Defining Object Type Using MDP Homomorphisms

Alicia Peregrin Wolfe and Andrew G. Barto

pippin@cs.umass.edu, barto@cs.umass.edu

Autonomous Learning Laboratory

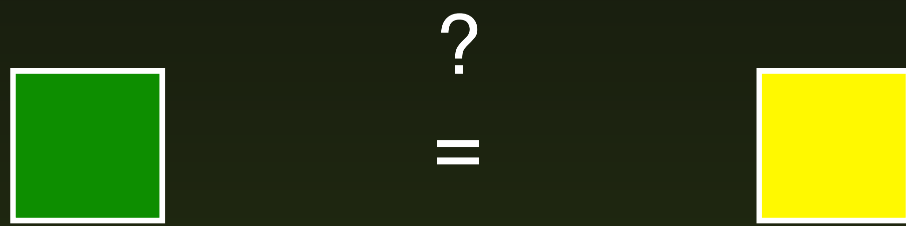
Department of Computer Science

University of Massachusetts, Amherst

Outline

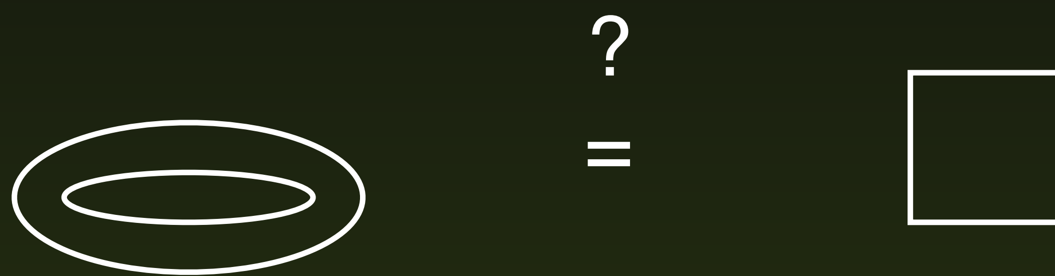
- Introduction: Object Type
- CMP Homomorphisms
- Object Homomorphisms
- Object Options
- Subtypes
- Discussion

Modeling Objects



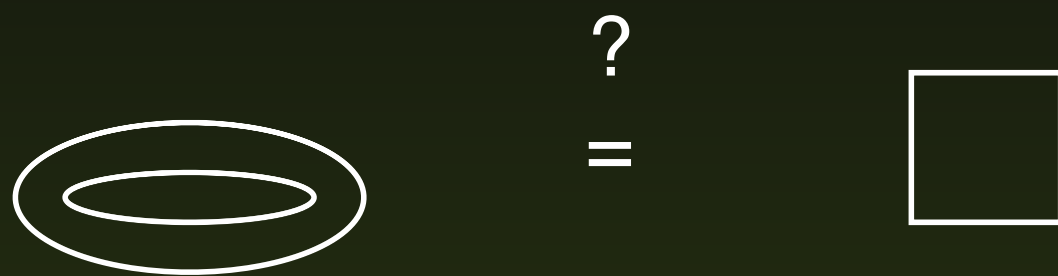
- Are green blocks the same as yellow blocks?
- Could the same policy be used to move both?

Modeling Objects



- Is a block the same as a plate?

Modeling Objects

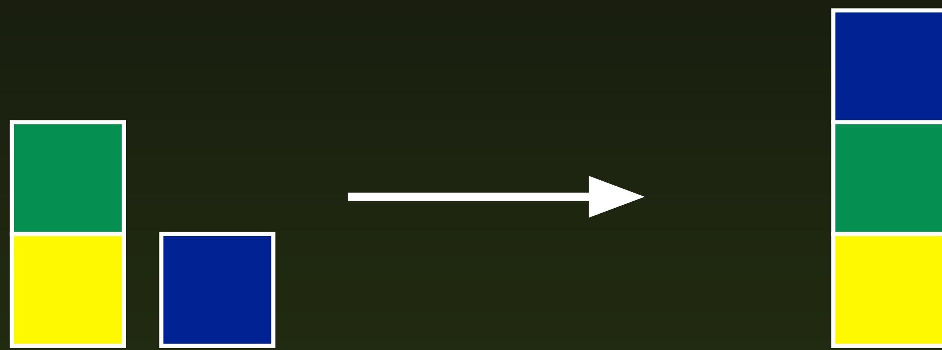


- Is a block the same as a plate?
- Can they be stacked the same way?

