BDI on Time

“the future of BDI is in the future”

first week of July 2023

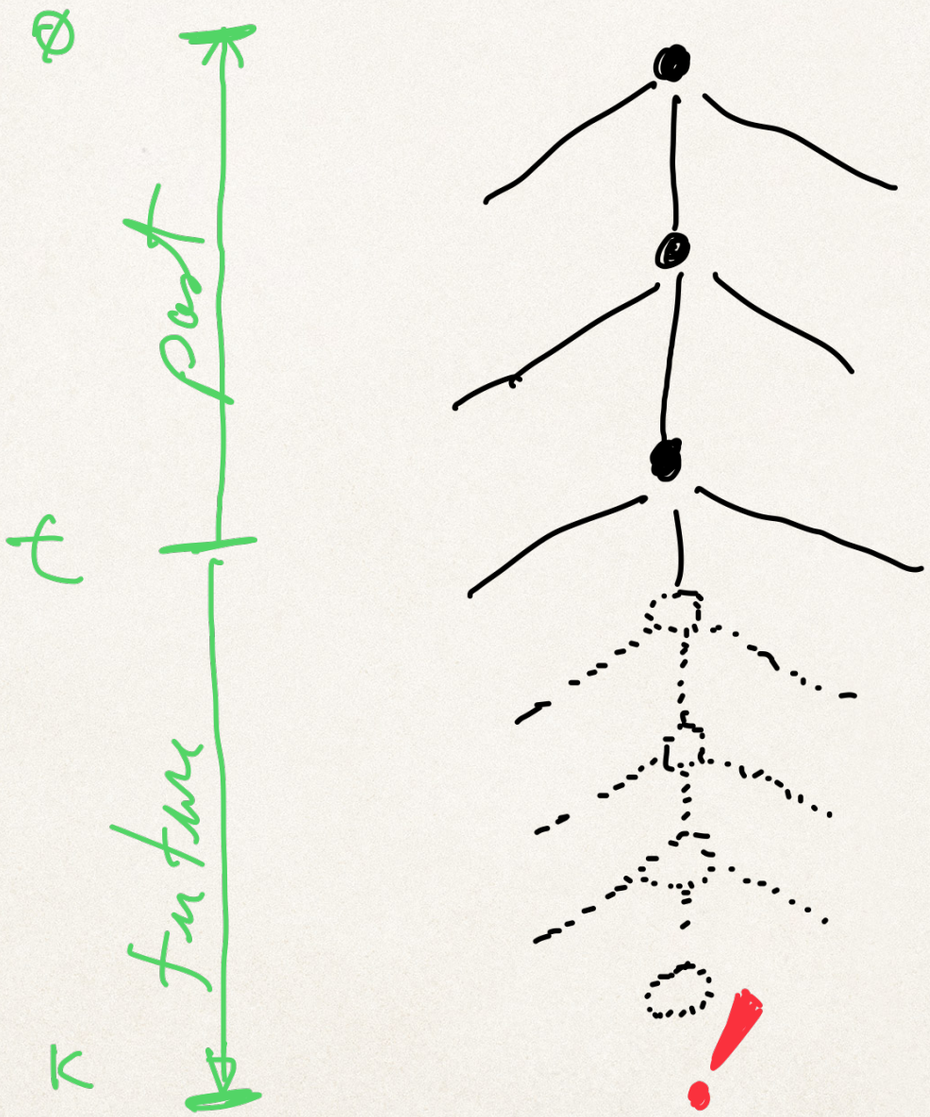
Agenda

- simulating the future
- agent deliberation based on future
- (initial) experiments
- single & multi-agent

Motivations To Consider Future & BDI

- BDI agents may do better (rational) decisions by *looking ahead*
- Foresee problems
- Realize better options
- …

Future Simulation



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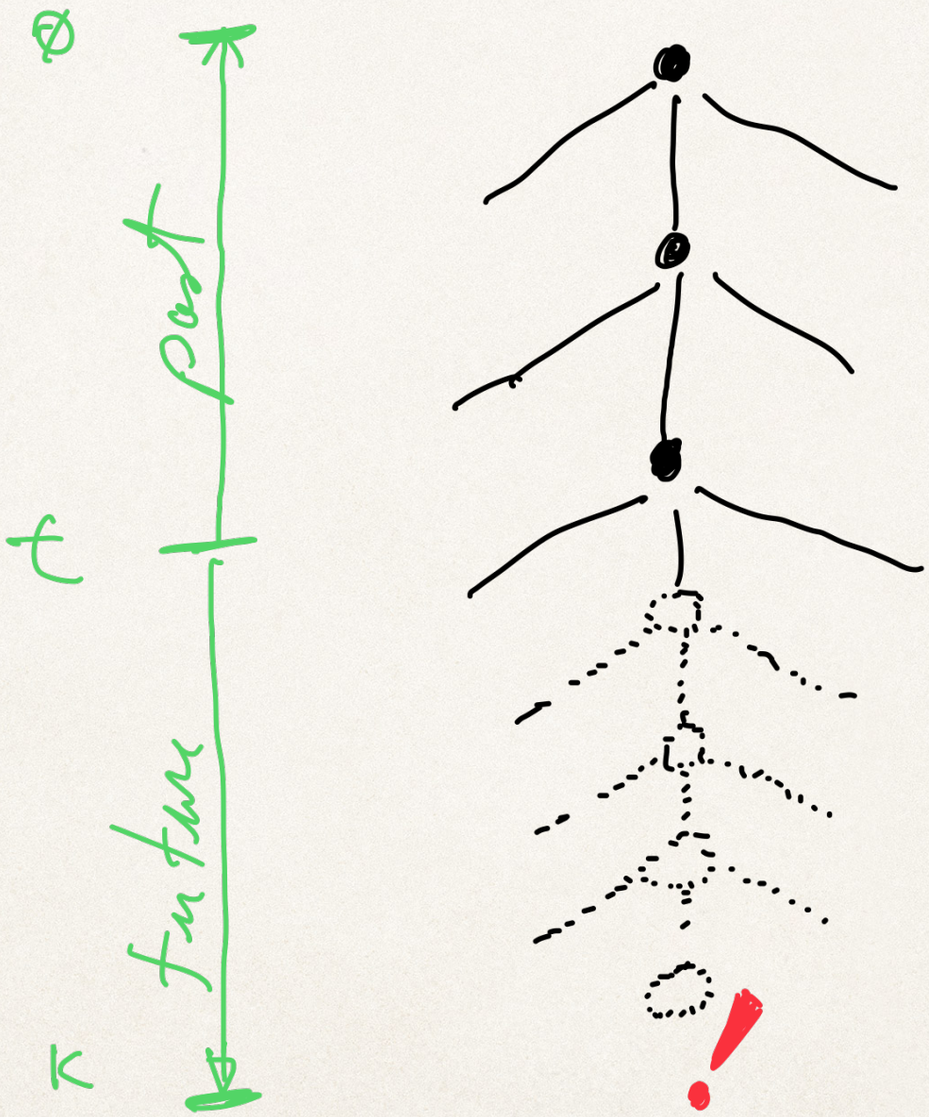


environment transitions

$$e : S \times A \to S$$

agent policy (as ordered options)

$$\pi : S \to A^n$$

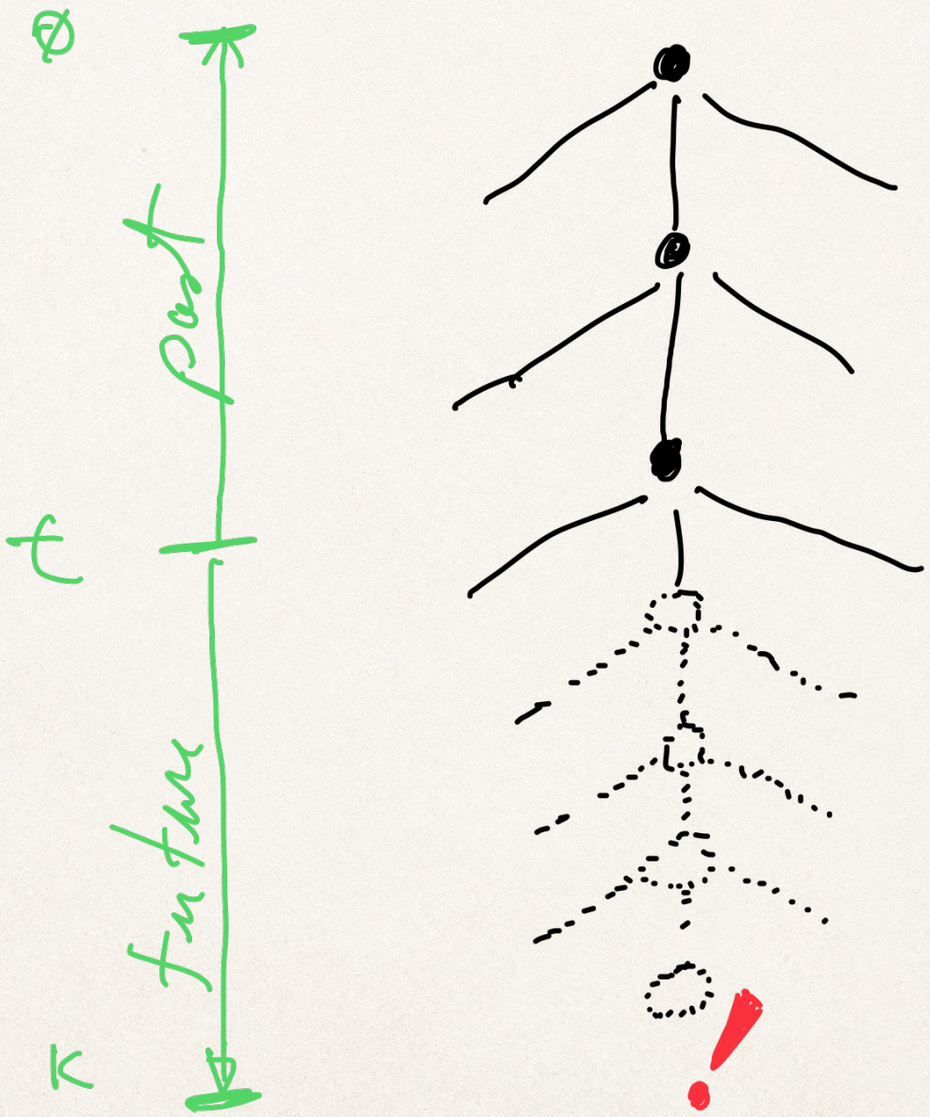
future state at k

$$f : S \times \mathbb{N} \times \mathbb{N} \to S$$

$$f(s,t,k) = \begin{cases} s & \text{if } t = k \\ f(s', t+1, k) & \text{if } t < k \end{cases}$$

$$s' = e(s, \pi(s)_1)$$

Future Simulation



fully observable

deterministic

single-agent

static

discret

envi

e :

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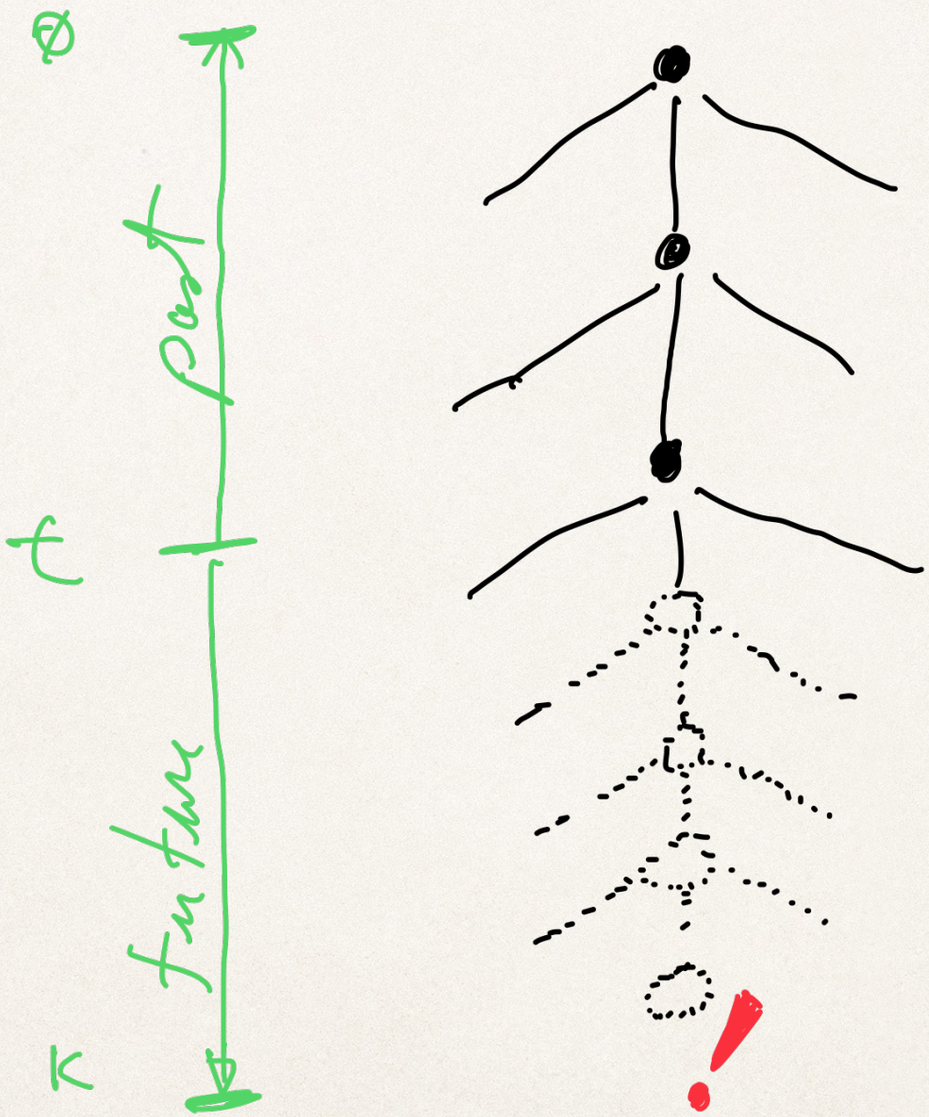
Types of Problem

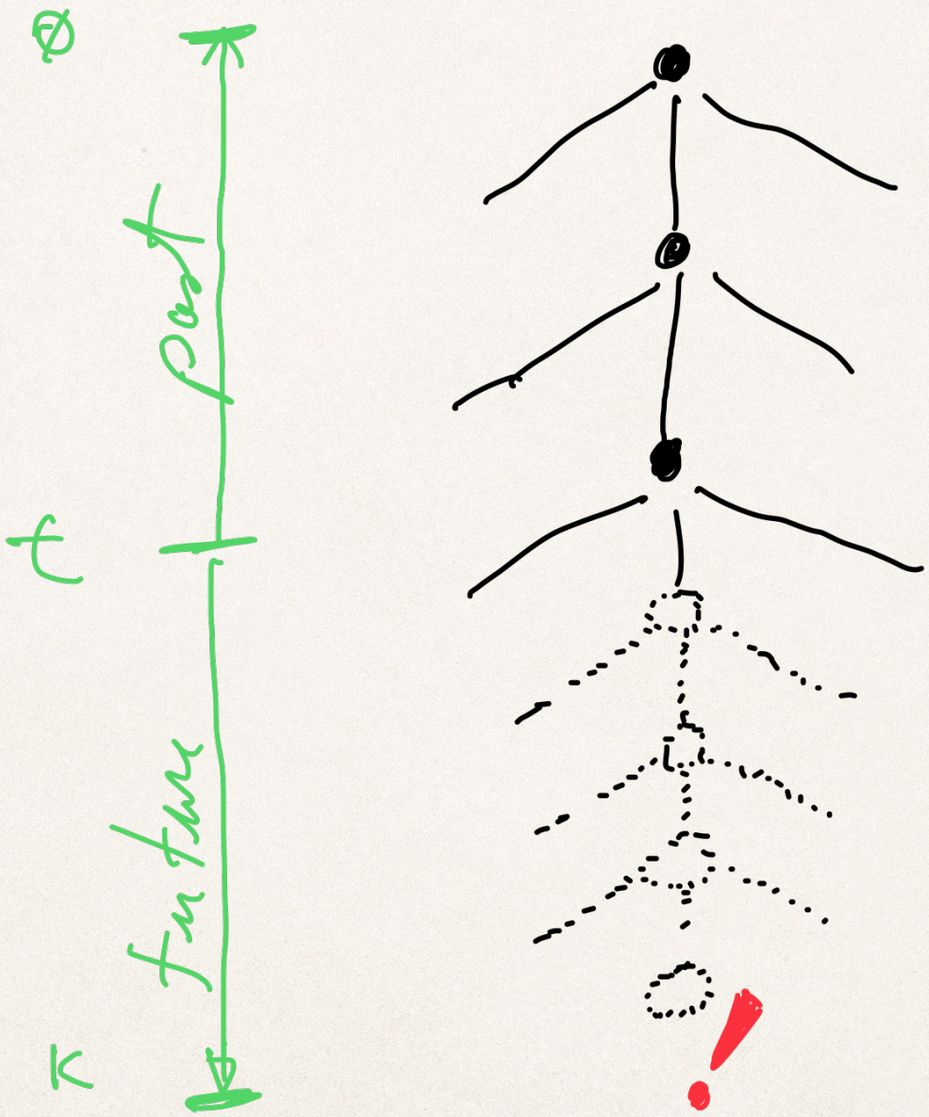


- internal:
  - no option, goal not achieved
  - norm / principle violation
  - ethical issues

- external:
  - undesired state
  - ethical issues

- …

What To Do?



