Manipulation in Unstructured Environments

[Kemp 09] [Sturm, Stachniss, Burgard 08] [Yan, Pollefeys 06]
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

\[ F(t) = (x_t, y_t, c_t) \]
What the Robot Sees…

\[ F(t) = (x_t, y_t, c_t) \]

Interaction
Perceiving 3D Models of Articulated Objects

\[ F(t) = (x_t, y_t, c_t) \]
Action 11
Incremental Learning and Transfer
Transfer Through Subgraph Isomorphism
Learning Symbolic Models of Stochastic Domains

\[ \text{pickup}(X) : \left\{ Y : \text{table}(Y), \text{on}(X, Y) \right\} \]

\text{inhand-nil} \\
\rightarrow \left\{ \\
\begin{array}{l}
.8 : \text{inhand}(X), \neg \text{on}(X, Y) \\
.1 : \text{no change} \\
.1 : \text{noise}
\end{array}
\right\}
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)=0.45, distance(c,d)=1.0

prismatic(ab,cd)

[Pasula, Zettlemoyer, Kalbling 2007]
Learned Rules After One Trial

**Context:** purple(X)

**Action:** push_right(X)

**Outcomes:**
1.0 prismatic()
Learned Rules After Several Trials

Context: yellow(X)
Action: push_backwardright(X)
Outcomes:
1.0 prismatic()
More Learned Rules

Context: numLeft(X)>0
Action: push_right(X)
Outcomes: 1.0 prismatic()

Context: numLeft(X)<=0
Action: push_right(X)
Outcomes: 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