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	U 6366102		
For group assignments, list each student's ID			
Course Code	ENGN 6423		
Course Name	Robotics		
Assignment number	Lab 4 – Part 1		
Assignment Topic			
Lecturer	Dr. Viorella Ila / Dr. Rob Mahony		
Tutor			
Tutorial (day and time)			
Word count		Due Date	05/11/2018
Date Submitted	04/11/18	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;
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- ✓ 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;
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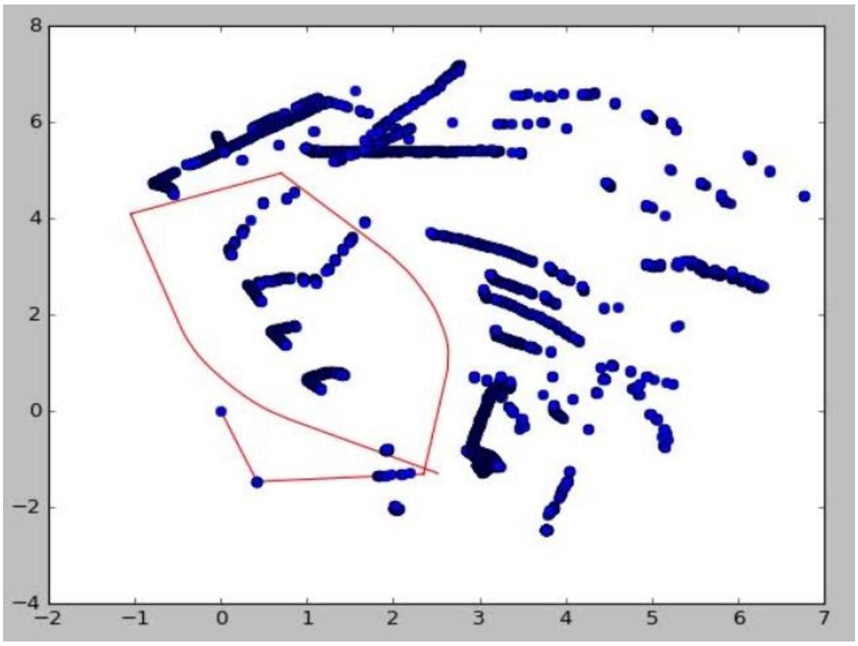
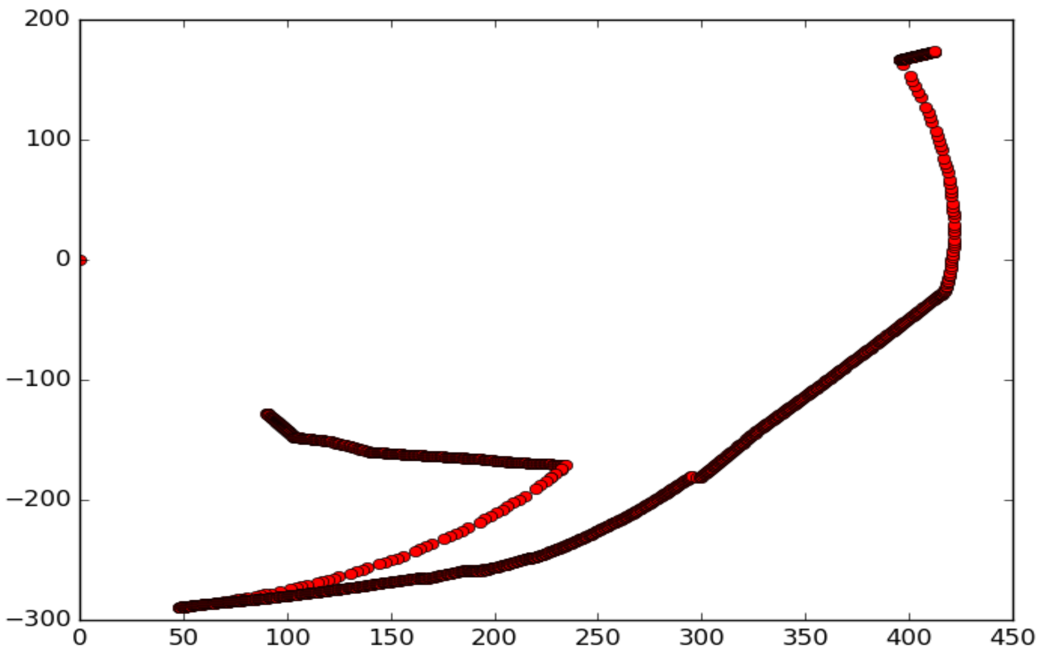
Task 1: Data Acquisition and Plotting

