Intro to CS 541 (AI Planning)

http://www.isi.edu/~blythe/cs541

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Syllabus outline (roughly)

- Techniques for generating plans (September)
- Representation for plans and time (end of Sept.)
- Controlling search (October)
- Planning and uncertainty (November, 1st half)
- Applications (November, 2nd half)

How grades will be assigned

- Homeworks: 30%
- Exams: 30%
  - mid-term and final
- Project: 30%
- Class participation and quizzes: 10%

Class projects

- We will put some suggested projects on the web page
  - Develop new features for or application of a planning system, e.g. constraint satisfaction planning on the grid
  - Investigate several planning systems on a class of domains
  - Relevant projects connected to your own research

- Talk to us about what you'd like to do.

- Initial proposals are due Sep 30th (~ 1 page)

  We will give feedback in first week of October

  Final proposals due Oct 9th

- Project presentations: Nov 25th and Dec 2nd, a written report due December 12th.
- AAAI deadline is Jan 20..

Sign-up sheet

- Please add your name and email address to out sign-up sheet.

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Generating plans

- Given:
  - A way to describe the world
  - An initial state of the world
  - A goal description
  - A set of possible actions to change the world

- Find:
  - A prescription for actions to change the initial state into one that satisfies the goal

Applications

- Mobile robots
  - An initial motivator, and still being developed
- Simulated environments
  - Goal-directed agents for training or games
- Web and grid environments
  - Composing queries or services
  - Workflows on a computational grid
- Managing crisis situations
  - E.g. oil-spill, forest fires, urban evacuation, in factories, …
- And many more
  - Factory automation, flying autonomous spacecraft, playing bridge, military planning, …

