Real-Time Interactive Control Interfaces for Multi-Robot Teams

Erik Karulf

M.S. Thesis Defense

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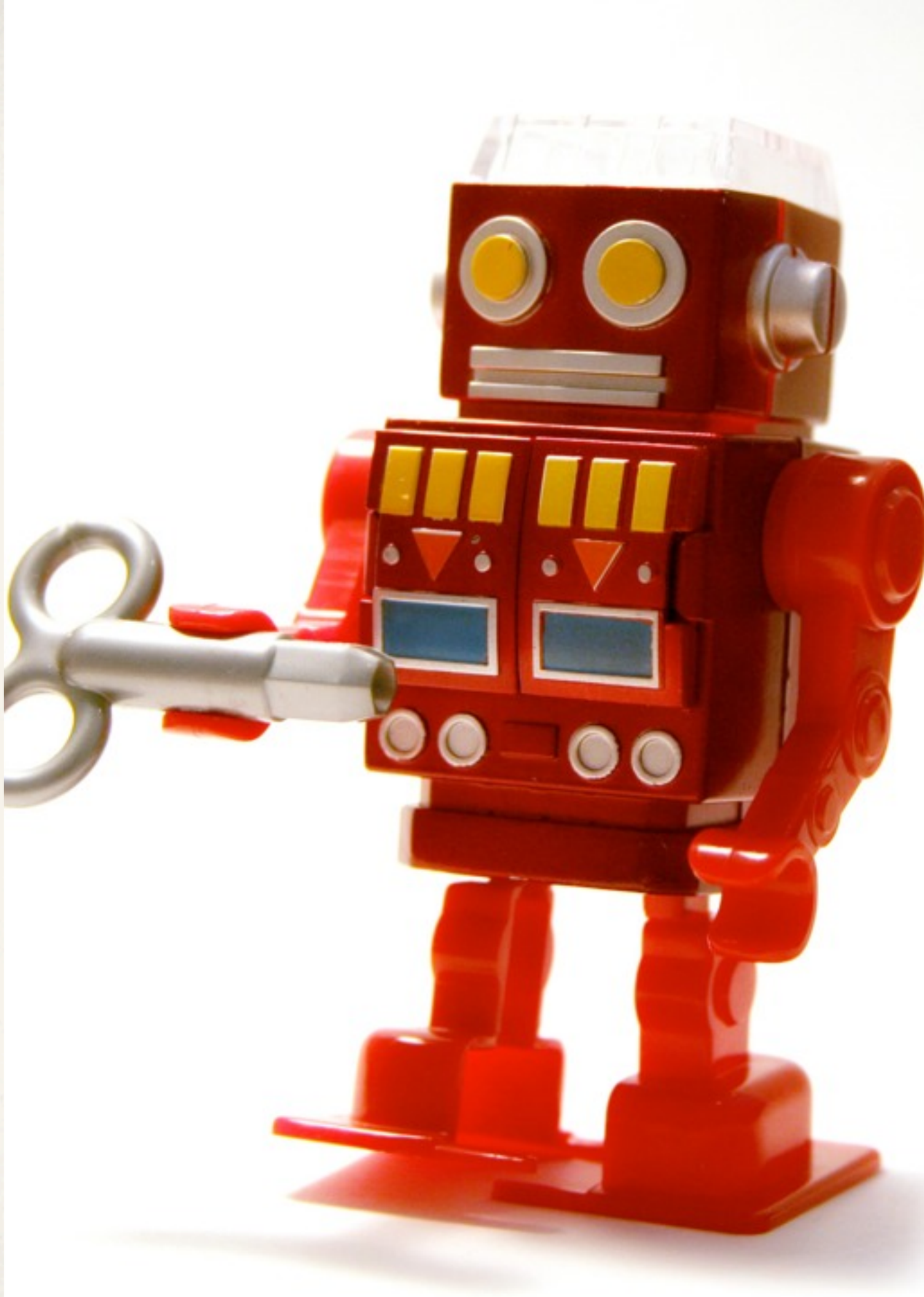
Overview

- Introduction and Research Motivation
- Prior Work and Context
- System Overview
- Experimental Setup
- Experimental Results
- Future Work

Research Motivation

- Research: control of multi-robot teams
- Concurrency
- Modularity
- Usability



Sasan Saidi - “Retro Robot”

Concurrency

Operator

Robot

Photo: Mario Alberto Magallanes Trejo - "Working 2"

Concurrency

Operators

Robots

Concurrency

Operator

Robots

Modularity

- Control software is written for a specific robot
- User interfaces are not designed to support multiple robot models

Flavio Takemoto - “Binary Code 1”

Usability

- Robot software is designed for engineers
- Video games designers work hard to make games usable
- Basic robot control parallels video game controls

Patricia Dekker - "Whizzkid"

Thesis

- Applying video game principles to HRI interfaces will improve usability.
- Design and implement a supervisory interface
  - Some prior work within robotics
- Design and implement teleoperation interface
- Develop mechanisms for quickly changing modes

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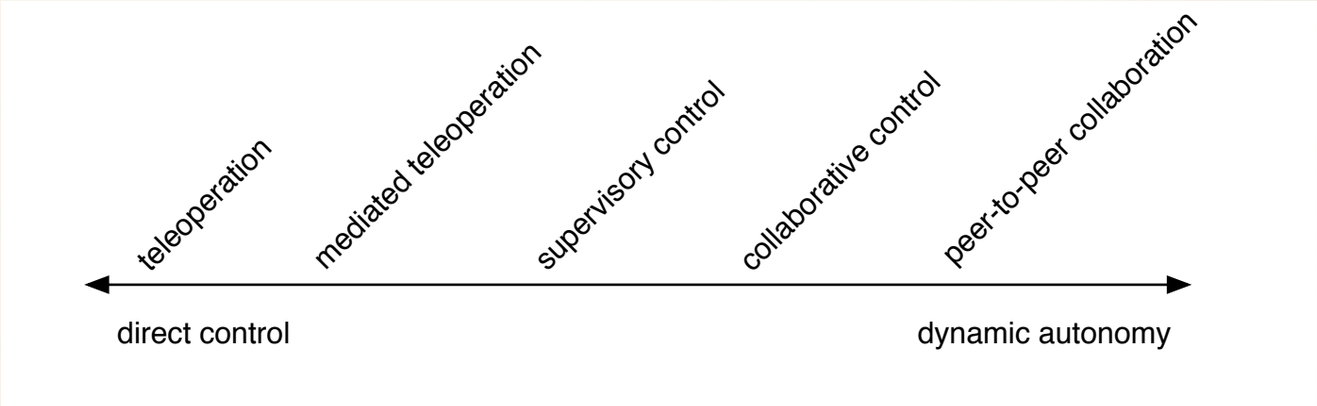
Human Robot Interaction

- Concepts
  - Autonomy
  - Information Exchange
- Prior Work
  - Teleoperation
  - Ecological Interfaces

Autonomy

- Independent robot behavior
- Scale of autonomy
- Sliding autonomy
  - Changing the level of autonomy dynamically



Goodrich

Information Exchange

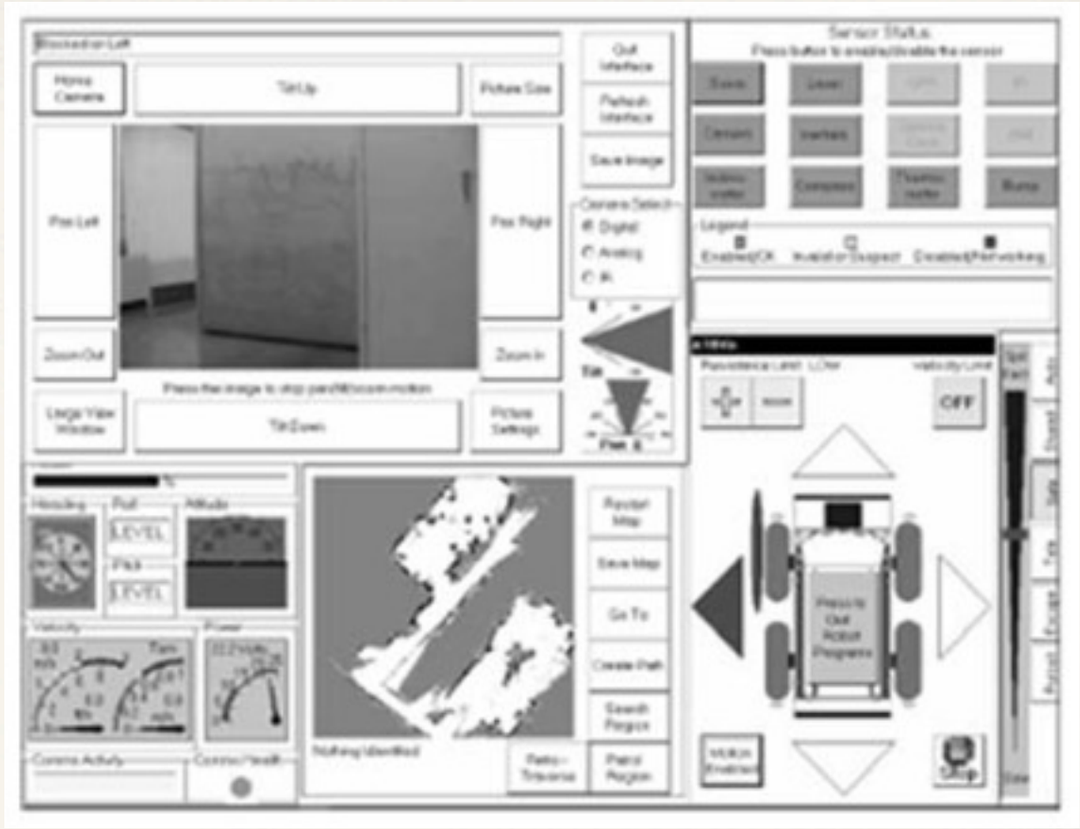
- Flow of data between the human and the robot
- “Sliding Information Exchange”
  - Provided information
  - Representation
  - Timeliness

Teleoperation

- Operation of machines at a distance
- Low degree of autonomy
- High degree of information exchange

IEEE Spectrum

Ecological Interfaces



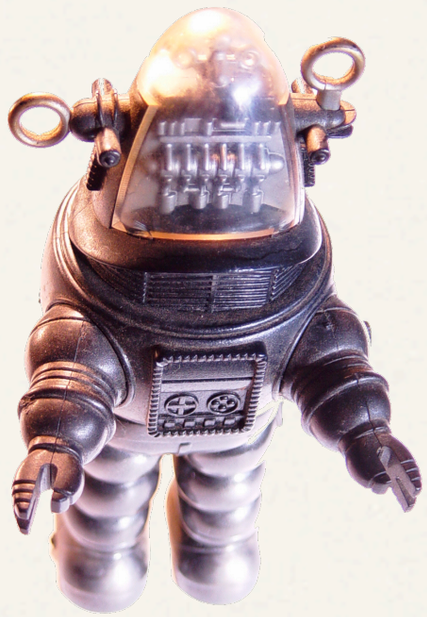
- Presenting state and relationships visually
- Allow user's cognitive processing on high level tasks

Robot Middleware

- ROS Organization
  - Nodes
  - Topics and Services
- ROS Libraries
  - Kinematic Tree
  - Maps and Navigation

