

# An Adaptive Brain-Computer Interface for Humanoid Robot Control

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## 1. The Problem

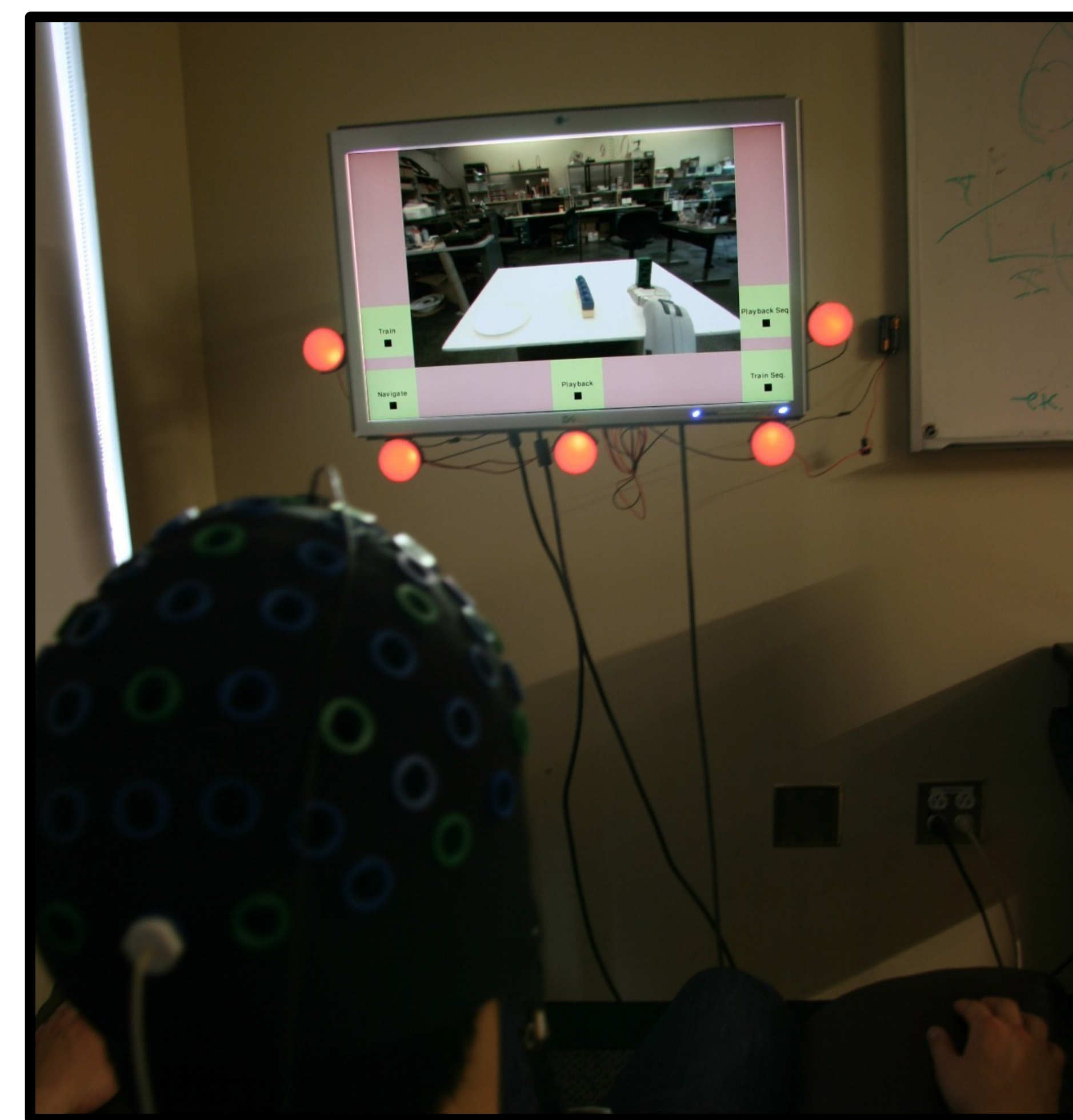
- Typical non-invasive BCI systems have very **low-throughput**
- Low-level moment-by-moment control tedious for users
- High-level commands easier to use, but coarse-grained control

