INTELLIGENT SYSTEMS QUALIFIER

Spring 2015

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

You are working with the Wild Dolphin Project (WDP), which has 30 years of underwater video footage of wild Atlantic spotted dolphins. As calves, these dolphins do not have spots, but as they grow older, each dolphin gets a unique set of spots that can be used to identify them (see image). More spots are added slowly, over years, and the theory is that one can use the spot patterns to estimate how old an individual is, even if you only see it once.

The WDP would like

1. to create a database of all the unique individuals in their 30 years of video. For each individual, they wish to recover all the video snippets of that dolphin.
2. to create a model to describe the changes in spotting over time and an automatic method that can be used to determine the age of an unknown individual.

Your job is to create a system to help them with this task. Besides the obvious problem that the

dolphins are at various angles and distances from the camera, they also flex their bodies while they swim (turning, flipping their tail, etc.). As sunlight filters through the waves, patterns of light are projected on their bodies, interfering with the spot pattern. Also, the water can be at various levels of murkiness (see bottom image), which further complicates the issue. However, the WDP does have some annotations of their data, where their hour long videos are partially annotated with names they assign for dolphins they know well and see often (e.g. 0:45.14 Rosebud; 1:12.00 Little Gash). For these dolphins, they know their birth dates, and every piece of video footage has a date stamp.

Describe the system you would make to help the WDP with their two goals above. What computer vision algorithms would you use for goal 1? for goal 2? How would you determine how well your system was working for each of the goals?

Perception #2

Given an arbitrary stereo rig (i.e., not axis aligned and possibly with different intrinsic parameters), describe the steps that are needed to do dense stereo reconstruction with and without stereo rectification. For the case of stereo rectification, go into detail about the rectification process itself.

Perception #3

Shape from X

a) Shape extraction from images (and videos) has become increasingly ubiquitous. List some of the classic well-known methods for shape extraction methods (i.e., what is X in Shape from X). Provide 2 sentence (i.e., very short) descriptions of up to 6 different methods of Shape from X.

b) The recent development of depth (RGBD) cameras has created an alternative approach to extracting shape information from a scene. Describe the principles and basic mathematical model for a structured light ranging system such as the depth camera in the Kinect version one. How does the configuration of the light source and camera effect the results? Pick two of your Shape from X methods from part a) and compare and contrast them with the Kinect depth camera. How will the quality of the outputs differ between the three methods? Identify a scenario in which one of your Shape from X methods would be likely to produce a better result than the Kinect depth camera.

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

KBAI #1

Laird, Newell, & Rosenbloom proposed SOAR as an architecture for general intelligence. Over the decades, it has come to be used specifically by AI researchers, while ACT-R (among others) are more favored by cognitive psychologists. What features / mechanisms / affordances of SOAR have made it more appropriate for AI research? How well does it succeed at being an "architecture for general intelligence?" based on what criteria?

KBAI #2

One of the common forms of learning in humans is learning by imitation. As you may expect, AI too is very interested in learning by imitation. Consider, as an example, a robot watching a human pour coffee from a pot into a mug. The robot may then itself try to pour coffee. Later, if asked to pour tea from a jug into a cup, the robot may transfer its knowledge of pouring to the new situation.

Develop a computational model for case-based learning by imitation using the above scenario as an example. Show the computational processes and knowledge representations.

KBAI #3

The four stages of case-based reasoning are retrieve, reuse, revise, and retain. In case-based planning the goal is to construct a plan that transforms the world from one state into another in which a goal situation holds, using cases when possible.

Part A. Create an example planning problem using STRIPS or PDDL operators such that the planning problem can be solved by (1) retrieval alone, (2) retrieval plus reuse, and (3) retrieval, reuse, and revision.

Part B. Provide an analysis of the computational complexity of retrieval, reuse, and revision. You do not need to provide a proof or specific technique, but provide the written intuition behind your analysis. For example, is retrieval linear, polynomial, sub-linear, NP, or worse?

Part C: Many practical implementations of case-based planning do not implement the revise stage. Provide a reason why this might be the case. Refer to your analyses in Part B if and when appropriate.

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

Machine Learning #1

Unbalanced training data: A team of machine learning engineers is asked to build a classifier to detect a rare disease. In the training set, there are 100 times as many negatively-labeled instances as positively-labeled instances. The classifier will be evaluated on F-measure.

1. If the training data is linearly separable, is logistic regression guaranteed to find a separator that gives 100% F-measure, despite the class imbalance? (Assume you can iterate training to convergence.) Why or why not?
2. If the training data is linearly separable, is Naive Bayes guaranteed to find a separator that gives 100% F-measure? Why or why not?
3. Suppose the training data is not linearly separable. Why might the logistic regression solution, which maximizes conditional likelihood, not maximize the F-measure on the training data?
4. As a solution, Alice proposes to "upsample" the positive instances in the training data, with each positive instance is replicated 100 times, so that there are an equal number of positive and negative instances. Bob proposes a different solution: re-weighting the logistic regression objective so that the positively-labeled instances are 100 times as important. Write down a re-weighted training objective for logistic regression, which will give an identical result to Alice's "upsampling" solution.

Machine Learning #2

The Russell & Norvig text teaches how to make a game player assuming that the opponent plays perfectly. However, one could take a "big data" approach to the problem as well. What would a big data approach mean in this case? Please list some of the standard algorithms that assume perfect opponent play and contrast this approach to a big data approach. Describe the benefits and weakness of each approach and how they might be used to create fun AI opponents for gamers. Use a specific game to help make your ideas concrete.

