Speaking Swarmish

Physical

∧Human-Robot Interface Design for Large Swarms of Autonomous Mobile Robots

James McLurkin[1], Jennifer Smith[2], James Frankel[3], David Sotkowitz[4], David Blau[5], Brian Schmidt[6]

1, 5, 6 CSAIL MIT COMPUTER SCIENCE AND ARTIFICIAL INTELLIGENCE LABORATORY

2, 3, 4 iRobot

My Position

- My Axe: As a community, we don't spend enough time working on (or give enough respect to) user and development interfaces for robotic systems
- As the field matures, popular interfaces will inevitability arise. We can either design thoughtful interfaces (good) or let them arise spontaneously (bad)
- This work describes a set of simple user interfaces that use ***Physical I/O*** to interface an unaided user to large* groups of robots
- Oooo! A new Acronym:

HMRI = **H**uman **M**ulti-**R**obot **I**nterface

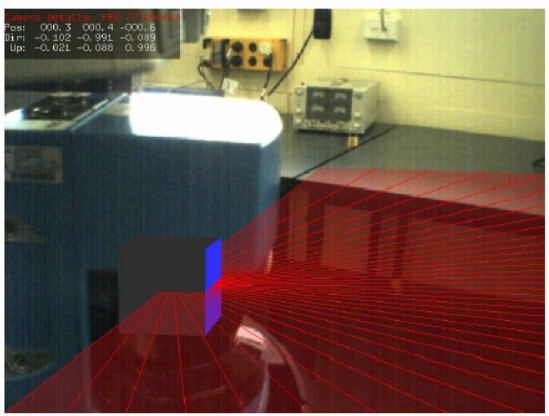
Now, we're ready to get some work done!

*Large ≈ 100. Your definition may vary.

The HMRI Problem

- Requirements
  - Get information to all the robots (programs, commands)
  - Get information about what all the robots are doing (internal state)
  - Get information from all the robots (mission sensors)
- Some Terms:
  - **Virtual I/O:** Interface with robots through computer
  - **Physical I/O:** Interface with robots directly
  - **Development Interface:** Interface for developers
  - **User Interface:** Interface for users

Related Work



(a) Laser data origin

(b) Laser data edge

Collett and MacDonald, 2006, “Developer Oriented Visualisation of a Robot Program”

StarCraft, Blizzard Entertainment, 1999

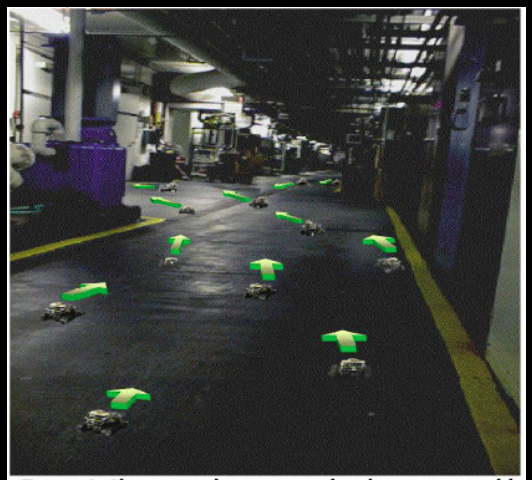
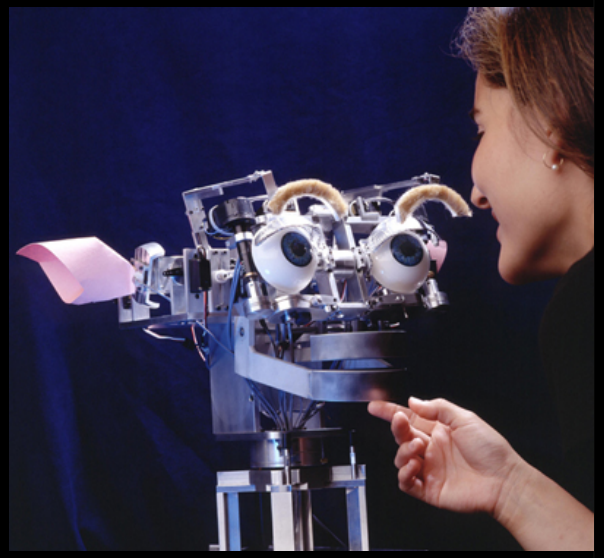


