WPI

Human Supervision of Multi-Robot Systems

A Major Qualifying Project by:

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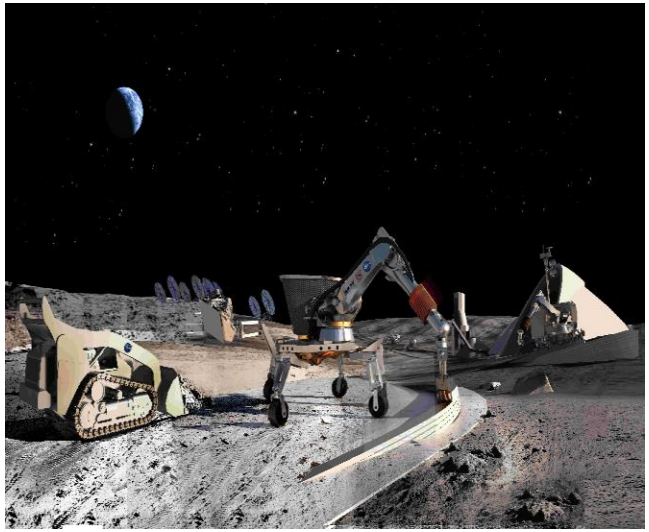
Motivation

- Tasks often require multiple agents
- Robots are quick, safe, and/or reliable
- Humans offer judgment and flexibility


[1], [2], [3]

Project Goals

- Develop a framework for human supervision of multi-robot systems
- Devise a test to evaluate the framework
- Assemble a team of robots to perform the test

Research and Inspiration

- Distributed coordination
- Task and role assignments
- Utility function calculations
- Human-robot interface design

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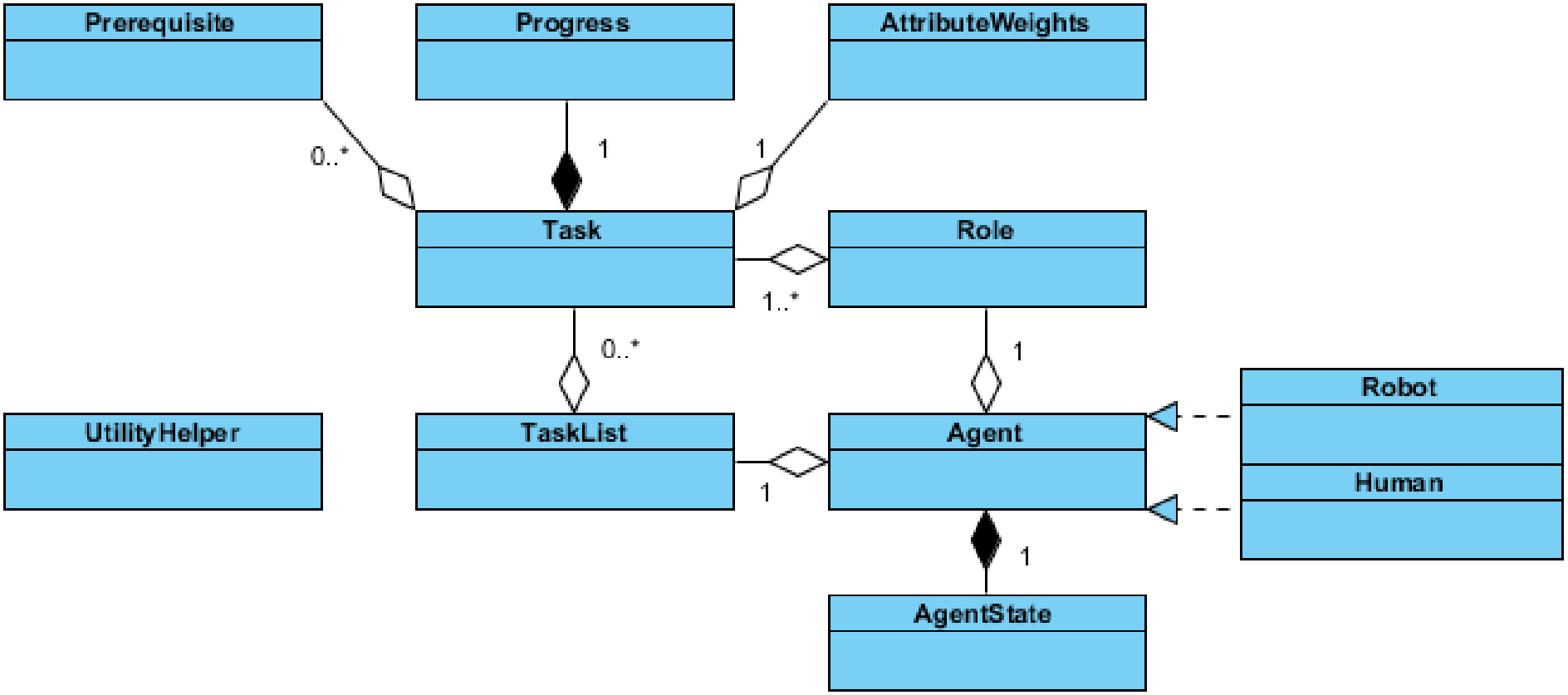
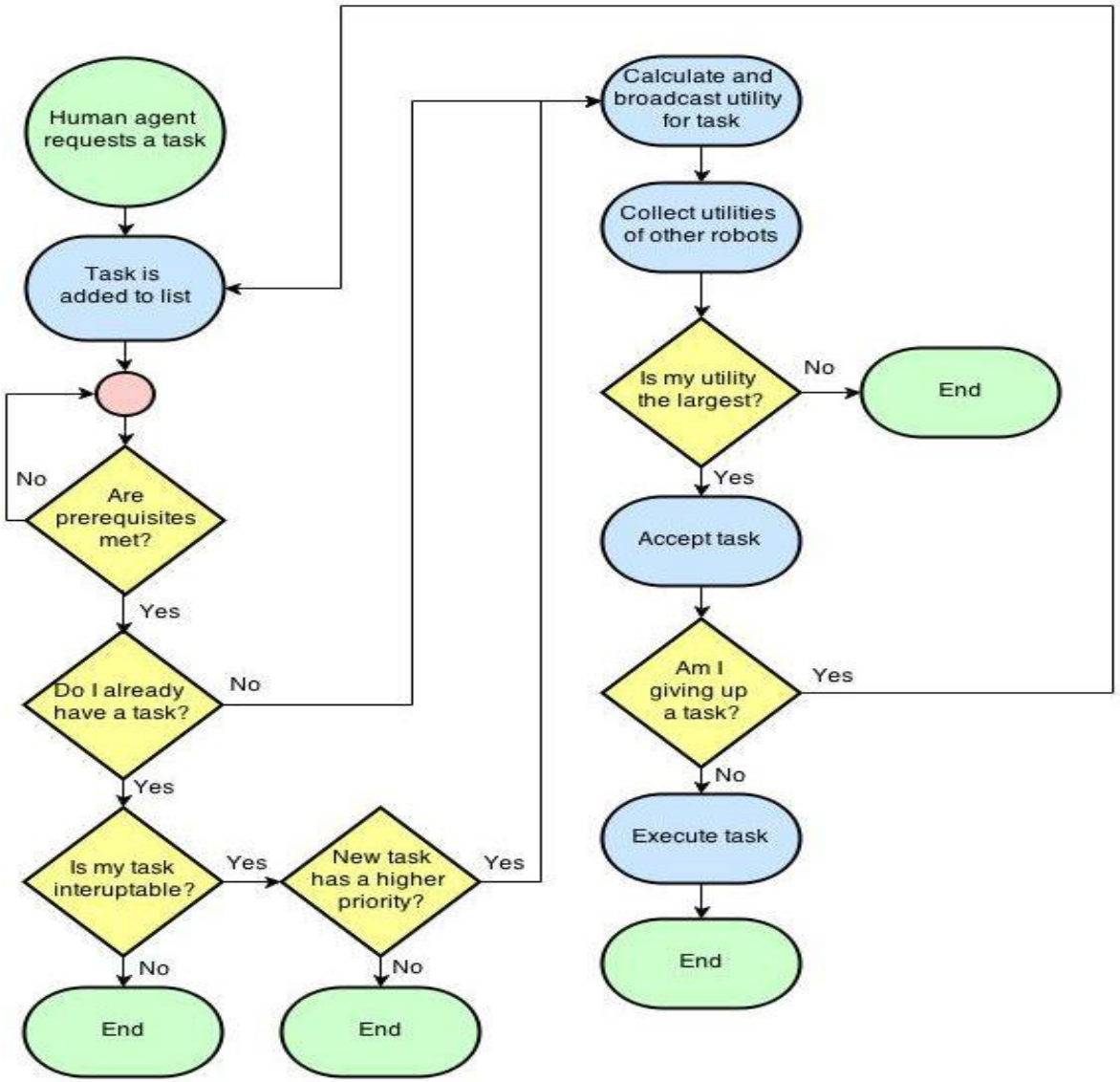
[5]

