A Basis for Robot Co-Knowledge

Tom Henderson

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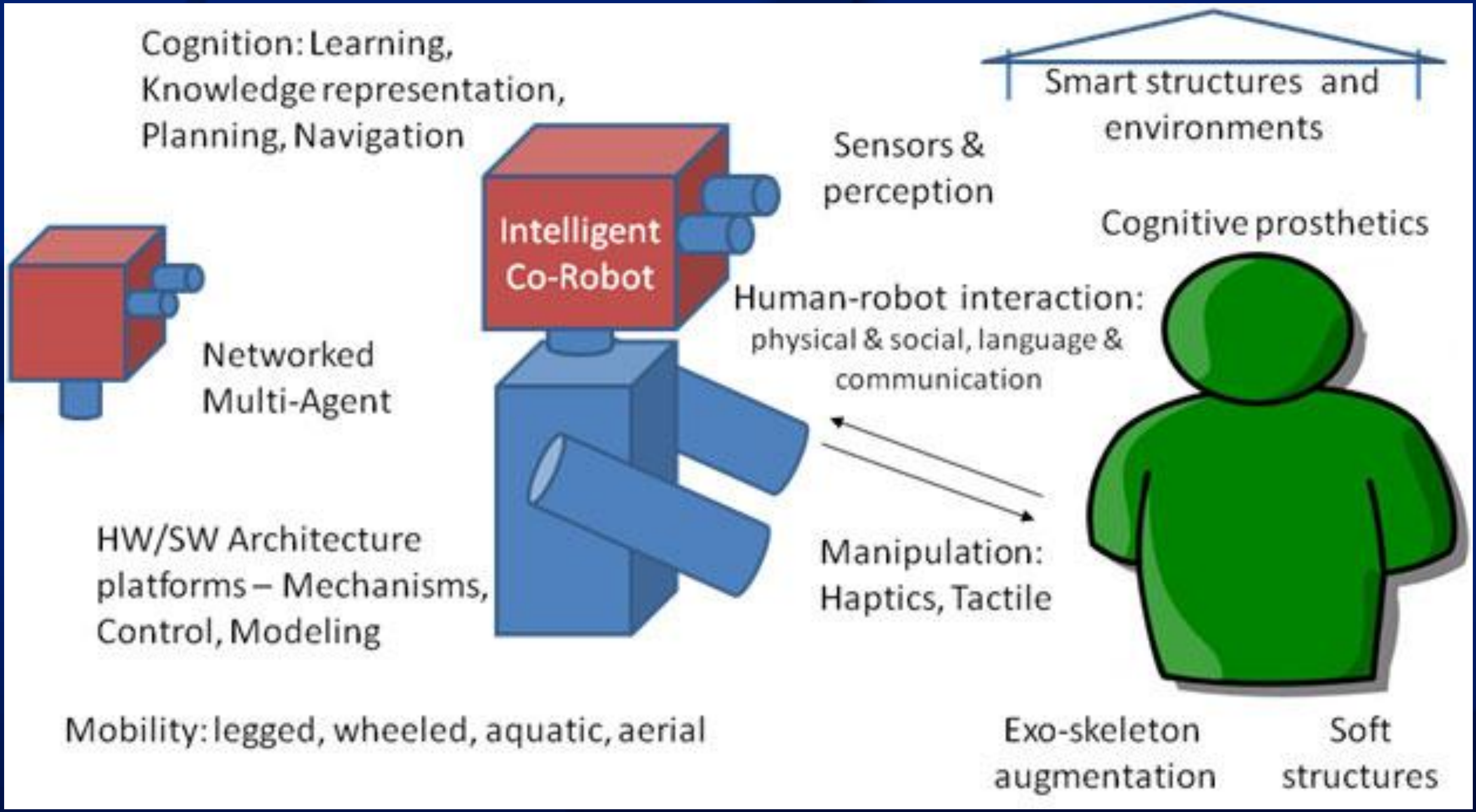
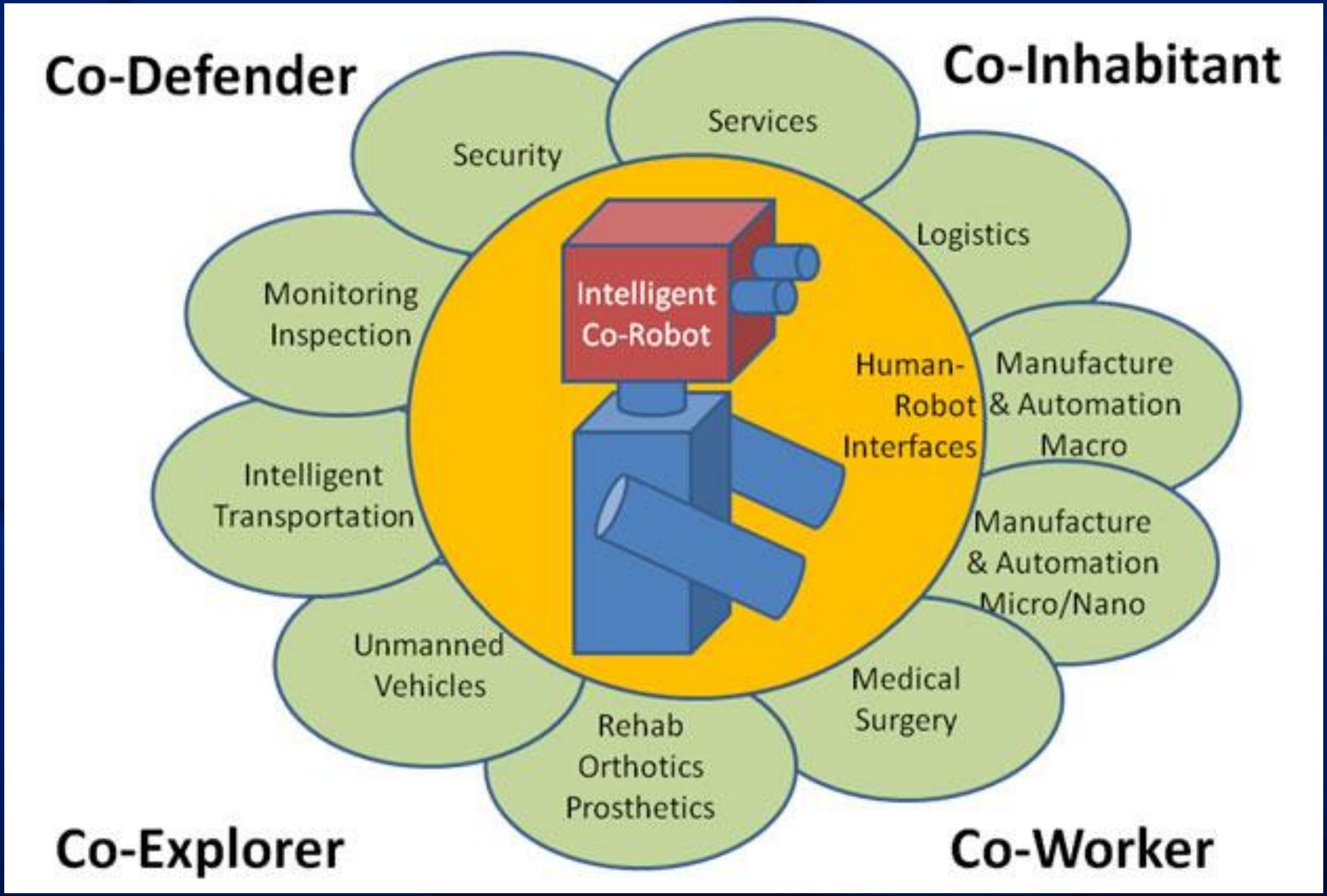
Context for Robot Knowledge Sharing