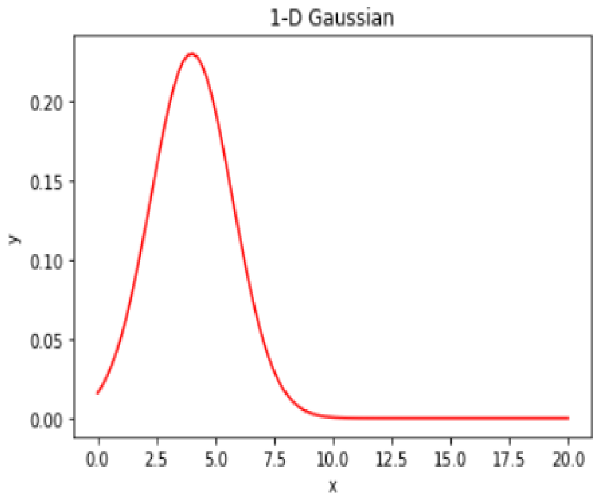


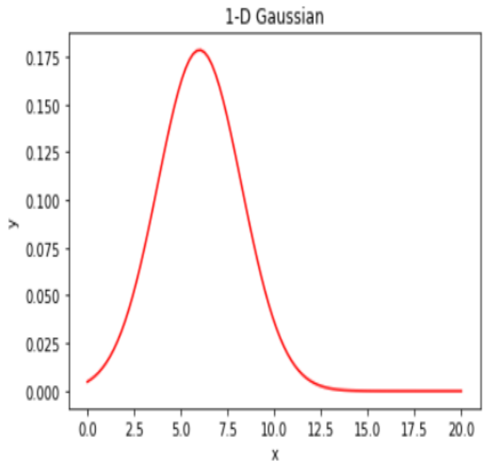
In plotting the rosbag[1, 2] files, the above is from sample 4 which shows the improper reading of the landmarks as it is plotted against the robot frame instead of the world frame. The trajectory followed by the robot is also shown in the graph.

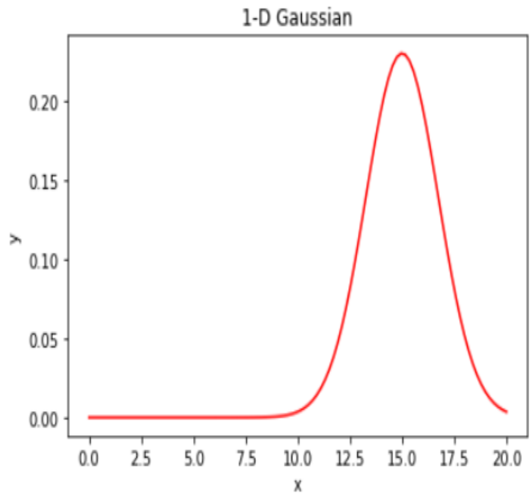


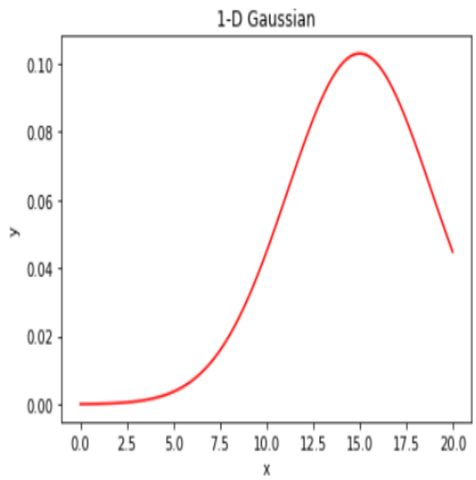
The above is from sample 1 which shows the trajectory followed by the robot is shown in the graph.