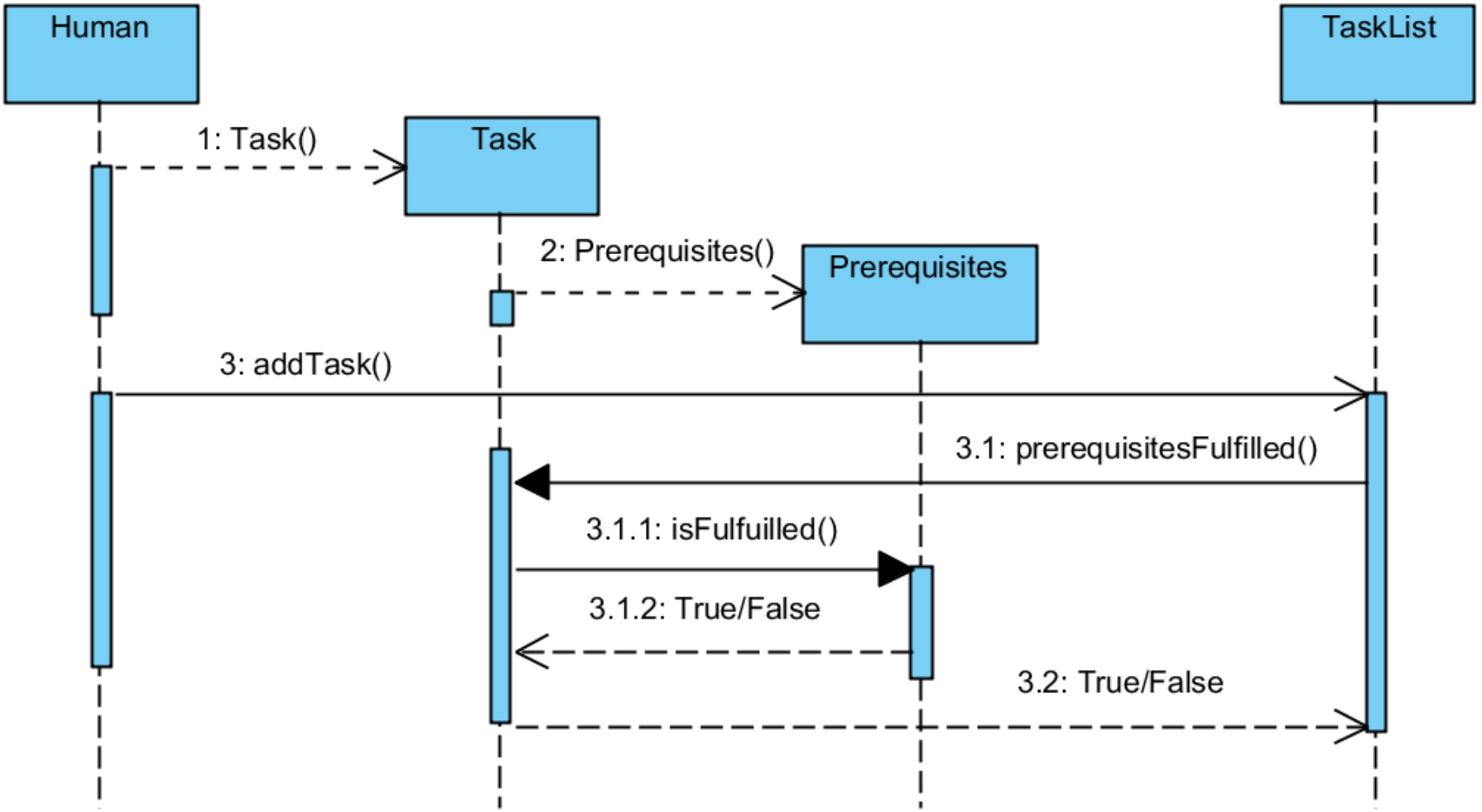
Framework Design



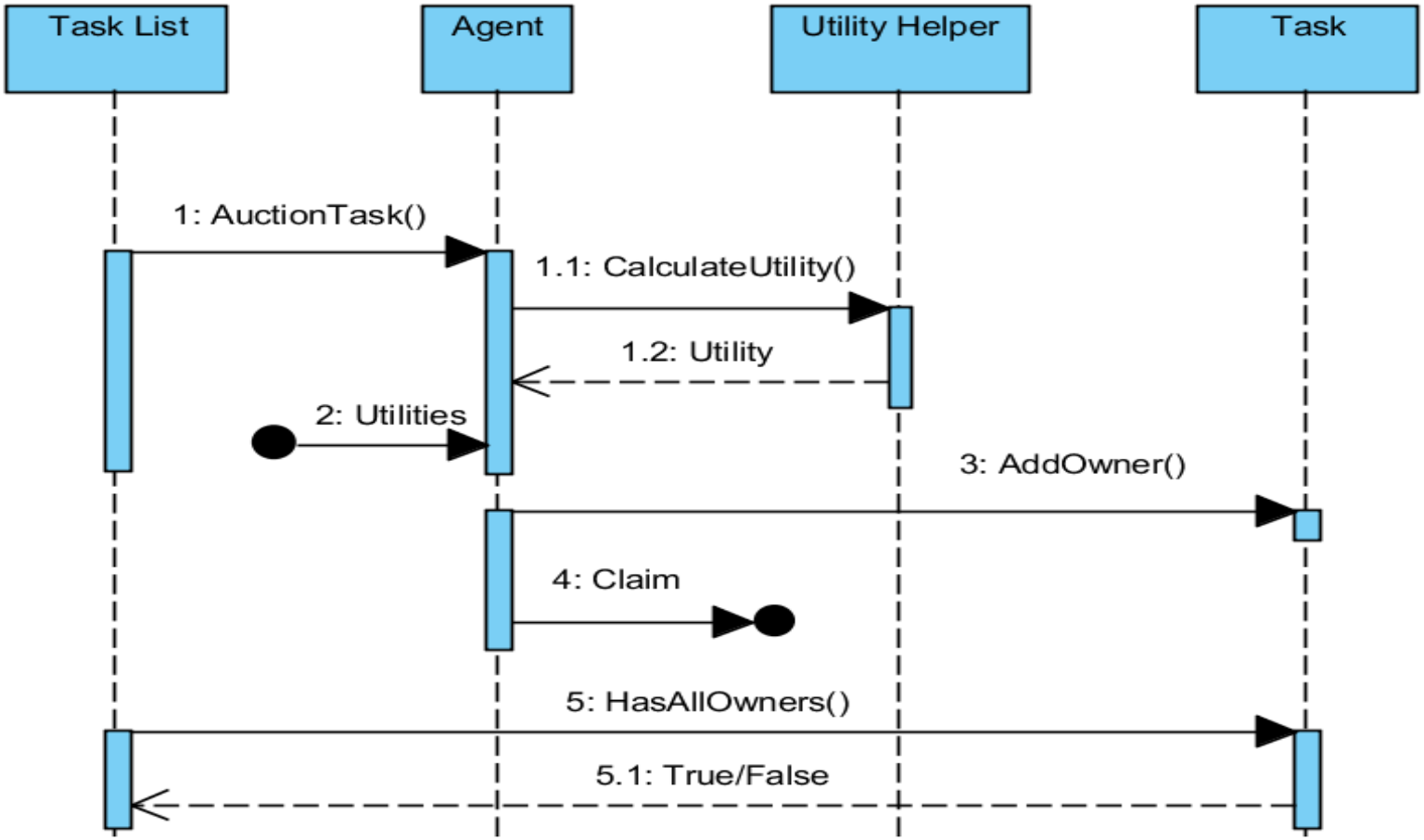
Framework Workflow (cont'd)