National Robotics Initiative



National Robotics Initiative



Our Previous Work

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RobotShare (2007)

RobotShare: a Framework for Robot Knowledge Sharing

Xiuyi Fan and Thomas C. Henderson

UUCS-07-009

School of Computing
University of Utah
Salt Lake City, UT 84112 USA

4 April 2007

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RobotShare (2008)

International Journal of Humanoid Robotics
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RobotShare: A Google*for Robots

Xiuyi Fan and Thomas C. Henderson

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Human Web vs Robot Web

Human

- Find info, including how-to-do (e.g., search engines based on words)
- Run codes on local machine (e.g., Java: universal machine)

Robot

- Find info (e.g., search engines based on ???)
- Run process on local robot (e.g., pick up glass requires reference models)

RobotShare (Find Info)

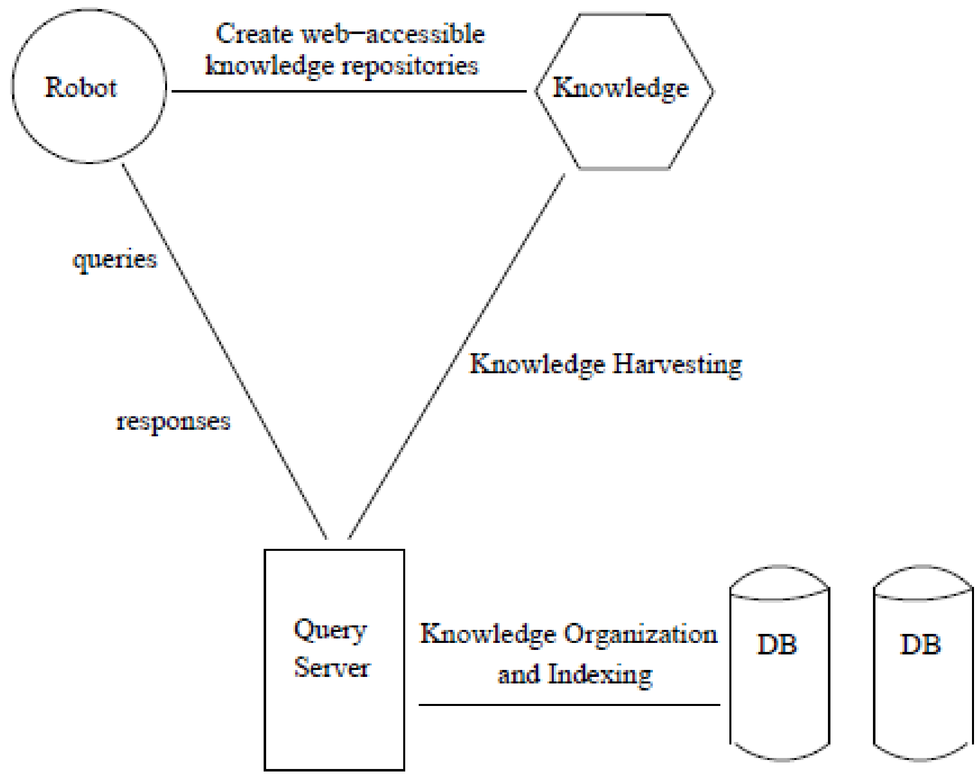


Figure 1: The RobotShare Framework.

RobotShare (cont'd)

Questions:

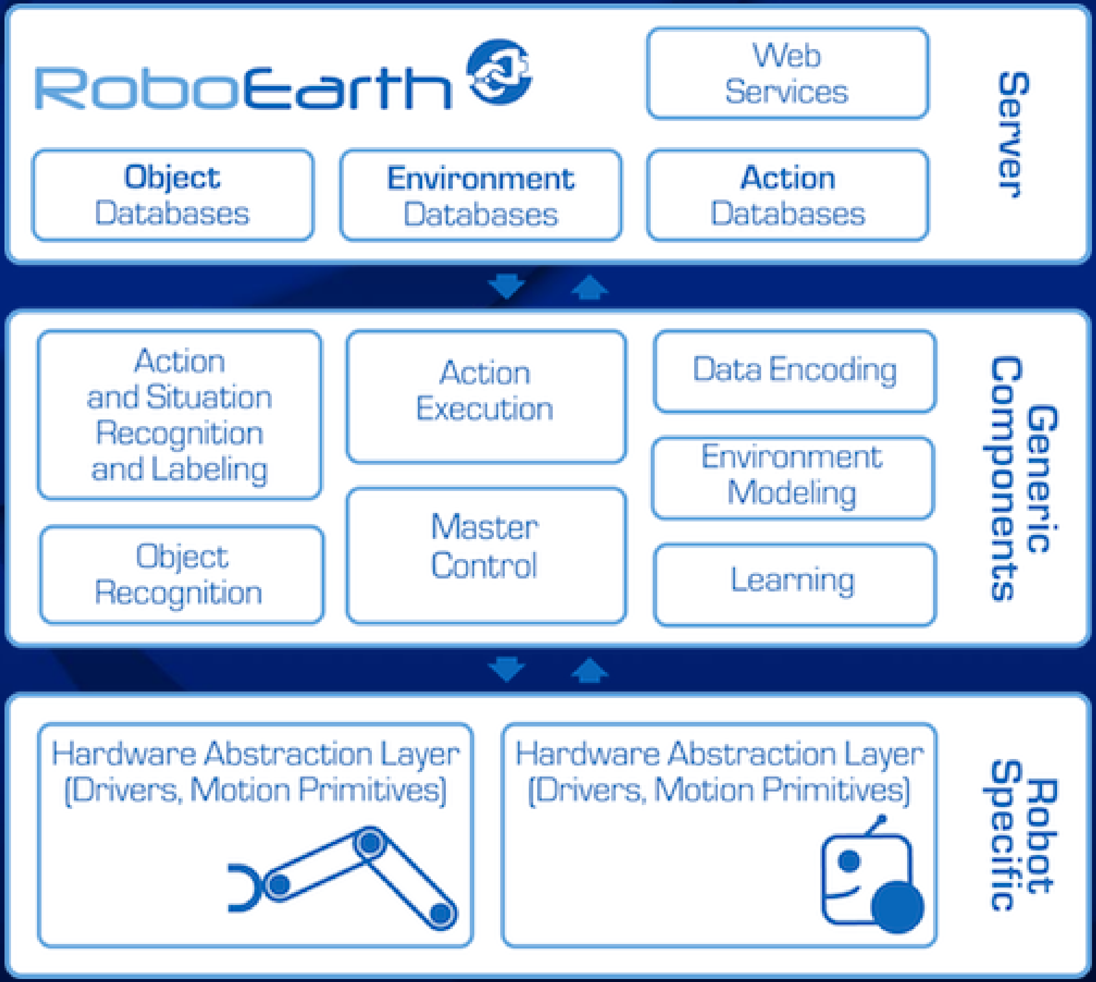
1. How does a robot communicate with RobotShare?
2. How does RobotShare process and answer a query?
3. How does one robot know if information stored on a website applies to its own environment?

