

Question 1.

- (a) Explain why a probabilistic approach is needed in the design and implementation of autonomous systems. [5 marks]
- (b) An autonomous robot system is utilized to clean the windows of an office environment. The windows have two conditions (states x_t): clean and unclean. There are no workers in the office to manually clean the windows, and the job is totally done using the above cleaning robot. When the robot approaches a particular window it has no prior knowledge about the condition of it. However, the robot has been programmed to believe that any window is in a clean state with only a prior probability of 0.37 when it is approached.

The windows are cleaned by a cleaning tool, which is not 100% reliable, attached at the end of the robotic arm. Note that the cleaning tool may also introduce dirt to the window due to the tool not being properly cleaned after each cleaning. The following probabilities for the cleaning action (u_t) are provided:

$$P(x_t = \text{is_clean} | x_{t-1} = \text{is_clean}, u_t = \text{clean}) = 0.92$$

$$P(x_t = \text{is_clean} | x_{t-1} = \text{is_unclean}, u_t = \text{clean}) = 0.81$$

The robot uses its camera sensor to identify the condition of the window, and the following probabilities regarding the camera observations (z_t) are provided:

$$P(z_t = \text{sense_clean} | x_t = \text{is_clean}) = 0.68$$

$$P(z_t = \text{sense_clean} | x_t = \text{is_unclean}) = 0.23$$

- i. Is the camera sensing system more capable of sensing a clean window or an unclean window? Justify your answer. [4 marks]
- ii. Suppose at time instance T the robot performs cleaning of the approached window, takes a camera observation and senses an unclean window. Bel and \overline{Bel} have their usual meanings.
 - α) Find $\overline{Bel}(x_T = \text{is_clean})$. [4 marks]
 - β) Find $Bel(x_T = \text{is_clean})$ after incorporating the observation. [8 marks]
 - γ) Will the robot perform cleaning again on the window based on the above state estimation? Justify your answer. [4 marks]

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