Automatic Extraction of Command Hierarchies for Adaptive Brain-Robot Interfacing

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This work was produced by undergraduate UW engineering students:

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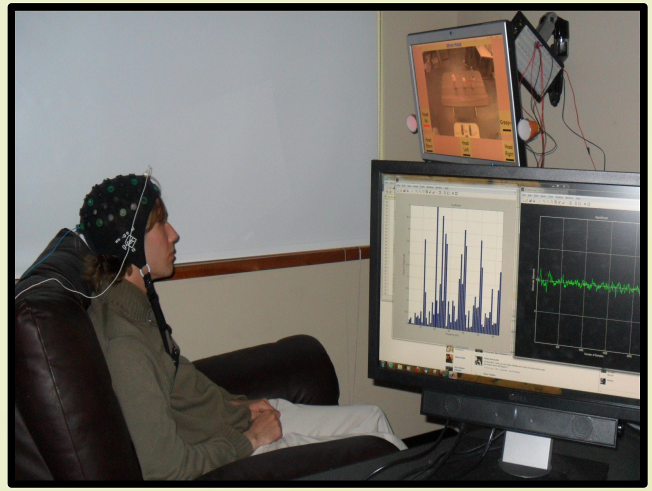
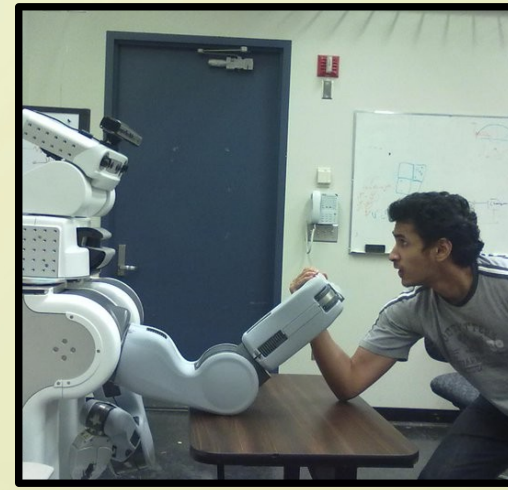


Griffin Nicoll



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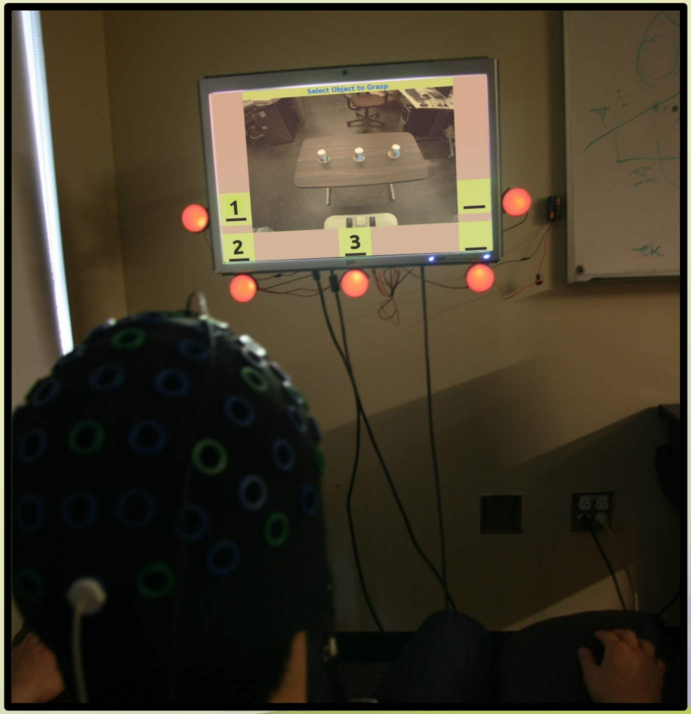
Acknowledgements

Center for Sensorimotor Neural Engineering

Brain-Computer Interfaces (BCIs) for severely paralyzed or “locked-in” persons.

- Artificial neural pathway
- Can we provide more independence via a BCI and a robotic proxy?