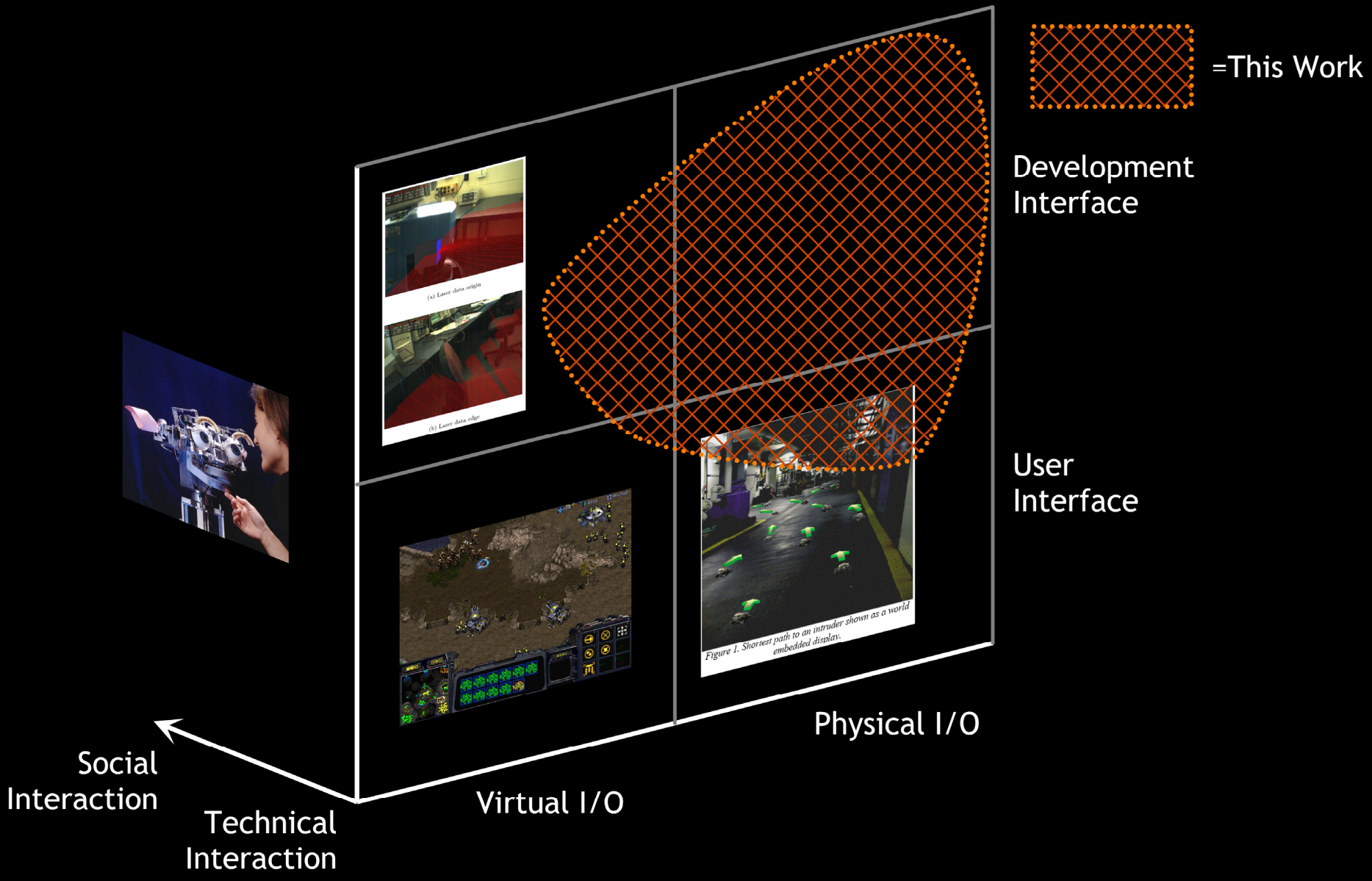
Figure 1. Shortest path to an intruder shown as a world embedded display.

Daily, Cho, Martin, Payton, 2002 “World Embedded Interfaces”