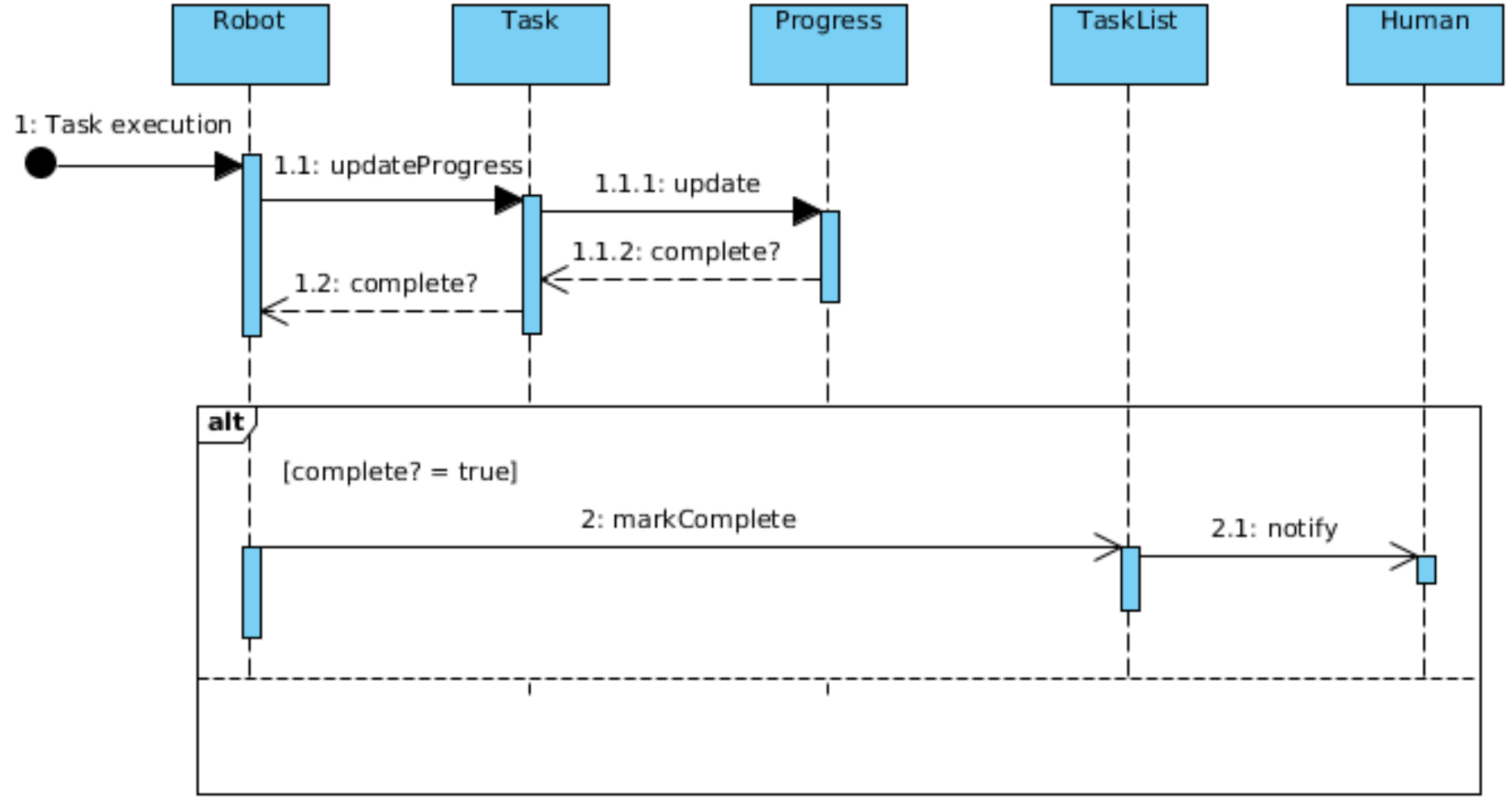
Framework Workflow



Framework Workflow (cont'd)



Framework Workflow (cont'd)



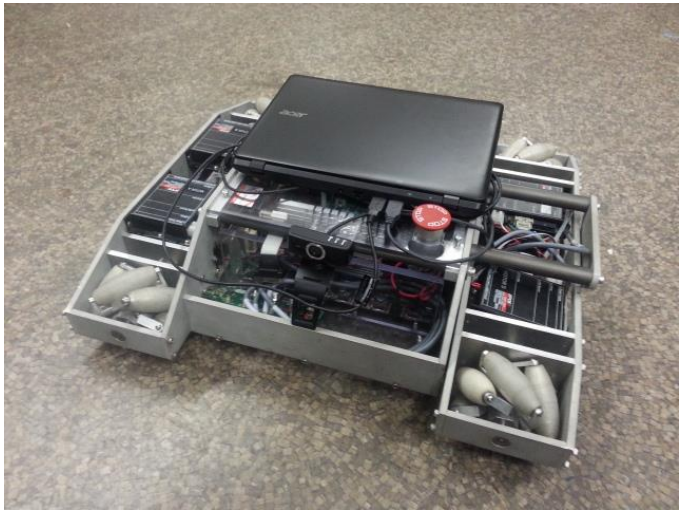
Testing The Framework

Evaluate the effectiveness of the framework:

- Unit tests of specific framework functions
- Search and discover mission

Robots

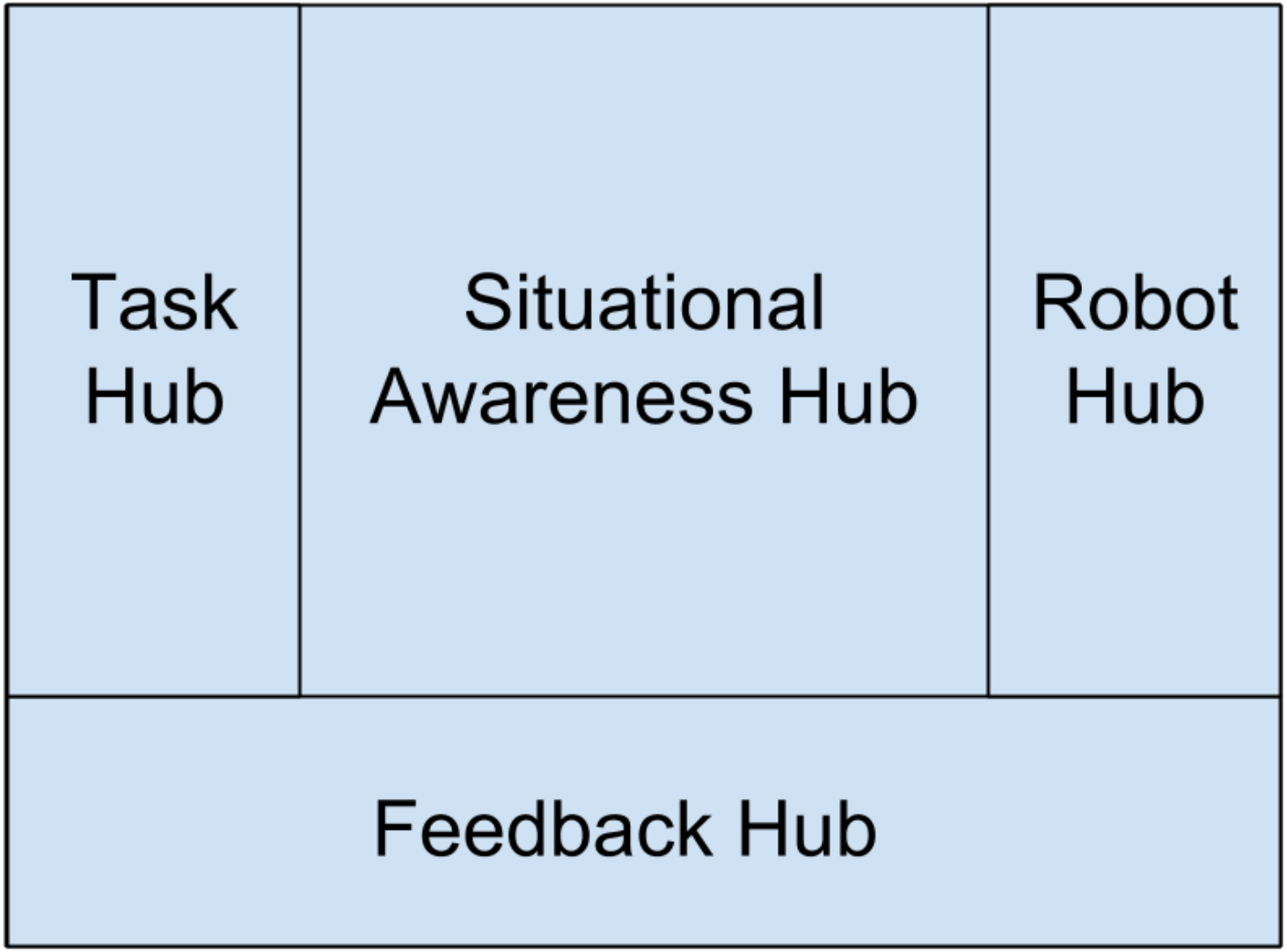
Turtlebot



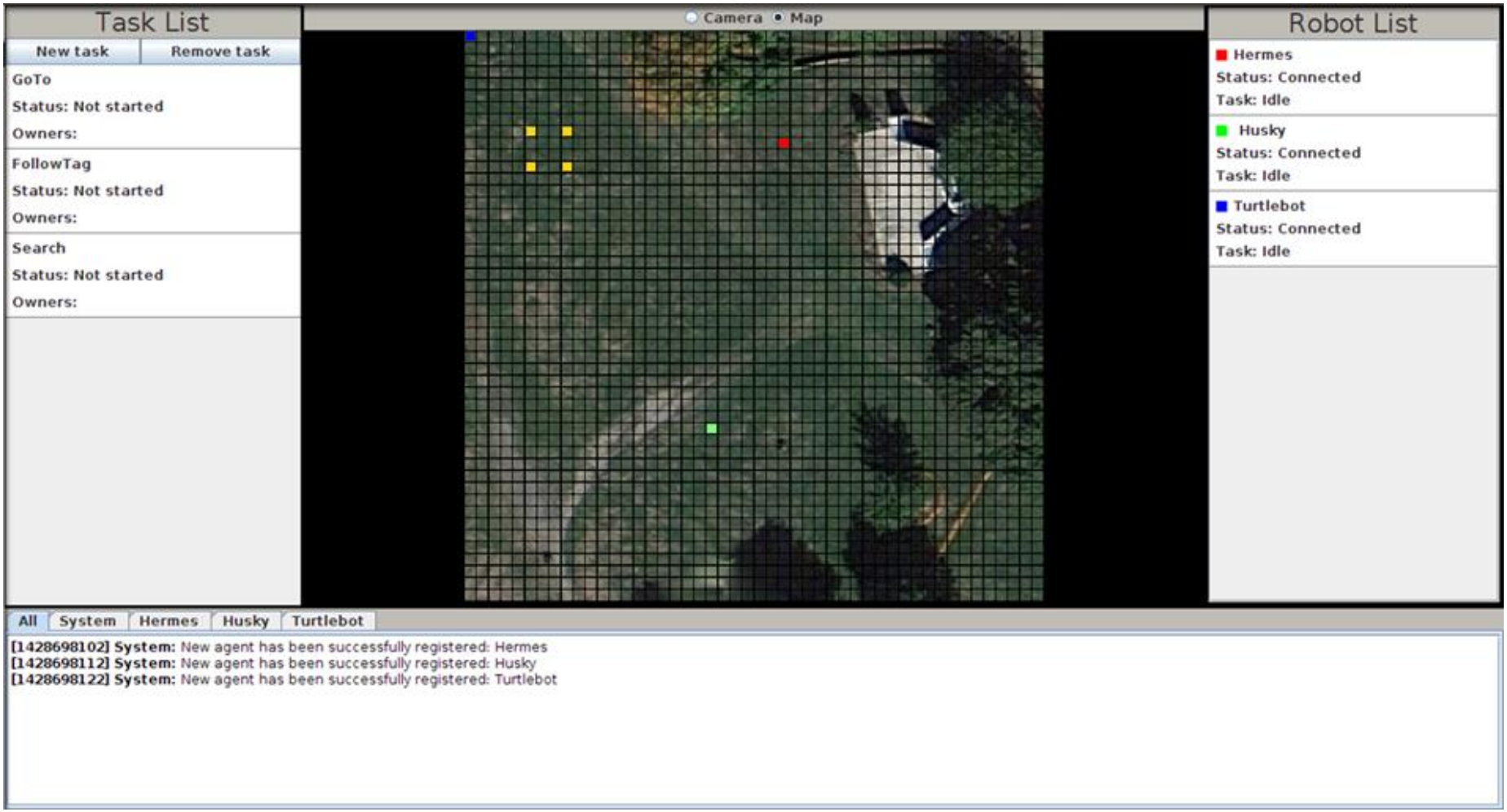
Hermes

Husky

Graphical User Interface

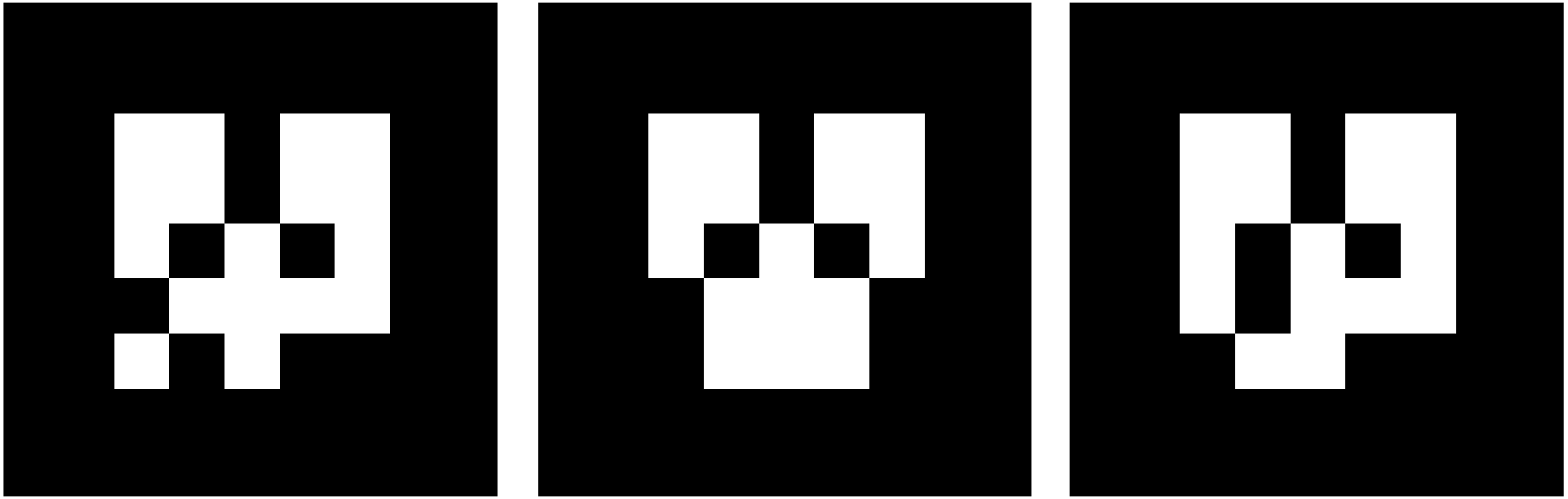


Graphical User Interface (cont'd)



