4.a

(a) **[4 points (Written)]** Suppose we have $K = 2$ cars and one time step $T = 1$. Write an expression for the conditional distribution $\mathbb{P}(C_{11}, C_{12} \mid E_1 = e_1)$ as a function of the PDF of a Gaussian $p_{\mathcal{N}}(v; \mu, \sigma^2)$ and the prior probability $p(c_{11})$ and $p(c_{12})$ over car locations. Your final answer should not contain variables d_{11}, d_{12}.

Remember that $p_{\mathcal{N}}(v; \mu, \sigma^2)$ is the probability of a random variable, v, in a Gaussian distribution with mean μ and standard deviation σ.

Hint: for $K = 1$, the answer would be

$$\mathbb{P}(C_{11} = c_{11} \mid E_1 = e_1) \propto p(c_{11}) p_{\mathcal{N}}(e_{11}; \|a_1 - c_{11}\|, \sigma^2).$$

where a_t is the position of the car at time t. You might find it useful to draw the Bayesian network and think about the distribution of E_t given $D_{t1}, \ldots, D_{tK}$.

P(C11, C12 | E1 = e1) ∝ p(C11) * p(C12 | C11, E1 = e1) * p(E1 | C11, C12)

- **p(C11)**: This is the prior probability of the first car being at location C11.
- **p(C12 | C11, E1 = e1)**: This is the conditional probability of the second car being at location C12 given that the first car is at C11 and the observed distance measurement is e1.
- **p(E1 | C11, C12)**: This is the probability of observing the distance measurement e1 given that the first car is at C11 and the second car is at C12.

4.b

[3 points (Written)] Assuming the prior $p(c_{1i})$ of where the cars start out is the same for all i (i.e. for all K cars), show that the number of assignments for all K cars $(c_{11}, \ldots, c_{1K})$ that obtain the maximum value of $\mathbb{P}(C_{11} = c_{11}, \ldots, C_{1K} = c_{1K} \mid E_1 = e_1)$ is at least $K!$.

You can also assume that the car locations that maximize the probability above are unique ($C_{1i} \neq c_{1j}$ for all $i \neq j$).

Note: you don't need to produce a complicated proof for this question. It is acceptable to provide a clear explanation based on your intuitive understanding of the scenario.

If the a priori probability $p(c1i)$ of where the cars will start is the same for all i (that is, all K cars), this means that initially we have no reason to prefer a particular place for any of the cars. the others. In other words, **every location is equally possible for every car.**

Now, let us consider the situation where we want to find the functions assigned to all vehicles (n11,…,c1K) that obtain the maximum value of *P*(*C*11=*c*11,…,*C*1*K*=*c*1*K* | *E*1=*e*1).is not considered. Because the regions that give rise to this probability are different, we essentially look for different regions of ξK that maximize the probability of the observed distances.

Since any position on any vehicle can be one of the initial positions, any position assignment will have the same initial probability if we try to represent the highest possible value given the observed distance $e1$. Therefore, the number of instructions that take the maximum possible value is at least $K!$.

This is because of a $K!$ acceptable capabilities at different locations, and each of these decisions represents a specific vehicle location assignment. Since every permutation can exist to first order, there will be at least $K!$ The task is to reach the maximum possible.

4.c

[2 points (Written)] For general K, what is the treewidth corresponding to the posterior distribution over all K car locations at all T time steps conditioned on all the sensor readings:

$$\mathbb{P}(C_{11} = c_{11}, \dots, C_{1K} = c_{1K}, \dots, C_{T1} = c_{T1}, \dots, C_{TK} = c_{TK} \mid E_1 = e_1, \dots, E_T = e_T)?$$

Briefly justify your answer.

For reference, the treewidth of a factor graph is defined as the maximum arity (number of variables that a factor depends on) of any factor created by variable elimination under the best variable elimination ordering. You can find further information, along with an example, that may be relevant to this problem here.

Note: the conditioning is already done, so the only factors remaining are for C_{ti} variables.

The treewidth is equal to the number of time steps T because each car location at each time step only depends on the previous time step, creating a chain structure.

5.a

5. **Ethics in Advanced Technologies**

(a) **[4 points (Written)]** You are in charge of public policy for an autonomous vehicle company headquartered in California. Your engineering team is making progress in designing a fully automated vehicle and would like to test it on real roadways. California would require that you apply for autonomous vehicle testing permits and meet regulatory standards designed to protect the safety of other motorists and pedestrians. Given these regulations, testing your vehicles in California secretly without a permit would be illegal. The Governor of Arizona has reached out to offer your company testing in the state without restrictions. Doing so would allow you to test more quickly and without making any changes to your vehicles[1]. On the other hand, testing in Arizona could be considered "ethics dumping," namely "doing research deemed unethical in a scientist's home country in a country or region with laxer ethical rules" and regulations[2].

Would testing in Arizona be "ethics dumping"? Be sure to explain why you think it is or isn't. Given your answer to this question and other factors you consider to be relevant, should you perform your tests in Arizona or comply with Californian standards? Justify your answer with a reason as to why.

What we expect: In 3-6 sentences, we expect:

- a yes or no answer to the ethics dumping question
- an explanation of why it is or isn't ethics dumping given the definition above
- a yes or no answer to whether the tests should be done in Arizona or California
- an explanation that justifies why the tests should be done in Arizona or California¡

Ethics Dumping: Yes, testing in Arizona would be considered "ethics dumping."

Explanation:

Testing in Arizona to evade California's safety regulations qualifies as ethics dumping since it involves conducting research that violates ethical standards in one's home jurisdiction by exploiting laxer regulations elsewhere. Therefore, to uphold ethical standards and prioritize public safety, it's advisable to comply with California's regulations rather than resorting to testing in Arizona.

Testing Location: Yes, The tests should be conducted in California.

Justification:

Focusing on safety: California's regulations prioritize the safety of all road users through rigorous testing protocols. Disregarding these regulations in favor of testing in Arizona undermines safety and ethical considerations. Respecting regulatory frameworks: Ethical development entails honoring the legal and ethical guidelines set forth in the company's home jurisdiction.

5.b

(b) [**4 points (Written)**] Dual-use technologies are technologies that serve two purposes, typically a military and a civilian purpose. Researchers developing dual-use technologies face a moral dilemma: though they may intend to improve only the peaceful use of the technology, any improvements they make aid others who use the technology in war or in non-state attacks or killings. Tracking of the kind developed in this assignment can be used in self-driving cars or in autonomous weapons systems, such as lethal drones that track people to kill them.

Imagine a researcher who develops a dual-use technology despite knowing about the lethal secondary use of the technology and despite the researcher considering this secondary use unethical. Would the researcher be partially morally responsible for improvements to the lethal use of the technology that result from their discoveries? If not, give one reason why not. If so, explain why they are partially responsible and explain what action(s) the researcher should take to address this (choosing another line of research, building a safeguard, or other)?

What we expect: A 3-6 sentence response that

- answers yes or no to whether the researcher would be partially morally responsible
- provides a reason why they would or would not be partially morally responsible
- if yes, describes an action they should take

- Yes, the researcher would be partially morally responsible.
- Reasoning: Despite not intending the lethal application, their awareness of the potential misuse and deliberate choice to continue research contributes to the harmful outcomes.
- Action: The researcher should advocate for safeguards or restrictions on the technology's use, possibly through public discourse, collaboration with policymakers, or the establishment of ethical guidelines to mitigate harm.