Kismet, Breazeal et. al., 1998-200X

HRI Design Space



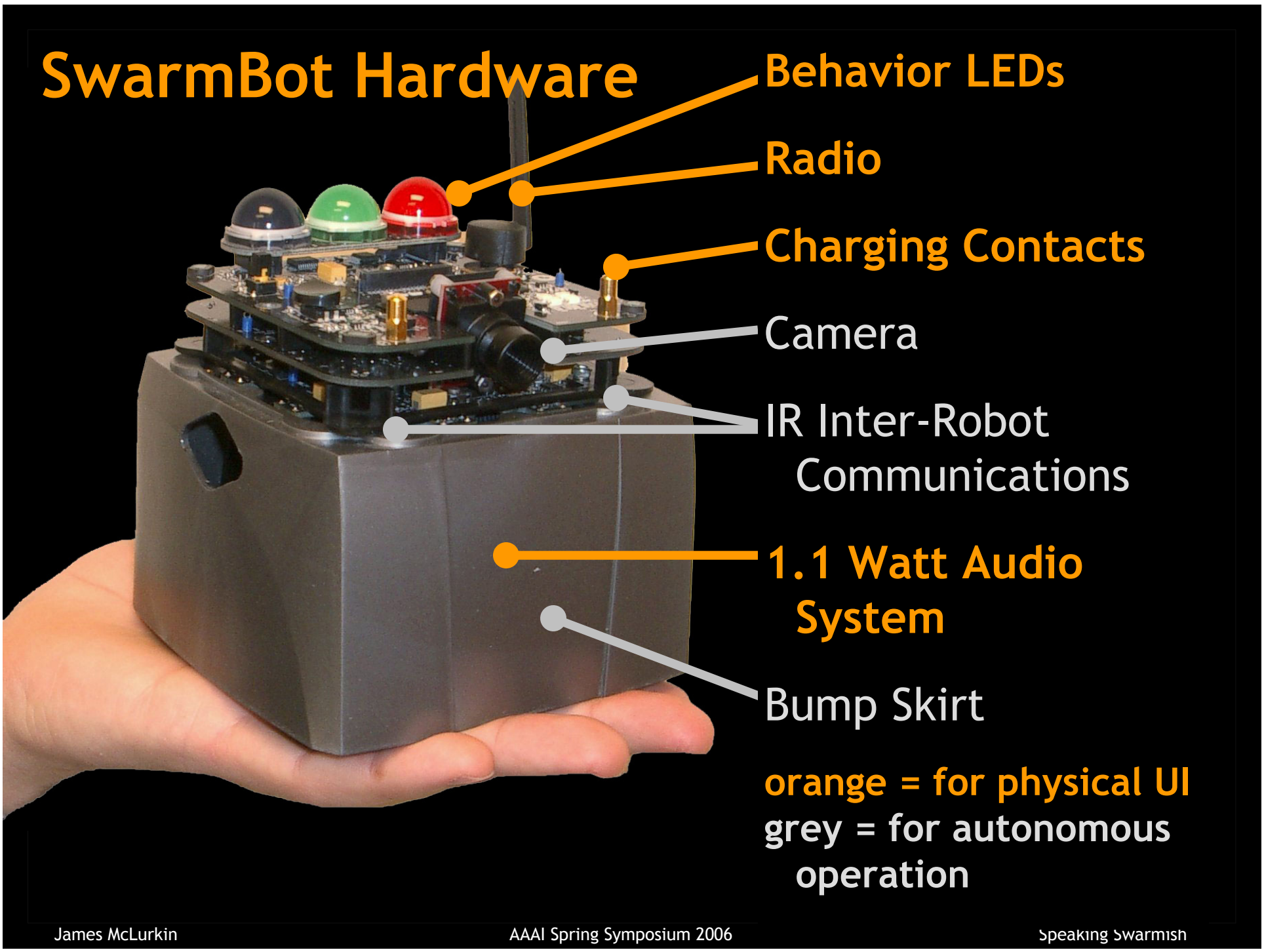
This Work

- **Physical Infrastructure** for hands-free operation
- **Centralized Control Software** for development, debugging and operation
- **Physical I/O** for ***in situ*** interaction
  - ***in situ*** = Allow the user to watch the robots while reading telemetry about individual and group behaviors
  - Displays on robots are useless on multi-robot systems
  - The Human perceptual system can process a vast amount of multi-modal real-time data
  - Allow the trained, but unaided user to “read” the swarm

Physical Infrastructure for HMRI

- Problem: The robots outnumber the humans
  - Anything you have to do to one robot, you have to do to all of them. This does not scale well.
- Solution: Hands-Free Design
  - The SwarmBot has dedicated hardware for the physical user interface
  - Basic Swarm-level tasks must be hands-free:
    - Remote Power On/Off
    - Autonomous Charging
    - Remote Programming
    - Efficient Transportation
    - Software for Centralized Command, Control, and Data Collection

SwarmBot Hardware



The Swarm “Extrastructure”

