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# Human Supervision of Multi-Robot Systems

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# WPI

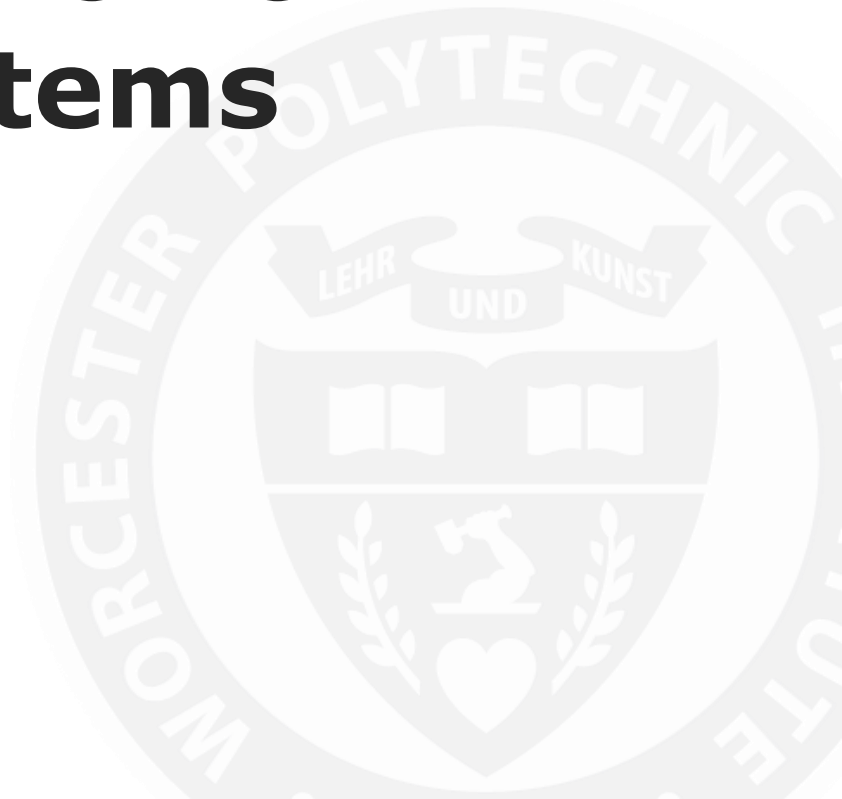
# Human Supervision of Multi-Robot Systems

A Major Qualifying Project by:

Donald Bourque

Thomas DeSilva

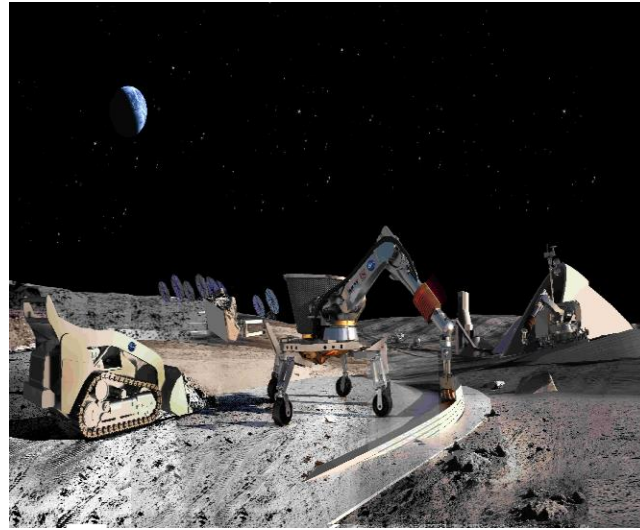
Nicholas Otero



# Motivation

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



[1], [2], [3]

# Project Goals

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- 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