Related Work

- Givan, R., Dean, T., & Greig, M. *Equivalence Notions and Model Minimization in Markov Decision Processes.* Artificial Intelligence, 2003
  - stochastic bisimulation
- Ravindran, B. & Barto, A. G. *SMDP Homomorphisms: An Algebraic Approach to Abstraction in Semi Markov Decision Processes.* IJCAI-03
  - MDP Homomorphisms
- CMP Homomorphisms (Wolfe, Barto, AAAI 2006)
  - If you are going to bother to build a model, use it for multiple tasks

Controlled Markov Processes



- Controlled Markov Process: (S, A, T)
- S: State set, A: Action set, $T : S \times A \times S \longrightarrow [0, 1]$

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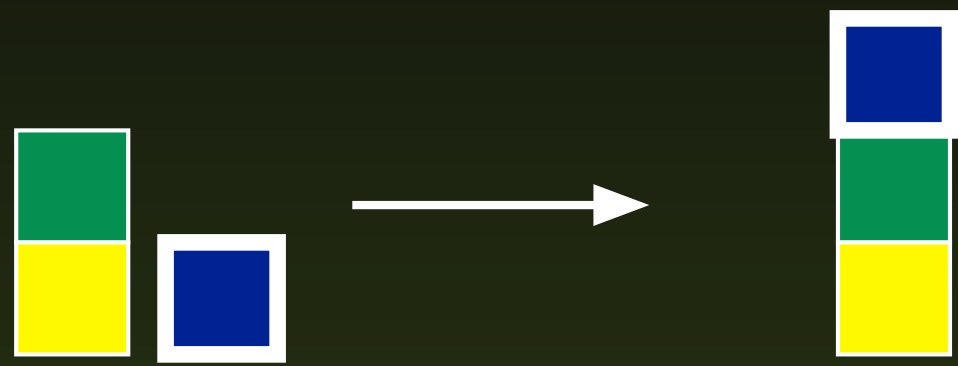
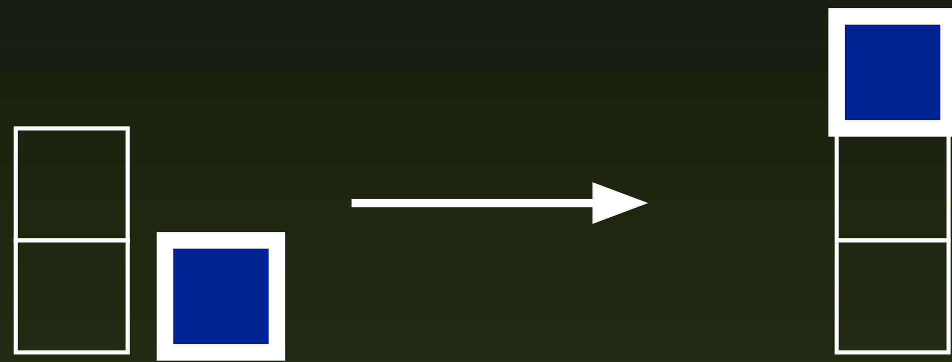


- Controlled Markov Process: (S, A, T)
- S: State set, A: Action set, $T : S \times A \times S \rightarrow [0, 1]$
- Add output variable: (S, A, T, y)
- $y : S \rightarrow Y$

