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Knowledge Representation and Reasoning

Project number 2:
Deterministic Action With Cost
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1 Introduction

A dynamic system (DS) is viewed as

- a collection of objects, together with their properties, and
- a collection of actions which, while performed, change properties of objects (in consequence, the state of the world).

Let C2 be a class of dynamic systems satisfying the following assumptions:

1. Inertia law
2. Complete information about all actions and fluent.
3. Only Determinism
4. Only sequential actions are allowed.
5. Characterizations of actions:
 - Precondition represented by set of literals(a fluent or its negation);if a precondition does not hold, the action is executed but with empty effect
 - Postcondition (effect of an action) represented by a set of literals.
 - Cost $k \in \mathbb{N}$ of an action, actions with empty effects cost 0. Each action has a fixed cost, if it leads to non-empty effects.
6. Effects of an action depends on the state where the action starts.
7. All actions are performed in all states.
8. Partial description of any state of the system are allowed.
9. No constraints are defined.

2 Syntax

A system is defined by a set of fluent **F**, actions **Ac** and Cost **k** $\in \mathbb{N}$ and characterized by signature **(F, Ac, k)**

A literal is either a fluent **f** or its negation $\neg f$.

A formula is any propositional combination of fluent:

$$\alpha :: \neg\alpha \mid \alpha \wedge \beta \mid \alpha \vee \beta \mid \alpha \rightarrow \beta$$

Two specific formulas:

1. \top : truth
2. \perp : falsity

The system and changes occurring within can be described through a sequence of statements defined in the table:

Statement	Format	Description
Initial Statement	Initially α	Initial condition α of the fluent.
Effect Statement	A causes α if g_1, \dots, g_k	If the action A is performed in any state satisfying g_1, \dots, g_k , then in the resulting state α holds.
Value Statement	α after $A_1 \dots A_n$	The condition α always (must) hold after performing the sequence $A_1 \dots A_n$ of actions.
Cost Statement	A cost n	Perform the cost of action A

Table 1: Syntax Table

3 Semantics

- A state is a mapping $\sigma : F \rightarrow 0, 1$. For any $f \in F$, if $\sigma(f) = 1$, then we say that f holds in σ and write $\sigma \models f$. If $\sigma(f) = 0$, then we write $\sigma \models \neg f$ and say that f does not hold in σ . Let σ stand for the set of all states.
- A state is a mapping $\sigma : F \rightarrow 0, 1$. For any $f \in F$, if $\sigma(f) = 1$, then we say that f holds in σ and write $\sigma \models f$. If $\sigma(f) = 0$, then we write $\sigma \models \neg f$ and say that f does not hold in σ . Let σ stand for the set of all states.
- A transition function is a mapping $\Upsilon : Ac \times \sigma \rightarrow \sigma$. For any $\sigma \in \sigma$ and for any $A \in Ac$, $\Upsilon(A, \sigma)$ is the state resulting from performing the action A in the state σ .
- A transition function is generalized to the mapping $\Upsilon^* : Ac^* \times \sigma \rightarrow \sigma$ as follows: $\Upsilon^*(\varepsilon, \sigma) = \sigma$, $\Upsilon^*((A_1, \dots, A_n), \sigma) = \Upsilon(A_n, \Upsilon^*(A_1, \dots, A_{n-1}))$.
- A transition function is generalized to the mapping $\Upsilon^* : Ac^* \times \sigma \rightarrow \sigma$ as follows: $\Upsilon^*(\varepsilon, \sigma) = \sigma$, $\Upsilon^*((A_1, \dots, A_n), \sigma) = \Upsilon(A_n, \Upsilon^*(A_1, \dots, A_{n-1}))$.

