Informatics 2D Tutorial 7 (Week 8): Solutions

Planning and Acting in the Real World

Problem description

This week’s tutorial builds on last week’s tea making domain. Your personal robotic assistant who helps you make tea has the following information:

- a set of predicates:
  - cup(c), kettle(k), containsWater(x) where x is either a cup or a kettle, containsTeabag(x) where x is usually a cup, waterIsHot() which takes no arguments.

- a set of actions:
  - Action(FillWithWaterFromTap(k),
    Precond: kettle(k) ∧ ¬containsWater(k),
    Effect: containsWater(k))
  - Action(AddTeabagToCup(c),
    Precond: cup(c) ∧ ¬containsTeabag(c),
    Effect: containsTeabag(c))
  - Action(PourWaterToCupFromKettle(c, k),
    Precond: kettle(k) ∧ cup(c) ∧ waterIsHot ∧ containsWater(k) ∧ ¬containsWater(c),
    Effect: containsWater(c))
  - Action(BoilWaterInKettle(k),
    Precondition: kettle(k) ∧ ¬waterIsHot() ∧ \(\prod\) containsWater(k)
    Effect: waterIsHot()

You ask the robot to make you two cups of tea \(C_1\) and \(C_2\). This goal state can be represented as follows:

\[\text{containsWater}(C_1) ∧ \text{containsWater}(C_2) ∧ \text{containsTeabag}(C_1) ∧ \text{containsTeabag}(C_2) ∧ \text{waterIsHot}()\]

Credits: Mihai Dobre, Alex Lascarides

\(^1\)This is the correct form. There was an error in this action on the question sheet.
1 Planning with certainty

With an initial state of:

\[ \text{kettle}(K) \land \text{cup}(C_1) \land \text{cup}(C_2) \]

and everything else being false, since we are operating under a closed world assumption, produce
a plan that takes you from the initial state to the goal state described above.

Answer

One plan that takes us from the initial state to the goal state could be:

0: \text{FillWithWaterFromTap}(K)
1: \text{BoilWaterInKettle}(K)
2: \text{PourWaterToCupFromKettle}(C_1, K)
3: \text{PourWaterToCupFromKettle}(C_2, K)
4: \text{AddTeabagToCup}(C_1)
5: \text{AddTeabagToCup}(C_2)

2 Conformant Planning

Assume that your robot does not have complete information about the state of the world at the
start of the problem, and has no sensing abilities either. Let’s assume that in the initial state
the robot knows that \( K \) is a kettle, \( C_1 \) and \( C_2 \) are cups, but does not know whether any of the
containers contain water or tea, or whether or not the water is hot.

1. Represent the agent’s belief state as a compact logical representation, which expresses the
agent’s ignorance about predicates by not mentioning them, and by explicitly mentioning
everything else in the world whether true or false.

2. Modify the description of your world by introducing new actions or by making changes to
existing actions to enable your robot to produce a conformant plan, i.e. a plan that works
regardless of what the true state of the world is at the start of the problem.

3. Give an example of a conformant plan to make two cups of tea for your updated domain.

Answer

1. The agent’s belief state would be:

\[ \text{kettle}(K) \land \text{cup}(C_1) \land \text{cup}(C_2) \land \neg\text{kettle}(C_1) \land \neg\text{kettle}(C_2) \land \neg\text{cup}(K) \]

2. To be able to achieve a conformant plan, we need to introduce an action that would en-
able us neutralize the unknown aspects of the world. We have no means of discovering
whether the containers contain water or teabags, so one action we can introduce would be to \( \text{EmptyContents}(x) \) of container \( x \):
Action(EmptyContents(x))
EFFECT : ¬containsWater(x) ∧ ¬containsTeabag(x)

this action allows us to deal with the uncertainty about the predicates containsWater(x) and containsTeabag(x)
But we still need to deal with the fact that we don’t know whether the water is hot or not.
One way around this would be to remove the precondition ¬waterIsHot() from the action BoilWaterInKettle(k) which would just allow the robot to switch the kettle on again even if the water is already hot.

3. One conformant plan we can produce is as follows:

0: EmptyContents(K)
1: EmptyContents(C1)
2: EmptyContents(C2)
3: FillWithWaterFromTap(K)
4: BoilWaterInKettle(K)
5: PourWaterToCupFromKettle(C1, K)
6: PourWaterToCupFromKettle(C2, K)
7: AddTeabagToCup(C1)
8: AddTeabagToCup(C2)

3 Contingent Planning

Assume that your robot has incomplete information about the state of the world at the start of the problem, but is equipped with sensing abilities that allow it to detect the true value of the unknown predicates.

1. Add sensing actions to the original domain (which excludes changes you’ve made in step 2) to allow your agent to produce contingent plans that examine the different possibilities for the predicates containsWater(x), containsTeabag(x), and waterIsHot().

2. Let’s say that the agent’s initial belief state is as follows:

kettle(K) ∧ cup(C) ∧ containsTeabag(C) ∧ ¬containsWater(C) ∧ containsWater(K)

this means that the agent does not know whether or not the water is hot. Write an example of a contingent plan that should result in a cup of tea in cup C.
Answer

1. We can add three percepts, each of which senses one of the possible unknown predicates:
   - $\text{Percept}(\text{containsWater}(x))$
   - $\text{Percept}(\text{containsTeabag}(x))$
   - $\text{Percept}(\text{waterIsHot}())$

2. An example of a contingent plan would be:
   
   \[
   \text{if } \text{waterIsHot}() \text{ then } \text{PourWaterToCupFromKettle}(C; K) \\
   \text{else } \text{BoilWaterInKettle}(K), \text{PourWaterToCupFromKettle}(C; K)\]
