16-350
Planning Techniques for Robotics

Planning Representations: Symbolic Representation for Task Planning

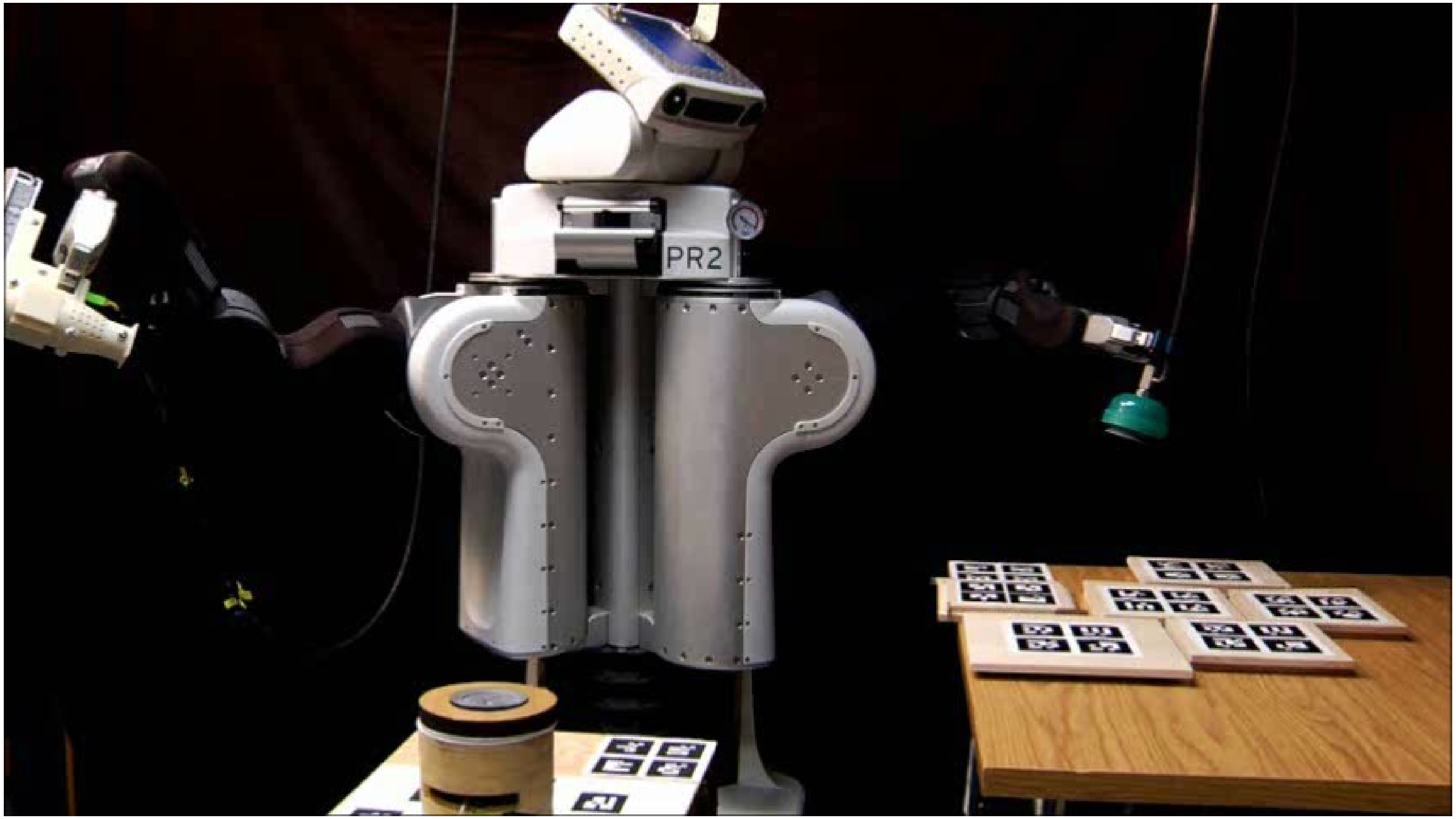
Maxim Likhachev

Robotics Institute

Carnegie Mellon University