- Let L be an action language of the class A over the signature $Y = (F, A_c)$. A structure for L is a pair $S = (\Upsilon, \sigma_0)$ where Υ is a transition function and $\sigma_0 \in \sigma$ is the initial state
- Let $s = (\Upsilon, \sigma_0)$ be a structure for L . A statement s is true in S , in symbols $S \models s$, iff if s is of the form f after A_1, \dots, A_n , then $\Upsilon((A_1, \dots, A_n), \sigma_0) \models f$;
- Let $s = (\Upsilon, \sigma_0)$ be a structure for L . A statement s is true in S , in symbols $S \models s$, iff if s is of the form f after A_1, \dots, A_n , then $\Upsilon((A_1, \dots, A_n), \sigma_0) \models f$; if s is of the form A causes f if g_1, \dots, g_k , then for every $\sigma \in \sigma$ such that $\sigma \models g_i, i = 1, \dots, k, \Upsilon(A, \sigma) \models f$.

Let D be an action domain in the language L over the signature $\Upsilon=(F, A_c)$.

A structure $S = (\Psi, \sigma_0, k)$ is a model of D iff

(M1) for every $s \in D, S \models s$;

(M2) for every $A \in A_c$, for every $f, g_1, \dots, g_n \in F$, and for every $\sigma \in \Sigma$, if one of the following conditions holds:

(i) D contains an effect statement

A causes \bar{f} for the cost k if $\bar{g}, \dots, \bar{g}_n$,

where $k \neq 0$ and $\sigma \models g_i$ for some $i = 1, \dots, n$

(ii) D does not contain an effect statement

A causes \bar{f} if g_1, \dots, g_n

then $\sigma \models f$ iff $\Psi(A, \sigma, k) \models f$. where $k = 0$.

4 Examples

4.1 Example 01

4.1.1 Description

Andrew wants to travel by his car to a place. Travelling costs him 100\$ if he uses fuel from the fuel tank of the car. If in case of emergency, Andrew is carrying a bottle of fuel as reserve, which can cost him 150\$ for travelling because it's a low quality fuel. Buying fuel costs him 200\$ and reserve costs him 250\$.

4.1.2 Representation

Initially we have:

1. Fuel
2. Reserve

Travel causes \neg fuel if fuel \vee reserve
Travel causes \neg reserve if \neg fuel \vee reserve
BuyF causes fuel if \neg fuel
BuyS causes reserve if \neg reserve

4.1.3 Calculation

$$\begin{aligned} \Sigma &= \{ \sigma_0, \sigma_1, \sigma_2, \sigma_3 \} \\ \sigma_0 &= \{ \text{fuel}, \text{reserve} \} & \sigma_1 &= \{ \neg \text{fuel}, \text{reserve} \} \\ \sigma_2 &= \{ \neg \text{fuel}, \neg \text{reserve} \} & \sigma_3 &= \{ \text{fuel}, \neg \text{reserve} \} \end{aligned}$$

$$\begin{aligned} \Psi(\text{BuyF}, \sigma_0) &= \sigma_0 & \Psi(\text{BuyS}, \sigma_0) &= \sigma_0 \\ \Psi(\text{BuyF}, \sigma_1) &= \sigma_0 & \Psi(\text{BuyS}, \sigma_1) &= \sigma_1 \\ \Psi(\text{BuyF}, \sigma_2) &= \sigma_3 & \Psi(\text{BuyS}, \sigma_2) &= \sigma_1 \\ \Psi(\text{BuyF}, \sigma_3) &= \sigma_3 & \Psi(\text{BuyS}, \sigma_3) &= \sigma_0 \end{aligned}$$

$$\begin{aligned} \Psi(\text{Travel}, \sigma_0) &= \sigma_1 & \Psi(\text{Travel}, \sigma_1) &= \sigma_2 \\ \Psi(\text{Travel}, \sigma_2) &= \sigma_2 & \Psi(\text{Travel}, \sigma_3) &= \sigma_2 \end{aligned}$$

