

About Life-Long Learning in Autonomous Manipulation

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Manipulation in Unstructured Environments

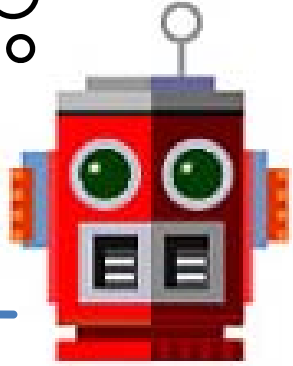
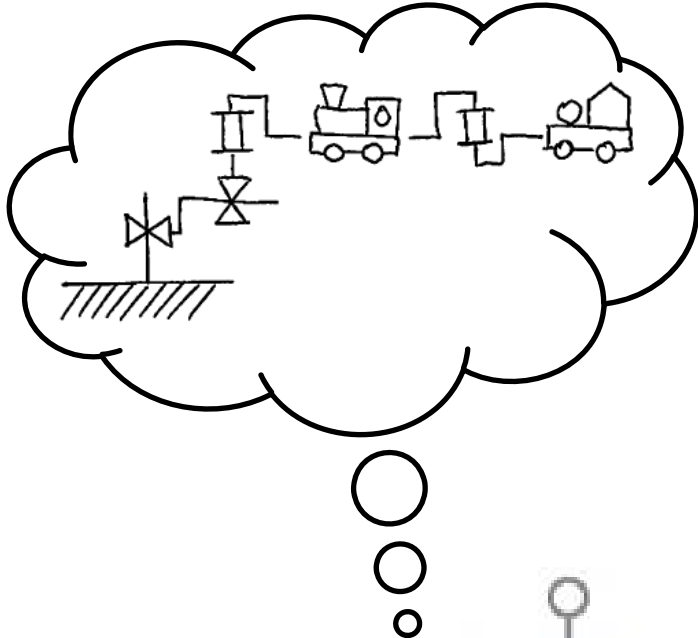


Lifelong Learning

Improve behavior based on experience

- ▶ Record experience (= sensorimotor trace)
- ▶ Categorize experiences
- ▶ Detect regularities / covariances / causalities
- ▶ Transfer insights to improve performance
- ▶ Expand behavioral capabilities

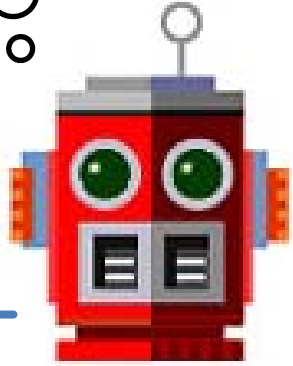
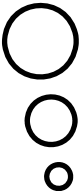
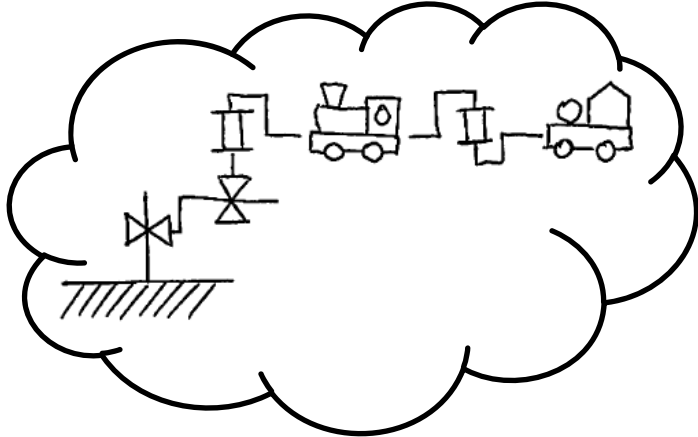
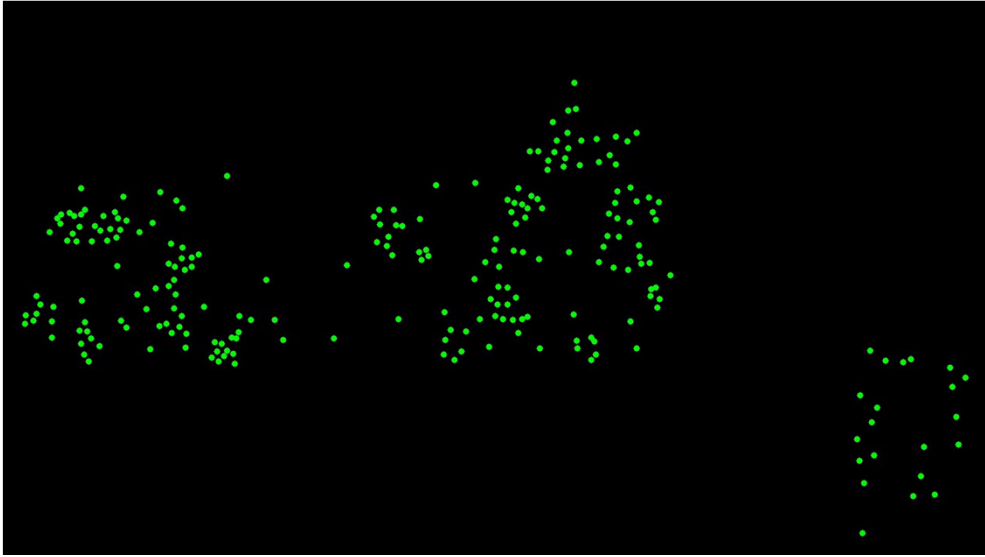
Perceiving 3D Models of Articulated Objects



