COMPSCI 570	**Instructor:** Ronald Parr
Homework 3	**Due:** Wednesday, March 24, 2021

Note: There are 4 questions, each with multiple parts. Each question starts on a new page.

1 Logic (40 points)

Consider the following set of facts:

1. All sheep either (have a mother and a father) or are a clone. (Note that this is an exclusive or, not inclusive or.)
2. Daisy is a sheep and is not a clone.
3. Dolly is a sheep and does not have a father.

(The name Dolly was chosen because the first cloned mammal was a sheep named Dolly.)

1.1 First Order Logic Conversion (10 points)

Write the above expressions in first order logic. You should have unary predicates called *sheep* and *clone*, and binary predicates called *mother* and *father*. To keep things simple, we are not requiring that the parents of sheep are also sheep.

1.2 CNF (10 points)

Convert your answers from the previous part to CNF.

For the two parts below, we suggest you use the following format to make your answers easier to type up: Rather than using a resolution tree of the form shown in class, number the statements in your answer to the preceding part, then add new, numbered statements using the following example style:

n: $(P(b) \vee Q(c))$ by resolving 3 with 4, substituting b for X.

Thus, your answer will be a list of numbered conclusions that should end with nil (for proof by refutation).

1.3 Resolution Proof I (10 points)

Provide a resolution proof that Daisy has a mother.

1.4 Resolution Proof II (10 points)

Provide a resolution proof that Dolly is a clone.

2 Planning (20 points)

Consider a simple planning problem for a Martian rover. The rover can be in one of three locations, a, b, or c. It can move from location X to location Y with the action: DRIVE(X,Y). Aside from the rover itself, there are two objects in the world, a scanner and a rock. We denote the location of an object with AT(OBJ, X), where OBJ could be the rover, the scanner, or a rock. The rover has a cargo bay called cargo, that can hold a single object. When an object is in the cargo bay, we'd say: AT(OBJ, cargo). When the cargo bay is empty, we'd say: EMPTY(cargo). It's also possible for the rock to be in the scanner, i.e., AT(rock, scanner). The robot can pick up an object, if it is at the same location as the object, and the cargo bay is empty with PICK(OBJ, X), which picks up the object at location X. The robot can drop off an object at location Y if it is carrying the object and it is in location Y with DROP(OBJ,Y), but it is also valid to do DROP(OBJ, scanner) if the robot and the scanner are both in the same location.

2.5 Action Descriptions (10 points)

Write down the action descriptions in PDDL for the actions: DRIVE, PICK, and DROP. Do not use negations except to indicate predicates that are deleted (the delete list in the older STRIPS notation). Do not us logical connectives other than AND, and avoid using quantification or equality in your specification. Here are a few things to think about when writing down your actions:

- Be careful to make sure that your actions ensure a logically consistent state at all times, e.g., it's impossible for an object to be in two places at the same time.
- You may find it helpful to assume that you have predicates that tell you the type of an entity in the world. For example, you can assume that there are predicates, rock(X) and scanner(X) which are true if X is a rock, or scanner, respectively. You also might find it useful to have predicates that indicate if something is a valid location to move to, e.g., location(X), which would be true for a, b, and c. If you choose to add additional predicates, be sure to explain what you are doing and why you are doing it.
- It's OK to have multiple definitions for the same action. For example, you could have two different versions of the drop action with different preconditions.
- Keep in mind that the robot can't carry itself and can't carry locations.

2.6 Plan (10 points)

Suppose the initial state is AT(rover, a), AT(scanner, b), AT(rock, c), and EMPTY(cargo). If the goal is: AT(rock, scanner), AT(scanner, a), provide a valid plan using the actions you've defined to achieve the goal.

3 Probability I (10 points)

Consider 3 binary random variables, A, B, and C. Suppose A and B have a uniform, random distribution, and that C is the exclusive OR (XOR) of A and B.

1. Compute the distribution $P(CA)$. (2 points)
2. Compute the distribution $P(C|B)$. (4 points)
3. Compute the distribution $P(AB|C)$ (4 points)

4 Probability II (10 points)

Consider a population that is 70% urban (U) and 30% non-urban ($\overline{U}$). Assume that there are only two parties for which one may vote. In this population, urban voters vote Democratic (D) with probability $\frac{4}{7}$: $P(D|U) = \frac{4}{7}$. Non-urban voters vote Republican (R) with probability $\frac{2}{3}$: $P(R|\overline{U}) = \frac{2}{3}$.

4.7 Marginal probabilities

What is the probability that a randomly selected voter will vote Democratic?

4.8 Conditional probabilities

What is the the probability that a randomly selected Democratic voter is urban? What about a randomly selected Republican voter?