Localization

- Needed to determine position of robots within the operating area
- Used Augmented Reality(AR) tags and wheel odometry
- Position belief was maintained by a rolling average filter



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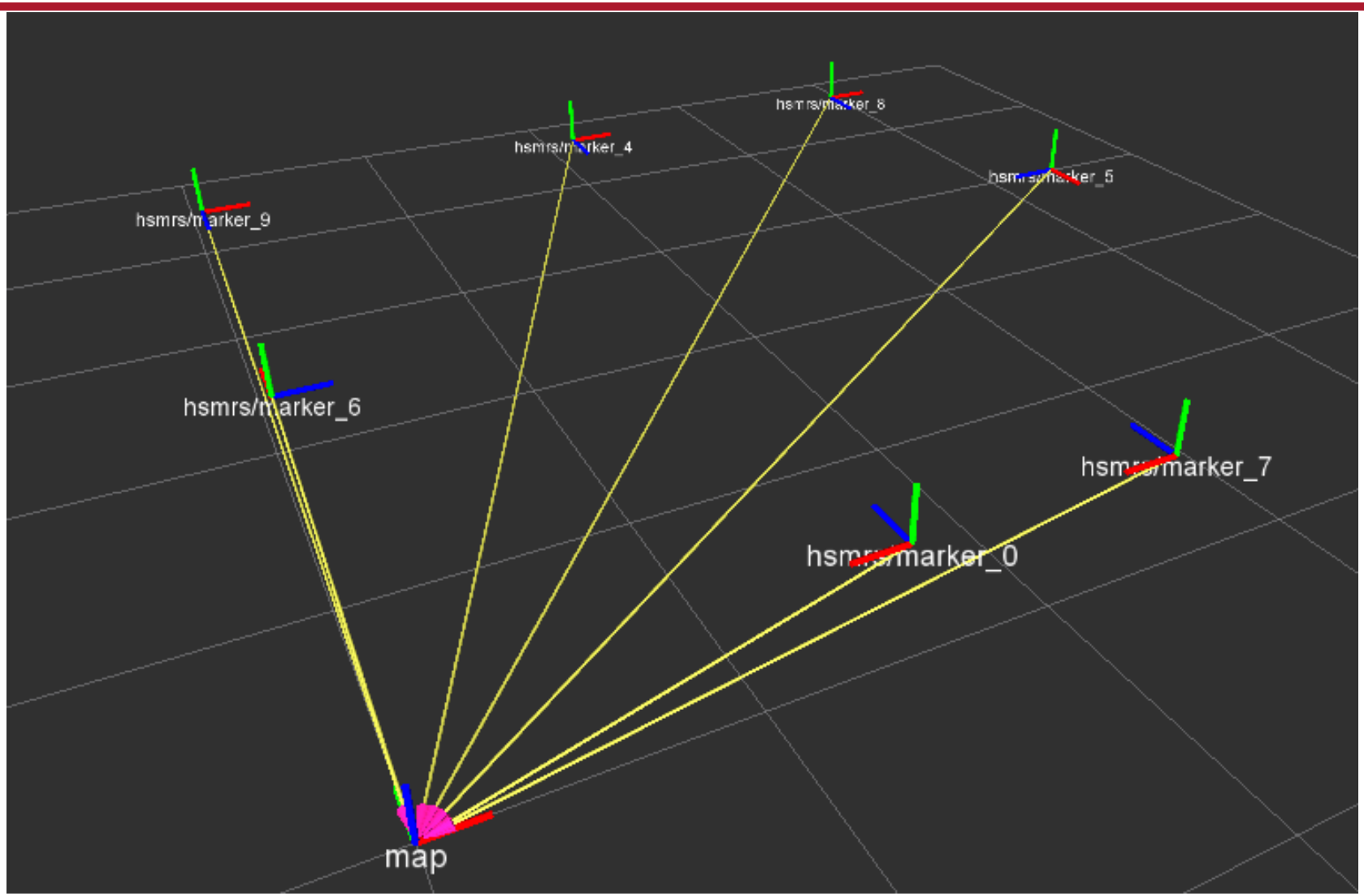
Localization