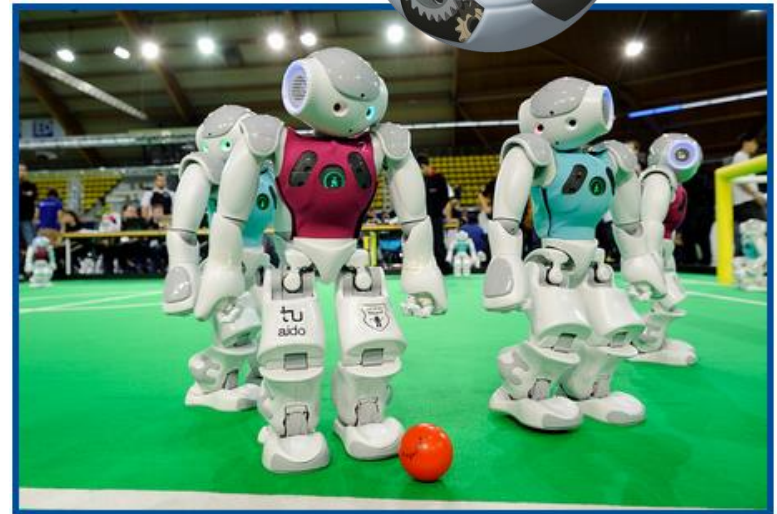
# Research and Inspiration

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

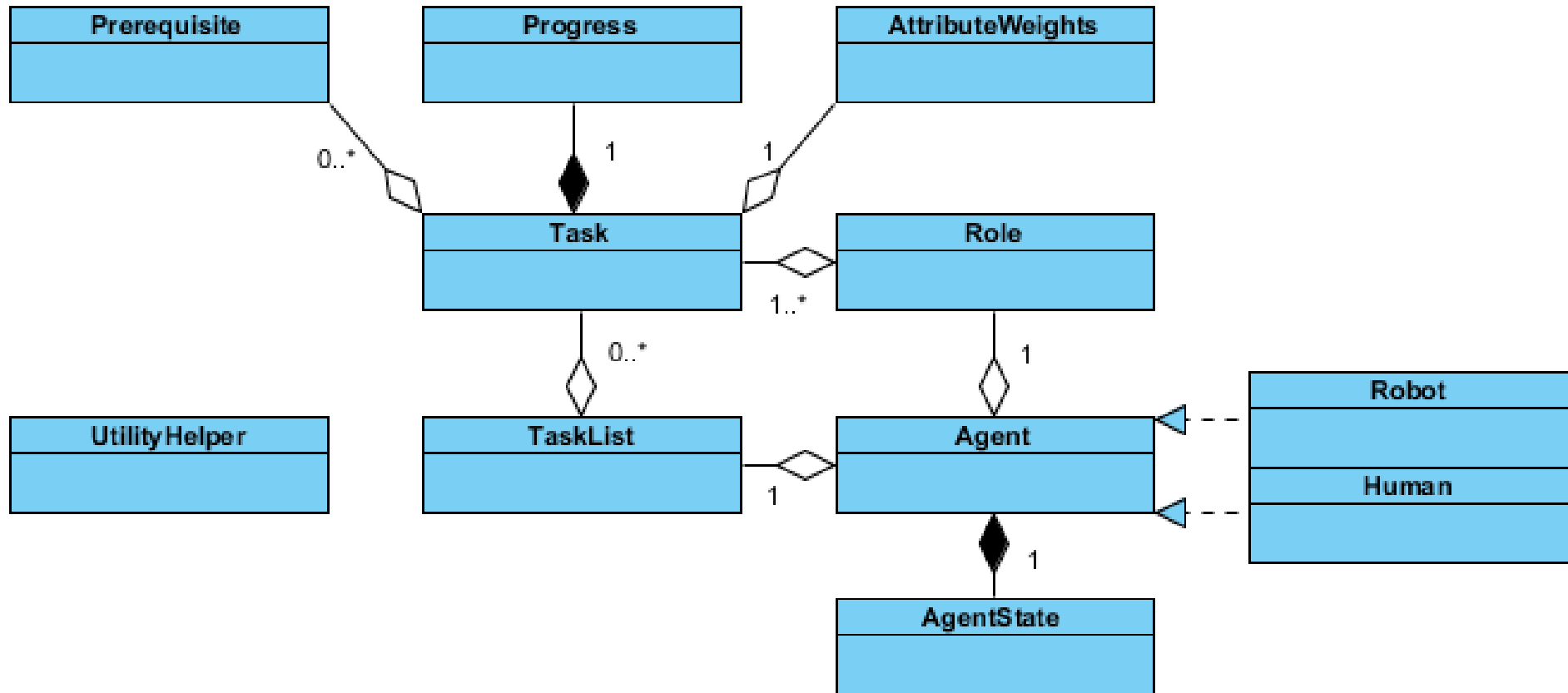


[4]

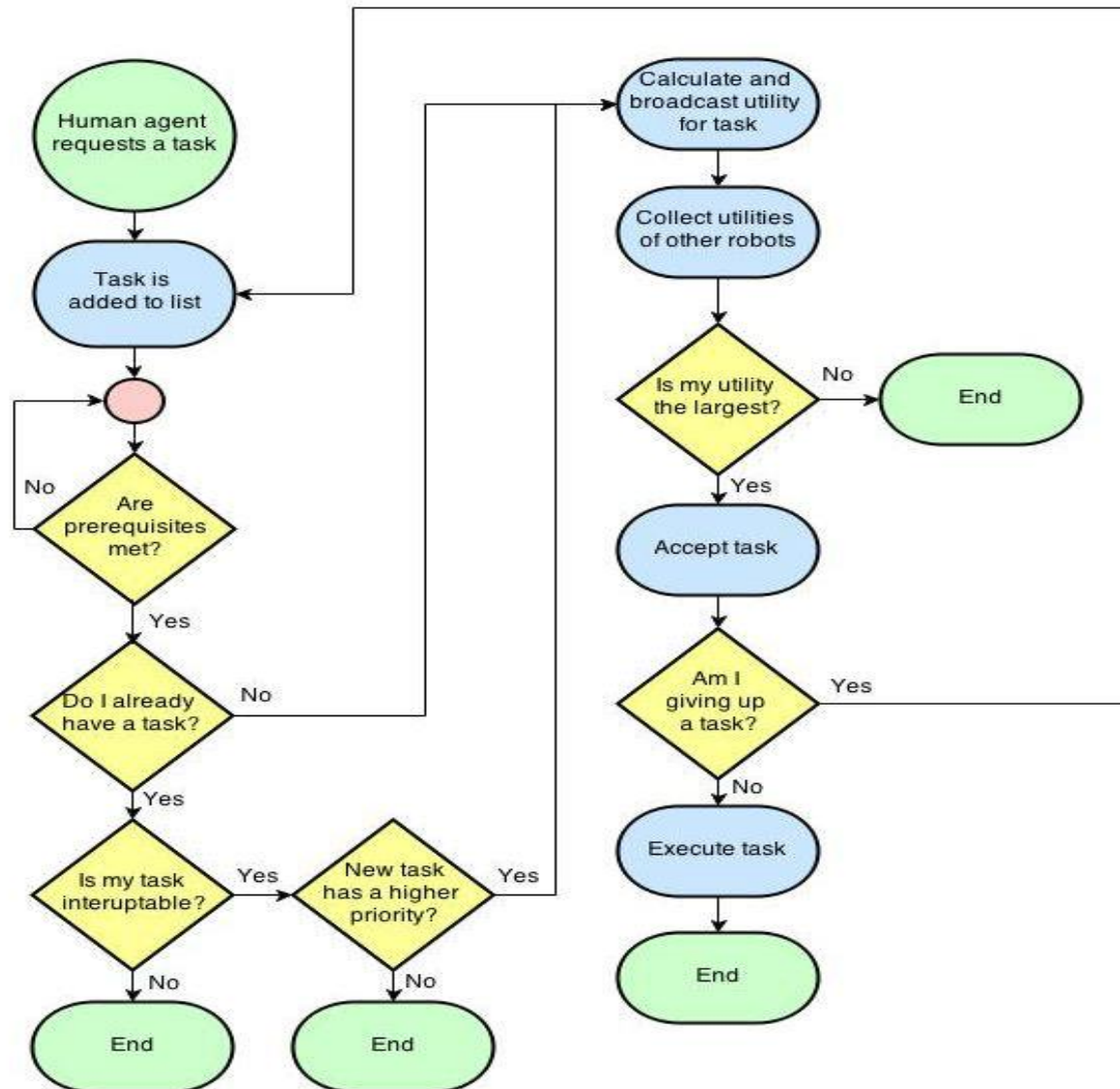


[5]