## 2. Our Approach

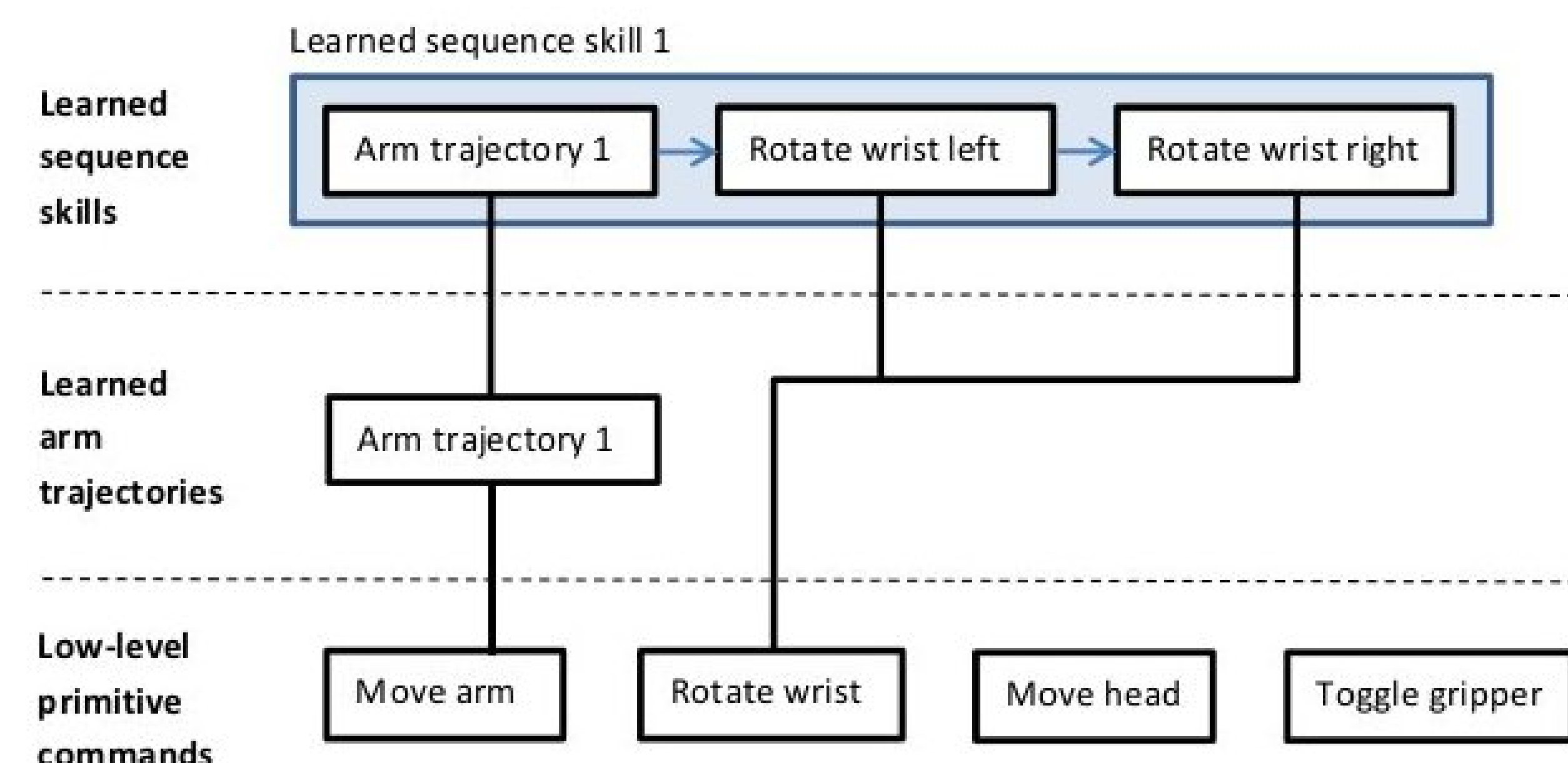
- Use lower-level commands to teach the robot new higher-level commands
- Learn chains of high- and low-level commands to perform complex tasks
- Work since Humanoids shows we can apply this approach to systems that use arbitrarily complex and robust robotics algorithms (e.g. grasping routines)

## 3. Example

- Use lower-level commands to learn how to maneuver the arm to the location of a bowl
- Combine learned trajectory with lower-level commands for rotating the wrist
- Remember this sequence as an even higher-level skill representing pouring milk on cereal

