CS545–Introduction to Robotics

Catalogue of Questions for Final Exam

1. (6 Points) Robotics can be divided in (at least) two major classes: mobile robotics (=robots on wheels), and manipulator robotics (robot arms, robot legs, etc.). Give 3 reasons why these two areas largely focus on different research topics.

2. (4 Points) Give the Kalman update equations for the estimated state $\hat{\mathbf{x}}^n$ given the linear dynamical system $\mathbf{x}^n = \mathbf{A}\mathbf{x}^{n-1} + \mathbf{B}\mathbf{u}^{n-1}$, where we can only observe the state $\mathbf{y}^n = \mathbf{C}\mathbf{x}^n$. Explain each symbol that you introduce in your equations.

3. (8 Points) In a data filtering problem, you are faced with the decision whether to use a Kalman filter or a Particle Filter filter. Give two pros and cons for each of the two filters:

4. (8 Points) There are two major paradigms that can be used to derive equations of motion. Give the name of both paradigms. Provide one positive and one negative side of each paradigm. Which physical principle lies behind the derivation of each of the two paradigms.

5. (7 Points) Motion plans made in task space (Cartesian space) must be transformed to plans in actuator space (joint angles) . What is the generic name for this problem? Can it be solved? If yes, are there any problems in finding a solution to this problem? If no, why?

6. (4 Points) When developing a robot control law, one can choose the path of Optimal Control or the path of Control Theory. Give one reason (=keyword) for and against each of the approaches.

7. (4 Points) Briefly describe the relationship between state estimation approaches and their corresponding SLAM approaches.

8. (4 Points) As part of the homework assignment, you constructed a potential field over an entire map. Describe how a robot would use a potential field approach using only local sensing information.

9. (4 Points) For inverse kinematics, the pseudo inverse with Null-space optimization is a popular method. Provide the formula for the differential inverse kinematics with this method, and explain all terms in the formula.

10. (4 Points) Your friend is considering implementing differential inverse kinematics with a Jacobian transpose method and a pseudo-inverse method. Give two points in favor of each of these two methods.

11. (2 Points) What can be problematic when trying to transform task space (operational space) coordinates to joint space coordinates? Give at least two possible problems.

12. (2 Points) What is the role of the *belief state* when using POMDPs? How is the belief state calculated?

13. (2 Points) What is the role of exploration when using online adaptive methods? Briefly describe what may happen if exploration is not used.

14. (2 Points) Given the general linear dynamical system:
$x^{n+1} = ax^n + bu^n$
$y^n = cx^n$
where is first equation describes the system dynamics, and the second equation the observation equation. What is the Kalman Filter update equation for this system to estimate the state x^n?

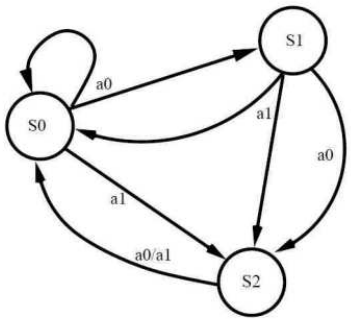
15. (2 Points) What is an Extended Kalman Filter?

16. (2 Points) Define the concept of *Partial Observability*. Why is it important in robot planning?

17. (4 Points) In the homework assignment, you implement Q-learning to learn control for the pole-cart problem. Describe the modifications you would make to use a model-based approach such as Dyna.

18. (4 Points) Briefly describe the relationship between MDPs and POMDPs. Describe a scenario where you would use each.

19. (6 Points) Perform one iteration of value iteration on the following MDP. Assume the value function is initialized to zeros. Show your work and report the resulting Q table and Value function.



$T(s, a_0, s')$		s'		
		s_0	s_1	s_2
s	s_0	0.2	0.8	0.0
	s_1	0.0	0.0	1.0
	s_2	1.0	0.0	0.0

$T(s, a_1, s')$		s'		
		s_0	s_1	s_2
s	s_0	0.0	0.0	1.0
	s_1	0.4	0.0	0.6
	s_2	1.0	0.0	0.0

	$R(s, a_0)$	$R(s, a_1)$
s_0	4	2
s_1	5	7
s_2	10	10