Examples of the OSCAR Planner in Operation

OSCAR_3.31 10/28/1999 12:25:57
Non-Linear-Planner-43

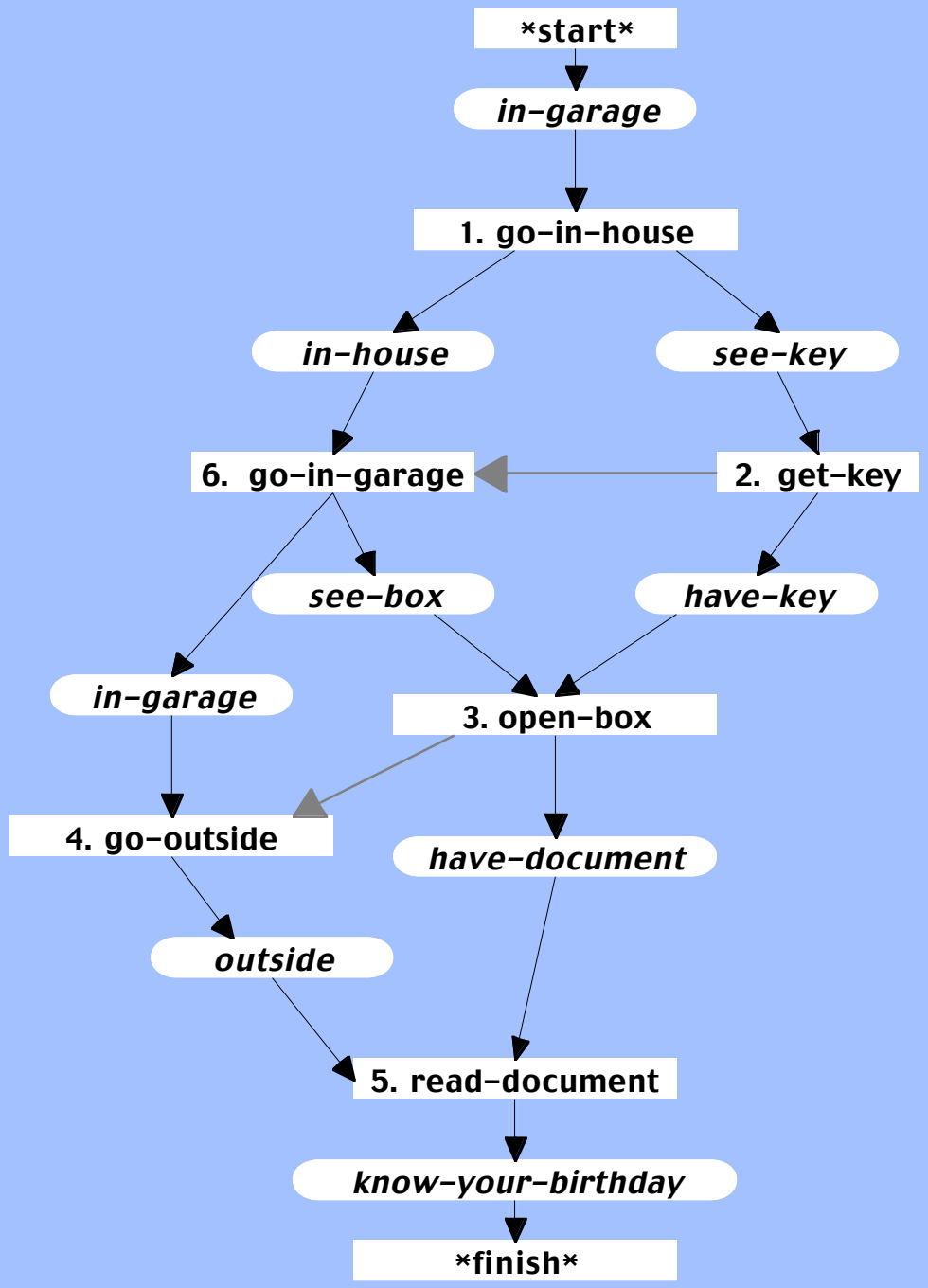
Goal-state:
know-your-birthdate
Given:
in-garage
see-box
((in-garage & go-in-house) =>
(see-key & (in-house & (~in-garage & (~outside & ~see-box)))))
((in-garage & go-outside) =>
(outside & (~in-house & (~in-garage & (~see-box & ~see-key)))))
((see-key & get-key) => have-key)
((in-house & go-to-garage) =>
(in-garage & (~in-house & (~outside & (see-box & ~see-key)))))
(((have-key & see-box) & open-box) => have-document)
(((have-document & outside) & read-document) => know-your-birthdate)

==========

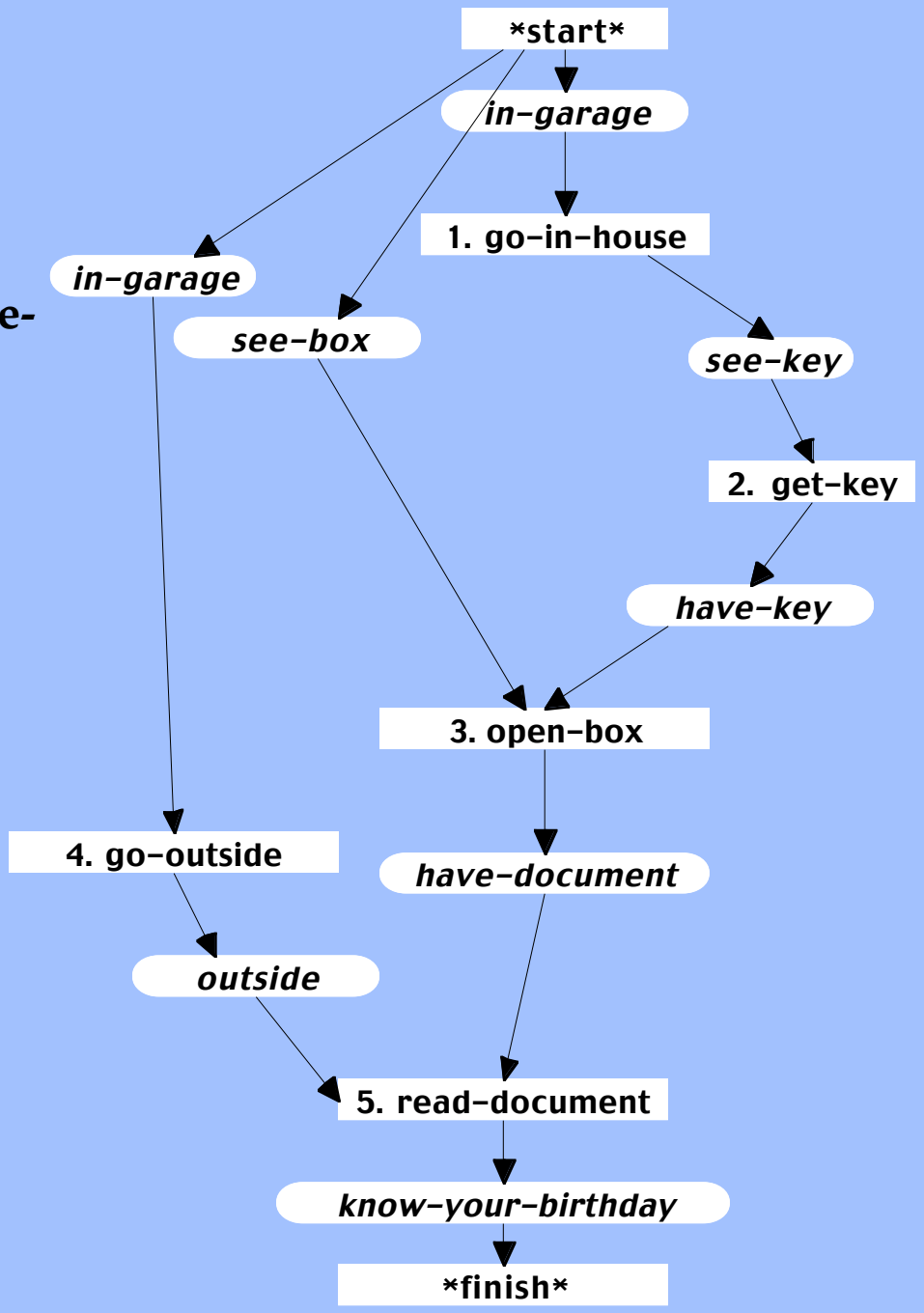
Elapsed time = 0.36 sec
Cumulative size of arguments = 94
Size of inference-graph = 133 of which 0 were unused suppositions.
70% of the inference-graph was used in the argument.
198 interests were adopted.
58 interests were discharged by nodes used in the solution.
29% of the interests were used directly in finding the solution.
The branching factor = 1.09
149 interest-schemes were constructed.
68 instantiated-premises were constructed.
256 cycles of reasoning occurred.
39 plans were constructed.