Task 2: State Estimation using Filtering

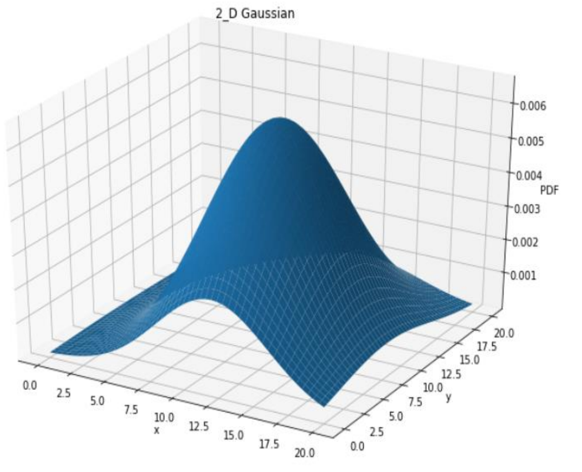


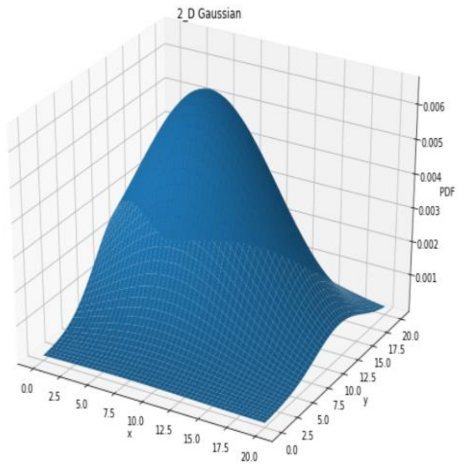


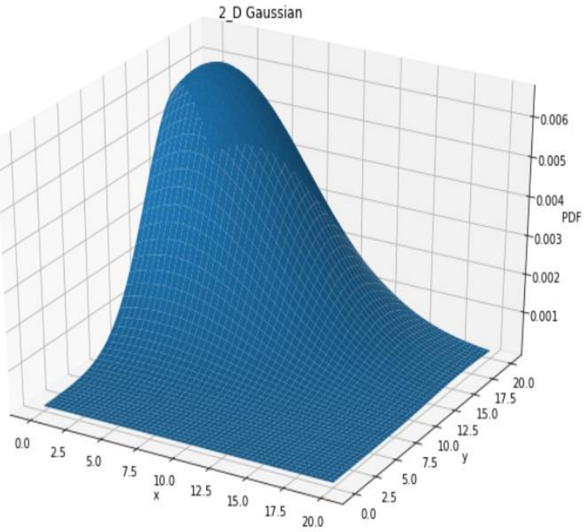


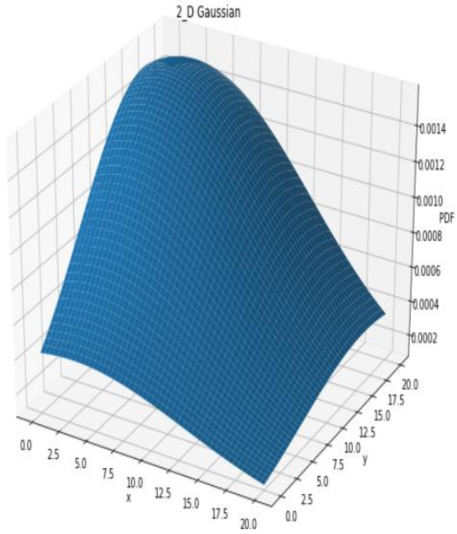


In one dimensional gaussian distribution changing the mean value shifted the distribution's peak value towards right/ left depending on the value of mean. Changing the values of variance narrowed/ widened on decreasing/ increasing the values respectively.