Goal: build a multi-format data search engine for robot knowledge sharing.

Other Approaches: RoboEarth

“At its core, RoboEarth is a World Wide Web for robots: a giant network and database repository where robots can share information and learn from each other about their behavior and their environment. Bringing a new meaning to the phrase ``experience is the best teacher,’’ the goal of RoboEarth is to allow robotic systems to benefit from the experience of other robots, paving the way for rapid advances in machine cognition and behaviour, and ultimately, for more subtle and sophisticated human-machine interaction.

RoboEarth (cont'd)



RoboEarth

- May lead to sharing at the knowledge level
- Allows sharing of human knowledge
- Requires basis for semantics of shared descriptions
- Still relies on human guided (programmed) schemas

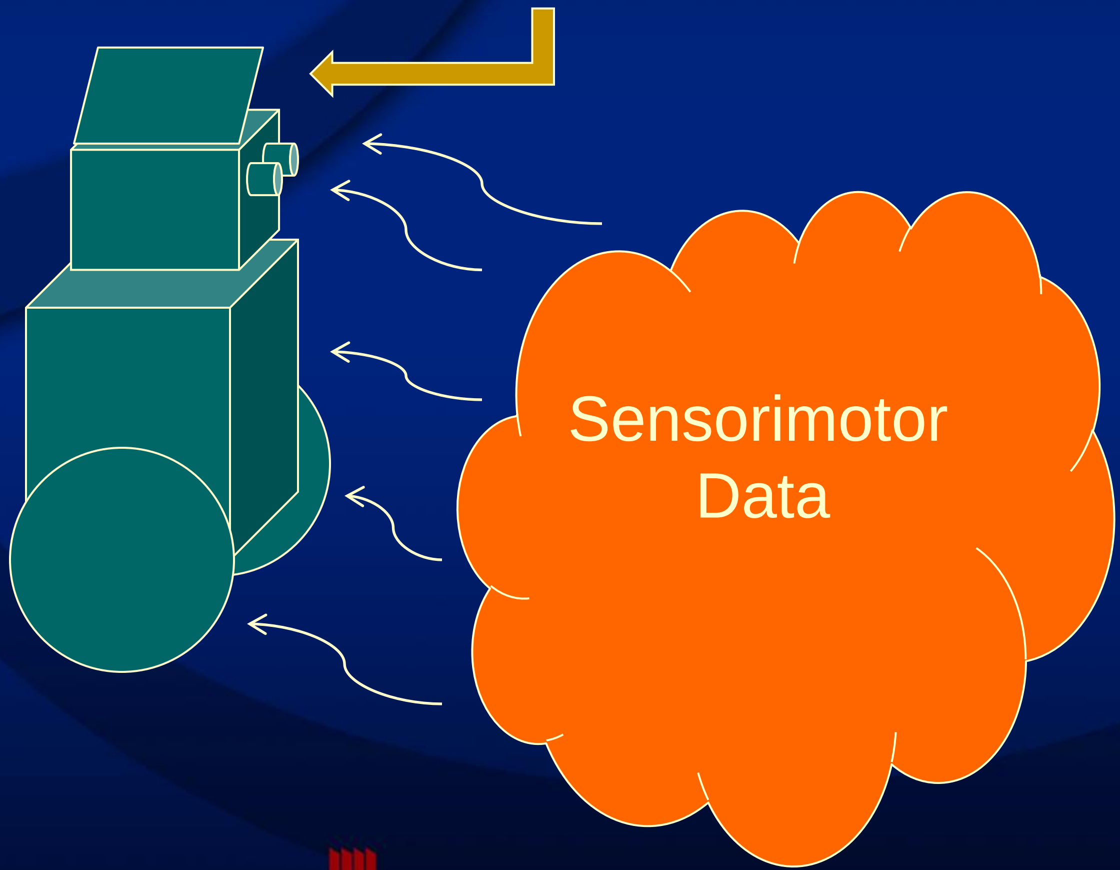
(My interpretations!!)