4.1.4 Graph

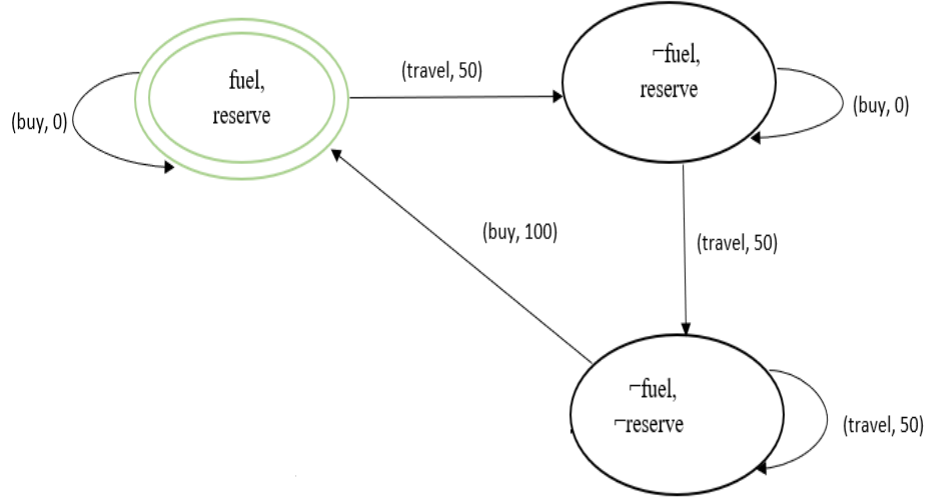


Figure 1: Example 01

4.2 Example 02

4.2.1 Description

John visits a painter to buy a specific painting. The cost of painting is 200\$ if its available in the shop. But if painting is not available then John needs to order a new one to be painted and will buy once its available. At any time only one copy of painting is available and another one to be ordered once sold.

4.2.2 Representation:

Fluents: available, sold.
Actions: BUY, ORDER.
BUY costs 200\$ **if** available
BUY costs 0\$ **if** \neg available
Order Cost: 0 \$
initially: \neg available \wedge \neg sold
BUY causes sold if available

ORDER causes available if \neg available
BUY causes \neg available

4.2.3 Calculation:

$$\begin{aligned}\Sigma &= \{ \sigma_0, \sigma_1, \sigma_2, \sigma_3 \} \\ \sigma_0 &= \{ \neg\text{available}, \neg\text{sold} \} \\ \sigma_1 &= \{ \neg\text{available}, \text{sold} \} \\ \sigma_2 &= \{ \text{available}, \neg\text{sold} \} \\ \sigma_3 &= \{ \text{available}, \text{sold} \} \\ \Psi(\text{BUY}, \sigma_0) &= \sigma_0 \\ \Psi(\text{ORDER}, \sigma_0) &= \sigma_1 \\ \Psi(\text{BUY}, \sigma_1) &= \sigma_2 \\ \Psi(\text{ORDER}, \sigma_1) &= \sigma_1 \\ \Psi(\text{BUY}, \sigma_2) &= \sigma_2 \\ \Psi(\text{ORDER}, \sigma_2) &= \sigma_1 \\ \Psi(\text{BUY}, \sigma_3) &= \sigma_2 \\ \Psi(\text{ORDER}, \sigma_3) &= \sigma_3\end{aligned}$$