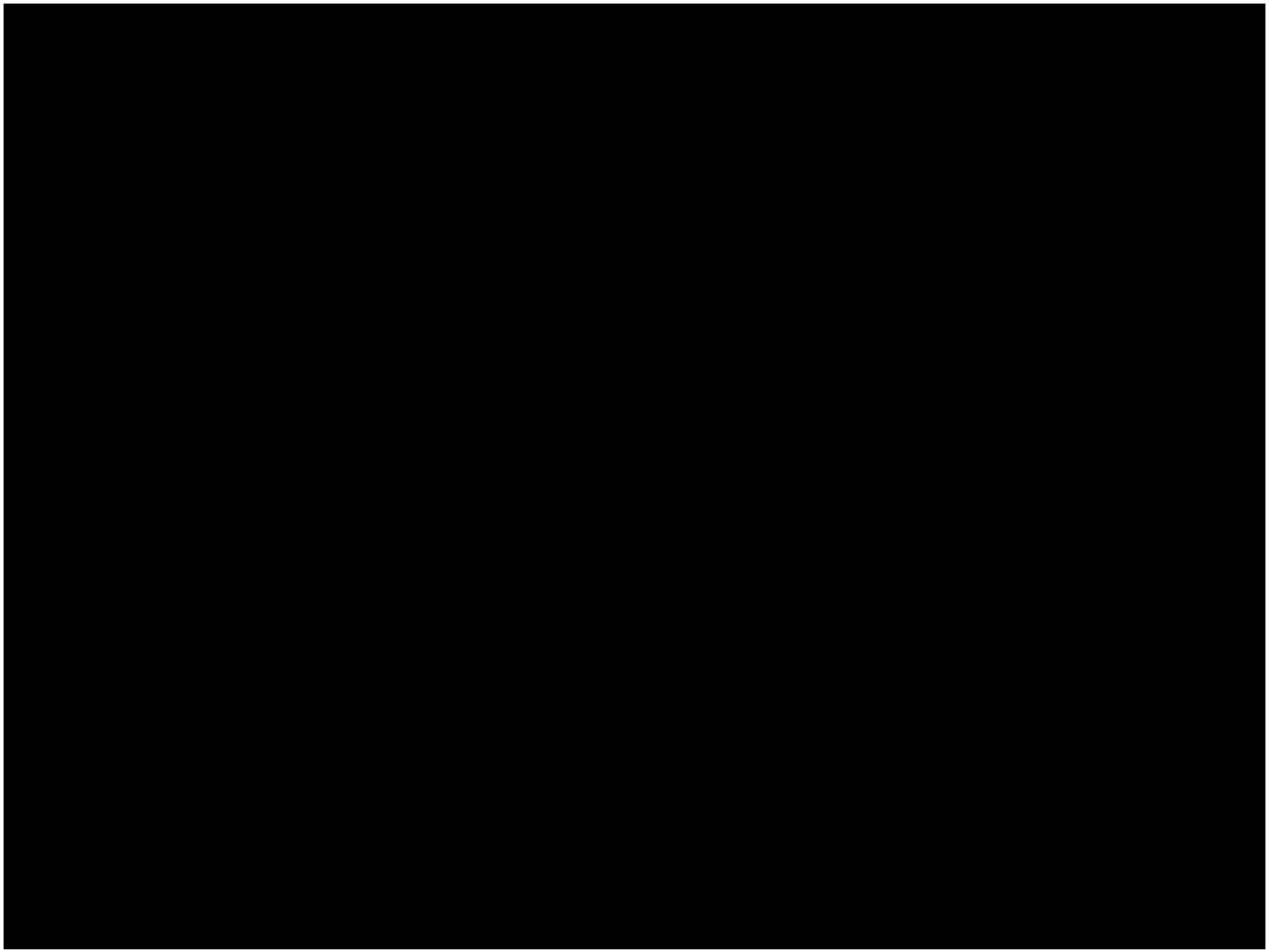
Results

- Hermes, Husky, and the Turtlebots were able to be represented in the system with different attributes.
- The bidding algorithm was able to assign tasks to robots who were the most capable of doing them.
- Roles allowed the user to exert coarse control over the task allocation process.
- The human supervisor was able to gain situational awareness using the camera view, the map view, and the help alert.
- The human supervisor could directly assign tasks, interrupt tasks and directly control one or more robots at a time.

Results (cont'd)

- Large amounts of latency in communications slowed the execution of the system.
- Prerequisites needed too much information to be practical.
- Localization methods had different levels of effectiveness on different platforms.

Video



References

[1] http://www.unocha.org/roap/about-us/emergency-response

[2] http://www.contourcrafting.org/space-colonies/

[3] http://www.dailymail.co.uk/news/article-2585981/Workers-casually-dismantle-cranes-used-build-Shanghai-Tower-knee-wobbling-2-000ft-up.html

[4]people.csail.mit.edu/rak/www/sites/default/files/pubs-/KneEtal13.pdf

[5] http://www.robocup2014.org/?p=893

[6] http://wiki.ros.org/ar_track_alvar

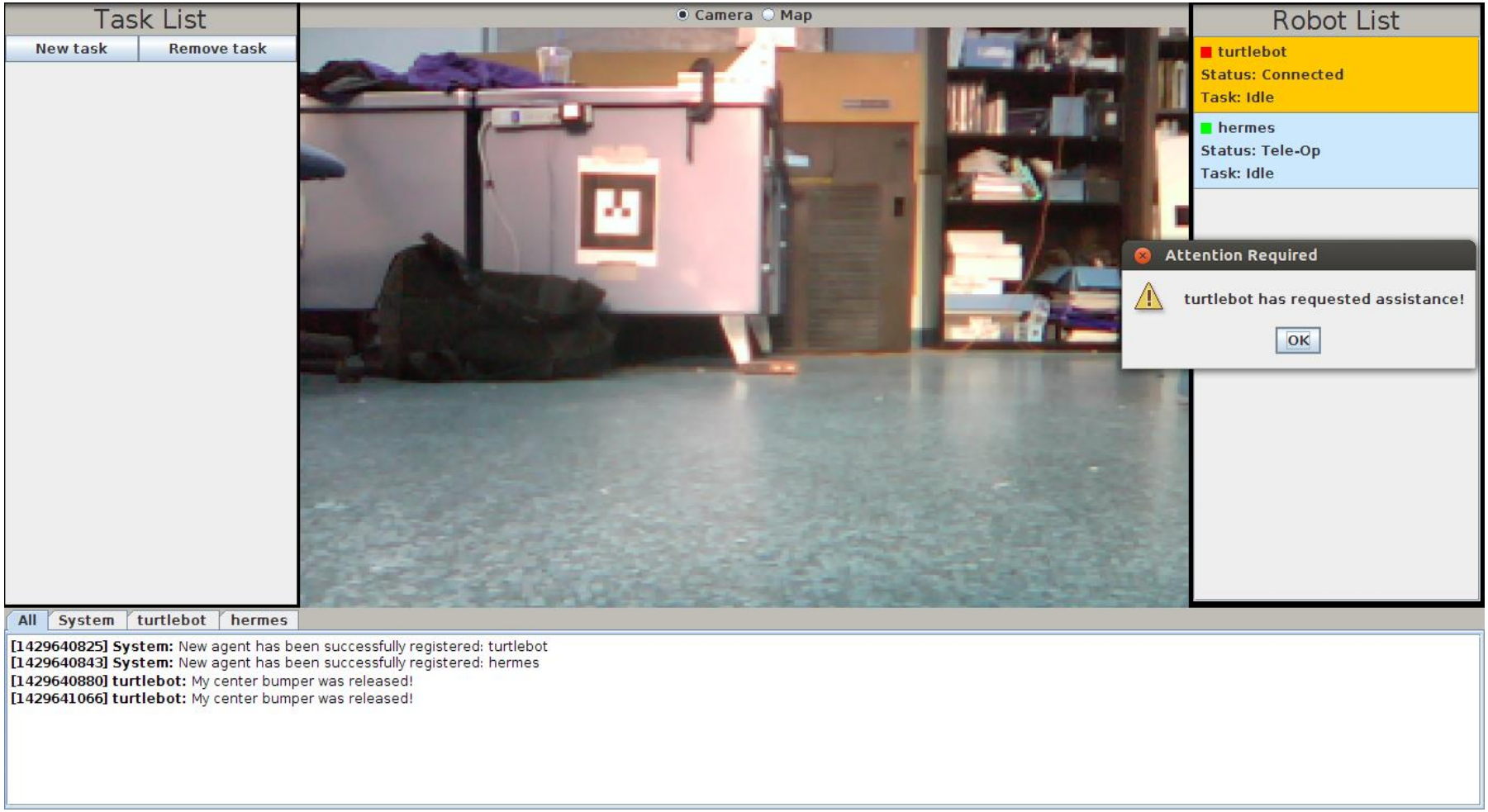
[7] http://www.bls.gov/news.release/pdf/cfoi.pdf

Questions?