CMP Homomorphisms

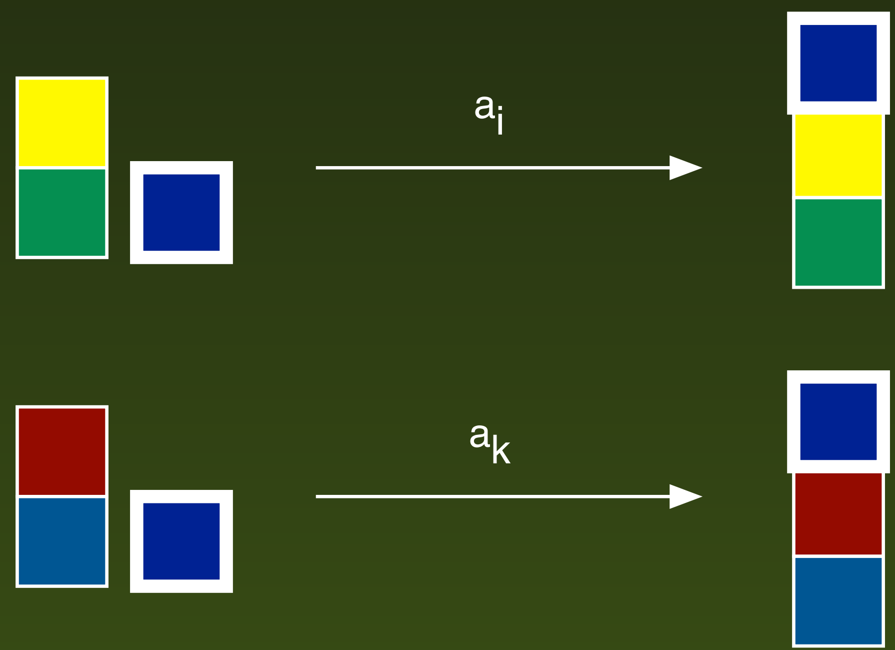


- Model which predicts one specific output variable
- Transitions occur between abstract states
- Can build policies for supported reward functions $r \circ y$

CMP Homomorphisms

- Partition of state and action spaces, with constraints:

$$\begin{aligned} y(f(s), g_s(a)) &= y(s,a) \\ T(f(s_i), g_s(a), f(s_j)) &= \sum_{s_k | f(s_j) = f(s_k)} T(s_i, a, s_k) \end{aligned}$$



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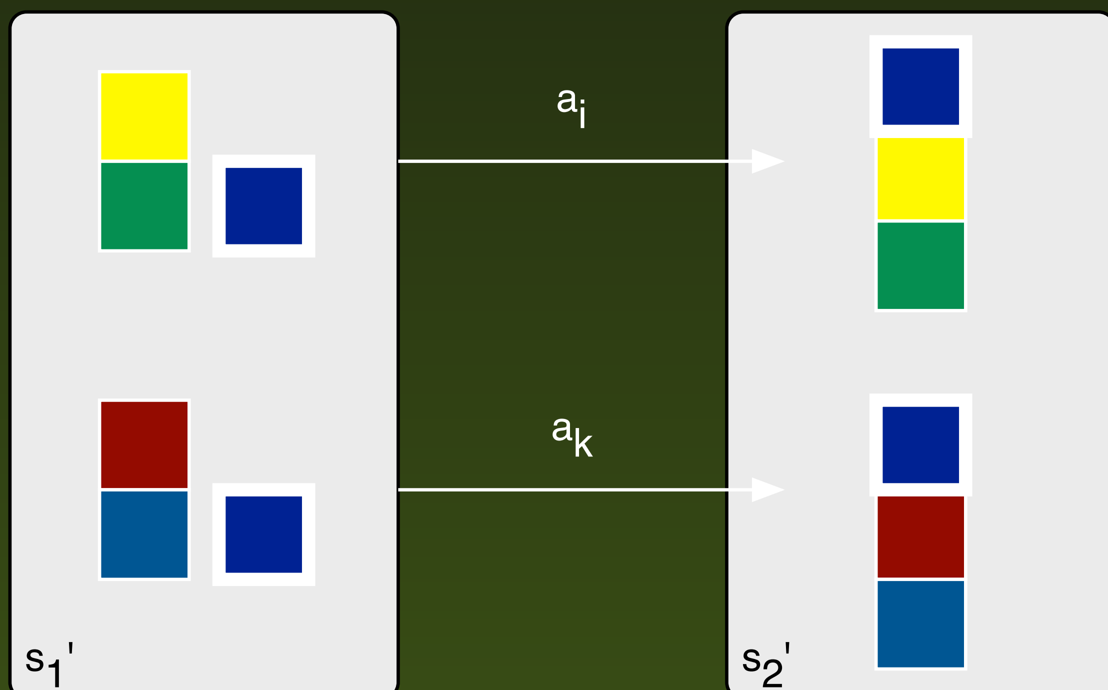