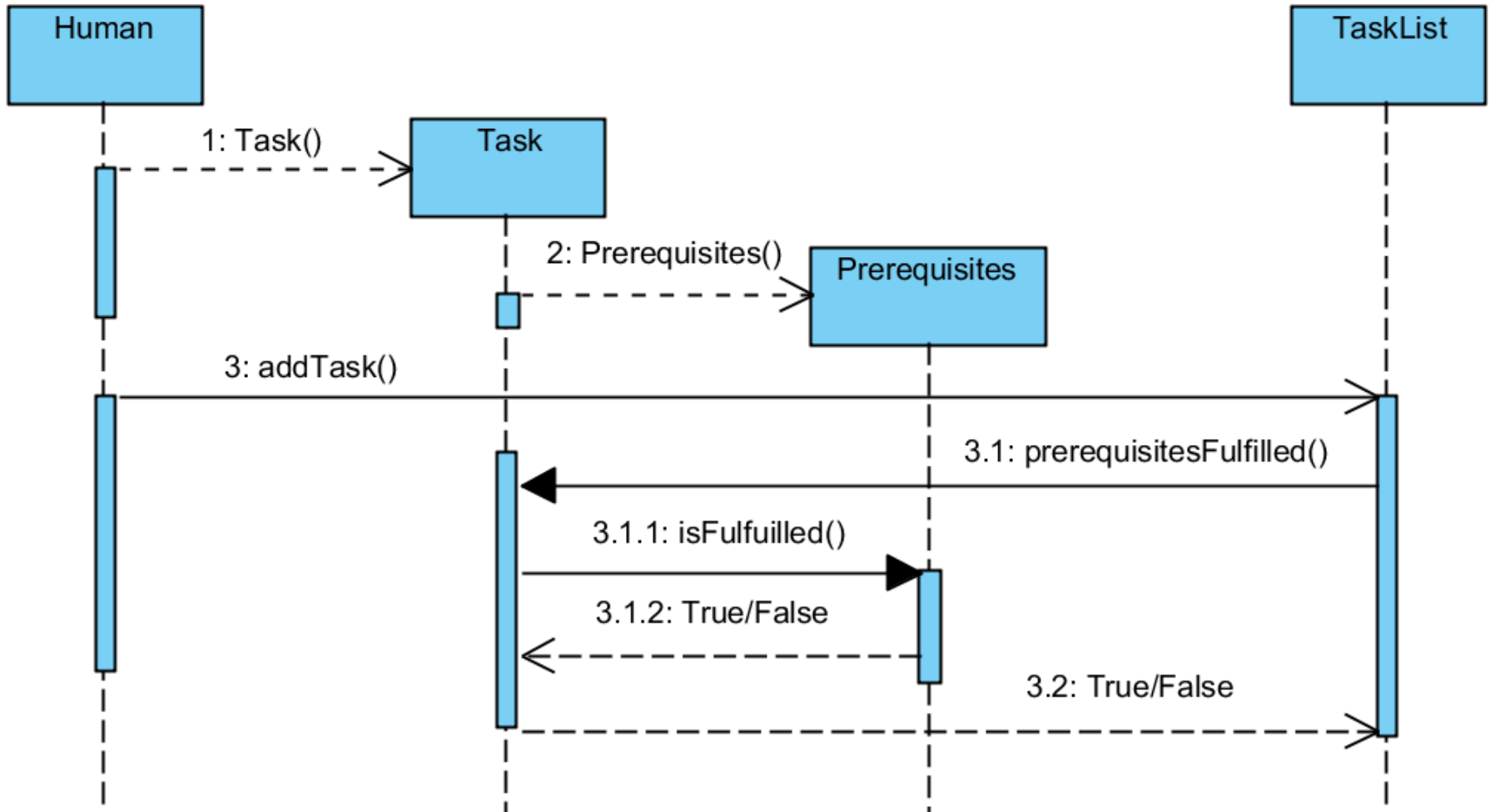
# Framework Design



# Framework Workflow (cont'd)

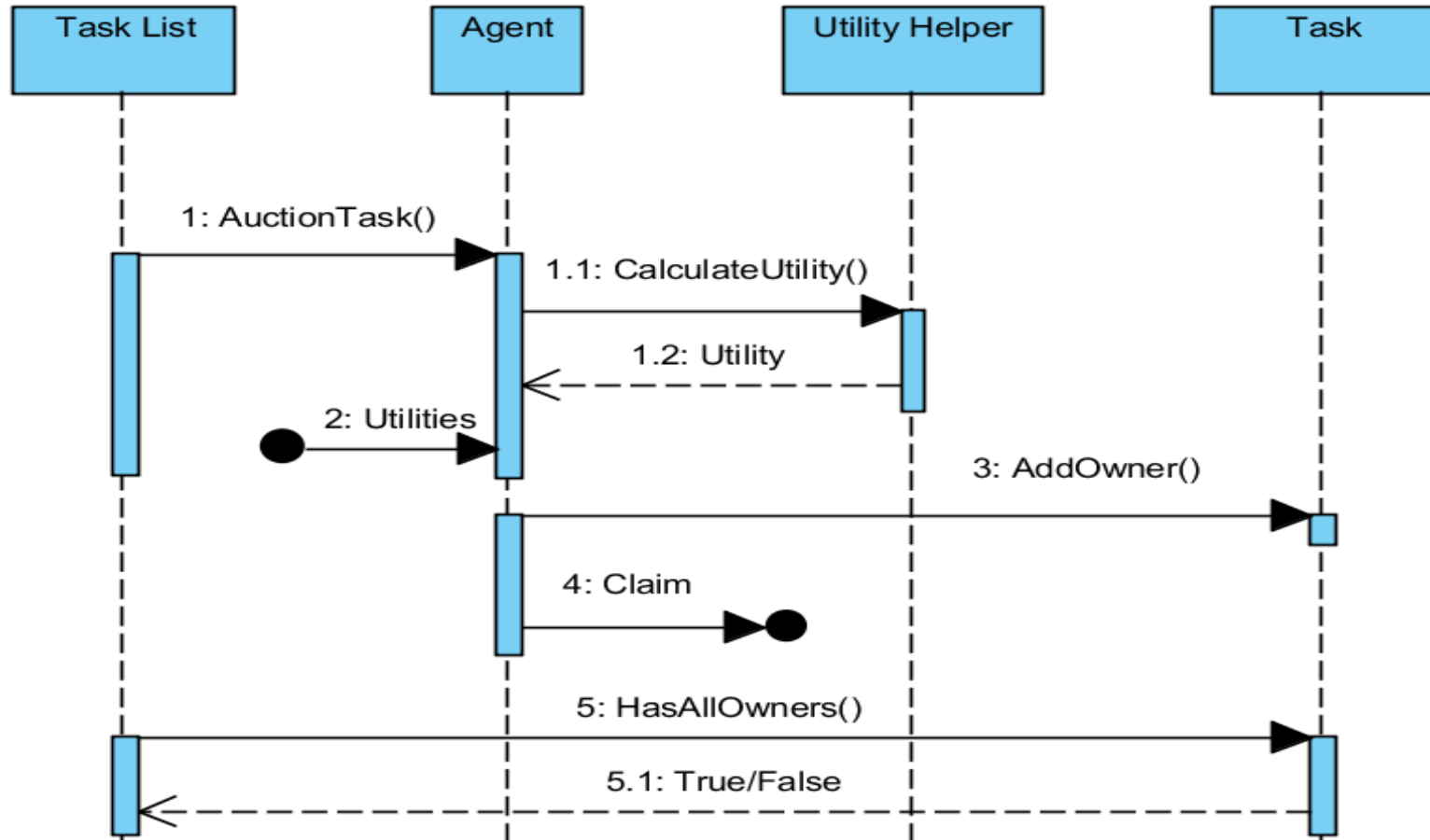


# Framework Workflow

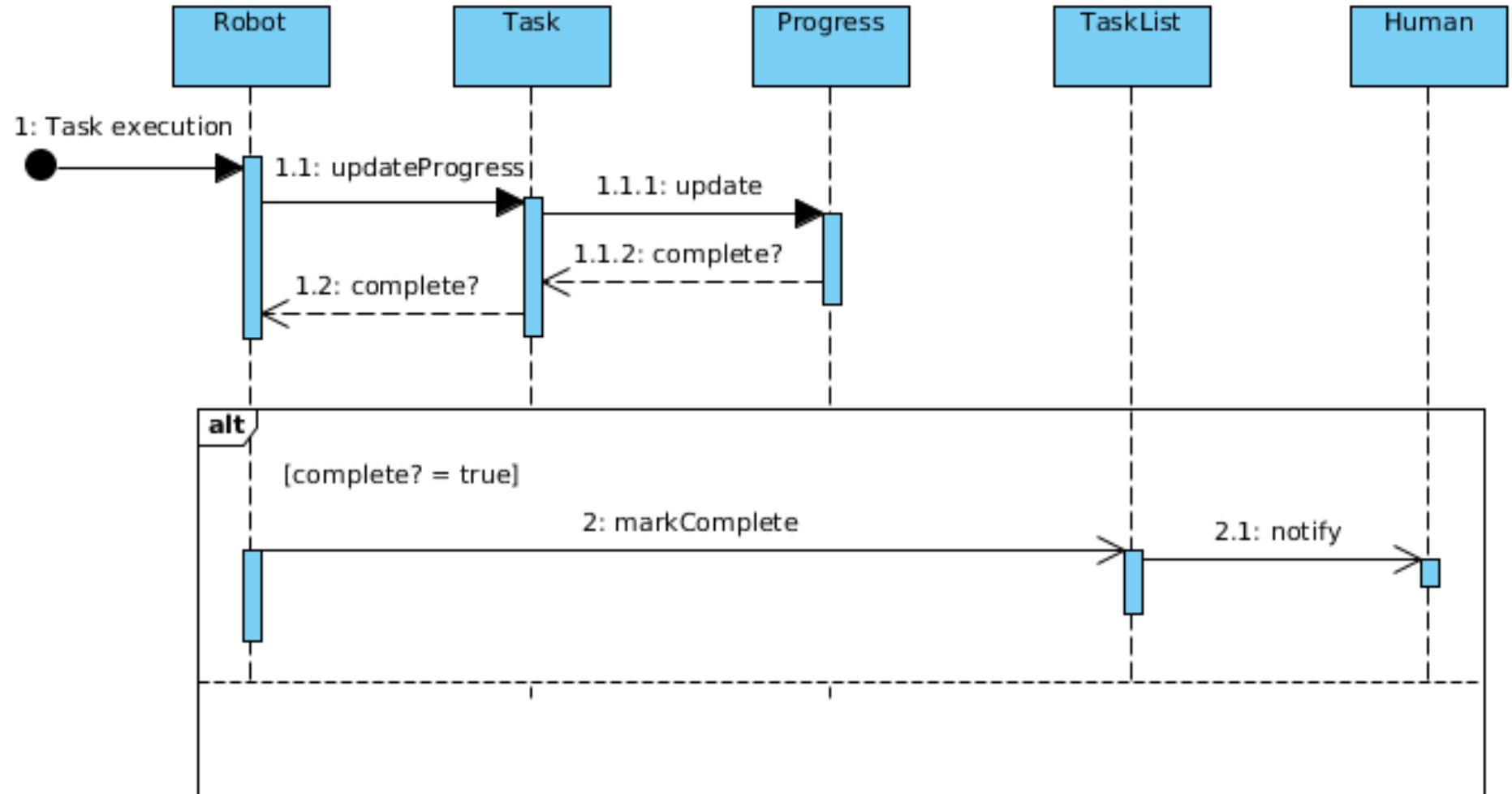




# Framework Workflow (cont'd)



# Framework Workflow (cont'd)



# Testing The Framework

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Evaluate the effectiveness of the framework:

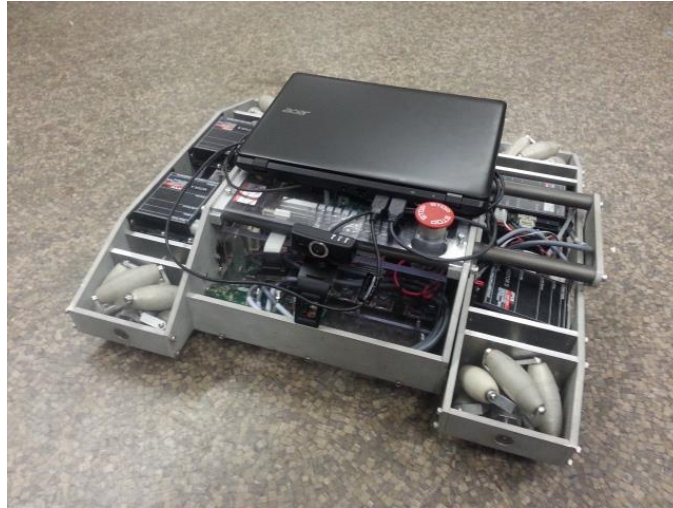
- Unit tests of specific framework functions
- Search and discover mission