Planning to Construct a Birdcage

- Robot takes in a 3D model of a birdcage it needs to build



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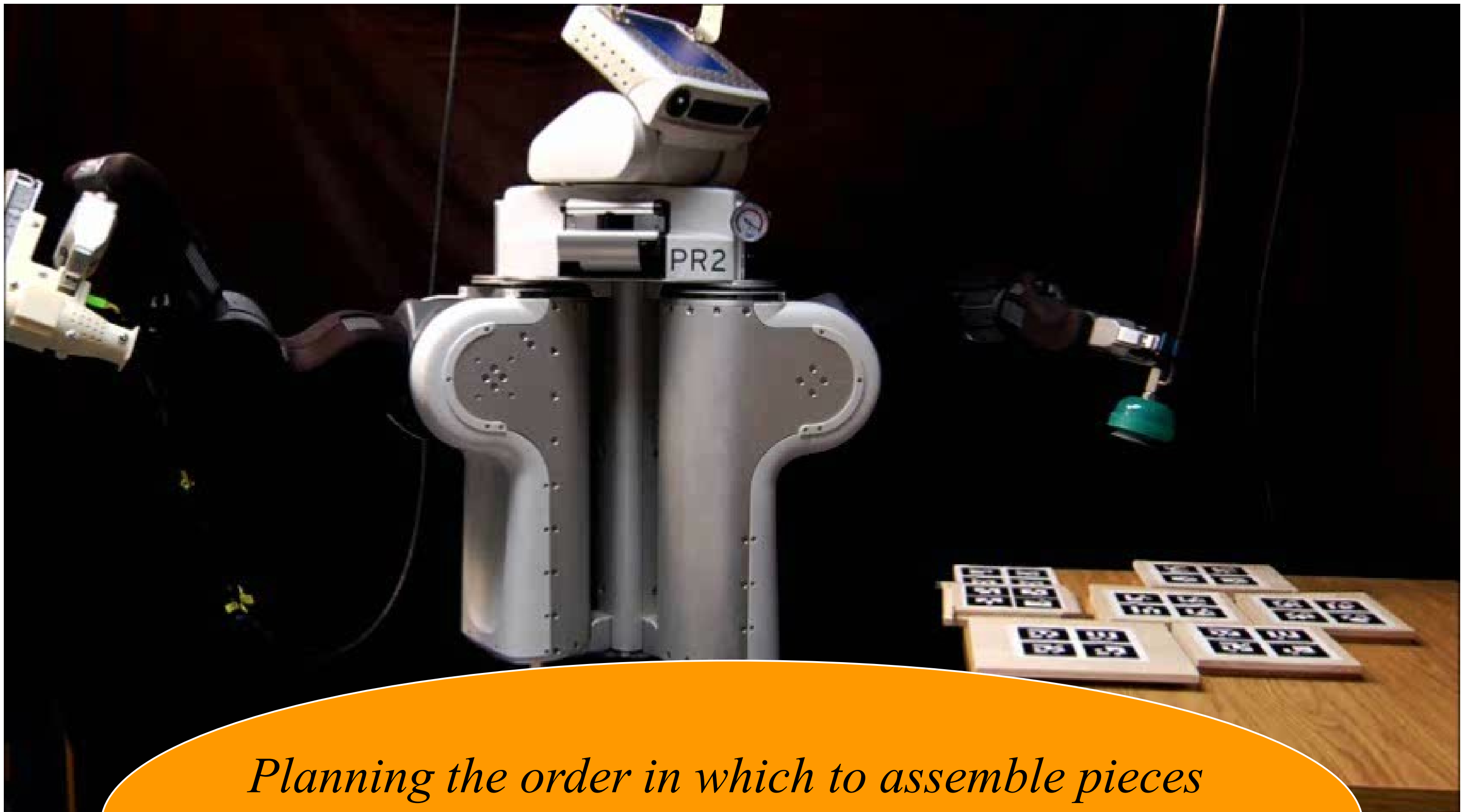


