Homework 2: Please work on the homework independently. It is due Tuesday, Sept 24th, in class.

A robot has a camera that detects obstacles with 80% probability (when there is an obstacle), a single bump sensor that detects imminent collisions (with an obstacle) with 98% probability (when an obstacle is 1 inch away), and a single cliff sensor that detects imminent falls off a cliff with 99% probability (when the cliff is 1 inch away). Note that, the camera cannot detect cliffs. The maximum delay between obstacle/cliff detection and a complete stop is 0.2 second. Safety requires that collisions and falls be avoided. Other than that, the faster the robot is done with the mission, the better.

1. Given the above safety and performance requirements, which of the following speeds would you recommend to run the robot at (circle the best answer)? **(1 point)**

- **a)** 2.4 inches/second
- **b)** 5 inches/second
- **c)** 12 inches/second
- **d)** 25 inches/second
- **e)** Solutions (a), (b) and (c) are equally good.

2. What do we mean by well-formed dependencies in a system? **(2 points)**

A more reliable component can use but may not depend on a less reliable one.

3. Assume that the aforementioned system is designed to use both the camera and the bump sensor to detect obstacles and to use the cliff sensor to detect cliffs. Further, assume that the robot stops in one of two cases: (i) when *both* the camera and the bump sensor indicate an obstacle, or (ii) when the cliff sensor indicates a cliff. Does this system have well-formed dependencies? (Yes/No) **(1 point)**

No.

4. If the answer to part 3 is yes, explain what dependencies are involved. You can list them, one per line, in the format: "*this* depends on *that*". If the answer to part 3 is no, what do you recommend to change so that dependencies are well-formed and safety maximized? **(2 points)**

Condition (i) should be: "(i) when *either* the camera *or* the bump sensor indicates an obstacle"

5. Now assume the logic is changed so that the robot stops if (i) *either* the camera or the bump sensor indicate an obstacle, or (ii) when the cliff sensor indicates a cliff. Assuming the robot is moving at a safe speed, what is the probability of collisions? **(1 point)**

P (collision | obstacle) = P (Camera miss | obstacle) P (bump miss | obstacle)

$= (1 – 0.8)(1 – 0.98) = 0.004$

P (collision) = P (collision | obstacle) P (obstacle) = 0.004 * 0.1 (see Piazza) = 0.0004

6. In the robot in part 5 above, assume that the camera does not have false positives (i.e., never indicates an obstacle when there is none) and assume that the bump sensor has a 2% chance of indicating a bump when in fact there is no obstacle. What is the probability that an obstacle is in the way when the bump sensor indicates an obstacle, but the camera does not? **(3 points)**

Let "O" denote "Obstacle", "B" denote bump sensor detection, and "C" denote camera detection. Also, let "¬" denote "not". Then:

$P (O|B,\neg C) = P (B,\neg C|O) P (O) / P (B,\neg C)$, where:

$P (B,\neg C) = P (B,\neg C|O) P(O) + P (B,\neg C|\neg O) P (\neg O)$

Thus:

$P (O|B,\neg C) = P (B|O) P (\neg C|O) P (O) / (P (B|O) P (\neg C|O) P (O) + P (B|\neg O) P (\neg C|\neg O) P (\neg O))$

$= 0.98 * 0.2 * 0.1 / (0.98 * 0.2 * 0.1 + 0.02 * 1 * 0.9) = 0.5213$