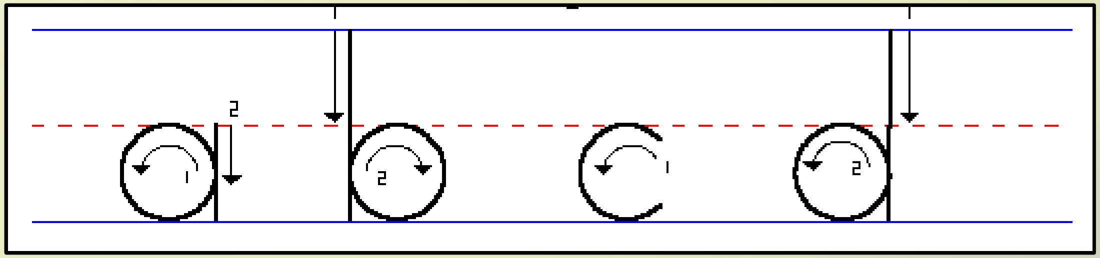
A Key Design Challenge

Non-invasive EEG

- Practical, but suffers from low throughput (< 60 bits/min)
- Fine-grained control impractical in long term
- But need flexibility to deal with a wide variety of situations

Hierarchical skill learning example:

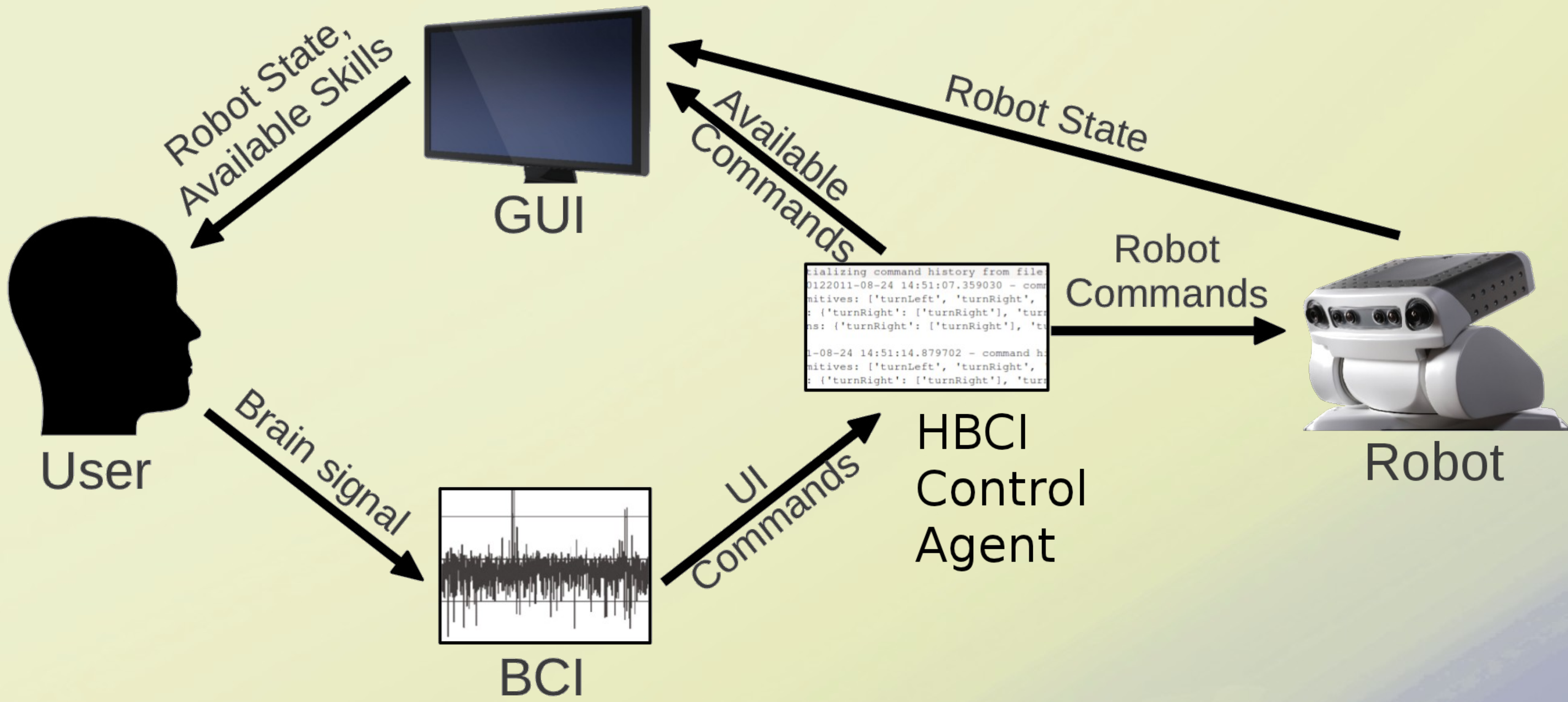
- Learn individual pen strokes
- Learn to put pen strokes together to form letters
- Learn to put letters together to form words
- Etc.



