Artificial Intelligence for Robotics I
Final Test

January 5th, 2023

Hand-in instructions

The answers for Propositional and First Order Logic questions can be submitted in handwritten form to the teacher, or in .pdf format (you can use pen-enabled devices or scan handwritten answers on paper) through the link made available on the Aulaweb page for the course "Artificial Intelligence for Robotics 1". Please try to be as clear as possible in your handwriting. The answer to the Planning question are to be submitted through Aulaweb, and you must supply two text files in PDDL language for your answer, one named `domain.pddl` for the domain and one named `problem.pddl` containing the definition of the problem instance. Your hand-in should be a single zipped file <*student_id* >_<*surname*>, and if you have more than one surname, please use camel case (not spaces) to separate words.

During the test you can consult your notes and other references on your PC or the internet (the exam is open-book). You must not ask help to your fellow colleagues or others. By submitting the exam, you implicitly state that you are adhering to this policy.

1 Propositional Logic

Formalize the following sentences where a group a fellow cyclists rides either on paved or gravel roads:

1. Piergiorgio and Luigi ride paved roads only.
2. Daniele and Francesco ride either gravel or paved roads, but not both.
3. Whenever Daniele rides on gravel, also Francesco rides with him.
4. Whenever Piergiorgio rides, also Luigi rides with him.

If we further assume that Francesco is not riding gravel and Luigi is not riding, can we conclude that Daniele is riding on paved roads and Piergiorgio is not riding at all? State your answer as a proof using a deduction mechanism of your choice or a semantic argument. Truth-tables are not accepted as an answer. (**Note**: the disjunction in sentence (2) is exclusive.)

2 First Order Logic

Consider the following first order theory about hobbies:

1. $\forall x.(Loves(x, cycling) \rightarrow Loves(x, hiking))$.
2. $\forall x.(Loves(x, hiking) \vee Loves(x, running))$.
3. $\exists x.\neg Loves(x, running)$.
4. $\exists x.(Loves(x, cycling) \vee Loves(x, hiking))$

and tell whether each of the following sentences is either a logical consequence of the theory or not:

1. $\exists x.(\neg Loves(x, cycling) \wedge \neg Loves(x, hiking))$.
2. $\forall x.(\neg Loves(x, cycling) \rightarrow \neg Loves(x, hiking))$.
3. $\forall x.(Loves(x, hiking) \vee Loves(x, running))$.
4. $\forall x.(Loves(x, running))$.
5. $\forall x.((Loves(x, running) \wedge \neg Loves(x, hiking)) \rightarrow \neg Loves(x, cycling))$.

Please state your answers using a deductive mechanism of your choice or a semantic argument.

3 Planning

Consider a one-handed pizza-making robot. The robot can access trays with dough (assume that the dough is already round-shaped, ready to be dressed), a container with cheese shreds, one with tomato sauce and a brick oven. To fix a pizza, the robot must fetch the tray with the dough, put tomato sauce and cheese on it and then bake the pizza (put it in the oven). Let us further assume that there are four optional toppings, namely ham, salame, olives and mushrooms, and a customer can choose to add at most one of them. The topping should be added before putting the pizza in the oven, but after cheese and tomato sauce have been added.

Formalize actions to fetch pizza trays, put tomato sauce, cheese shreds and toppings. Consider that only one action can be perfomed at a time, and that the sequence tomato - cheese - topping must always be respected to make a proper pizza. Consider a scenario where there are three pizza trays and three customers ask for pizza margherita (no extra topping), pizza marinara (add olives) and pizza boscaiola (add mushrooms), respectively. Write the planning domain and a problem file corresponding to the scenario described. (**Note**: assume there is an infinite supply of tomato sauce and cheese shreds.)