$$F(t) = (x_t, y_t, c_t)$$

Interaction

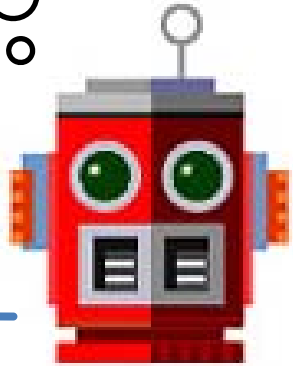
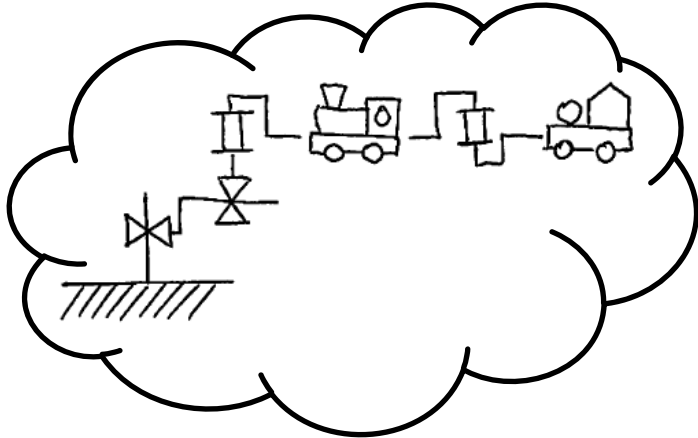
What the Robot Sees...