ROS Organization

- Nodes
- Messages
- Topics
- Services



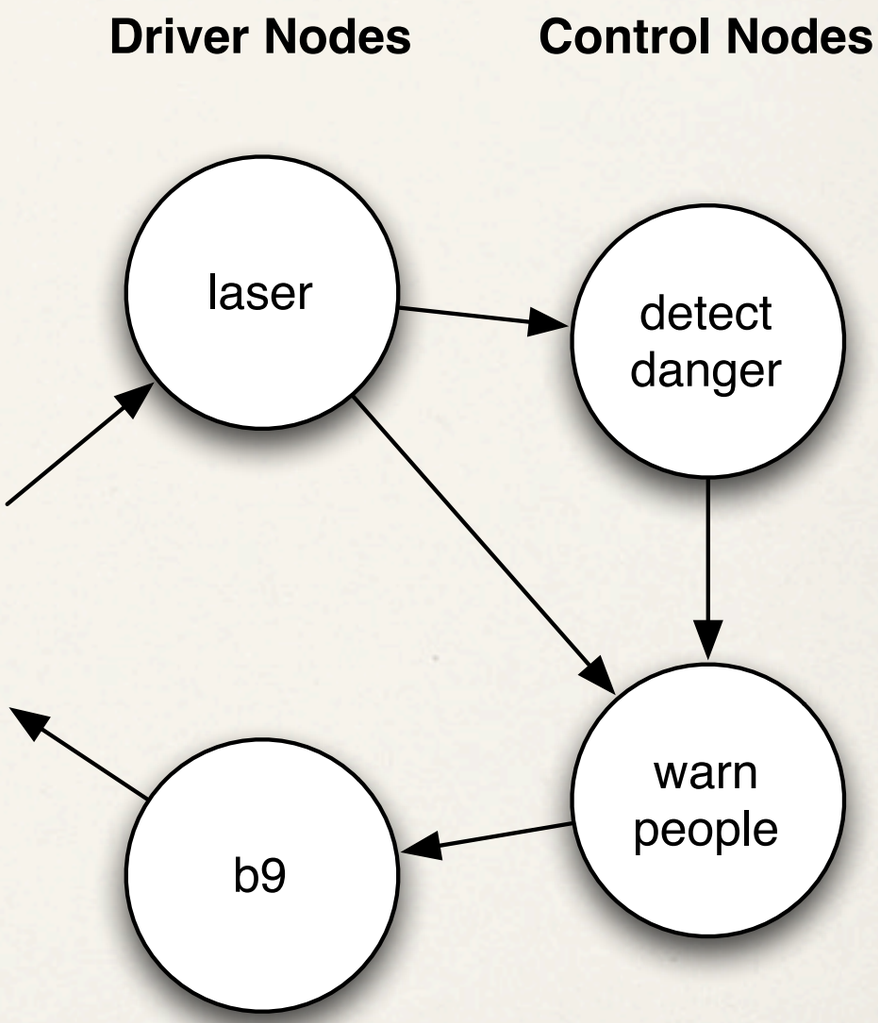
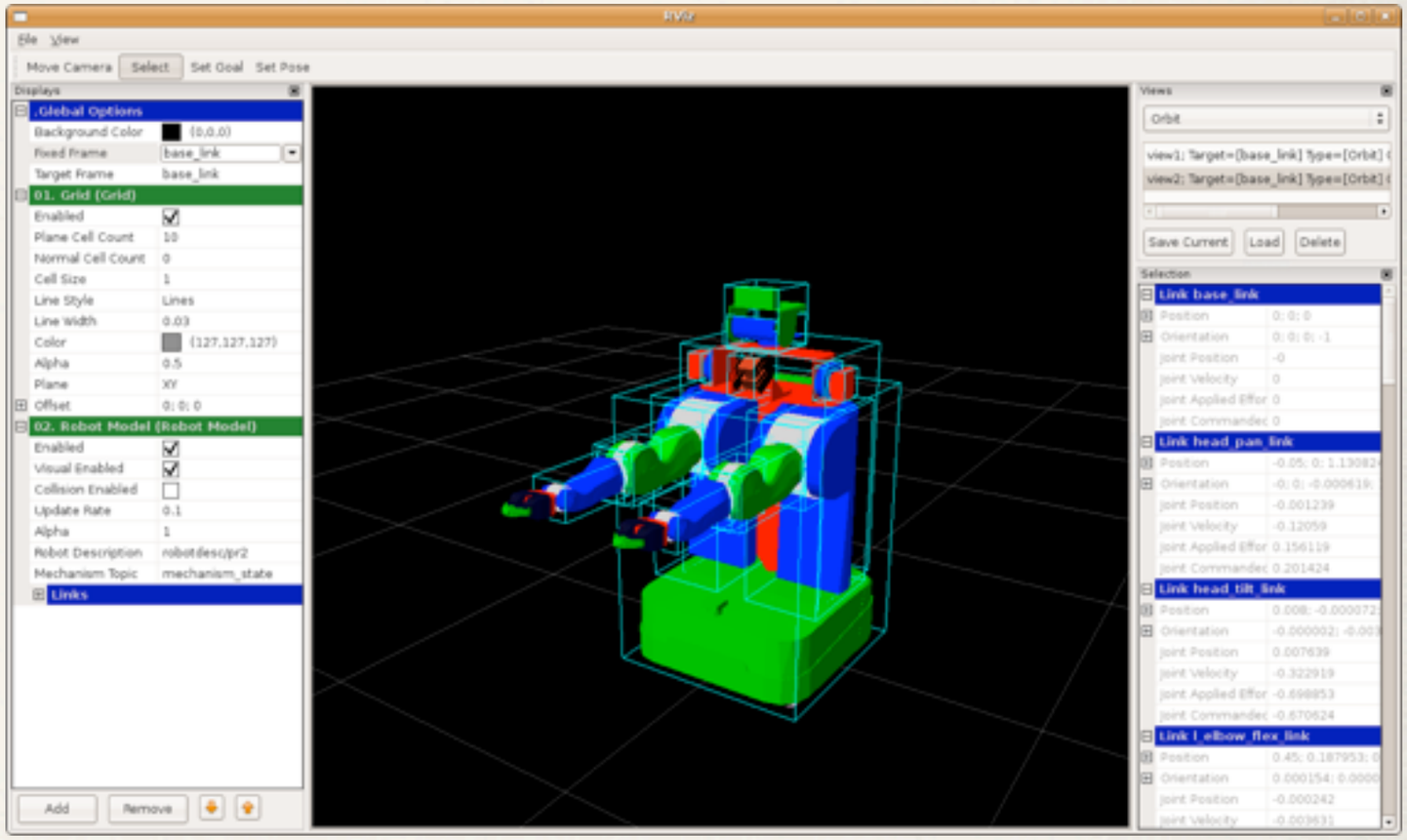


Photo: Dog Madic - "Robbie"

ROS Libraries

- ROS.org
- tf : Kinematic tree
- 2dnav: Mapping, path planning, obstacle avoidance



Video Games

- Sandbox Games
- Real-Time Strategy Games

Sandbox Games

- Immersive environment
- Non-linear storyline
- Emphasis on exploration

Strategy Games

- Real-Time Strategy
- Large number of units
- Large terrain

Blizzard Entertainment: Starcraft 2

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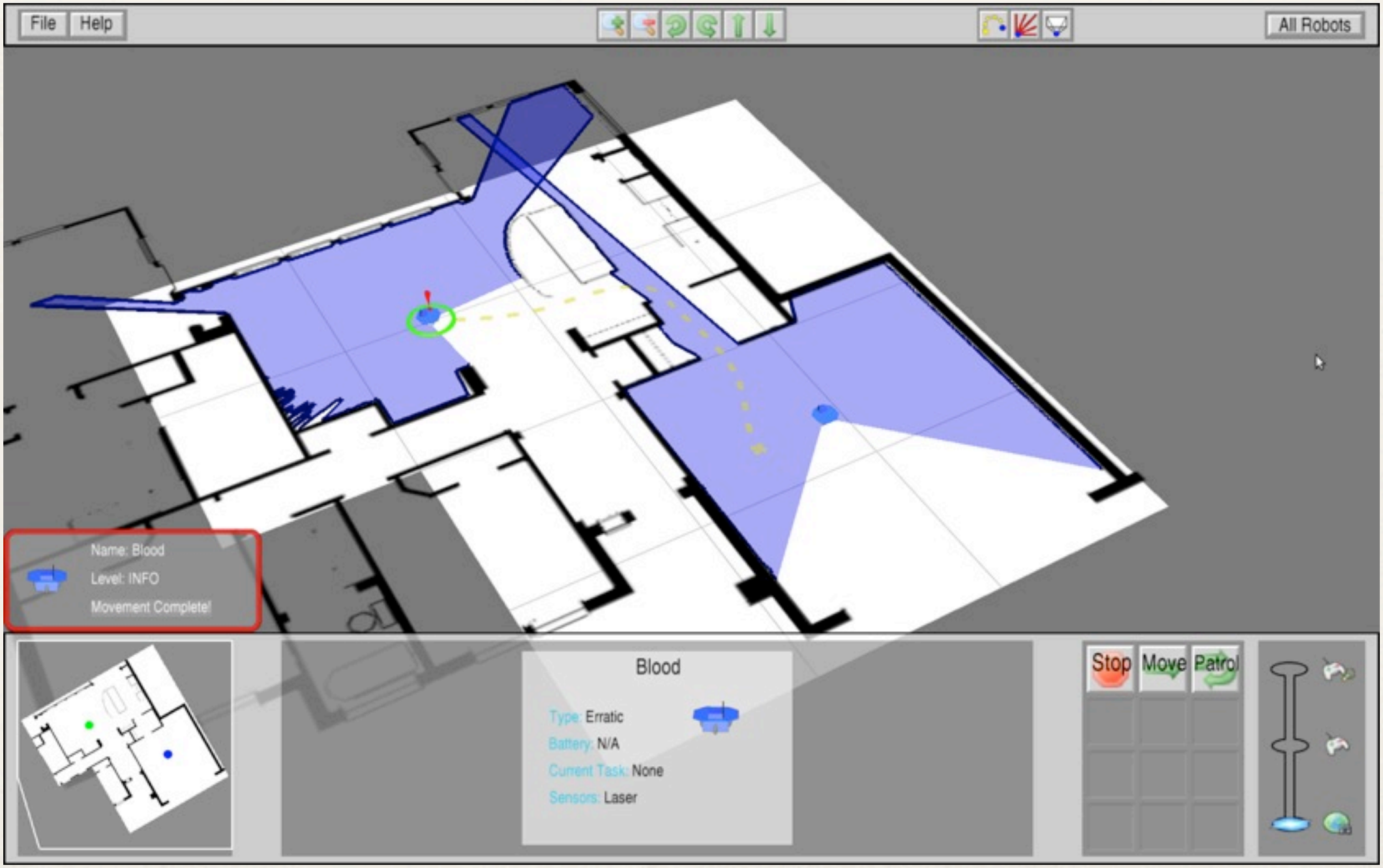
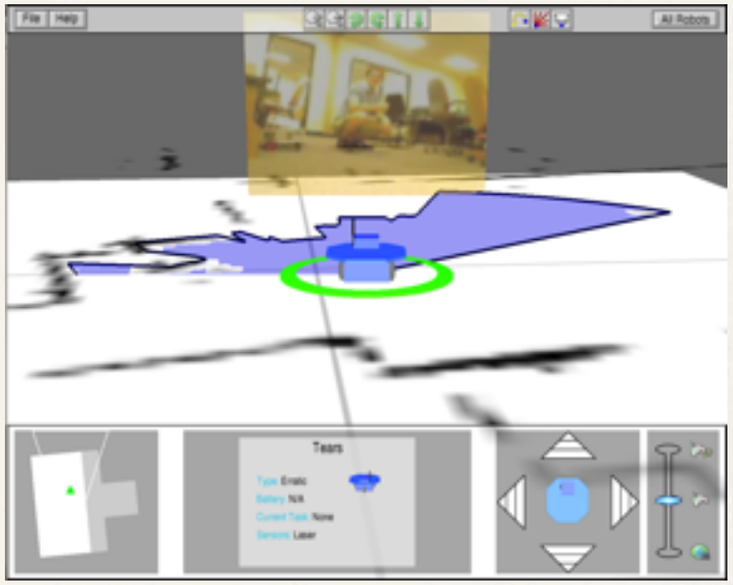
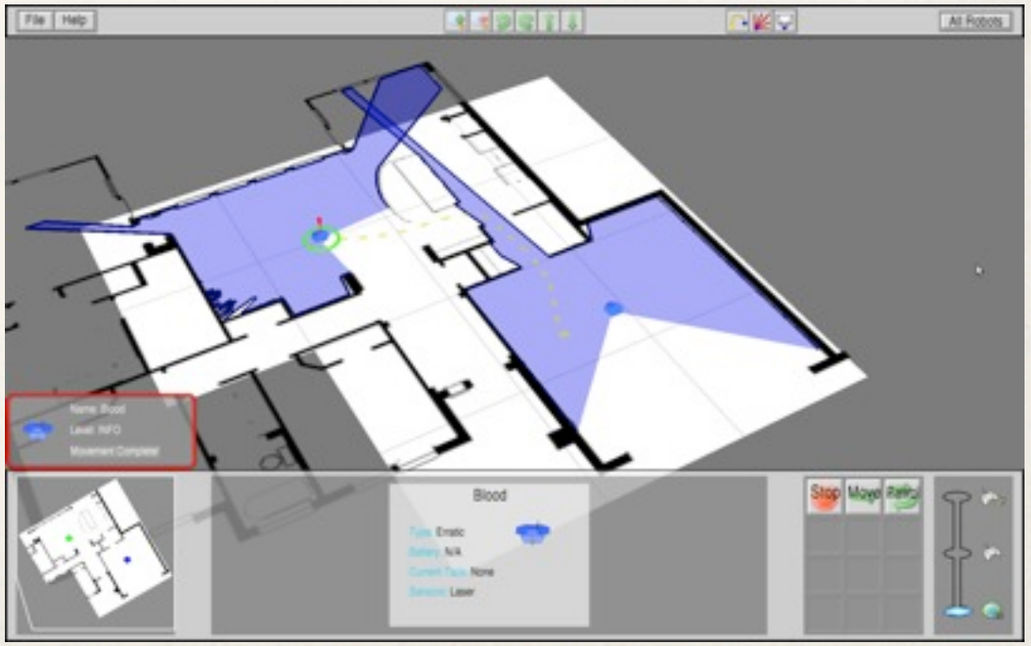
Real-Time Interactive Display Environment