So, there seems to be some effort to develop frameworks to share, …

BUT …

Issue: How Knowledge is Acquired

1. Install Basic Learning Mechanisms



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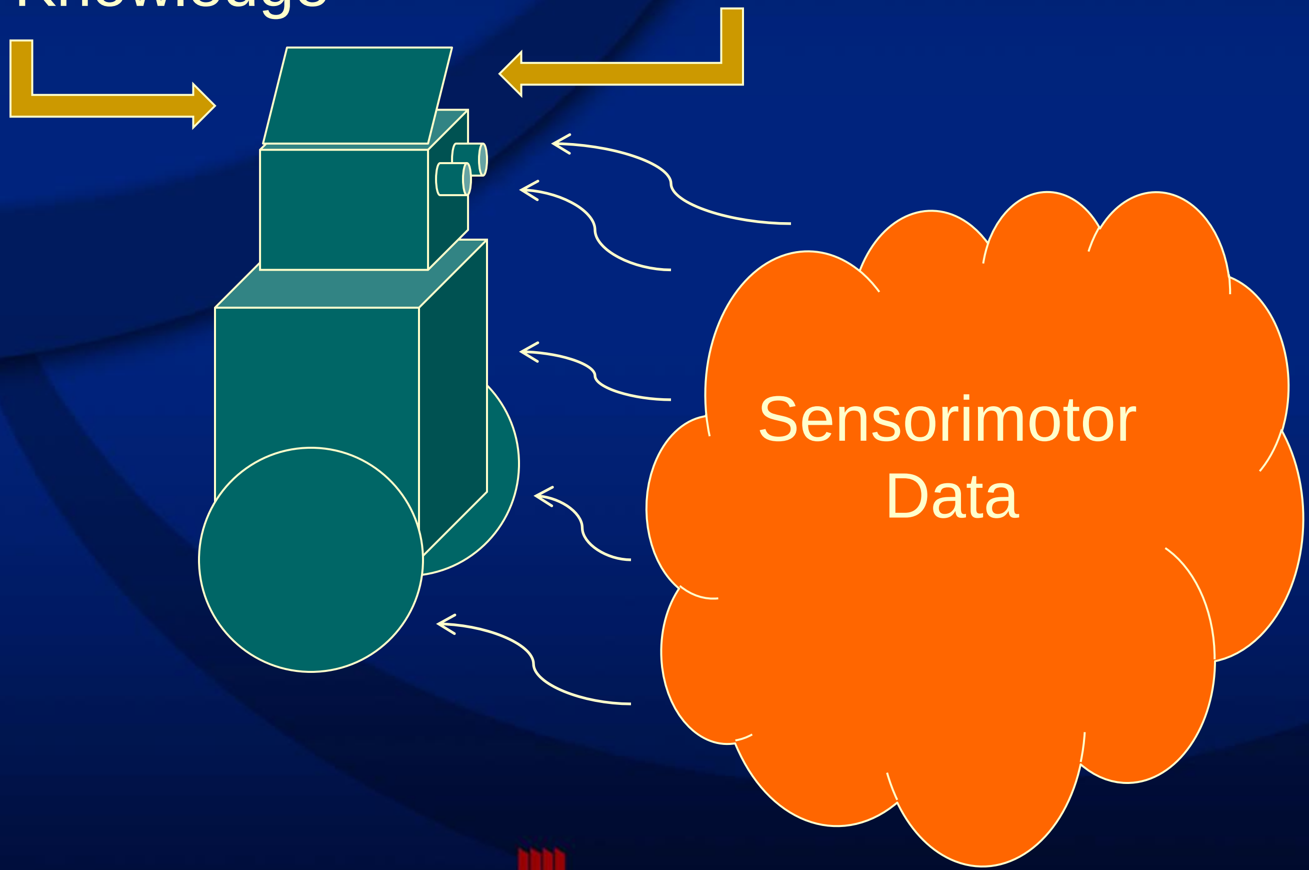
How Knowledge is Acquired

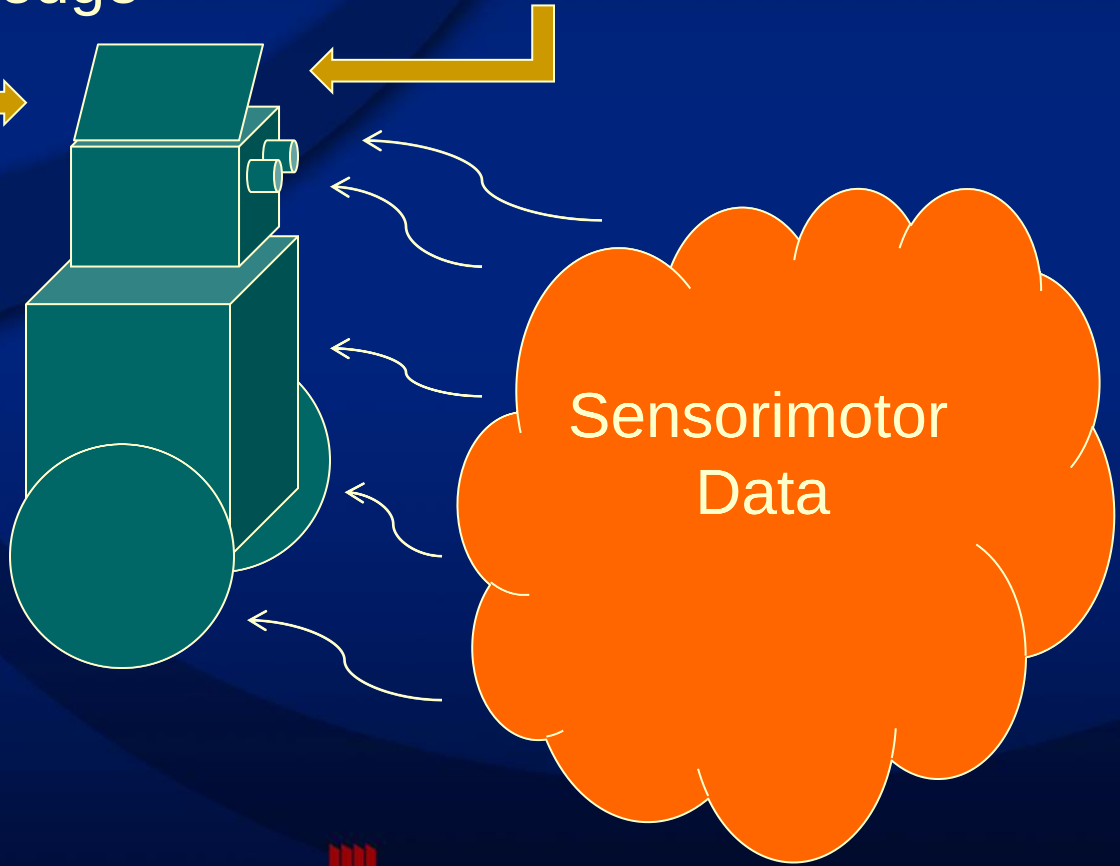
2. Include Some Innate Knowledge vs 1. Install Basic Learning Mechanisms