$$F(t) = (x_t, y_t, c_t)$$

Interaction

Perceiving 3D Models of Articulated Objects

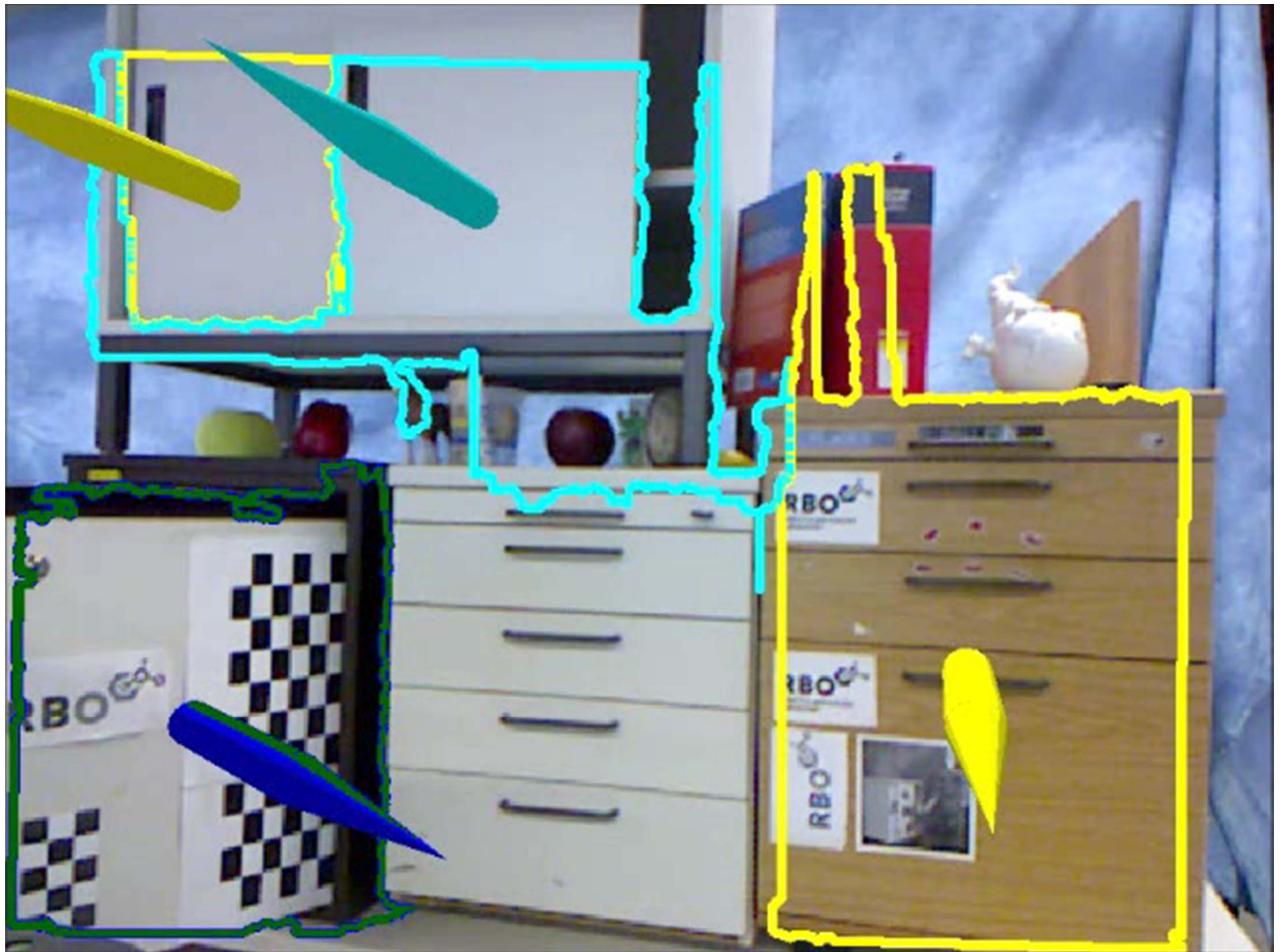


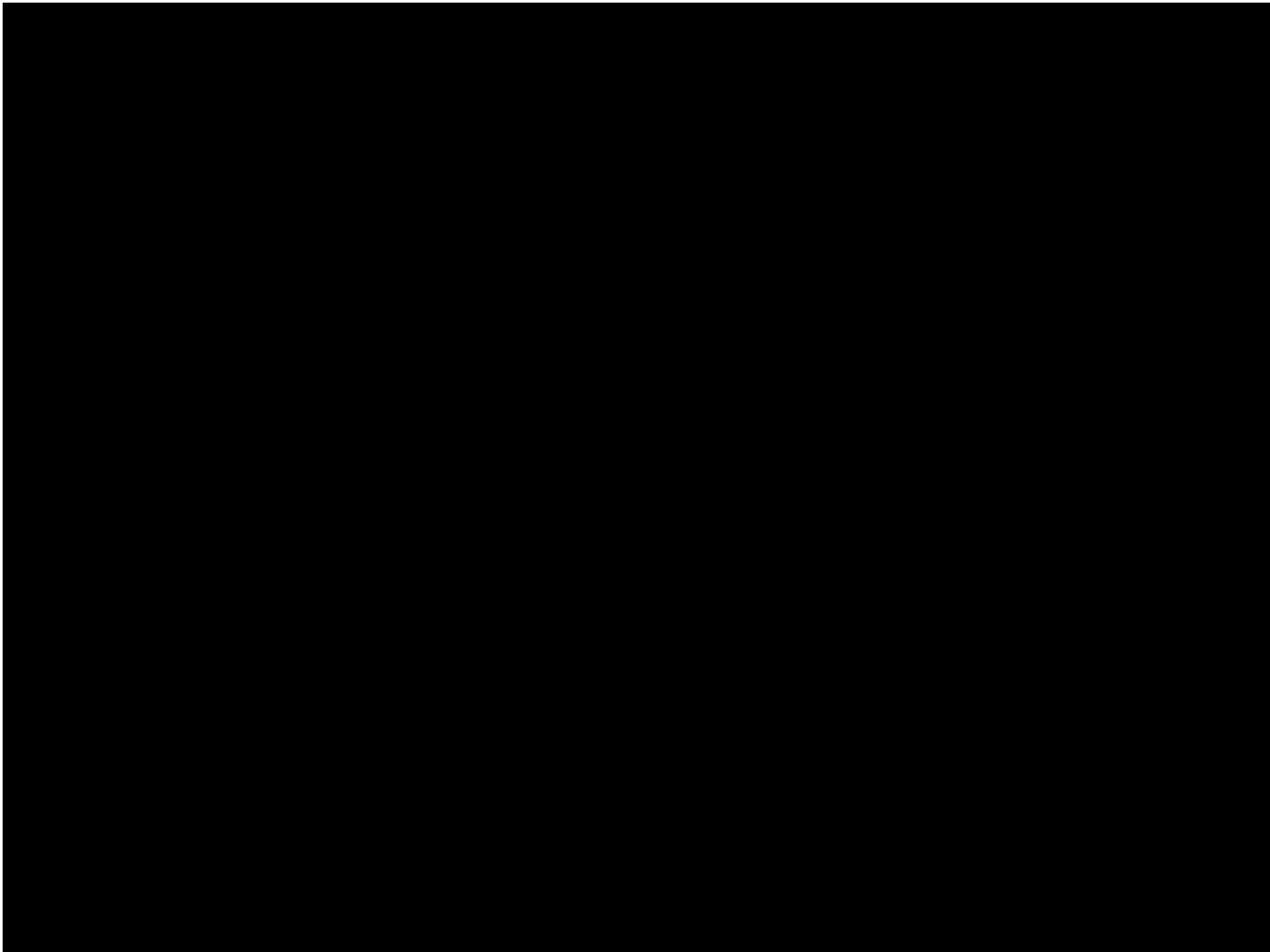
$$F(t) = (x_t, y_t, c_t)$$