RIDE User Interface

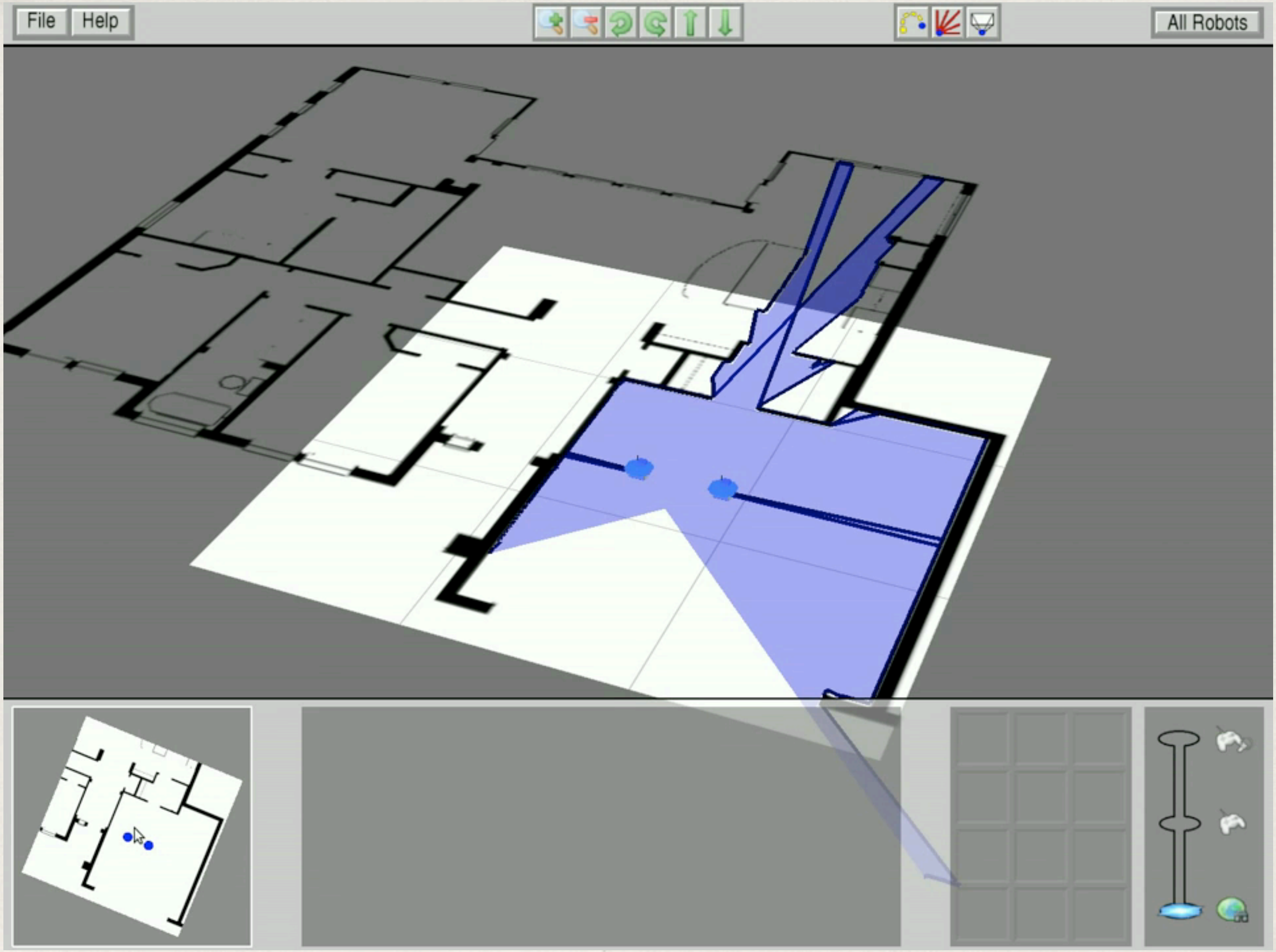
- Application
  - Widget System
  - Mode Switching
- Direct Control
- Supervisory Control
  - Task System
  - Notification System





