

Symbolic Manipulation Planning with Discovered Object and Relational Predicates

Alper Ahmetoglu, Erhan Oztop, Emre Ugur

How to learn high-level predicates from raw observation?

onTop(x, y)? onRight(x, y)? occupied(x)?

OBJECT ENCODER
 $\sigma(\text{yellow}) = \square \square \dots \square$
 $\sigma(\text{blue}) = \square \square \dots \square$
 $\sigma(\text{red}) = \square \square \dots \square$
 $\sigma(\text{green}) = \square \square \dots \square$

RELATION ENCODER
 Relation 1
 Relation N
 $\sigma(\text{red}, \text{blue}) = 1$

Action representation
 $\sigma(\text{yellow}) = \square \square$
 $\square \square$
 $\square \square$
 $\square \square$

EFFECT DECODER
 Predict effects of action ...

... to learn object symbols and relations

Raw observation **Symbolic representation** **Lifted representation** **Operators**

pick-place(o₁, center, o₂, center)
pick-place(o₁, left, o₂, left)
pick-place(o₂, center, o₁, center)
pick-place(o₁, left, o₂, left)

$\theta = \{?a/o_1, ?b/o_2, ?c/o_3\}$

```

(:action a_center_b_center
 :parameters (?a ?b ?c)
 :precondition (and
  (not (= ?a ?b)) (not (= ?a ?c)) (not (= ?b ?c))
  (p0 ?a) (not_p1 ?a) (not_p2 ?a) (p3 ?a)
  (p0 ?b) (not_p1 ?b) (p2 ?b) (not_p3 ?b)
  (p0 ?c) (not_p1 ?c) (not_p2 ?c) (p3 ?c)
  (not_r0 ?a ?a) (r0 ?a ?b) (r0 ?a ?c)
  (not_r0 ?b ?a) (not_r0 ?b ?b) (r0 ?b ?c)
  (not_r0 ?c ?a) (not_r0 ?c ?b) (not_r0 ?c ?c))
 :effect (and (not_r0 ?a ?b) (not_r0 ?a ?b)))
  
```

Prediction in raw point clouds ...

... and planning via symbols and relations.