Problem Set 1 for ABE 598 Autonomous Decision Making in the Real World

Due on February 24, 2017

Total: 150 points
10 problems

Problems from book are marked with the name of the book's first author, show your work for all problems

1. Russell and Norvig 1.2 (10 points)
2. Russell and Norvig 1.14 (provide citations) (10 points)
3. Provide a formulation of the wolf, the sheep, the cabbage, and the astronaut problem discussed in class. What needs to be known (perceived)? what are the higher-level decisions to make? What control actions would be driven once the higher level decisions are made? (10 points)
4. Formulate the problem of a team of robots autonomously vacuuming a home in the least amount of time. What needs to be known (perceived)? what are the higher-level decisions to make? What control actions would be driven once the higher level decisions are made? (10 points)

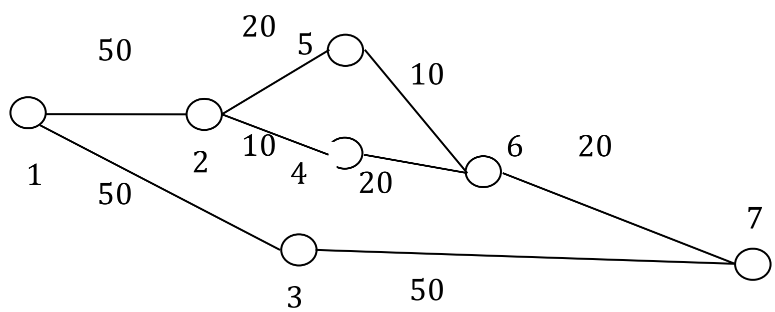
Problem 5: Prove that KL divergence is always non-negative. Hint: Use Jensen's inequality (10 points)

Problem 6: Derive the Kalman Filter from a Bayesian perspective, using the Chapman-Kolmogrov equation and Bayes law. Hint: You need the expressions for joint and marginal distribution of two Gaussian distributions. You can use Simmi Sarkka's slides. (10 points)

The next few problems in this problem set are computer implementation problems. You are free to use any programming language of your choice, including MATLAB. You will submit the code with your assignment. Your code will be graded on its style, commenting, and readability. You are suggested to use good programming techniques, such as writing functions for repeating tasks, indenting your code properly, and choosing most efficient operations (e.g. use matrix manipulations in MATLAB instead of for loops).

Problem 7 (20 points)

Implement breadth first and depth first search to find the optimal path from node 1 to node 7 in the following graph search problem



The numbers 1 to 7 denote the index of the vertex. The numbers on the edges denote the cost to traverse from one vertex to the other.
Present your answer as a sequence of vertices and the total cost of the entire transition.
What is the optimal sequence and cost? Does your algorithm achieve it?
Report the number of total computation time and calculations (you can count the number of times the search function was called).

Problem 8: (20 points)
Grid search
Consider a 5 by 5 grid world. We would like to find a path from one end of the grid to the other end, that is from location (1,1) to location (5,5). Implement the following algorithms to find this path:

1. Breadth first search
2. Depth first search

3. RRT
4. (RRT*, bonus 10 for implementing RRT*)

A matlab function called gridworld_HWproblem.m and gridworld_trans_HW.m have been added to Box. gridworld_HWproblem.m shows how the transition function gridworld_trans_HW.m can be used to generate state transitions in the gridworld domain when actions are taken.

Present your answer as a plot.
If optimality is defined as the least number of transitions required to reach the goal state, then what is *an* optimal path? Does your algorithm achieve it? Compare the performance in terms of time to solution and optimality of the solution for all the algorithms. Report the number of total computation time and calculations for each algorithm (you can count the number of times the search function was called).