Machine Learning #3

Joint probabilities

(a) Consider two discrete variables x and y, each having three possible states, $x, y \in \{0,1,2\}$. Construct a joint distribution p(x,y) over these variables, so that the following three properties hold:

1. There exists some unique $\hat{x}$ that maximizes the marginal p(x)
2. There exists some unique $\hat{y}$ that maximizes the marginal p(y)

3. The joint probability p($\hat{x}$, $\hat{y}$) = 0.

In addition to writing out the probability table for the joint distribution, write the expressions for the marginal probabilities.

(b) Note that in part (a), there were three possible states for x and y. Can this same problem be posed with only two states? If so, show how. If not, explain why not.

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

Robotics #1

Rogue Access Point Mapping:
We're designing a robotic system to patrol a large building and localize rogue access points. Rogue access points are access points users maybe setting up to facilitate logging on the corporate network with their mobile device. For simplicity, we consider a single floor.

a) To localize the access points, the robot patroller will first have to localize itself. After specifying the choice of sensors to achieve the task, discuss what solutions would be suitable to implement a localization layer, and which one you would chose.

b) To provide guarantees that all access points have been identified, we need to implement an exploration and coverage strategy. Assuming a static environment and static access points, discuss possible solutions, and, if applicable, their consequence in terms of map representation choice.

c) The exploration strategy above will probably require a planning layer. Assuming the robot patroller is a differential robot, discuss what solutions would be available for this layer and which one you would chose.

d) How is this task different from a autonomous vacuum cleaner? Could we imagine combining the two behaviors?

Robotics #2

Over US$1,000,000,000,000 worth of goods are picked from 100,000 warehouses worldwide. 80% of those items are picked by hand. Here is a video on a particular type of order picking (http://youtu.be/aJA-YFALAW8) typical of automobile manufacturers. You are starting a 10-year national initiative to solve the problem shown in the video using a humanoid robot (many small hand-sized parts being picked from many different bins and being placed into one of a few bins). Detail the problems involved, the methods you will use to solve those problems, and the metrics and experiments you will use to determine your level of success each year of the program.

Robotics #3

You have to develop a learning controller for a (physical) soccer-playing robot. The task and setup are as follows: The robot has a differential drive motion platform with sensors mounted on top. The sensor field of view is limited to 180 degrees. The robot can sense the angular direction and approximate distance to both the ball and the goal, assuming they are within the finite field of view of the sensing system. The controller can drive the left and right drive wheels independently. Every time the robot scores a goal, a new ball is dropped randomly on the (enclosed) field. The goal of the robot is to score as many goals possible in 10 minutes. The robot is going to be trained for some fixed period of time (say 3 days).

You must build a learning controller to enable the robot to solve this task. Explain how your learner would would work. (Be as specific as possible.) What would your states and actions be and why? Explain how your controller addresses the following issues: Is it able (or not) to predict the movement of the ball with certainty (i.e., the ball might move away from the robot when pushed); What is the size of the state space; How long it would take to train the robot; Does the time horizon of 10 minutes matter? Why or why not?

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

Cognitive Science #1

In the introduction to his book "The Emotion Machine" Marvin Minsky writes (see http://web.media.mit.edu/~minsky/ Introduction.html):

"So naturally, psychologists tried to imitate physicists – by searching for compact sets of laws to explain what happens inside our brains. However, this book will argue that this quest will fail because no simple such set of laws exists … Once we recognize that our brains contain such complicated machinery, this suggests that we need to do the opposite of what those physicists did: instead of searching for simple explanations, we need to find more complicated ways to explain our most familiar mental events."

You don't need to read Minsky's book or even the introduction to answer this question. The above snippet is all you need here.

(a) Give an example of an universal law or principle from cognitive science. Please be specific: When I ask for an example, I am asking for details of the knowledge representation and the reasoning method.

(b) Give an example of multiple, specialized abilities (or agencies) cooperating to address a complex problem. Again, be specific. Give the architecture, for example.

(c) Given these examples, do you agree or disagree with Minsky?

Cognitive Science #2

Barsalou claims that perceptual symbols are modal and analogical. They are modal because they are represented in the same systems as the perceptual states that produced them. They are analogical because they are modal; the structure of a perceptual symbol corresponds to the perceptual state that produced it. Analogical reasoning, the identification of analogical concepts, has mostly been researched using amodal representations. Explain how perceptual symbols can be used for analogical reasoning; i.e. explain how perceptual symbol systems can determine whether two concepts are analogous. Be as precise as possible, making reference to connectionist perceptual states and and simulators when necessary. Alternatively, explain why perceptual symbols cannot be used for analogical reasoning.
(cognitive science continues next page)

Cognitive Science #3

A worldwide debate is going on now regarding the use of lethal force by robotic systems. One of the most serious points of contention is regarding the assessment of proportionality (i.e., using the right level of force for a particular military situation and no more).

Human commanders have traditionally done this by using their own experience to guide their judgment based on past circumstances. Some argue that no machine can ever replicate this ability. But we know that there are algorithms that can learn from experience, case-based reasoning being one of them.

1) Can you explain the underlying processes by which a human might use their intuition and past experience to guide the application of force in novel situations?

2) Do you think it is possible to automate this process or is there something that is uniquely human that prevents this type of judgment from being automated? (the question here is not whether it should or shouldn't be done, just whether or not it is possible).

3) If you were to try and design a case-based reasoning (CBR) system to do this, explain how you might capture knowledge from experienced commanders and use it in future circumstances? Show an architecture that might be capable of so doing.

4) Apart from the ethical considerations, is there anything that makes this CBR-proportionality system fundamentally different than a medical diagnosis or legal CBR system?