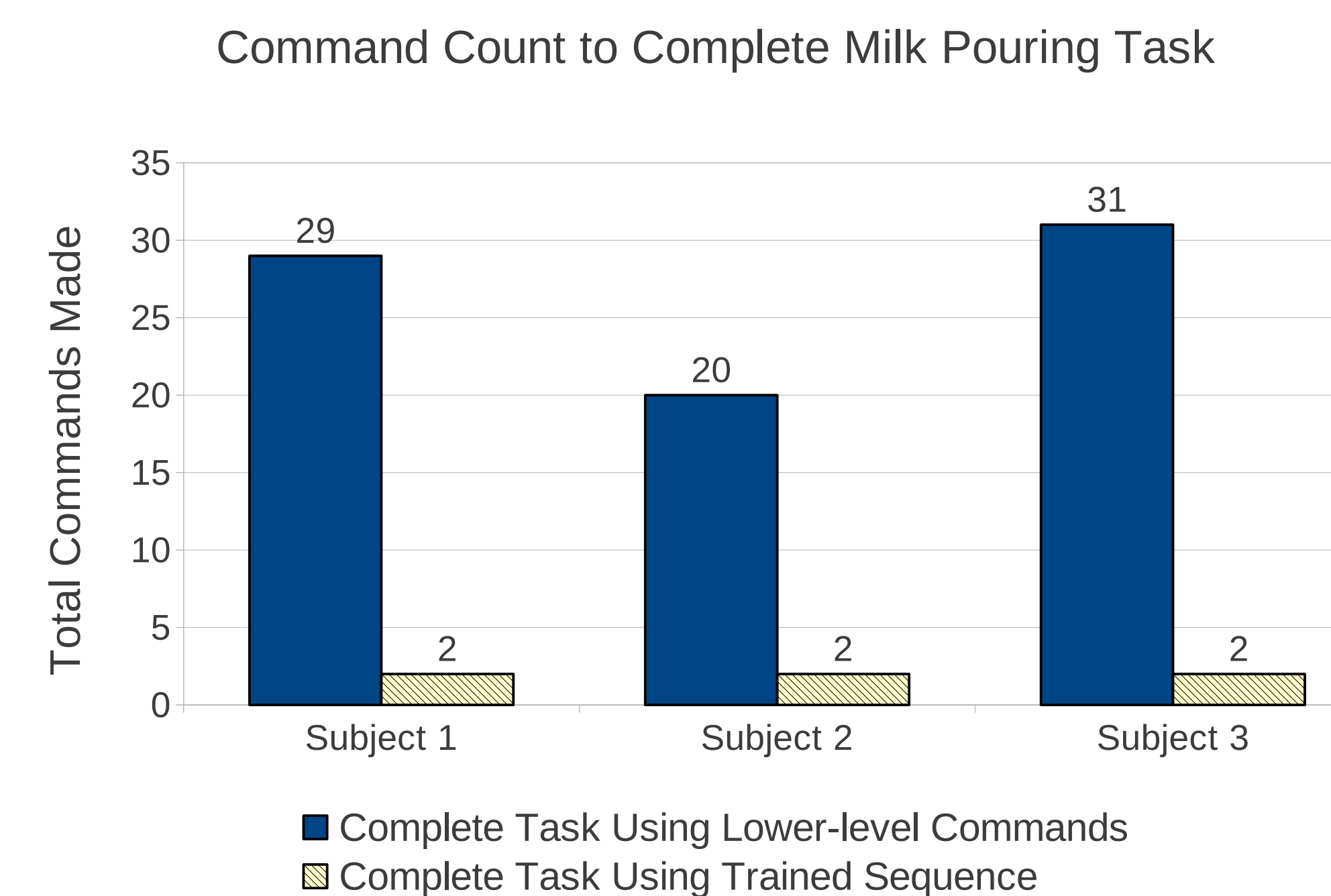


User controlling a Willow Garage PR2 Robot



We build command hierarchies in order to create command abstraction on the fly. This results in an increase in effective throughput of the BCI system by allowing the user to do more with fewer commands.