Planning the order in which to assemble pieces is an example of Task Planning

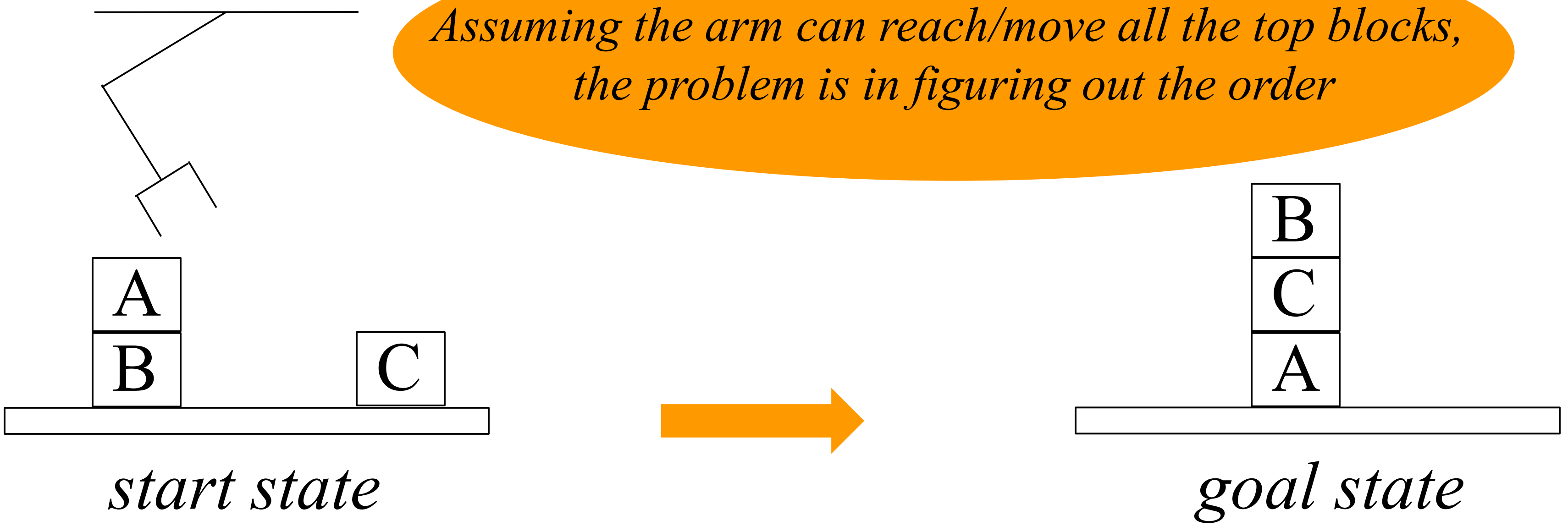
Famous "Blocksworld" Example

- Planning to re-order the blocks

Famous "Blocksworld" Example

- Planning to re-order the blocks

Assuming the arm can reach/move all the top blocks, the problem is in figuring out the order



Famous "Blocksworld" Example

- Planning to re-order the blocks

Actions:

Move(b,x,y) – moves block b from x to y

MoveToTable(b,x) – moves block b from x to table y

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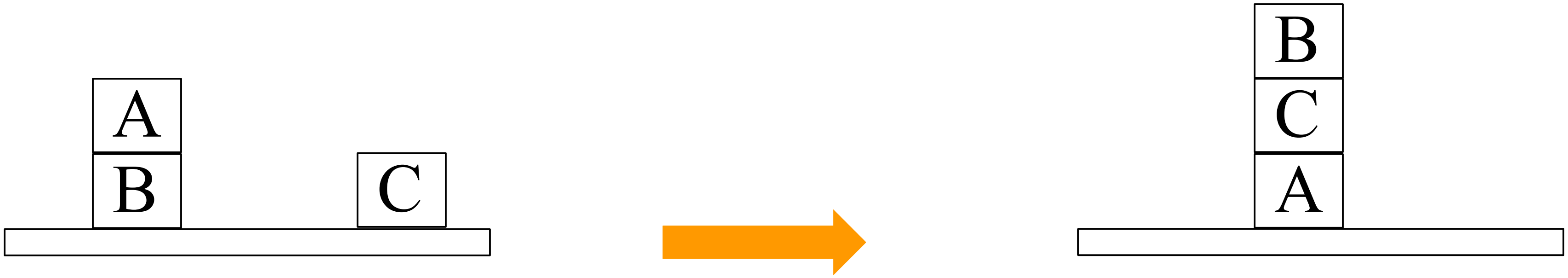