Interaction

x2





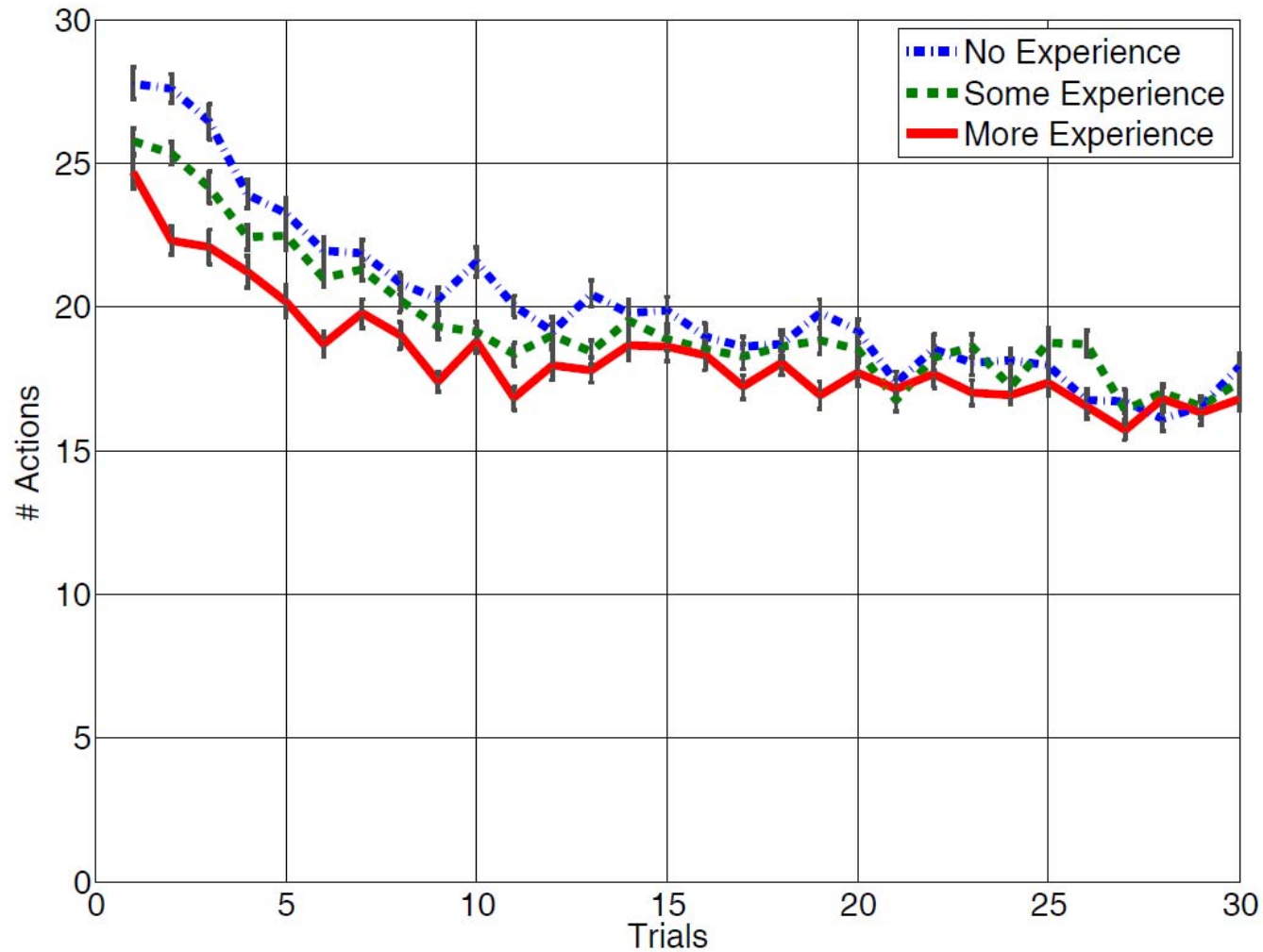
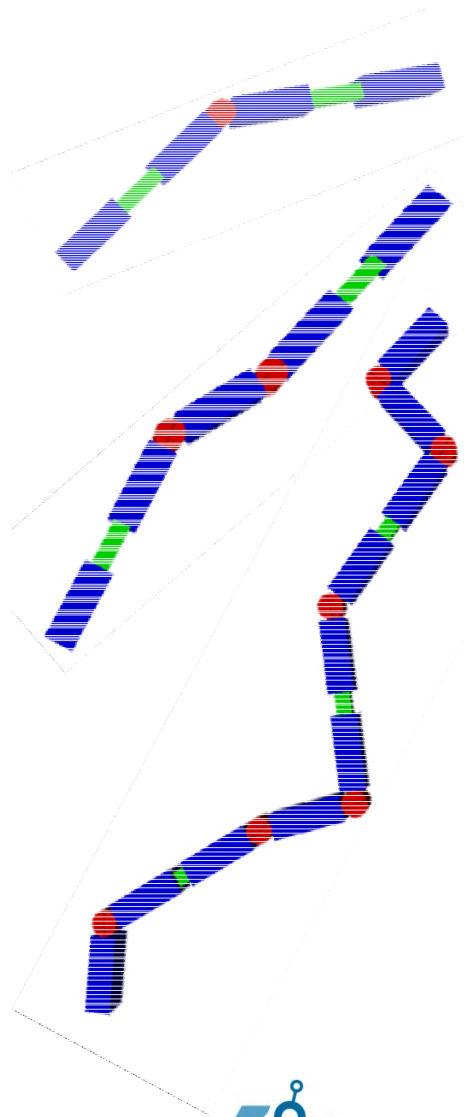