Docking

Long-Range Navigation

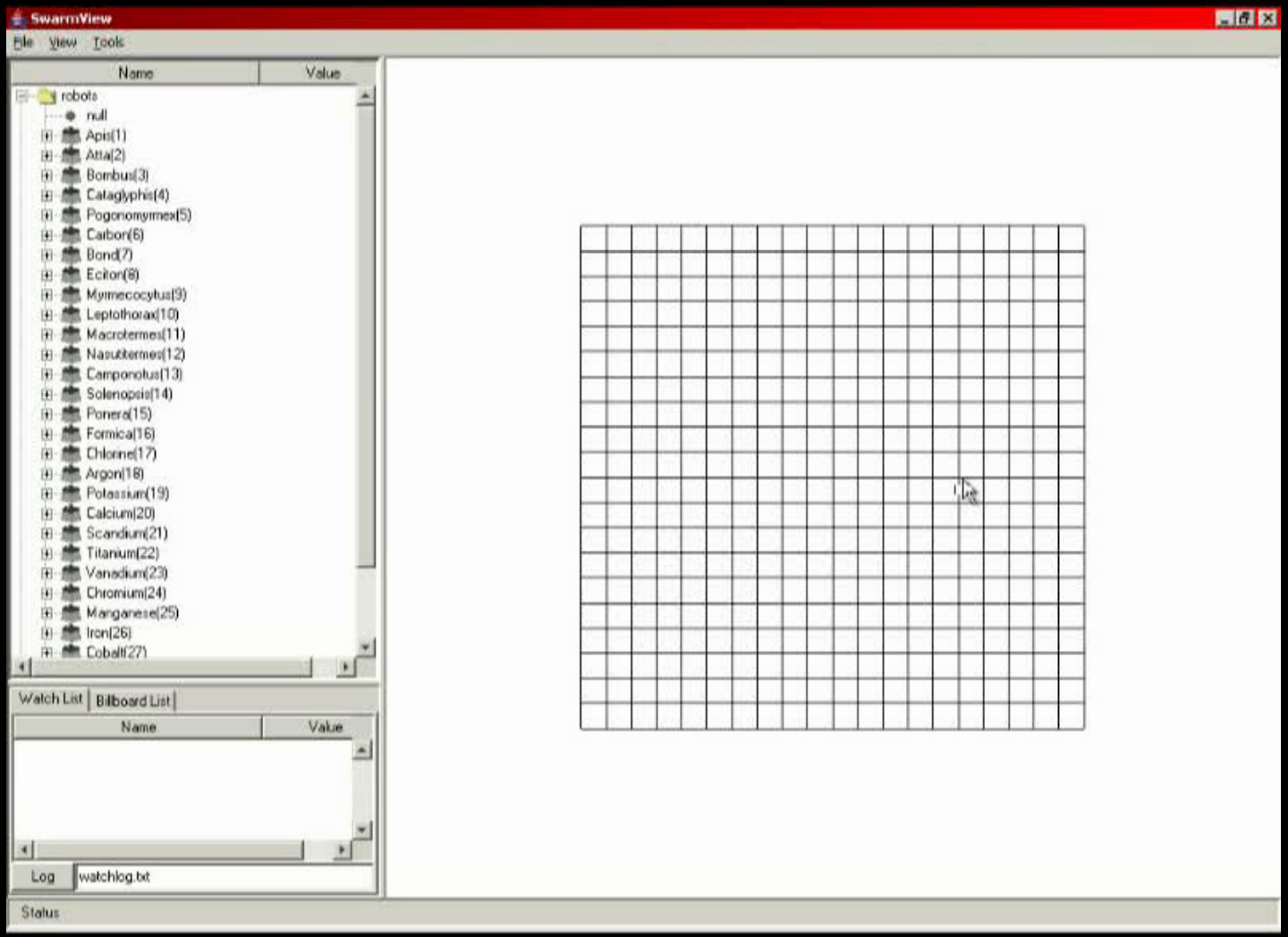
Very Long-Range Navigation

Remote Downloading System

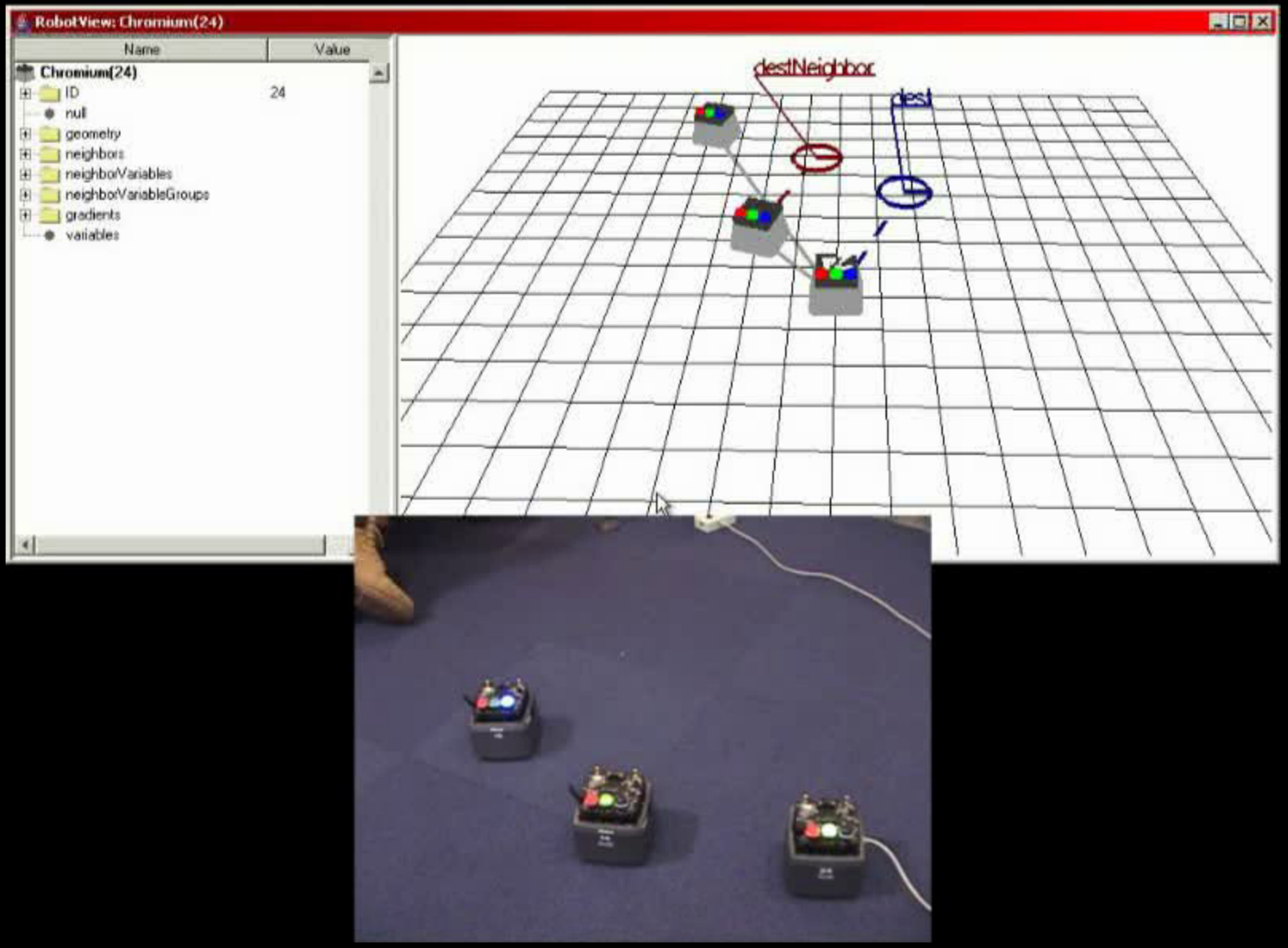
- [diagram of remote downloading procedure goes here] (waive hands furiously)