start state *goal state*

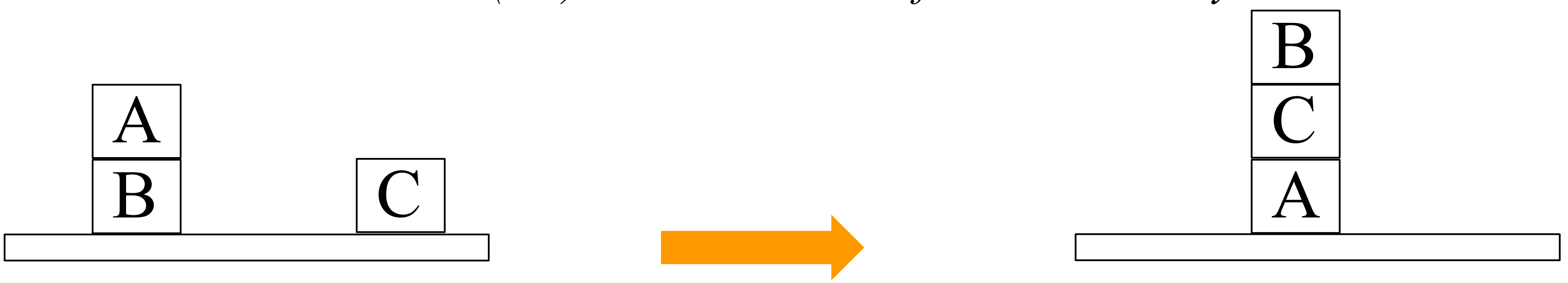
What is a plan that achieves the goal?

Defining it as a Graph Search (State-space Search)

- Planning to re-order the blocks

Actions:

Move(b,x,y) – moves block b from x to y
MoveToTable(b,x) – moves block b from x to table y



start state *goal state*

Any ideas for how to represent a state in a graph?

Defining it as a Graph Search (State-space Search)

- Planning to re-order the blocks

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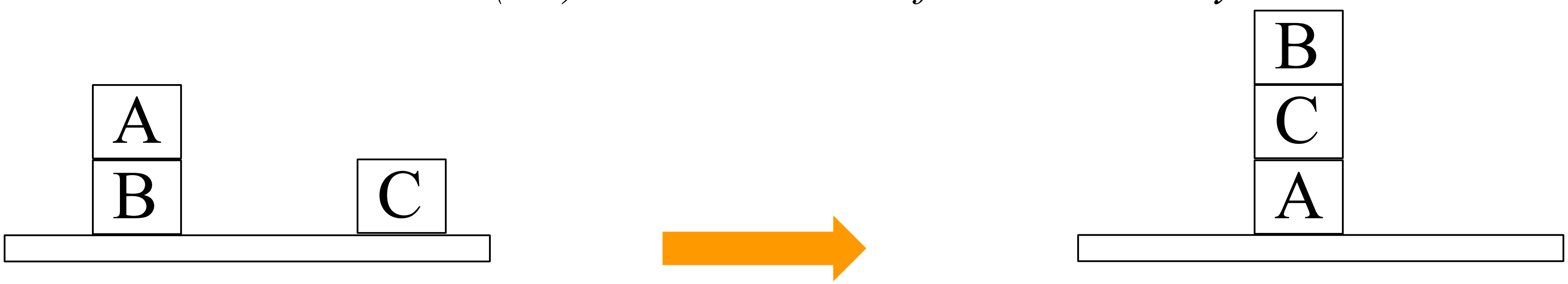

start state *goal state*

A=on B
B=on table
C=on table

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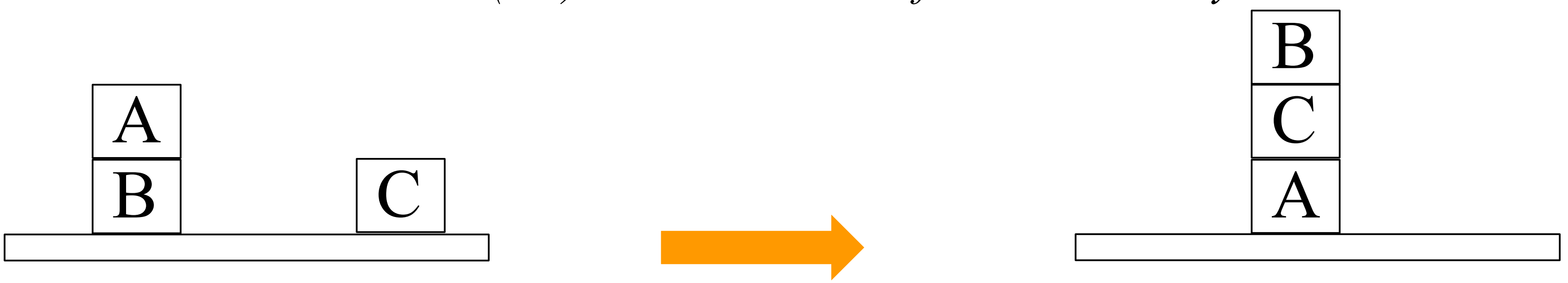