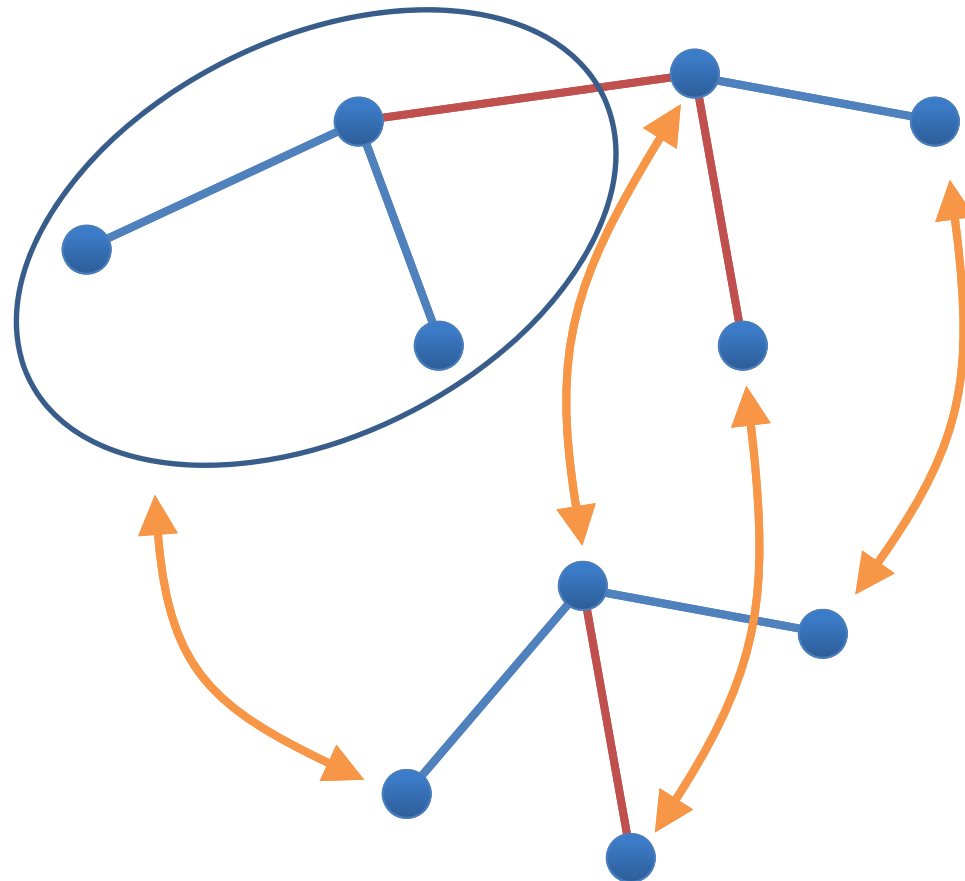
Action 11



Incremental Learning and Transfer



Transfer Through Subgraph Isomorphism



Learning Symbolic Models of Stochastic Domains

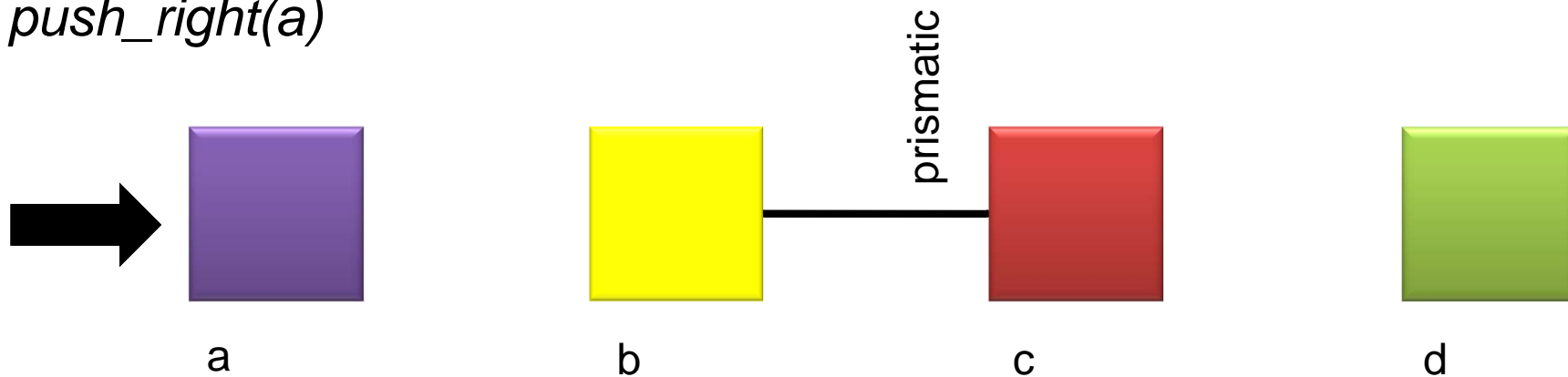