# Robots

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Turtlebot



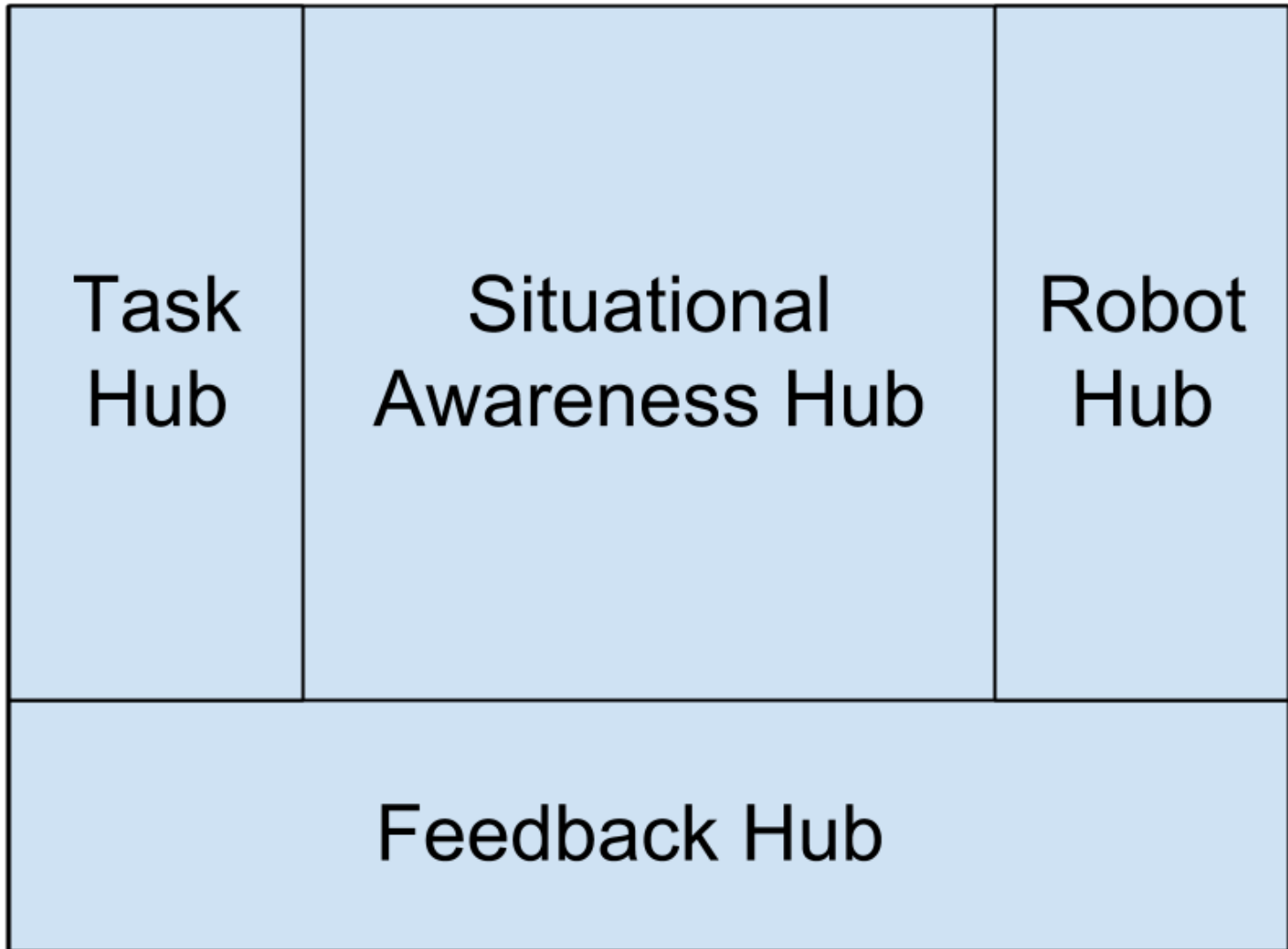
Hermes



Husky

# Graphical User Interface

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# Graphical User Interface (cont'd)

**Task List**

New task Remove task

GoTo  
Status: Not started  
Owners:

FollowTag  
Status: Not started  
Owners:

Search  
Status: Not started  
Owners:

Camera Map

**Robot List**

■ Hermes  
Status: Connected  
Task: Idle

■ Husky  
Status: Connected  
Task: Idle

■ Turtlebot  
Status: Connected  
Task: Idle

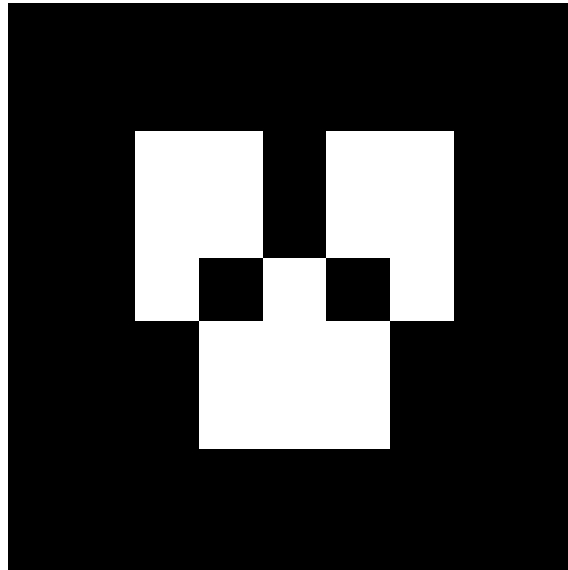
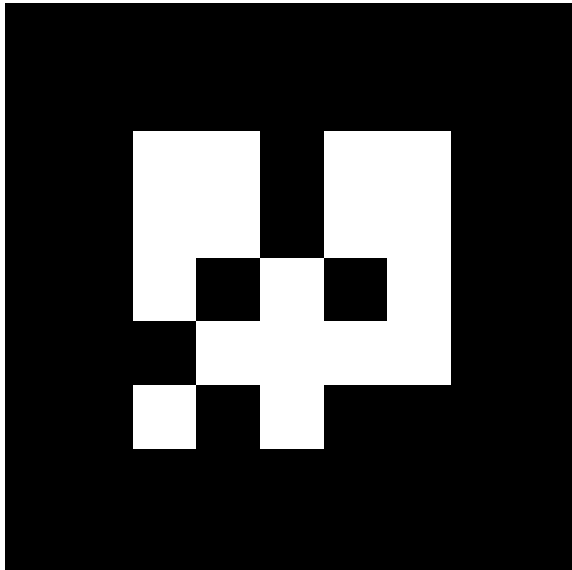
All System Hermes Husky Turtlebot