Hierarchical BCI (HBCI):

- User performs tasks with lower-level skills
- HBCI observes user to learn higher-level skills
- User can execute higher-level skills directly
- Raises effective throughput of the interface
- Can work independently of the choice of BCI paradigm

System Overview



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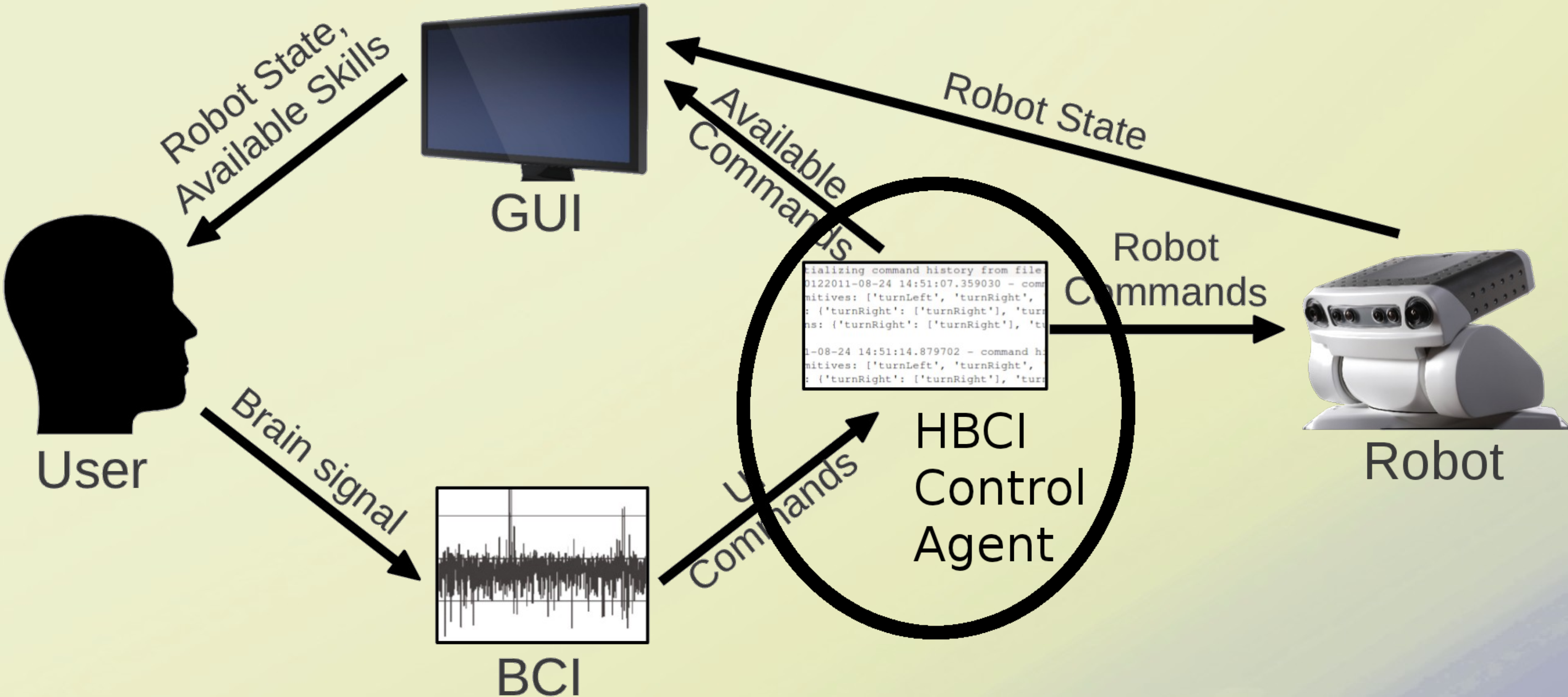
System Overview



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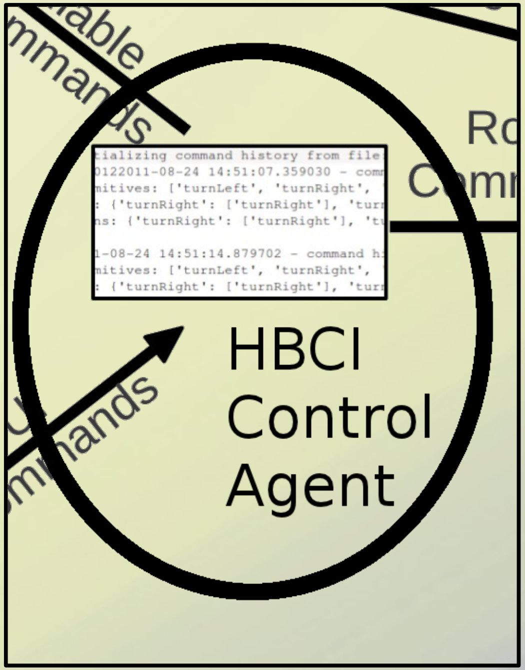
System Overview

