Phybots: A Toolkit for Making Robotic Things

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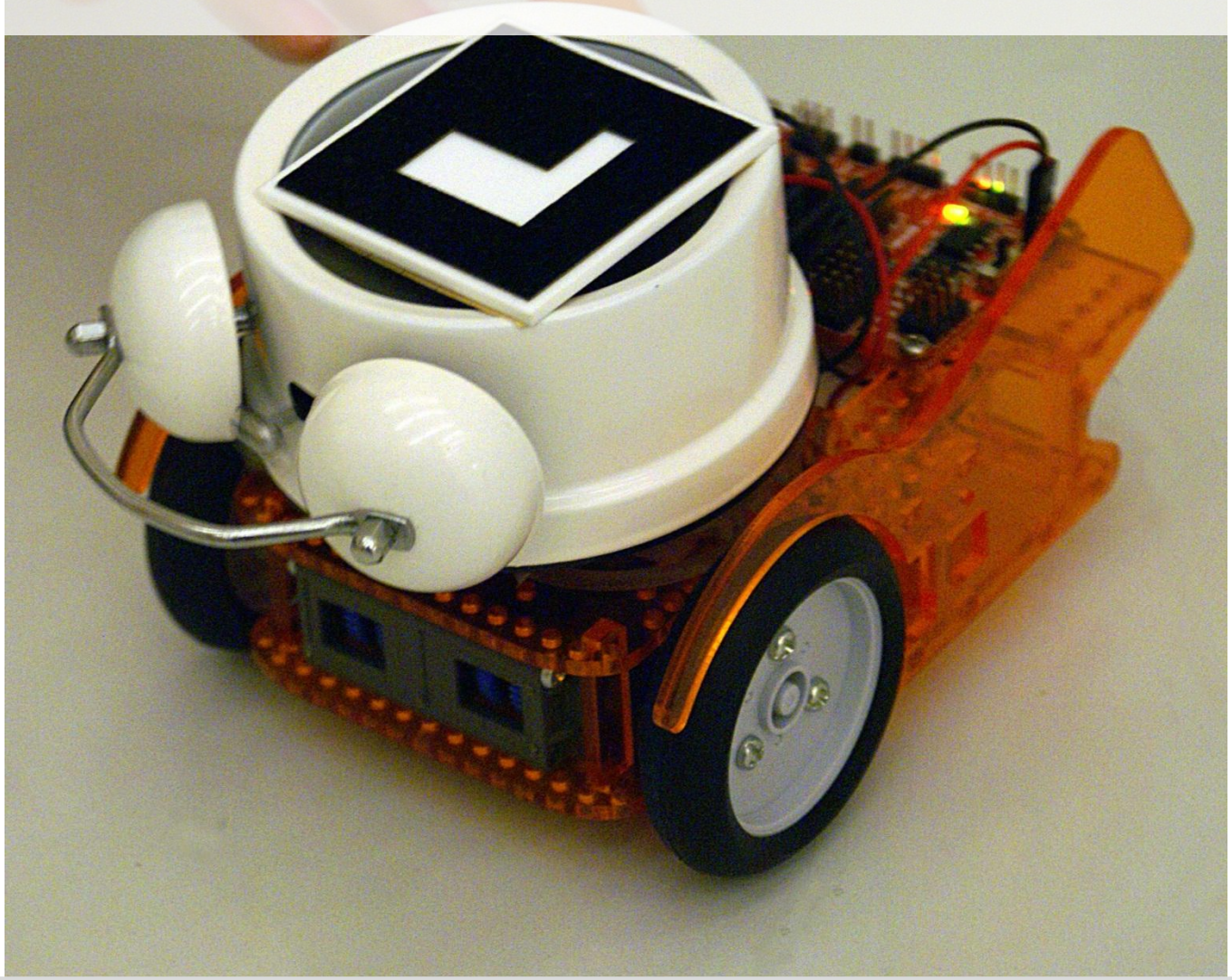
14th June, DIS2012