[1428698102] System: New agent has been successfully registered: Hermes  
[1428698112] System: New agent has been successfully registered: Husky  
[1428698122] System: New agent has been successfully registered: Turtlebot

# Localization

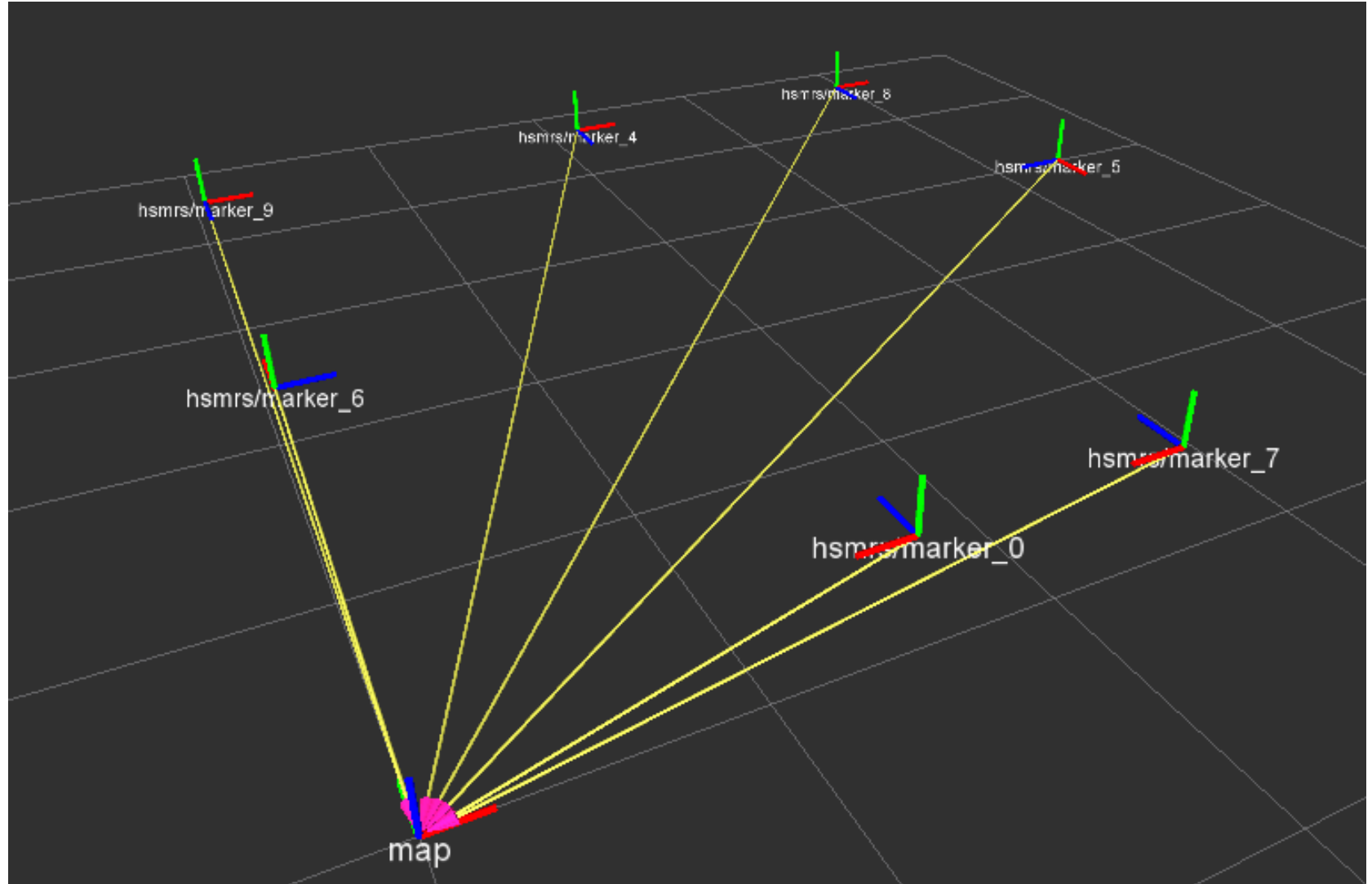
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- Needed to determine position of robots within the operating area
- Used Augmented Reality(AR) tags and wheel odometry
- Position belief was maintained by a rolling average filter



[6]

# Localization





# Results

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- 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.