- stop
- reconsider options
  - now (t)
  - near the problem (k)
  - in the past (0..t)
    (requires backtrack of actions)
- give up the intention

What To Do?

- stop
- reconsider options

what caused the problem?
[very difficult to answer]
[I will skip that]

actions)

- give up the intention

What To Do?

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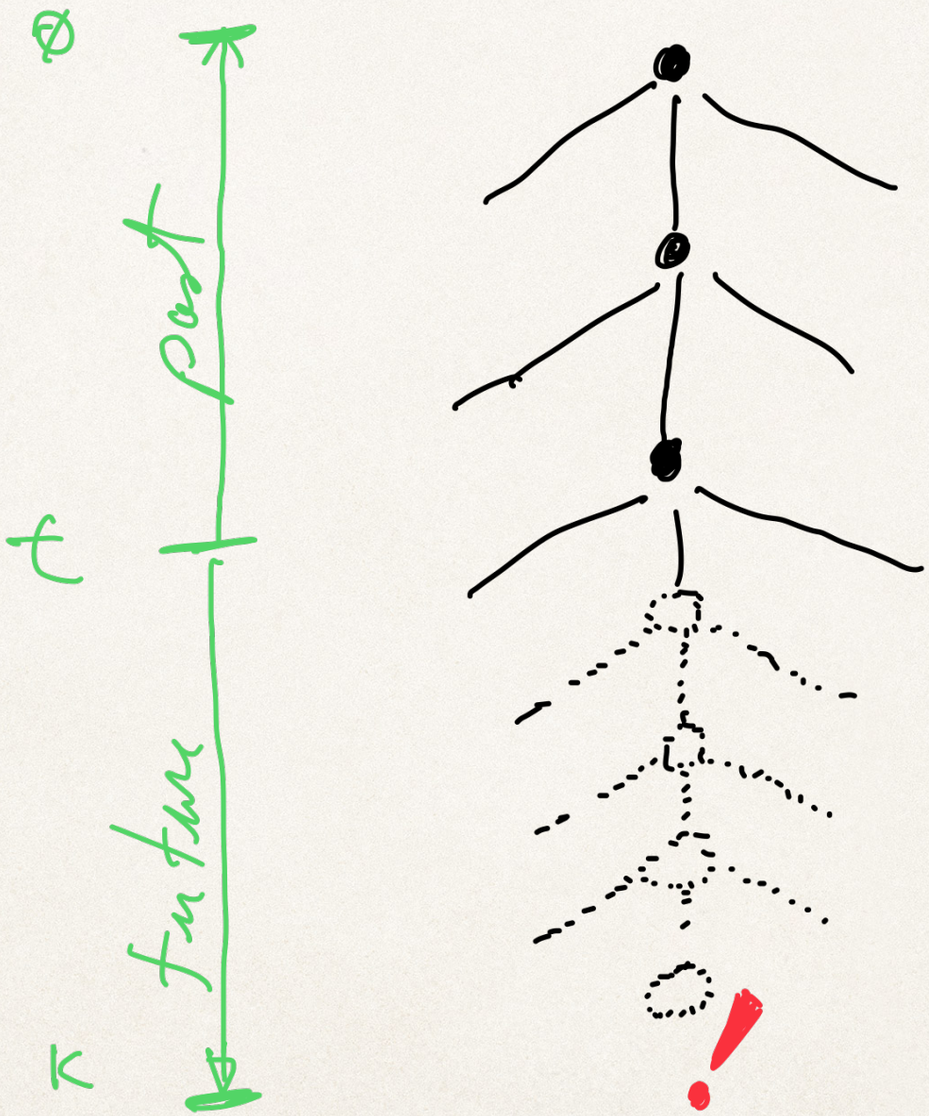
- reconsider options

what caused the problem?
[very difficult to answer]
[I will skip that]

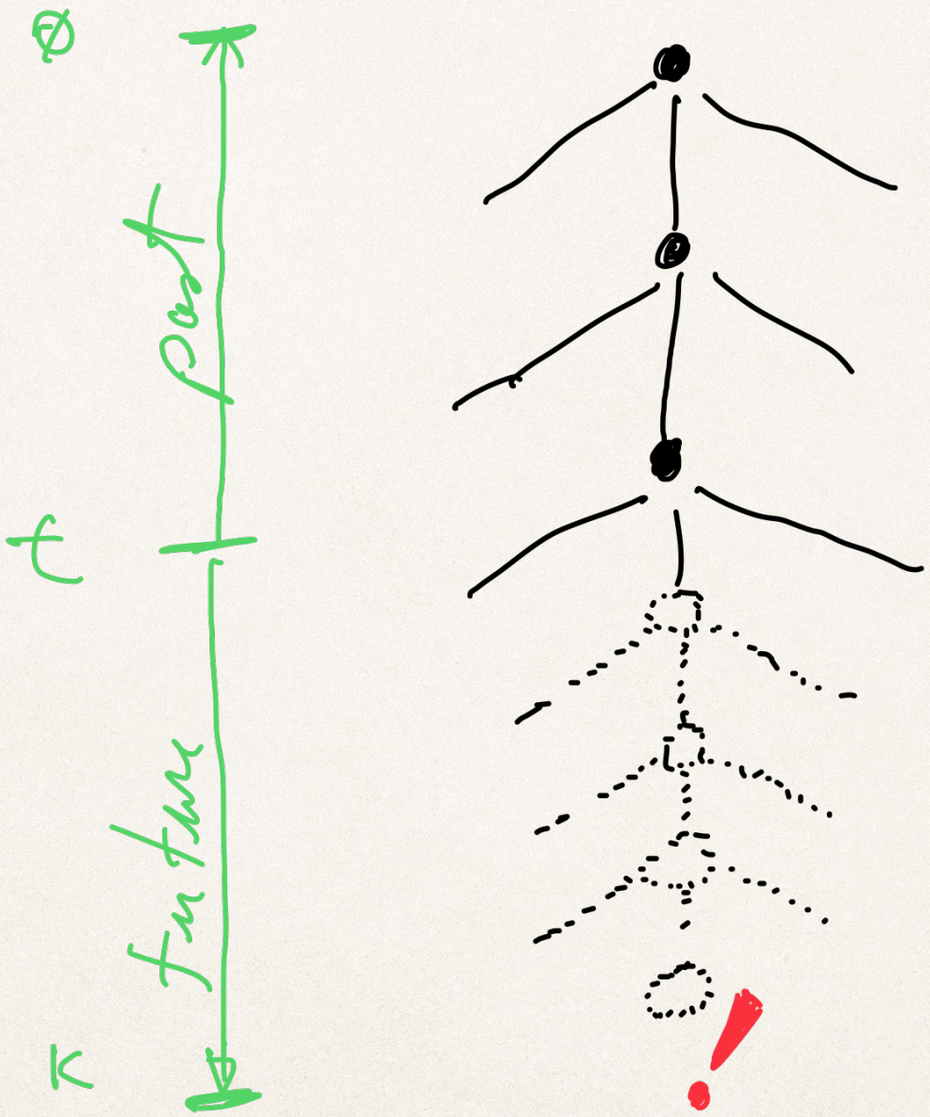
select an option with “nice” future [without problems]

(Initial) Delimitations



- revise options from now on ($t..k$)
- what option?
  [revision strategy]

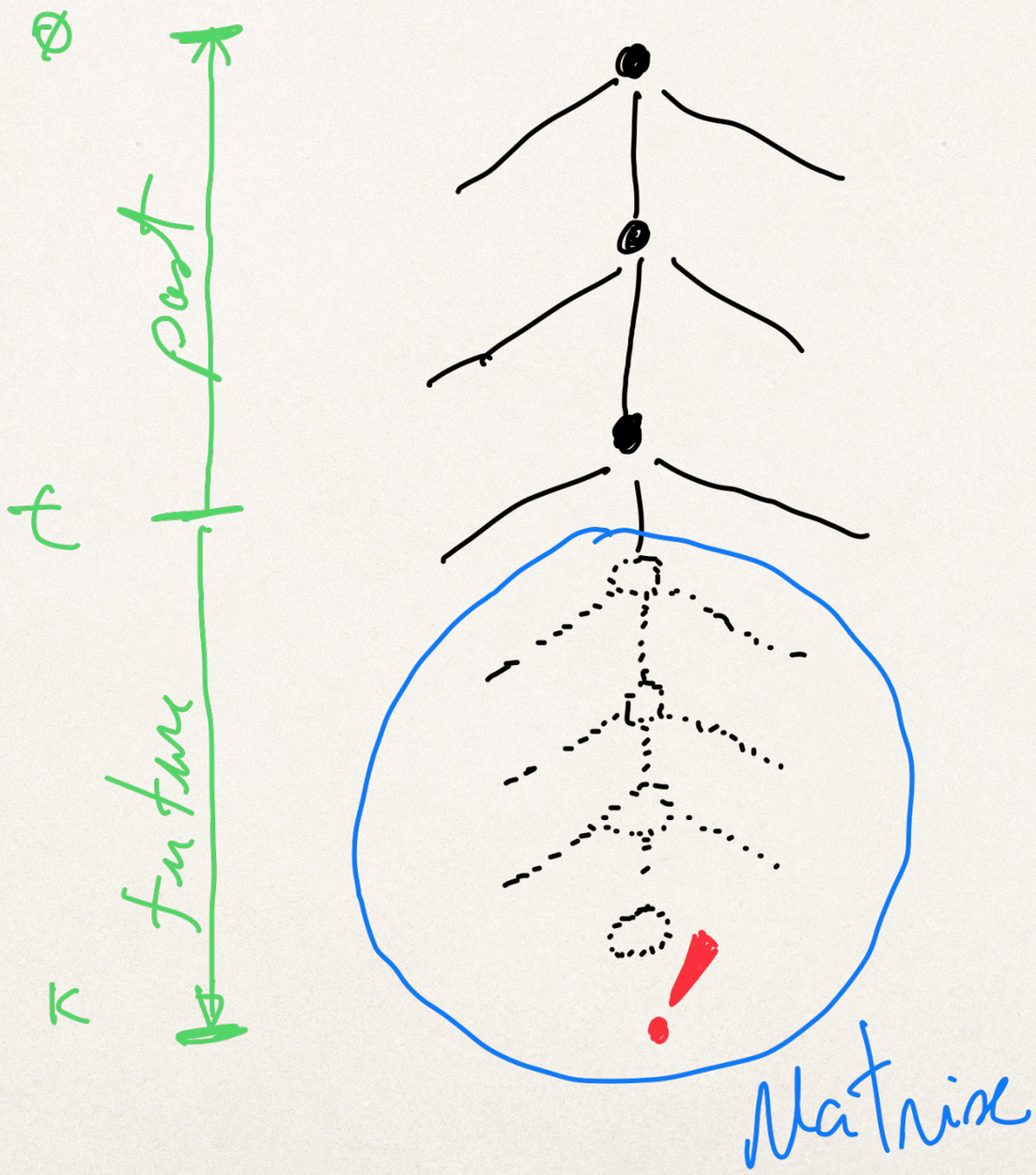
(Initial) Delimitations



- revise options from now on ($t..k$)
- what option?
  [revision strategy]

```
move to experiments to
help to answer
```

Jason(F)

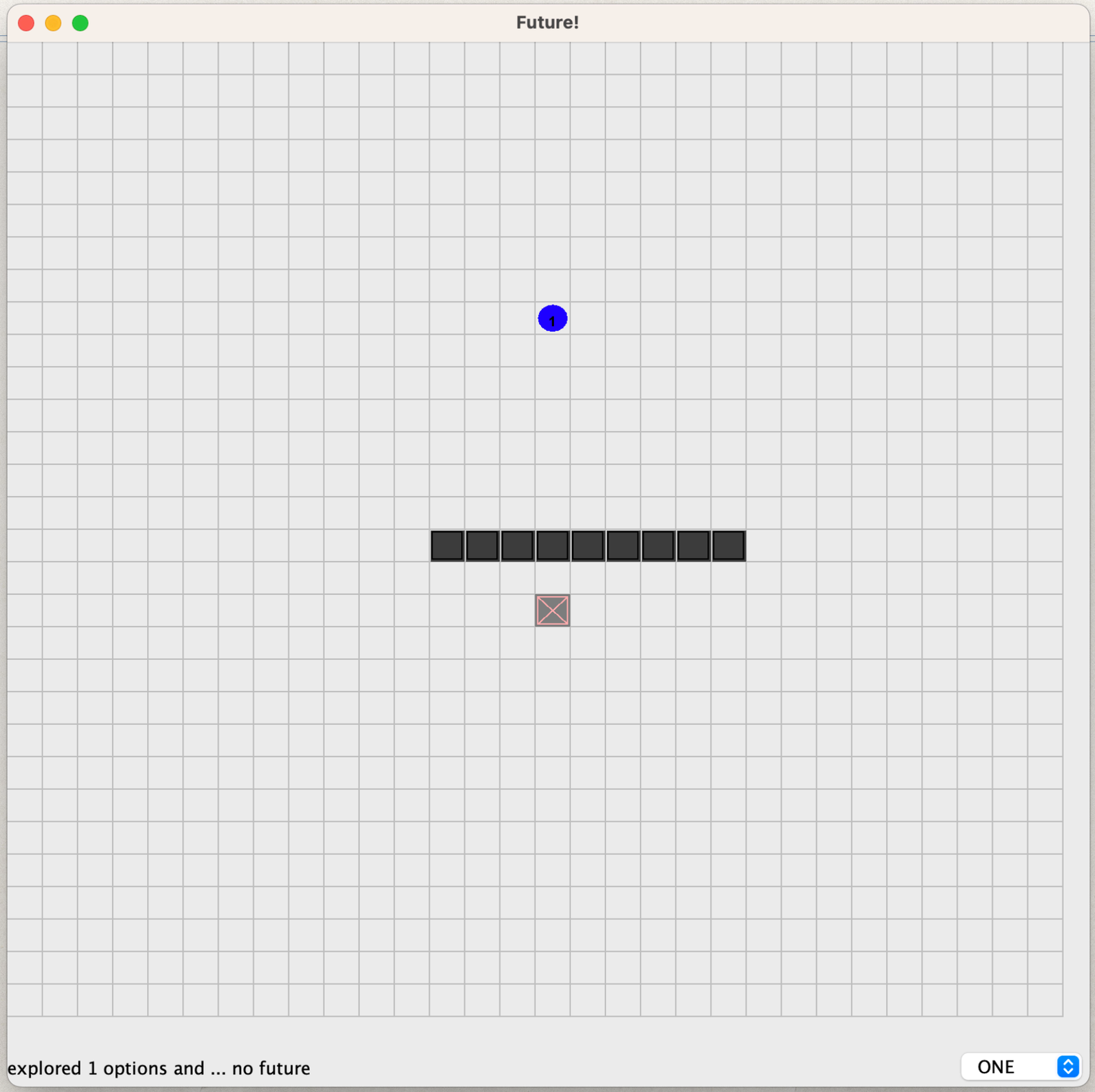


execution modes:
- normal
- **matrix** mode
  (simulated environment)

at time *t*:
- clone itself into another agent
- run it in the matrix
- until success, failure, timeout