How Knowledge is Acquired

2. Include Some Innate Knowledge

1. Install Basic Learning Mechanisms

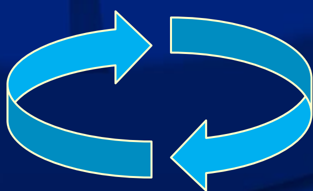


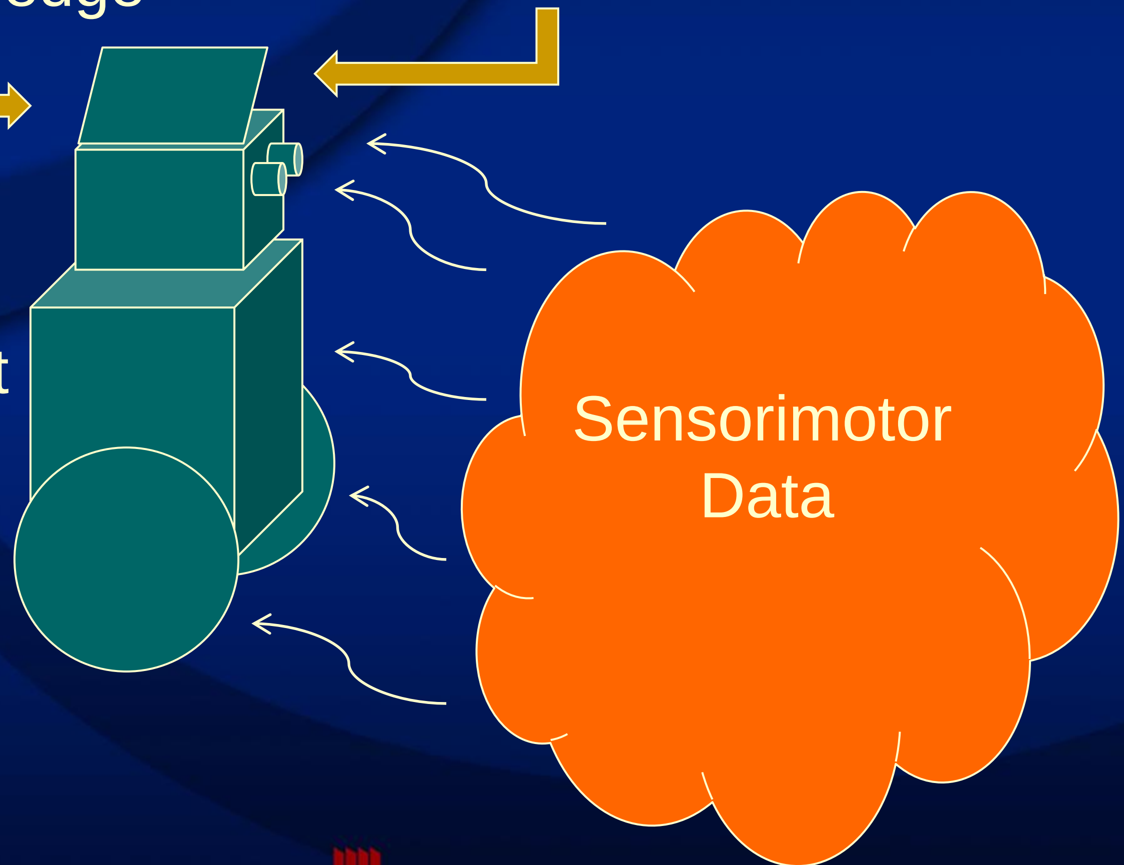
3. Sensorimotor Reconstruction: Self-Knowledge

How Knowledge is Acquired

2. Include Some Innate Knowledge

1. Install Basic Learning Mechanisms





4. Cognitive Content Symbolic vs Dynamical Systems

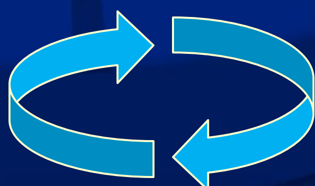
3. Sensorimotor Reconstruction: Self-Knowledge

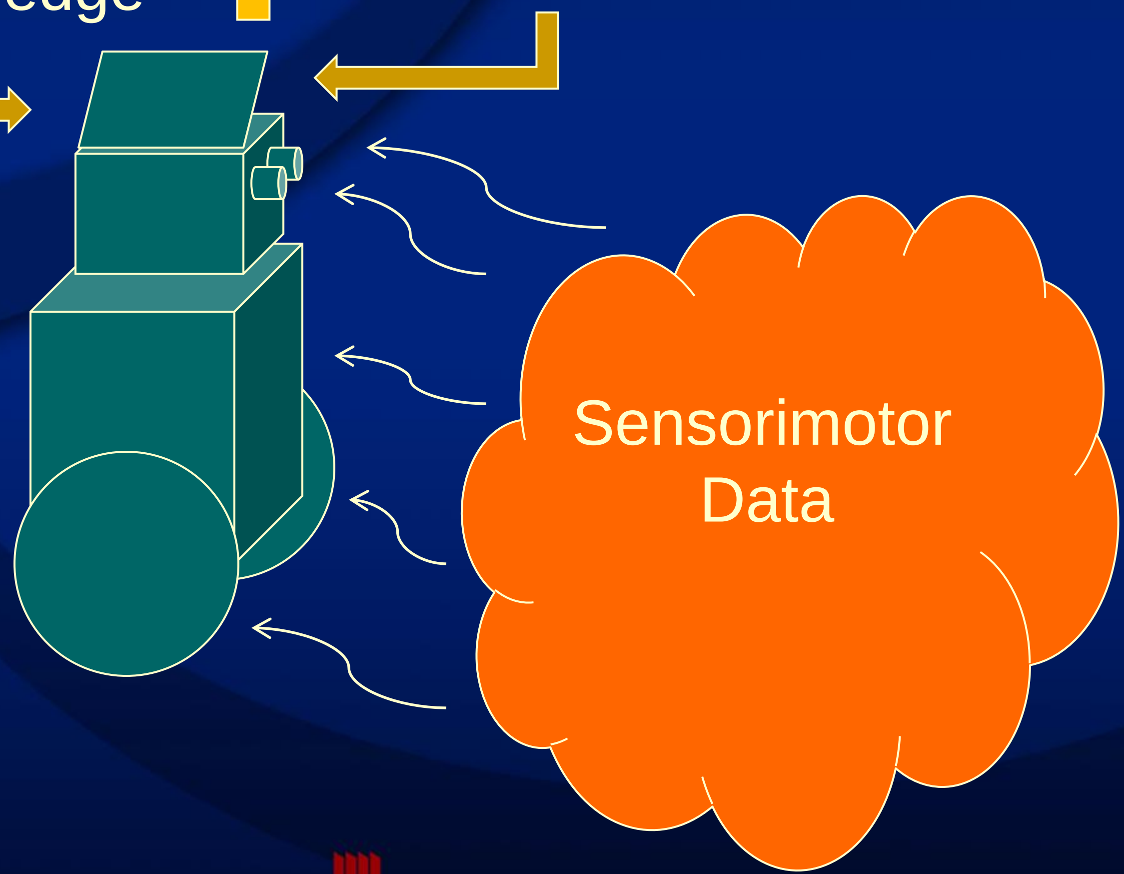
How is Knowledge Shared?

Basis for Sharing?

1. Install Basic Learning Mechanisms

2. Include Some Innate Knowledge





4. Creating Cognitive Content

3. Sensorimotor Reconstruction: Self-Knowledge

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Sharing What?

- Physical Symbol Systems: cognition as a computer → Share machines/formulas?
- Artificial Neural Networks: cognition as a neural network → Share topology/weights?
- Dynamical Systems: cognition as differential equations → share equations?

Thoughts

- Difficult to see a general way to share across these paradigms
- Difficult to see how sharing occurs within some paradigms
- Constraints from these issues should inform approaches to knowledge sharing as well as proscribe some

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How does U Mass' Arny convey "how to throw a ball" to Willow Garage's PR2?

Knowledge Sharing?

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Our current ideas … (see Poster in Workshop!)

