Question 3.

Assume that you are working on the development of a self-driving car (Fig. Q3) that uses a particle filter for localization. The car is equipped with a GPS sensor, a LiDAR sensor, an IMU sensor, and wheel encoders.

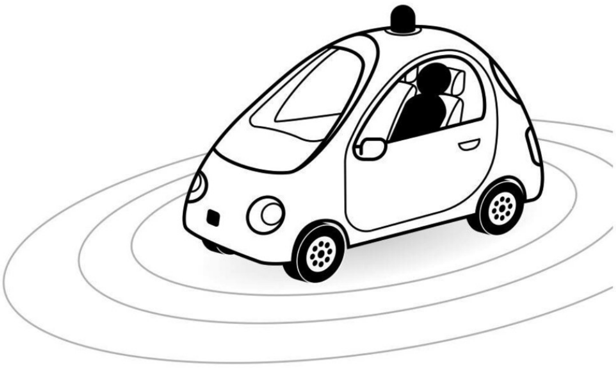

Figure Q3: Prospective self-driving car

(a) Discuss the role of resampling in a particle filter. Why is it necessary? [5 marks]

(b) Describe how you would initialize the particle filter for localization of the self-driving car. Assuming a 2D setting, specify the state variables you would use and the initial distribution of particles. [5 marks]

(c) Consider a simplified scenario where your self-driving car is localized in a 1D environment. You have four (4) particles with positions $p_1 = 2.0$, $p_2 = 3.5$, $p_3 = 4.0$, and $p_4 = 5.5$. The LiDAR sensor reports a measurement of 4.2 with 0 mean and 0.5 standard deviation Gaussian noise. Calculate the weights of each particle using a Gaussian likelihood model. Normalize the weights.
Hint: The likelihood model $p(z|x)$ should compare the actual measurement (z) to predicted mean measurement given a certain position (x) using a Gaussian distribution. [8 marks]

(d) Using the weights calculated in (c), compute the effective number of particles $\hat{N}_{eff}$. Comment on the degeneracy of the filter. [3 marks]

(e) Imagine your self-driving car is moving in an urban environment where GPS signals are occasionally lost due to tall buildings. How would the particle filter handle this situation to maintain accurate localization? [4 marks]

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