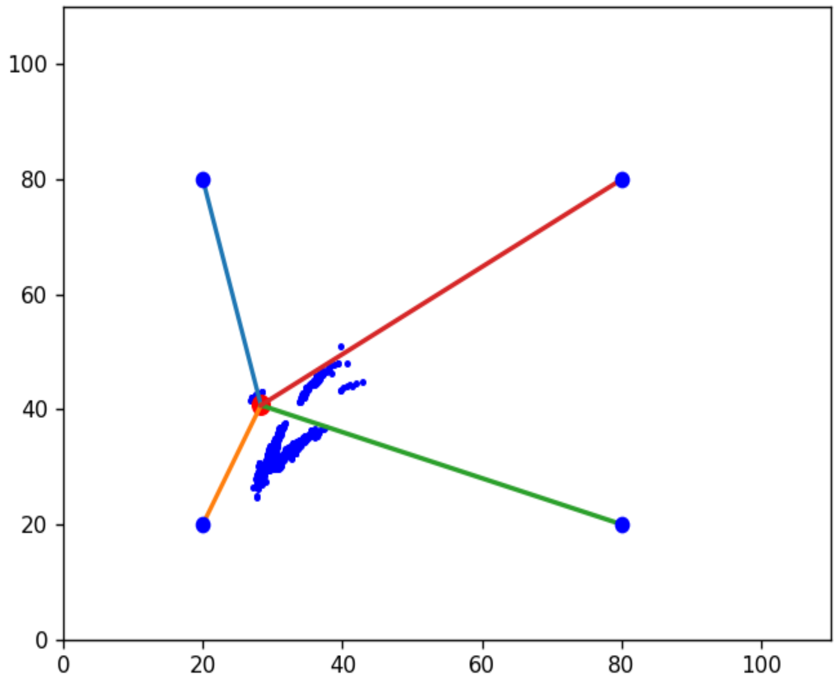




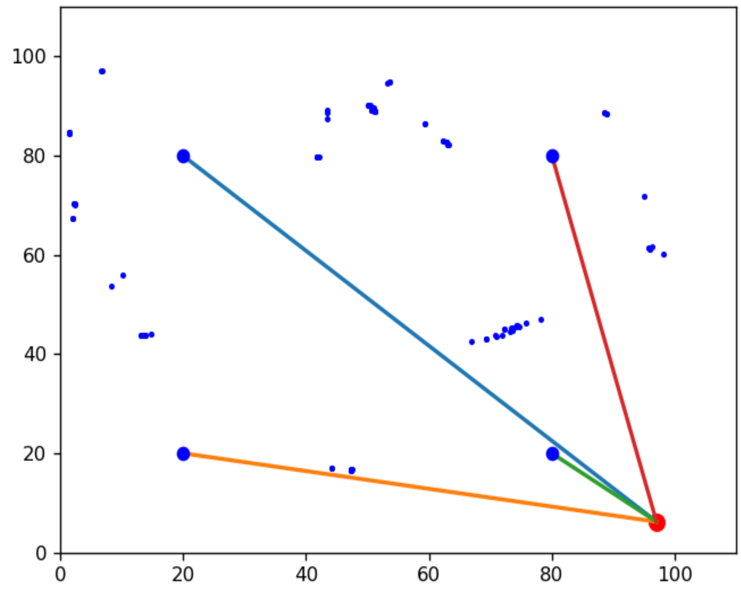




In two dimensional gaussian distribution changing the mean value shifted the distribution's peak value towards right/ left depending on the value of mean. Changing the values of variance narrowed/ widened the curve on decreasing/ increasing the values respectively.



When the particle filter for robot simulation was run using the default values, the particles almost converged at the right robot's position. In the above graph the forward_noise was increased which resulted in error in motion of the robot itself.



In analysing the particle filter increasing the sensor_noise and reducing N resulted in the above graph which clearly shows the scattered nature of the particles and their struggle to converge in the right location of the robot which is primarily caused due to the sensor noise. Through this analysis I was able to clearly understand the working nature of the particle filters in which initial scatter of the particle and number of particles play a predominant role in the convergence.

In practical world, the noise parameters can be improved by placing more reliable sensors on the robot or computing the location of the robot through readings from a number of sensors.

Question 1:

Bayesian formula:

Bayesian formula is given by the equation,

P(A|B) = P(B|A) P(A) / P(B) [3]

where P(A|B) is the conditional probability of occurrence of event A given that B is true

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P(A) is the probability of occurrence of event A

P(B) is the probability of occurrence of event B (not equal to zero)

Total Probability theorem:

Given n mutually exclusive events A_1, A_2 …. A_n whose probability sums to unity then

$$P(B) = P(B|A_1) * P(A_1) + P(B|A_2) * P(A_2) + \ldots + P(B|A_n) * P(A_n) \text{ [3]}$$

where B is an arbitrary event and $P(B|A_i)$ is the conditional probability of B given A_i.

Markov Assumption:

The assumption states that in any environment that is to be mapped, the robot's location is the only state in the environment that can affect the sensor readings of the robot. i.e., the environment must not include dynamic moving objects. [3]

Simultaneous Localisation and Mapping:

Simultaneous Localisation and Mapping is defined as the process of estimation of the robot's pose and mapping the environment at the same time.

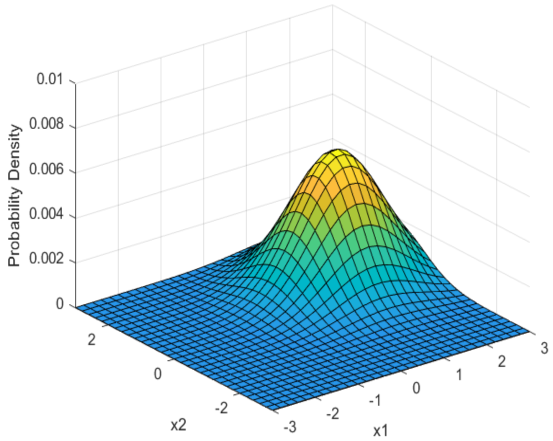
Multivariate distribution:

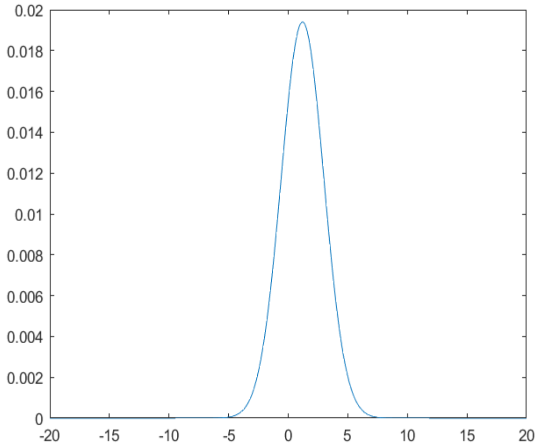
Multivariate normal distribution is given by

$$p(x) = \frac{1}{\sqrt{\det(2\pi\Sigma)}} \exp\ ((-1/2) * (x-\mu)^T \Sigma^{-1} (x-\mu)) \text{ [3, 4]}$$

where μ is the mean of the distribution, Σ is the covariance which gives the relationships between other variables and the considered variable.

Question 2:





The above two curves are the distribution of prior in both one dimensional and two - dimensional cases given.

Derivation of weighted sum of two normal distributions[4]

Assuming the variables X and Y are independent,

$$X \sim N(u_1, s_1) \quad Y \sim N(u_2, s_2)$$

$$Z = w_1 * X + w_2 * Y$$

$$w_1 * f_x(x) = \frac{w_1}{\sqrt{2\pi}s_1} e^{\frac{-(x-u_1)^2}{2{s_1}^2}}$$

$$w_2 * f_y(y) = \frac{w_2}{\sqrt{2\pi}s_2} e^{\frac{-(y-u_2)^2}{2{s_2}^2}}$$

$$f_z(x) = \int_{-\infty}^{\infty} \frac{w_2}{\sqrt{2\pi}s_2} e^{\frac{-(y-u_2)^2}{2{s_2}^2}} - \frac{w_1}{\sqrt{2\pi}s_1} e^{\frac{-(x-u_1)^2}{2{s_1}^2}} dx$$

$$= w_1 w_2 \int_{-\infty}^{\infty} \frac{1}{\sqrt{2\pi}\sqrt{2\pi}\, s_1 s_2} e^{\frac{-(s_1^2(\frac{z-w_1 x}{w_2}-u_2)-\, s_2^2(x-u_1)^2)}{2{s_1}^2{s_2}^2}} dx$$

$$= w_1 w_2 \int_{-\infty}^{\infty} \frac{1}{\sqrt{2\pi}\sqrt{2\pi}\, s_1 s_2} e^{-\frac{-\left(s_1^2\left(\left(\frac{z}{w_2}\right)^2+\left(\frac{w_1}{w_2}x\right)^2+u_2^2-2\frac{w_1}{w_2}xz-\frac{2zu_2}{w_2}+\frac{2w_1 x\, u_2}{w_2}\right)+s_2^2\,(x^2+u_1^2-2xu_1)\right)}{2\, s_2^2 s_1^2}} dx$$

$$= w_1 w_2 \int_{-\infty}^{\infty} \frac{1}{\sqrt{2\pi}\sqrt{2\pi}\, s_1 s_2} e^{-\frac{-\left(\left(s_1^2\frac{w_1^2}{w_2^2}+s_2^2\right)x^2-2s_1^2\left(\left(\frac{2zw_1}{w_2}-\frac{2w_1u_1}{w_2}\right)+2u_1s_2^2\right)+s_1^2\left(\frac{z^2}{w_2^2}+u_2^2-\frac{2zu_2}{w_2}\right)+s_2^2u_1^2\right)}{2\, s_2^2 s_1^2}} dx$$

$$= w_1 w_2 \int_{-\infty}^{\infty} \frac{1}{\sqrt{2\pi} s_3 \sqrt{2\pi}\ \frac{s_1 s_2}{s_3}}\ e^{\frac{-\left(x^2 - \left(2x \frac{s_1^2 (x-u_2)+s_2^2 u_1}{s_3^2} \right) + \left(\frac{s_1^2 \left(z^2+u_2^2-2zu_2\right)+s_2^2 u_1^2}{s_3^2} \right) \right)}{2\left(\frac{s_1 s_2}{s_3}\right)^2}}\ dx$$

u1 – mean of X distribution

u2 – mean of Y distribution

s1 – variance of X distribution

s2 – variance of Y distribution

s3 – variance of Z distribution

References

[1] *ROS Documentation*.

[2] B. G. Morgan Quigley, and William D. Smart, *Programming Robots with ROS*. 2015.

[3] S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics*. MIT Press, 2005.

[4] Rob, Mahony, Viorella, Ila, "Lecture Notes / slides," *ENGN 6627 Robotics*,