RIDE Demonstration Video

Thanks to Parker Dunton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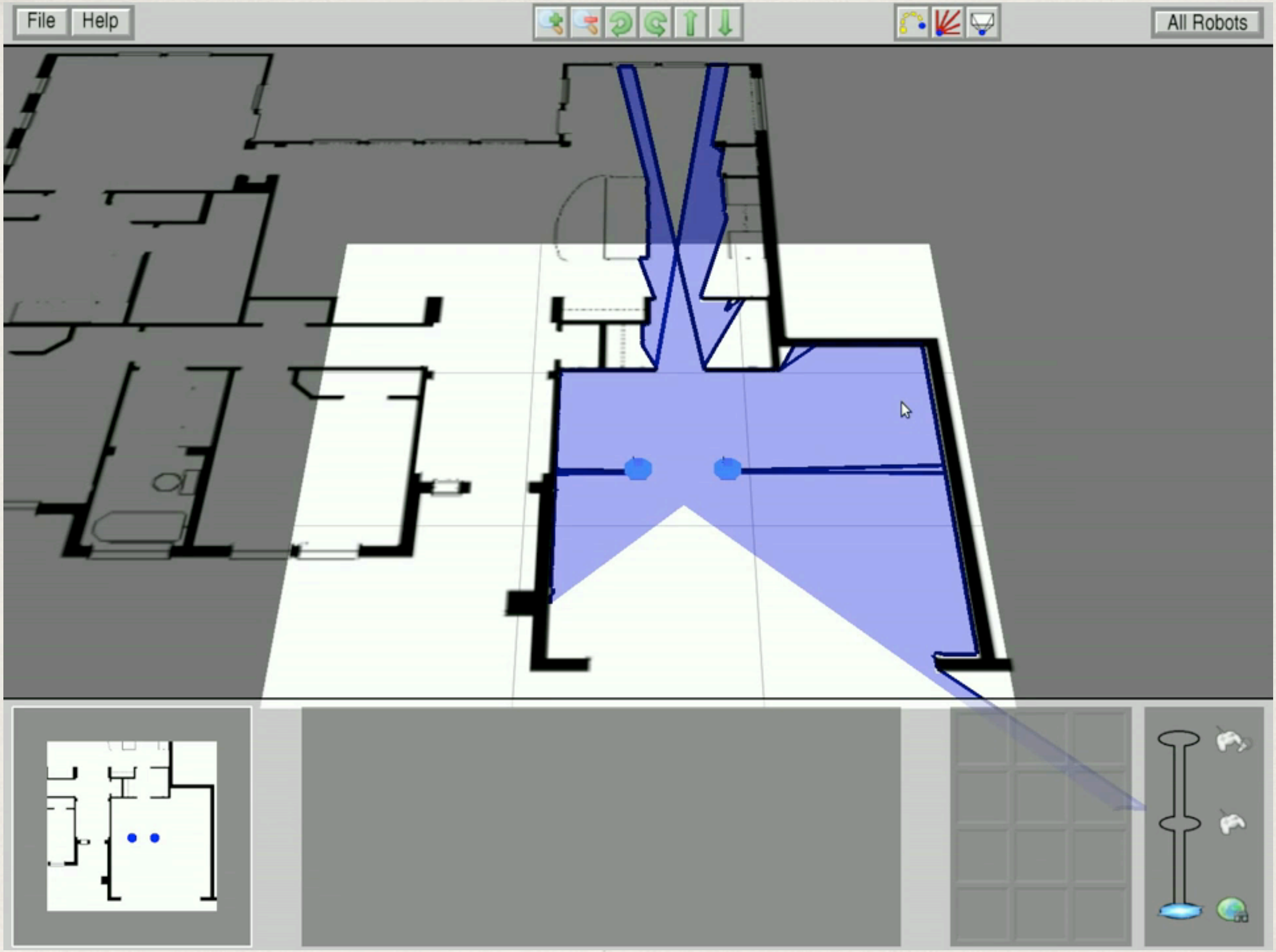
Help
All Robots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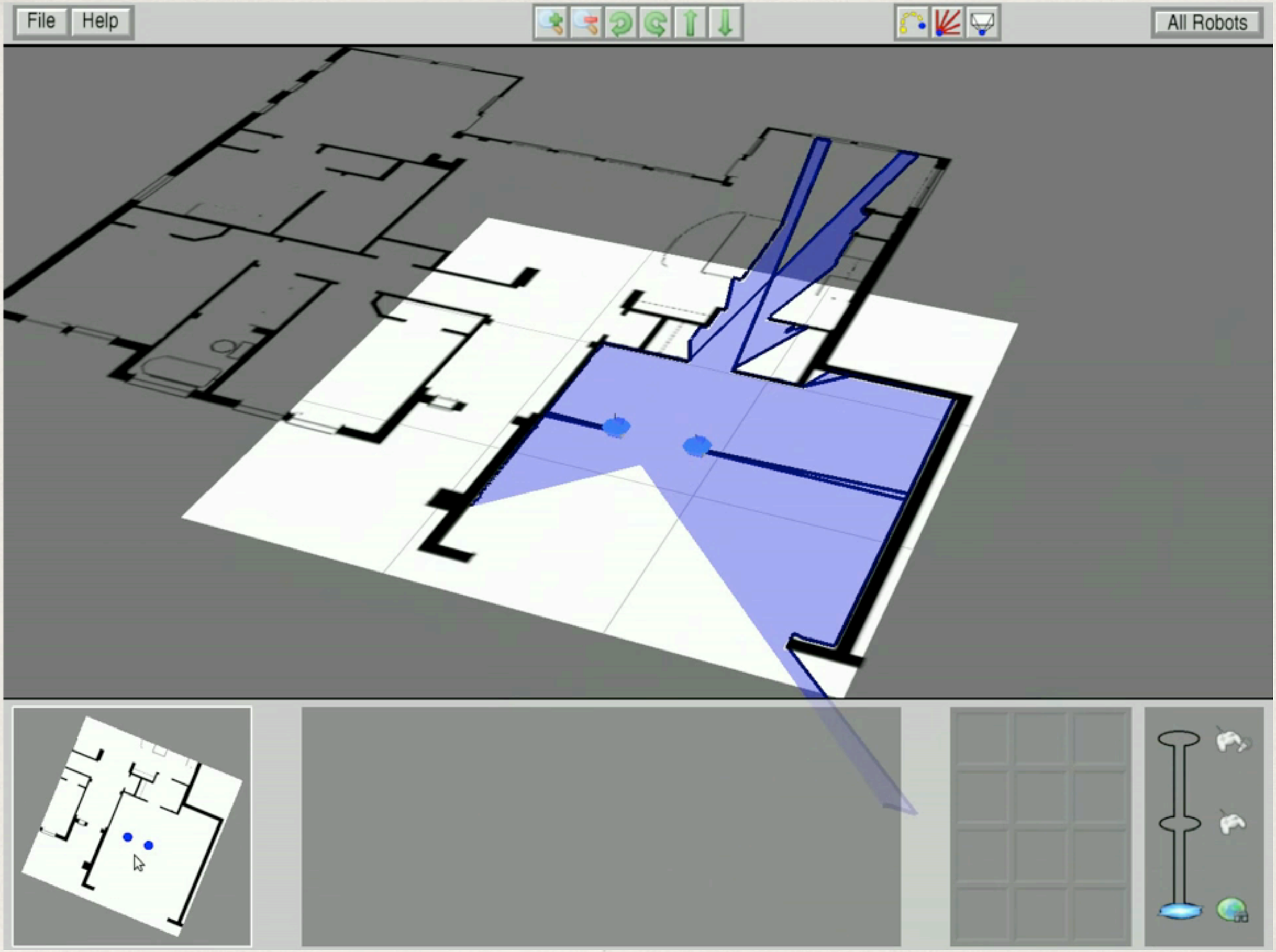
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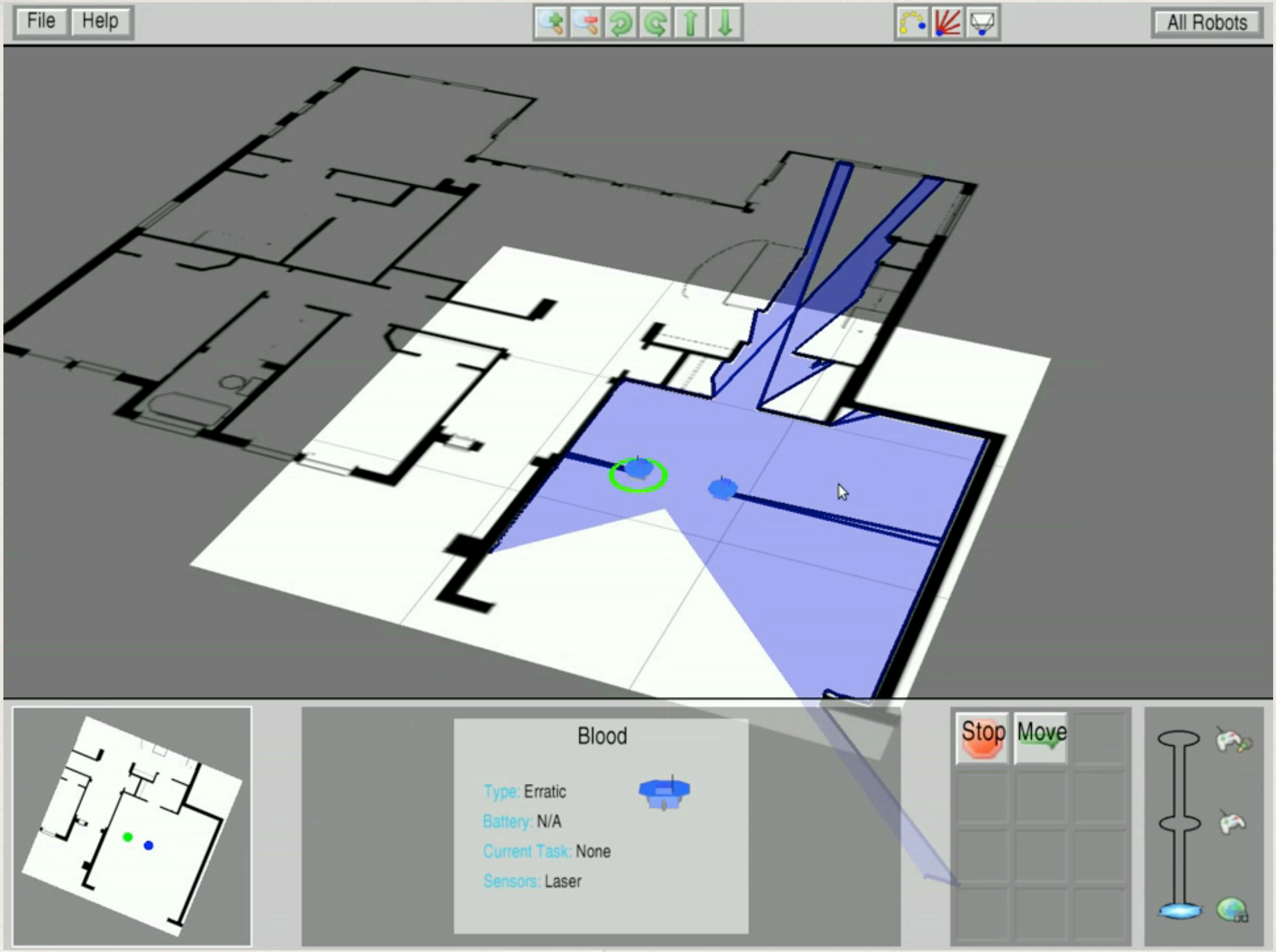
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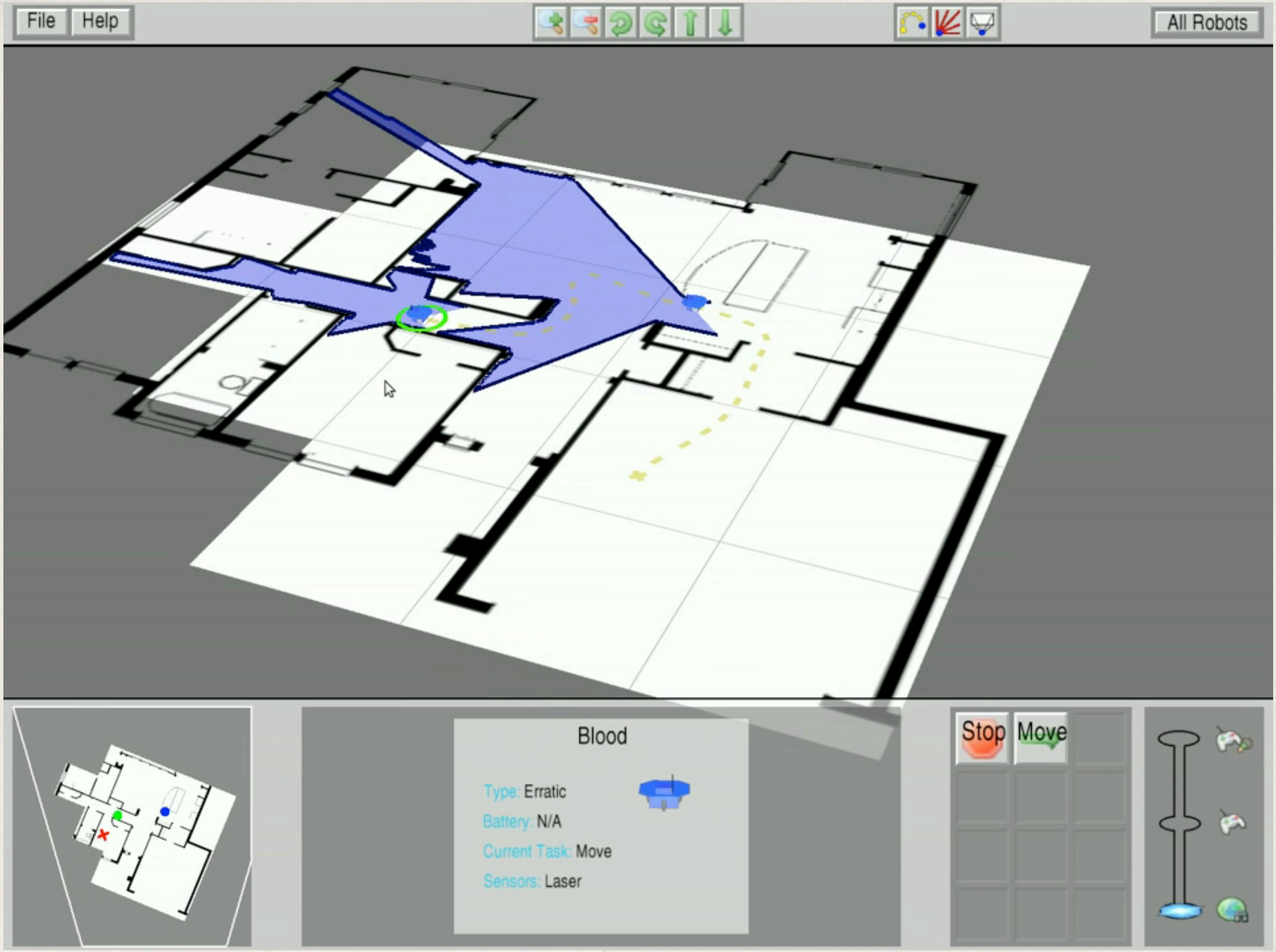
Help
All Robots
Blood
Type: Erratic
Battery: N/A
Current Task: None
Sensors: Laser
Stop
Move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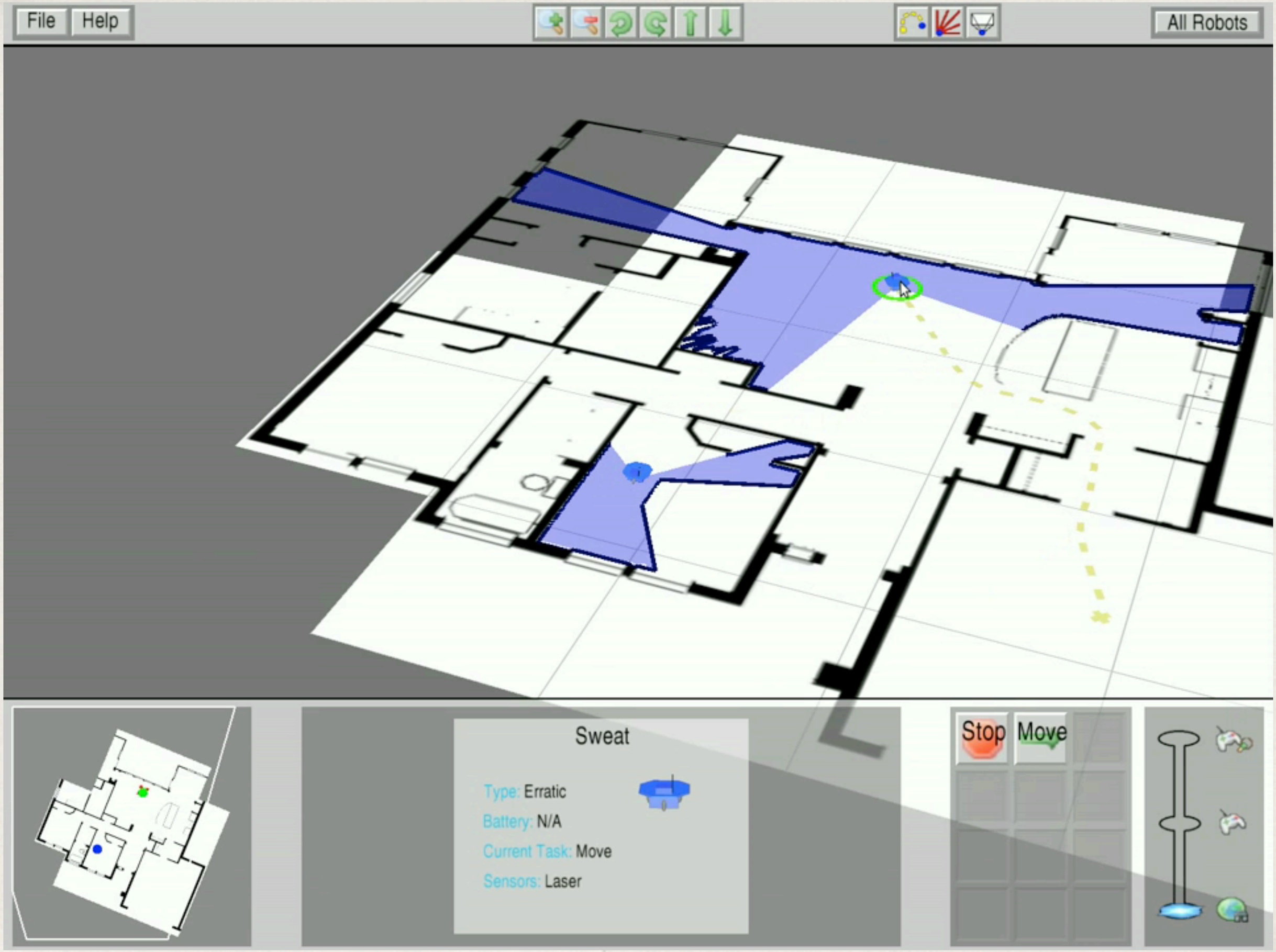