$pickup(X) : \{ Y : table(Y), on(X, Y) \}$

inhand-nil

$\rightarrow \begin{cases} .8 : inhand(X), \neg on(X, Y) \\ .1 : \text{no change} \\ .1 : \text{noise} \end{cases}$

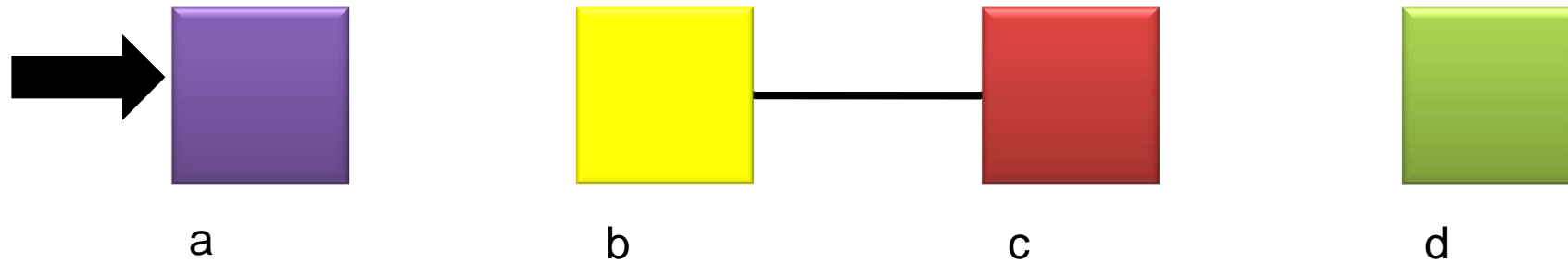
A Simple Manipulation Task

push_right(a)