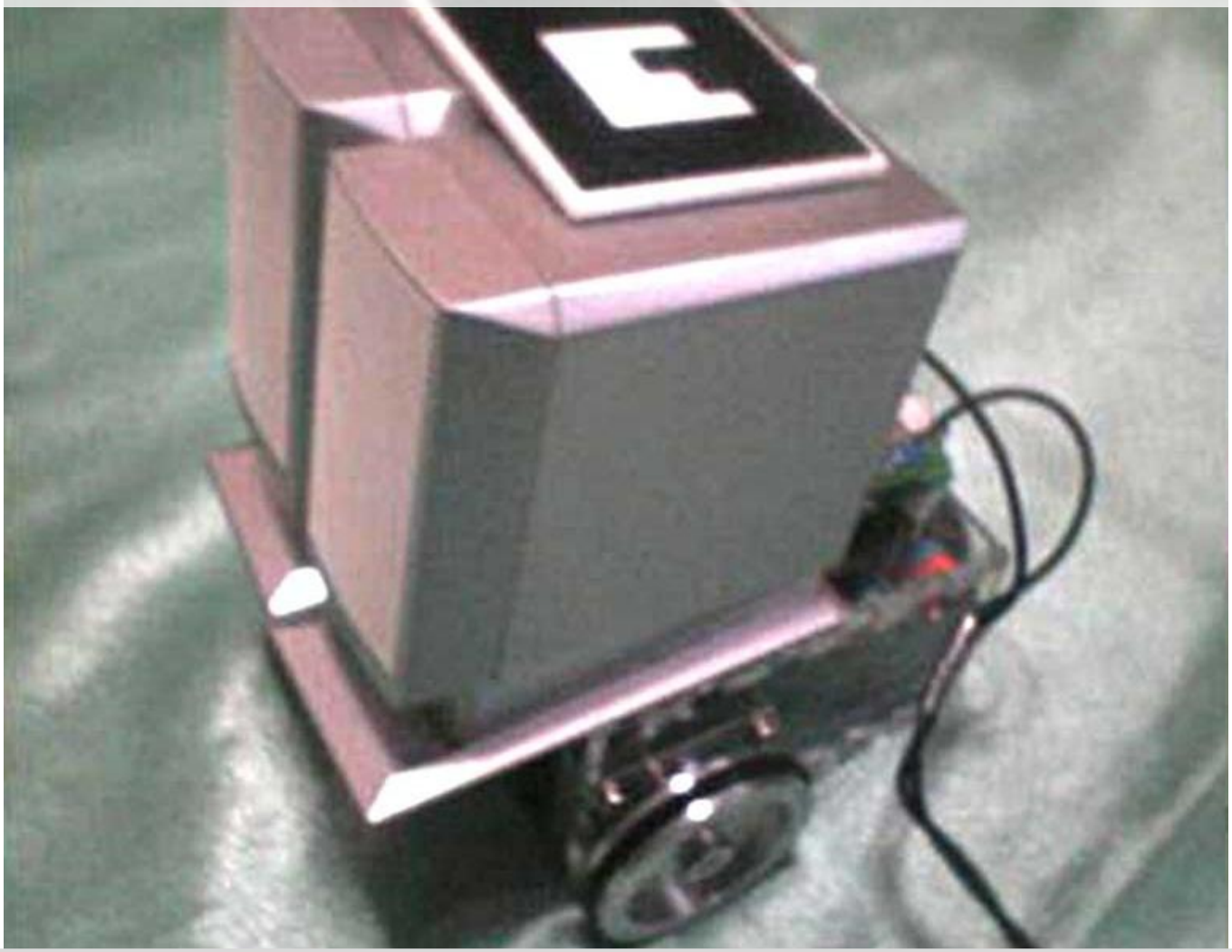
Motivation

Adding mobility to our daily objects

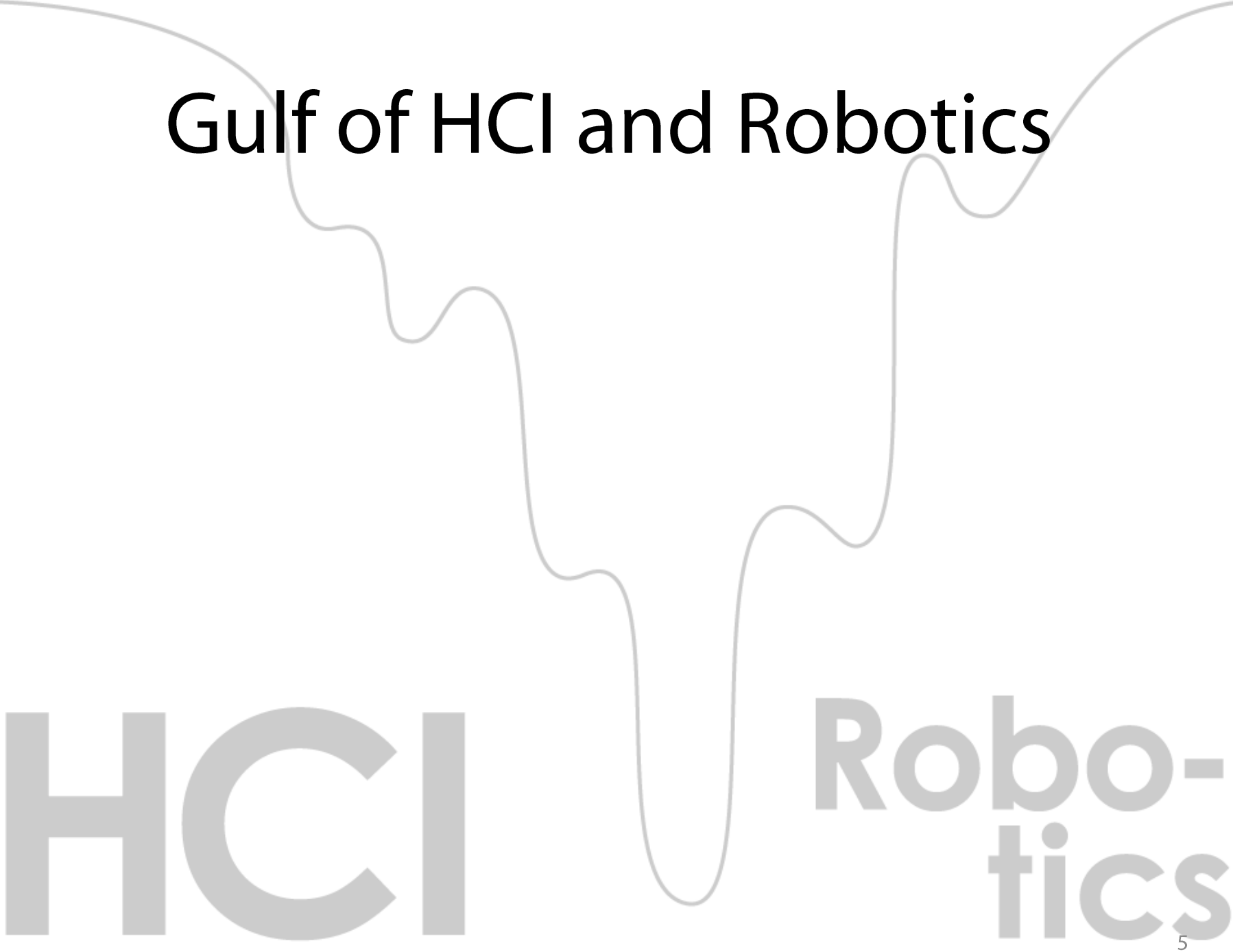
Alarm Clock



Speaker



Gulf of HCI and Robotics



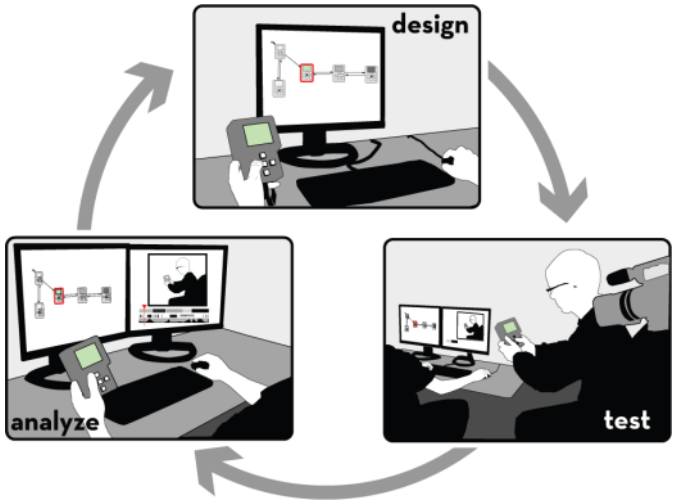
Toolkits for Physical UIs

- Software abstraction of actuators and sensors

[Phidgets '99]

[Arduino '05]

- Support for iterative development process



[d.tools '06]

Gulf of HCI and Robotics

Toolkit for:	**Physical UIs**
Target users:	HCI researchers & Interaction designers
Focus:	Prototyping
Software API:	Low-level&Static
Hardware:	Small&Cheap

Phidget Kit, $200

Toolkits for Robot Programming

- Middleware for distributed environment

ROS.org Microsoft Robotics Developer Studio 2008 R3 Player

- Collection of algorithms

Carmen Robot Navigation Toolkit OpenCV

- Education and entertainment

[LEGO '06]