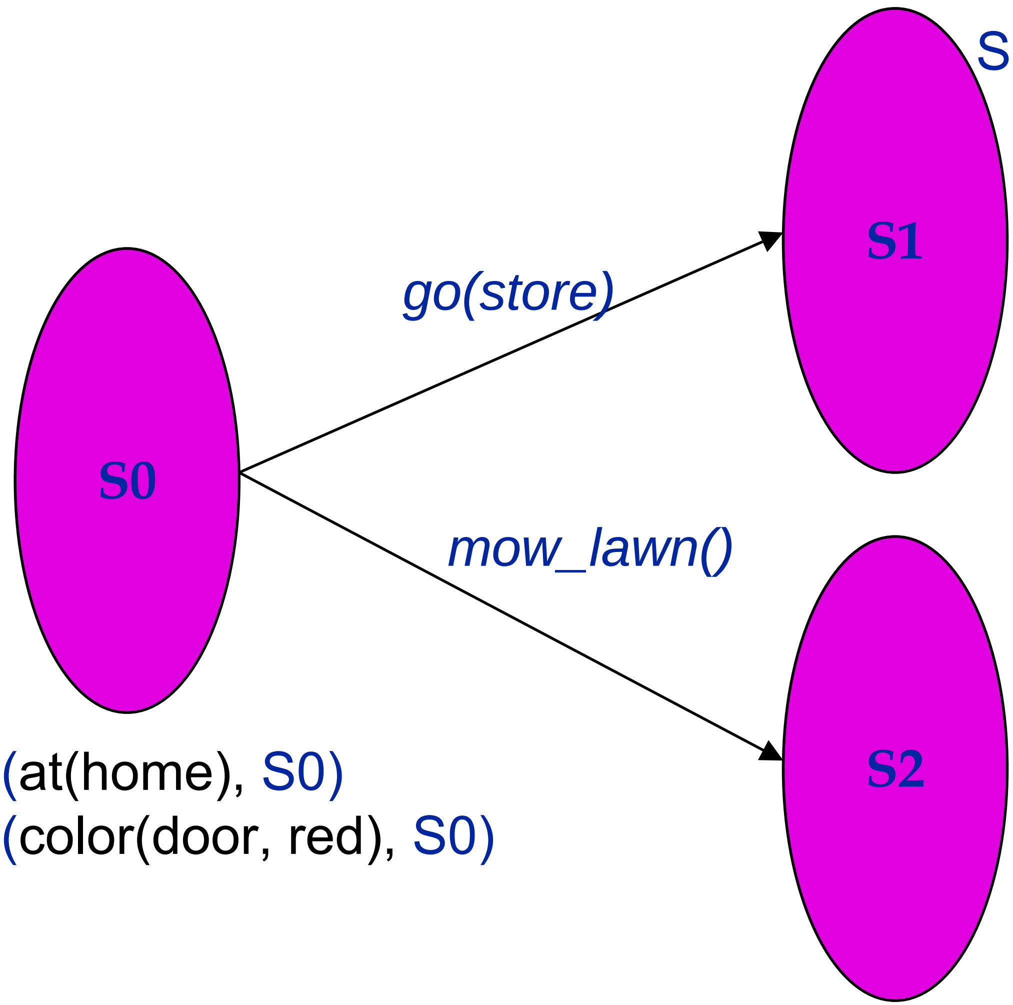
Representing change

- As actions change the world OR we consider possible actions, we want to:
  - Know how an action will alter the world
  - Keep track of the history of world states (have we been here before?)
  - Answer questions about potential world states (what would happen if..?)

The situation calculus (McCarthy 63)

- Key idea: represent a snapshot of the world, called a ‘situation’ explicitly.
- ‘Fluents’ are statements that are true or false in any given situation, e.g. ‘I am at home’
- Actions map situations to situations.

S1 = **result**(*go(store),* S0)



¬ **holds**(at(home), S1)
holds(at(store), S1)

holds(at(home), S0)
holds(color(door, red), S0)

Frame problem

- I go from home to the store, creating a new situation S'. In S':
  - My friend is still at home
  - The store still sells chips
  - My age is still the same
  - Los Angeles is still the largest city in California…

- How can we efficiently represent everything that hasn't changed?

Successor state axioms

- Normally, things stay true from one state to the next -- unless an action changes them:

holds(at(X),result(A,S)) iff A = go(X)
or [holds(at(X),S) and A != go(Y)]

- We need one or more of these for every fluent.

- Now we can use theorem proving to deduce a plan.
- Class dismissed!

Well, not quite..

- Theorem proving can be really inefficient for planning
- How do we handle concurrent events? uncertainty? metric time? preferences about plans? …

Strips (Fikes and Nilsson 71)

- For efficiency, separates theorem-proving within a world state from searching the space of possible states
- Highly influential representation for actions:
  - Preconditions (list of propositions to be true)
  - Delete list (list of propositions that will *become* false)
  - Add list (list of propositions that will *become* true)

Example problem:

Initial state: at(home), ¬ have(beer), ¬ have(chips)

Goal: have(beer), have(chips), at(home)

Actions:

Buy (X):
- Pre: at(store)
- Add: have(X)

Go (X, Y):
- Pre: at(X)
- Del: at(X)
- Add: at(Y)

Frame problem (again)

- I go from home to the store, creating a new situation S'. In S':
  - The store still sells chips
  - My age is still the same
  - Los Angeles is still the largest city in California…
- How can we efficiently represent everything that hasn't changed?
  - Strips provides a good solution for simple actions

Ramification problem

- I go from home to the store, creating a new situation S'. In S':
  - I am now in Marina del Rey
  - The number of people in the store went up by 1
  - The contents of my pockets are now in the store..
- Do we want to say all that in the action definition?

Solutions to the ramification problem

- In Strips, some facts are inferred within a world state,
  - e.g. the number of people in the store
- ‘primitive’ facts, e.g. at(home) persist between states unless changed. ‘inferred’ facts are not carried over and must be re-inferred.
  - Avoids making mistakes, perhaps inefficient.

Questions about Strips

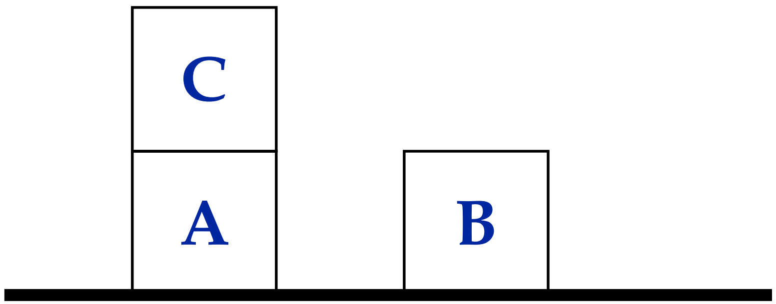
- What would happen if the order of goals was
  at(home), have(beer), have(chips) ?