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Help
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Sweat
Type: Erratic
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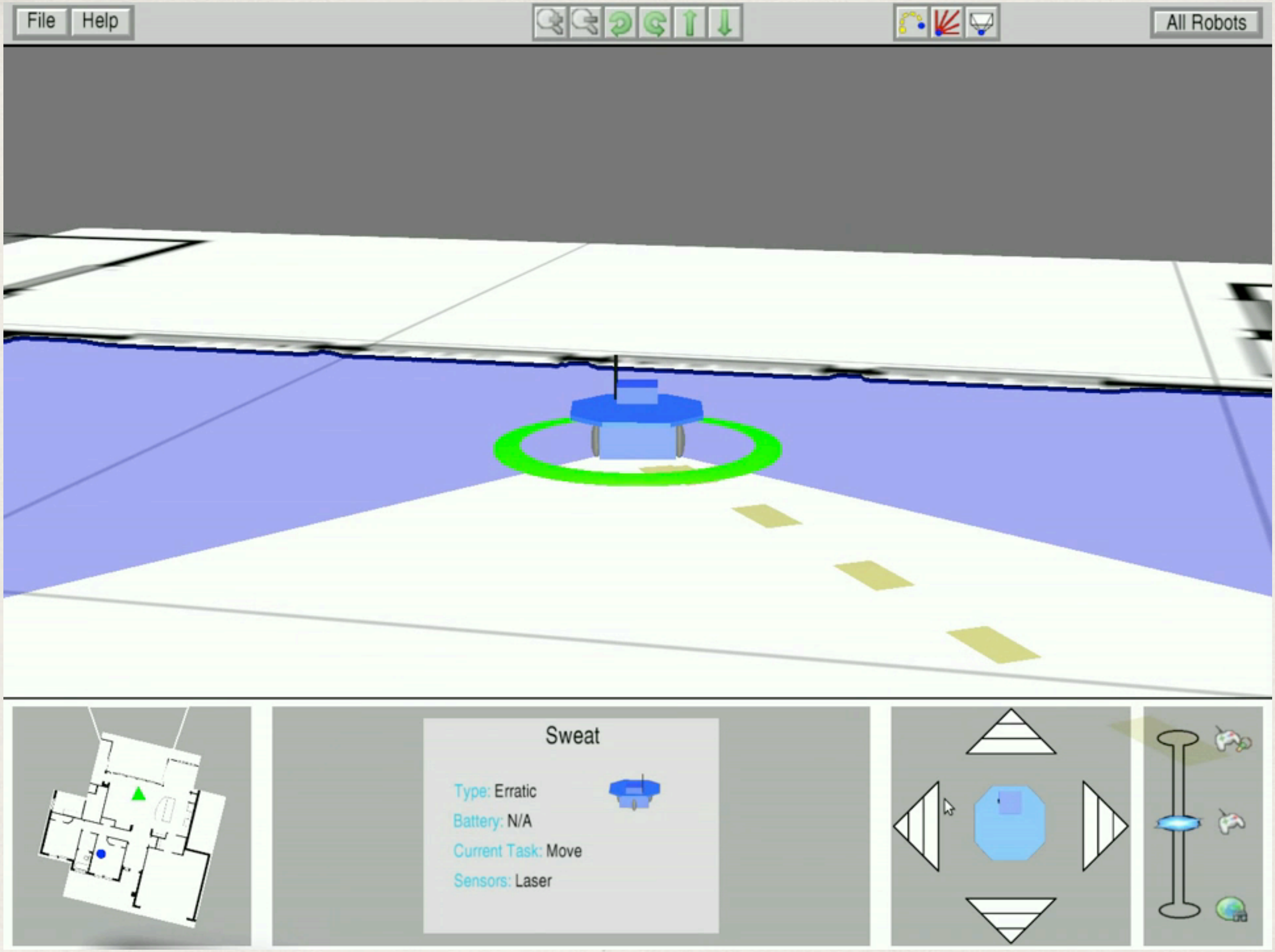
Current Task: Move
Sensors: Laser
Stop
Move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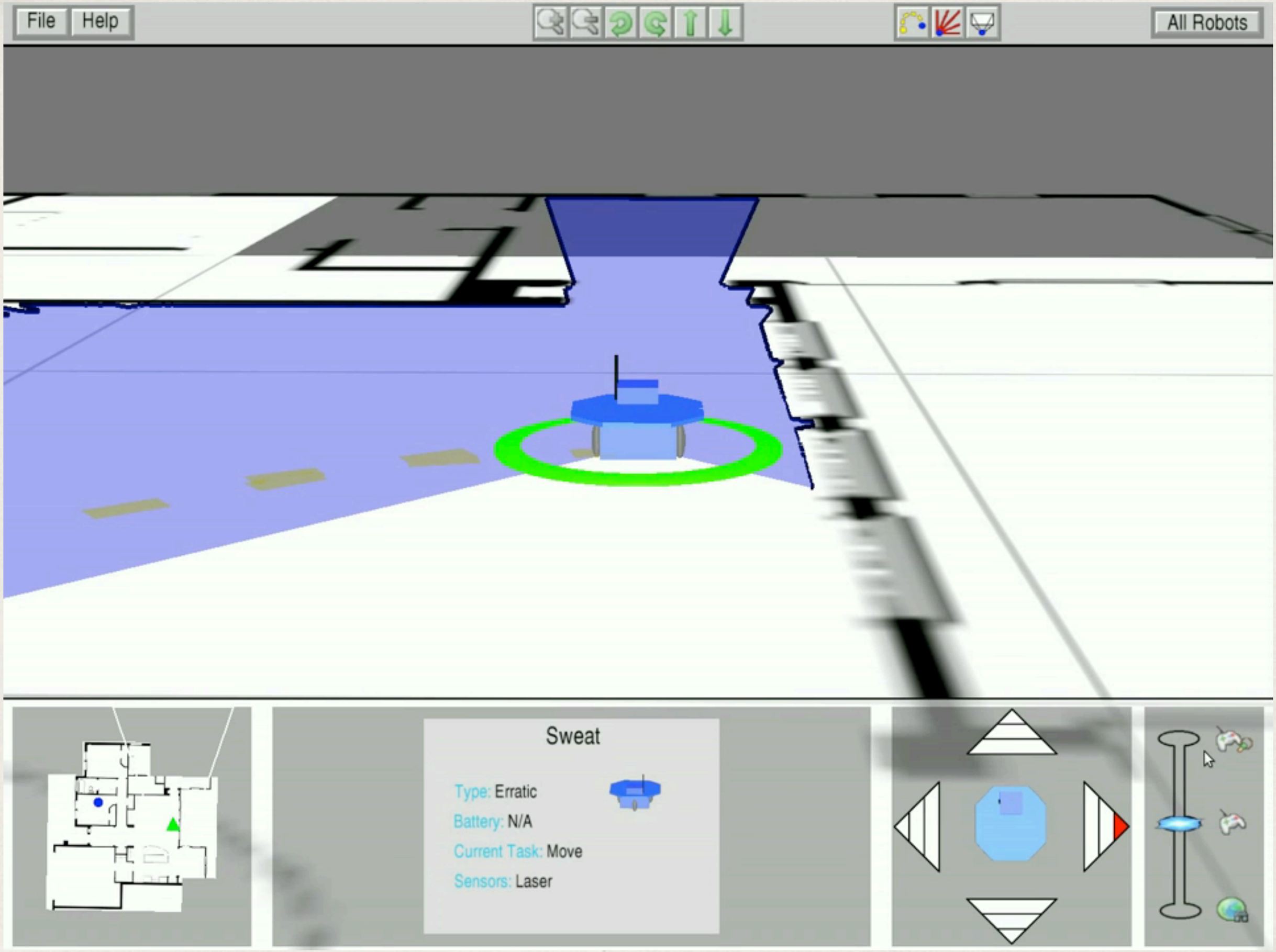
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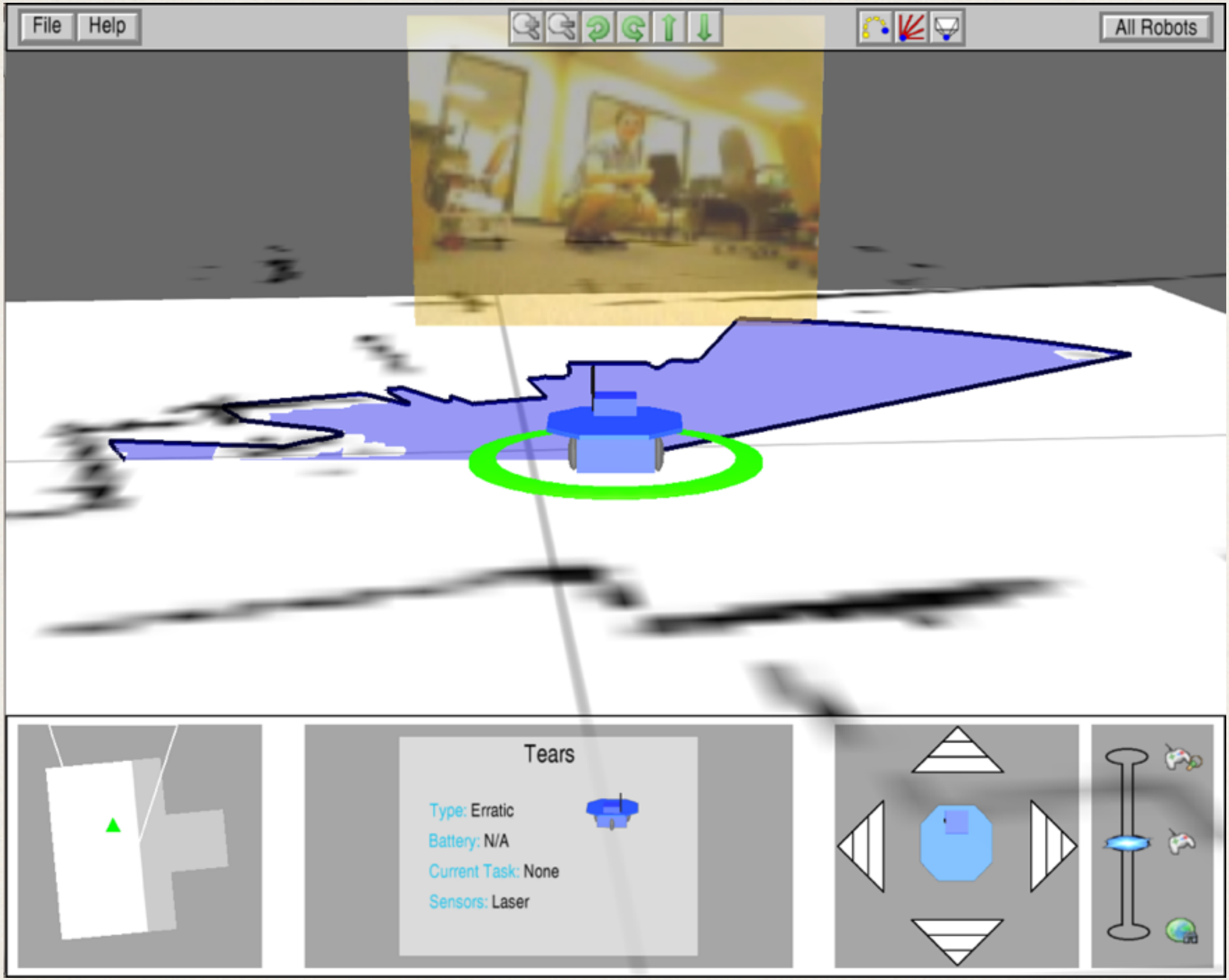
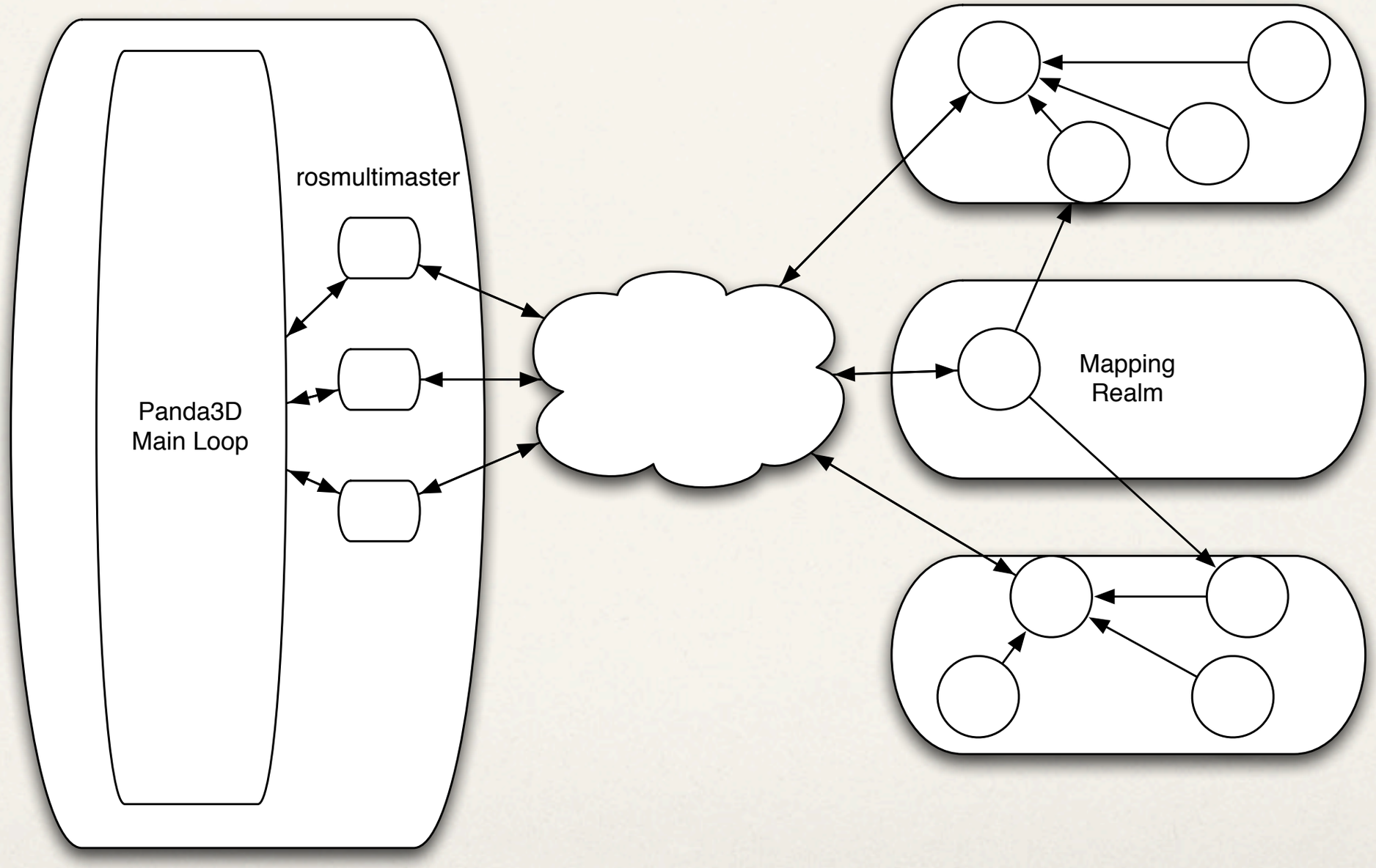
Current Task: Move
Sensors: Laser