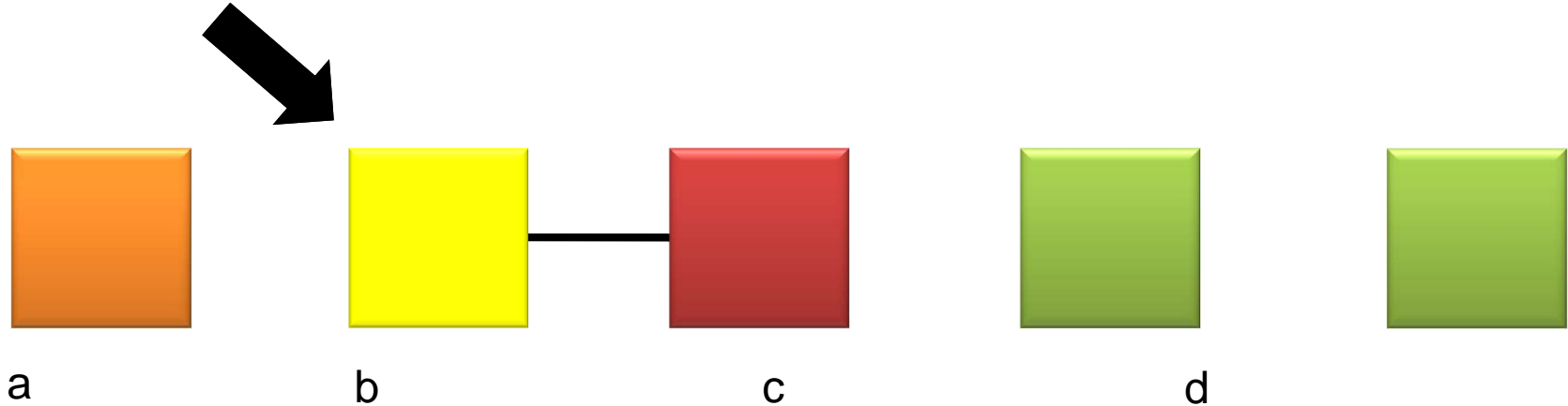
purple(a), yellow(b), red(c), green(d),
right(a,b), right(b,c), right(c,d),
distance(a,b)=1.0, distance(b,c)=10.45, distance(c,d)=0.0
prismatic(ab,cd)

Learned Rules After One Trial



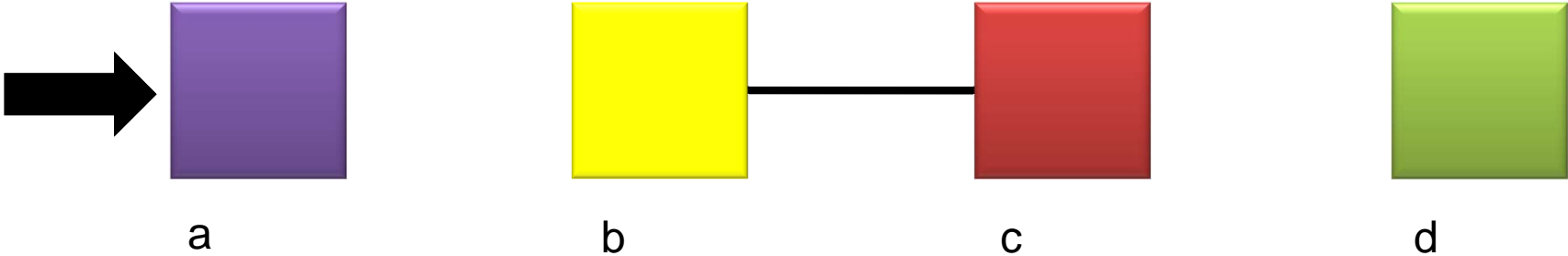
<i>Context:</i>	purple(X)
<i>Action:</i>	push_right(X)
<i>Outcomes:</i>	
1.0	prismatic()

Learned Rules After Several Trials



<i>Context:</i>	yellow(X)
<i>Action:</i>	push_backwardright(X)
<i>Outcomes:</i>	
1.0	prismatic()

More Learned Rules



<i>Context:</i>	$\text{numLeft}(X) > 0$
<i>Action:</i>	push_right(X)
<i>Outcomes:</i>	
1.0	prismatic()

<i>Context:</i>	$\text{numLeft}(X) \leq 0$
<i>Action:</i>	push_right(X)
<i>Outcomes:</i>	
1.0	-

Conclusion



- ▶ What exactly is lifelong learning?
- ▶ How does LLL differ for continuous and symbolic domains?
- ▶ How can the two domains be integrated? (grounding)
- ▶ How to achieve generalization?
 - within a task?
 - across tasks?
- ▶ How to trust/verify/revise/remove your generalization?
 - exploration / exploitation

Robotics and Biology Lab @ TU Berlin