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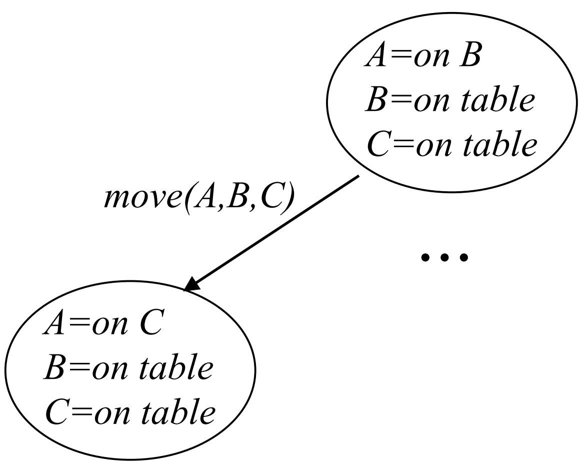

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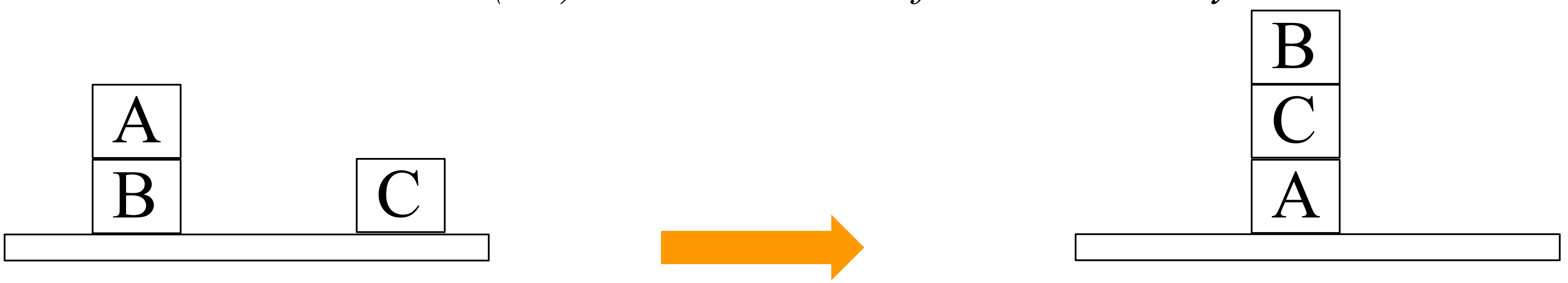

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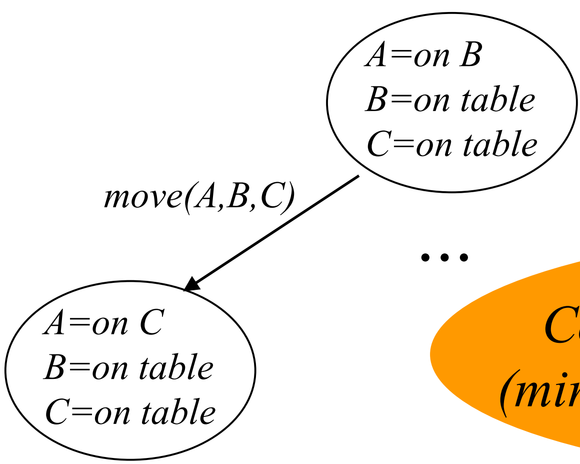

Cost of each edge is often set to 1
(minimization of the total # of actions)

