INF5390-2102 – Kunstig intelligens

Exercise 2 Solution

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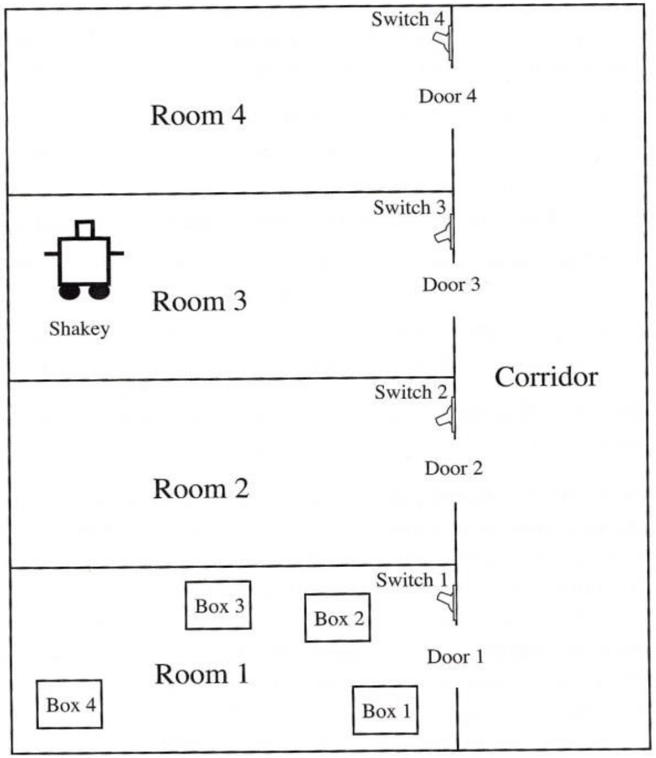
Exercise 2.1: Agents That Plan (INF5390-08)

- The figure shows the robot Shakey in a world consisting of 4 rooms along a corridor, where each room has a door and a light switch. Shakey can move from location to location, push boxes, climb up and down boxes, and switch lights on and off. He can only reach switches by standing on a box.
- The rooms, doors, corridor and switches mentioned are given location constants. You will also need to define constants for initial locations of Shakey and the boxes, as well as a predicate *In* to define that a position is in a room.



Exercise 2.1: Agents That Plan (INF5390-08) (cont.)

- Shakey's 6 actions are:
  - *Go(x,y,r)* which requires that Shakey be *At x* and that *x* and *y* are locations in the same room *r*. By convention a door joining two rooms is in both of them.
  - *Push(b,x,y,r)*: Push a box *b* from location *x* to location *y* in the same room *r*.
  - *ClimbUp(b), ClimbDown(b)*: Climb up and down a box *b*.
  - *TurnOn(l), TurnOff(l)*: Turn on and turn off light switch *l* (by convention, we use the switch constants both for the locations of the switches and for the objects that can be switched on/off).
- Your tasks are the following:
  - *1.1 Write down PDDL sentences for Shakey's 6 actions and the initial state shown in the figure.*
    1.2 Show a plan for Shakey to switch on light Switch 2 using Box 2 to stand on.

Representation of actions

- An *action schema* has three components
  - √ *Action* description: Name and parameters (universally quantified variables)
  - √ *Precondition*: Conjunction of positive literals stating what must be true before action application
  - √ *Effect*: Conjunction of positive or negative literals stating how situation changes with operator application
- Example
  - √ ***Action****(Fly(p, from, to),*
    PRECOND: *At*(*p, from*) ∧ *Plane(p)* ∧
    Airport(from) ∧ *Airport(to),*
    EFFECT: ¬ *At*(*p, from*) ∧ *At(p, to))*

How are planning actions applied?

- Actions are *applicable* in states that satisfy its preconditions (by binding variables)
  - State: $At(P_1, JFK) \wedge At(P_2, SFO) \wedge Plane(P_1) \wedge Plane(P_2) \wedge Airport(JFK) \wedge Airport(SFO)$
  - Precondition: $At(p, from) \wedge Plane(p) \wedge Airport(from) \wedge Airport(to)$
  - Binding: $\{p/P_1, from/JFK, to/SFO\}$
- State after executing action is same as before, except positive effects added (*add list*) and negative deleted (*delete list*)
  - New state: $At(P_1, SFO) \wedge At(P_2, SFO) \wedge Plane(P_1) \wedge Plane(P_2) \wedge Airport(JFK) \wedge Airport(SFO)$

Shakey's actions in PDDL

- ***Action**(Go(x, y, r),*
  PRECOND: $Location(x) \wedge Location(y) \wedge Room(r) \wedge$
  $In(x, r) \wedge In(y, r) \wedge At(Shakey, x)$,
  EFFECT: $\neg At(Shakey, x) \wedge At(Shakey, y))$
- ***Action**(Push(b, x, y, r),*
  PRECOND: $Box(b) \wedge Location(x) \wedge Location(y) \wedge Room(r) \wedge$
  $In(x, r) \wedge In(y, r) \wedge At(b, x) \wedge At(Shakey, x)$,
  EFFECT: $\neg At(b, x) \wedge \neg At(Shakey, x) \wedge$
  $At(b, y) \wedge At(Shakey, y))$
- ***Action**(ClimbUp(b),*
  PRECOND: $Box(b) \wedge Location(x) \wedge At(b, x) \wedge At(Shakey, x) \wedge$
  $\neg On(Shakey, b)$,
  EFFECT: $On(Shakey, b))$

Shakey's actions in PDDL (cont.)