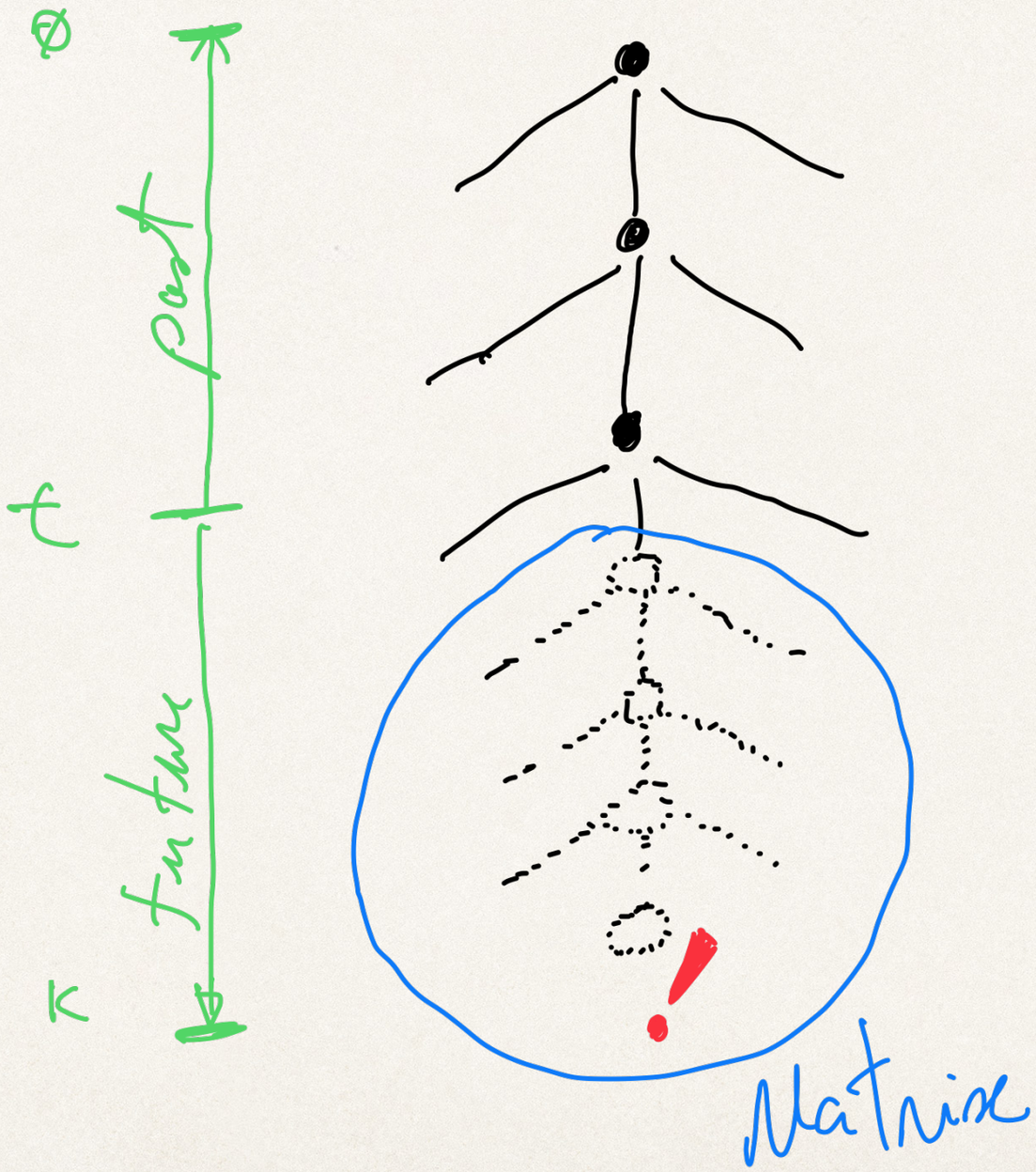
branching is given by plan options
[not actions]

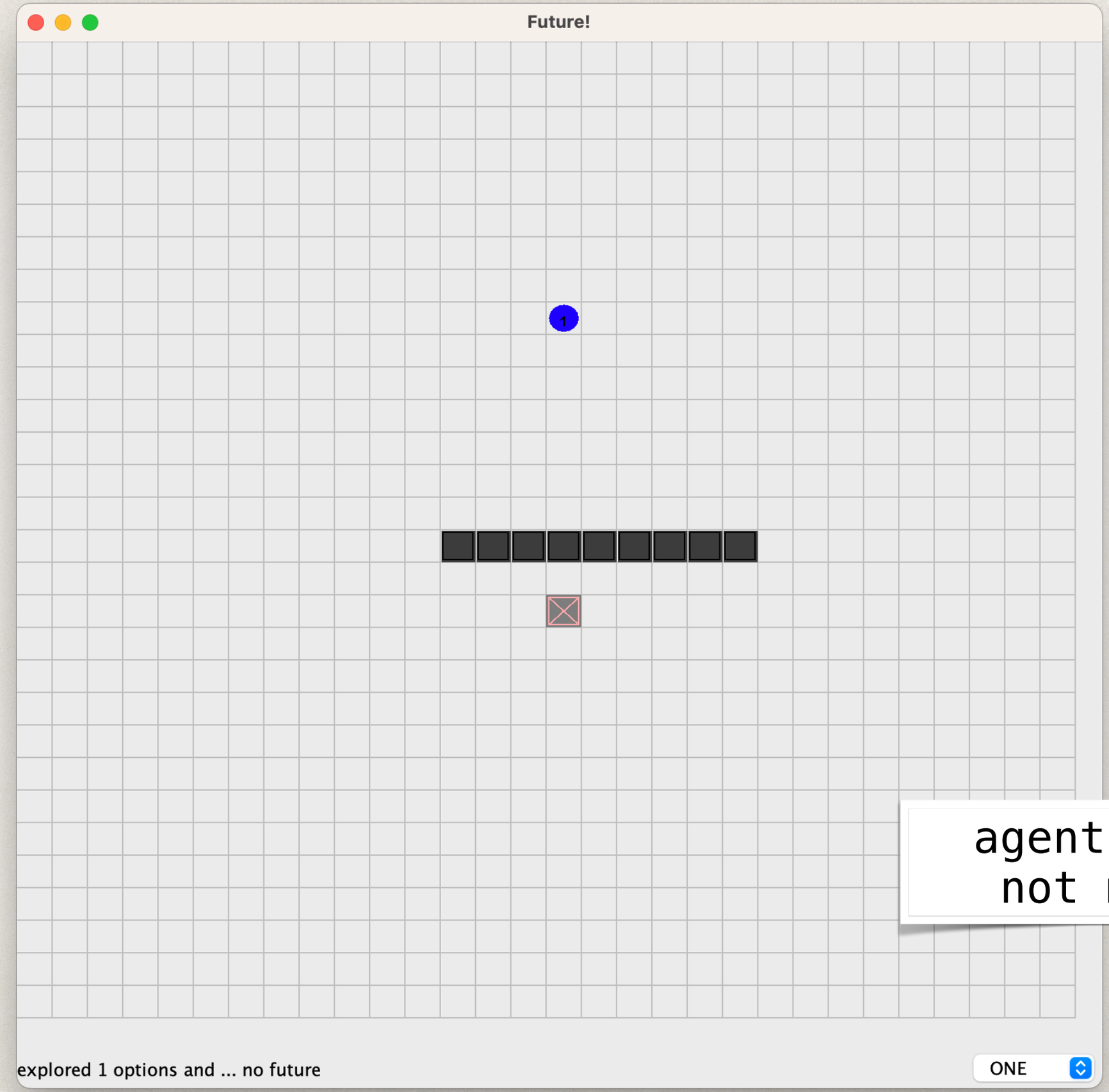
Grid Scenario



```
5  +destination(X,Y) <- !pos(X,Y). // create a goal when my destination is perceive
6  -destination(X,Y) <- .drop_all_desires. // drop everything if my destination is
7
8  @  [preference(0)] +!pos(X,Y) : pos(X,Y).
9  @s [preference(D)] +!pos(X,Y) : ok(s) & distance(s ,D) <- s;  !pos(X,Y).
10 @sw[preference(D)] +!pos(X,Y) : ok(sw)& distance(sw,D) <- sw; !pos(X,Y).
11 @se[preference(D)] +!pos(X,Y) : ok(se)& distance(se,D) <- se; !pos(X,Y).
12 @w [preference(D)] +!pos(X,Y) : ok(w) & distance(w ,D) <- w;  !pos(X,Y).
13 @e [preference(D)] +!pos(X,Y) : ok(e) & distance(e ,D) <- e;  !pos(X,Y).
14 @n [preference(D)] +!pos(X,Y) : ok(n) & distance(n ,D) <- n;  !pos(X,Y).
15 @nw[preference(D)] +!pos(X,Y) : ok(nw)& distance(nw,D) <- nw; !pos(X,Y).
16 @ne[preference(D)] +!pos(X,Y) : ok(ne)& distance(ne,D) <- ne; !pos(X,Y).
17
18 // checks if go to some direction is possible (free cell)
19 ok(D) :- next(D,X,Y) & free(X,Y).
20
21 next(s ,X  ,Y+1) :- pos(X,Y). // my next location if doing south
22 next(sw,X-1,Y+1) :- pos(X,Y).
23 next(se,X+1,Y+1) :- pos(X,Y).
24 next(w ,X-1,Y  ) :- pos(X,Y).
25 next(e ,X+1,Y  ) :- pos(X,Y).
26 next(n ,X  ,Y-1) :- pos(X,Y).
27 next(nw,X-1,Y-1) :- pos(X,Y).
28 next(ne,X+1,Y-1) :- pos(X,Y).
29
30 free(X,Y) :- X >= 0 & Y >= 0 & w_size(W,H) & X < W & Y < H & not obstacle(X,Y).
31 distance(Dir,Dist) :- next(Dir,X,Y) & destination(GX,GY) &
32                        Dist = math.sqrt( (X-GX)**2 + (Y-GY)**2 ).
```