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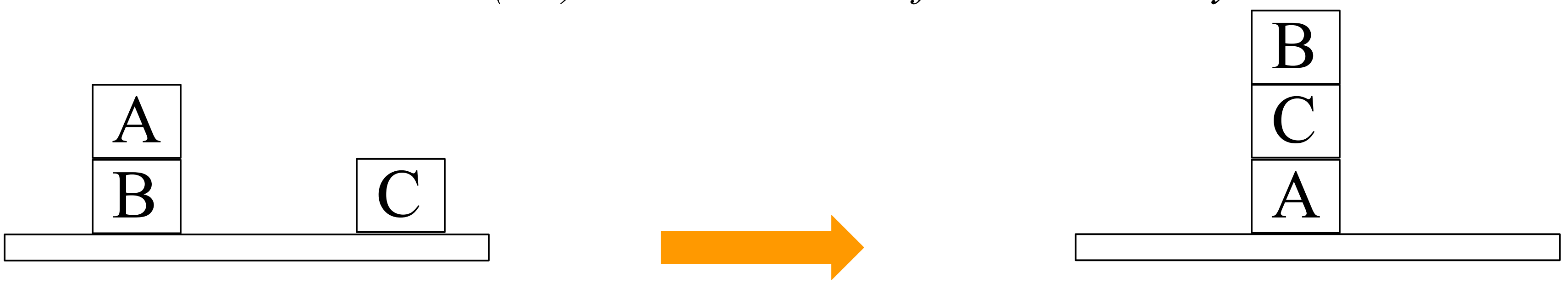

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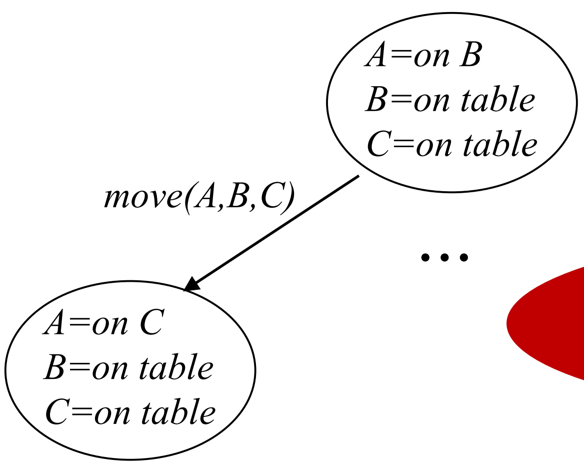

Any ideas for heuristics?

Generic Representation of Symbolic Planning Problems

We would like to be able to represent ANY planning problem with a single representational language that allows for the definition of: STATES, ACTIONS, GOAL

Generic Representation of Symbolic Planning Problems

- STRIPS (=Stanford Research Institute Problem Solver)

State Representation:

Goal Representation:

Action Representation:

Generic Representation of Symbolic Planning Problems

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State Representation:

conjunction of positive(true) literals [redacted]

(e.g, On(A,B)^On(B,Table)^On(C,Table)^Block(A)^Block(B)^Block(C)^Clear(A)^Clear(C))

Goal Representation:

Action Representation:

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Goal Repr

***Closed-world assumption**:*
any conditions not mentioned in the state are assumed to be false

Action Representation:

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What is it for this goal?

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Could be partially-specified

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Goal: any state where A is directly on the table

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Action Representation:

***Preconditions**: conjunction of positive(true) literals that must held true in order for the action to be applicable*

***Effect**: conjunction of positive(true) literals showing how the state will change (what should be deleted and added)*

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What are preconditions & effect for MoveToTable(b,x) action?

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MoveToTable(b,x)
Precond: On(b,x)^Clear(b)^Block(b)
Effect: On(b,Table)^Clear(x)^~On(b,x)