1. Some innate structures shared by all robots

- Symmetry detectors and operators
- Operate from sensor/actuator level on up
- Exploit SE(3), SO(3), etc.
- Use embodiment coordinates (not XYZ frame)

Our current ideas (cont'd)

2. Consider role of symmetry in structural bootstrapping (e.g., in EU Xperience project)

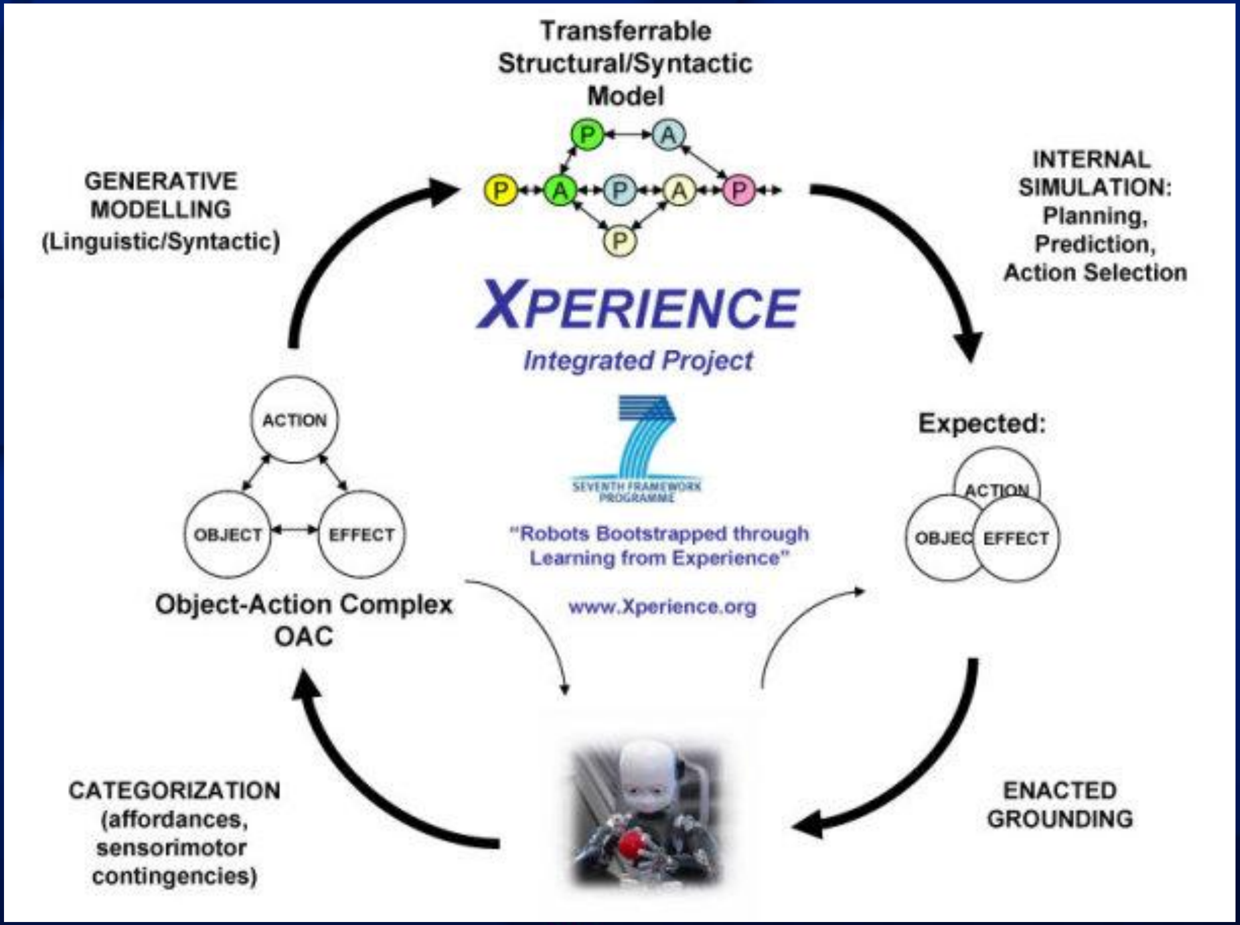
- Sensorimotor (SM) level (as in previous slide)
- More abstract level (derived from SM level)
- Linguistic level (vocabulary of symbols derived from abstract level)

➔ Share at second two levels

Structural Bootstrapping (Xperience Project)

"The Xperience project addresses this problem by structural bootstrapping, an idea taken from language acquisition research: knowledge about grammar allows a child to infer the meaning of an unknown word from its grammatical role together with understood remainder of the sentence. Structural bootstrapping generalizes this idea for general cognitive learning: if you know the structure of a process the role of unknown actions and entities can be inferred from their location and used in the process. This approach will enable rapid generalization and allows agents to communicate effectively."

Structural Bootstrapping (Xperience Project)



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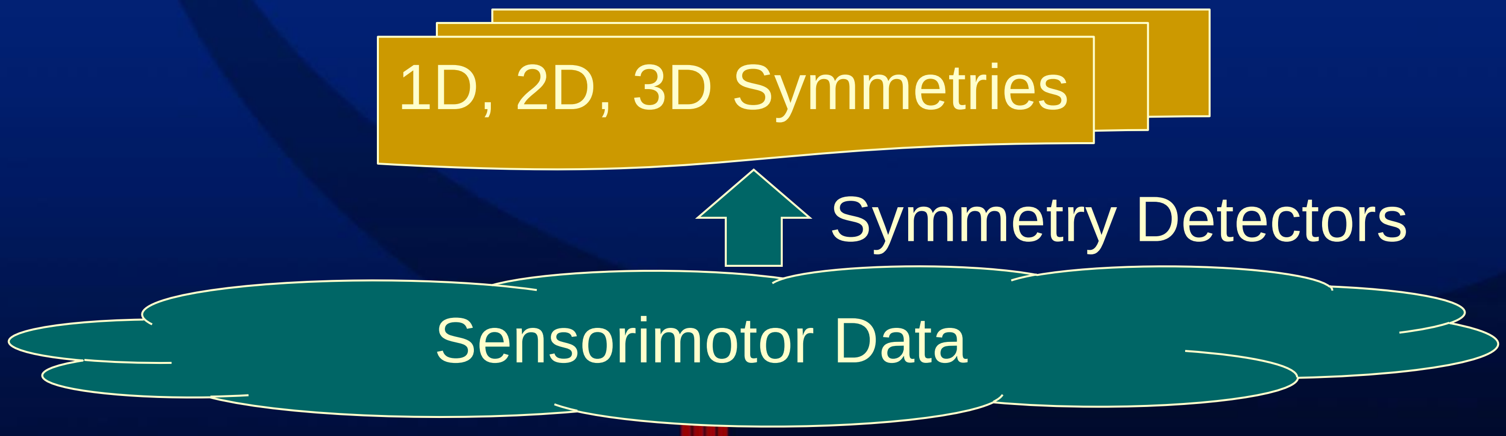
Symmetry Based Structural Bootstrapping