- When Strips returns a plan, is it always correct? efficient?

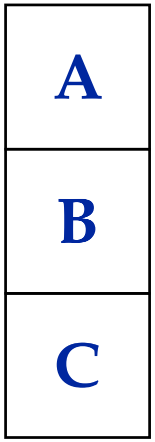
- Can Strips always find a plan if there is one?

Example: blocks world (Sussman anomaly)

Initial:



Goal:



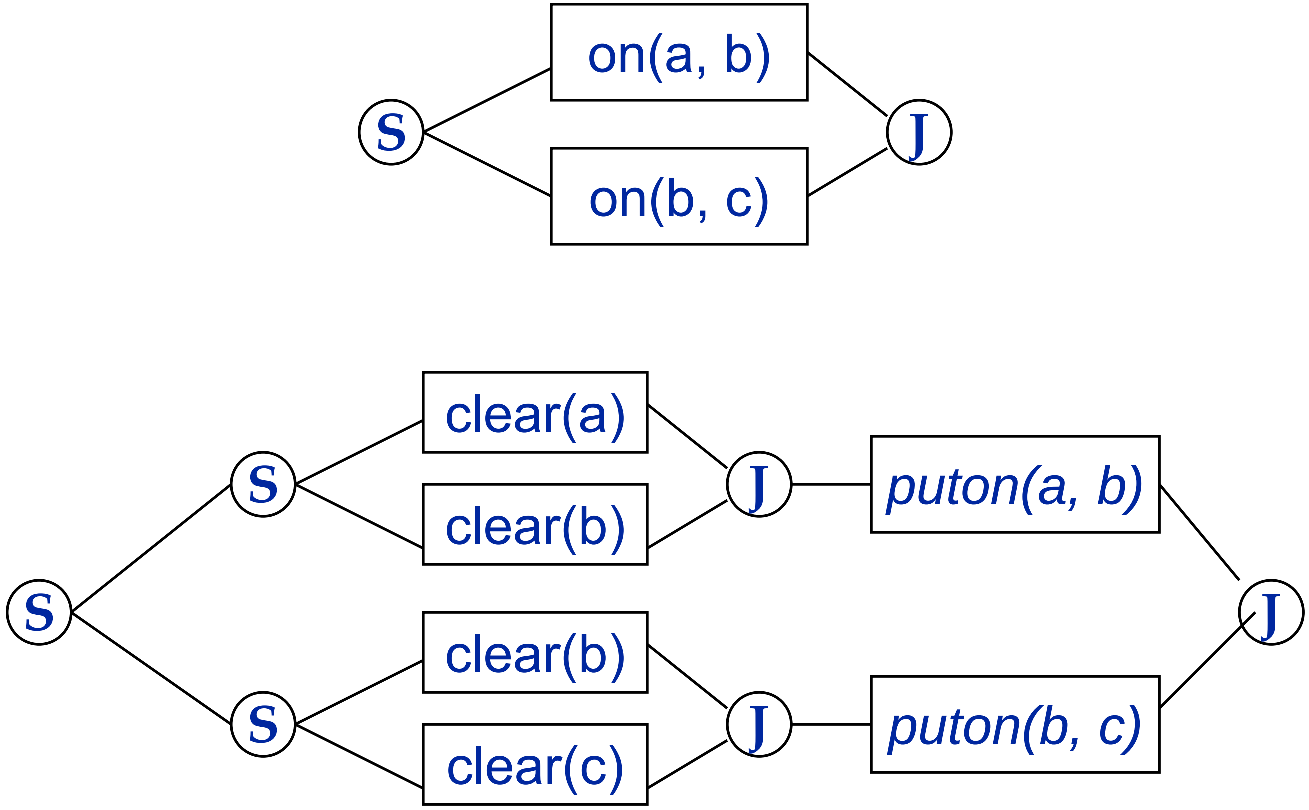
State I: (on-table A) (on C A) (on-table B) (clear B) (clear C)

Goal: (on A B) (on B C)