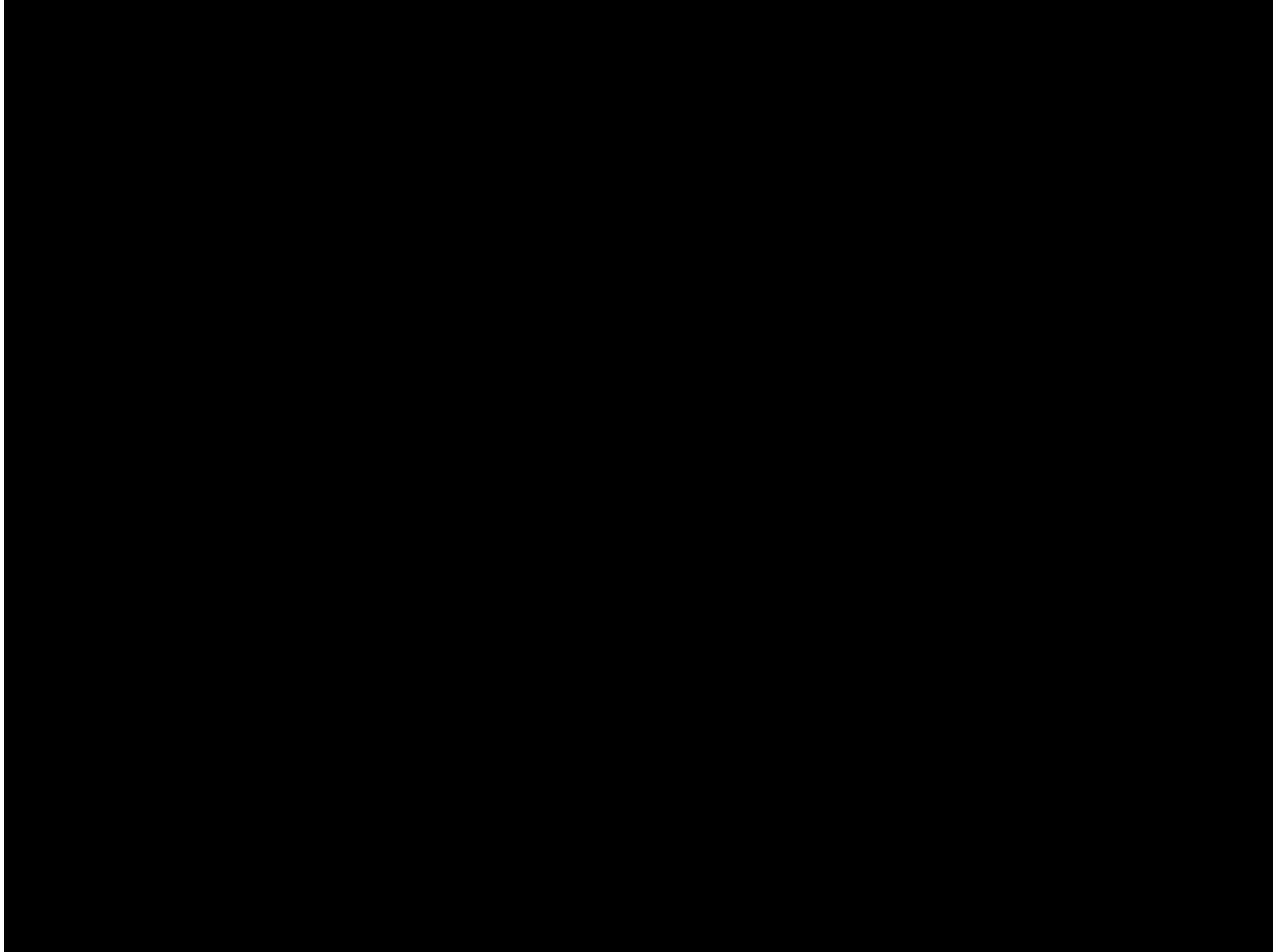
# Results (cont'd)

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- 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

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# References

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- [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](http://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](http://wiki.ros.org/ar_track_alvar)
- [7] <http://www.bls.gov/news.release/pdf/cfoi.pdf>

# Questions?



# Motivation Follow Up

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- 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.

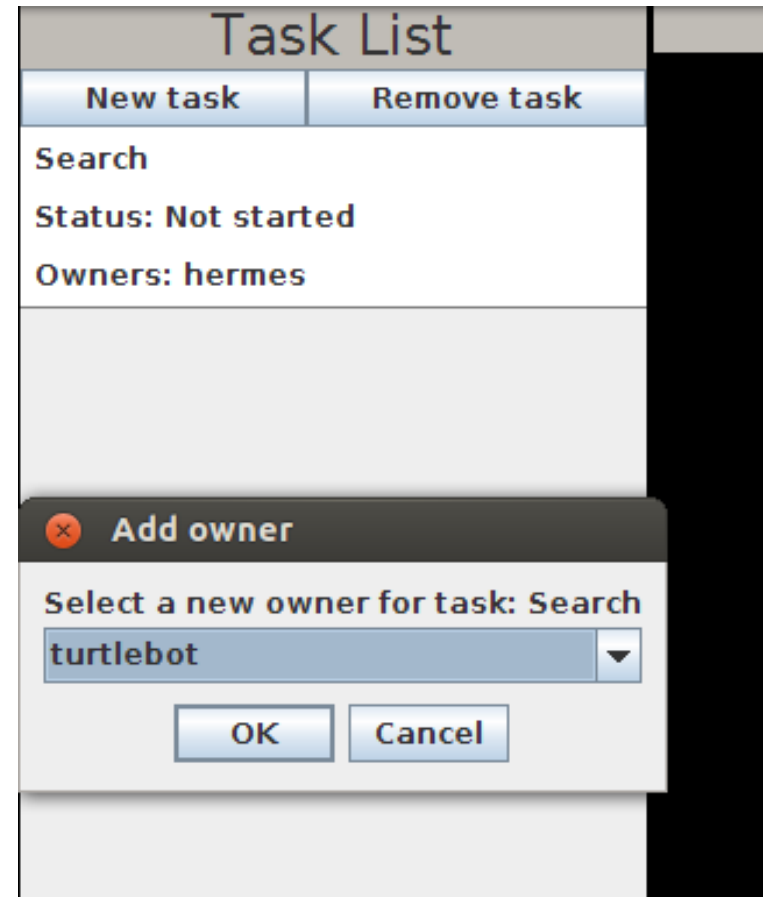
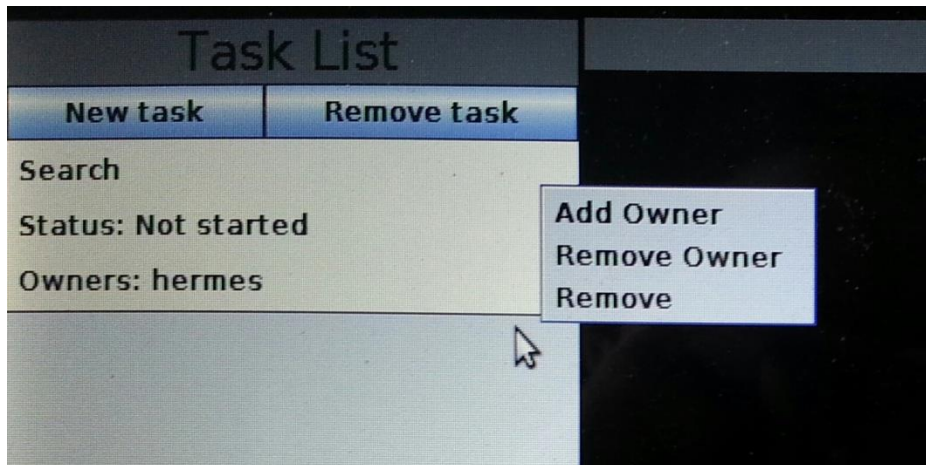
# GUI Follow Up – Request Help