Plan #39
PLAN-STEPS:
(1) go-in-house
causal-links:
0 --in-garage--> 1
(2) get-key
causal-links:
1 --see-key--> 2
ordering-constraints:
2 > 1
(6) go-to-garage
causal-links:
1 --in-house--> 6
ordering-constraints:
6 > 2
(3) open-box
causal-links:
2 --have-key--> 3
6 --see-box--> 3
ordering-constraints:
3 > 6
(4) go-outside
causal-links:
6 --in-garage--> 4
ordering-constraints:
4 > 3
(5) read-document
causal-links:
3 --have-document--> 5
4 --outside--> 5
ordering-constraints:
5 > 4
GOAL: know-your-birthdate
established by:
5 --> know-your-birthdate

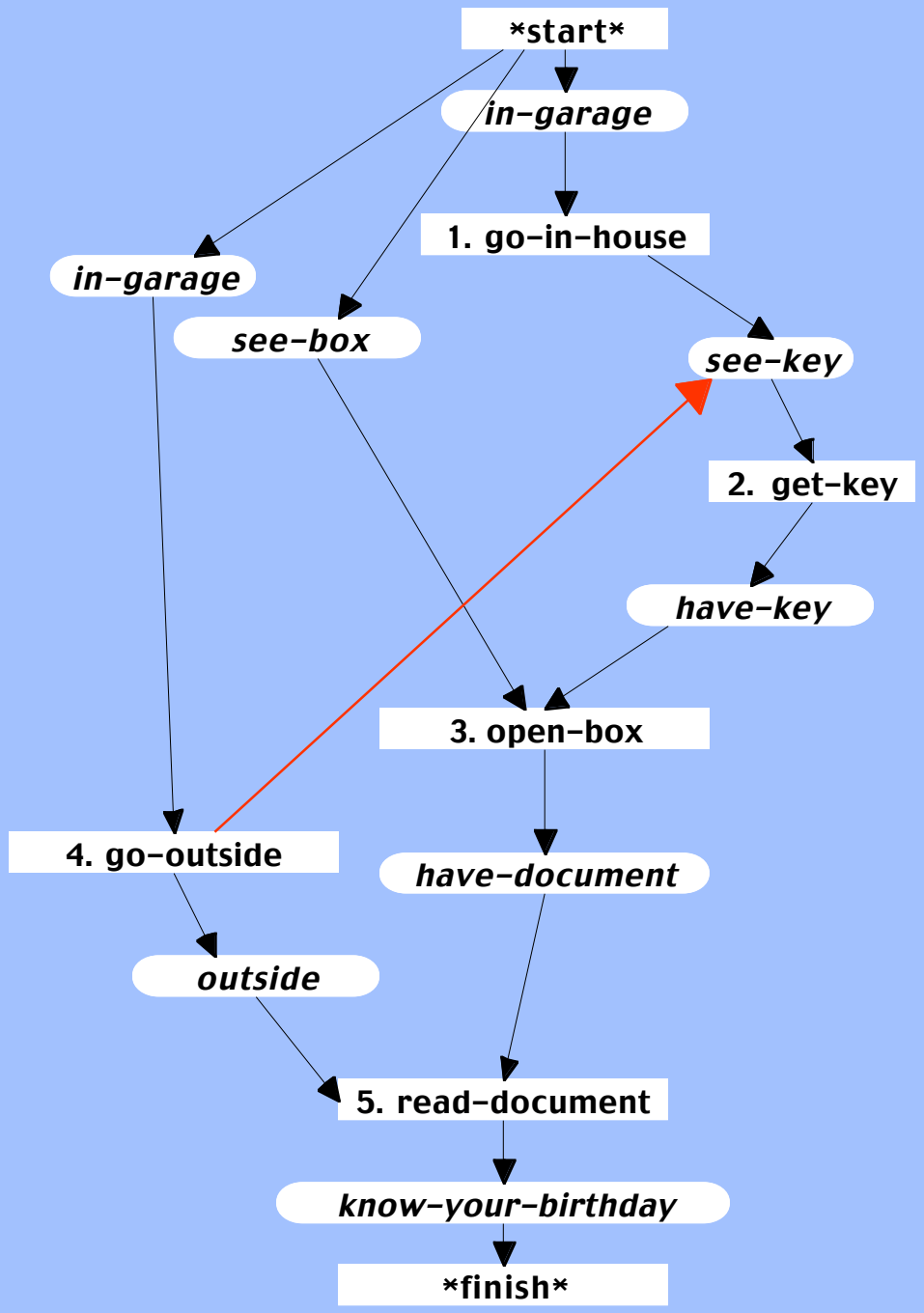
Plan 39
The solution



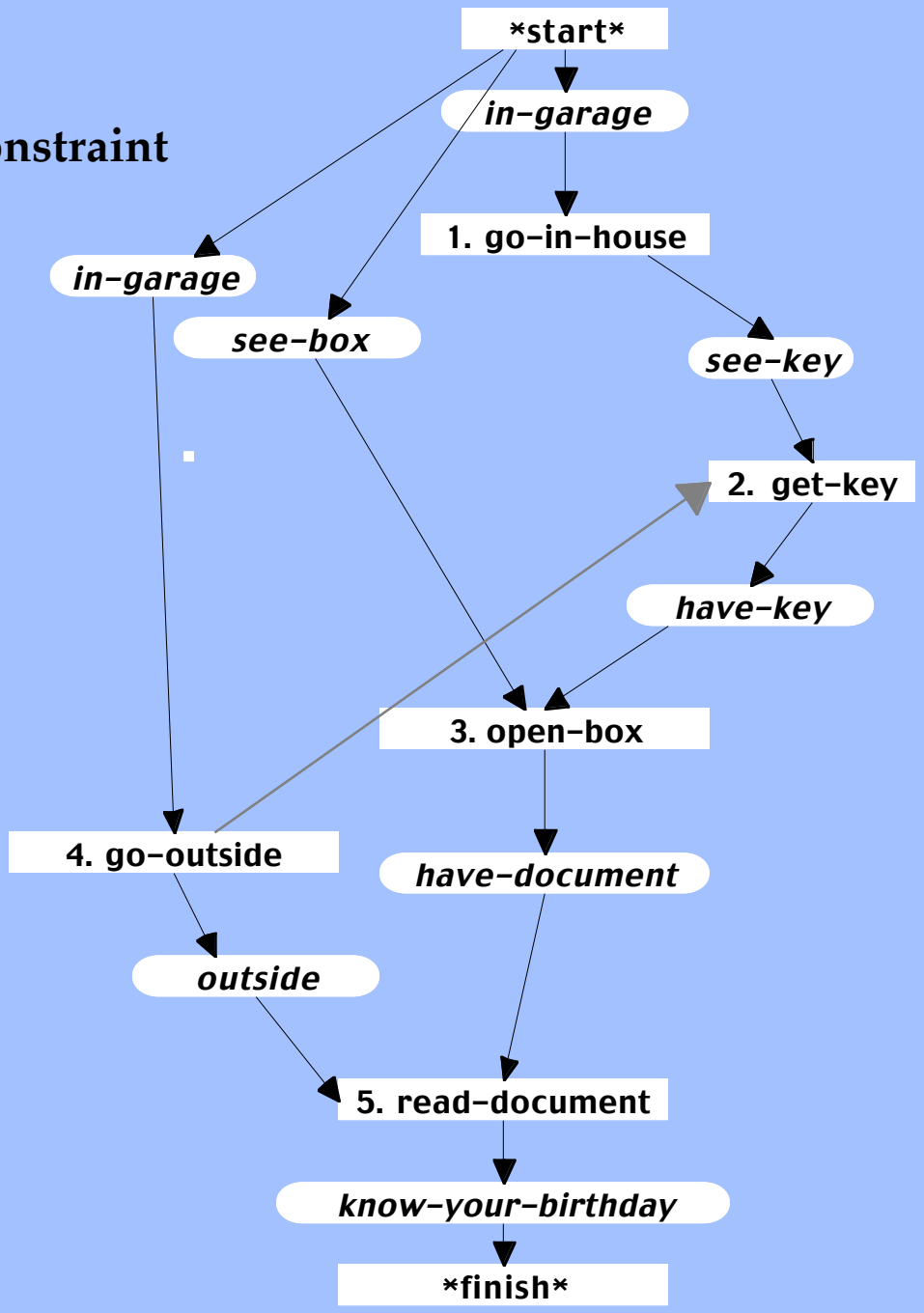
Plan 12 constructed by goal-regression, null-plan, and split-conjunctive-goal.