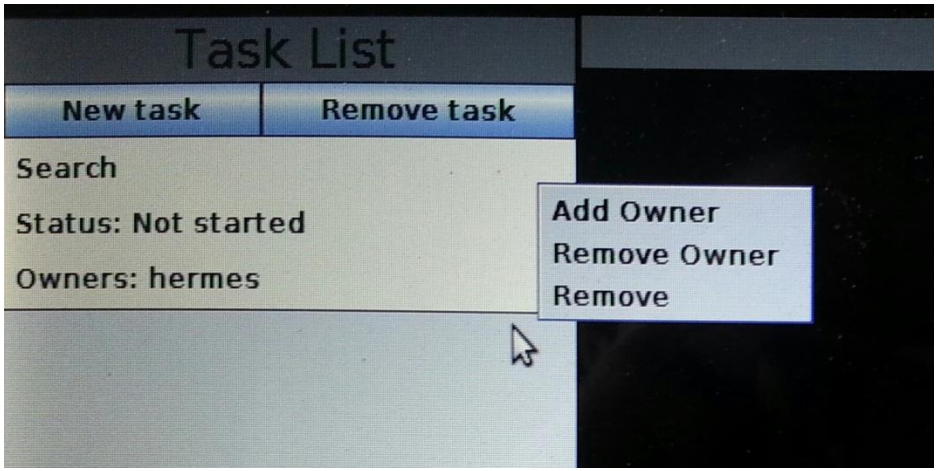
Motivation Follow Up

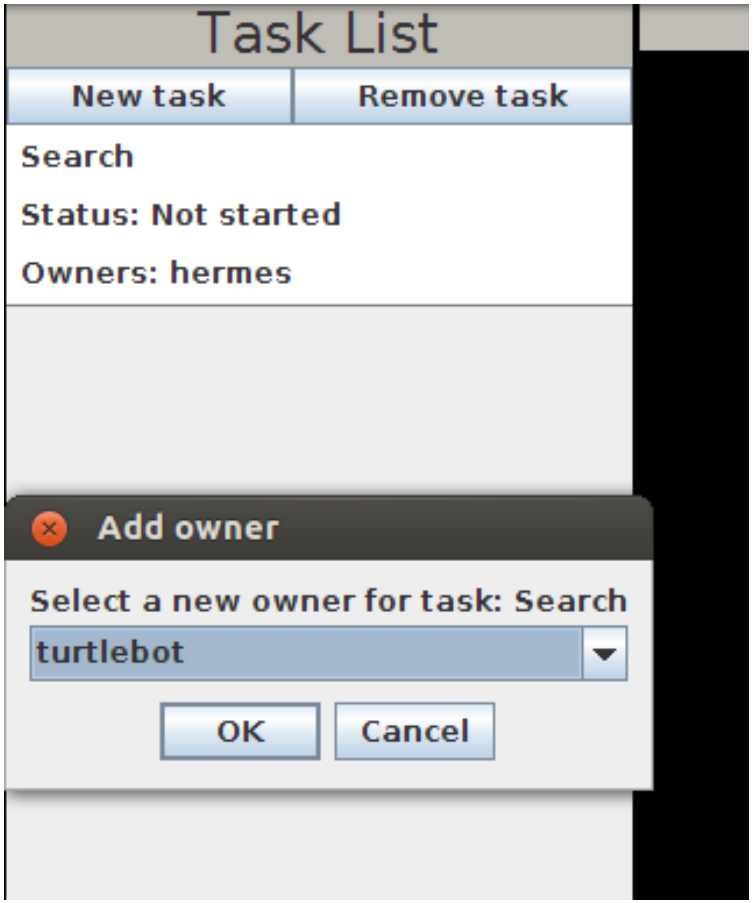
- As of 2013 [7]:
  - 100 fatalities(33%) were reported in the manufacturing industry which may have been preventable through robots.
  - 294 fatalities(37%) involving falling and 80 fatalities(10%) involving proximity to dangerous machines were reported in the construction industry. These could be prevented with human supervised robot teams.
- In space environments, teams of humans are difficult to maintain and could be replaced by robots. However, human supervision and judgment is still needed.
- Hazardous environments such as Fukushima Daiichi could require multi-robot systems with human supervision.