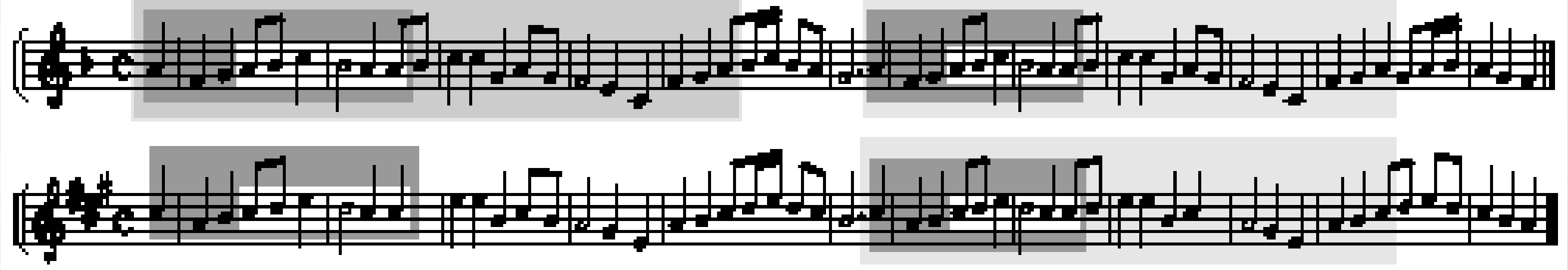
HBCI Control Agent:

- Extracts patterns from history of user actions
- Prunes patterns which are:
  - shorter than 3 commands
  - appear less than twice
  - other pruning
- Presents patterns as higher-level skills
- Decodes stored patterns to send to robot



Sequitur Algorithm [Nevill-Manning and Witten 1997]

- Extracts context-free grammar from sequence of discrete symbols
- Applied to J.S. Bach:



Sequitur Algorithm [Nevill-Manning and Witten 1997]

- User input:

  a b c d e f a b 0 d e f a b c d e f

- Sequitur returns:

  R0 -> R1 c R2 0 R2 c R3

  R1 -> a b

  R2 -> R3 R1

  R3 -> d e f

- After pruning user would see only R2, R3

Algorithm 2 – Maximum-length Chaining

Maximum-length chaining:

- Stochastic model helps deal with input noise
- Prefers long chains for maximum throughput increase
- Intuition: iteratively concatenate to observed sequences while next input can be reliably* predicted
  - Example: if 'c' always appears after 'a b', then discard 'a b' and begin again with 'a b c'
  - *'Reliable' determined by a probability threshold

Maximum-length chaining:

- User input:

  a b c d e f a b 0 d e f a b c d e f

- Max-chaining returns:

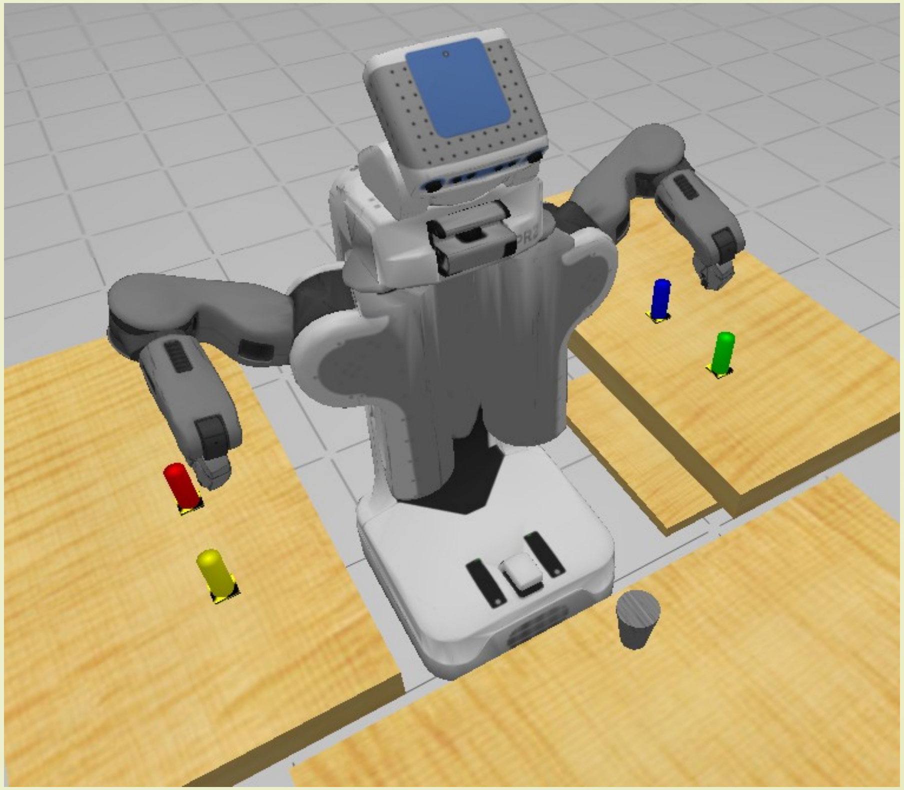
  d e f a b

  a b c d e f

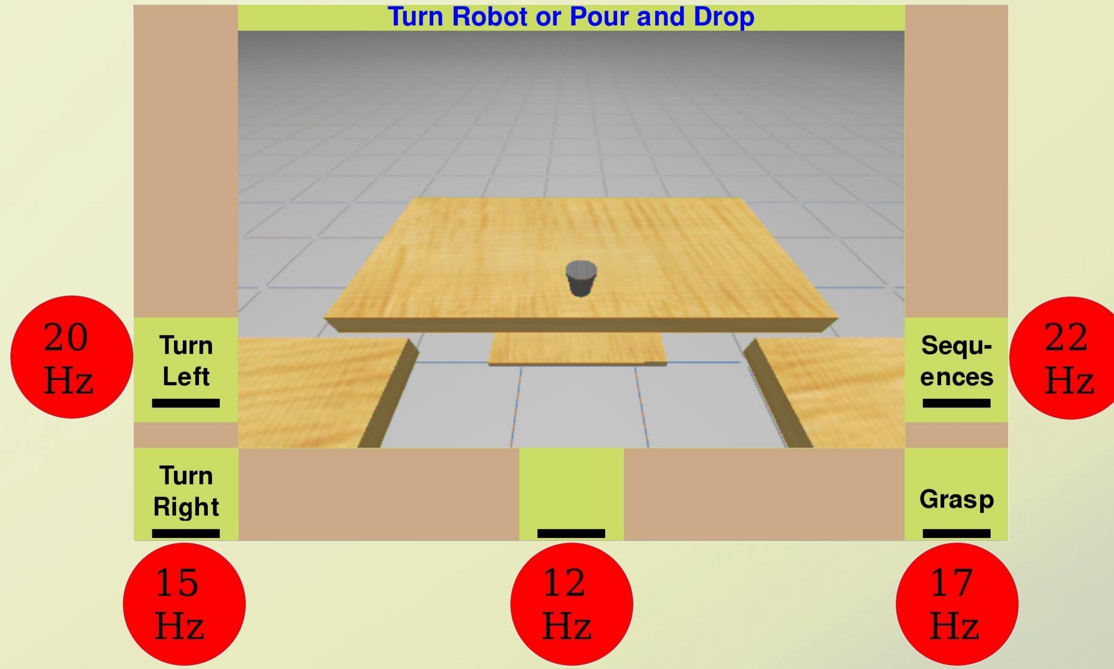
- Recognizes intended control sequence

  a b c d e f

The Experiment



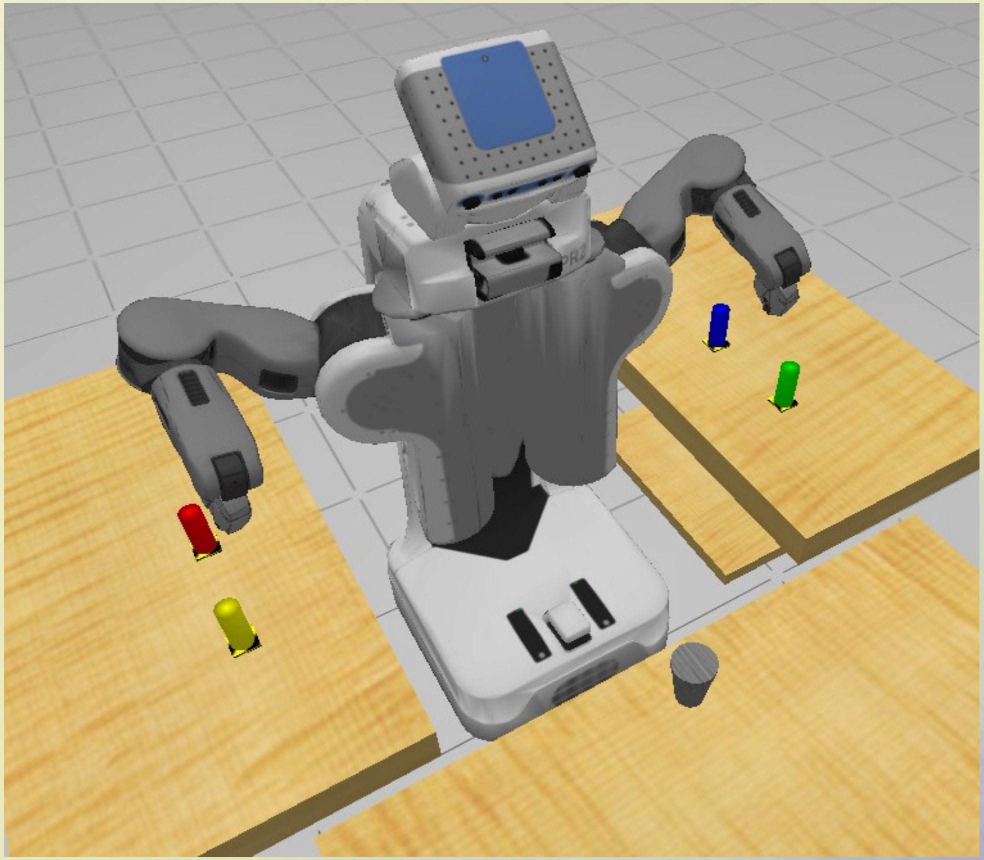
Ingredient mixing task w/simulated PR2



Example GUI screen; user sees robot's view, stimuli on perimeter of screen