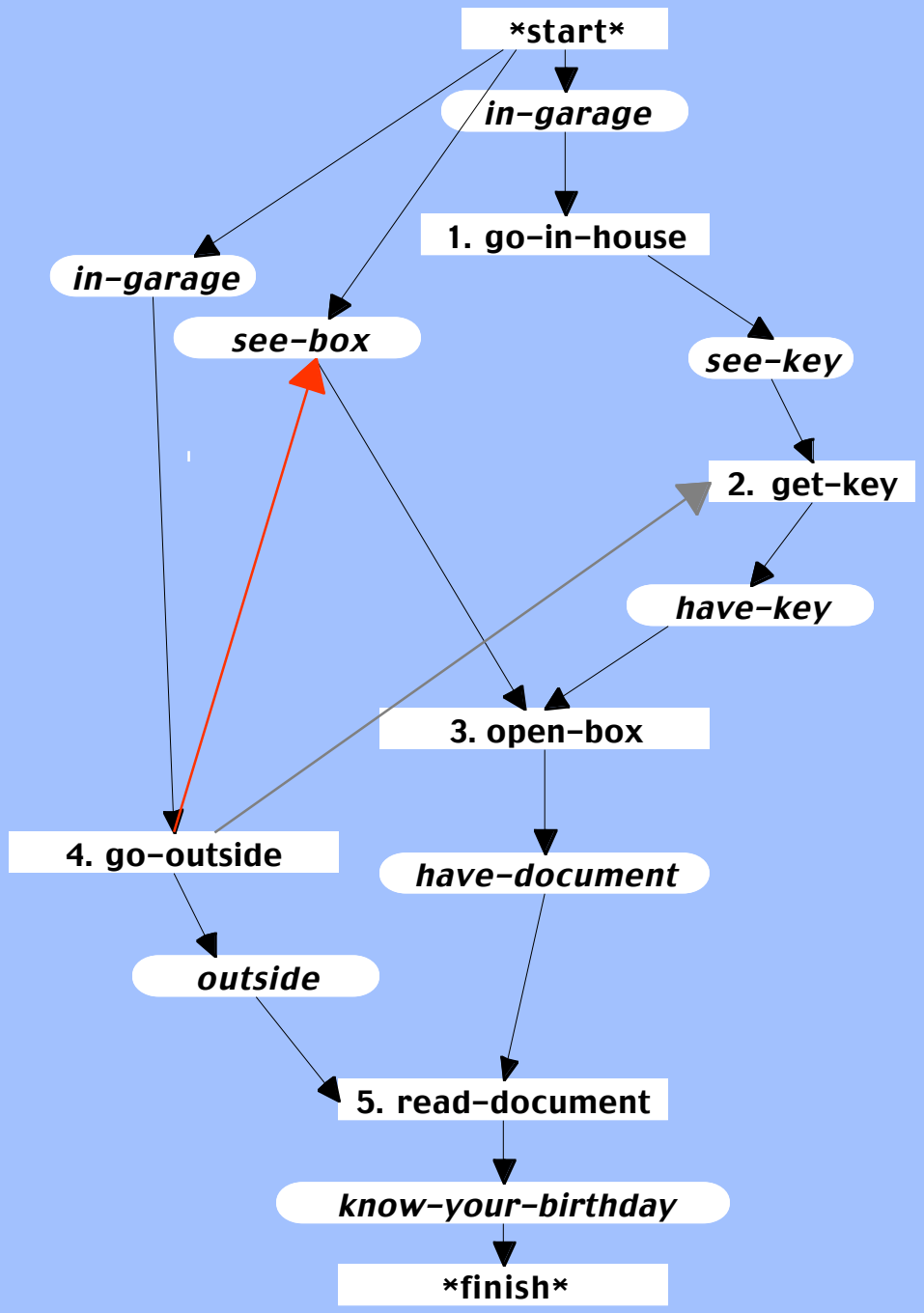
Plan 12
undermining



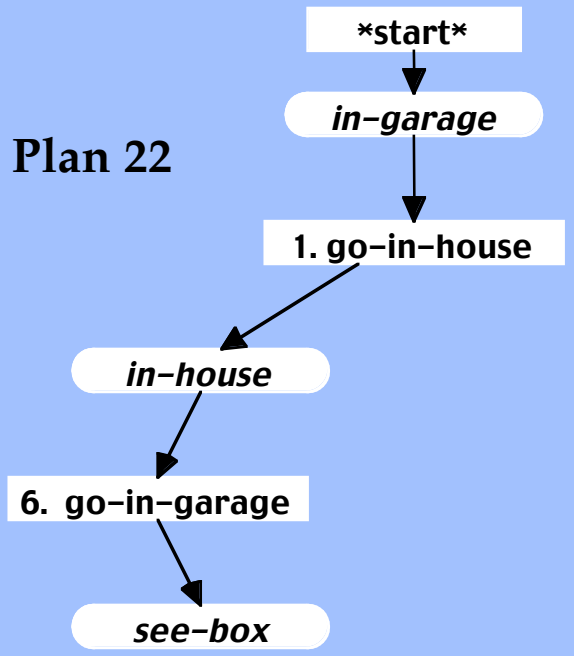
Plan 15
add-ordering-constraint
to plan 12

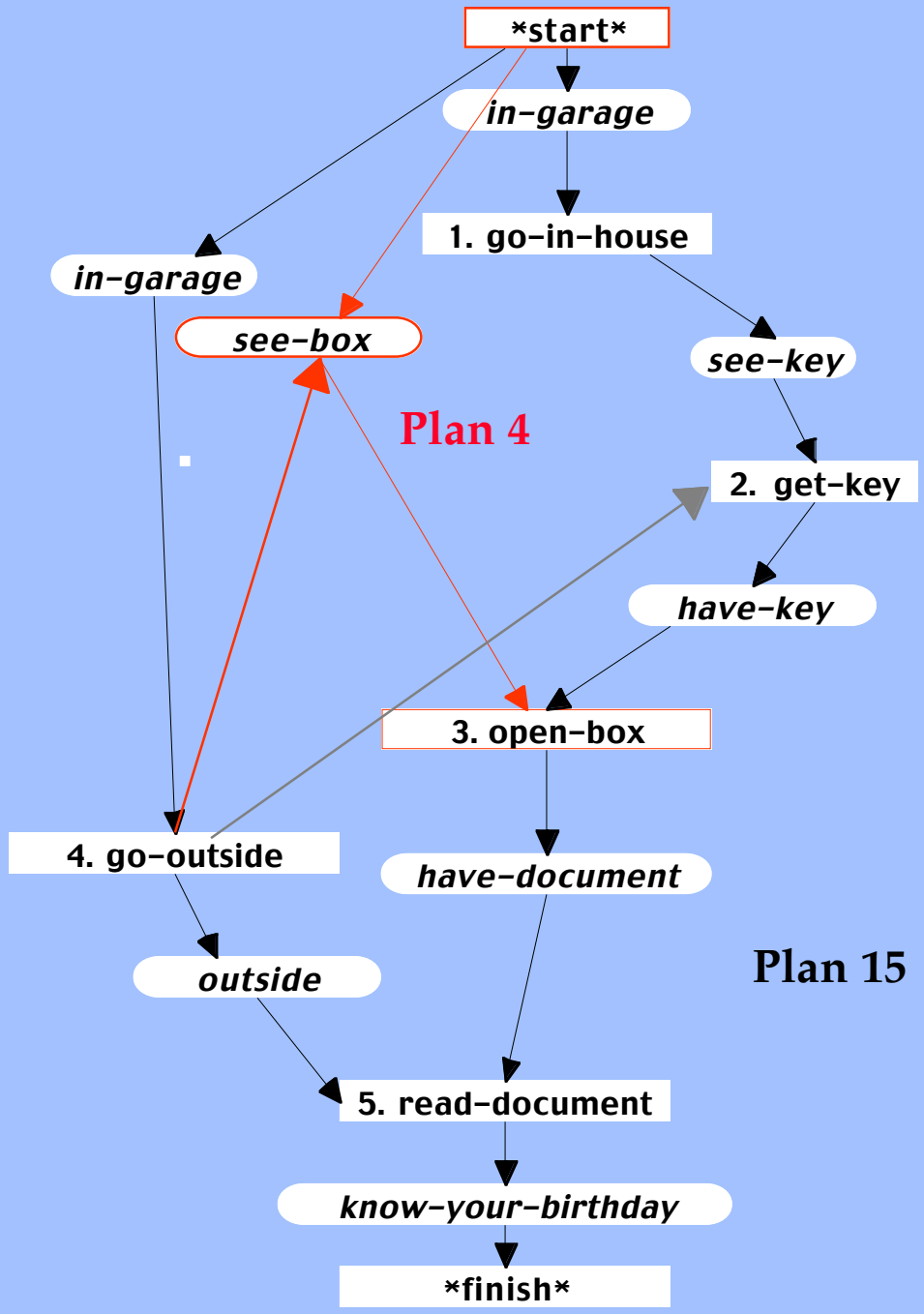


Plan 15
undermining



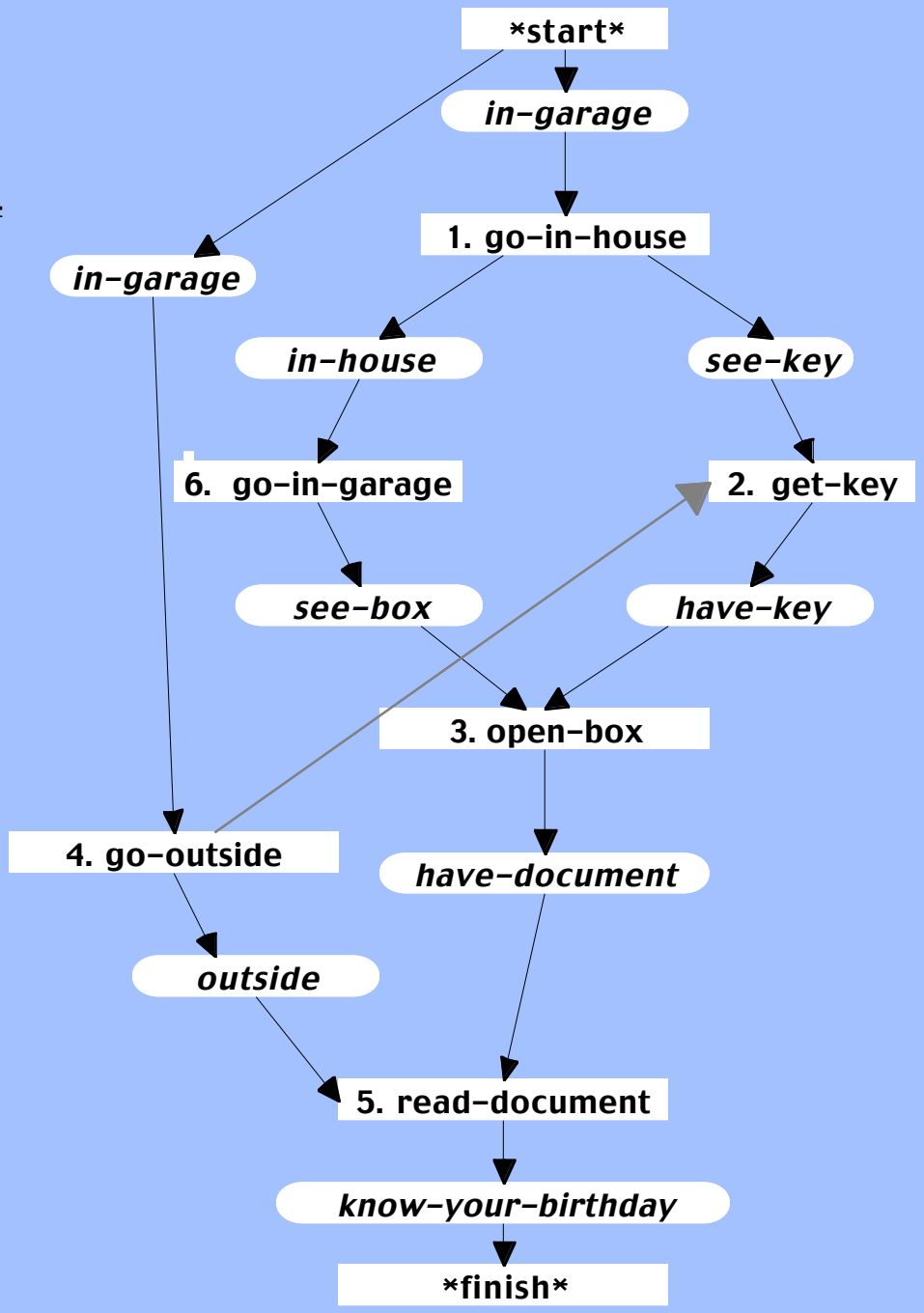
Plan 22 reuses nodes from plan 27 and will replace plan 4



