INTELLIGENT SYSTEMS QUALIFIER

Spring 2013

Each IS student has two specialty areas. Answer all 3 questions in each of your specialty areas.

You will be assigned an identifying number and are required to hand in printed or written copies of your answers with each page identified only by that number. This process enables us to grade your answers anonymously. You should NOT identify yourself explicitly by name on your answer sheets or implicitly by referring in the first person to your work (my project on ABC).

Please answer each question starting on a new page, with your answer following the text of the question.

Place any relevant references that you cite in an answer at the end of that answer, NOT in a separate section at the end of the whole exam.

If you have any questions or feel it necessary to make any assumptions in your answers, do not seek clarification from faculty or staff. Simply record your assumptions as part of your answer.

If one of your areas is **Perception**, answer the three questions below:

Perception #1

The Deformable Parts Model (Felzenschwalb et. al. PAMI) has become a standard approach for object detection and recognition, based on its success in recent years in the Pascal Visual Object Categorization competitions.

a) What are three of the key ideas that are the basis for this method? Describe how the method exploits each of these ideas.

b) What are the weaknesses of the DPM approach to detection and recognition? Give examples of two categories of objects which would be difficult to detect and recognize using this approach.

c) Recently deep learning methods have demonstrated impressive performance in the Pascal VOC challenge. Give one strength and one weakness of deep learning in comparison to DPM.

Perception #2

The Harris detector has deep roots in computer vision. Briefly describe it. How does it relate to the SIFT operator? What is specific to the Harris detector, that does not apply to SIFT. In recent times, we have seen other forms of detectors become popular, namely LoG (Laplacian of Gaussian), DoG (Difference of Gaussians) and DoH (Determinant of the Hessian). What are these and how do these address the issue of feature detection? Finally, as we move to video analysis, we have seen extensions of these feature detectors to the temporal. In brief, describe the concept of Space-Time Interest Points (STIPS) and how they are used. (Optional) Describe the limitations of STIPs.(NOTE: Please provide very brief answers to each of the questions. We are looking for synthesis of each of these methods. There is NO trick or hidden insight).

Perception #3

In many cases a mobile platform (car, plane, boat) is controlled by a human driver, and we can surmise he/she makes decisions about how to drive the vehicle based on the environment. Suppose you are given the problem of estimating the optimal state of the vehicle, using sensors like GPS, IMU, wheel-encoders and the like.

a) Exploratory: What are the ways one could take the human intent into consideration? What types of statistical inference methods are available to do so? What are the closest perception problems that you can think of that address similar questions?

b) Design: pick one of the answers from a) and create a rough outline of how you would go about implementing this. Pay attention to how this could be done efficiently, in real-time.

c) Evaluation: how would you evaluate the system? what metrics would you use? what datasets?

d) Dissemination: what would be an appropriate venue for this work? Who would be the target audience?

If one of your areas is **Planning & Search**, answer the three questions below:

Planning & Search #1

A common problem in sampling-based planning is that of narrow passages. It is highly unlikely that samples will be placed inside the narrow passages and therefore plans cannot be constructed even for rather simple environments.

1) Demonstrate an example of a problem with a narrow passage that would pose a challenge to an RRT planner. Draw, label it and demonstrate why the RRT would struggle to find a solution.

2) Present two distinct strategies for handling narrow passages. For each strategy explain why it might work well, its advantages and drawbacks. Consider the completeness and computational efficiency of your methods in as much depth as possible.

Planning & Search #2

Hierarchical Planning is re-emerging as a popular paradigm in fields ranging from classical planning to motion control. It is distinct from typical state-space planning which searches either from the start or goal state over possible actions.

1) Present a data structure and algorithm that could be used to implement hierarchical planning.

2) Describe at least two advantages of hierarchical planning over alternative methods. At least one of these advantages should clearly indicate that hierarchical planning is more expressive than state space planning.

3) For each of the two advantages provide an example that clearly demonstrates the theoretical and/or computational gains of this planning strategy over other alternatives.