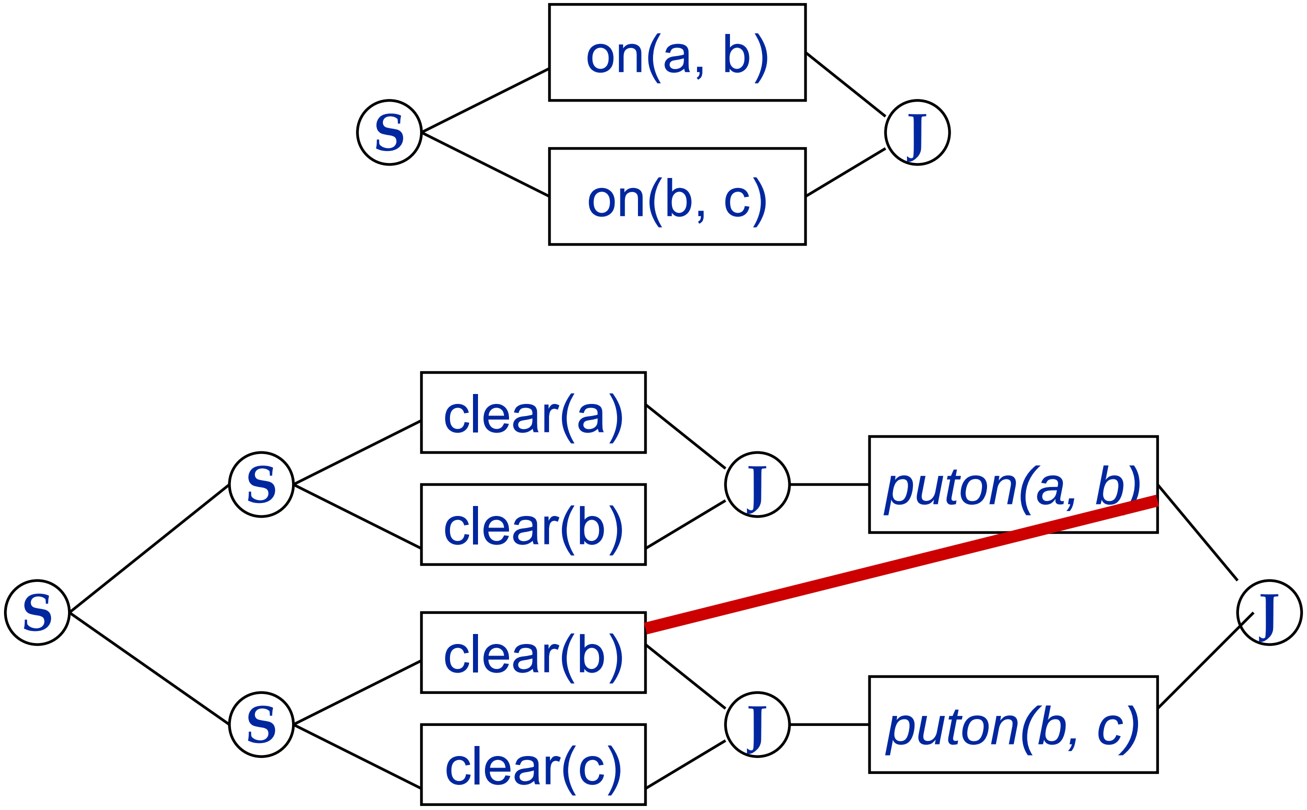
Noah (Sacerdoti 75)

- Explicitly views plans as a partial order of steps. Add ordering into the plan as needed to guarantee it will succeed.
- Avoids the problem in Strips, that focussing on one subgoal forces the actions that resolve that goal to be contiguous.