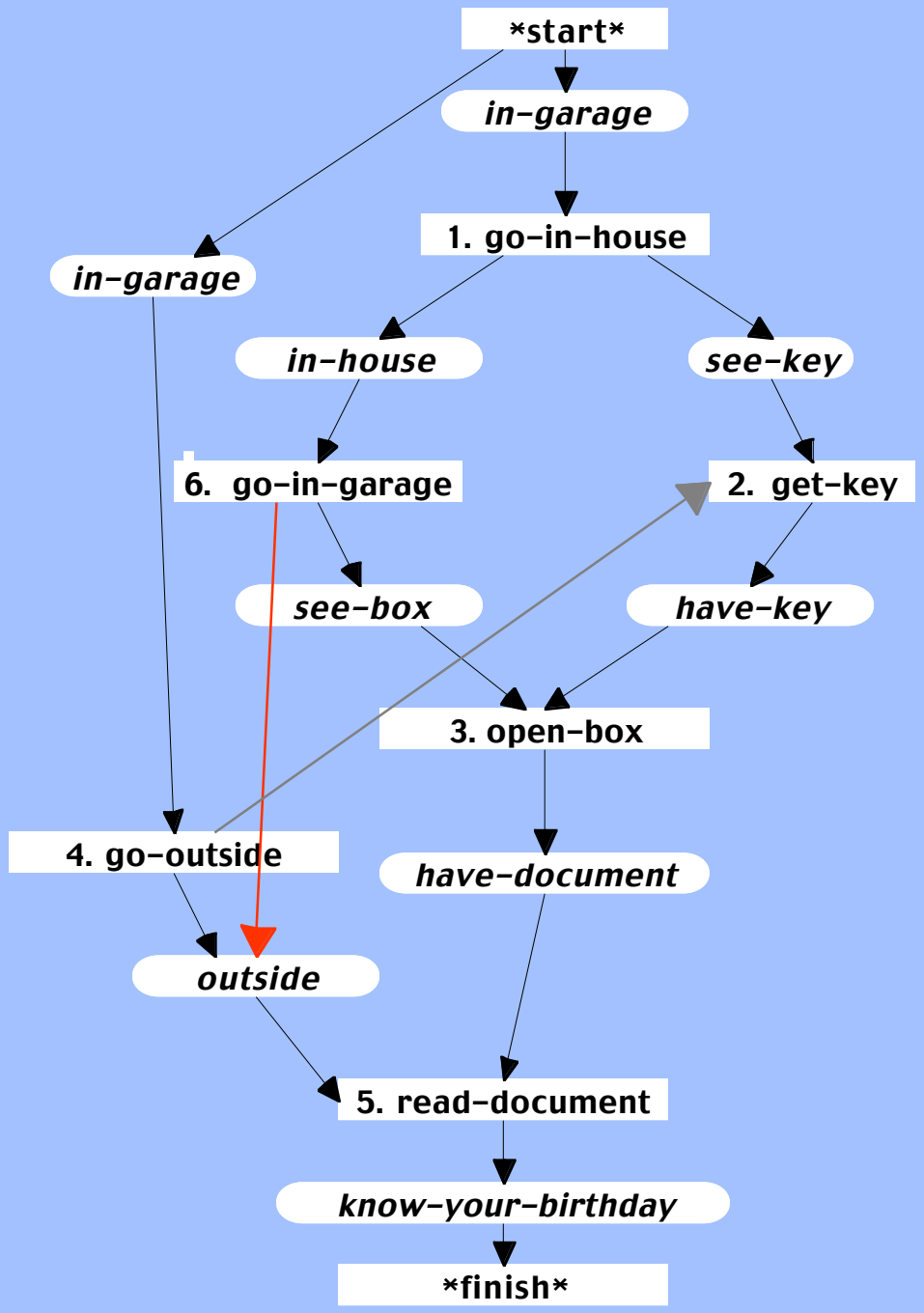


This could have been constructed without reuse-nodes, because no goal is repeated.

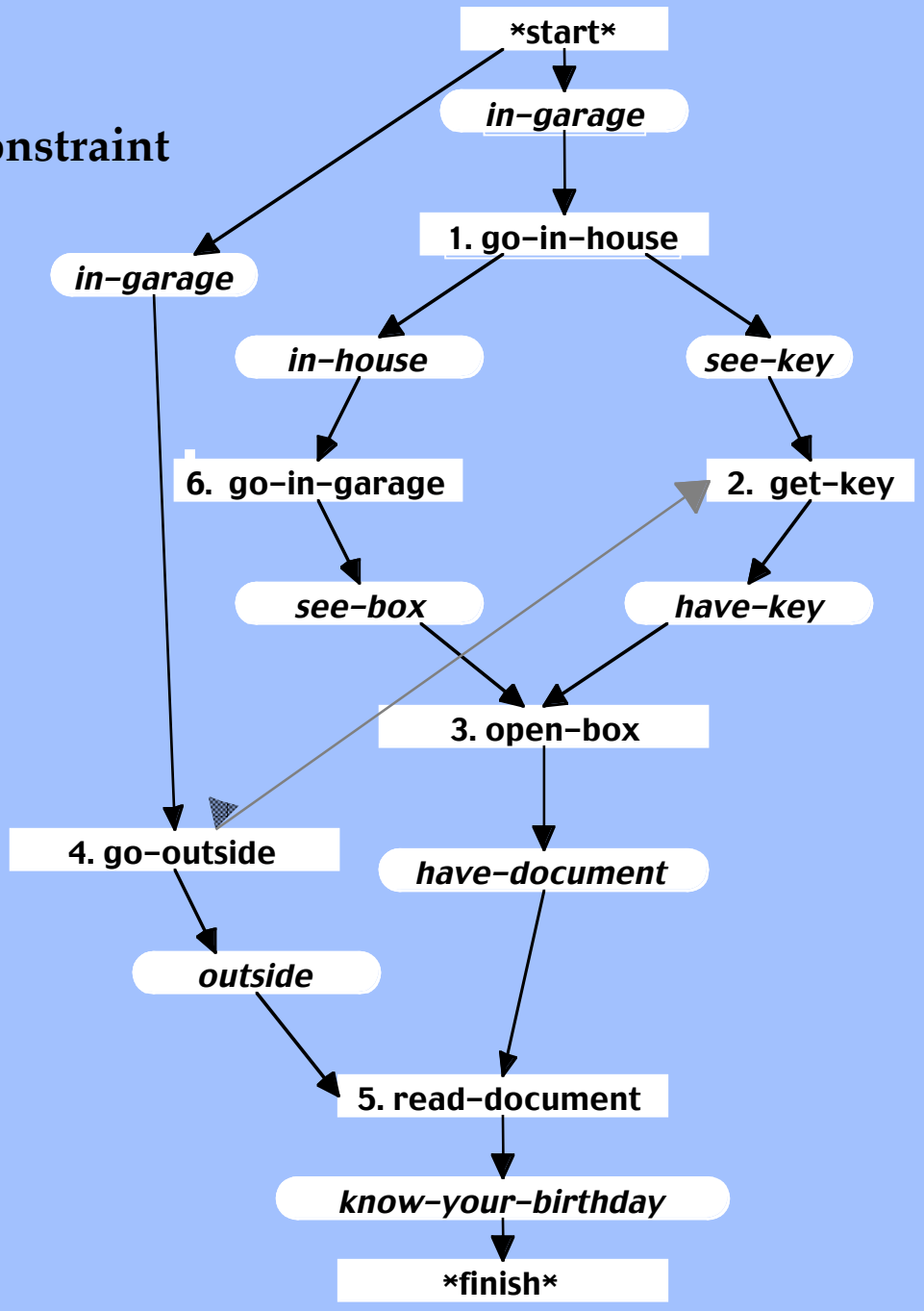
Plan 23
reuse-nodes,
replacing plan 4
by plan 22
in plan 15