File
Help
All Robots
Tears
Type: Erratic
Battery: N/A
Current Task: None
Sensors: Laser

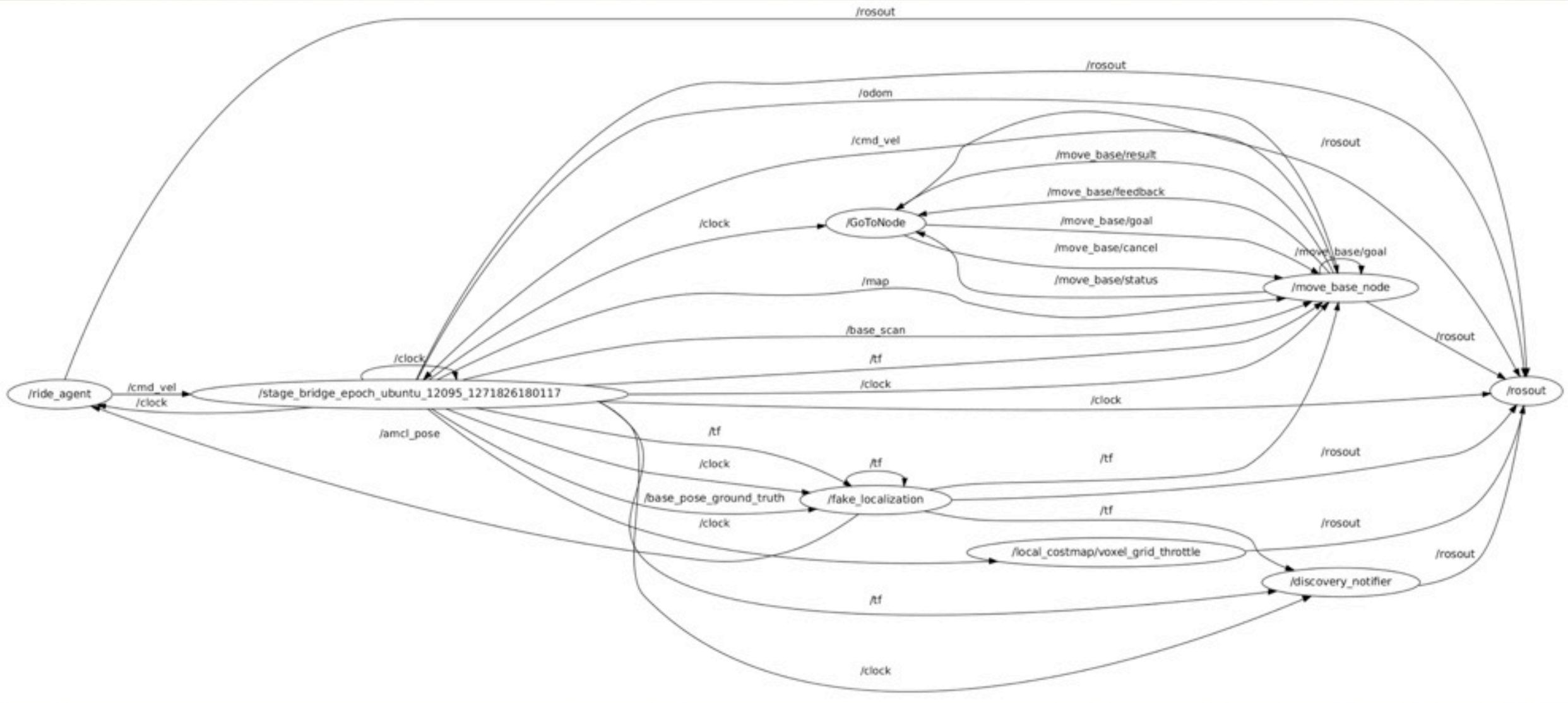
RIDE Implementation

- ROS Universe Design
  - Physical Robot Realm
  - Simulation Robot Realm
  - Mapping Realm
- Support Libraries
  - rosmultimaster
  - simulator_bridge
  - roslaunch_tools
  - pymp
- Panda3D
  - Threading
  - Robot Specification Syntax

