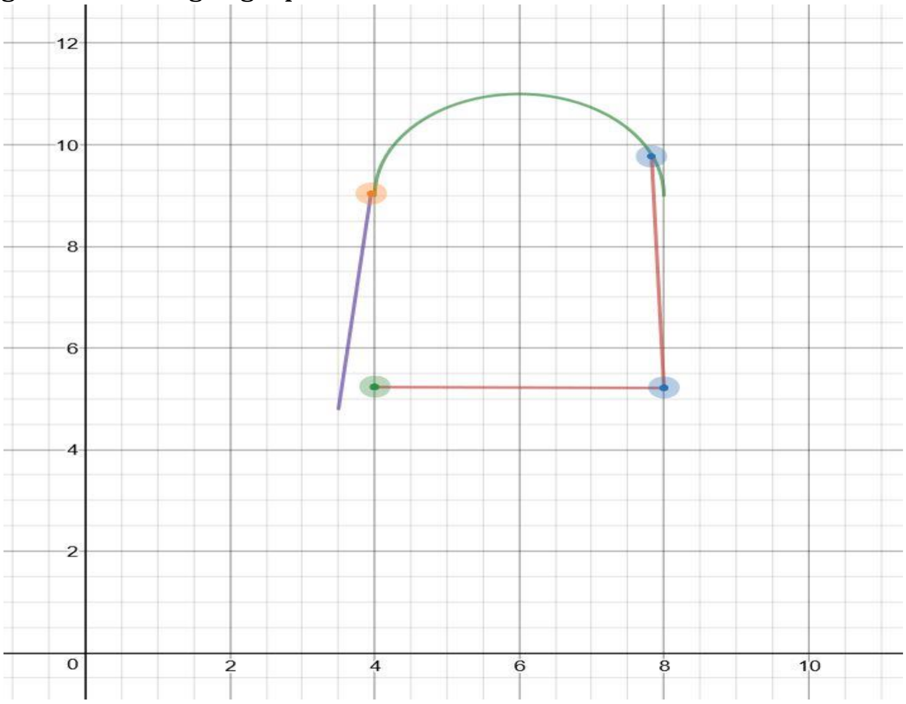

3. The graphs shown here are ideal, robot's paths on three trials.
The following graph is the ideal path designated for the robot and the graph is scaled by 2 for clarity.



The following graph shows uncalibrated robot moving over the designated path which is unacceptable as it largely deviates from its original path. It invites the robot to be calibrated which in turn will improve the accuracy of the path traced.