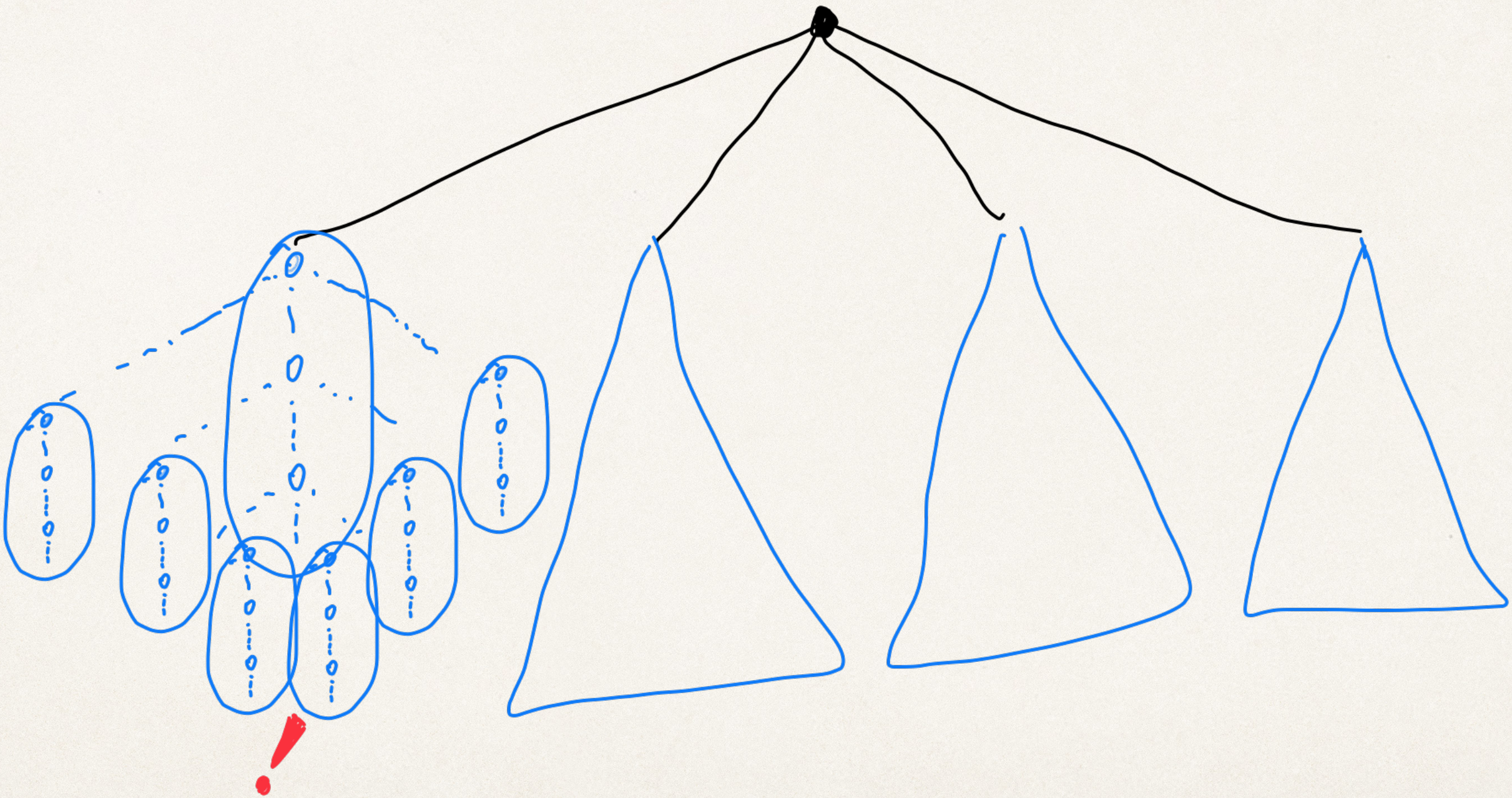
Strategy ONE





agent does not move

Strategy SOLVE_P —Search Tree



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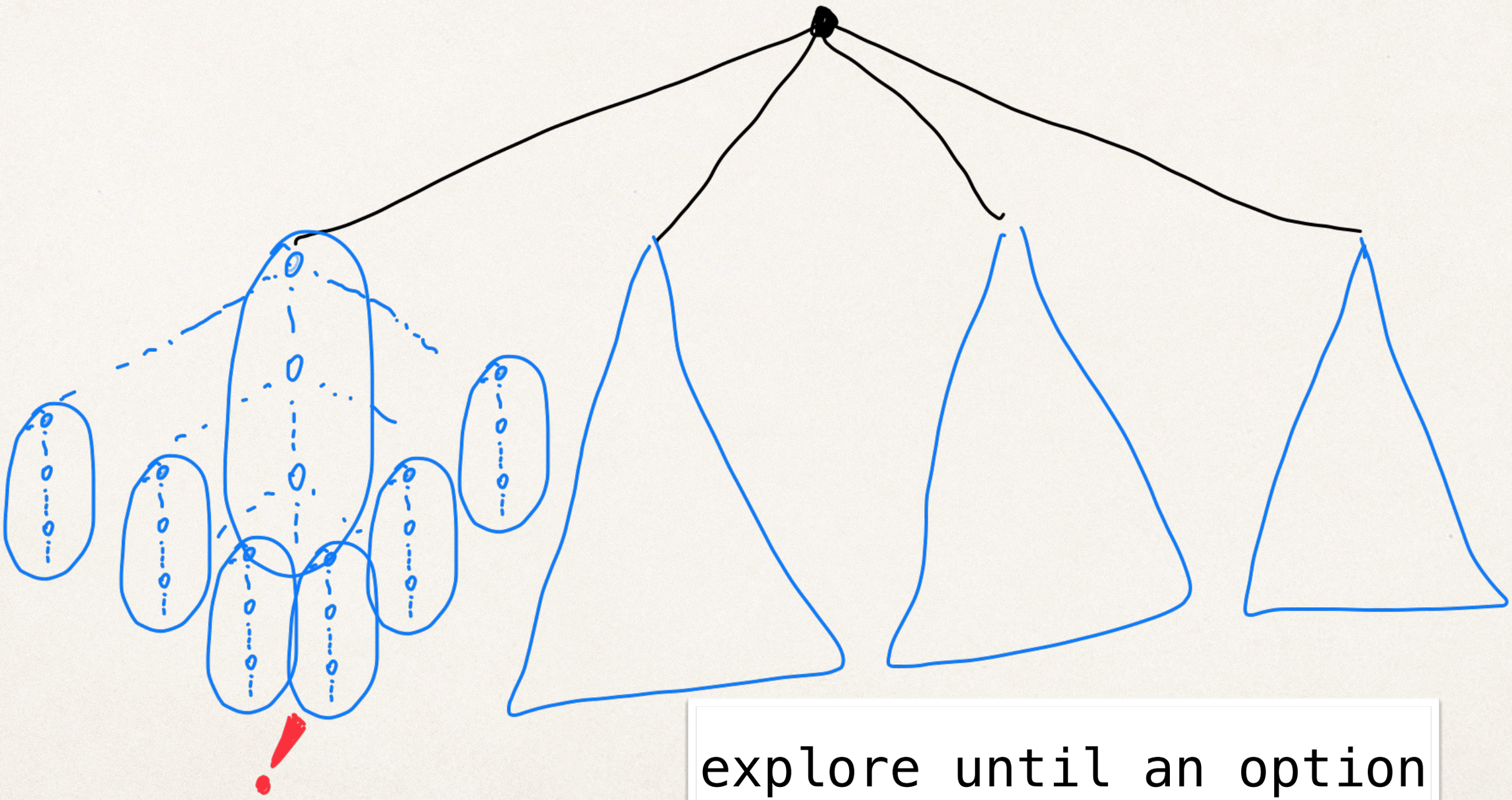
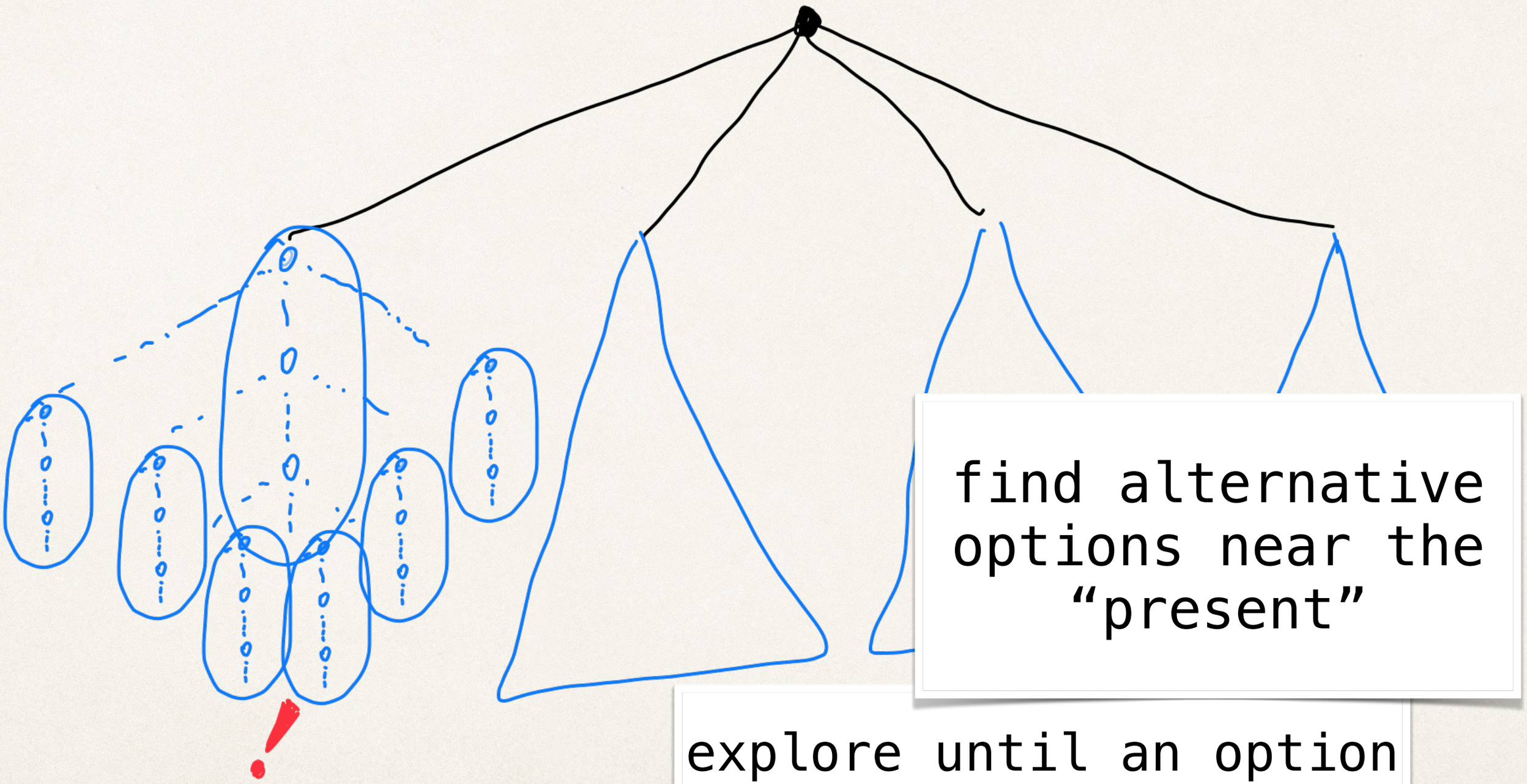


explore until an option leads to a good future

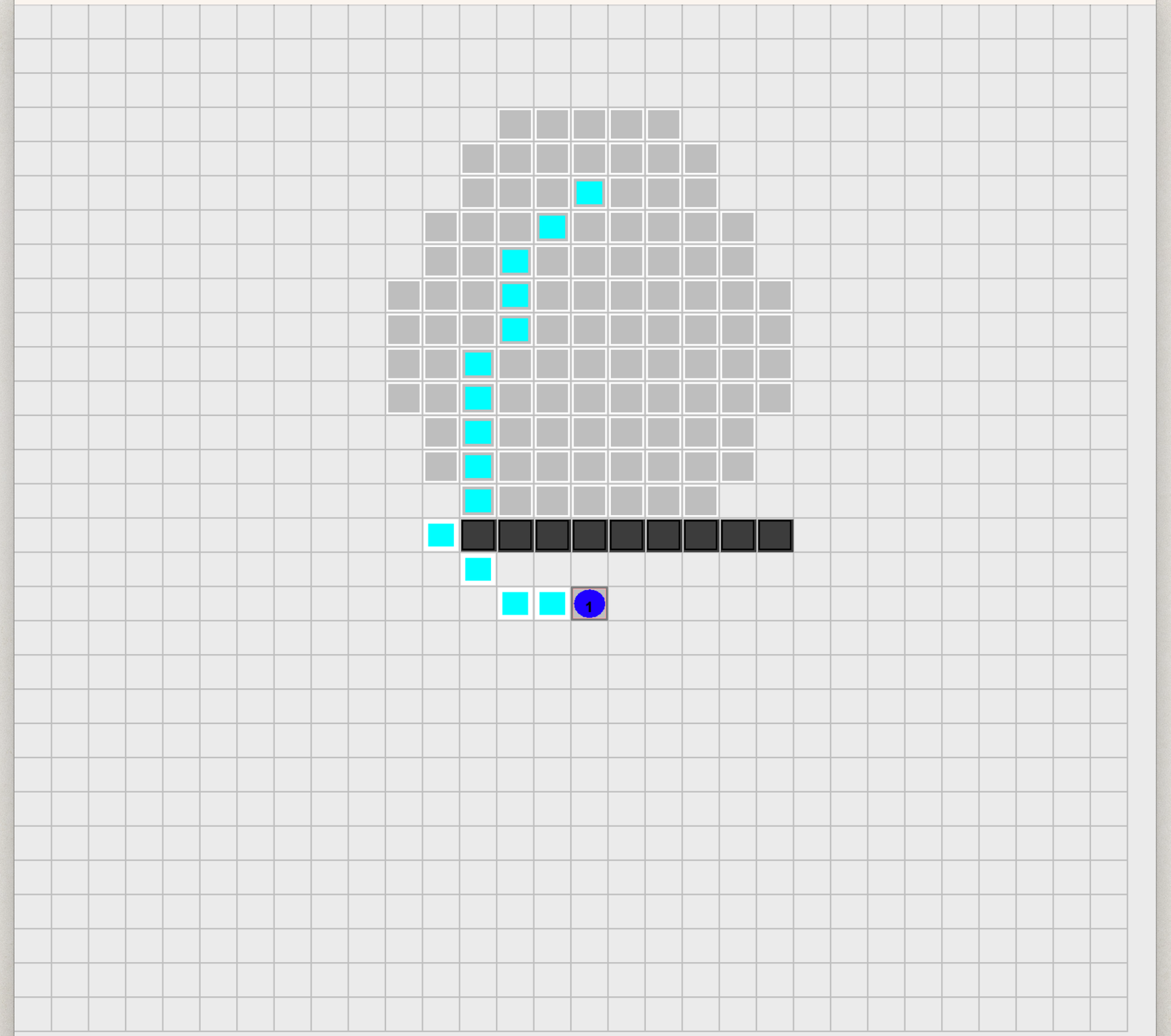
Strategy SOLVE_P —Search Tree



find alternative options near the “present”

explore until an option leads to a good future

Future!

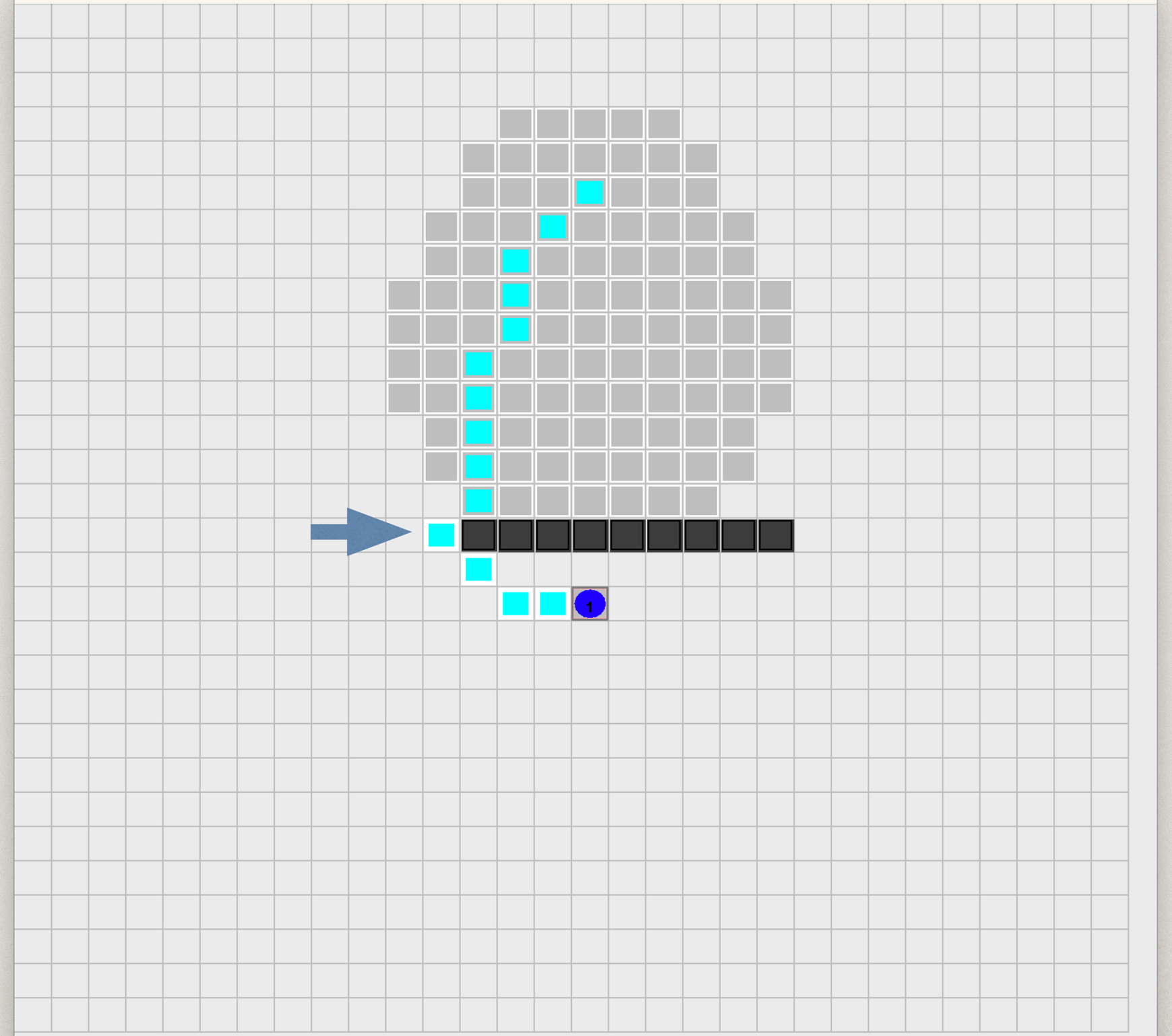


explored 542 options to find a nice future. depth=16 visited=7307.

SOLVE_P

--

Future!



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SOLVE_P

--

point where the agent can follow its policy again

Future!

explored 542 options to find a nice future. depth=16 visited=7307.