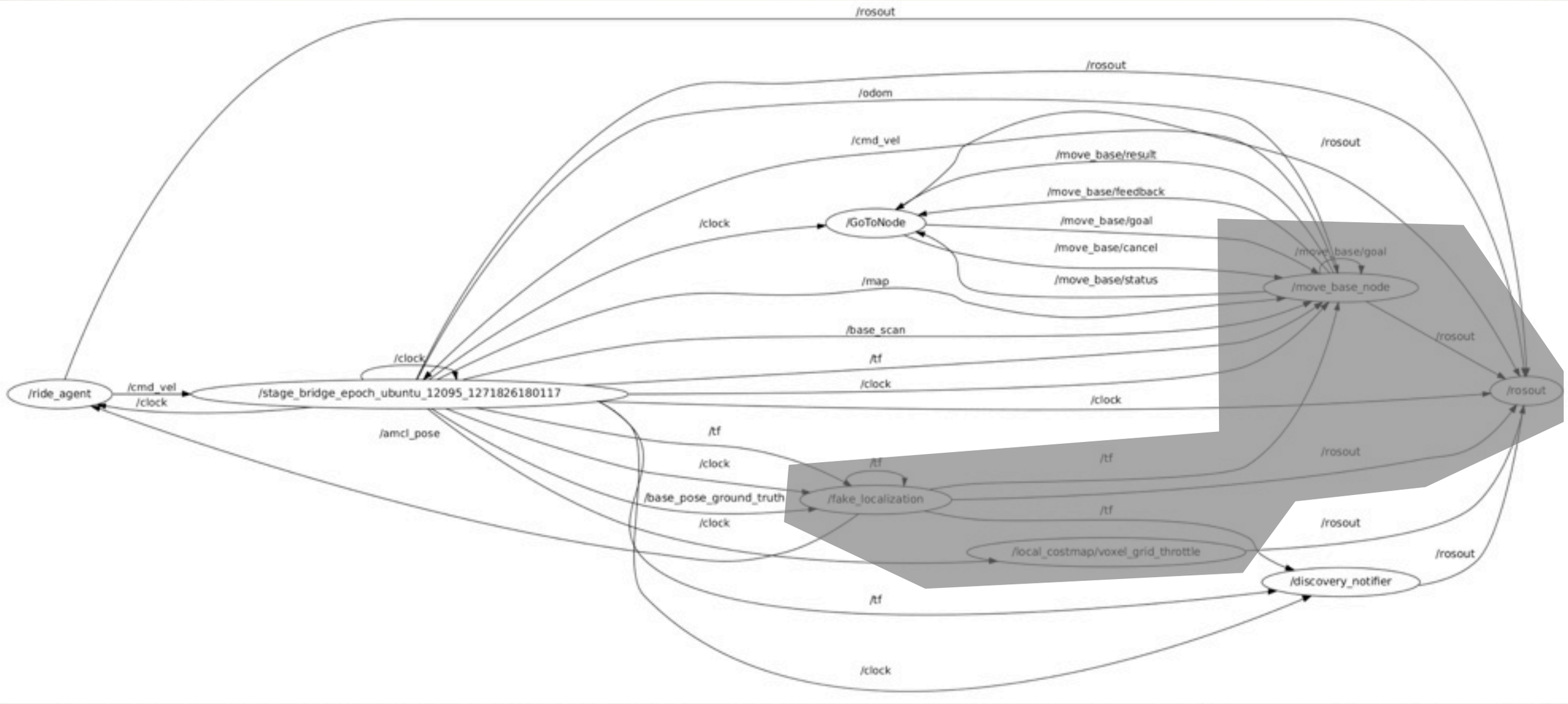
RIDE Universe Design



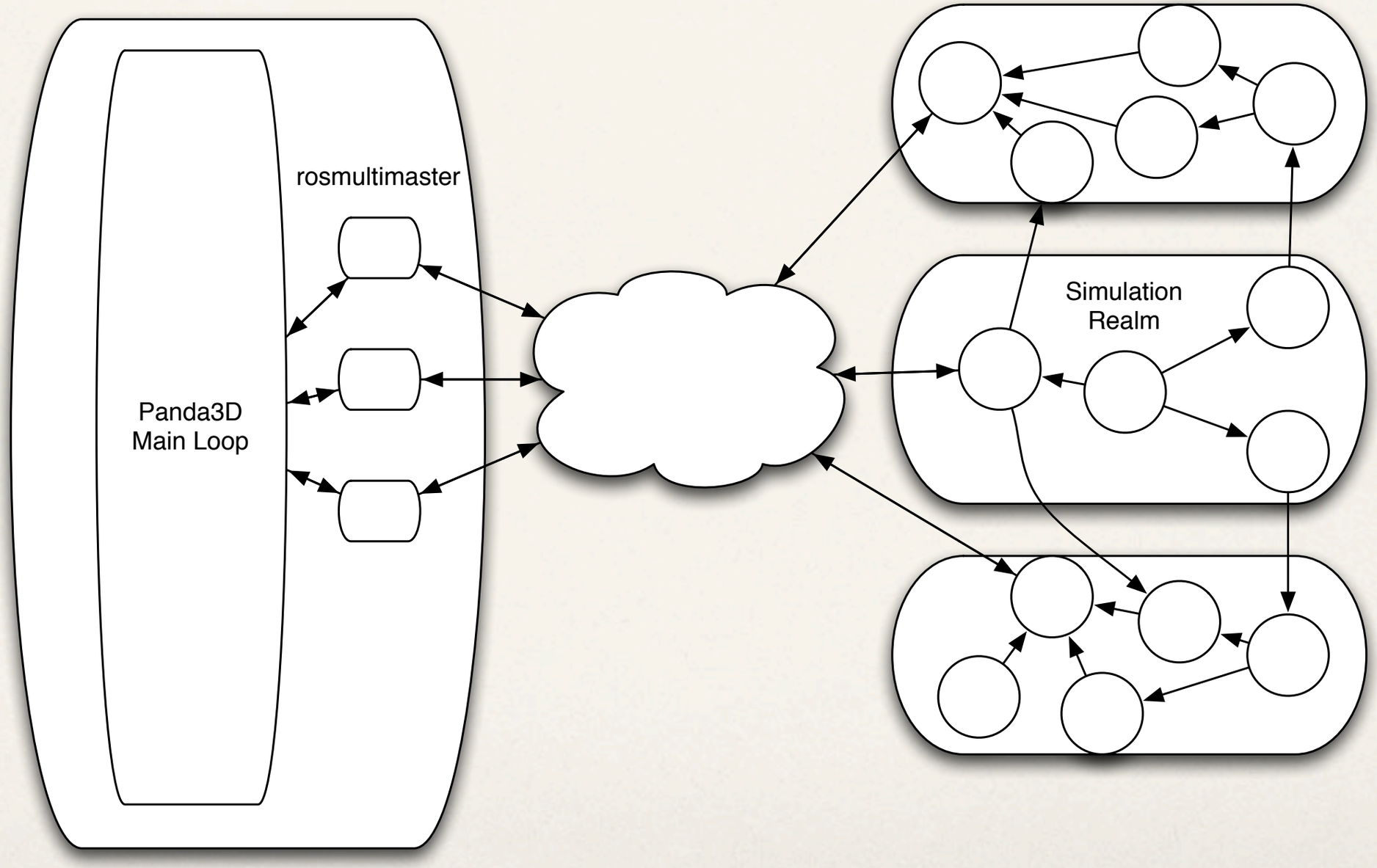
RIDE Robot Realm



RIDE Robot Realm



RIDE Simulation Universe Design



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Experimental Setup

- Hypothesis
- Experimental Procedure
  - Introduction and Training
  - Experiments
  - Post Questionnaire

Hypothesis

- Thesis: Applying video game principles to HRI interfaces will improve usability.
- Test: Notifications from the robot to the user will decrease the amount of time to complete tasks

User Study Introduction

- IRB approved user study
- Pre-experiment questionnaire on user background
- User training
  - Robot movement & perception
  - Speak-aloud
  - User interface controls

Experiment

- Randomized two-condition within subject experiment
  - Control run
  - Notifications enabled
- Given two robots in a small house
- Asked to find three hidden boxes

Post-Experiment

- Survey
- Semi-structured interview
- Compensation

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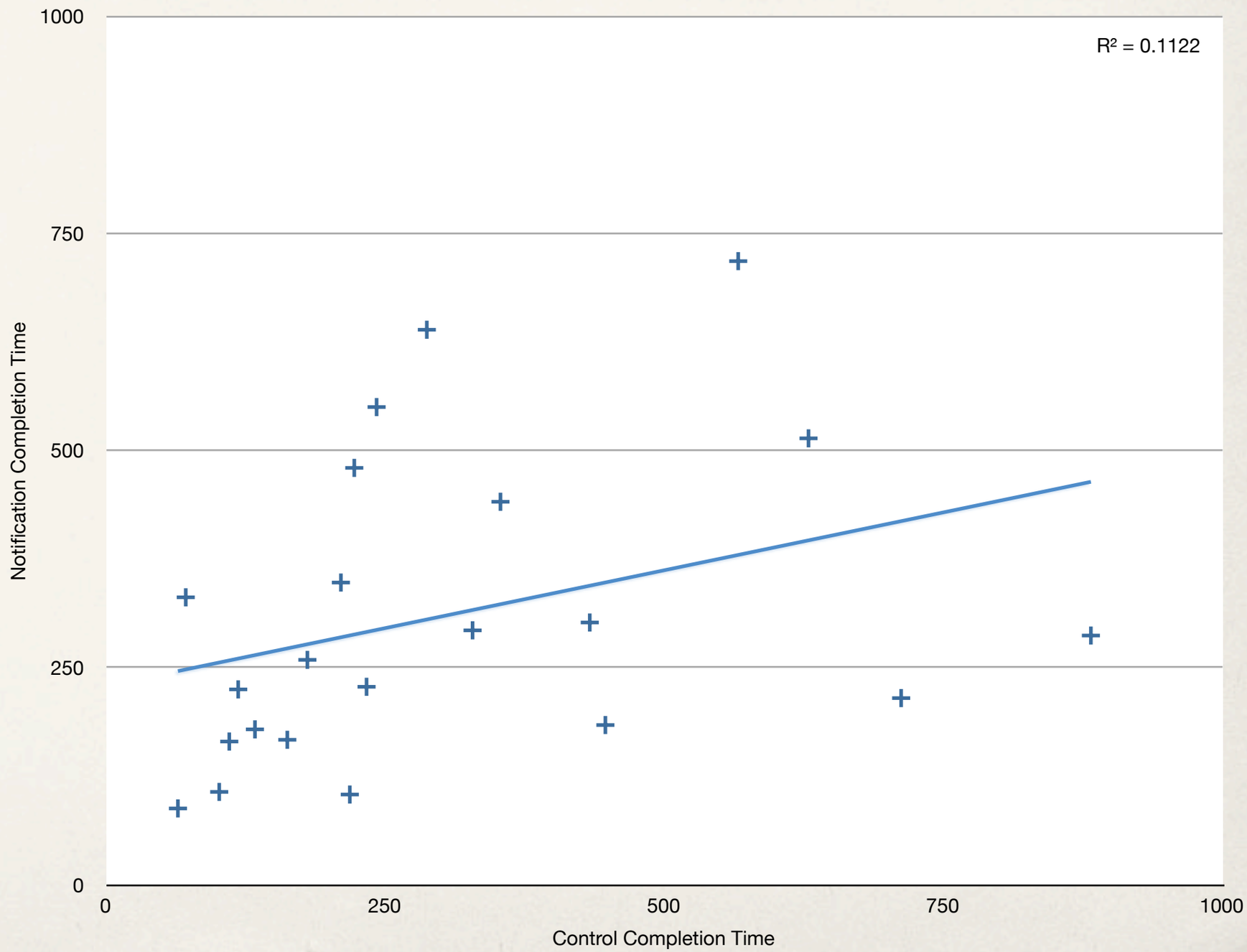
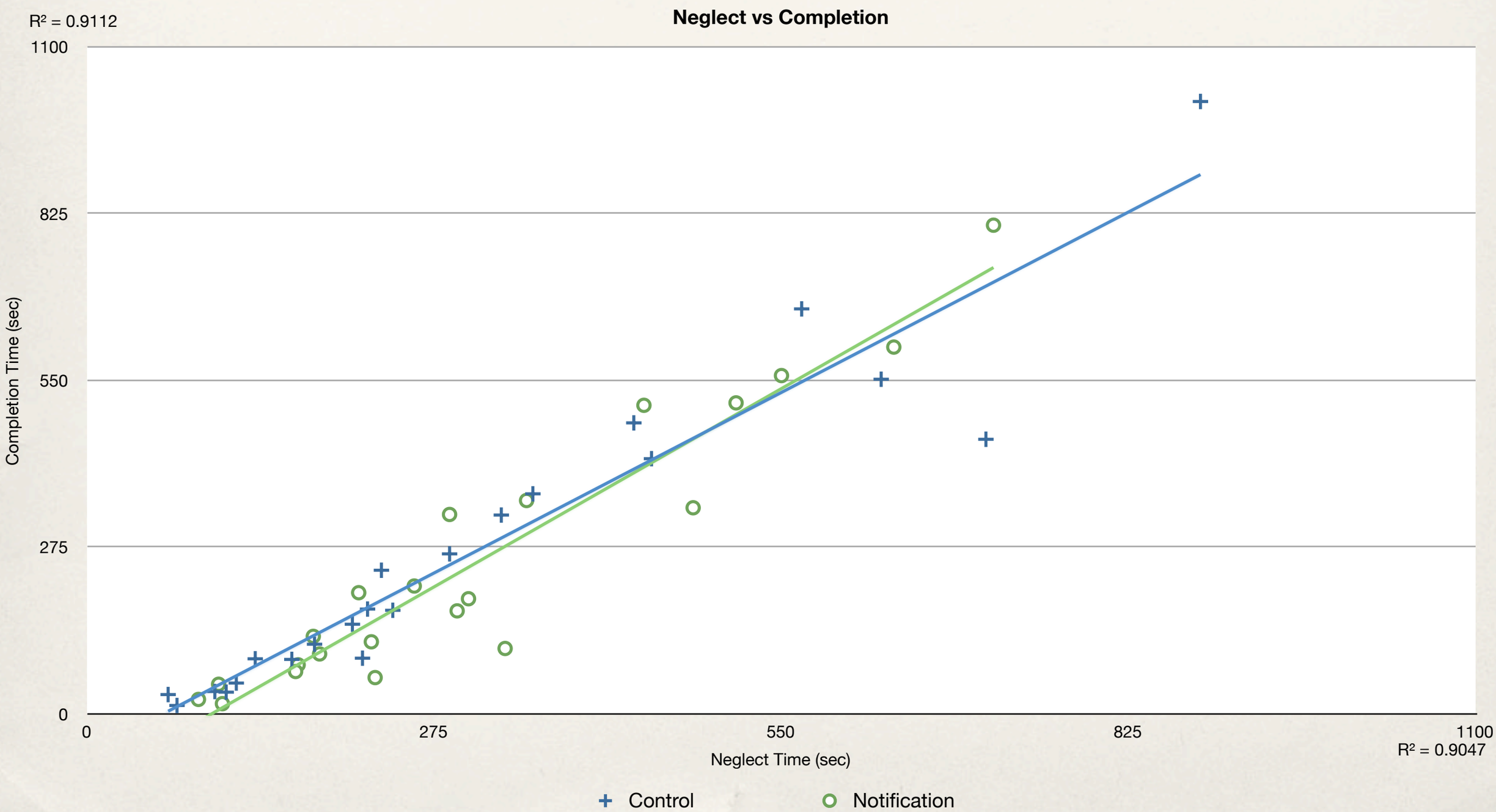
Notification Results