Planning & Search #3

In robot planning we typically talk about RRT and PRM as two different strategies to build effective strategies for search. Explain the main differences between the two strategies for an environment as shown below.

```
+------------------------------+
|                              |
| * start                      |
|                              |
+--------------| |--------------+
|                              |
| x goal                       |
|                              |
+------------------------------+
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Explain the behavior of each of the two strategies. How would they perform compared to a heuristic such as D*? Characterize the types of environments that are well suited for each of the two techniques.

If one of your areas is **Machine Learning**, answer the three questions below:

Machine Learning #1

In American college football, there are roughly 100 teams, and each team plays roughly 12 games per season. In this setup, a matchup of two teams rarely occurs twice. Each game produces a numerical outcome (e.g., 45-28), and small point differentials generally indicate that the teams are closely matched.

a) Assume that you have the record of outcomes for 10 games per team. Using only the previous scores, design a method that will predict the outcome of the next game. Be sure to control for strength of schedule (so that teams will be penalized less for losing to strong opponents, and rewarded less for beating weak ones).

b) Assume that some teams will perform unusually well against others -- for example, southern teams might perform especially well against midwestern ones, although the relevant grouping need not be geographical and is not known in advance. Describe how you would model this, using either matrix/tensor factorization or a latent variable model. Can you see how to use data from previous seasons to improve this?

c) Assume that results from the beginning of each season become less relevant over time. Describe how you would add a temporal component to your model to improve accuracy.

Machine Learning #2

Markov Decision Processes are a well-studied mechanism for modeling decision processes, and have proven extremely successful. On the other hand, the MDP formalism focuses on the single agent case, thus avoiding several multi-agent problems or hiding complexity inside the transition model, making it difficult for an agent to act optimally under a variety of common conditions.

a) Formally define an extension of MDPs and reinforcement learning to the multi-agent case. What are the requirements of a policy in this case? How does the Bellman equation change, if at all?

b) What are some of the theoretical and computational problems that arise in your extension? Is this even a particular reasonable way to proceed?

c) Briefly propose some solutions to the problems you identify. Briefly compare and critique these solutions.

Machine Learning #3

Probabilistic Graphical Models (PGMs) are important tools for performing probabilistic inference and learning.

a) What are the differences between Bayesian networks and Markov networks? For each of these two types, give an example application. What is a latent variable? Why do we include them in models? What are the similarities and the differences between latent variables and model parameters? How can they both be inferred from data?

b) A basic issue in PGMs is the intractability of exact inference. What is the source of intractability? Give an example of a PGM for which inference is intractable. Give two algorithms for approximate inference in PGMs and briefly describe how they work. For each method, describe its advantages and disadvantages.

c) What is the difference between Bayesian learning and discriminative training? Give an example of each in the context of PGMs.

If one of your areas is **Robotics**, answer the three questions below:

Robotics #1

Consider deceptive behavior - nature is replete with examples of it: bluffing, lying, cheating just to name a few. These are evidenced in many cases by relatively simple animals (e.g., squirrels) all the way through humans. Deception confers advantages to the animal deceiver, often in terms of food gathering or mating, and in extreme cases it may be necessary for survival to outwit predators.

Now consider robots:

1) What would be a good example of a situation when a robot should use deceptive behaviors? Even if you find the concept objectionable (i.e., you view it as fundamentally morally wrong), nonetheless think about it in terms of when it might confer advantage to the robot. Describe the situation you chose in some detail. It can be for any kind of robot: from a vacuum cleaner to a humanoid and everything in between - but just pick one example and describe it clearly and show what advances are achieved and how.

2) There exist a range of robotic architectures from reactive to deliberative to hybrid, each with certain advantages that are suited for particular types of ecological niches and possessing various behavioral or planning competencies. Describe a robotic architecture and/or associated behaviors that could exhibit the deceptive behavior for the situation you described in (1). Explain how it would work in some detail focussing primarily on the deception aspects.

3) What kinds of metrics would you use to measure the effectiveness of this deceptive behavior? Outline a Human-Robot Interaction (HRI) experiment that would test the effectiveness of your architectural design in (2).

Robotics #2

In Simultaneous Localization and Mapping (SLAM) we can use a variety of different estimation techniques such as EKF, Particle Filters or a Graphical Model as a basis for the process. What are the main differences between the 3 techniques? Typical challenges for doing SLAM are

a) features with a poor signal to noise ratio,
b) handling of ambiguous data association,
c) non-linear process models,
d) introduction of topological constraints.

How can each of the challenges be addressed in each of the three techniques mentioned above?

Robotics #3

The Kinect is an amazing sensor, which is becoming very popular in robotics. One possible way in which to use it is for robot manipulation. Specifically, suppose you would like to use it to figure out how to optimally grasp an object.

a) The kinect is both RGB and Depth. What information does RGB provide? What does Depth provide? How do they compliment each other

b) How would you go about it when the kinect is statically mounted and you can only take one measurement? What would you estimate? How would you then grasp the object?

c) Now assume that you can move the kinect around and you can take (exactly) 3 measurements. How does the problem change? What is the optimal set of measurements? How would you compute this?

d) What changes if you can move the kinect around indefinitely long? Also discuss when would you stop sensing and start acting, and how that would be computed.

e) How would you learn from experience? Would anything change in the above story?