- ***Action****(ClimbDown(b),*
  PRECOND: $Box(b) \wedge Location(x) \wedge At(b, x) \wedge On(Shakey, b)$,
  EFFECT: $\neg\, On(Shakey, b))$
- ***Action****(TurnOn(l),*
  PRECOND: $Switch(l) \wedge Location(x) \wedge At(l, x) \wedge$
  $Box(b) \wedge At(b, x) \wedge On(Shakey, b)$,
  EFFECT: $TurnedOn(l))$
- ***Action****(TurnOff(l),*
  PRECOND: $Switch(l) \wedge Location(x) \wedge At(l, x) \wedge$
  $Box(b) \wedge At(b, x) \wedge On(Shakey, b)$,
  EFFECT: $\neg\, TurnedOn(l))$

Initial state and goal in PDDL

- ***Init***(*Room(Room1)* $\wedge$ ... $\wedge$ *Room(Room4)* $\wedge$ *Room(Corridor)* $\wedge$
  Location(Door1) $\wedge$ ... $\wedge$ *Location(Door4)* $\wedge$
  In(Door1, Room1) $\wedge$ *In(Door1, Corridor)* $\wedge$ ... $\wedge$
  In(Door4, Room4) $\wedge$ *In(Door4, Corridor)* $\wedge$
  Location(Switch1Loc) $\wedge$ ... $\wedge$ *Location(Switch4Loc)* $\wedge$
  In(Switch1Loc, Room1) $\wedge$ ... $\wedge$ *In(Switch4Loc, Room4)* $\wedge$
  Box(Box1) $\wedge$ ... $\wedge$ *Box(Box4)* $\wedge$
  Location(Box1InitLoc) $\wedge$ ... $\wedge$ *Location(Box4InitLoc)* $\wedge$
  At(Box1, Box1InitLoc) $\wedge$ ... $\wedge$ *At(Box4, Box4InitLoc)* $\wedge$
  In(Box1InitLoc, Room1) $\wedge$ ... $\wedge$ *In(Box4InitLoc, Room1)* $\wedge$
  Location(ShakeyInitLoc) $\wedge$ *In(ShakeyInitLoc, Room3)* $\wedge$
  At(Shakey, ShakeyInitLoc))

Goal and plan to achieve goal

- ***Goal***(*On(Shakey, Box2)* $\wedge$ *TurnedOn(Switch2))*

- ***Plan***(*Go(ShakeyInitLoc, Door3, Room3),*
  Go(Door3, Door1, Corridor),
  Go(Door1, Box2InitLoc, Room1),
  Push(Box2, Box2InitLoc, Door1, Room1),
  Push(Box2, Door1, Door2, Corridor),
  Push(Box2, Door2, Switch2Loc, Room2),
  ClimbUp(Box2),
  SwitchOn(Switch2))

Exercise 2.2: Agents That Reason Under Uncertainty (INF5390-10)

- Show from first principles including the definition of conditional probability that:

$$P(A \mid B \wedge A) = 1$$

Basic probability notation (cont.)

- Probability *distribution* of variable **P**(v)
  - **P**(*Weather*) = (0.7, 0.2, 0.08, 0.02)
- *Joint* probability distribution
  - Table of probabilities for all *combinations*: **P**(v_1, v_2)
  - **P**(*Weather*, *Cavity*) is a 4 x 2 table of probabilities (must sum to 1)
  - *Full joint distribution*: all domain variables included
- *Conditional* (posterior) probability: $P(A|B)$
  - $P(Cavity|Toothache) = 0.8$
- *Product rule:*
  - $P(A \wedge B) = P(A|B)\ P(B)$
  - $P(A \wedge B) = P(B|A)\ P(A)$
  - $P(A|B) = P(A \wedge B) / P(B)$

Axioms of probability

- Basic axioms

$$0 \le P(A) \le 1$$

$$P(True) = 1 \quad P(False) = 0$$

$$P(A \vee B) = P(A) + P(B) - P(A \wedge B)$$

- All other properties can be derived, e.g.

$$P(A \vee \neg A) = P(A) + P(\neg A) - P(A \wedge \neg A)$$

$$P(True) = P(A) + P(\neg A) - P(False)$$

$$1 = P(A) + P(\neg A)$$

$$P(\neg A) = 1 - P(A)$$

Expression derived

$P(A \mid B \wedge A)$ - Initial

= $P(A \wedge (B \wedge A))/P(B \wedge A)$ - Product rule (3rd form)

= $P(A \wedge B \wedge A)/P(B \wedge A)$ - Remove parentheses

= $P(B \wedge A \wedge A)/P(B \wedge A)$ - $\wedge$ is commutative

= $P(B \wedge A)/P(B \wedge A)$ - $A \wedge A = A$

= 1