- Status tones are separated by 25ms, and are still clear and easy to disambiguate

SwarmCraft GUI

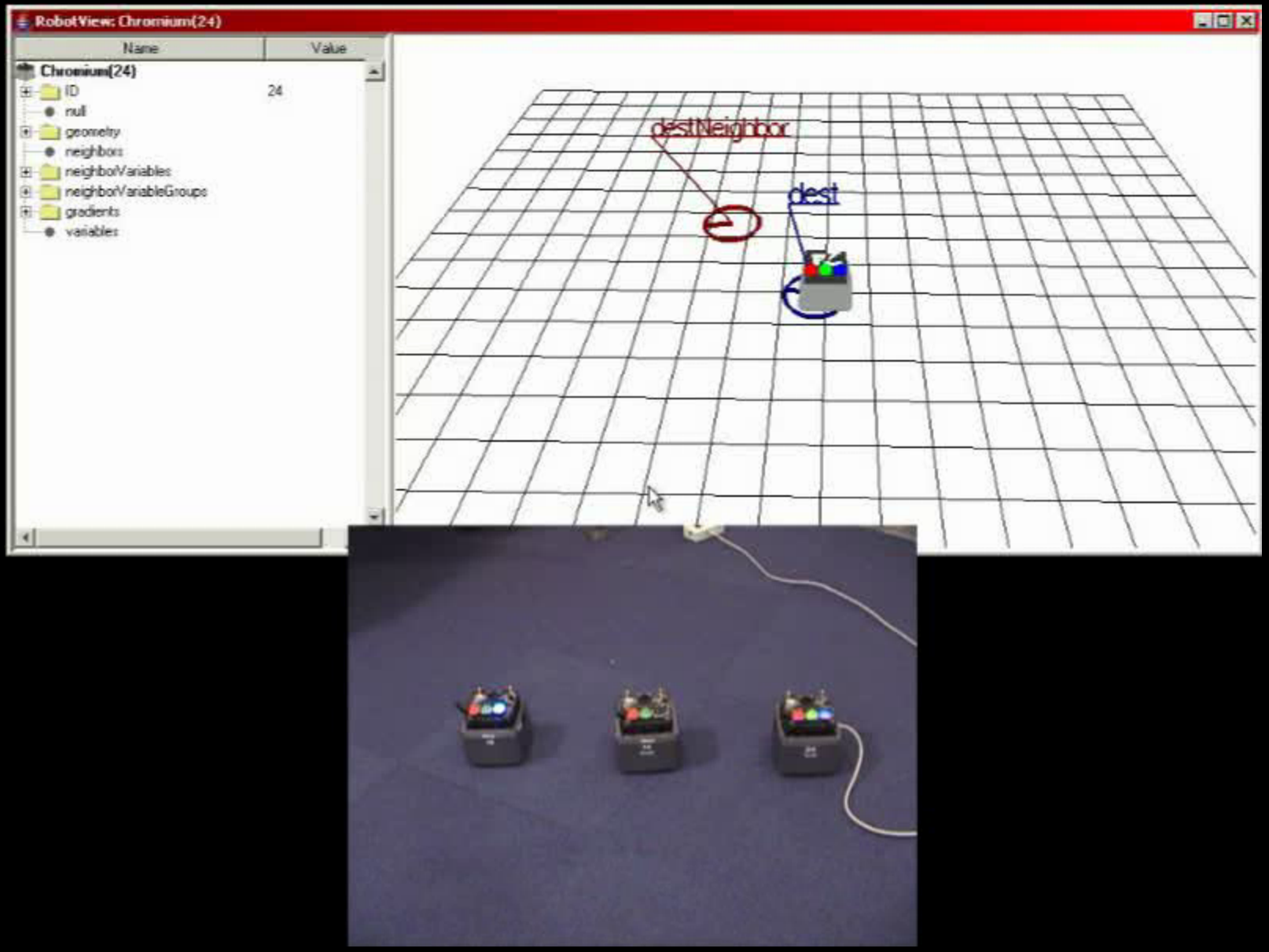
- Virtual I/O: Real-Time data collection and visualization
- Necessary, but not sufficient