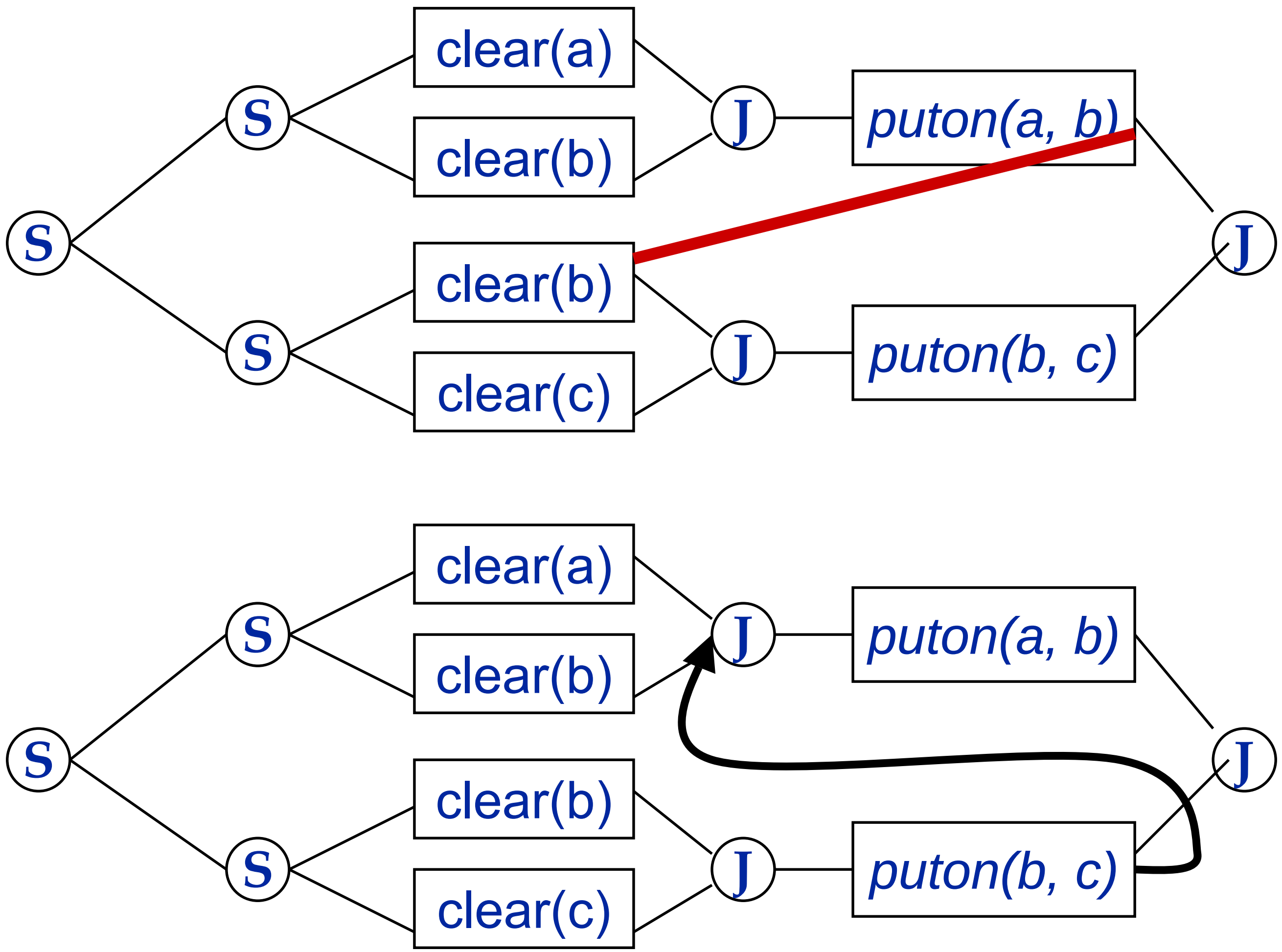
Nets Of Action Hierarchies

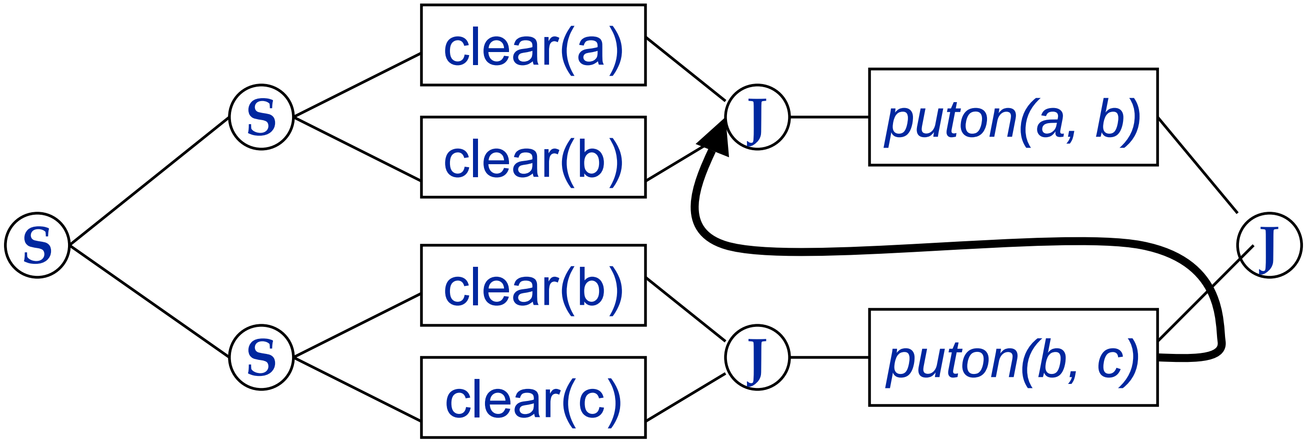