SOLVE_P

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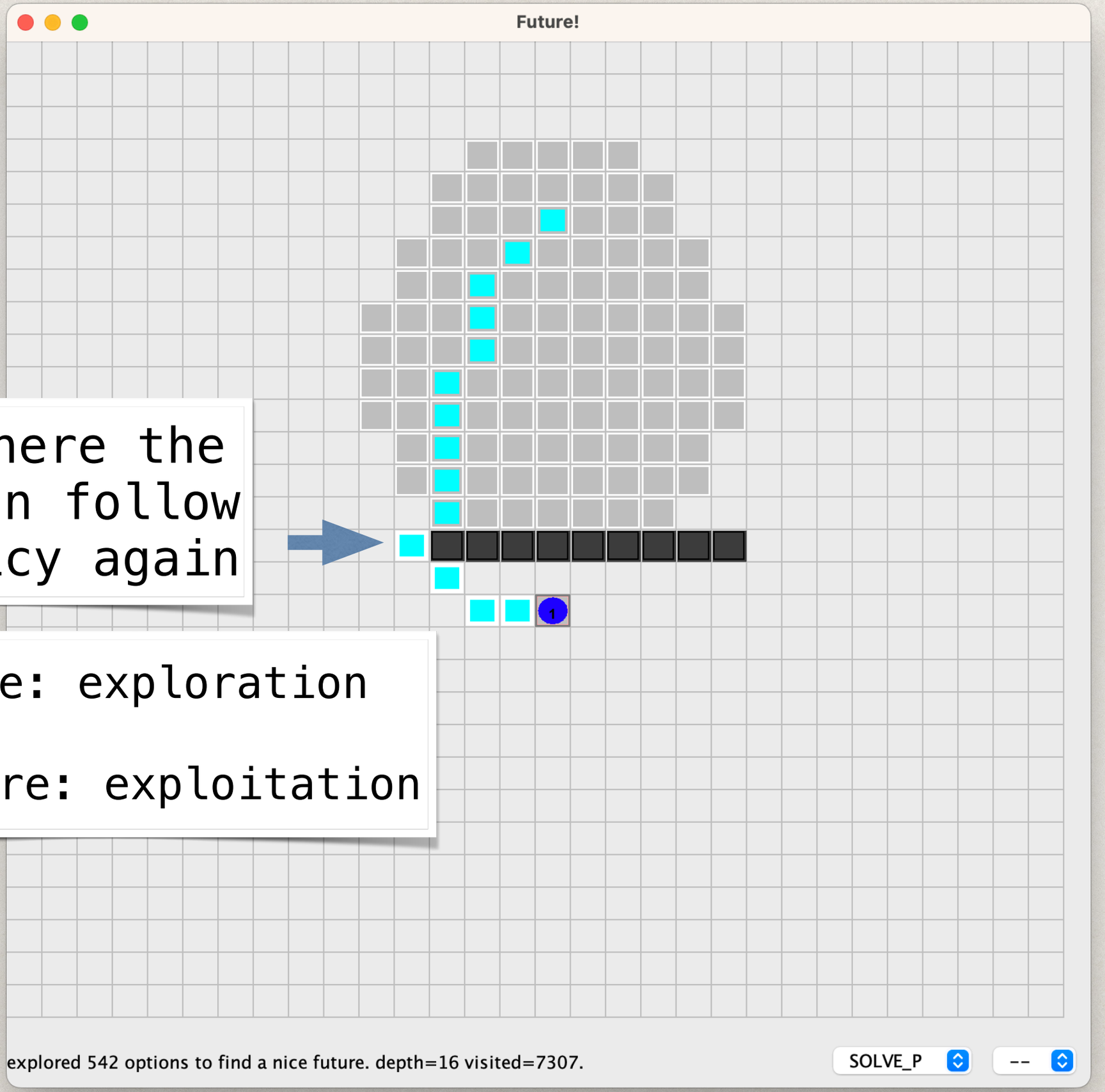
point where the agent can follow its policy again