Multi-phase experiment:

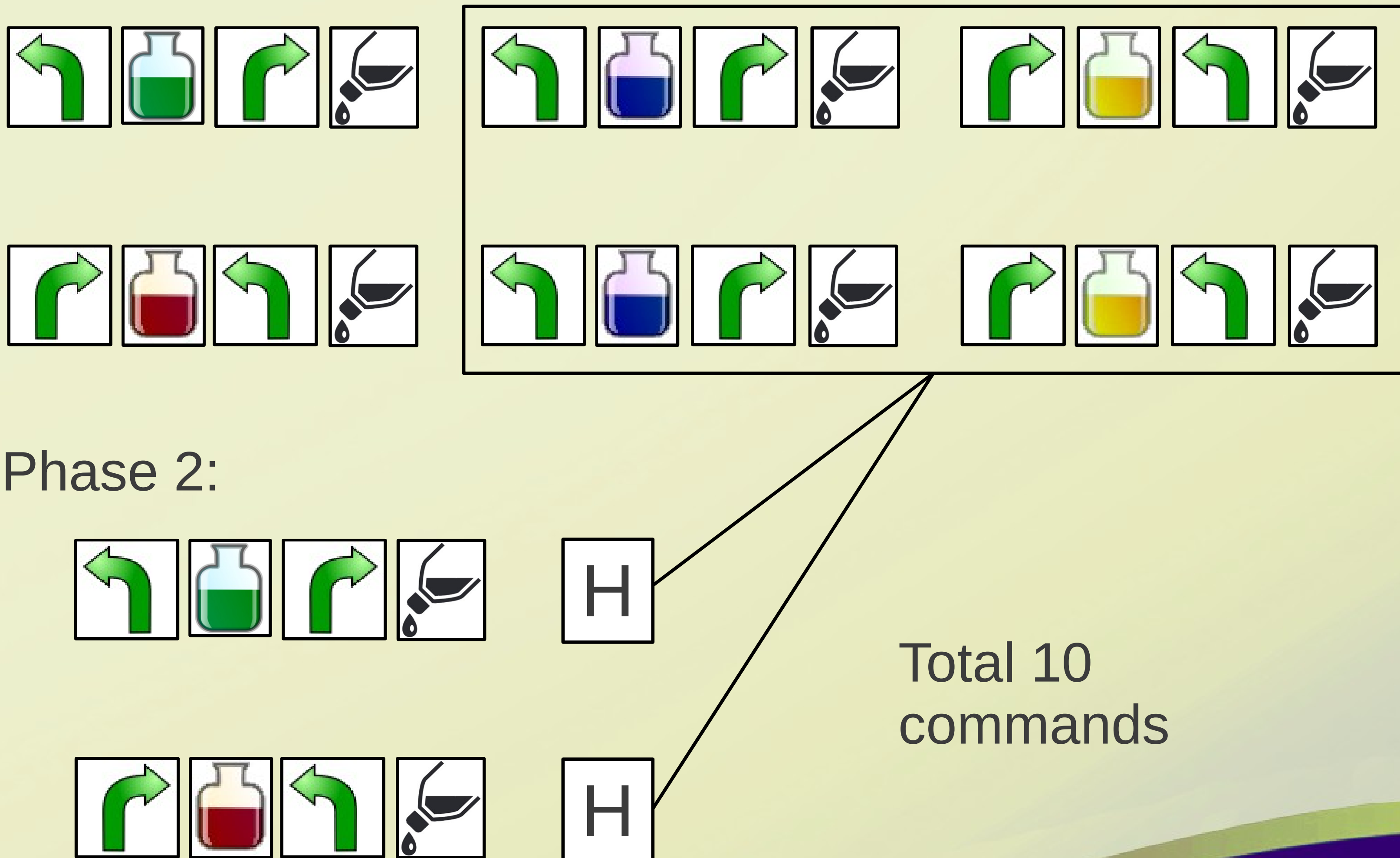
- Each user given two recipes to mix
- In each phase, the user mixes both recipes
- Order they are mixed varies
- Four phases per experiment
- User runs experiment twice – once with each algorithm
- Abstracted commands make later phases easier