[Topobo '04]

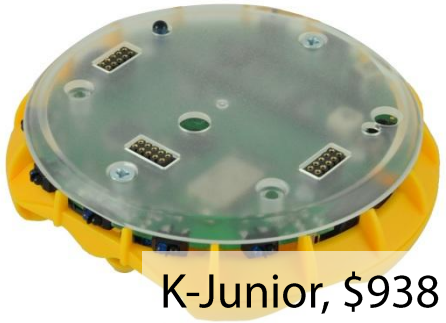
[Pyro '05]

```
robot.translate(distan
ce);
robot.rotate(angle);
```

Gulf of HCI and Robotics

Toolkit for:	**Physical UIs**	**Robots**
Target users:	HCI researchers & Interaction designers	Robotics people
Focus:	Prototyping	Reliability
Software API:	Low-level&Static	High-level&Extensible
Hardware:	Small&Cheap	Medium-Large&Expensive

Phidget Kit, $200



K-Junior, $938

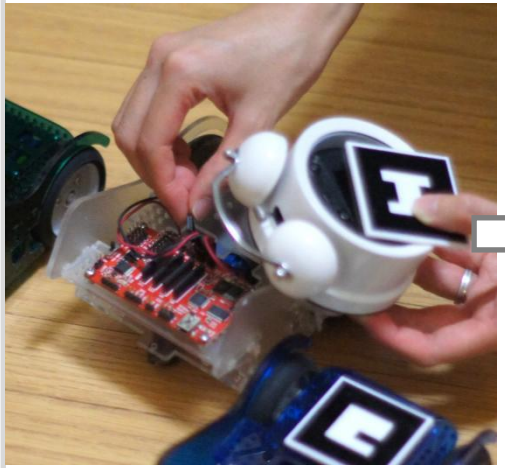
Gulf of HCI and Robotics

Toolkit for:	**Robotic Things**
Target users:	HCI researchers & Interaction designers
Focus:	Prototyping
Software API:	High-level&Extensible
Hardware:	Small&Cheap

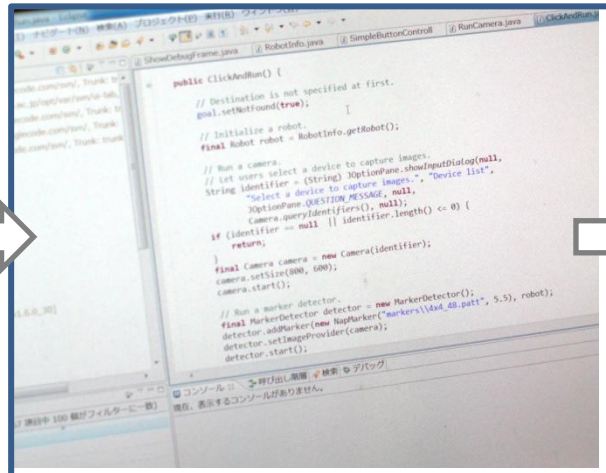
Goal of Phybots

- Add mobility to physical objects
  - In a cheap and easy way
  - Through high-level and extendible API
  - With support for the whole prototyping process

Prototyping with Phybots

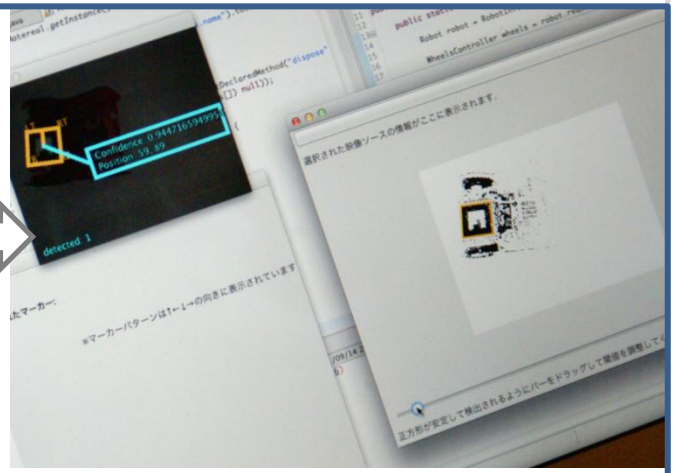


Hardware construction



Programming with built-in API

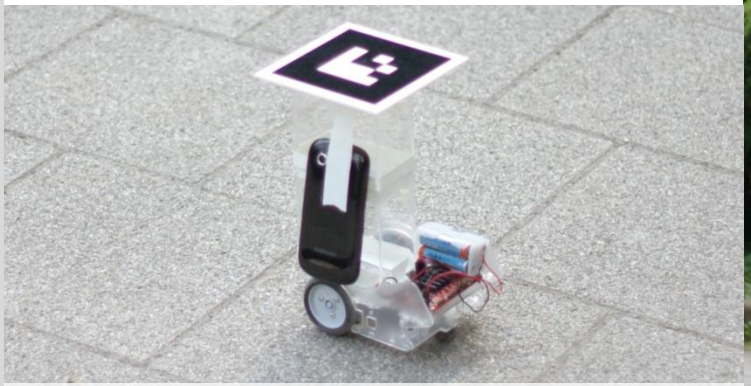
(Extend API when needed)