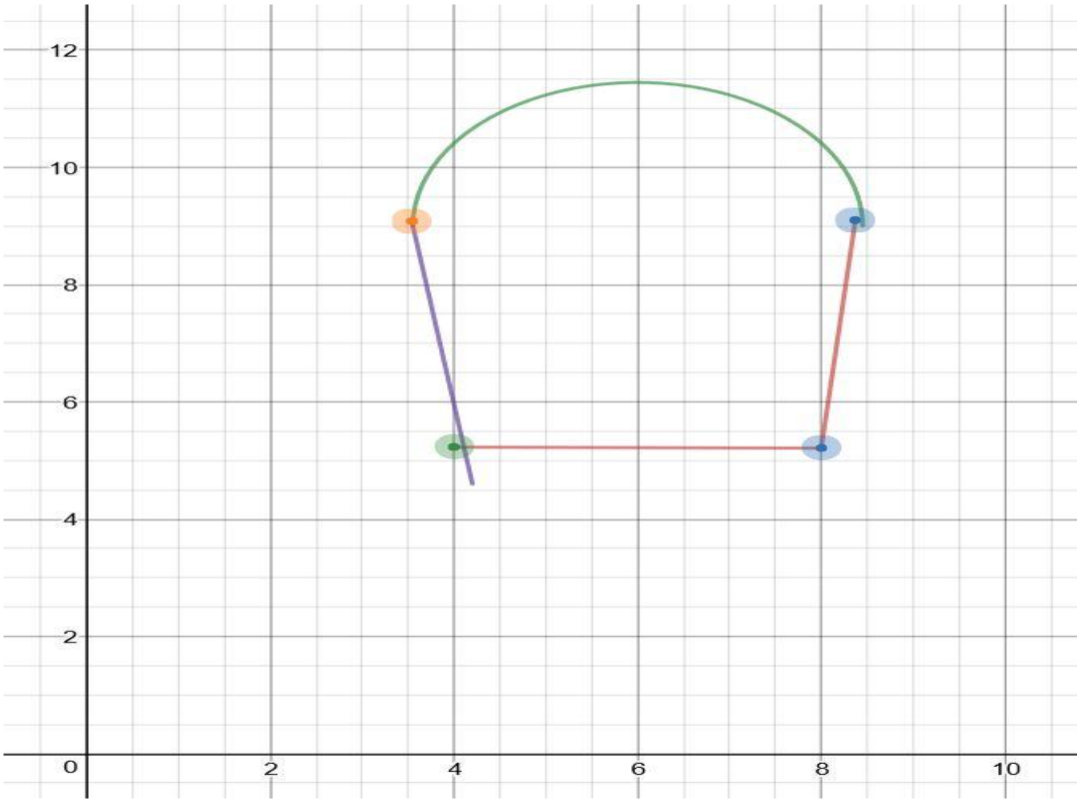


The following graph is the result of understeering of the robot. The graph is plotted to every x and y values sent out and stored in the text file by odometer for every timestep that the bot was running. Initial and final zeros thrown by the odometer are omitted as the bot had stopped moving. The graph values are scaled by 2 to generate a larger graph

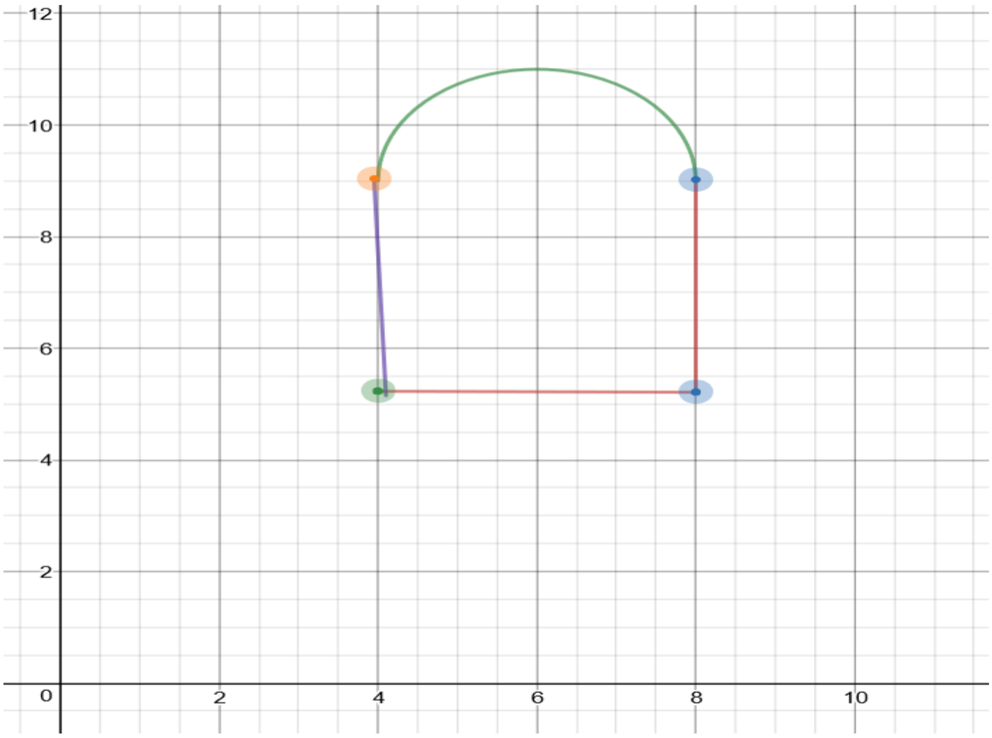


The following graph is the result of oversteering of the robot. The graph is plotted to every x and y values sent out and stored in the text file by odometer for every timestep that the bot was running. Initial and final zeros thrown by the odometer are omitted as the bot had stopped moving. The graph values are scaled by 2 to generate a larger graph.

The insight gained through these graphs is that not only internal but also external factors like carpet texture, floor bumps also caused the robot to deviate from its designated path.



After countless trials, we managed to move the robot almost in its designated path with minor deviations. The graph is plotted to every x and y values sent out and stored in the text file by odometer for every timestep that the bot was running. Initial and final zeros thrown by the odometer are omitted as the bot had stopped moving. The graph values are scaled by 2 to generate a larger graph.



4.

a.

$$\begin{pmatrix} x_1 \\ y_1 \\ \theta_1 \end{pmatrix} = \begin{pmatrix} \cos(\omega\delta t) & -\sin(\omega\delta t) & 0 \\ \sin(\omega\delta t) & \cos(\omega\delta t) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x - x_0 \\ y - y_0 \\ \theta \end{pmatrix} + \begin{pmatrix} x_0 \\ y_0 \\ \omega\delta t \end{pmatrix}$$