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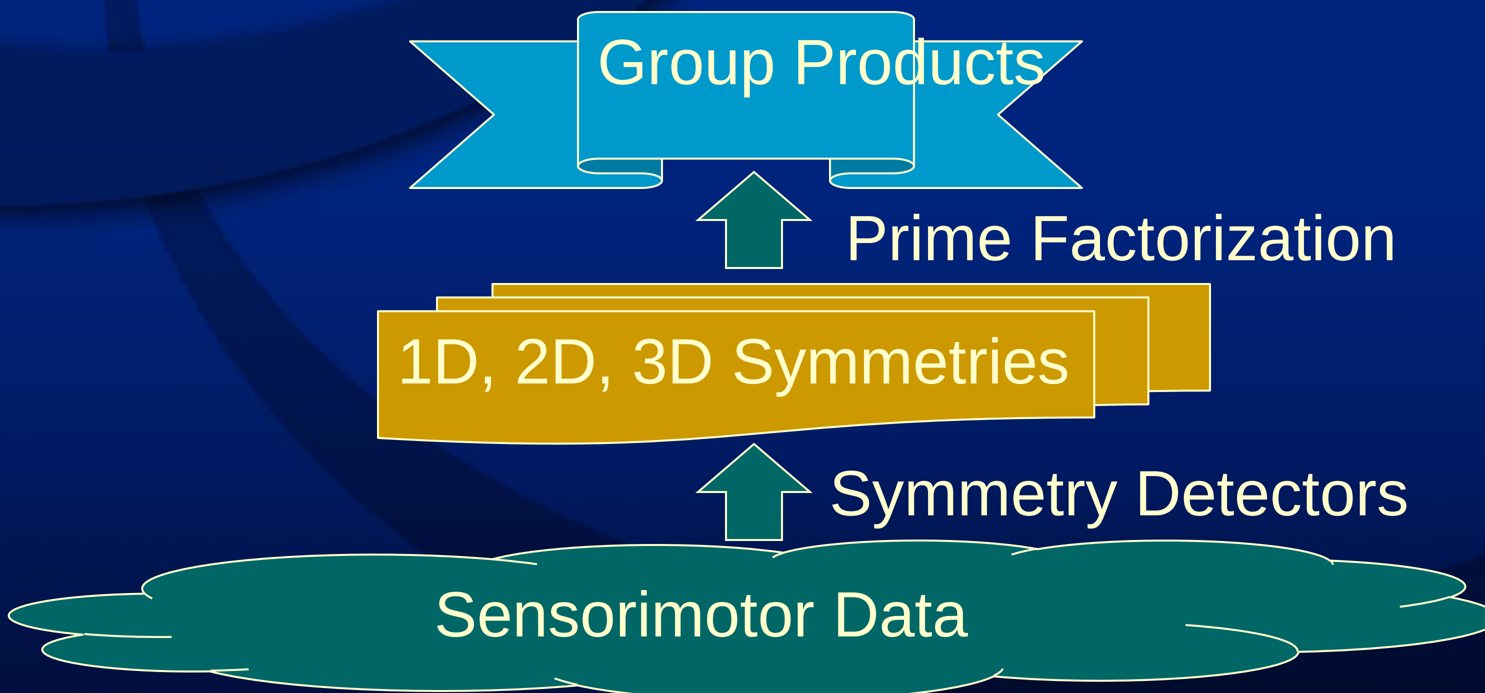
Symmetry Based Structural Bootstrapping