Test with runtime debug tool

Localization and Locomotion API

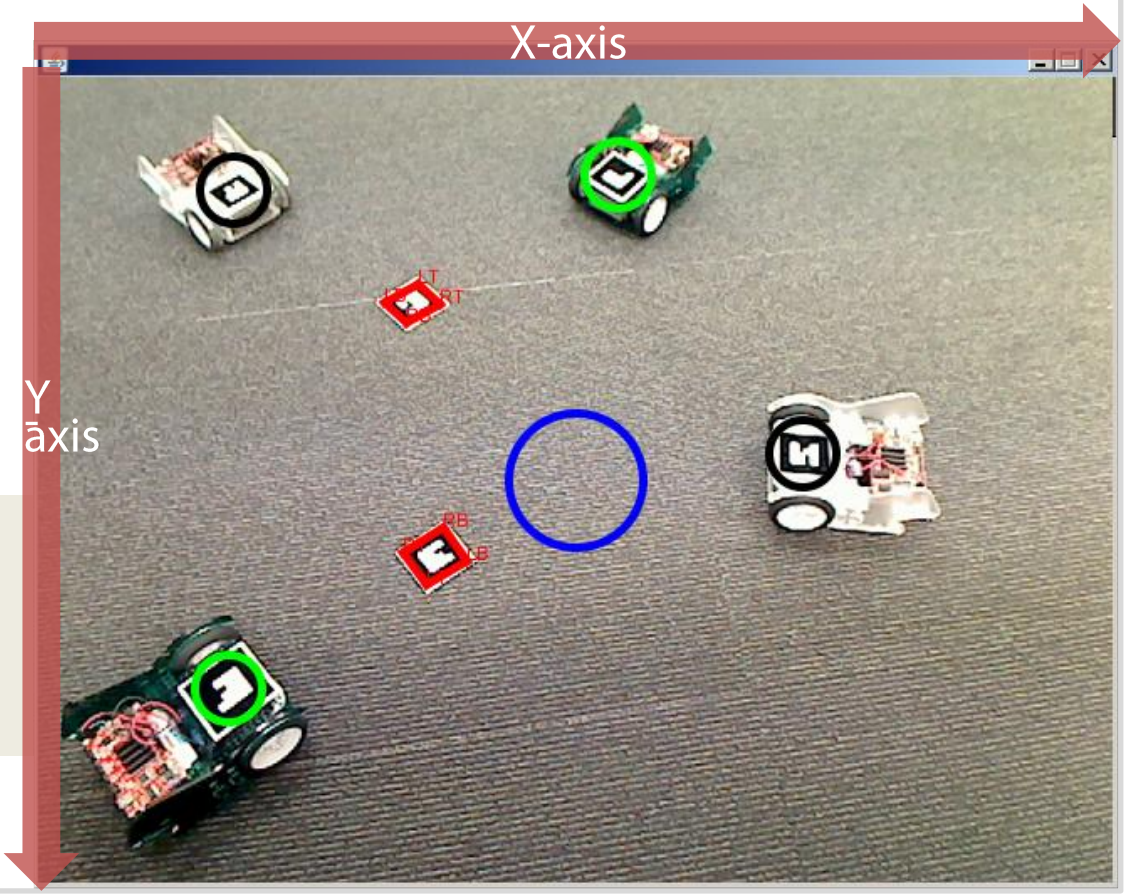
- Hardware setup: easy and cheap
  - Camera
  - PC or Mac
  - Robotic things



From our user study:
Miniature drive recorder

Localization and Locomotion API

- Navigation by global coordinates
  - Move
  - Push
  - TracePath




```
Task move = new Move(
                mouseX, mouseY);
move.assign(robot);
move.start();
```