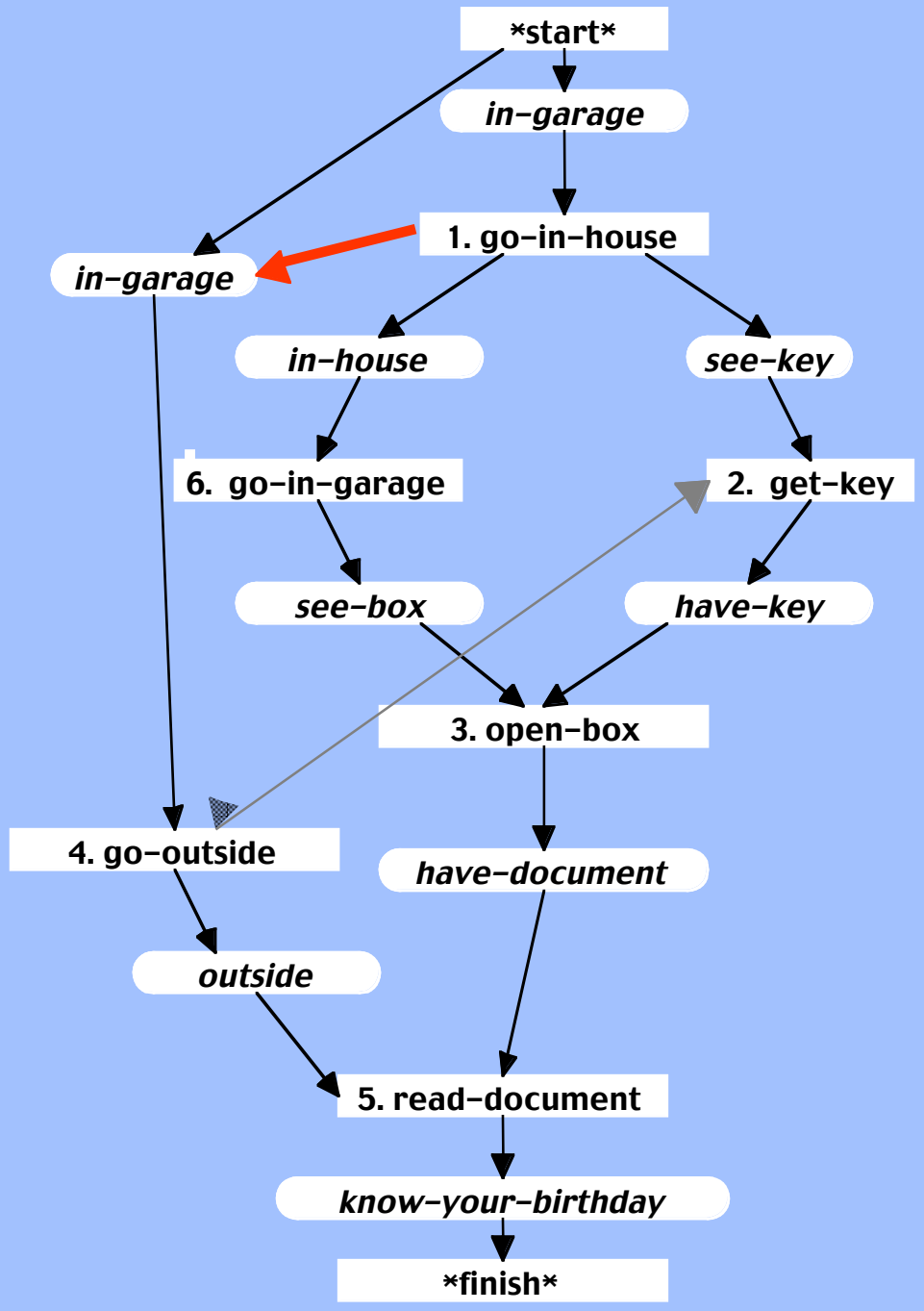
Plan 23
undermining



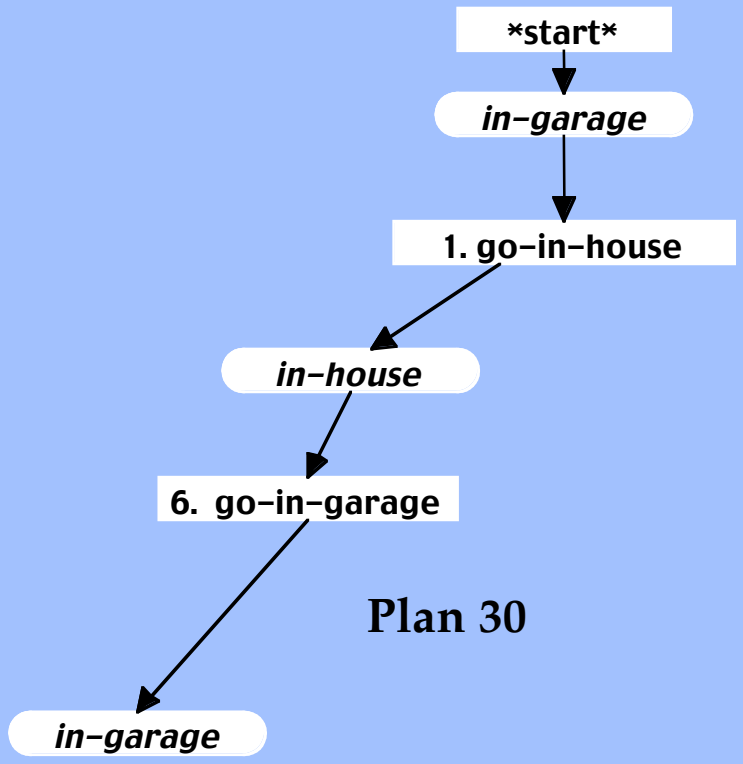
Plan 27
add-ordering-constraint
to plan 23



Plan 27
undermining



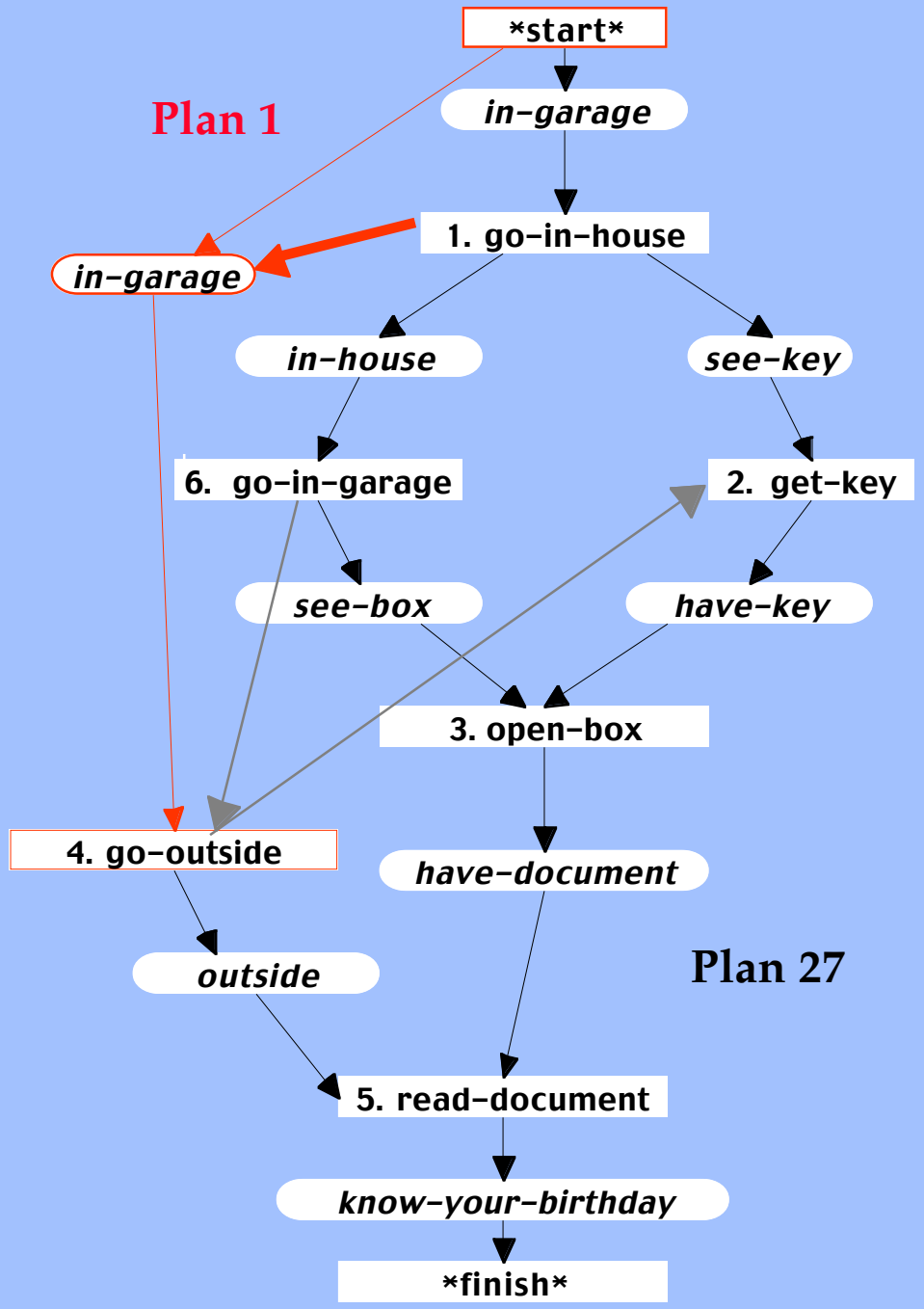
Plan 30 reuses nodes from plan 27
and will replace plan 1