SwarmCraft GUI



SwarmCraft GUI



Group Exercise: Conversational Swarmish

Three different color lights: red, green, blue

\+ Two blinking patterns: sine and square

\+ Many frequencies

= 108 patterns than can each be read in ≤ 500ms

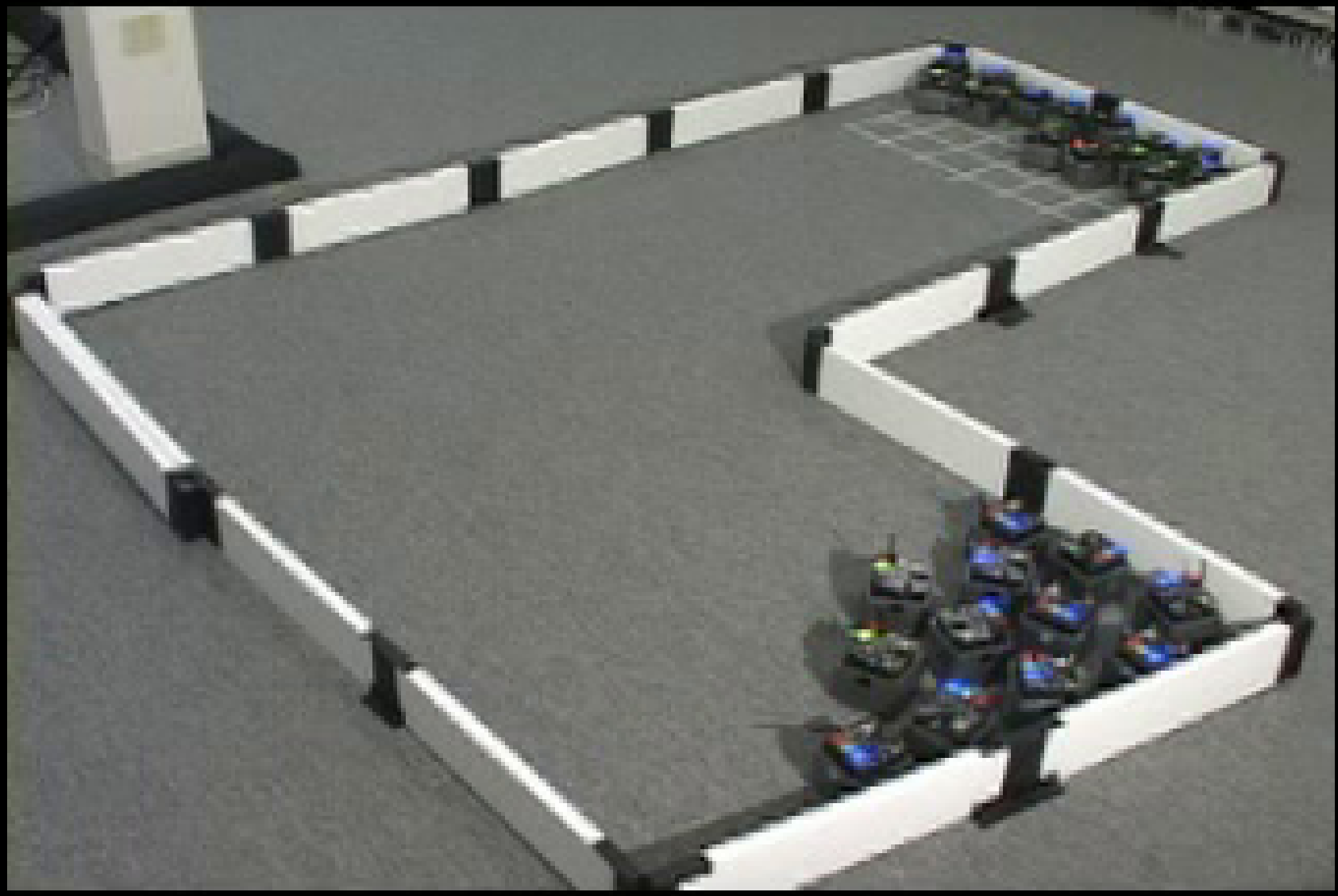
Clumping