From our user study:
Beach flags with obstacles

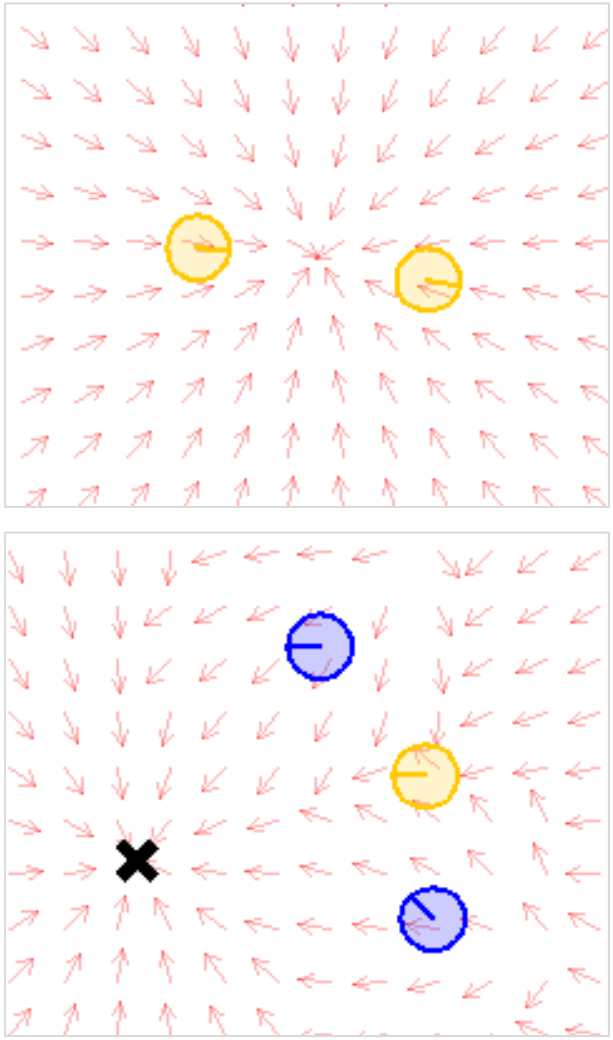
Localization and Locomotion API

- Vector field navigation
  - Easy design of new behavior

    ex) Follow another robot

  - Combination of existing fields

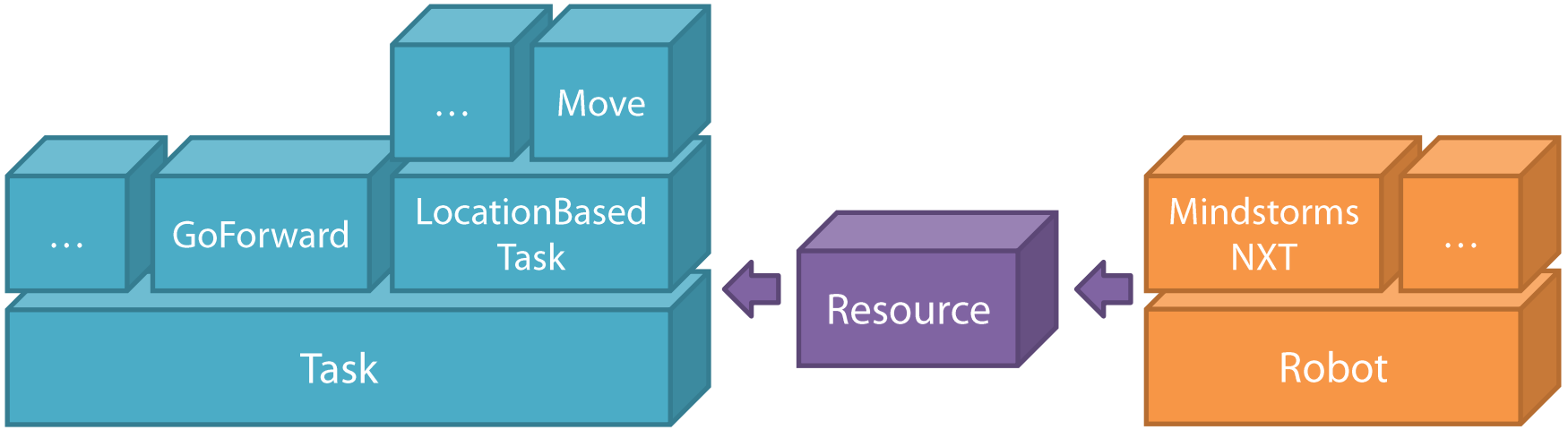
    ex) Move + collision avoidance



Extensible Software Architecture

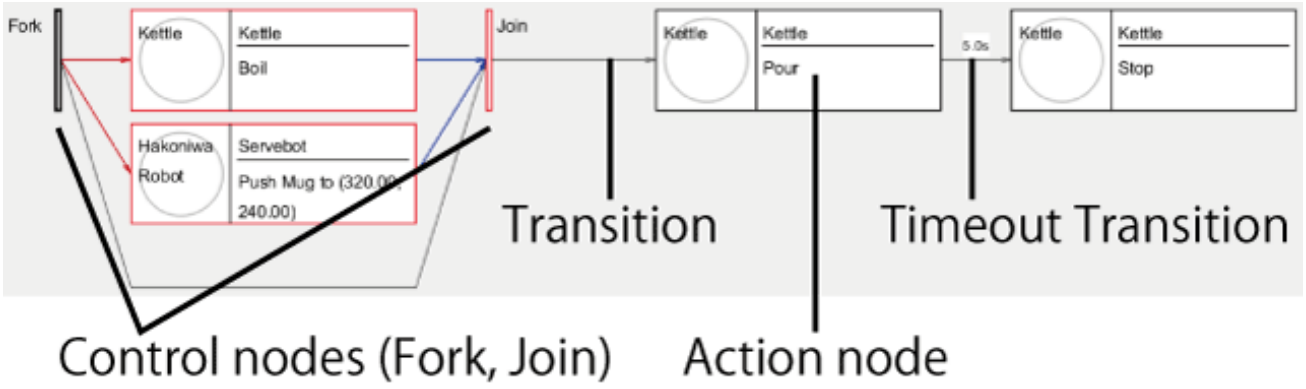
- *Robot*, *Resource* and *Task* abstraction
  - *Robot* passes one or more *Resources* to *Task*.

    ex) *MindstormsNXT* passes *DifferentialWheels* to *Move*.



Extensible Software Architecture

- *Workflow* for higher-level task management



ex) Moving mug:

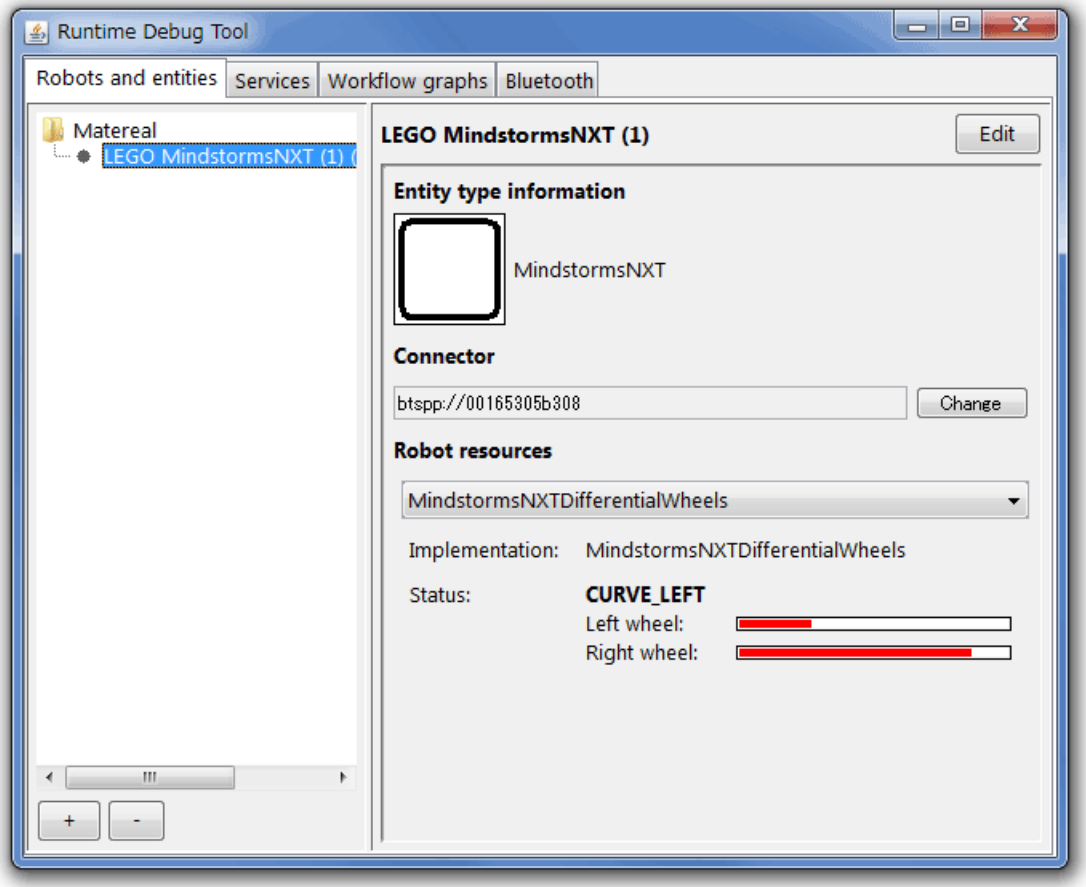
1. Move to the position just under the electric kettle
2. Wait for the kettle to boil the water
3. Wait for the kettle to pour the hot water
4. Move to the position in front of the user