Plan 30

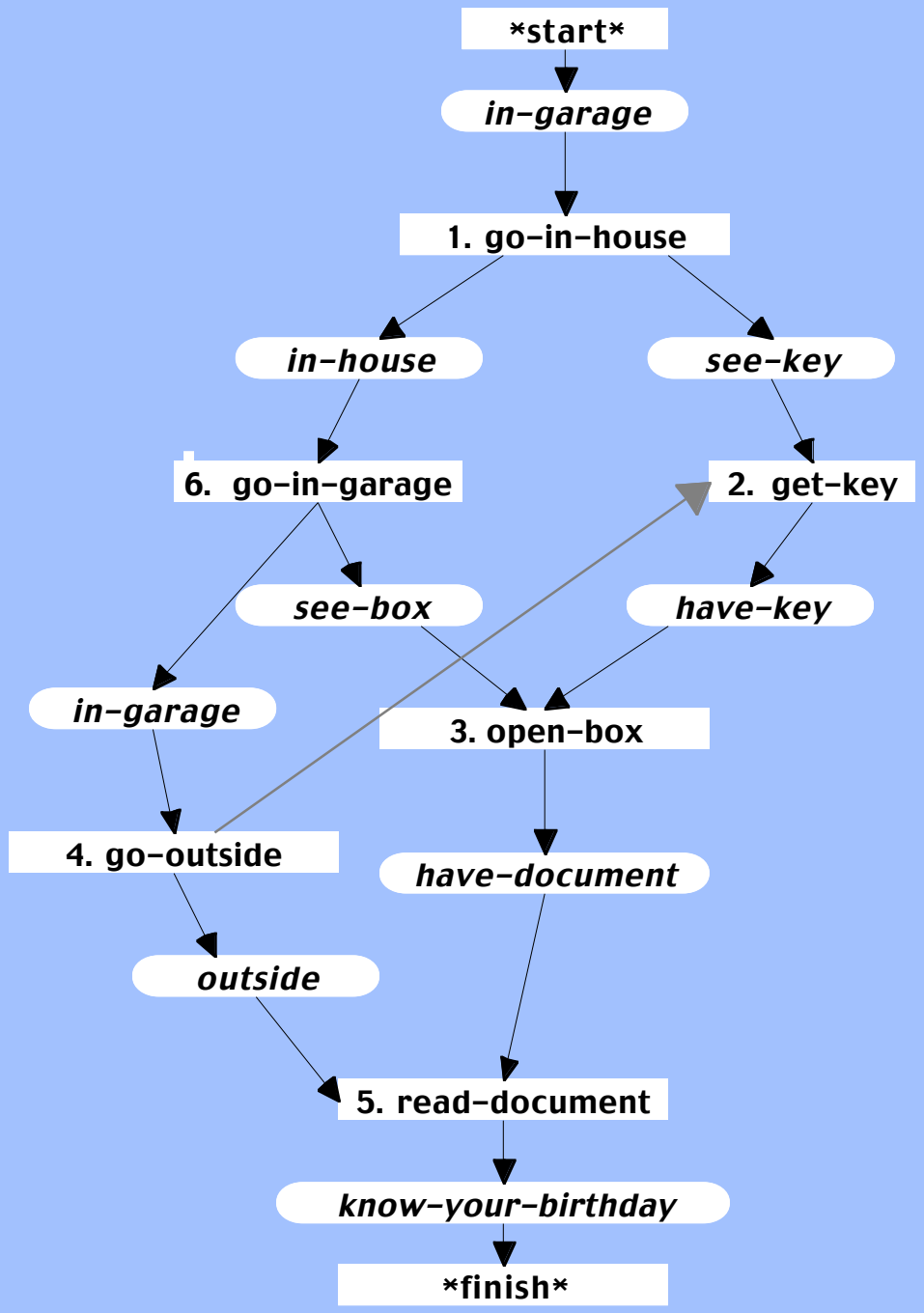
This repeats the goal
in-garage.