Nets Of Action Hierarchies

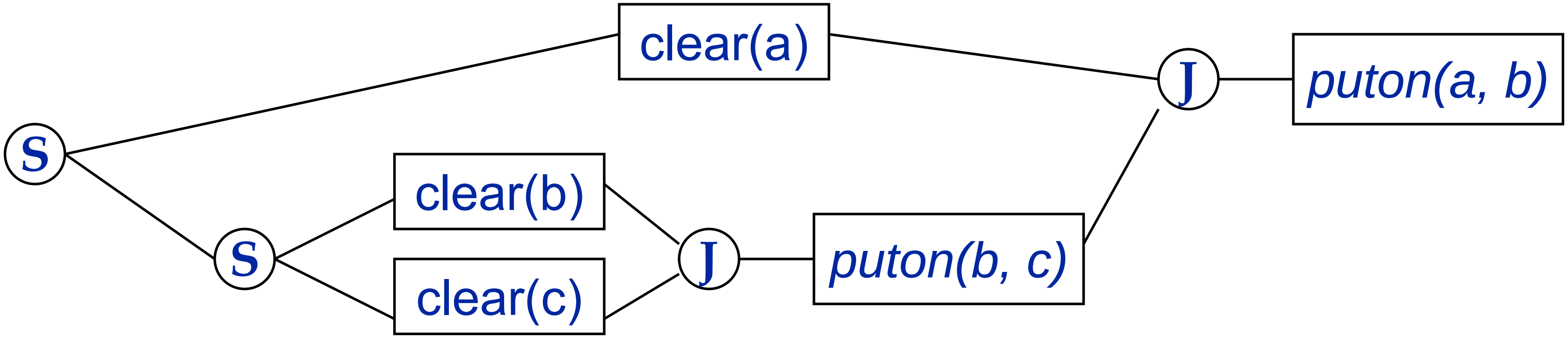


Resolve conflicts 'critic':