Runtime Debug Tool

- Entity Monitor
- Service Monitor
- Workflow Monitor

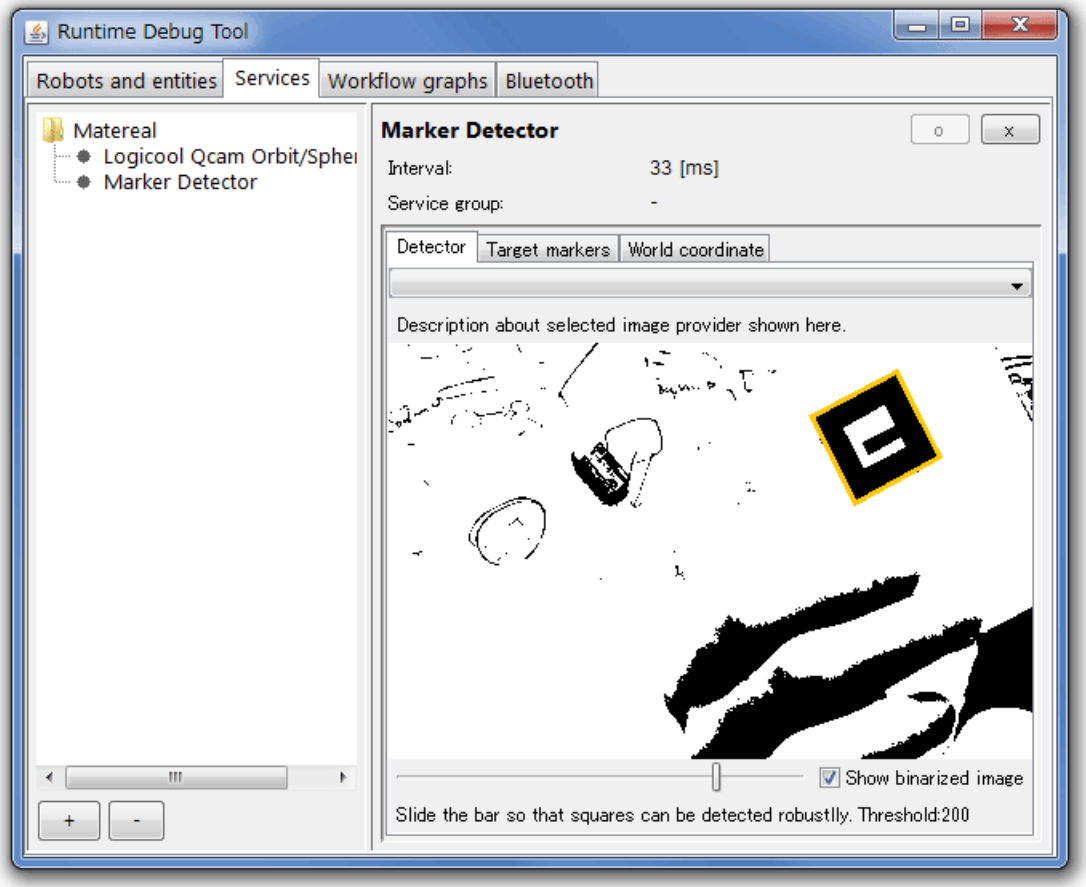
Runtime Debug Tool

Entity Monitor



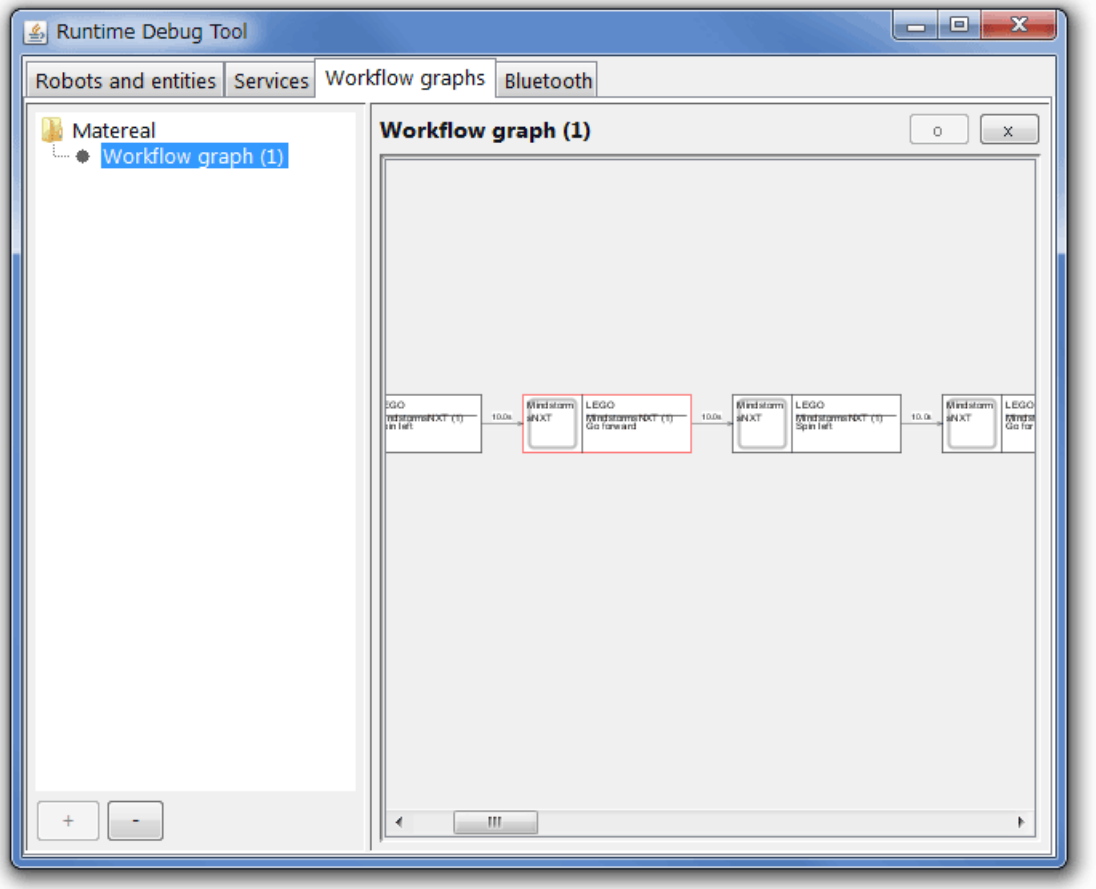
Runtime Debug Tool

Service Monitor



Runtime Debug Tool

Workflow Monitor



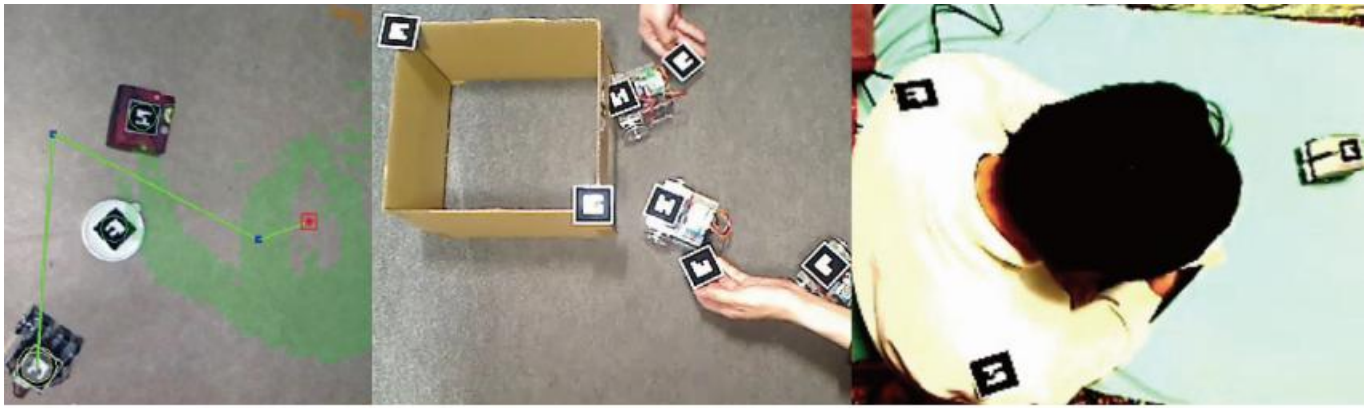
User Studies

1. Alpha version deployment
   - To graduate students
2. Current version deployment
   - To HCI students
   - To robotics students