Plan 1

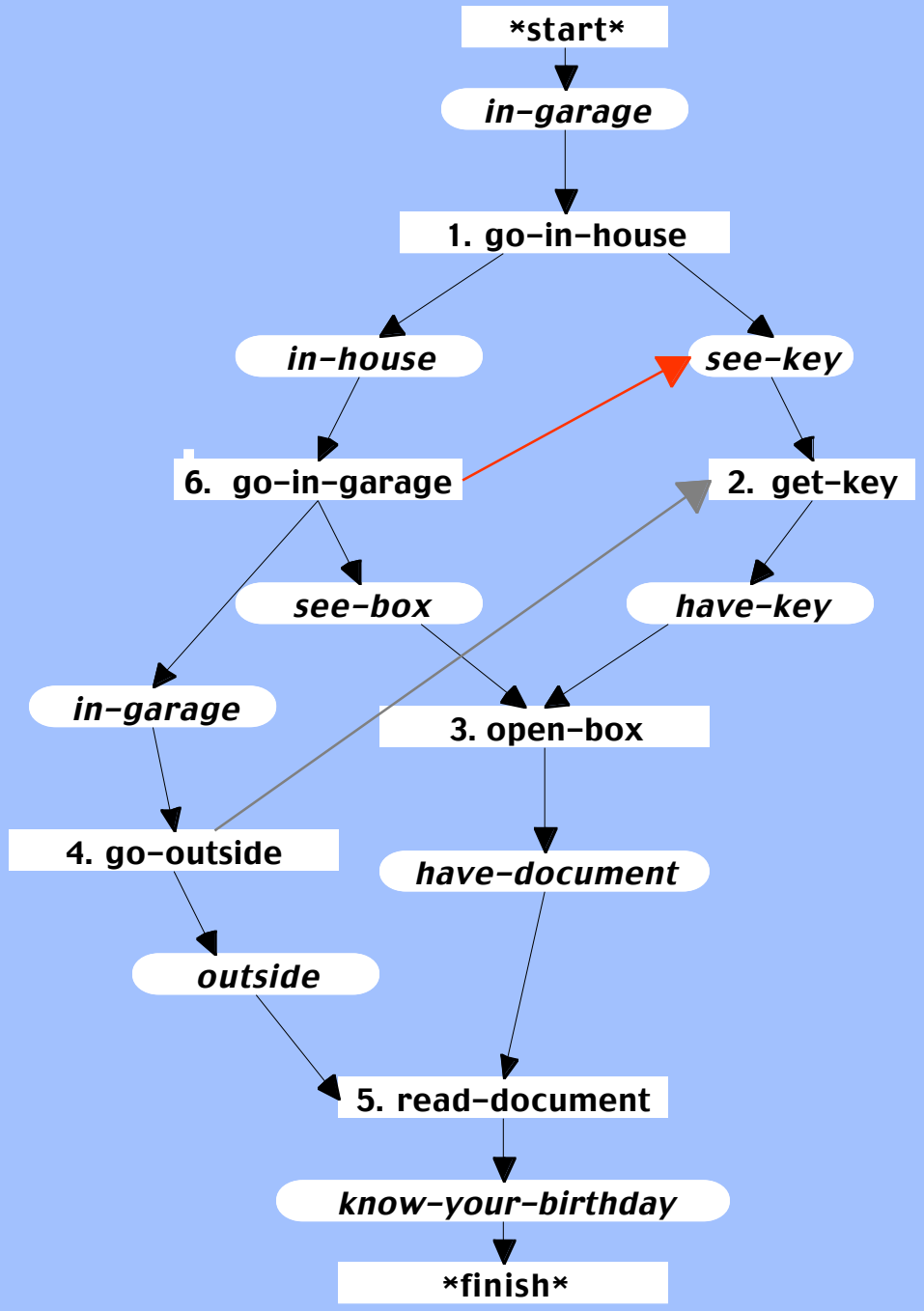


Plan 27

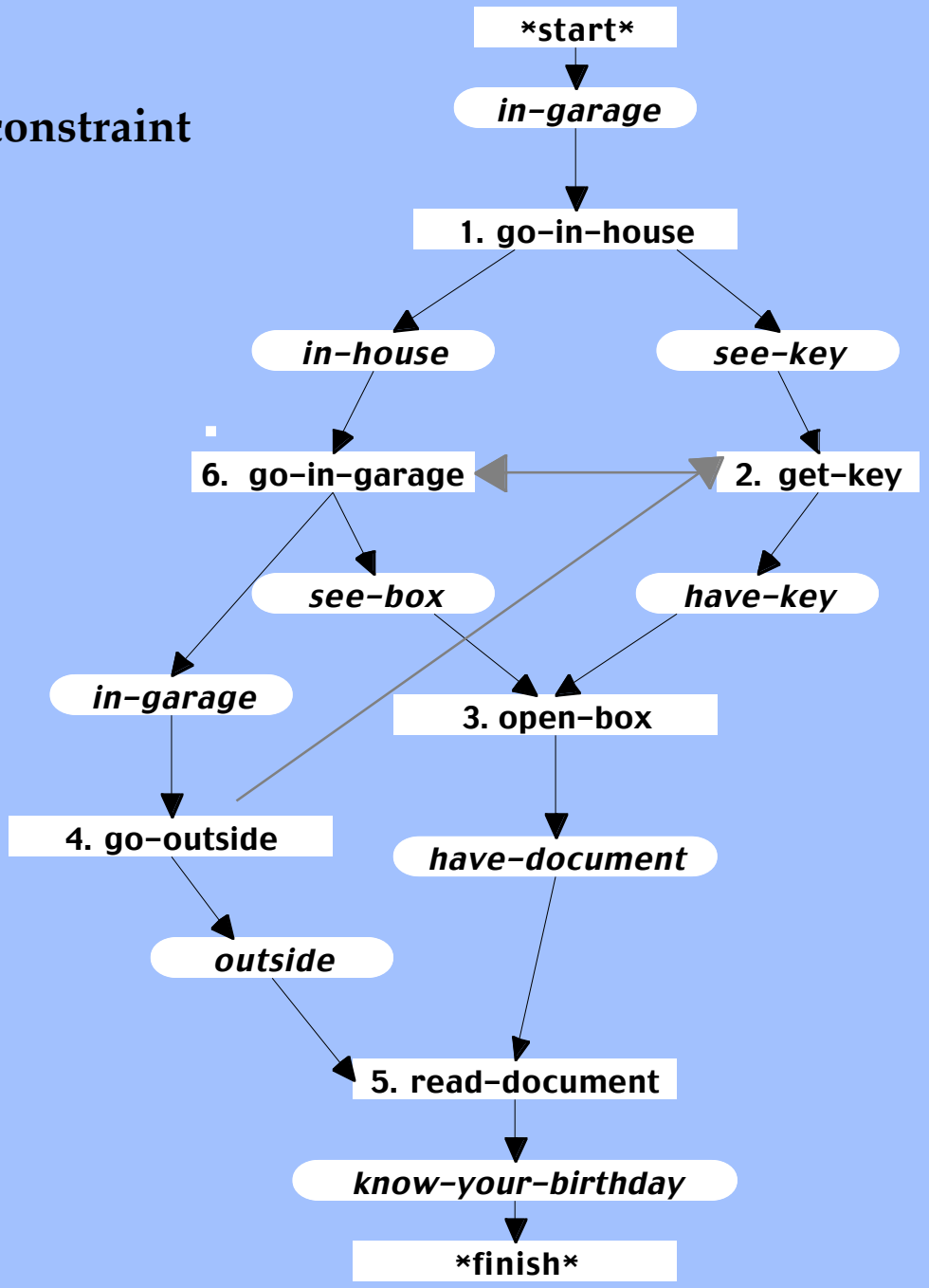
Plan 32
reuse-nodes,
replacing plan1
by plan 30
in plan 27



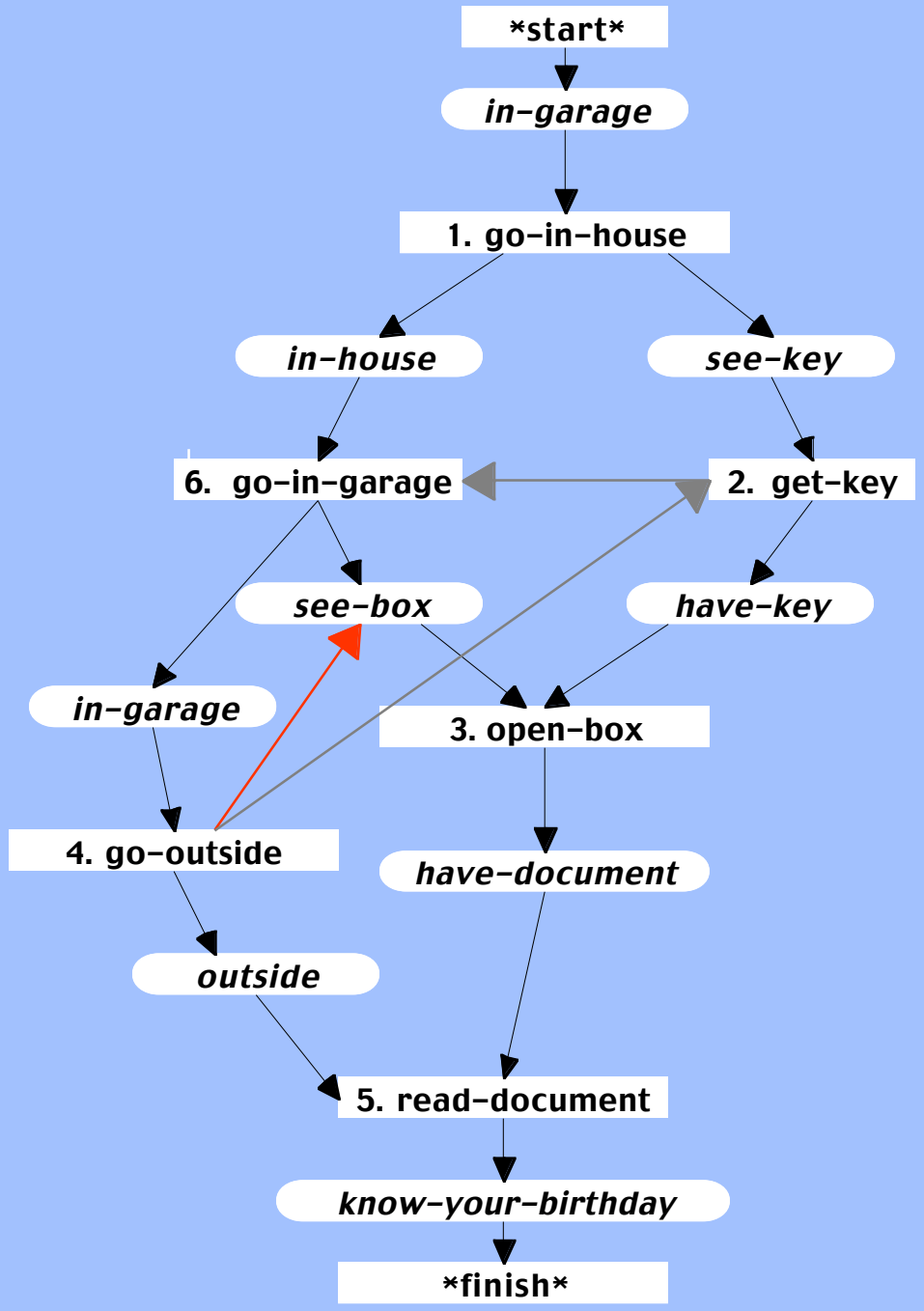
Plan 32
undermining



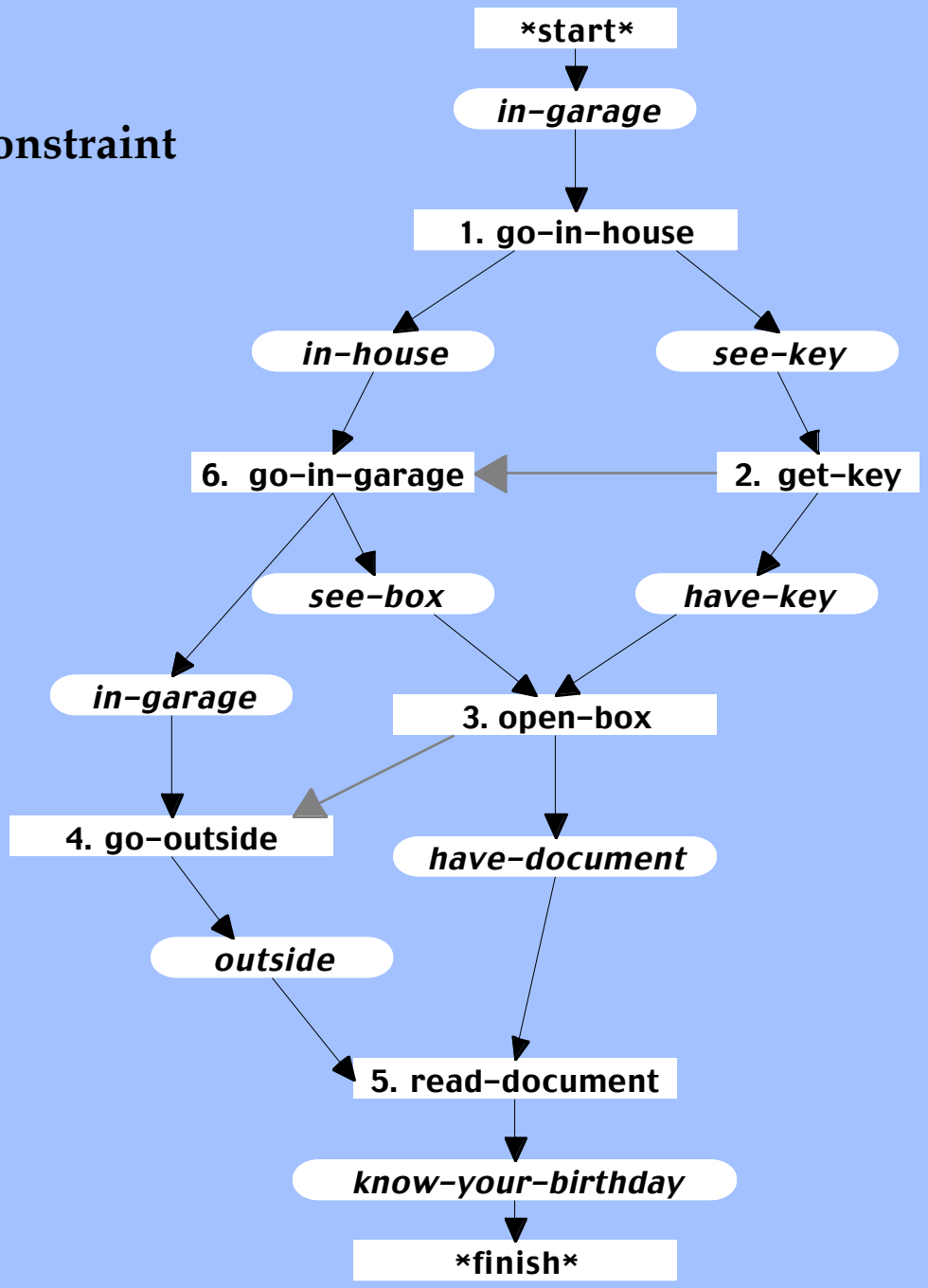
Plan 36
add-ordering-constraint
to plan 32