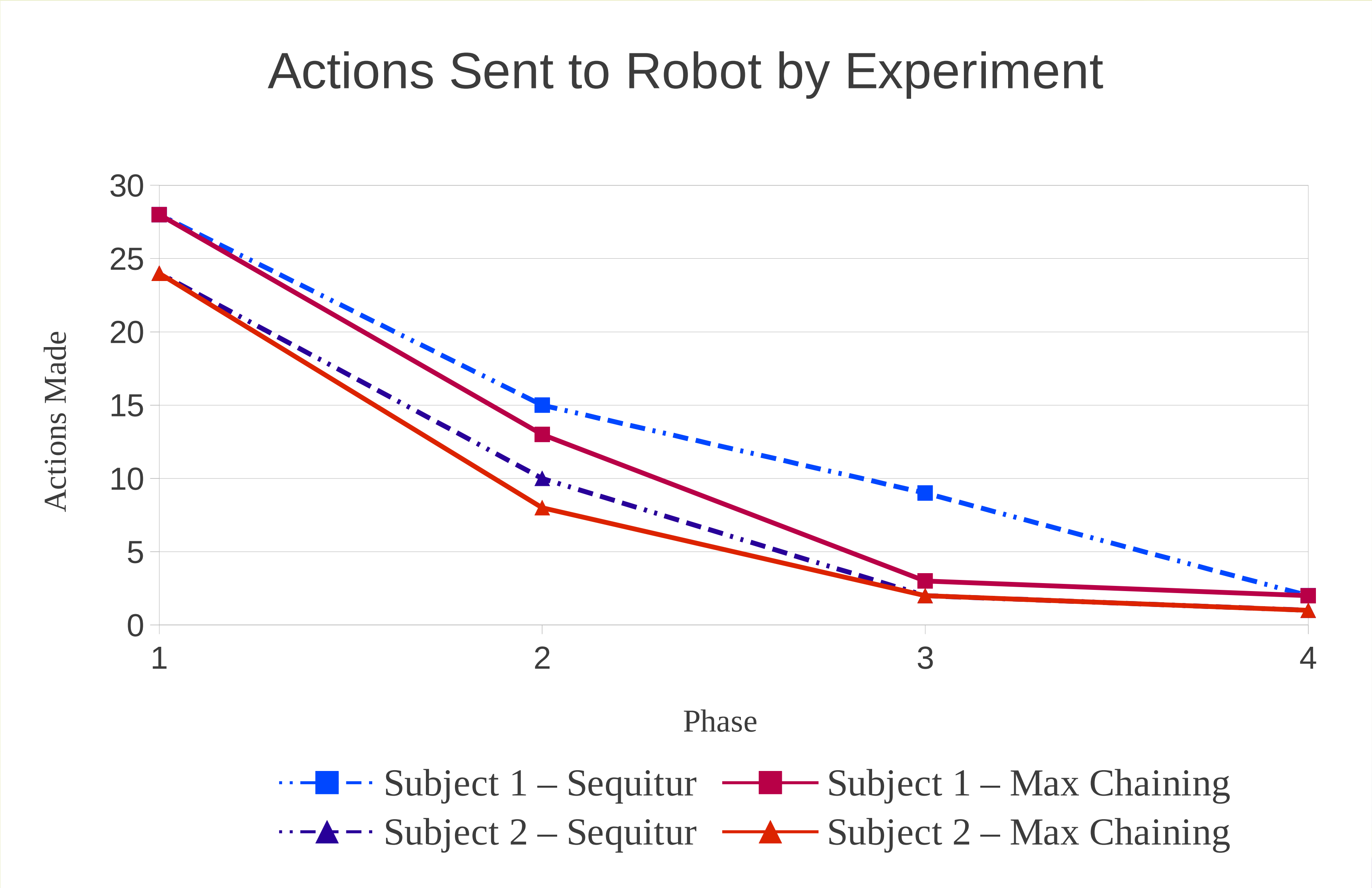
Example Results

Recipes: Green, Blue, Yellow | Red, Blue, Yellow

Phase 1:



Results – User Study



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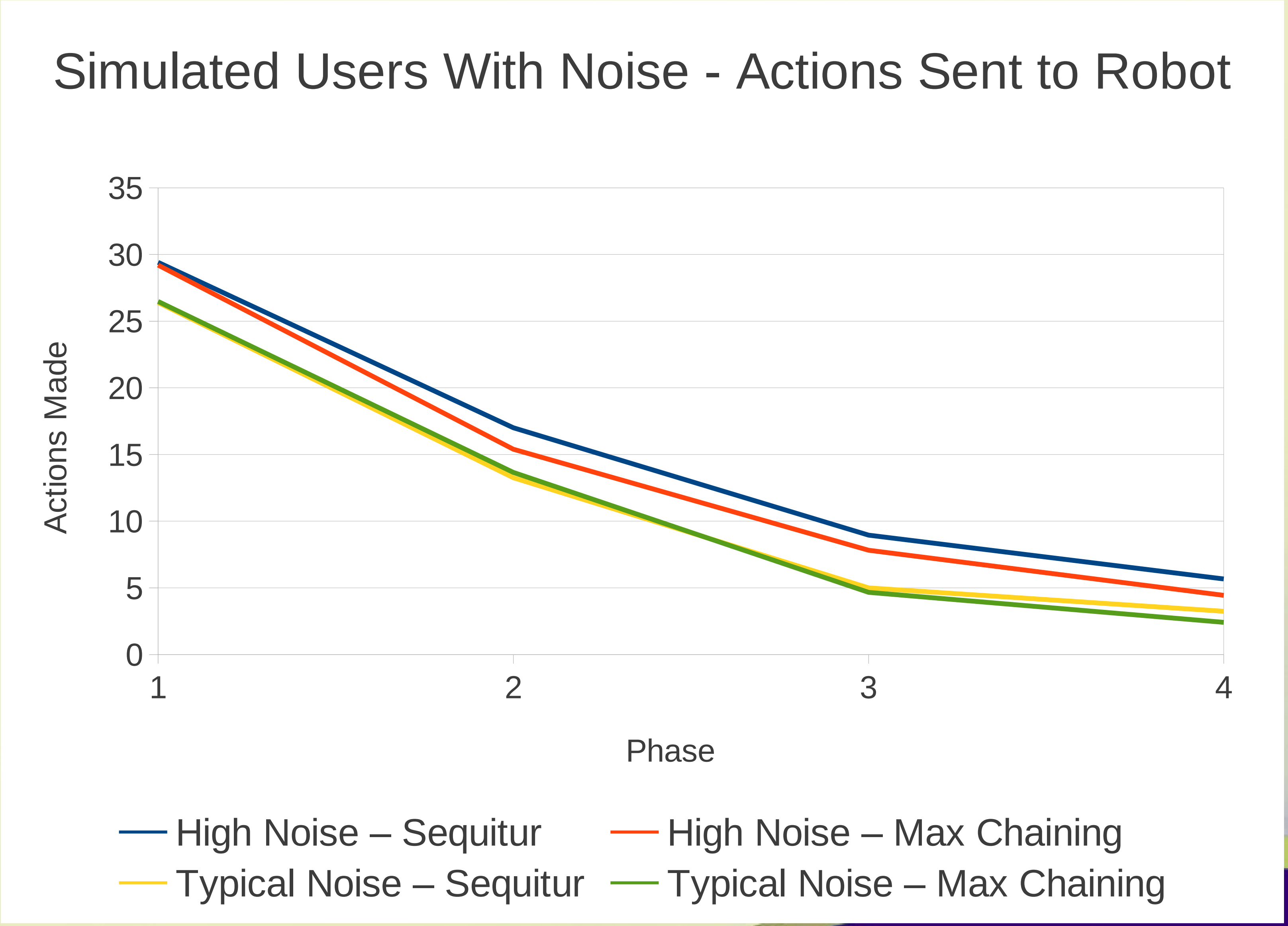
Results – Simulated Users

Simulated user experiment:

- 1000 simulated users run the same set of experiments
  - 500 average noise, 500 high noise
- High noise = each command 2.5 times higher probability of mistake

Results – Simulated Users



Improvements / Challenges

- Scalability:
  - Simple demonstration showed short, simple skills
  - HCI issue: how do we present longer, more complicated skills?
  - How do we make use of the state space?
- Dealing with contingency:
  - What if something goes wrong during execution?

Fin.