Orientation

Navigation

Dispersing

Dispersion

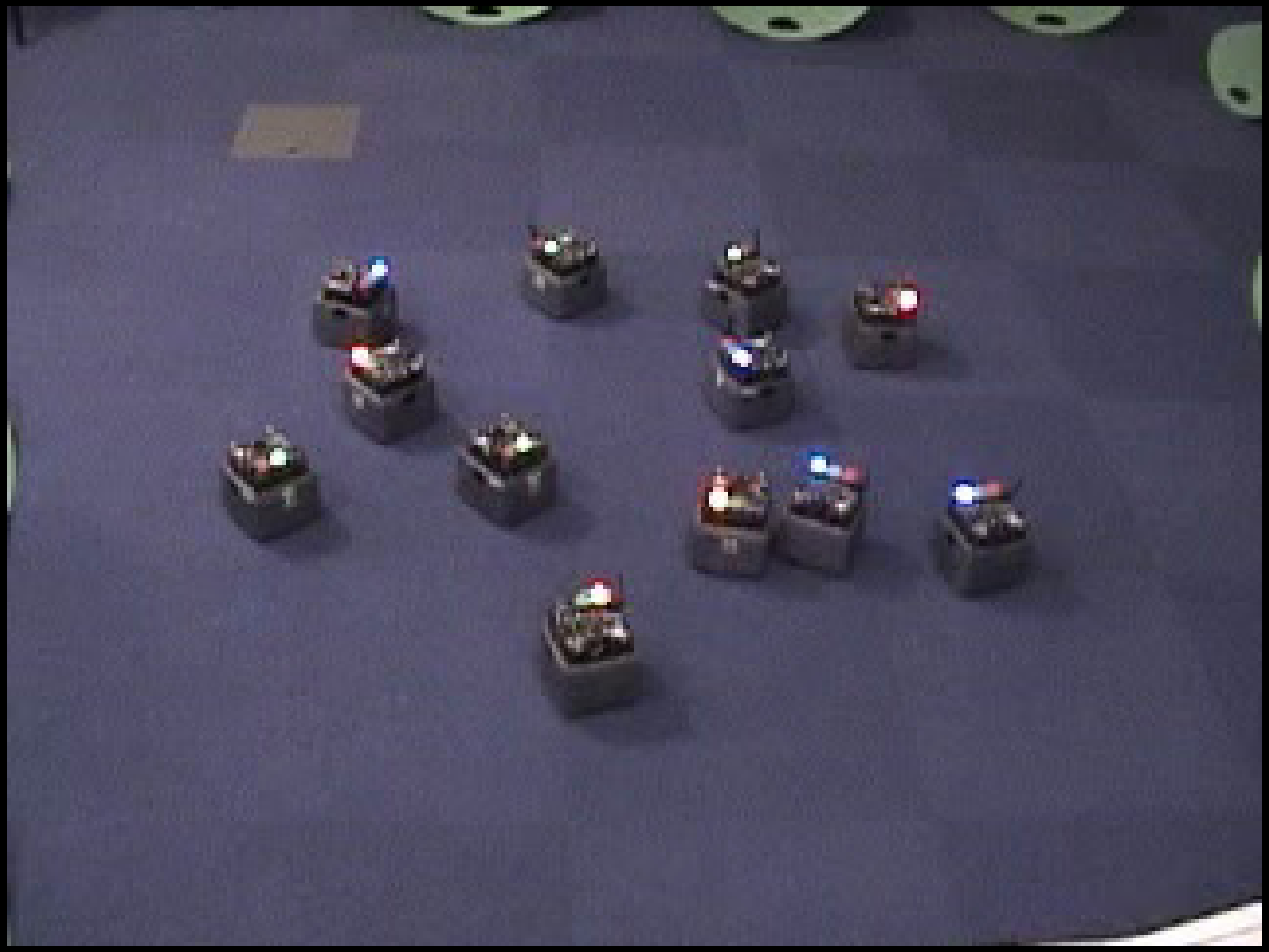


BubbleLine

BubbleLine: Flip

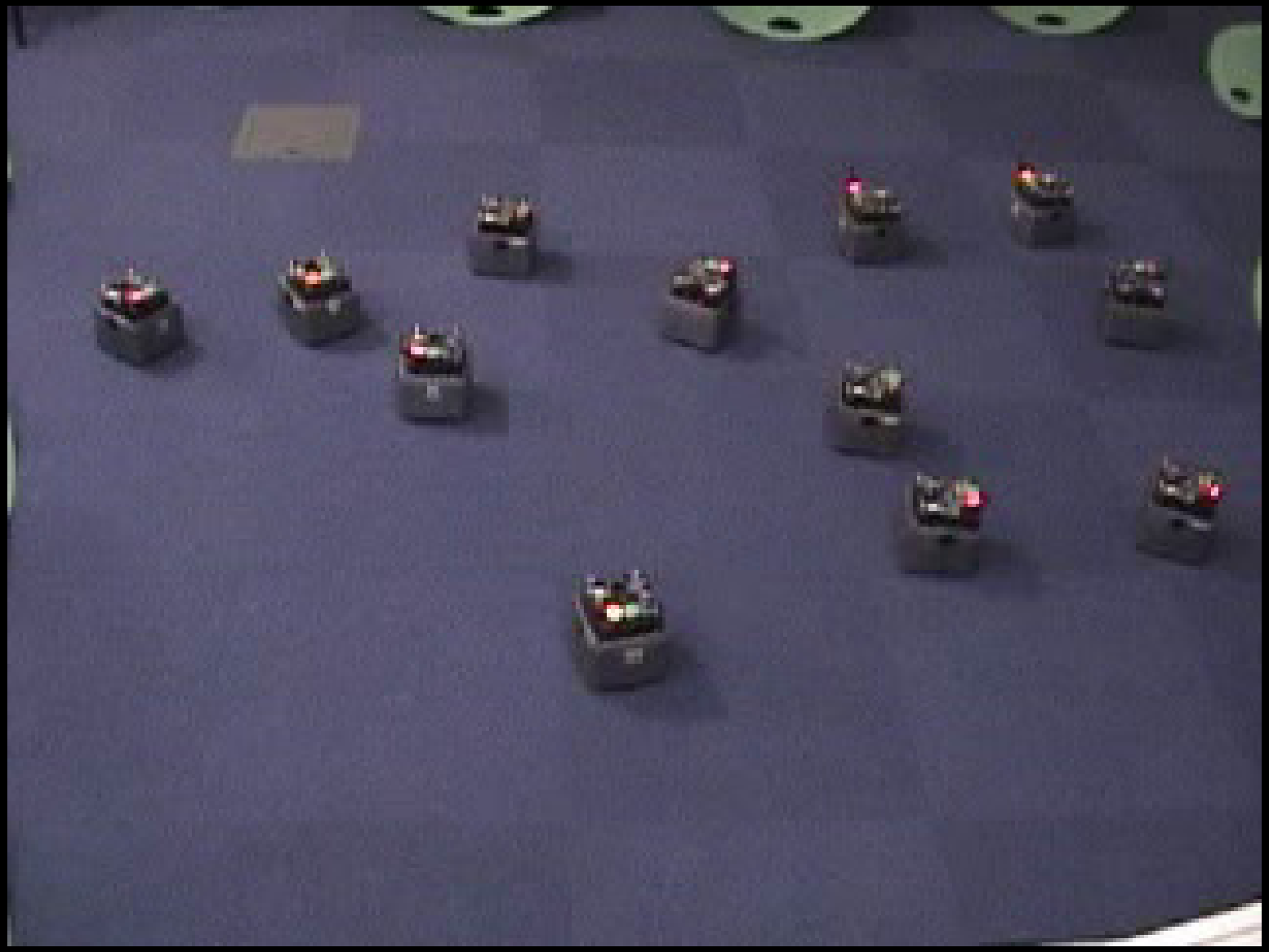
DTA: Extreme Comms-Line

DTA: Extreme Comms

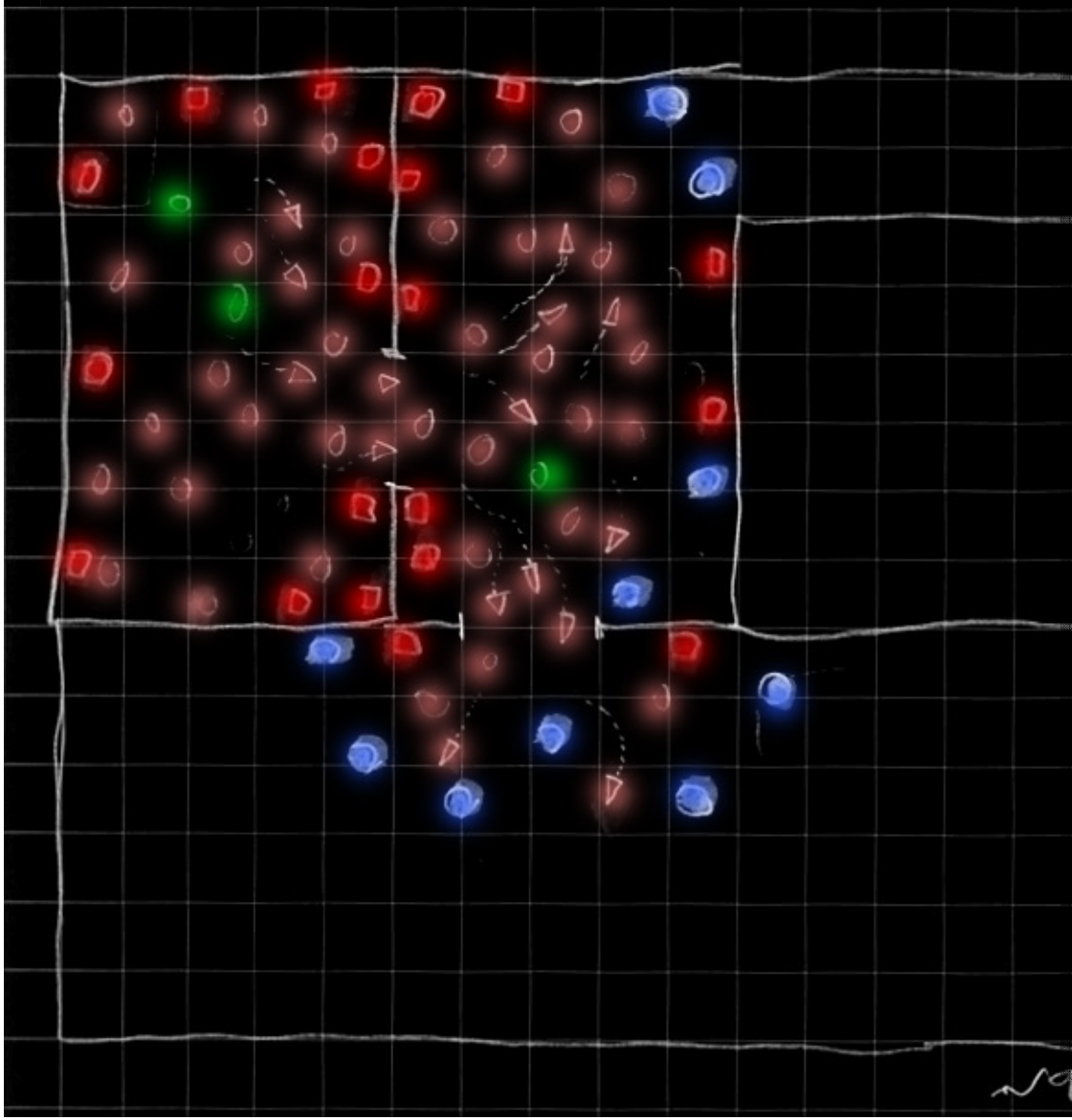


DTA: Card Dealers (Clumping)