GUI Follow Up – Request Help

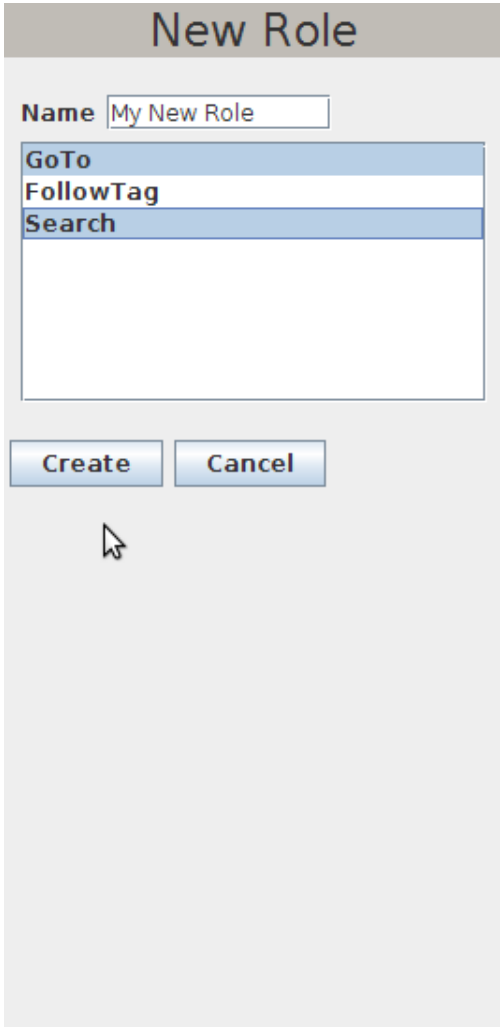


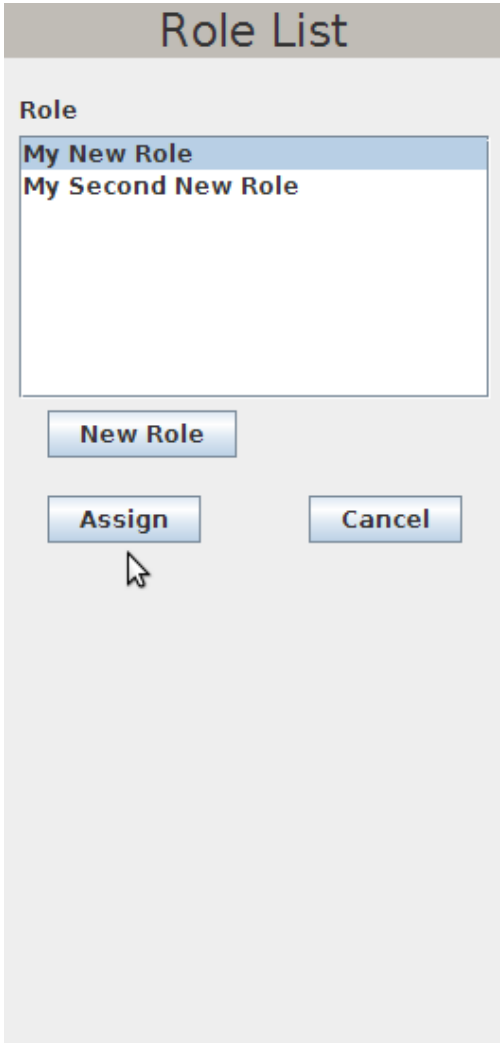
GUI Follow Up – Edit tasks

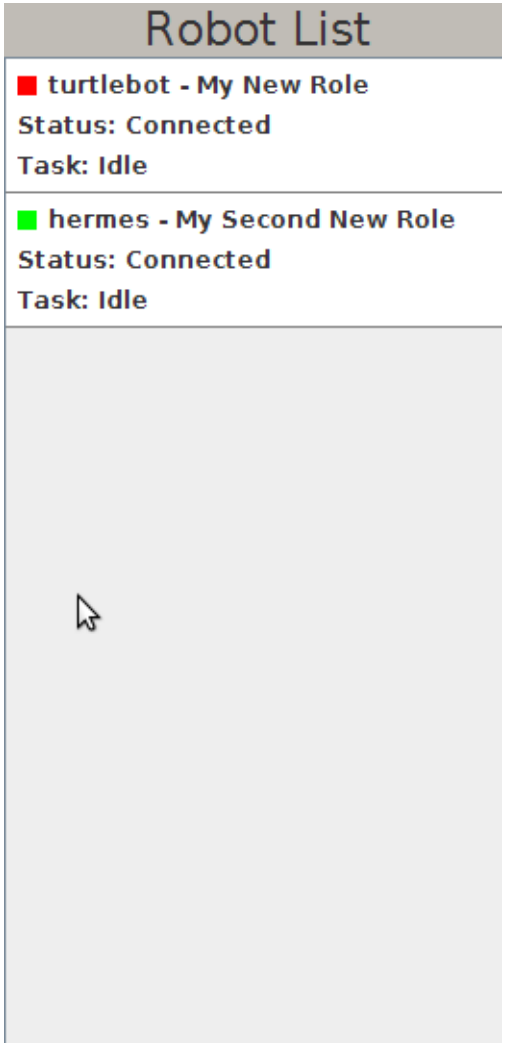




GUI Follow Up – Roles

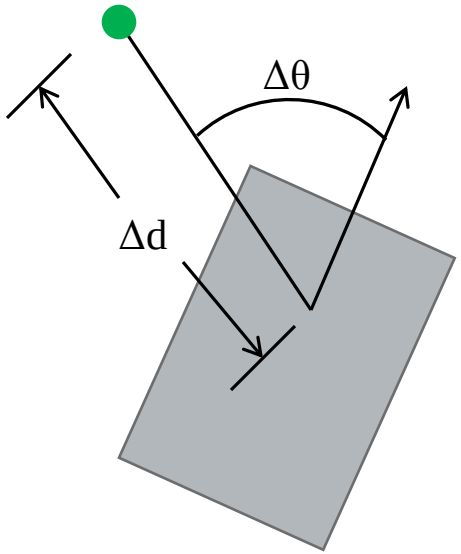






Path Planning and Execution

- Path planning was implemented using A*
- Path execution was accomplished using a piecewise proportional controller:

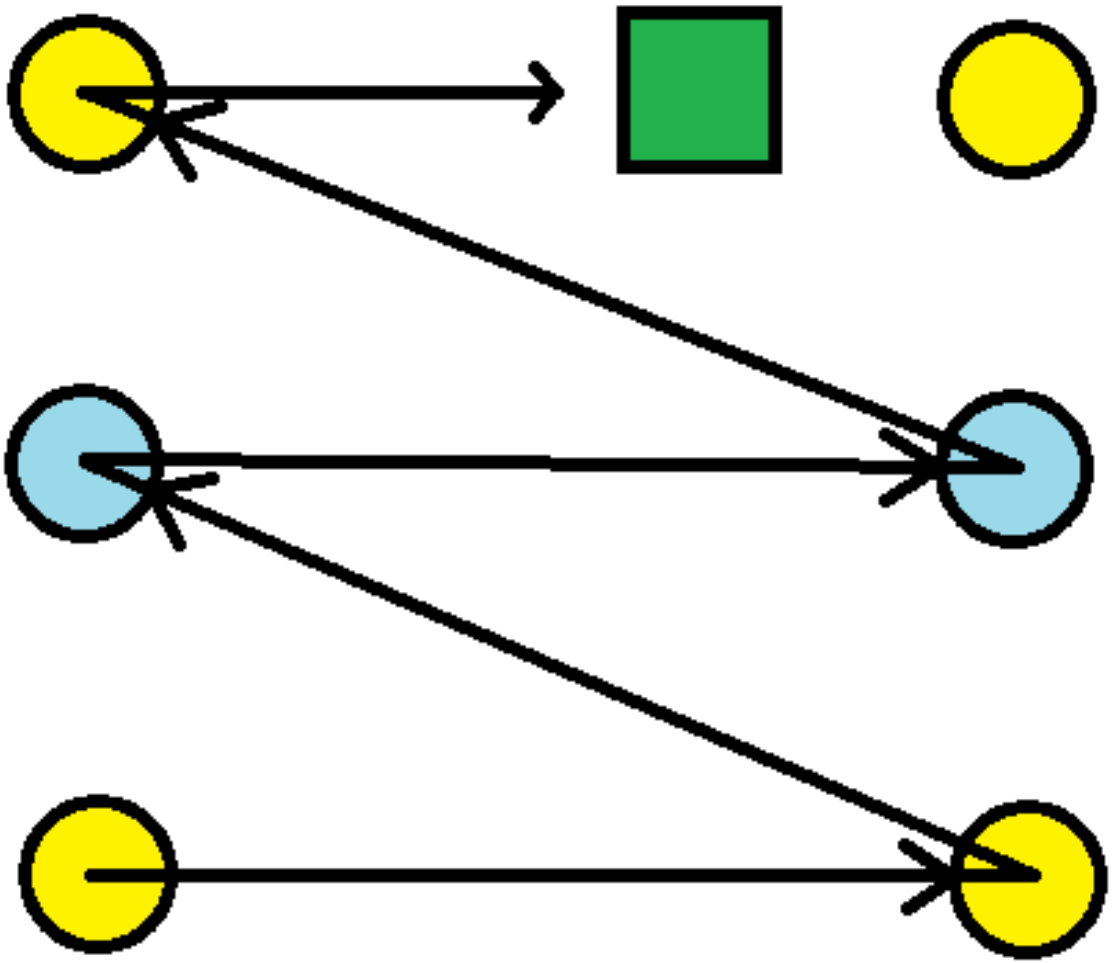


$$\omega = K_\omega \Delta\theta$$

$$v = \begin{cases} 0, & \Delta\theta > \varepsilon \\ K_v \Delta d, & \Delta\theta \leq \varepsilon \end{cases}$$

Where:
ω and **v** are the robot's angular and linear velocities
$\mathbf{K_\omega}$ and $\mathbf{K_v}$ are the proportional gains for angular and linear velocity
ε is the allowable angular error before linear motion is initiated.

Navigation Follow Up



Communications Follow Up

- Pings to router > 10s
- Network traffic generated by system < 60kb/s
- Processor load on supervisor's computer <20%
- Improved performance when operating in Gateway Garage

- Possible cause was using overcrowded wireless channels

Utility Function

$$\sum aw$$

$$a = attribute\ value$$
$$w = weight$$