Course Work for Grad Students

- 11 groups formed of 15 graduate students
- Provided:
  - Software: Alpha version of Phybots that only provides localization and locomotion API
  - Hardware: Robot kit
    - Camera
    - Robot
    - Visual markers

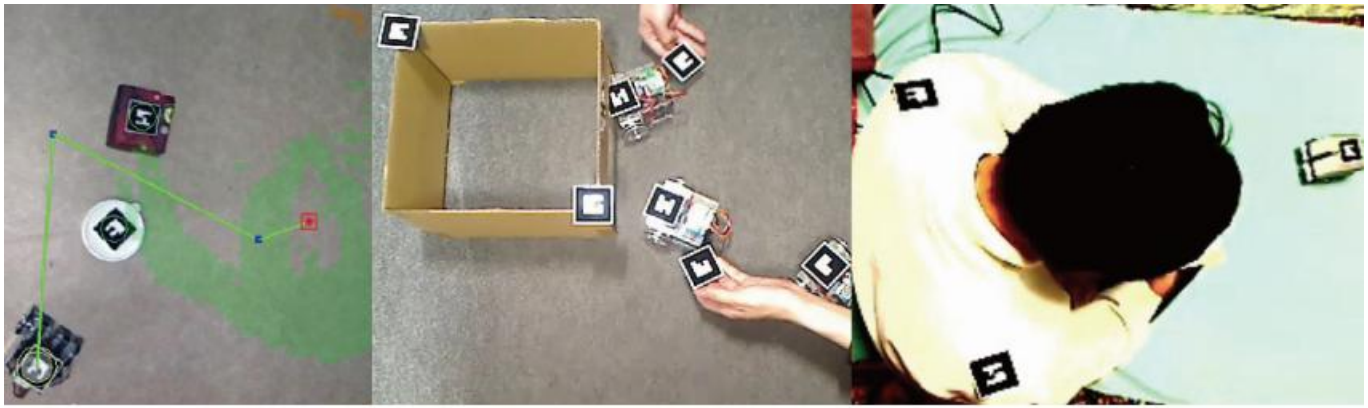
Results & Lessons Learned



Grab and go Sheep game Moving speaker

- Lessons learned:
  - Mere mobility was not enough.
  - Most apps only used a single API call.
  - Parameter configuration was painful.

Results & Lessons Learned



Grab and go Sheep game Moving speaker

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  - **Extendibility is important.**
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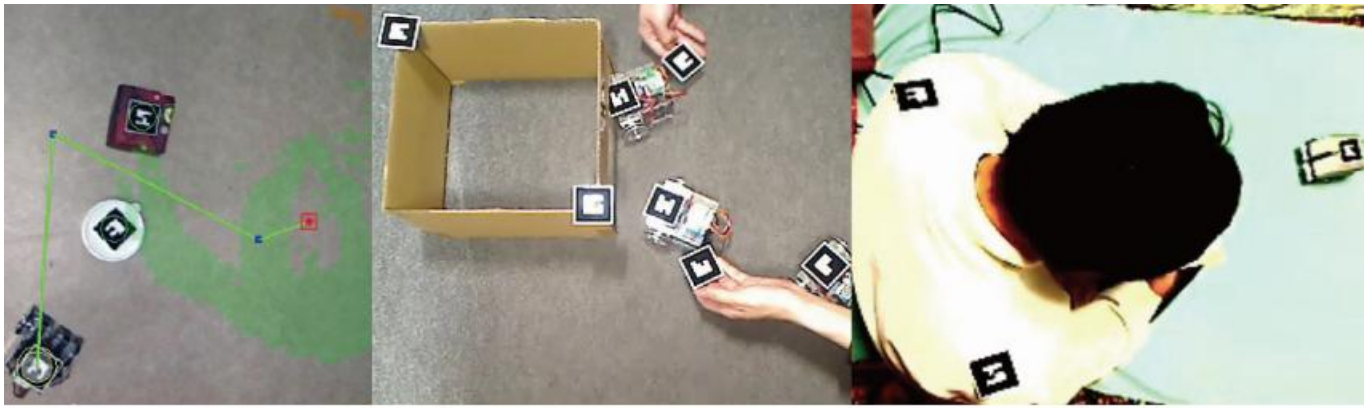
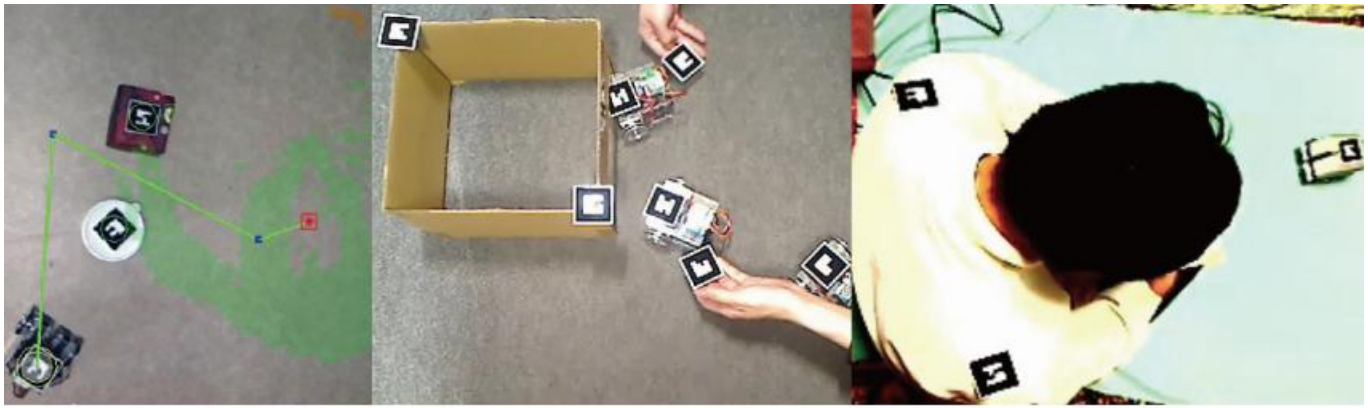
Results & Lessons Learned



Grab and go Sheep game Moving speaker

- Lessons learned:
  - **Extendibility is important.**
  - **Higher-level task management is desired.**
  - Parameter configuration was painful.