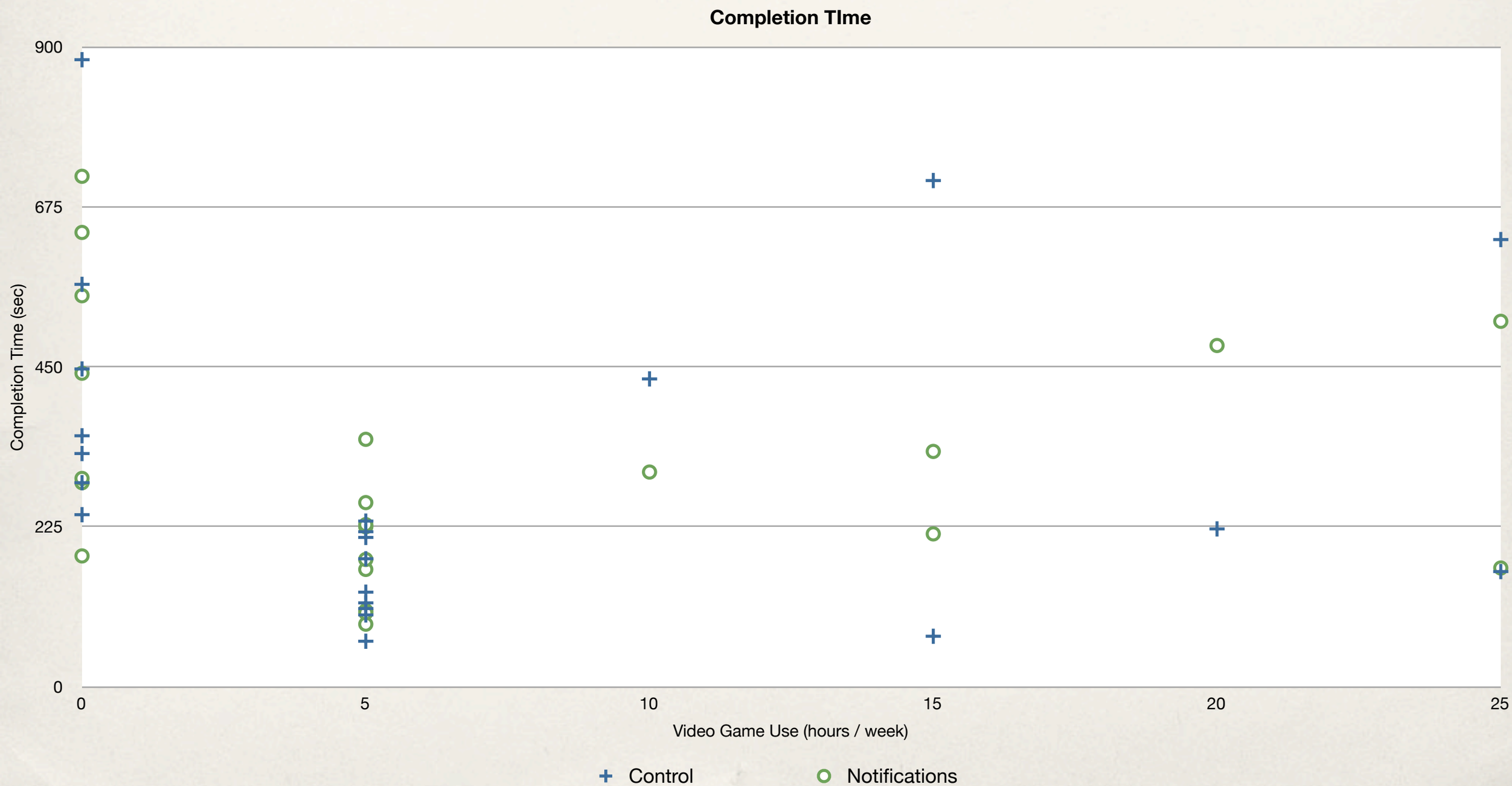
User	Control	Notifications
17-10	566	718
17-17	222	480
17-19	101	107
18-13	287	639
19-09	162	167
19-10	447	184
19-11	210	348
19-12	882	287
19-13	328	293
19-15	71	331
29-15	64	88
29-16	242	550
29-17	118	225
30-11	233	228
30-15	110	165
30-17	629	514
30-18	433	302
31-12	712	215
31-13	133	179
31-14	353	441
31-16	218	104
31-17	180	259
Mean	**175.6**	**143.7**
Variance	**226.2**	**184.4**
T-Test	**0.9115**	



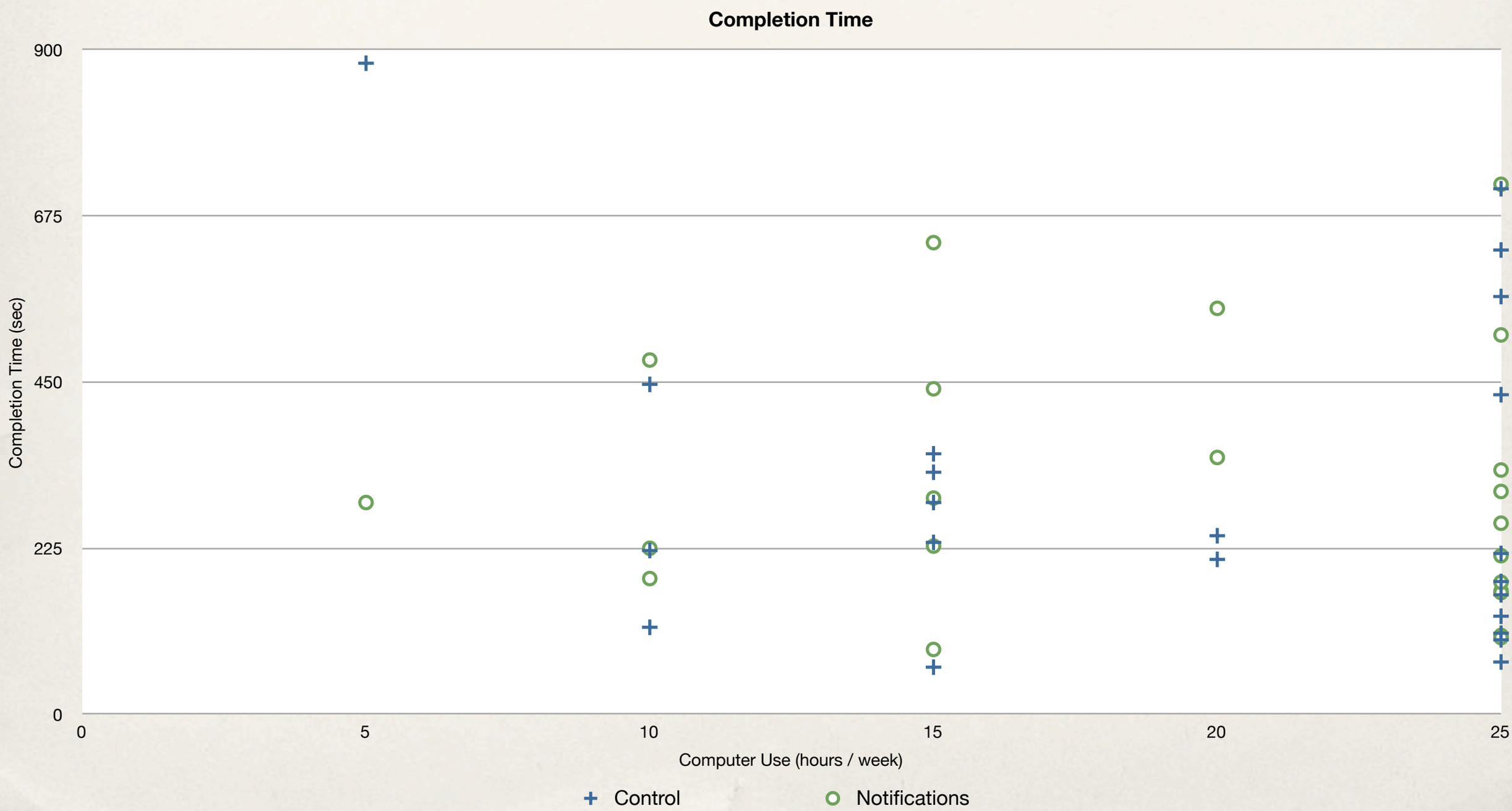
Neglect Time



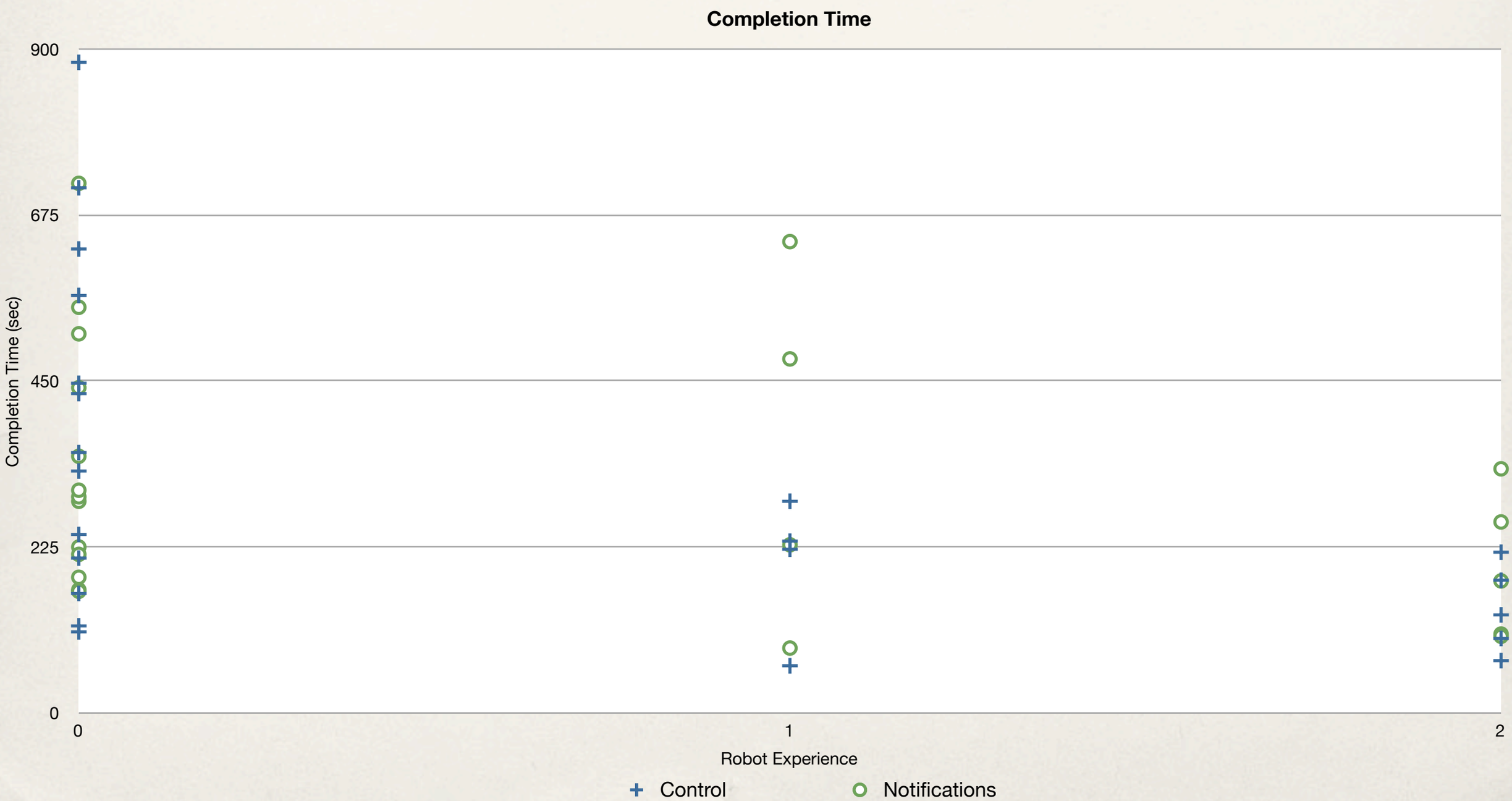
Video Game Use



Computer Use



Robot Experience



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Future Work

- Revised user study
- User interface refinements
- Backend Enhancements

Revised User Study

- Run user study at video game convention
  - Pre-trained user pool
  - No application training
- Larger map & more robots
- Actionable tasks

User Interface Changes

- Sensor coverage history
- Wall extrusion
- Behavioral expectations

Backend Changes

- Performance optimizations
  - Latency reduction
  - Support for 25+ robots
  - Reduce memory footprint

RIDE Effort

- User Interface
  - Prototyping
  - UI Framework
  - Direct Mode
  - Supervisory Mode
- ROS
  - rosmultimaster
  - pymp
  - roslaunch_tools
- wu-ros-pkg.sf.net
- Developer Documentation
- User Documentation
- Robot Models
- User Study
  - Preparation
  - Execution
- Logging Framework
- Robot Behaviors

RIDE Effort - Individual

- User Interface
  - Prototyping
  - UI Framework
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Thanks!

- Researchers
  - Parker Dunton
  - Marshall Strother
  - Jim Stevens
  - Dan Lazewatsky
  - David Lu!!
- High School Intern
  - Max Witt
- CSE 320 Students
  - Don Ding
  - Alex Maul

Questions?

Thank you for your time.