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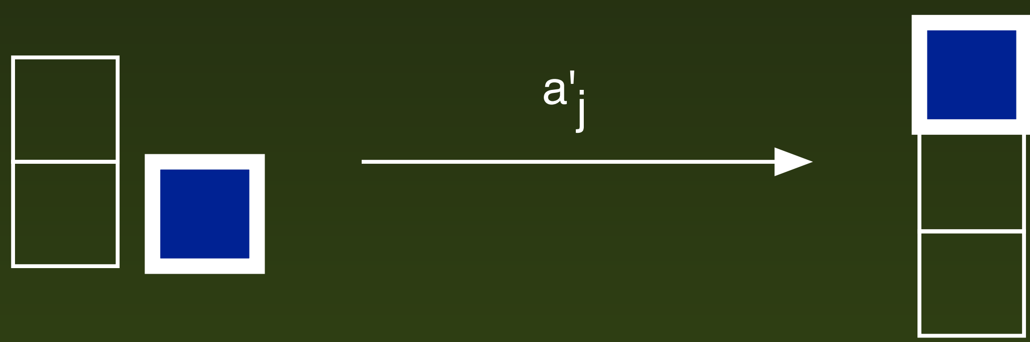

Object CMPs

- Output is $z \circ w_o$ where w_o singles out object o, and z singles out a feature
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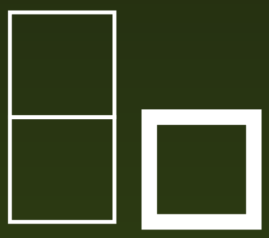

Generalization

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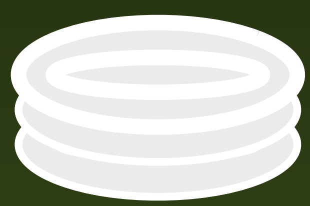

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Lifting Policies

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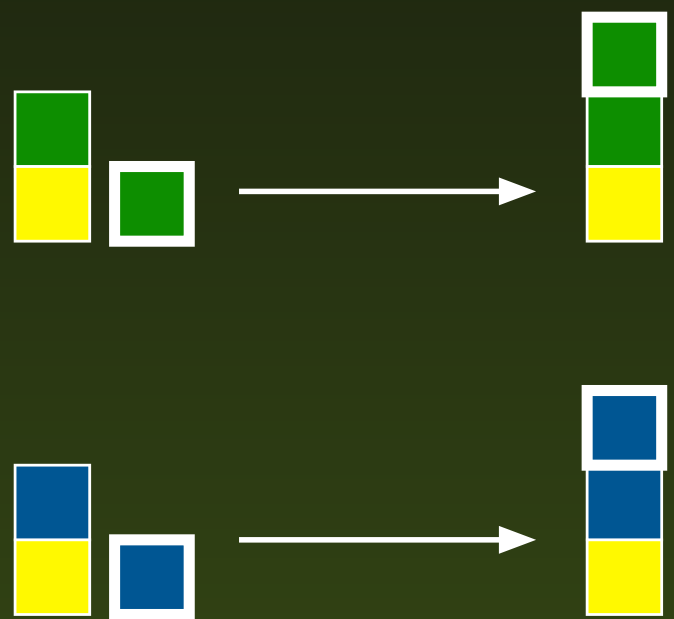
- Reverse mapping to find the corresponding action in the CMP