Plan 36
undermining



Plan 39
add-ordering-constraint
to plan 36



Stuart Russell's Flat Tire Problem

Given:

(:type wheel1 wheel)
(:type wheel2 wheel)
(:type hub isa-hub)
(:type nuts are-nuts)
(:type boot container)
(intact wheel2)
(in jack boot)
(in pump boot)
(in wheel2 boot)
(in wrench boot)
(on wheel1 hub)
(on-ground hub)
(tight nuts hub)
~(locked boot)
~(is-open boot)
~(inflated wheel2)
~(unfastened hub)

Goal-state:

~(is-open boot)
(in jack boot)
(in pump boot)
(in wheel1 boot)
(in wrench boot)
(tight nuts hub)
(inflated wheel2)
(on wheel2 hub)

(all x :type container)(((~(locked x) & ~(is-open x)) & (open-up x)) => (is-open x))
(all x :type container)(((is-open x) & (close x)) => ~(is-open x))
(all x)(all y :type container)((((in x y) & (is-open y)) & (fetch x y)) => ((have x) & ~(in x y)))
(all x)(all y :type container)((((have x) & (is-open y)) & (put-away x y)) => (~(have x) & (in x y)))
(all x :type are-nuts)(all y :type isa-hub)((((have wrench) & ((tight x y) & (on-ground y))) & (loosen x y))
=> ((loose x y) & ~(tight x y)))
(all x :type are-nuts)(all y :type isa-hub)((((have wrench) & ((loose x y) & (on-ground y))) & (tighten x y))
=> ((tight x y) & ~(loose x y)))
(all x :type isa-hub)((((on-ground x) & (have jack)) & (jack-up x)) => (~(on-ground x) & ~(have jack)))
(all x :type isa-hub)((~(on-ground x) & (jack-down x)) => ((on-ground x) & (have jack)))
(all x :type are-nuts)(all y :type isa-hub)(((~(on-ground y) & (~(unfastened y) & ((have wrench) & (loose x y)))) & (undo x y))
=> ((have x) & ((unfastened y) & (~(on x y) & ~(loose x y)))))
(all x :type are-nuts)(all y :type isa-hub)(((~(on-ground y) & ((unfastened y) & ((have wrench) & (have x)))) & (do-up x y))
=> ((loose x y) & (~(unfastened y) & ~(have x))))
(all x :type wheel)(all y :type isa-hub)(((~(on-ground y) & ((on x y) & (unfastened y))) & (remove-wheel x y))
=> ((have x) & ((wheeless y) & ~(on x y))))
(all x :type wheel)(all y :type isa-hub)((((have x) & ((wheeless y) & ((unfastened y) & ~(on-ground y)))) & (put-on-wheel x y))
=> ((on x y) & (~(have x) & ~(wheeless y))))
(all x :type wheel)((((have pump) & (~(inflated x) & (intact x))) & (inflate x)) => (inflated x))

Stuart Russell's Flat Tire Problem

Plan #200
AN-STEPS:
1) (open-up boot)
causal-links:
0 --~(is-open boot)--> 1
0 --~(locked boot)--> 1
2) (fetch jack boot)
causal-links:
0 --(in jack boot)--> 2
1 --(is-open boot)--> 2
ordering-constraints:
2 > 1
4) (fetch wrench boot)
causal-links:
1 --(is-open boot)--> 4
0 --(in wrench boot)--> 4
ordering-constraints:
4 > 1
5) (loosen nuts hub)
causal-links:
0 --(on-ground hub)--> 5
4 --(have wrench)--> 5
0 --(tight nuts hub)--> 5
ordering-constraints:
5 > 4
3) (jack-up hub)
causal-links:
0 --(on-ground hub)--> 3
2 --(have jack)--> 3
ordering-constraints:
3 > 2
3 > 5
6) (undo nuts hub)
causal-links:
3 --~(on-ground hub)--> 6
0 --~(unfastened hub)--> 6
4 --(have wrench)--> 6
5 --(loose nuts hub)--> 6
ordering-constraints:
6 > 3
7) (remove-wheel wheel1 hub)
causal-links:
3 --~(on-ground hub)--> 7
0 --(on wheel1 hub)--> 7
6 --(unfastened hub)--> 7
ordering-constraints:
7 > 6
8) (put-away wheel1 boot)
causal-links:
1 --(is-open boot)--> 8
7 --(have wheel1)--> 8
ordering-constraints:
8 > 7
9) (fetch pump boot)
causal-links:
0 --(in pump boot)--> 9
1 --(is-open boot)--> 9
ordering-constraints:
9 > 1
10) (inflate wheel2)
causal-links:
9 --(have pump)--> 10
0 --~(inflated wheel2)--> 10
0 --(intact wheel2)--> 10
ordering-constraints:
10 > 9
11) (fetch wheel2 boot)
causal-links:
1 --(is-open boot)--> 11
0 --(in wheel2 boot)--> 11
ordering-constraints:
11 > 1
12) (put-on-wheel wheel2 hub)
causal-links:
3 --~(on-ground hub)--> 12
6 --(unfastened hub)--> 12
11 --(have wheel2)--> 12
7 --(wheeless hub)--> 12
ordering-constraints:
12 > 7
12 > 11
19) (do-up nuts hub)
causal-links:
3 --~(on-ground hub)--> 19
4 --(have wrench)--> 19
6 --(unfastened hub)--> 19
6 --(have nuts)--> 19
ordering-constraints:
19 > 12
18) (jack-down hub)
causal-links:
3 --~(on-ground hub)--> 18
ordering-constraints:
18 > 19
14) (put-away jack boot)
causal-links:
1 --(is-open boot)--> 14
18 --(have jack)--> 14
ordering-constraints:
14 > 18
15) (put-away pump boot)
causal-links:
1 --(is-open boot)--> 15
9 --(have pump)--> 15
ordering-constraints:
15 > 10
17) (tighten nuts hub)
causal-links:
4 --(have wrench)--> 17
19 --(loose nuts hub)--> 17
18 --(on-ground hub)--> 17
ordering-constraints:
17 > 18
16) (put-away wrench boot)
causal-links:
1 --(is-open boot)--> 16
4 --(have wrench)--> 16
ordering-constraints:
16 > 17
13) (close boot)
causal-links:
1 --(is-open boot)--> 13
ordering-constraints:
13 > 8
13 > 11
13 > 14
13 > 15
13 > 16
GOAL:
(~(is-open boot) &
((in jack boot) &
((in pump boot) &
((in wheel1 boot) &
((in wrench boot) &
((tight nuts hub) &
((inflated wheel2) &
(on wheel2 hub))))))))
established by:
8 --> (in wheel1 boot)
10 --> (inflated wheel2)
12 --> (on wheel2 hub)
13 --> ~(is-open boot)
14 --> (in jack boot)
15 --> (in pump boot)
16 --> (in wrench boot)
17 --> (tight nuts hub)

OSCAR's Performance on Stuart Russell's Flat Tire Problem

Elapsed time = 7.39 sec
Cumulative size of arguments = 396
Size of inference-graph = 565 of which 0 were unused suppositions.
70% of the inference-graph was used in the argument.
961 interests were adopted.
288 interests were discharged by nodes used in the solution.
29% of the interests were used directly in finding the solution.
The branching factor = 1.02
679 interest-schemes were constructed.
257 instantiated-premises were constructed.
1112 cycles of reasoning occurred.
200 plans were constructed.

Planning and Searching

- Planning is generally characterized as search.
- Early planners searched the state-space, but that was immense and they could not solve hard problems.
- For a simplified version of the flat tire problem:

```
(number-of-plans *start-state* *operators*
 '((tight nuts hub) (on wheel2 hub)) 12)
```

```
There are 1,367,478,242 plans of length 12
for a branching factor of 5.77
There are 273 plans of length 12 establishing
        ((tight nuts hub) (on wheel2 hub))
The effective branching factor is 3.61
```

Planning and Searching

- Modern planners have been described as “searching the plan-space”.
- This consists of the space of (partial) plans produced in the course of searching for the solution.
- But this space is entirely dependent on the planning algorithm, and is not characteristic of the problem itself.
- In particular, the branching factor does not tell us how hard the problem is — just how hard it is *for this planner.*
- Note that OSCAR’s branching factor for the flat-tire problem is just 1.02. This hardly qualifies as search.

Planning and Searching

- My conjecture is that humans can only solve problems with very small branching factors, relative to their planning algorithm.
- OSCAR constructs plans much like human beings do.
- Most automated planners take search seriously, but this makes the problems harder than they need be.
- OSCAR is able to solve hard problems very efficiently (but also very slowly compared to other planners).