before: exploration

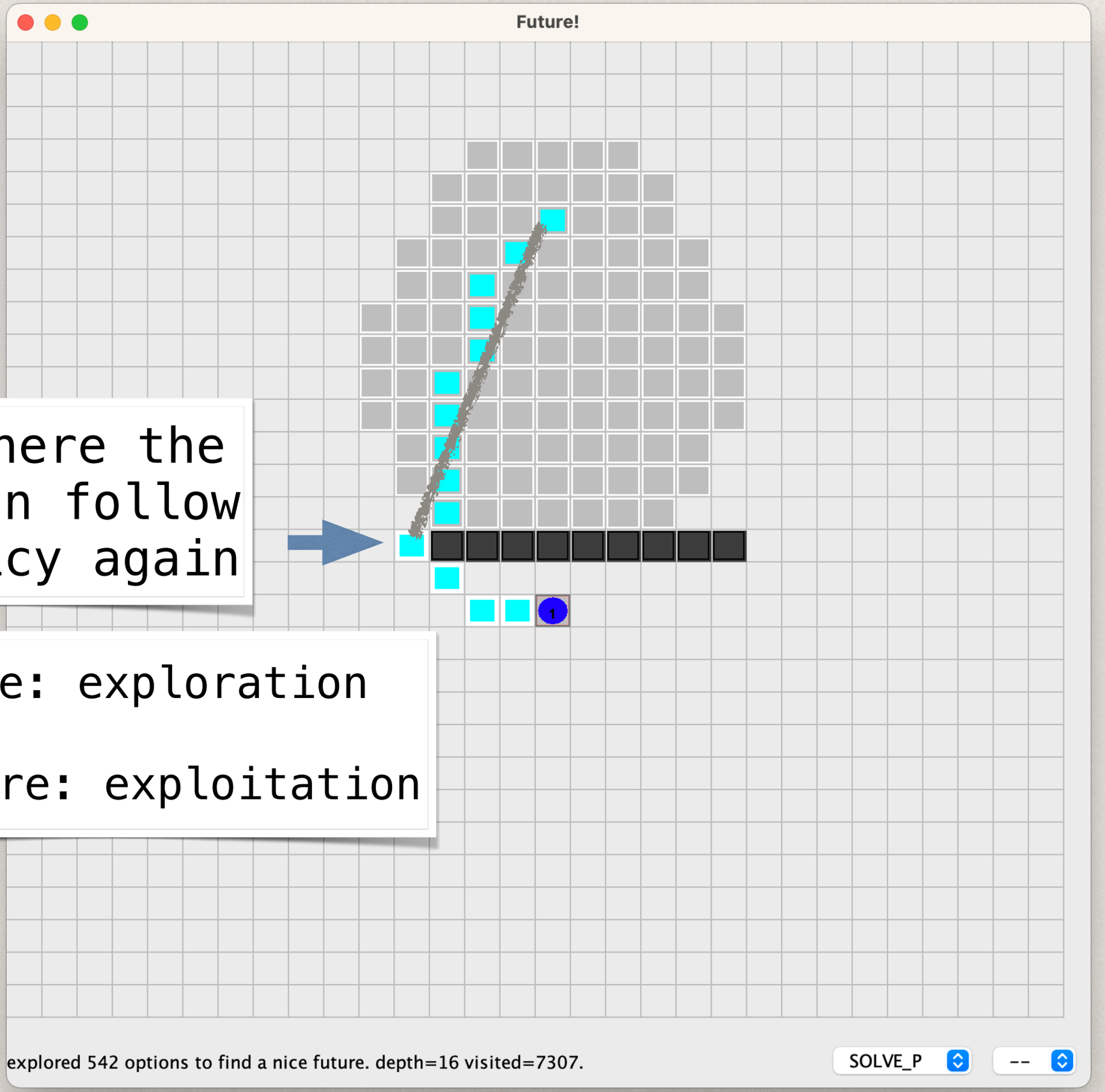
from here: exploitation



point where the agent can follow its policy again

before: exploration

from here: exploitation

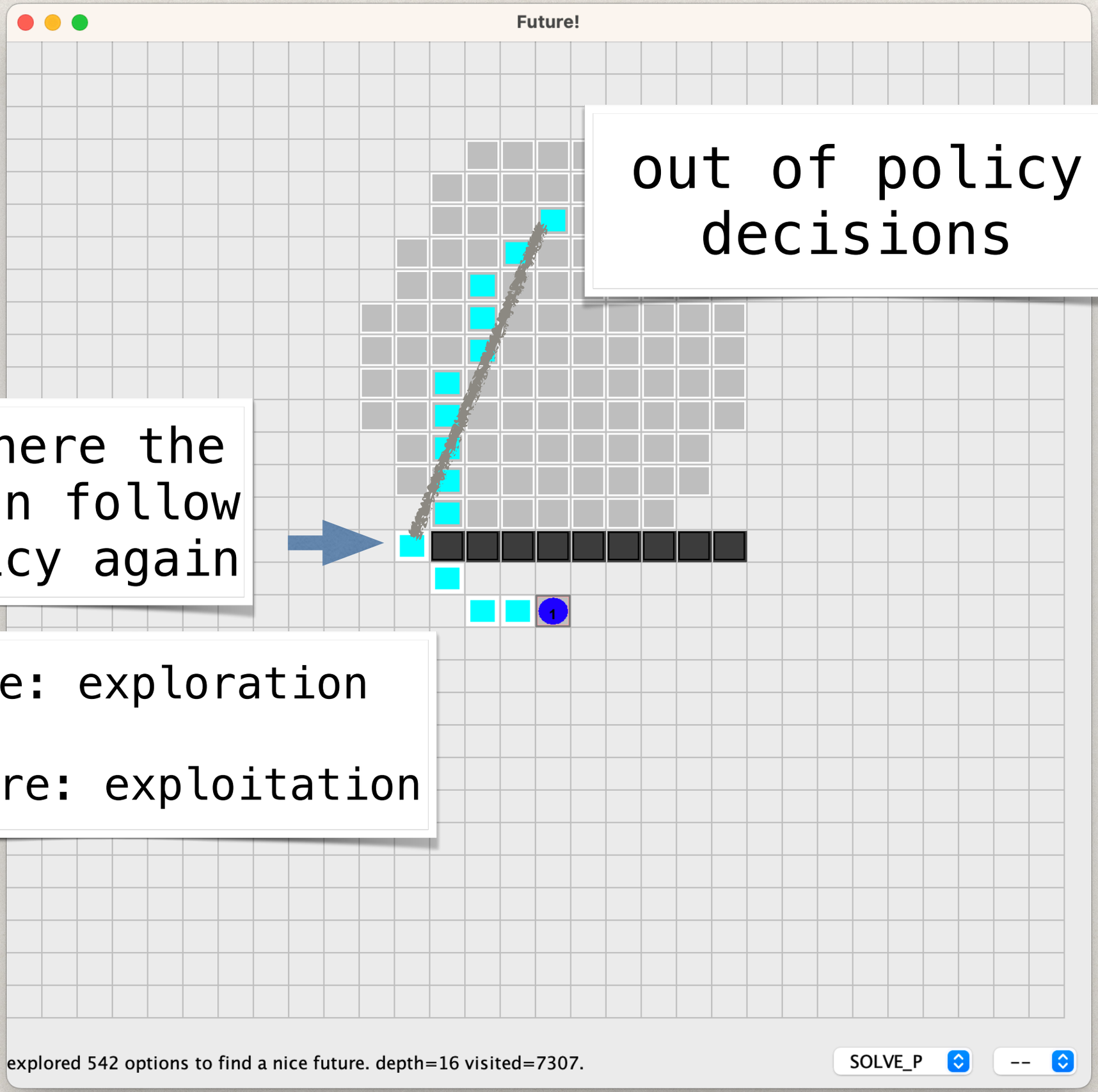


point where the agent can follow its policy again

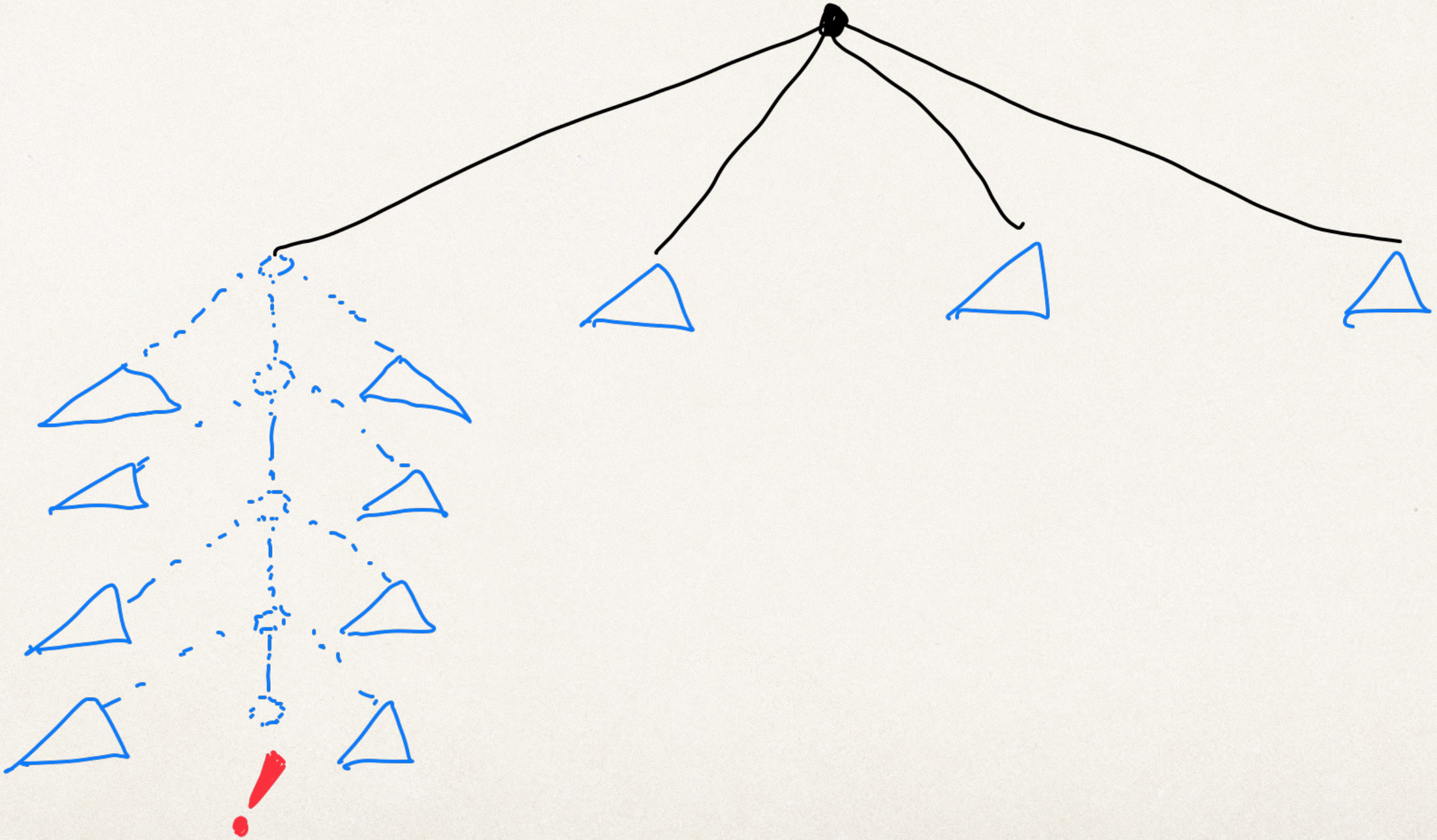
out of policy decisions

before: exploration

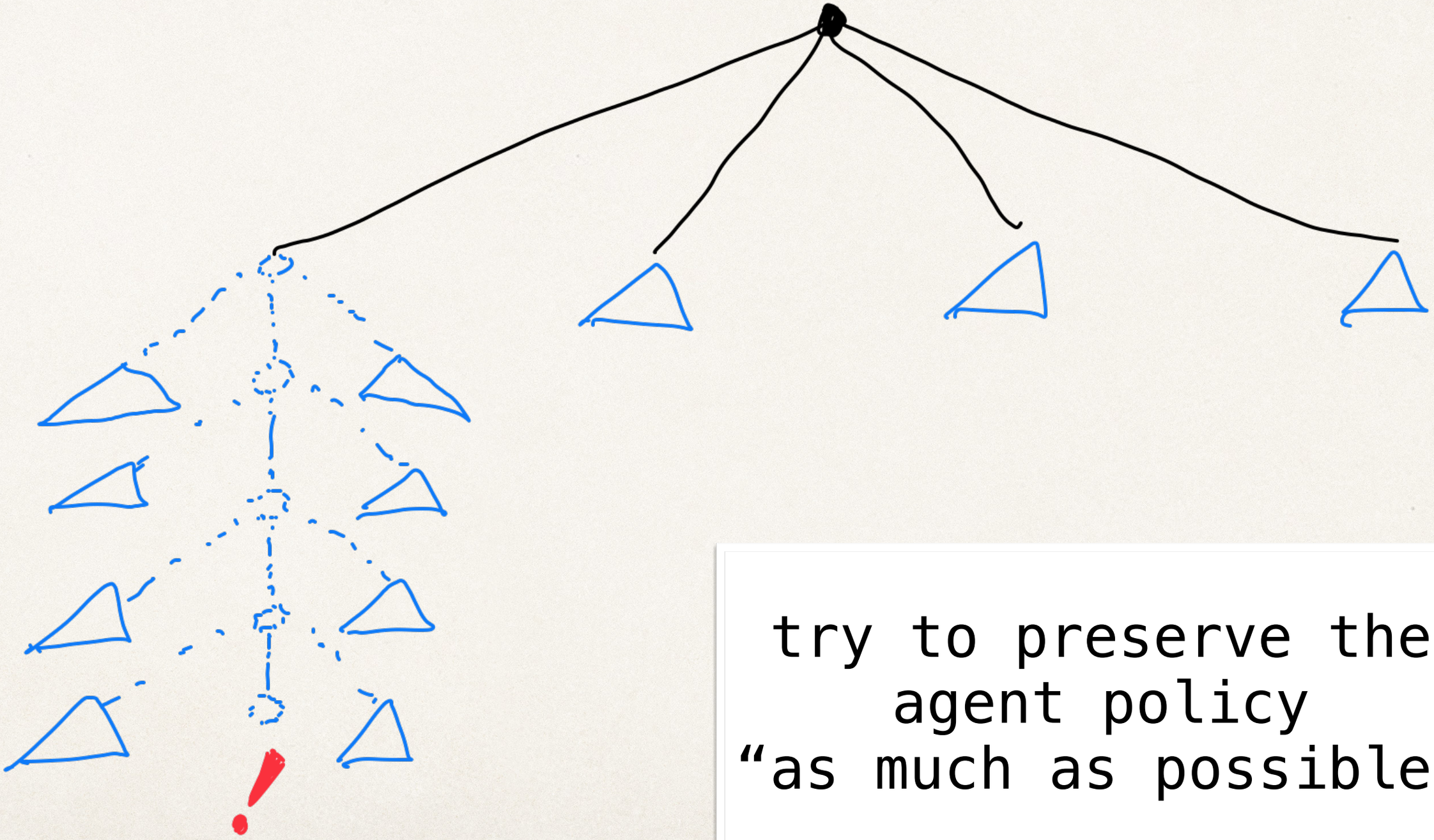
from here: exploitation



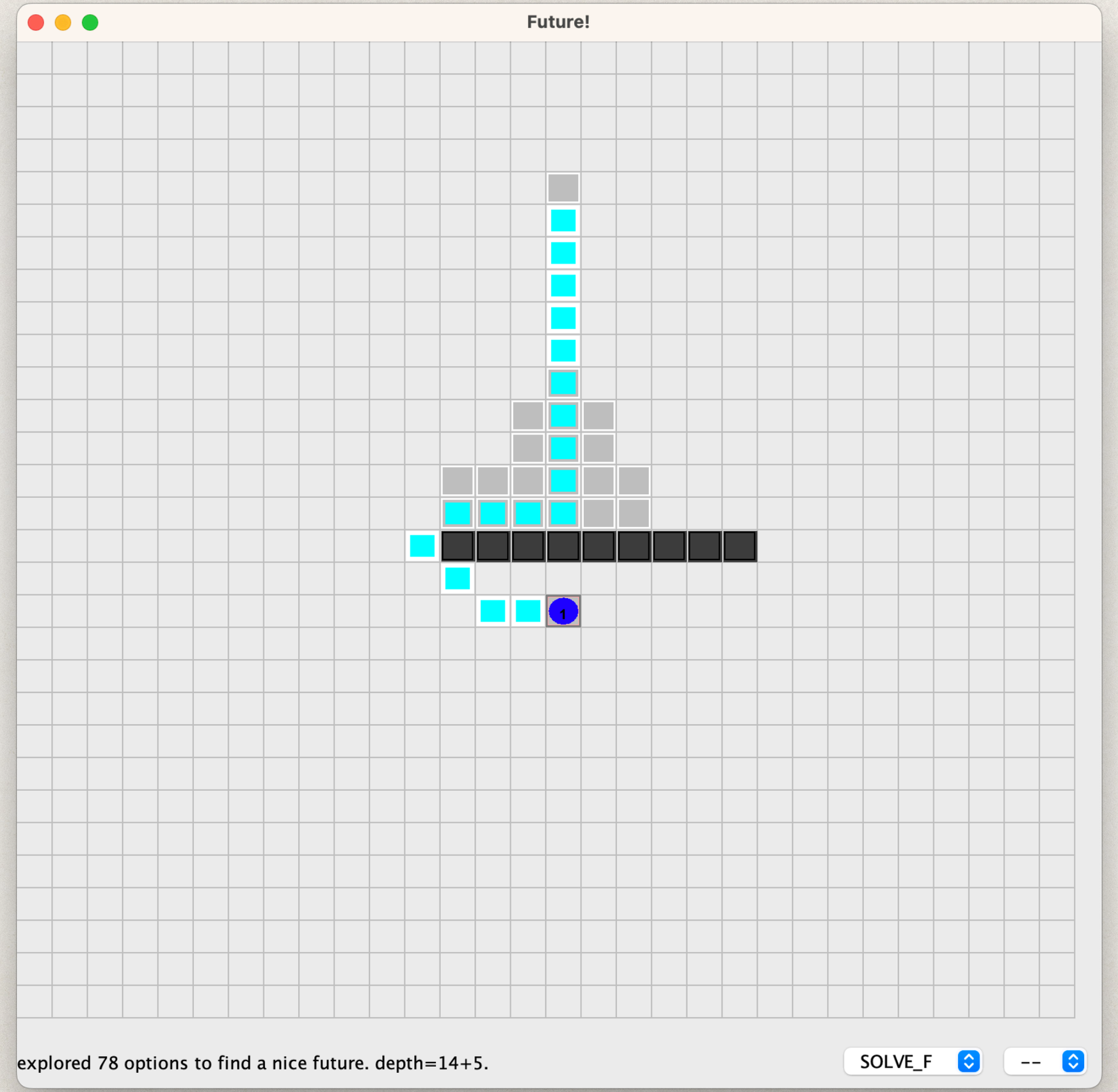
Strategy SOLVE_F

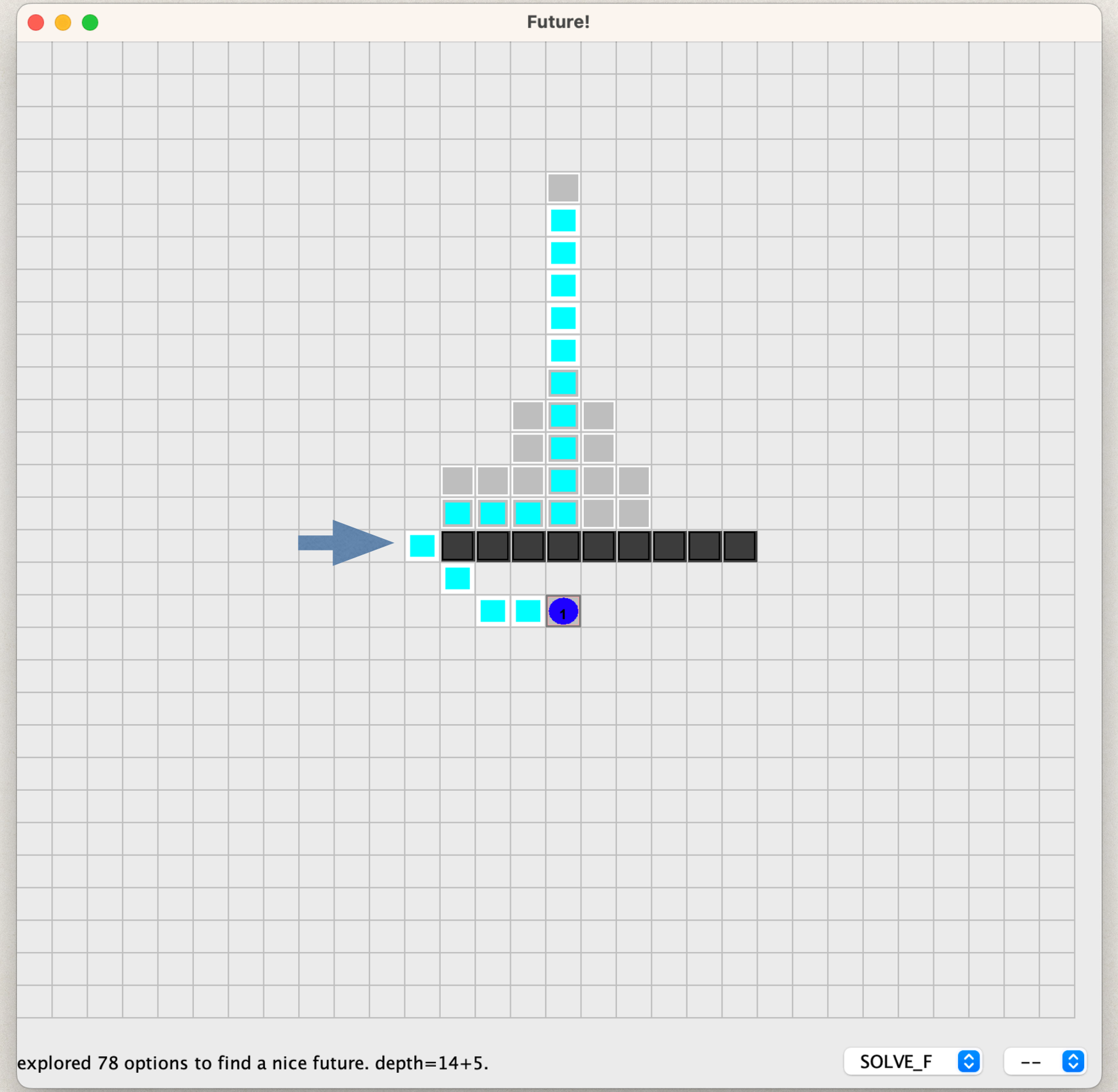


Strategy SOLVE_F



try to preserve the
agent policy
“as much as possible”


Future!
1
explored 78 options to find a nice future. depth=14+5.
SOLVE_F
--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point where the agent can follow its policy again

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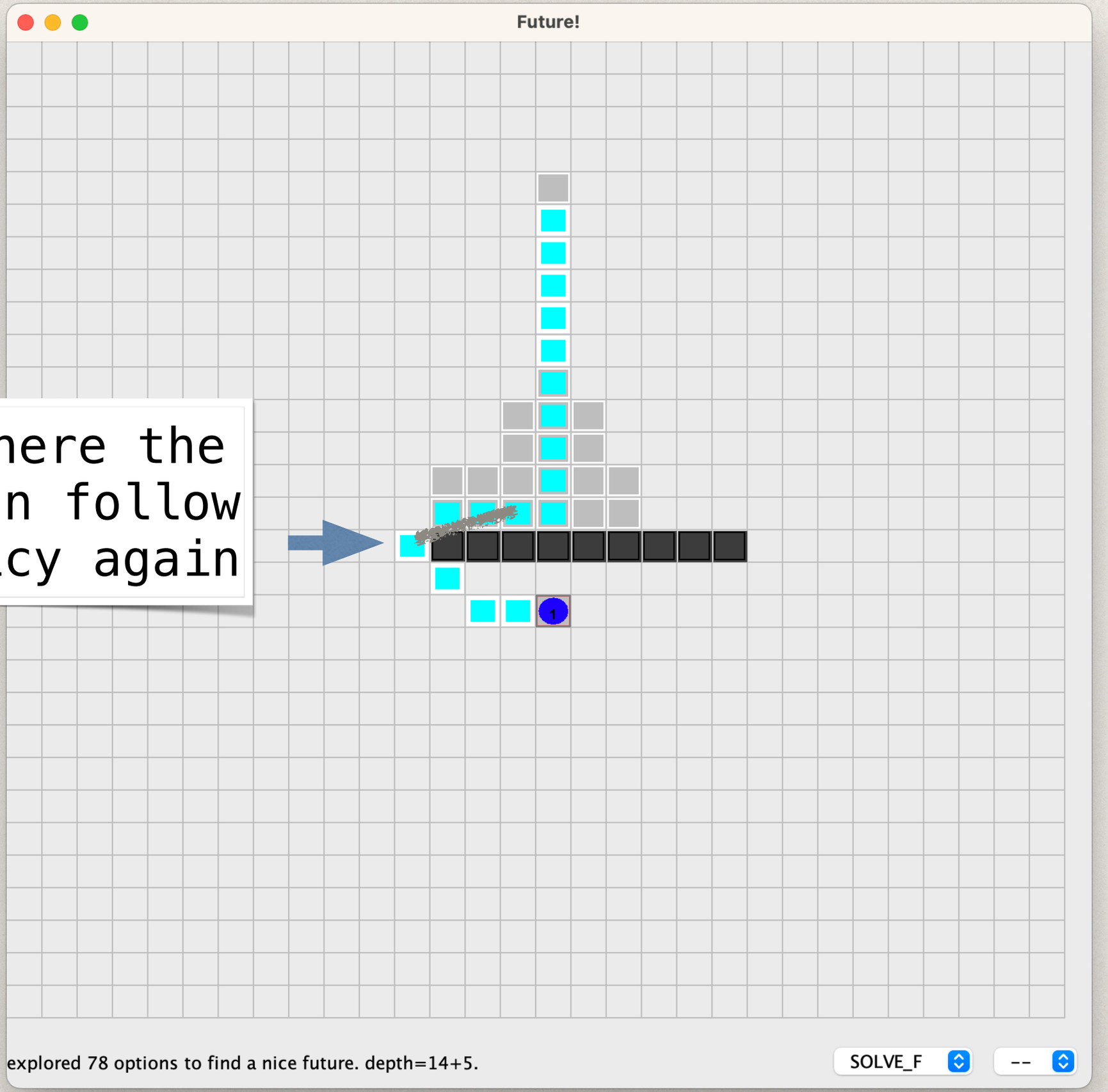

Future!