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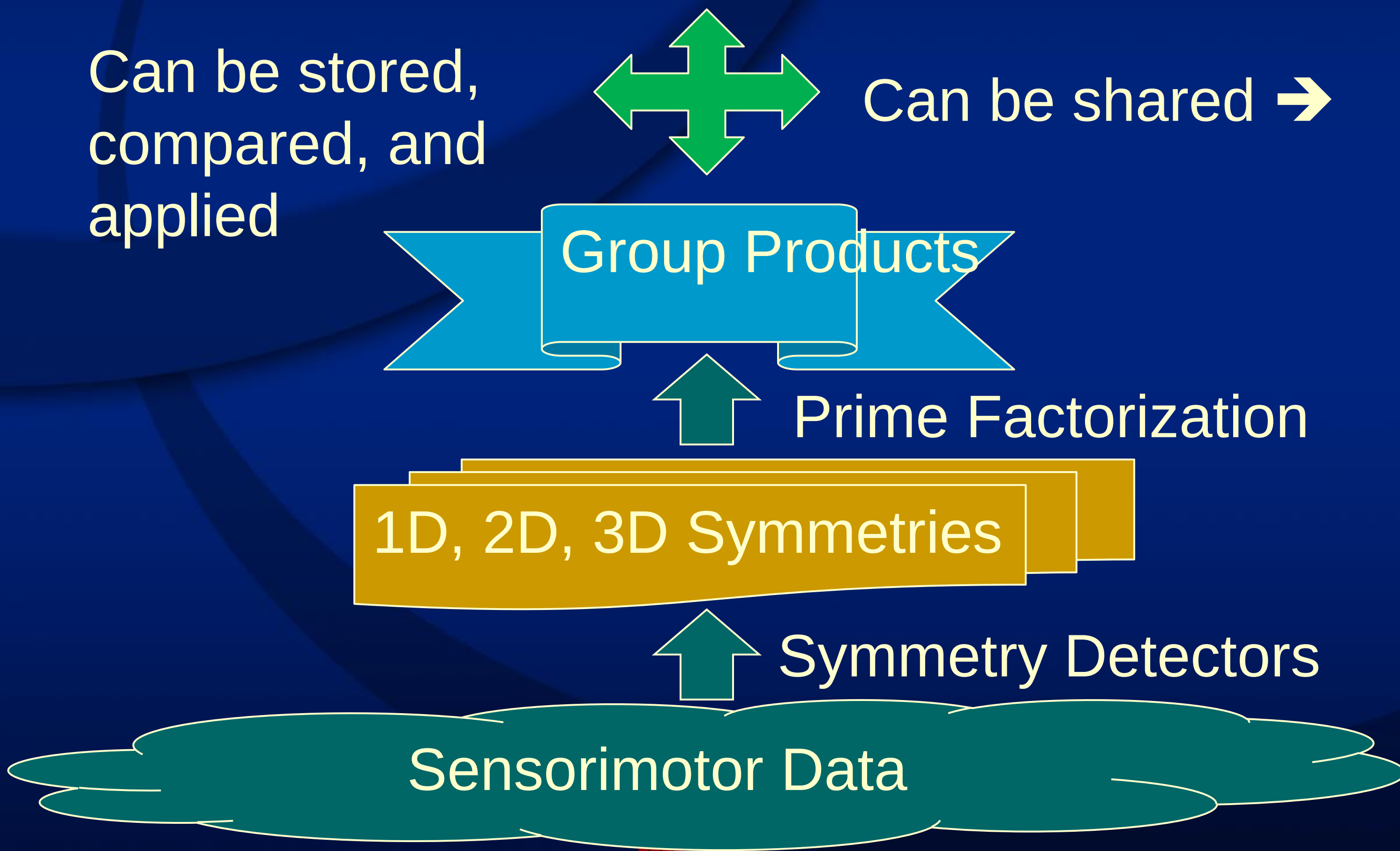
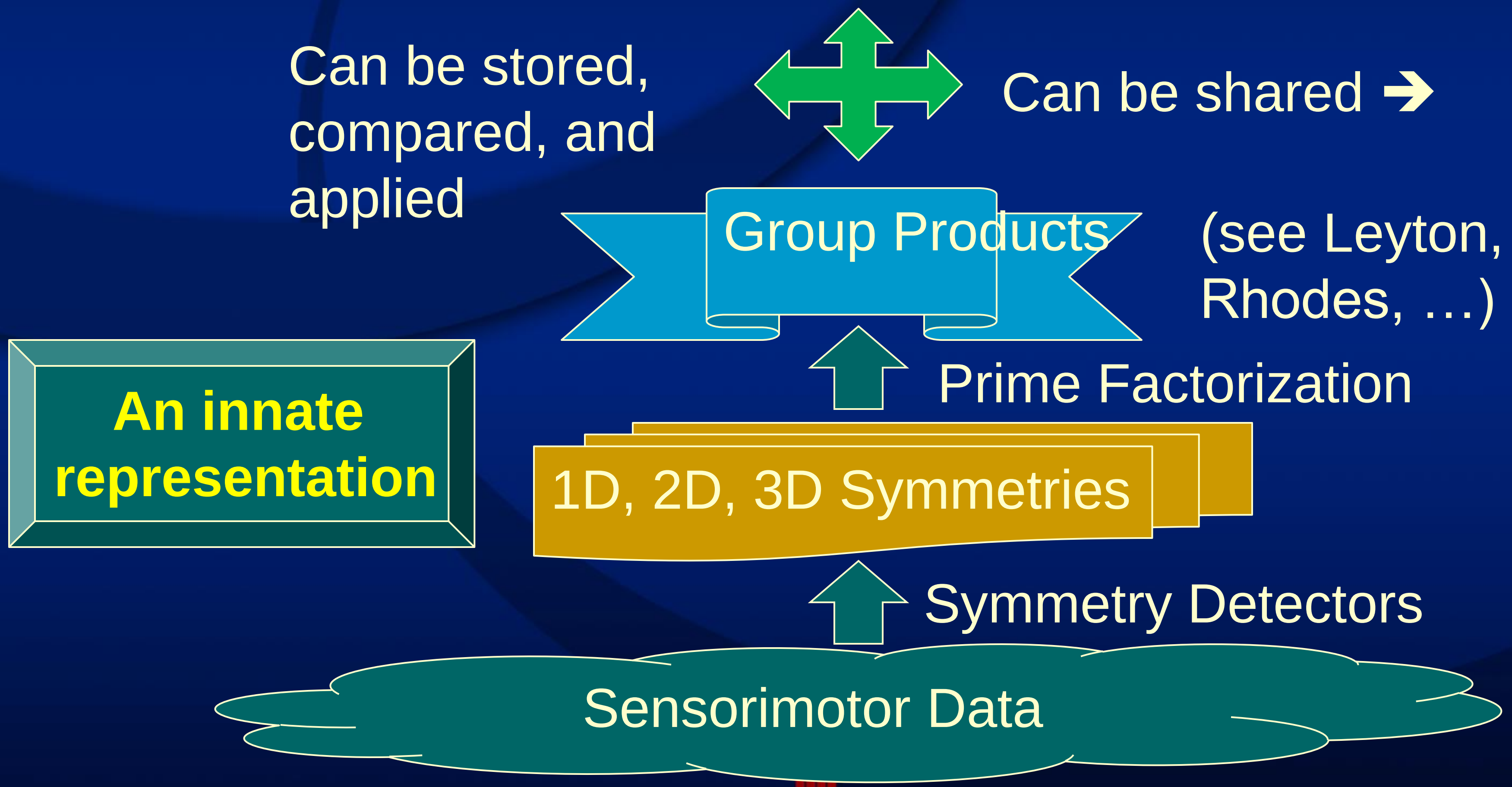


Symmetry Based Structural Bootstrapping



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Group-Theoretic Bootstrapping (IROS 2011)

2011 IEEE/RSJ International Conference on
Intelligent Robots and Systems
September 25-30, 2011. San Francisco, CA, USA

Bootstrapping sensorimotor cascades: a group-theoretic perspective

Andrea Censi   Richard M. Murray

***Abstract*—The bootstrapping problem consists in designing agents that learn a model of themselves and the world, and utilize it to achieve useful tasks. It is different from other learning problems as the agent starts with uninterpreted observations and commands, and with minimal prior information about the world. In this paper, we give a mathematical formalization of this aspect of the problem. We argue that the vague constraint of having "no prior information" can be recast as a precise algebraic condition on the agent: that its behavior is invariant to particular classes of nuisances on the world, which we show can be well represented by actions of groups (diffeomorphisms, permutations, linear transformations) on observations and commands. We then introduce the class of bilinear gradient dynamics sensors (BGDS) as a candidate for learning generic robotic sensorimotor cascades. We show how framing the problem as rejection of group nuisances allows a compact and modular analysis of typical preprocessing stages, such as learning the topology of the sensors. We demonstrate learning and using such models on real-world range-finder and camera data from publicly available datasets.**

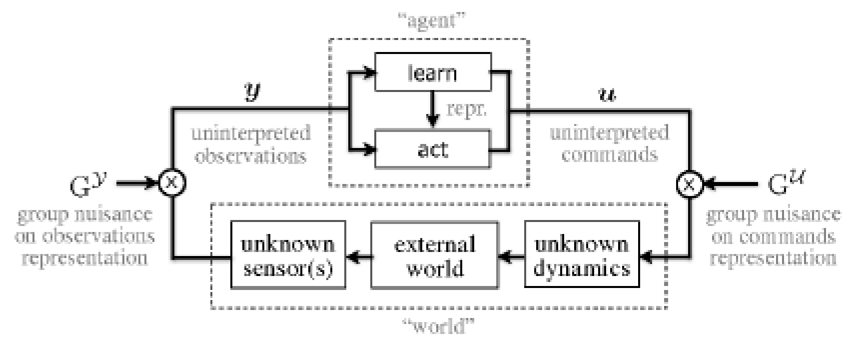

Figure 1. We consider the problem of designing agents that learn a model of the world, including their own dynamics, with "no prior information" about the system. So far, there has not been a precise formalization of this notion. In this paper, we argue that the agent not needing certain information/assumptions is equivalent to the algebraic condition of its *behavior* being *invariant* to certain classes of lossless transformations of input and output signals. Such transformations are well modeled by group actions (e.g., permutations, linear transformations, diffeomorphisms). This language allows to define exactly the limits of a bootstrapping agent in terms of the group nuisances it can tolerate.

Questions?