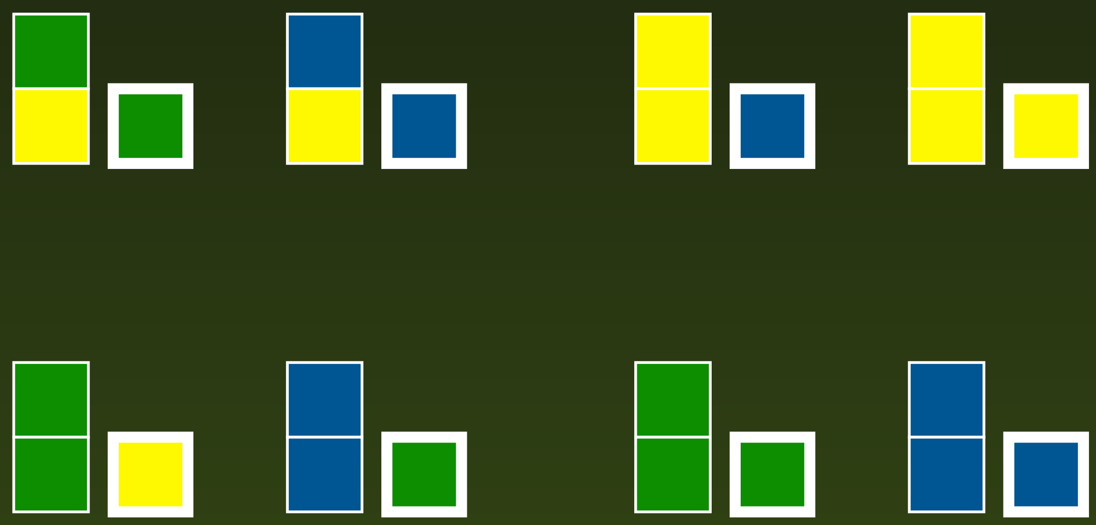


Object Options

- Suboal option:
  - reward function r
  - termination function β
- Object option: both are function of z
- Only need to find policies for types, not specific objects

Object Type: Subtypes

- What if all blue and green blocks stick to blocks of the same color, but yellow do not?
- Sample states:



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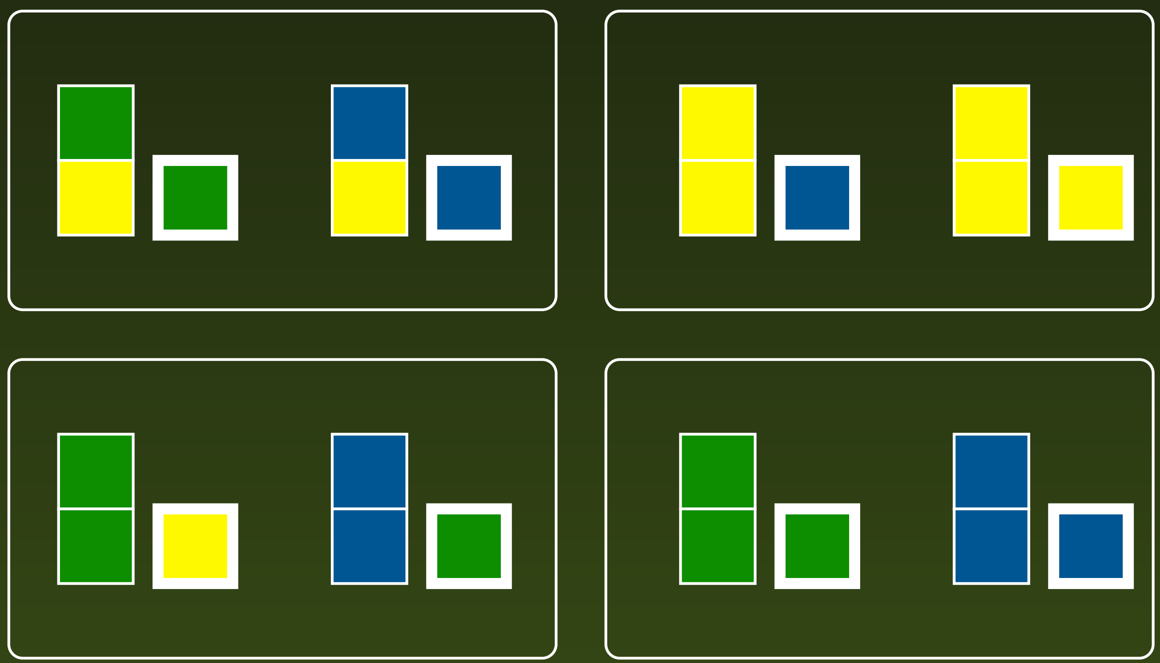

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Object CMPs

- Equivalence criteria:
  - $\forall$ CMPs M_k
  - h_i the reduction of $M_k, z \circ w_{o_i}$
  - $\exists h_j, M_l, h_j$ a reduction of $M_l, z \circ w_{o_j}$
  - Such that $h_i(M_k, z \circ w_{o_i}) = h_j(M_l, z \circ w_{o_j})$
  - Then $o_j \preceq o_i$ under the output z

Discussion

- View environment from point of view of a single object
  - could be another agent
- Alternate method: add "pointer" to state space
  - one large model over all types
- HM framework does not generalize to more objects
  - Can’t use reduction for 3 blocks to learn about 4
  - Find the relations which will generalize from examples of reductions
  - Build a generic reduction