4.2.4 Graph

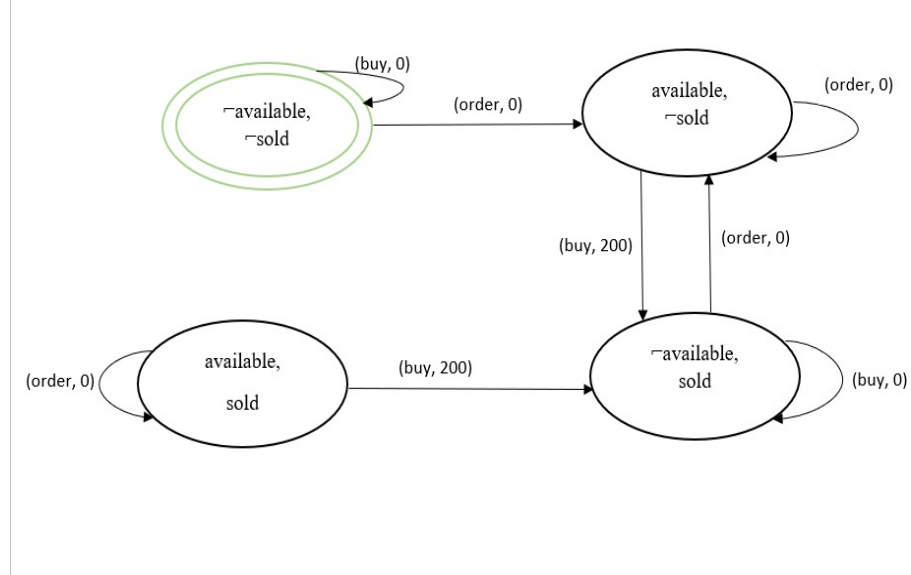


Figure 2: Example 02

4.3 Example 03

4.3.1 Description

There is a man. He can cook, eat, and play. Cooking makes food cooked. he can eat food if it is cooked. After eating he feels not hungry, and food is not cooked again. He can play. Playing makes him hungry. He just can play if he is not hungry. He just cooks when there is no food is cooked. Initially, he is hungry, and no food is cooked. In terms of energy, eating costs 5, cooking costs 15, playing costs 20.

4.3.2 Representation in language

Fluents: cooked, hungry.

Actions: cook, eat, play.

eat cost 5

cooking cost 15
 play cost 20
 initially $\neg\text{cooked} \wedge \text{hungry}$
 cook causes cook if $\neg\text{cooked}$
 eat causes $(\neg\text{cooked} \wedge \neg\text{hungry})$ if cooked
 play causes hungry if $\neg\text{hungry}$

4.3.3 Calculation

$$\Sigma = \{\sigma_0, \sigma_1, \sigma_2, \sigma_3\}$$

$$\begin{aligned}\sigma_0 &= \{\neg\text{cooked}, \text{hungry}\} \\ \sigma_1 &= \{\text{cooked}, \text{hungry}\} \\ \sigma_2 &= \{\neg\text{cooked}, \neg\text{hungry}\} \\ \sigma_3 &= \{\text{cooked}, \neg\text{hungry}\}\end{aligned}$$

$$\begin{aligned}\psi(\text{eat}, \sigma_0) &= \sigma_0 \\ \psi(\text{cook}, \sigma_0) &= \sigma_1 \\ \psi(\text{play}, \sigma_0) &= \sigma_0\end{aligned}$$

$$\begin{aligned}\psi(\text{eat}, \sigma_1) &= \sigma_2 \\ \psi(\text{cook}, \sigma_1) &= \sigma_1 \\ \psi(\text{play}, \sigma_1) &= \sigma_1\end{aligned}$$

$$\begin{aligned}\psi(\text{eat}, \sigma_2) &= \sigma_2 \\ \psi(\text{cook}, \sigma_2) &= \sigma_3 \\ \psi(\text{play}, \sigma_2) &= \sigma_1\end{aligned}$$

$$\begin{aligned}\psi(\text{eat}, \sigma_3) &= \sigma_2 \\ \psi(\text{cook}, \sigma_3) &= \sigma_3 \\ \psi(\text{play}, \sigma_3) &= \sigma_1\end{aligned}$$

4.3.4 Graph

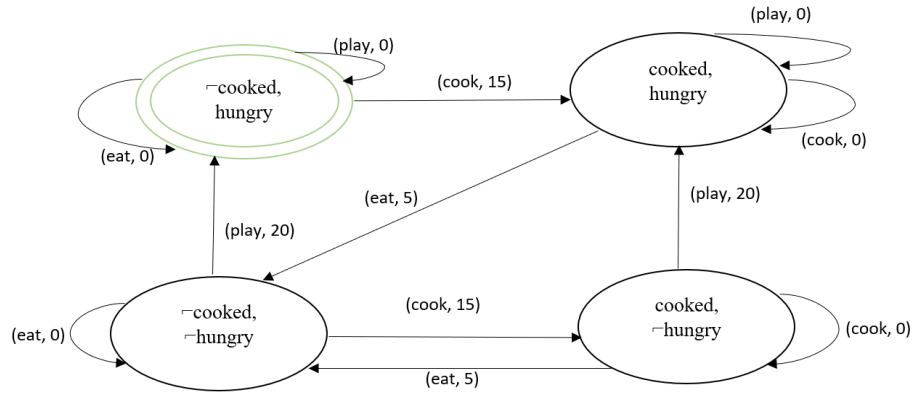


Figure 3: Example 03

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