Problem 9 (30)
Kalman Filter

Consider the following linear system with state x, input u, and output y

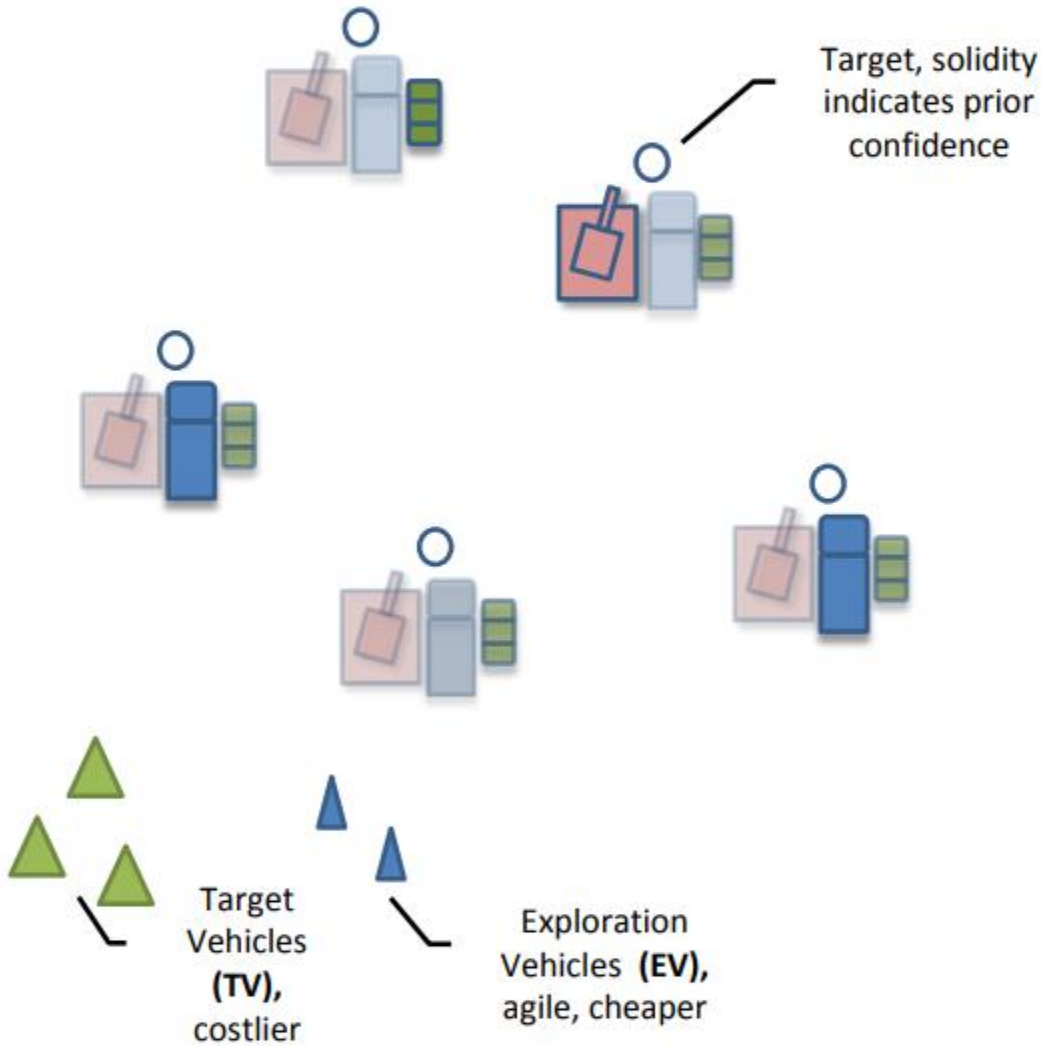
$$\dot{x} = \begin{bmatrix} -1 & -5 \\ 6 & -1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u + \zeta$$
$$y = [0 \quad 1]x + \omega$$

where ζ is two dimensional zero mean Gaussian process noise with covariance 0.01, and ω is zero mean measurement noise with covariance 0.1.

A file called KF_problem.m has been uploaded. It simulates the output of the above system with a time-step of 0.01 seconds for 10 seconds for a sinusoidal system input u. The variable X_HAT_STORE in that file can contain your Kalman filter output, however, right now it records zero.

Design a Kalman filter state observer for estimating x. Compare the state estimates from your filter with the actual state.

Problem 10 (20 points):
For the following problem, it is highly recommended that calculations use fractions and not decimals. Consider the Value of Information task assignment problem, where we have 2 exploration vehicles. In the following scenario, we have 5 targets whose probability mass functions (pmfs) are given in the below table.



Probability of Each Vehicle Category Prior to Observation

	P(Tank)	P(Car)	P(Bus)
Location 1	1/10	4/5	1/10
Location 2	4/5	1/20	3/20

Location 3	1/10	7/10	1/5
Location 4	1/3	1/3	1/3
Location 5	2/5	1/2	1/10

Calculate the entropy of each location and rank each location from highest entropy to the lowest entropy.

Suppose that you send the exploration vehicles to <u>only</u> the 2 locations with the highest entropy with respect to the pmf in the above table. **Calculate the Kullback-Leibler divergence between the 2 highest entropy locations using the appropriate pmfs from the below table as the models updated due to the observation of your 2 exploration vehicles.**

Probability of Each Vehicle Category After Observation

	P(Tank)	P(Car)	P(Bus)
Location 1	1	0	0
Location 2	99/100	1/200	1/200
Location 3	1/10	8/10	1/10
Location 4	1/2	1/2	0
Location 5	2/5	1/2	1/10

Bonus question: What additional pmf is needed to calculate the Mutual Information (Entropy Reduction)?