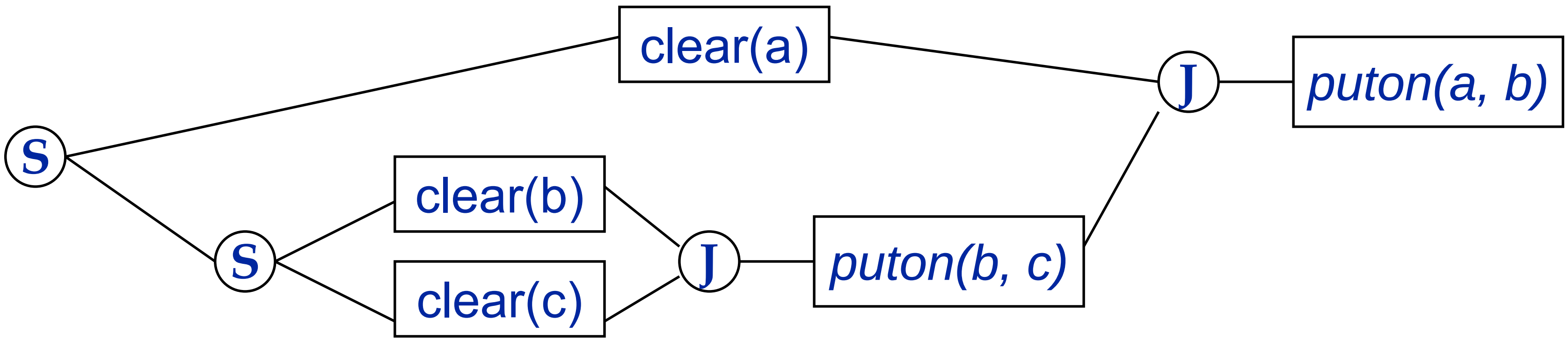


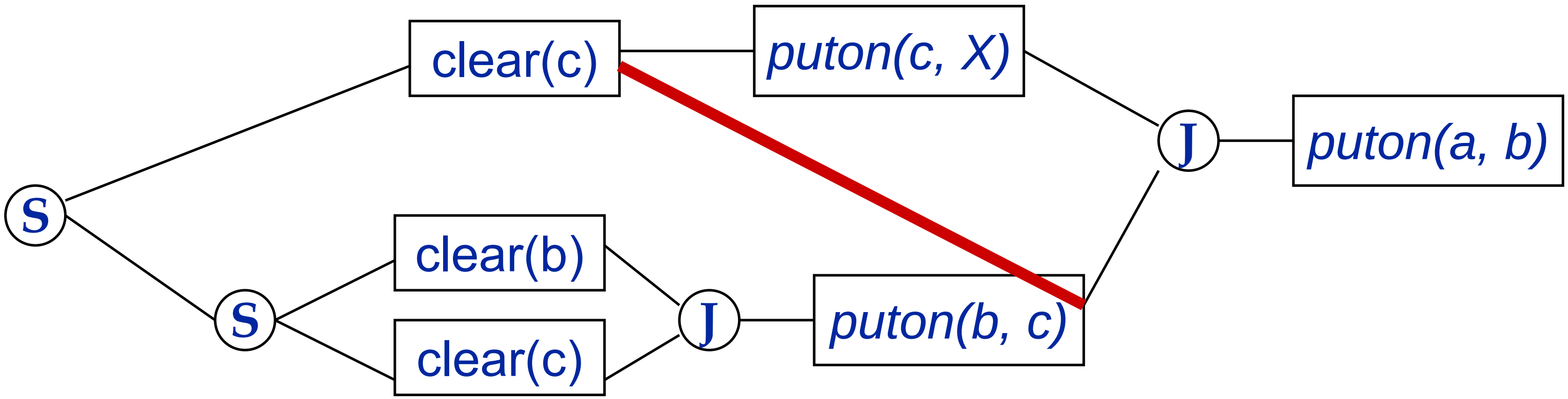


S
S
S
clear(a)
clear(b)
clear(b)
clear(c)
J
J
puton(a, b)
puton(b, c)
J

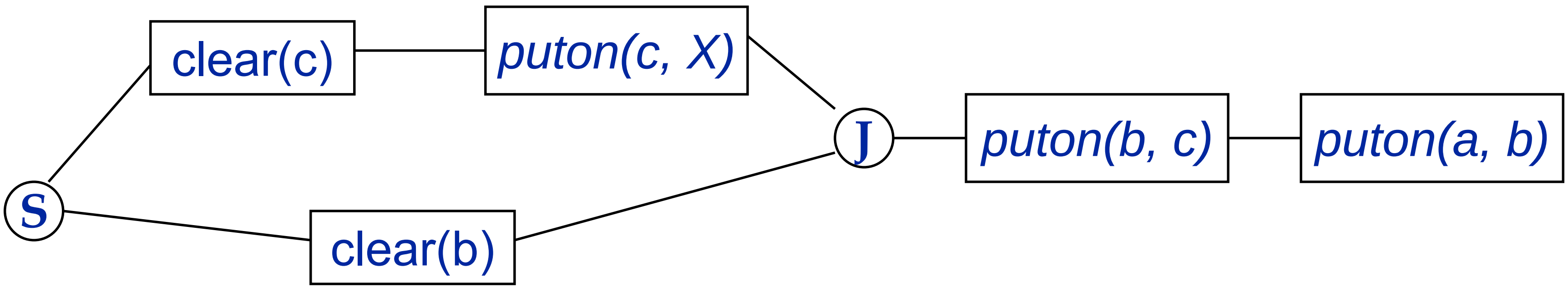


S
S
clear(a)
clear(b)
clear(c)
J
puton(b, c)
J
puton(a, b)


clear(a)
S
J
puton(a, b)
clear(b)
S
J
puton(b, c)
clear(c)


clear(c)
puton(c, X)
J
puton(a, b)
S
clear(b)
S
J
puton(b, c)
clear(c)

Final plan



Strips and Noah: assumptions and discussion points