DTA: Tree-Recolor



Application: “Directed Dispersion”



- FrontierBot
- WallBot
- InteriorBot
- ChargingBot
- GuideBot

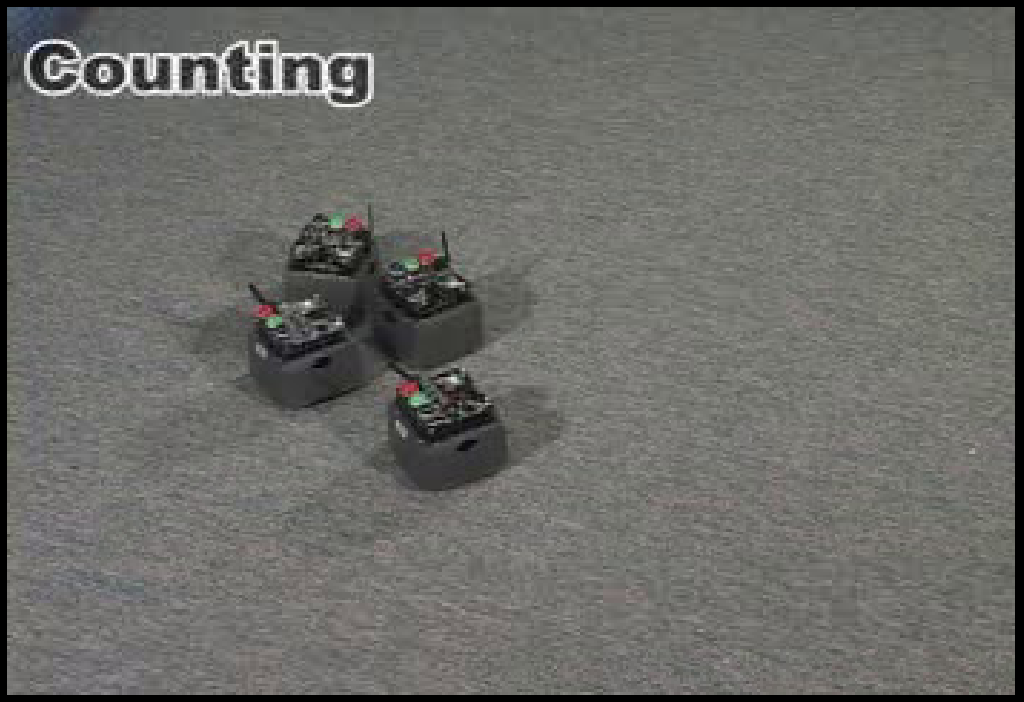
SWARM TREK


Thu Jan 29 18:49:05 2004
• Blue=Frontiers Red=Interior Green=Charging White=Guides


Thu Jan 29 13:15:44 2004

Limitations of Swarmish

- Have not found a good way to represent continuous quantities
- Current lexicon has about 108 usable patterns
- Sounds need to be carefully designed to work together
  $\Rightarrow$ lots of trial and error



Future Work

- Careful analysis of the human perceptual system and its bandwidth limitations
- How to optimally leverage multi-modal input
  - Rich non-speech and non-text interfaces
- Simple Augmented Reality Devices
  - Hand-held tools to query robots: Tricoder-like device

Conclusion

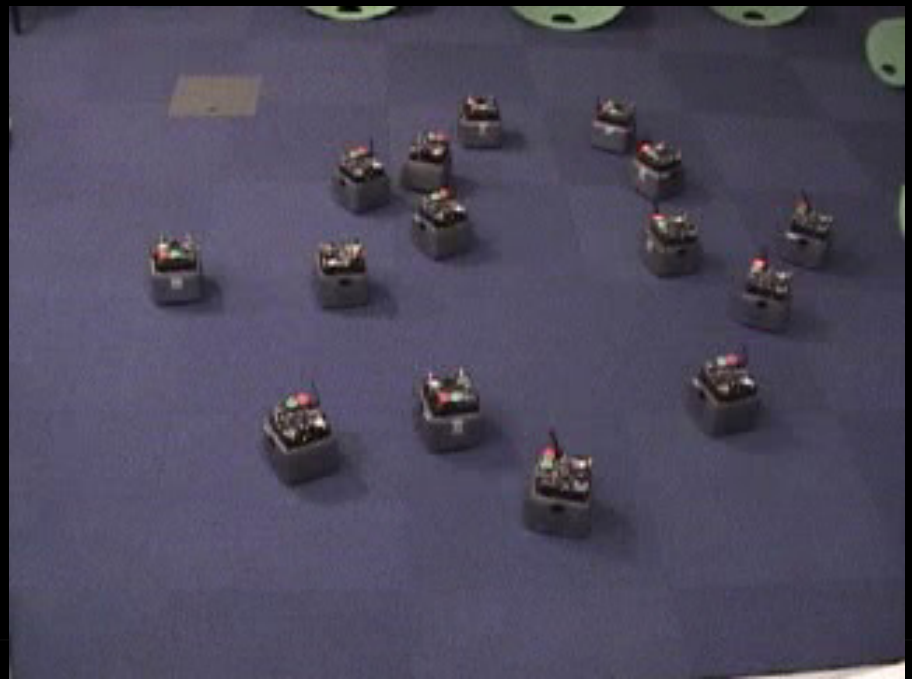
HMRI $\Rightarrow$ Usability $\Rightarrow$ Efficiency $\Rightarrow$

((Debug Cycles)/Second)++ $\Rightarrow$

((Ideas Tested)/Second)++ $\Rightarrow$

(Software Quality)++ $\Rightarrow$

(Publications/Second)++



Questions?