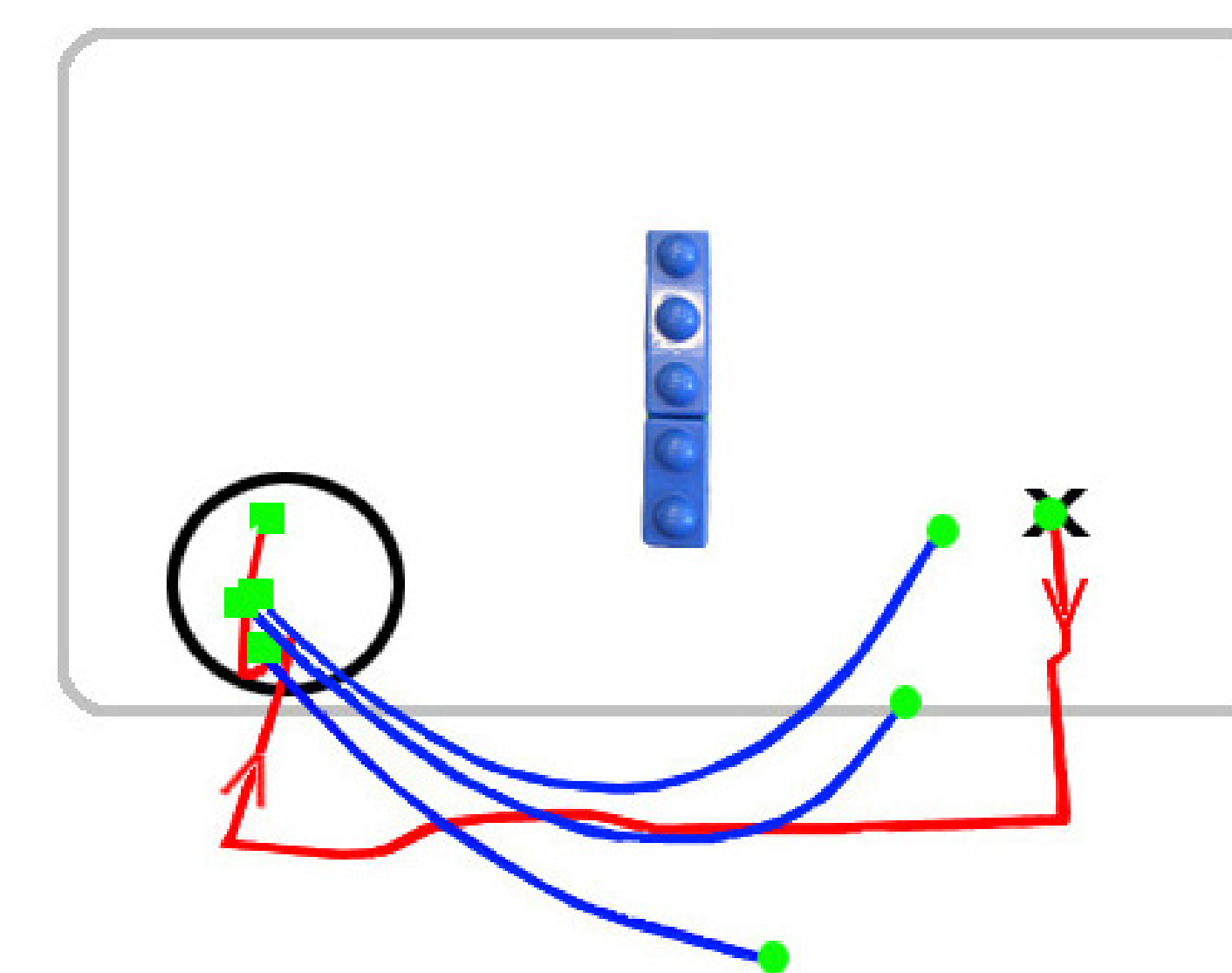
## 4. Results and Conclusions



- Building command abstractions on the fly results in an **increased effective throughput** of the BCI
- **Combines scalability with efficiency**
- Learning over command sequences **allows the system to perform more complex tasks** since it avoids dimensionality problems associated with learning over high-dimensional state spaces

## 5. Ongoing Work

- Using sequence-learning algorithms to automatically extract patterns from user's command history (ICRA submission)
- More advanced user studies of hierarchical command learning for BCI



Red indicates training path; blue indicates examples of the robot's autonomous navigation given the learned policy; the black circle is the target area.

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