out of policy decisions

point where the agent can follow its policy again

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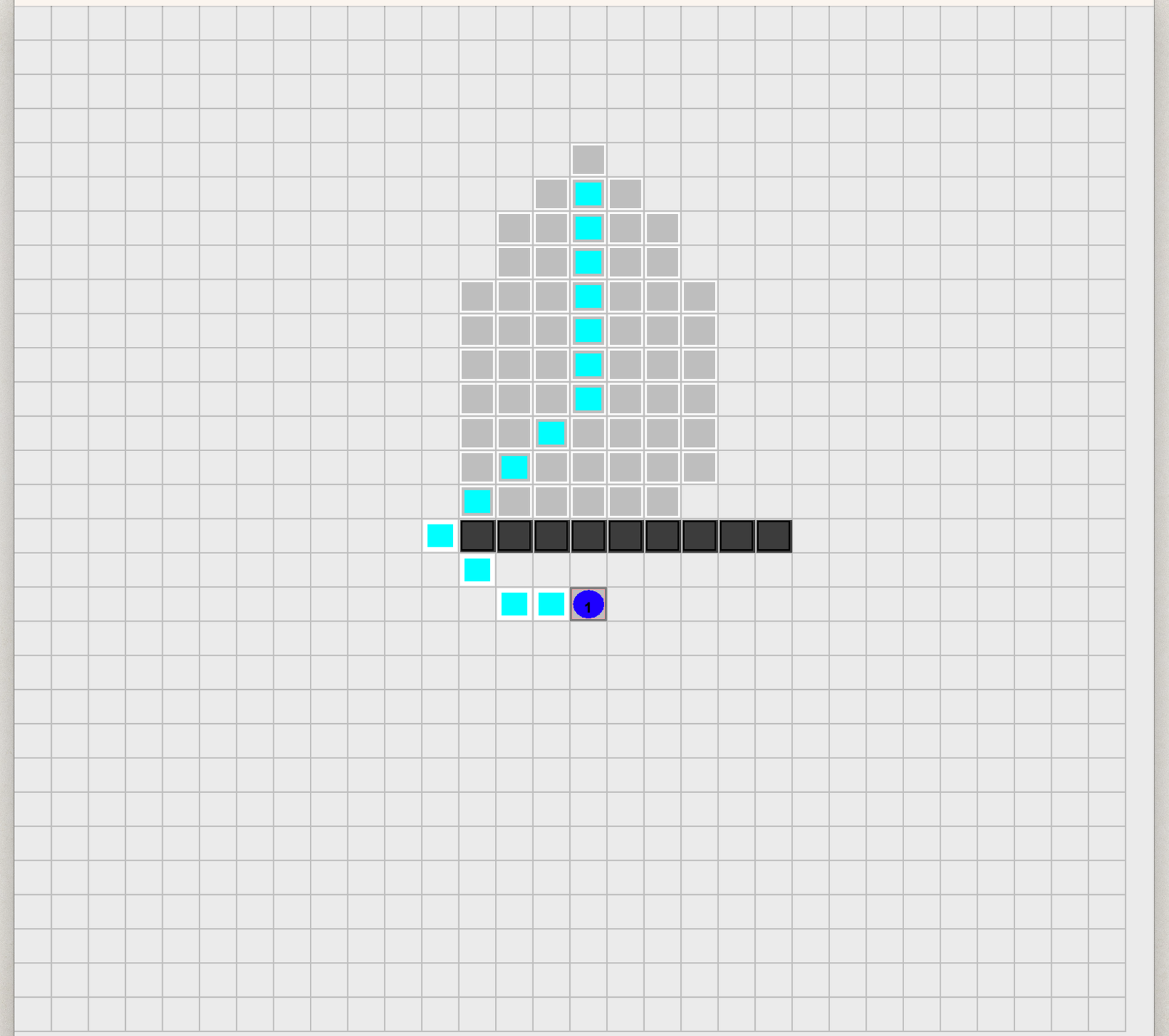
SOLVE_F

--

Future!

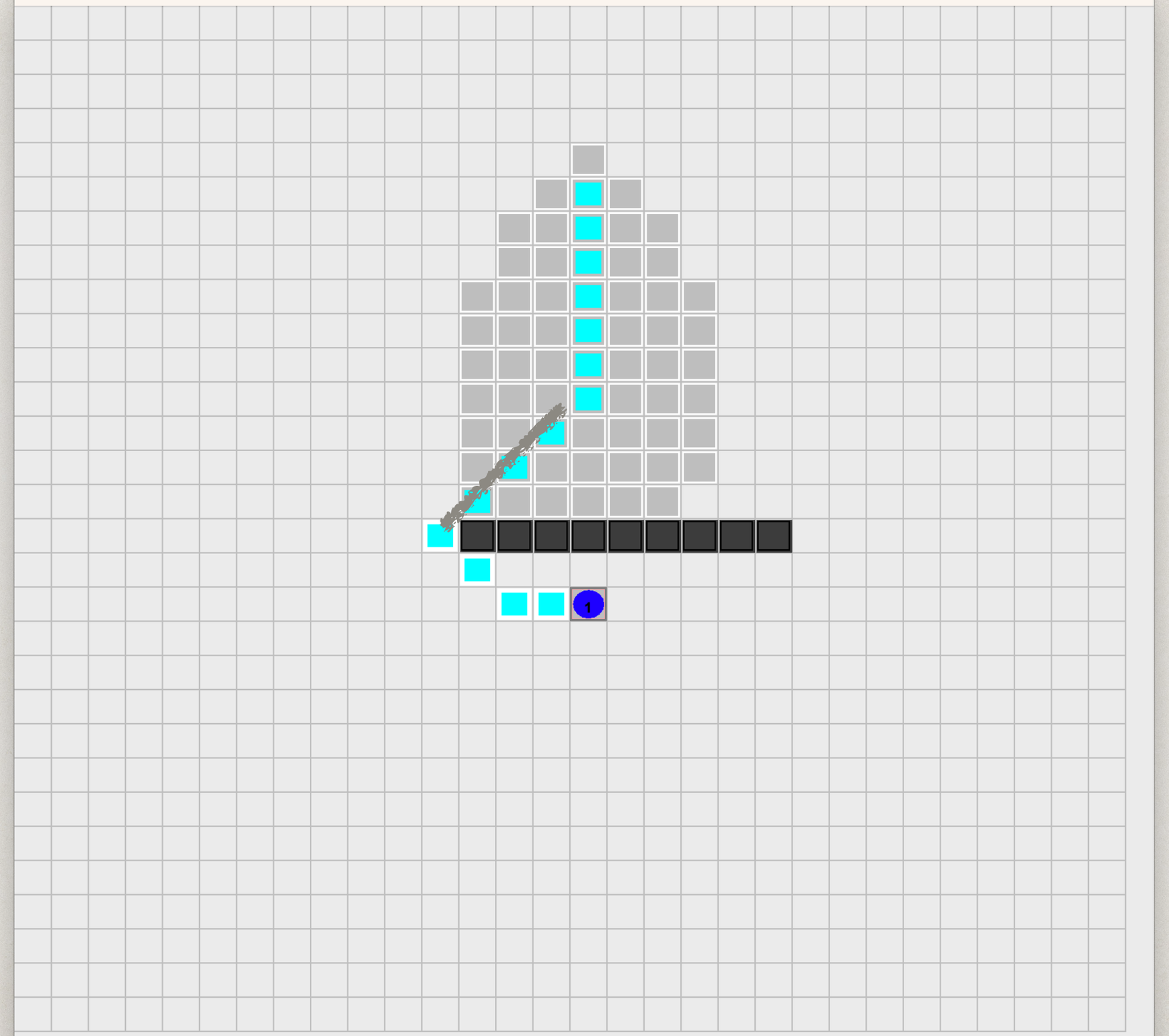


explored 225 options to find a nice future. depth=11+5.

SOLVE_M

--

Future!



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SOLVE_M

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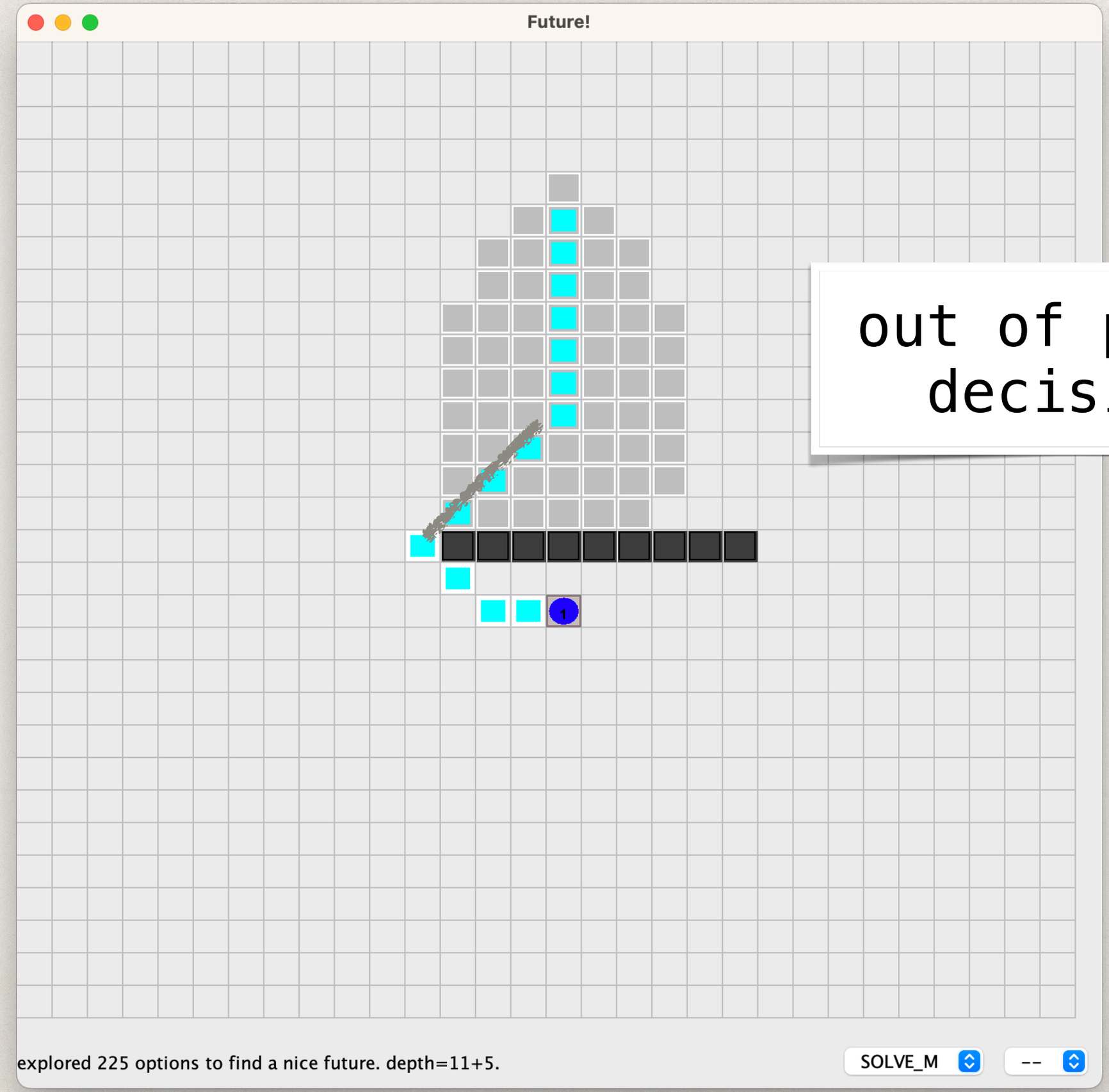
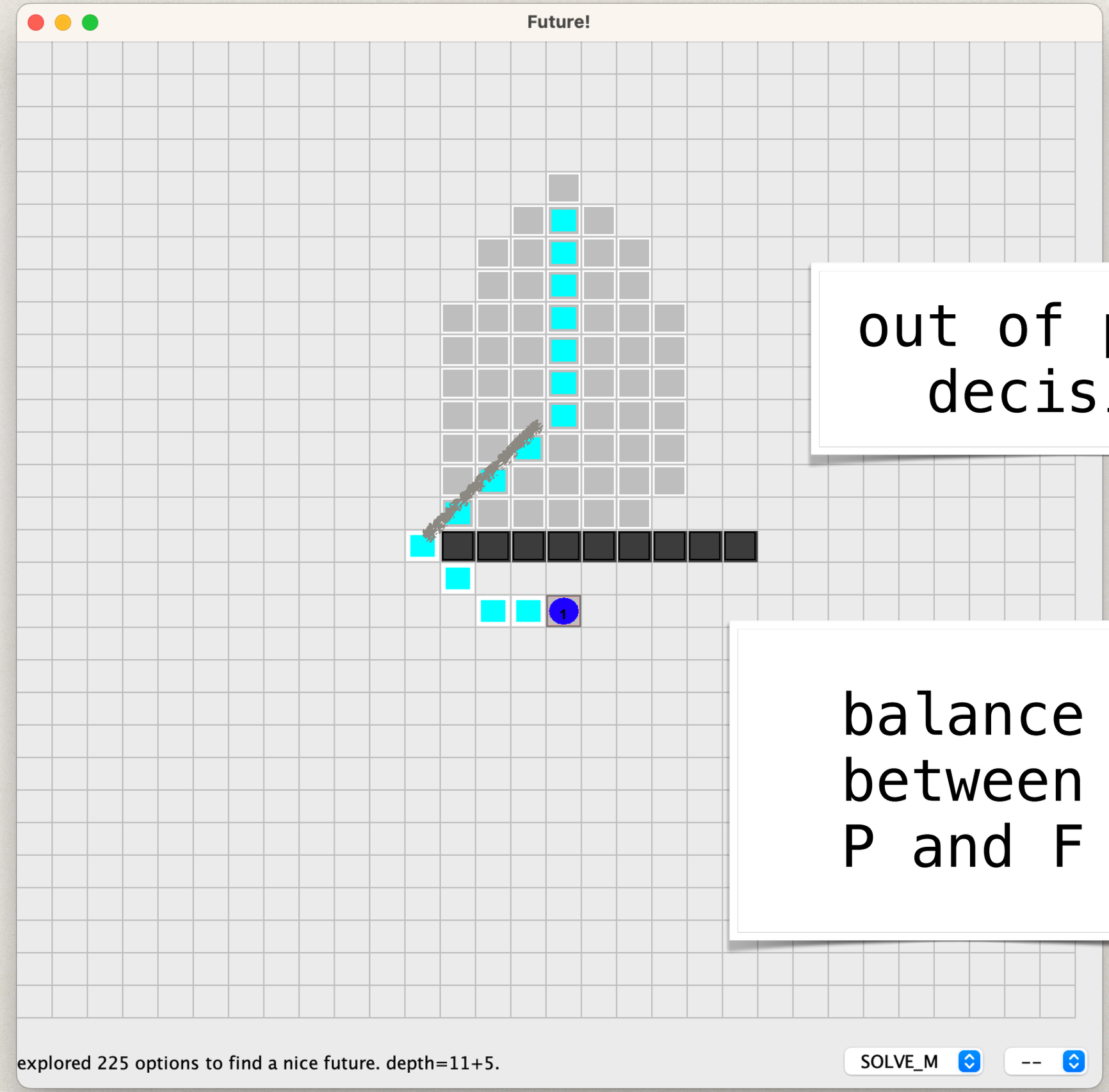


out of policy decisions



out of policy decisions

balance between P and F

version 1.1

Scenario line

little "detour"

Scenario U

good for the agent policy, need to anticipate that entering the U is not a good option