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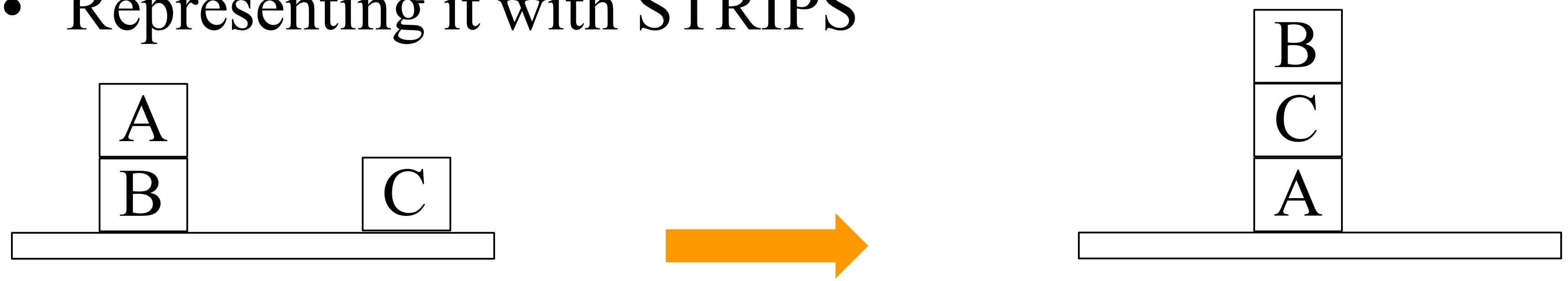
Back to the Example

- Representing it with STRIPS



Start state:

On(A,B)^On(B,Table)^On(C,Table)^Block(A)^Block(B)^Block(C)^Clear(A)^Clear(C)

Goal state:

On(B,C)^On(C,A)^On(A,Table)

Actions:

<u>MoveToTable(b,x)</u>

Precond: On(b,x)^Clear(b)^Block(b)

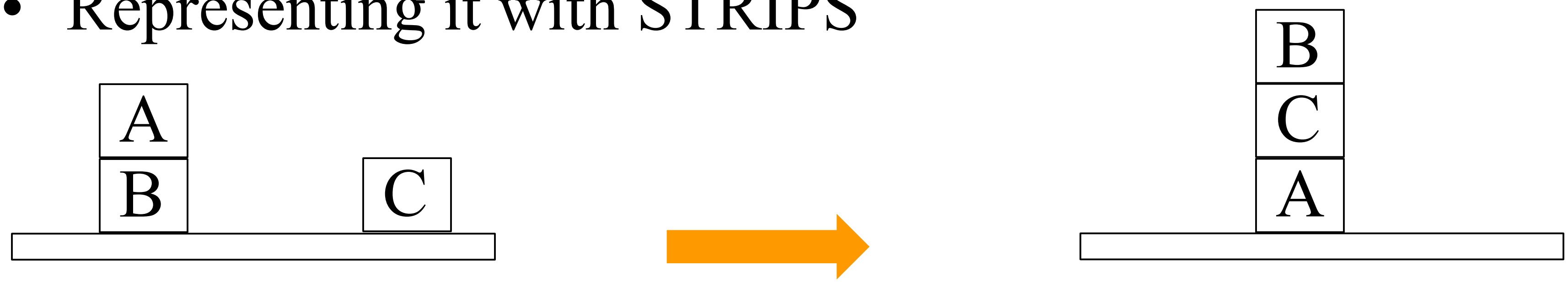
Effect: On(b,Table)^Clear(x)^~On(b,x)

<u>Move(b,x,y)</u>

Precond: On(b,x)^Clear(b)^Clear(y)^Block(b)^Block(y)^(b~=y)

Effect: On(b,y)^Clear(x)^~On(b,x)^~Clear(y)

- Representing it with STRIPS



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Goal state:

On(B,C)^On(C,A)^On(A,Table)

Actions:

Problem (domain) specification

<u>*MoveToTable(b,x)*</u>

Precond: On(b,x)^Clear(b)^Block(b)

Effect: On(b,Table)^Clear(x)^~On(b,x)

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- Representing it with STRIPS

B

We can now write a (domain-independent) program
that takes in such specifications
and automatically provides a function GetSuccessors(state S, action A)
required for implicit graph construction

Start state:

This graph can be
searched with A or any other search*

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Goal state:

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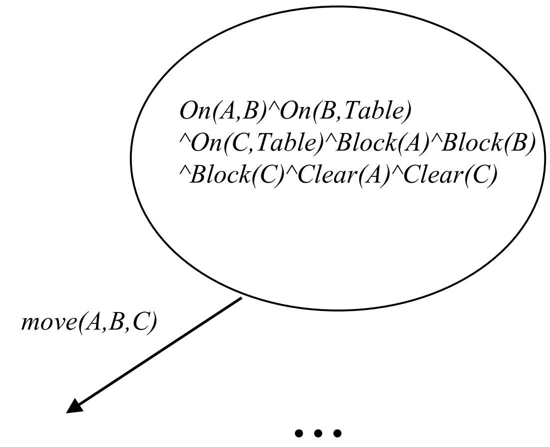

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- Representing it with STRIPS

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required for implicit graph construction

This graph can be
searched with A or any other search*

*This is often referred to as **domain-independent planning***

Start state:

On(A,B)^On(B,Table)^On(C,Table) ... Clear(C)

Goal state:

On(B,C)^On(C,A)^On(...

Actions:

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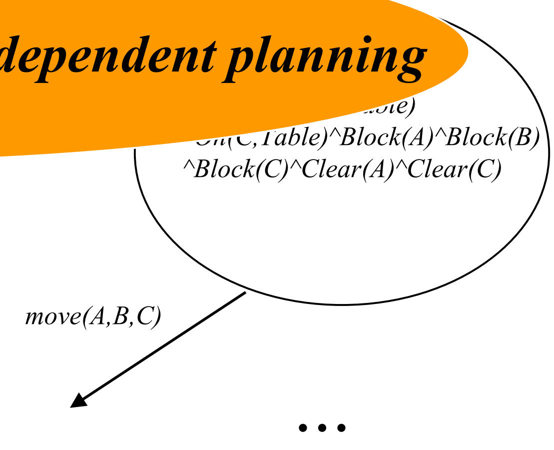

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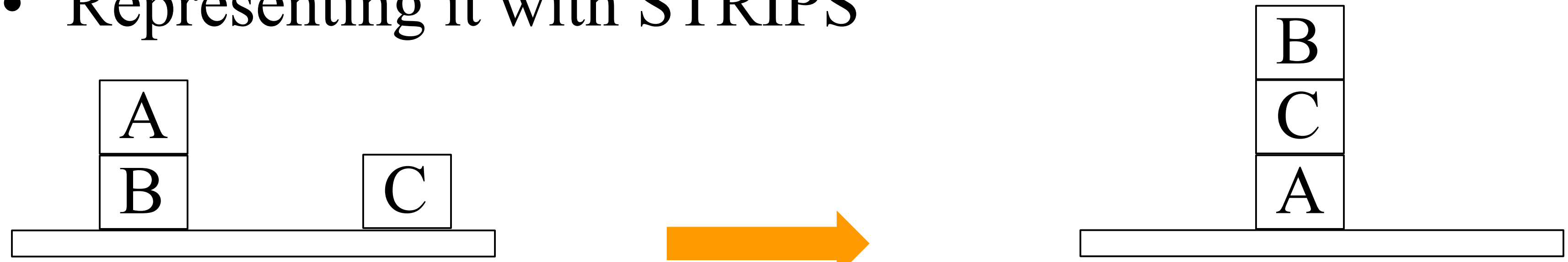
- Representing it with STRIPS



Any ideas for ***domain-independent heuristics?***

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Goal state:

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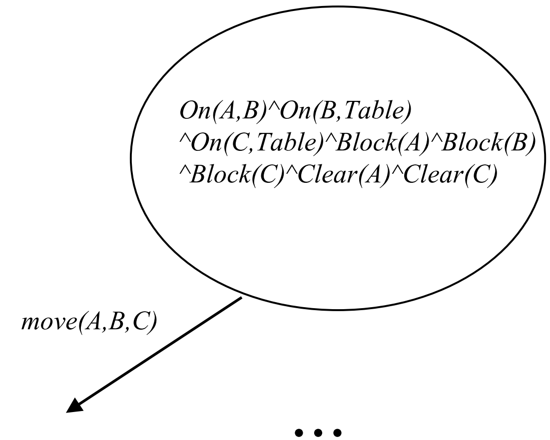

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Summary

- Task planning typically abstracts away lower-level planning (continuous motion/path planning) and focuses on finding a sequence of higher level actions required to achieve a task
- STRIPS (and its latest extensions such as ADL and PDDL) allow for translating compact representations of domains/problems into implicit graphs
- A* (and its variants including weighted A*) can be used to search these implicit graphs