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7. State Space Search: An example

To solve a problem by using a State Space Search procedure it is necessary to: (i), define a representation of states; (ii), define all possible actions; (iii), specify the initial state; (iv), specify the goal states; and (v), choose a suitable search strategy.

Representation of states

The representation of states should be:

- *sufficiently informative* (i.e., it has to contain all information relevant for the solution of the problem);
- *nonredundant* (i.e., it should not contain unnecessary information, nor replicate the same informative content more than once);
- *efficient* (i.e., it should make it be possible to easily check whether an action is applicable, and if so efficiently compute the state resulting from the execution of an action).

Definition of actions

The definition of an action should specify: (i) the applicability conditions of the actions (i.e., the features of a state that make it possible to execute an action in the state); (ii) the effects of the actions (i.e., how a state is modified if the action is applied to it).

Often the number of different actions can be reduced by making action more general through the use of input parameters. However, reducing the number of actions too much may make the description of actions more complex. A balance between generality and complexity of the action descriptions should be sought. In any case, if an action is parametric, do not forget that when a node is expanded the action must be executed *with all the possible values of its parameters*.

Definition of the initial state

The initial state is a single state, which has to be specified.

Definition of the goal states

The set of goal states may be defined by giving a list of specific states, of by defining a Boolean function, which when applied to a state will return *true* if the state is a goal state and *false* otherwise.

Choice of the search strategy

When all action costs are identical, BF search can be applied, but only to small problems. DF search (possibly in its BT variant) can be used only if the depth of the search tree is finite and all solutions are at the same depth. Otherwise ID is the best choice.

When costs are not all identical, UC can be used if no good heuristics can be found, but A* is preferable if a good heuristics can be defined.

An example

This problem is a (moderately) 'politically correct' version of a famous puzzle, usually known as *Missionaries and Cannibals*.

Boys and Girls. To go from place P to place Q, three boys and three girls have to use a motor bike (which is initially at P). The motor bike can carry a maximum of two people, therefore several trips will be necessary. Since boys are notoriously untrustable, in no case should the number of boys present at P or Q be larger than the number of girls, if any, present at the same place.

Representation of states

As the motorbike (M), the three boys (B) and the three girls (G) must be either at P or at Q, it is sufficient to represent which of them is at one of the two places, for example at P.

The representation of the objects that are present at P may take the form $\langle M,B,G \rangle$, where:

- $M \in \{0,1\}$: 1 means that the motor bike is at P, 0 means that it is not at P, and is therefore at Q;
- $B \in [0..3]$: B is the number of boys currently at P, therefore $3-B$ is the number of boys currently at Q;
- $G \in [0..3]$: G is the number of girls currently at P, therefore $3-G$ is the number of girls currently at Q.

Definition of actions

Exactly 10 different actions are possible, but we can represent them as two different parametric actions, each with two parameters. The two actions will be PQ(b,g) and QP(b,g), where:

- b and g take values from [0..2] and respectively represent the number of boys and girls travelling with the motorbike from P to Q (in the case of action PQ(b,g)) or from Q to P (in the case of action PQ(b,g)).

For example:

- QP(1,1): one boy and one girl use the motorbike to go from Q to P.

The applicability conditions and the effects of such actions can be described as follows. Note that:

B	number of boys at P before executing the action
G	number of girls at P before executing the action
$3-B$	number of boys at Q before executing the action
$3-G$	number of girls at Q before executing the action
$B-b$	number of boys remaining at P after the execution of the action
$G-g$	number of girls remaining at P after the execution of the action
$3-B+b$	number of boys that will be at Q after the execution of the action
$3-G+g$	number of girls that will be at Q after the execution of the action

PQ(b,g):

can be executed in state $\langle M,B,G \rangle$ iff:

$1 \leq (b+g) \leq 2$	at least one and no more than two people travel on the motorbike
$(b \leq B)$ and $(g \leq G)$	the people travelling on the motorbike were at P
$M = 1$	the motorbike is at P
$(g = G)$ **or** $(B-b \leq G-g)$	either no girl remains at P, or the number of boys remaining at P does not exceed the number of girls remaining at P
$(G-g = 3)$ **or** $(3-B+b \leq 3-G+g)$	either no girl will be at Q, or the number of boys that will be at Q does not exceed the number of girls that will be at Q

has the effects:

$M = 0$

$B = B-b$

$G = G-g$

QP(b,g):

analogous to PQ(b,g).

Definition of the initial state

The initial state is: $\langle 1,3,3 \rangle$

Definition of the goal states

The set of goal states is: $\langle *,0,0 \rangle$, where $*$ is either 0 or 1. (It is easy to see that the final value of M must be 0, but we need not give this piece of information to the search procedure.)

Choice of the search strategy

BF graph search (feasible because the search space is small) or ID.

A* does not seem to be an interesting option, because it is difficult to see when a state is 'closer' to the goal than another state.

A solution of length 11:

action	state
	$\langle 1,3,3 \rangle$ (initial)
PQ(2,0)	$\langle 0,1,3 \rangle$
QP(1,0)	$\langle 0,2,3 \rangle$
PQ(2,0)	$\langle 0,0,3 \rangle$
QP(1,0)	$\langle 1,1,3 \rangle$
PQ(0,2)	$\langle 0,1,1 \rangle$
QP(1,1)	$\langle 1,2,2 \rangle$
PQ(0,2)	$\langle 0,2,0 \rangle$
QP(1,0)	$\langle 1,3,0 \rangle$
PQ(2,0)	$\langle 0,1,0 \rangle$
QP(1,0)	$\langle 1,2,0 \rangle$
PQ(2,0)	$\langle 0,0,0 \rangle$