Scenario H

bad for the policy

updated HERE

scenario	strategy	visited	steps to solution	steps out of polity	steps in policy
line	SOLVE_P	419	*15*	9	6 (40%)
	SOLVE_M	217	*15*	4	11 (73%)
	SOLVE_F	*78*	18	4	14 (*77%*)
U	SOLVE_P	*112*	*24*	20	4 (*16%*)
	SOLVE_M	286	*24*	20	4 (*16%*)
	SOLVE_F	374	28	24	4 (14%)
H	SOLVE_P	2006	*26*	22	4 (*15%*)
	SOLVE_M	2028	*26*	22	4 (*15%*)
	SOLVE_F	2001	28	24	4 (14%)

Results

- move the agent out of its policy
  (while exploiting its policy as much as possible)

- SOLVE_P: change option as **soon** as possible
  + shorter plan
  - more exploration

- SOLVE_F: change option as **latte** as possible
  + less exploration
  - not so good plan

About the Agent Program

- the agent program (that defines its policy) is the (how-to) **knowledge** the programmer gives to the agent

- without it, we (may) have tradicional search (to consider this **K** distinguishes Jason(S) from search)

- if **K** is very very bad designed, we (may) have tradicional search [if, at least, **K** gives options]

- if **K** very very well designed, Jason(F) does nothing (the future of the policy is always good)

possible behaviors (ok | not ok)

required "energy"

possible behaviors (ok | not ok)

agent policy

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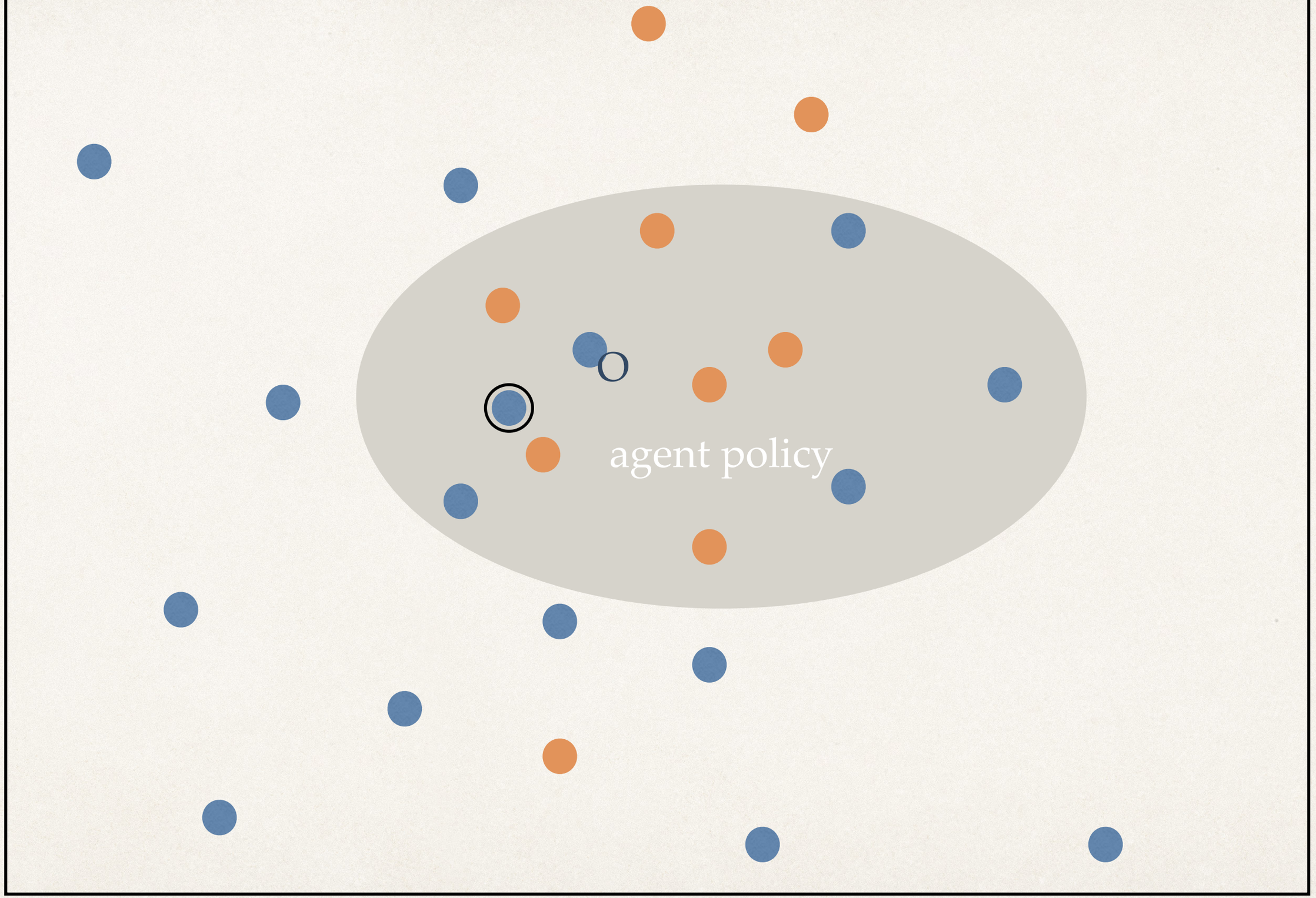

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P

O

agent policy

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required "energy"

P

O

F

agent policy

possible behaviors (ok | not ok)

required "energy"

P

M

O

F

agent policy

possible behaviors (ok | not ok)

required "energy"

P

M

O

F

search space

Questions

- is it just search? planning? monte carlo?
  [it is inspired on all these, but…]
  [we have the agent policy]
  [no adversarial]

- does agent policy (options + preference) play as heuristic? [i guess so — preference part]
  [Jason(F) scapes from preference when it isn't ok]

- is it optimal?
  [no] [maybe if preference + cost are considered]

Questions

- does it work for any kind of agent program?
  [it works if the program produce *enough* options]
  [just one option: nothing to do; several options (with no preference): usual search]

- does it work without preference?
  [yes, but less efficient]

- how much do we depend on preferences? [for efficiency]
  can we survive without? [yes]

Jason(F) 1.1

- initial scenarios

- handles
  internal problem (goal not achieved)

- strategies: one, solve_(p | m | f)

- generic for any Jason program
  [+ environment model]

Multi-Agent

- Requires model of others
  - ask them for their model
    - they are as me
    - developer provides
- cooperation implies that changes in “path” may be more critical

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agent i policy (as ordered options)

$$\pi_i : S \to A^n$$

future state at k

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$$f(s,t,k) = \begin{cases} s & \text{if } t = k \\ f(s', t+1, k) & \text{if } t < k \end{cases}$$

$$s' = e(s, \pi_1(s)_1, \pi_2(s)_1, \dots)$$

Multi-Agent

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  - ask them for their model
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envi

e

ager

options)

$$\pi_i : S \to A^n$$

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```
fully observable

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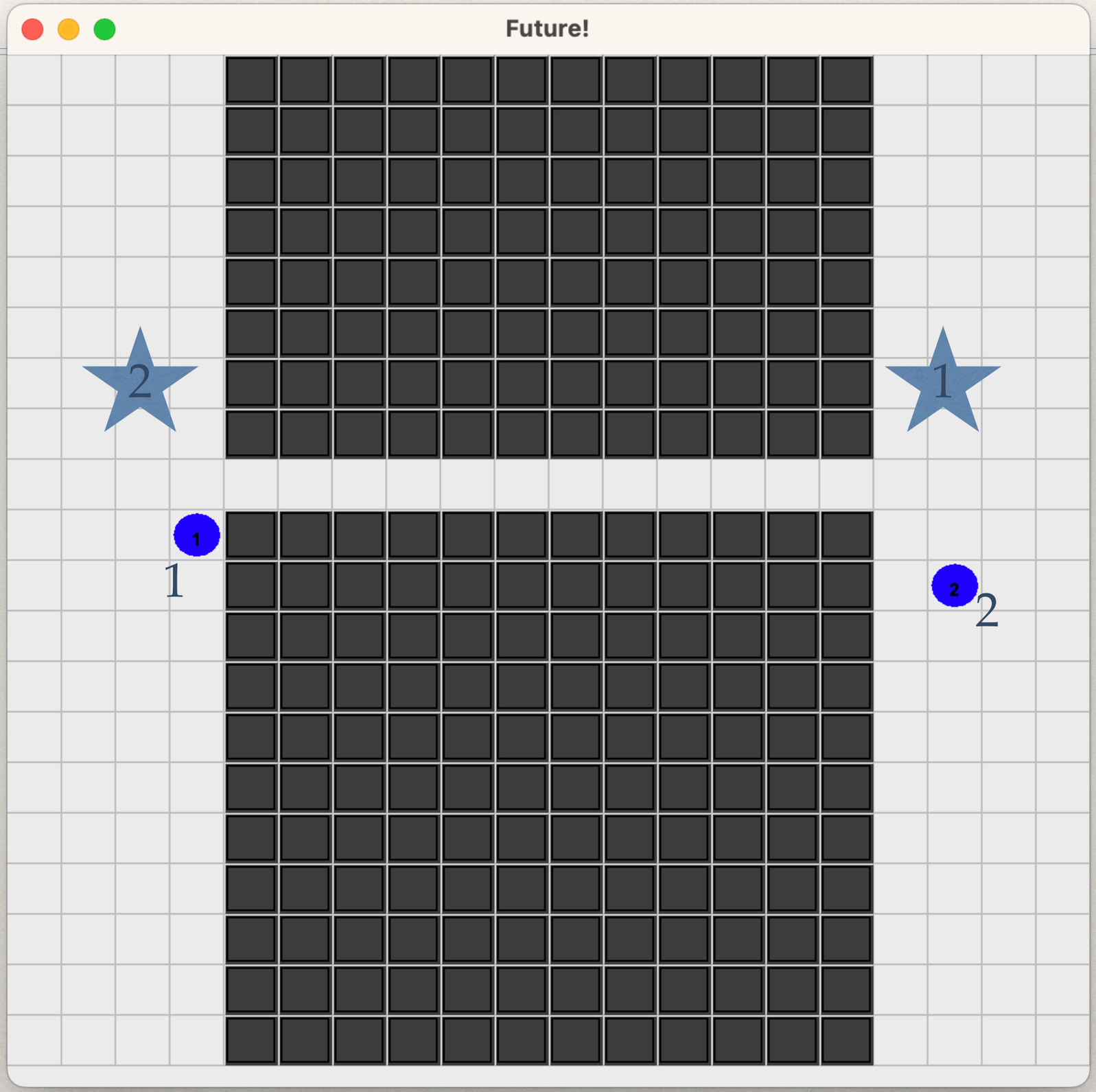
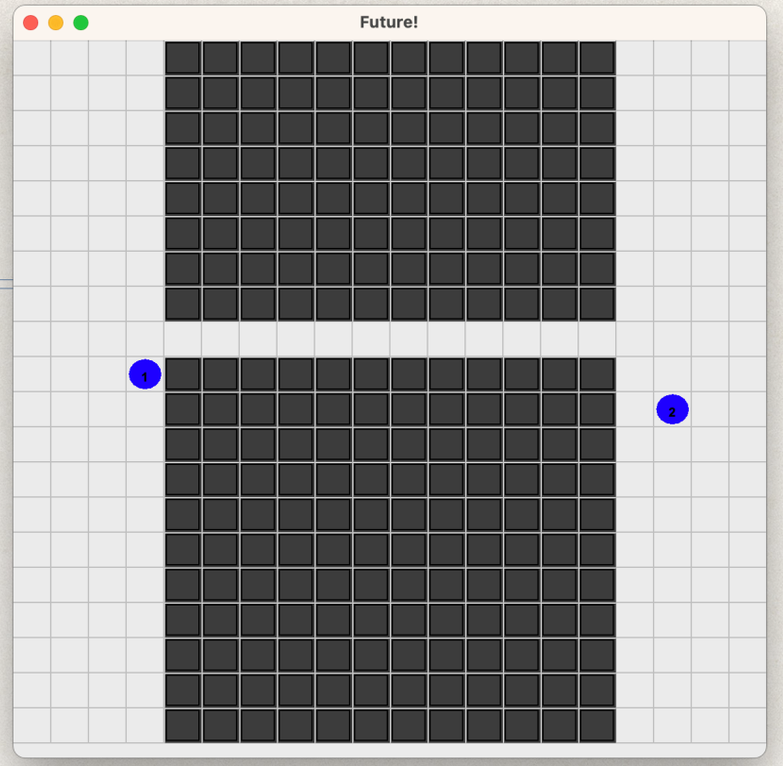
Bridge Scenario



Strategies



- none: both agents are blocked in the middle of the bridge
- left agent with **one**: right agent crosses, left agent gives up
  - or has a **recovery plan** to wait and try again latter
    (this is the best solution for this problem)
- left agent with **solve_p**: right agent crosses, left waits and then crosses
  (takes quite a while to find a good option)

Results

updated HERE

strategy	solve	matrices	visited	steps	steps in policy
NONE	no	0	∞	∞	∞ (100%)
ONE	no	1	25	—	0 (0%)
ONE [1]	yes	15 [2]	15	15	15 (100%)
SOLVE_P	yes	942	8333	27	21 (77%)

solve_p is slower to find options
(higher cost of building matrixes)

Jason(F) 1.3

- **matrix with multi-agents**
  [no communication considered]

- others are simulated as regular (non-Jason(F)) agents

- (still) internal problem (goal not achieved)

- strategies: one, solve_(p | m | f)

- generic for any Jason program
  [+ environment model]
  [model of others is trivial in Jason, just get their state]

Remarks for Multi-agent case

- **Nothing** new or special for the multi-agent case (!)
- From the Jason(F) agent perspective, others are part of the environment
  - only their actuation in the environment is indeed perceived
- if both agents are Jason(F), both will wait 5 steps and then try to cross at the same time!
  - some coordination strategy should (must?) be put in placed (e.g., a leader that decides who cross)

Jason(F) 1.4

- Problem detection vs Problem resolution
  - detection is based on strategy ONE in selectOption
  - resolution based on internal action that produces a new plan (from search in future options)

```
-!pos(X,Y)[error(no_future),error_msg(M)]
    : pos(CX,CY) // my location
   <- .print("Failure for goal pos(",X,",",Y,"): ",M);
      jason.future.plan_for(
           pos(X,Y),
           { @[cost(0), preference(0)] +!pos(X,Y) : pos(CX,CY) },
           Plan, "SOLVE_M");
      .add_plan(Plan, chunking, begin);
      !pos(X,Y).
```

(Un)Certainty

environment transitions

$e : S \times A^n \times S \rightarrow [0,1]$

$e(s, a_1, a_2, \ldots, s')$ is the probability of s′ from s doing a

agent i policy (as ordered options)

$\pi_i : S \rightarrow A^n$

state and certainty in the future

$f : S \times \mathbb{N} \times \mathbb{N} \rightarrow S \times [0,1]$

$$f(s,t,k) = \begin{cases} s,1 & \text{if } t = k \\ s', e(s, \ldots s')\, f(s', t+1, k)_2 & \text{if } t < k \end{cases}$$

$s' = \max_{s''} e(s, \pi_1(s)_1, \pi_2(s)_1, \ldots, s'')$ most probable next state

fully observable

stochastic

dynamic

environment

deterministic

agent

multi-agent

discret

Evaluation

- Measure:
  - efficiency (steps to achieve a goal),
  - (computational) cost,
  - steps in policy, …
- Varies
  - uncertainty of the environment
  - how far to look ahead
  - strategies (solve p, m, f)

Next Steps

- Relax assumptions (deterministic environment, …)
- More scenarios (more complex and realistic)
- Running in background
- Opportunistic options
  oracle: “your policy is ok, but you could do better”
- Consider backtrack (options in the past)
- Other types of problem (internal state, norm violation)
- Shared matrix
- Related work

What to Measure?

- time & memory
- reactiveness
- efficiency & efficacy