Results & Lessons Learned

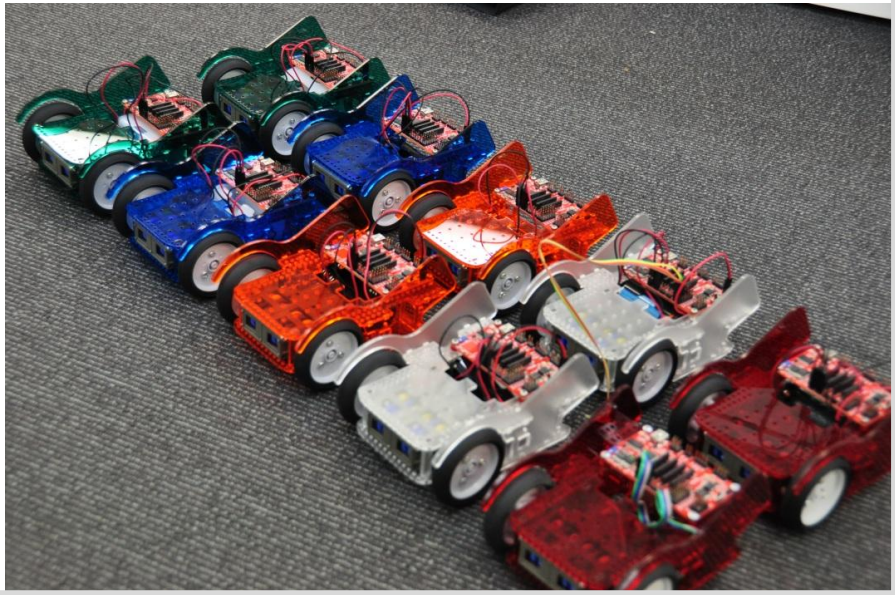


Grab and go Sheep game Moving speaker

- Lessons learned:
  - **Extendibility is important.**
  - **Higher-level task management is desired.**
  - **Support for testing phase is needed.**

Workshop for HCI Students

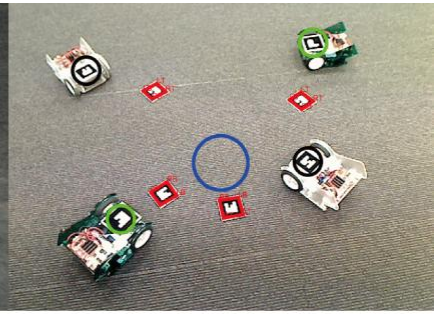
- 3 undergrad and 4 grad students from HCI labs
- Provided:
  - Software: Current version of Phybots
  - Hardware: Robot kit
    - Same as the previous study except for the robot.



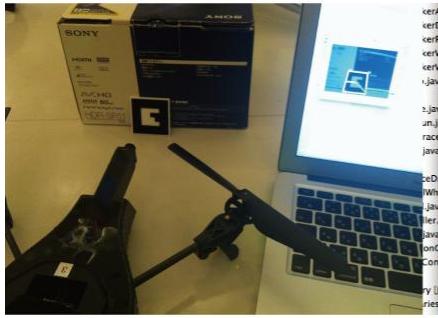
Ikimo http://www.inmojo.com/ikimo/

Results

1. Miniature drive recorder

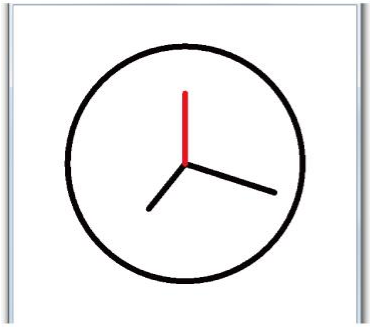


2. Beach flags with obstacles

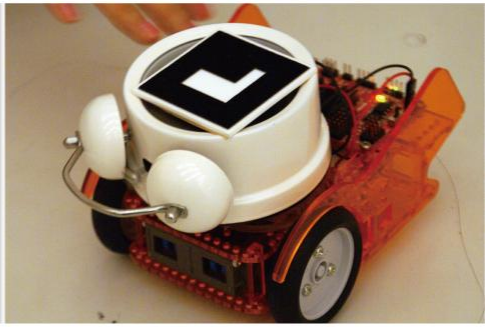


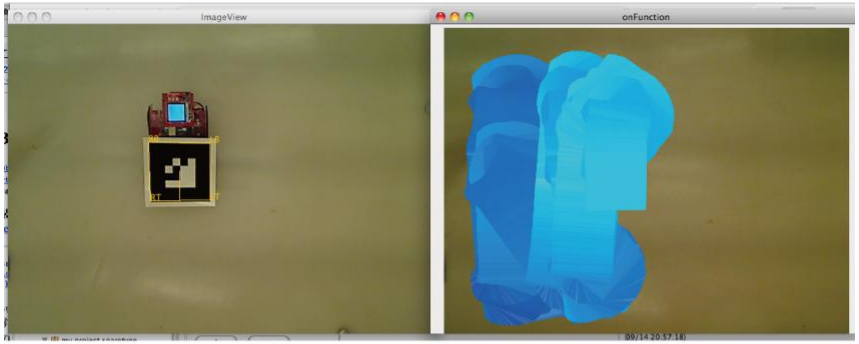
3. MatereARdrone

4. Cameraman robot



5. Alarm clock





6. Hawk view

7. Serving robot

Lessons Learned

- Feedback for robotics:
  - Effectiveness of GUI for controlling robots (while typical Human-Robot Interaction focuses on direct interaction between people and robots.)
- Inner class madness:
  - Chains of event listeners resulted in spaghetti code.
  - Workflow API helped cleaning the code.

Workshop for Robotics Students

- 2 graduate students from a robotics lab
- Provided:
  - Same as the previous study
- Asked:
  - Comparison between Phybots and a famous robotics toolkit (ROS)

Lessons Learned

- Too much abstraction is not good for prototyping
  - Boilerplate
    - Many lines of code for configuration
  - No direct access to the world model
    - Many lines of code to get a specific class instance
  - Too many things to learn before coding
    - Many modules with tiny purposes

Future Work for the Toolkit

- Tighter integration with toolkits for robotics
  - Phybots can be implemented as a module for ROS.
- Kinect camera instead of a normal webcam
  - Phybots can benefit from its depth/skeleton info.
- Support for local tasks
  - Two-dimensional coordinates was sufficient for global locomotion but for local tasks such as picking up an object.




Phybots

- A toolkit for prototyping "robotic things"
  - Localization and Locomotion API
  - Extensible Architecture
  - Runtime Debug Tool
- Open-source software available at http://phybots.com