

Planning (01)

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Planning – a definition

“Planning is the reasoning side of acting. It is an explicit deliberation process that chooses and organises actions, on the basis of their expected outcomes, in order to achieve some objective as best as possible.” [Ghallab et al., 2003]

Application examples:

spacecraft flying (NASA)

Mars rover control (NASA)

power supply restoration (EDF)

elevator control (Shindler, Rockwell)

sheet-metal bending (Amada)

operations planning (DSTO-NICTA)

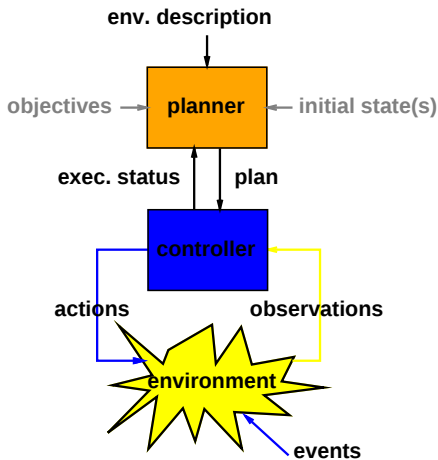
bridge playing (University of Maryland)

QRIO (Sony)



QRIO robot

Planning agents



An informal definition of planing

- ▶ Given
 - ▶ a description of the environment (model)
 - ▶ a set of objectives
 - ▶ the initial state(s) of the environment

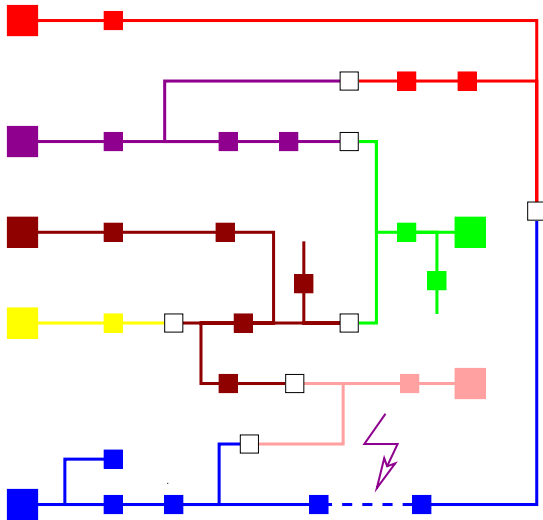
- ▶ Problem:
 - ▶ Control the environment by performing actions so as to allow only acceptable execution sequences, with a minimum cost

- ▶ Solution
 - ▶ Plan

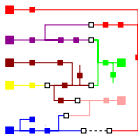
A formal(?) definition of planning

- ▶ Typical ingredients of a planning model:
 - ▶ a set of states S
 - ▶ a set of events E and a set of actions $A \subseteq E$
 - ▶ a transition function $\gamma : S \times E \rightarrow (S \times [0, 1])$
 - ▶ a set of observations O
 - ▶ an observation function: $\lambda : S \rightarrow 2^O$
 - ▶ a set of possible initial states $S_I \subseteq S$
 - ▶ a cost function on execution sequences
 - ▶ conditions defining the acceptable execution sequences
- ▶ Problem:
 - ▶ Control the environment by performing actions so as to allow only acceptable execution sequences, with a minimum cost
- ▶ Solution (plan):
 - ▶ sequence (partially or totally ordered) of actions
 - ▶ a policy $O \rightarrow A$
 - ▶ an automaton
 - ▶ ...

Example: power supply restoration



Example: power supply restoration (rest)



- ▶ states??: topology *i.e.* switches and circuit breaker, connections (lines) and consumption for each line, faulty status of the lines, open/closed position of the switches and the circuit breakers, *etc.*
- ▶ observations??: faults, power sensors
- ▶ events??: faults, open/close a switch or a circuit breaker
- ▶ acceptable sequences??: do not violate capacity constraints, supply all the non faulty lines, do not connect two circuit breakers
- ▶ cost??: (balanced) number of actions, power margins

Classical planning assumptions

Finite: S , E and O are finite

Static, simple agent: $E = A$

Deterministic: $S_I = \{s_I\}$, if the action a is applicable in state s ,
 $\gamma(s, a) = \{(s', 1)\}$

Fully observable: $O = S$ and $\lambda(s) = \{s\}$

Implicit time: no duration, instantaneous actions

Reachability goals: a sequence is acceptable if it leads to a state in S_G

Sequential: the solution is a sequence of actions

Cost function: the number of actions (= length of the sequence)

Off-line planning: planner does not know execution status

The classical planning model is:

- ▶ a finite set of states S
- ▶ a finite set of actions A
- ▶ a transition function $\gamma : S \times A \rightarrow S$
- ▶ an initial state s_0
- ▶ a set $S_G \subseteq S$ of goal states

Classical planning problem

Given a model (S, E, γ, s_0, S_G) , find the smallest sequence of actions $\langle a_1, \dots, a_n \rangle$ such that:

- ▶ $\forall i \in \{1, \dots, n\}, a_i \in A$
- ▶ let $\forall i \in \{1, \dots, n\}, s_i$ be recursively defined by the existing state $\gamma(s_{i-1}, a_i)$, then $s_n \in S_G$

linear plans: totally ordered set of actions $\langle a_1, \dots, a_n \rangle$.

Produced by state-based planning approaches.

non-linear plans: partially ordered set of actions $(\{a_1, \dots, a_n\}, \prec)$ such that any linearisation is a totally ordered plan. Produced by plan-state planning approaches.

parallel plans: sequence of parallel actions $(\{a_{1,1}, \dots, a_{1,l(1)}\}, \dots, \{a_{1,k}, \dots, a_{1,l(k)}\})$, special case of partially ordered plan. Produced by graph-based planning approaches.