[3]

$$\omega\delta t = (v_r - v_l)\delta t / l$$

$(x_0, y_0) - Origin\ of\ world\ frame.$

$\omega - angular\ velocity$

b.1. l = 0.5 m v_r = 0.3 ms^{-1} v_l = 0.3 ms^{-1} t = 3s

Let the origin of the world frame be (0,0)

x = 1.5 m y = 2 m $\theta = 180$ (degrees) $\omega\delta t = 0$

$$\begin{pmatrix} x_1 \\ y_1 \\ \theta_1 \end{pmatrix} = \begin{pmatrix} \cos(0) & -\sin(0) & 0 \\ \sin(0) & \cos(0) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1.5 - 0 \\ 2 - 0 \\ 180 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1.5 \\ 2 \\ 180 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 1.5 \\ 2 \\ 180 \end{pmatrix}$$

In this problem, the velocities of the wheels are equal and in the same direction, so the robot moves linearly in the direction of the velocities.

b.2

l = 0.5 m v_r = -0.1 ms^{-1} v_l = 0.1 ms^{-1} t = 1s

$$\omega\delta t = -0.4$$

$$\begin{pmatrix} x_2 \\ y_2 \\ \theta_2 \end{pmatrix} = \begin{pmatrix} \cos(-0.4) & -\sin(-0.4) & 0 \\ \sin(-0.4) & \cos(-0.4) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1.5 - 0 \\ 2 - 0 \\ 180 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ -0.4 \end{pmatrix}$$

$$= \begin{pmatrix} 0.99 & 0.0069 & 0 \\ -0.0069 & 0.99 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1.5 \\ 2 \\ 180 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ -0.4 \end{pmatrix}$$

$$= \begin{pmatrix} 1.4988 \\ 1.9665 \\ 179.6 \end{pmatrix}$$

In this problem, the velocities of the wheels are equal and opposite, so the robot rotates about its own axis and slightly moves off its base due to angular velocity.

b.3

l = 0.5 m $v_r = 0\ ms^{-1}$ $v_l = 0.2\ ms^{-1}$ t = 2s

$$\omega\delta t = -0.8$$

$$\begin{pmatrix} x_2 \\ y_2 \\ \theta_2 \end{pmatrix} = \begin{pmatrix} \cos(-0.8) & -\sin(-0.8) & 0 \\ \sin(-0.8) & \cos(-0.8) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1.4988 - 0 \\ 1.9665 - 0 \\ 179.6 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ -0.8 \end{pmatrix}$$

$$= \begin{pmatrix} 0.99 & 0.0139 & 0 \\ -0.0139 & 0.99 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1.4988 \\ 1.9665 \\ 179.6 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ -0.8 \end{pmatrix}$$

$$= \begin{pmatrix} 1.5111 \\ 1.9260 \\ 178.8 \end{pmatrix}$$

In this problem, the velocities of the wheels are different so, the robot moves pivoted about the slower wheel with the resultant velocity.

5.

$$\begin{pmatrix} x_t \\ y_t \\ \theta_t \end{pmatrix} = \begin{pmatrix} \delta s\,.\cos(\theta + \delta\theta) \\ \delta s\,.\sin(\theta + \delta\theta) \\ \delta\theta \end{pmatrix} + \begin{pmatrix} x_{t-1} \\ y_{t-1} \\ \theta_{t-1} \end{pmatrix}$$

$$\begin{pmatrix} \delta_t x \\ \delta_t y \\ \delta_t \theta \end{pmatrix} = \begin{pmatrix} \delta s\,.\cos(\theta + \delta\theta) \\ \delta s\,.\sin(\theta + \delta\theta) \\ \delta\theta \end{pmatrix}$$

$$\delta_t x = \delta s\,.\cos(\theta + \delta\theta)$$

$$\delta_t y = \delta s\,.\sin(\theta + \delta\theta)$$

$$\delta_t \theta = \delta\theta$$

$$\delta s = (\delta s_{\,r} - \delta s_{\,l})/2$$

$$\delta\theta = (\delta s_{\,r} - \delta s_{\,l})/b$$

$\delta s_{\,r} - distance\ traavelled\ by\ the\ right\ wheel$

$\delta s_{\,l} - distance\ travelled\ by\ the\ left\ wheel$

$b - distance\ between\ the\ wheels\ of\ the\ differential\ drive\ robot$

[4, 5]

References:

[1] J. Borenstein, Liqiang Feng "Measurement and correction of systematic odometry errors in mobile robots," *IEEE Transactions on Robotics and Automation,* pp. 869-880, 1996.
[2] B. G. Morgan Quigley, and William D. Smart, *Programming Robots with ROS*. 2015.
[3] T. Hellström, "Kinematics Equations for Differential Drive and Articulated Steering "*,* Available: http://www8.cs.umu.se/kurser/5DV122/HT13/material/Hellstrom-ForwardKinematics.pdf
[4] Roland Siegwart, Illah R Nourbaksh, *Introduction to Autonomous Mobile Robots*. MIT Press, 2004.
[5] D. R. Mahony, "Lecture Notes / slides," *ENGN 6627 Robotics,*