The screenshot displays a GUI for robot control. On the left is a 'Task List' panel with 'New task' and 'Remove task' buttons. The center is a camera view of a white turtlebot in a room, with 'Camera' and 'Map' view options above it. On the right is a 'Robot List' panel showing two robots: 'turtlebot' (red square, Status: Connected, Task: Idle) and 'hermes' (green square, Status: Tele-Op, Task: Idle). An 'Attention Required' dialog box is overlaid on the robot list, containing a warning icon and the text 'turtlebot has requested assistance!' with an 'OK' button. At the bottom is a log window with tabs for 'All', 'System', 'turtlebot', and 'hermes'. The log contains the following messages:

- [1429640825] System: New agent has been successfully registered: turtlebot
- [1429640843] System: New agent has been successfully registered: hermes
- [1429640880] turtlebot: My center bumper was released!
- [1429641066] turtlebot: My center bumper was released!

# GUI Follow Up – Edit tasks

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# GUI Follow Up – Roles

### New Role

Name


GoTo
FollowTag
Search



### Role List


Role

My New Role
My Second New Role



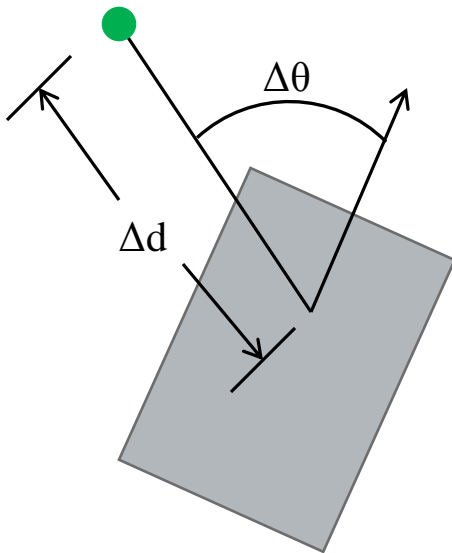
### Robot List

<span style="color: red;">■</span> turtlebot - My New Role Status: Connected Task: Idle
<span style="color: green;">■</span> hermes - My Second New Role Status: Connected Task: Idle



# Path Planning and Execution

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



$$\omega = K_{\omega} \Delta\theta$$

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

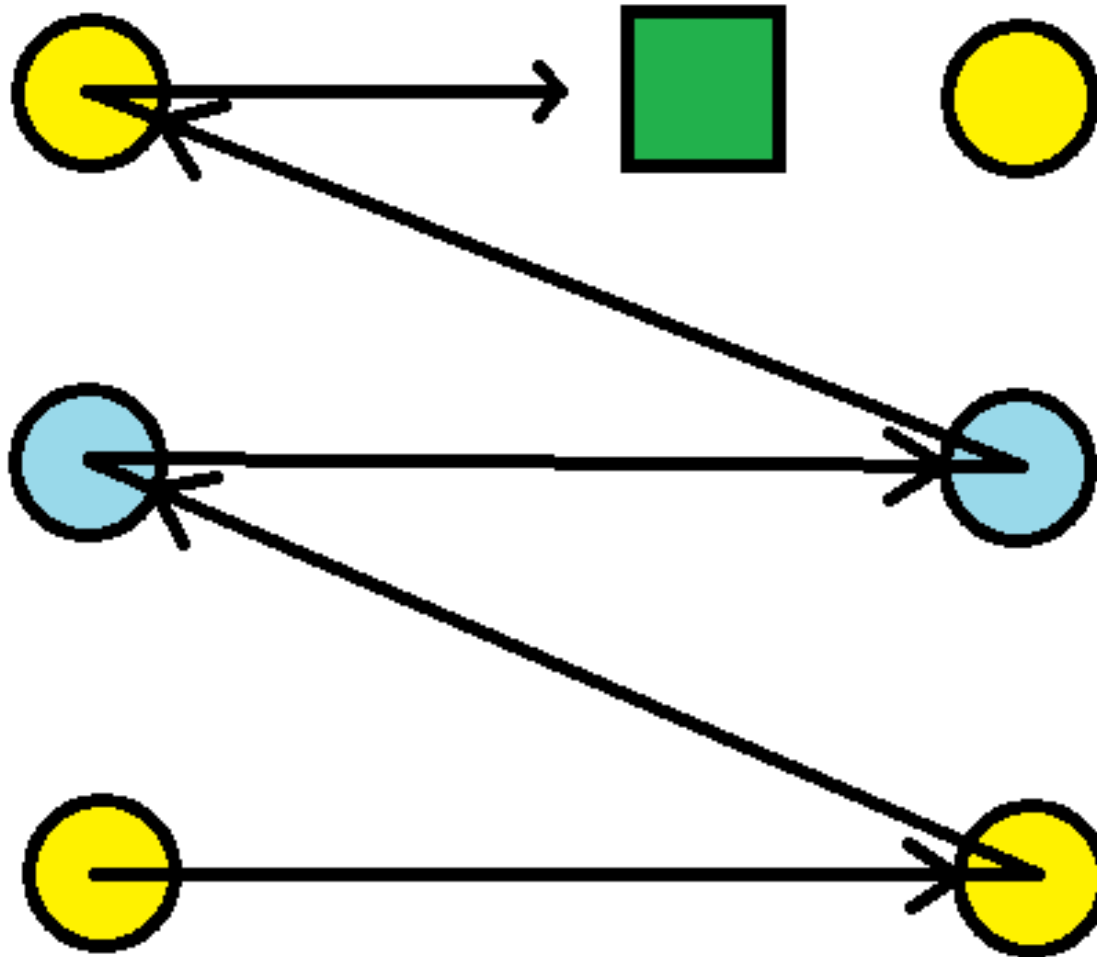
Where:

$\omega$  and  $v$  are the robot's angular and linear velocities  
 $K_{\omega}$  and  $K_v$  are the proportional gains for angular and linear velocity

$\epsilon$  is the allowable angular error before linear motion is initiated.

# Navigation Follow Up

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# Communications Follow Up

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- 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

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$$\sum aw$$

*a = attribute value*  
*w = weight*