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Human Robotic Swarm Interaction Using An Artificial Physics Approach

LT Brenton Campbell

ADVISORS:

Asst Professor Dr. Timothy Chung

Senior Lecturer Richard Harkins

Monterey, California

WWW.NPS.EDU

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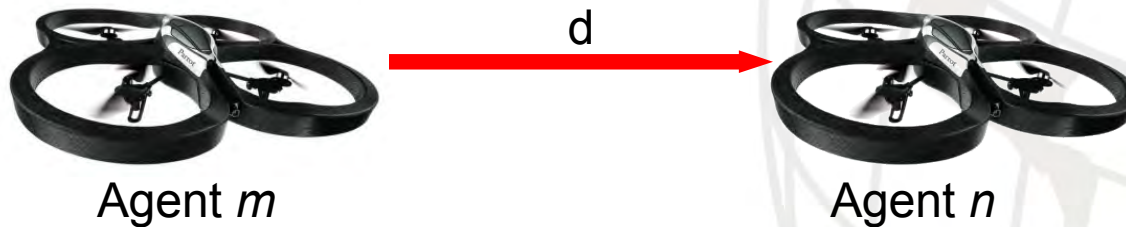
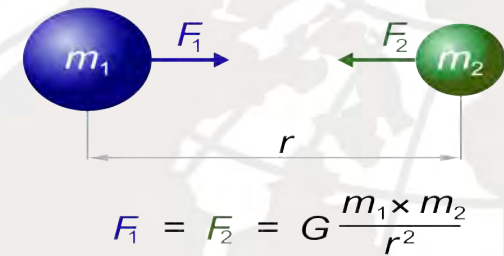
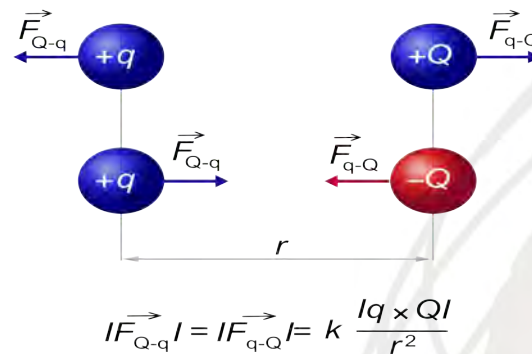
Artificial Physics (AP)

- Based on Newtonian Physics $\vec{F} = m \vec{a}$
- Each agent is treated as a point particle
 - Position x
 - Velocity v
- Discrete time step used to approximate continuous behavior

$$\Delta x = \vec{v} \Delta t$$

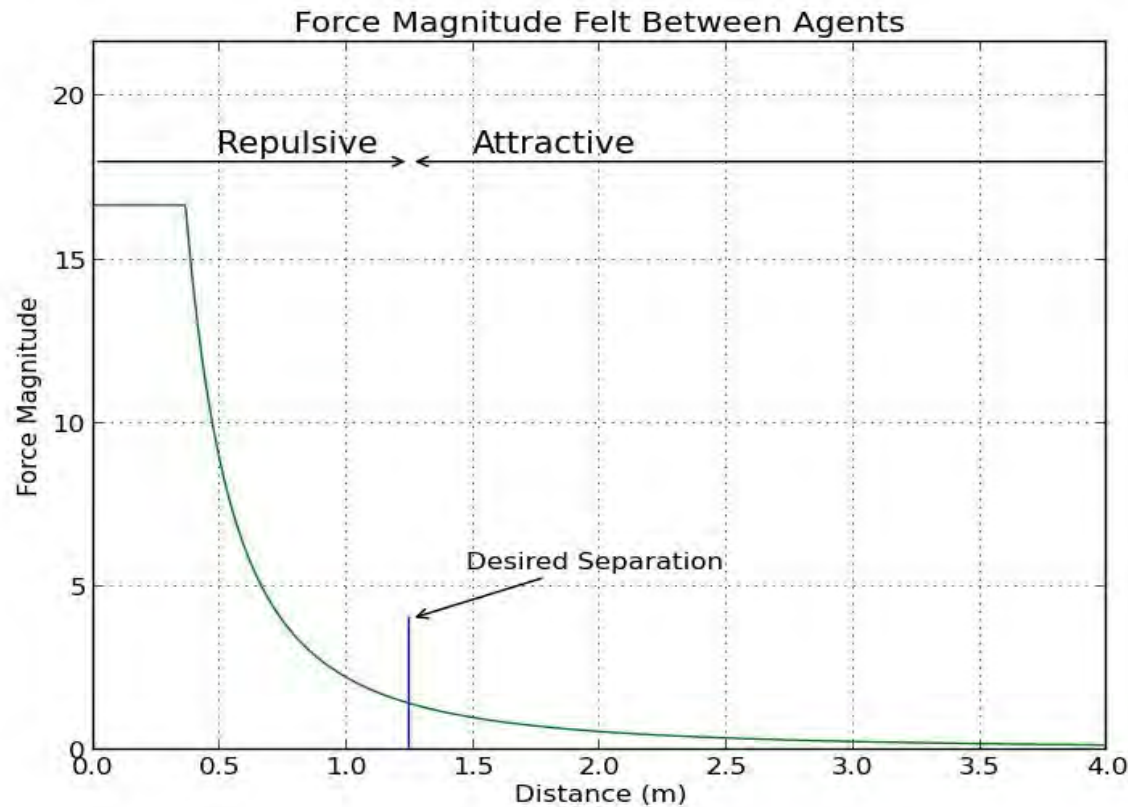
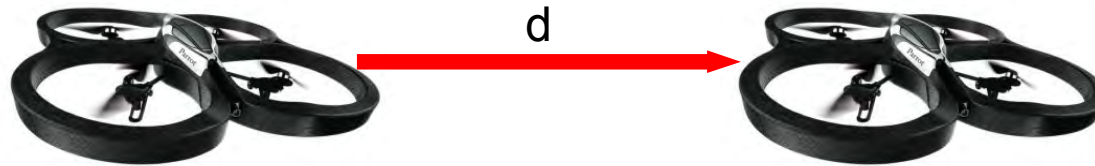
$$\Delta v = \frac{\vec{F} \Delta t}{m}$$

- Modeled after natural forces but not constrained to them
 - Attractive
 - Repulsive

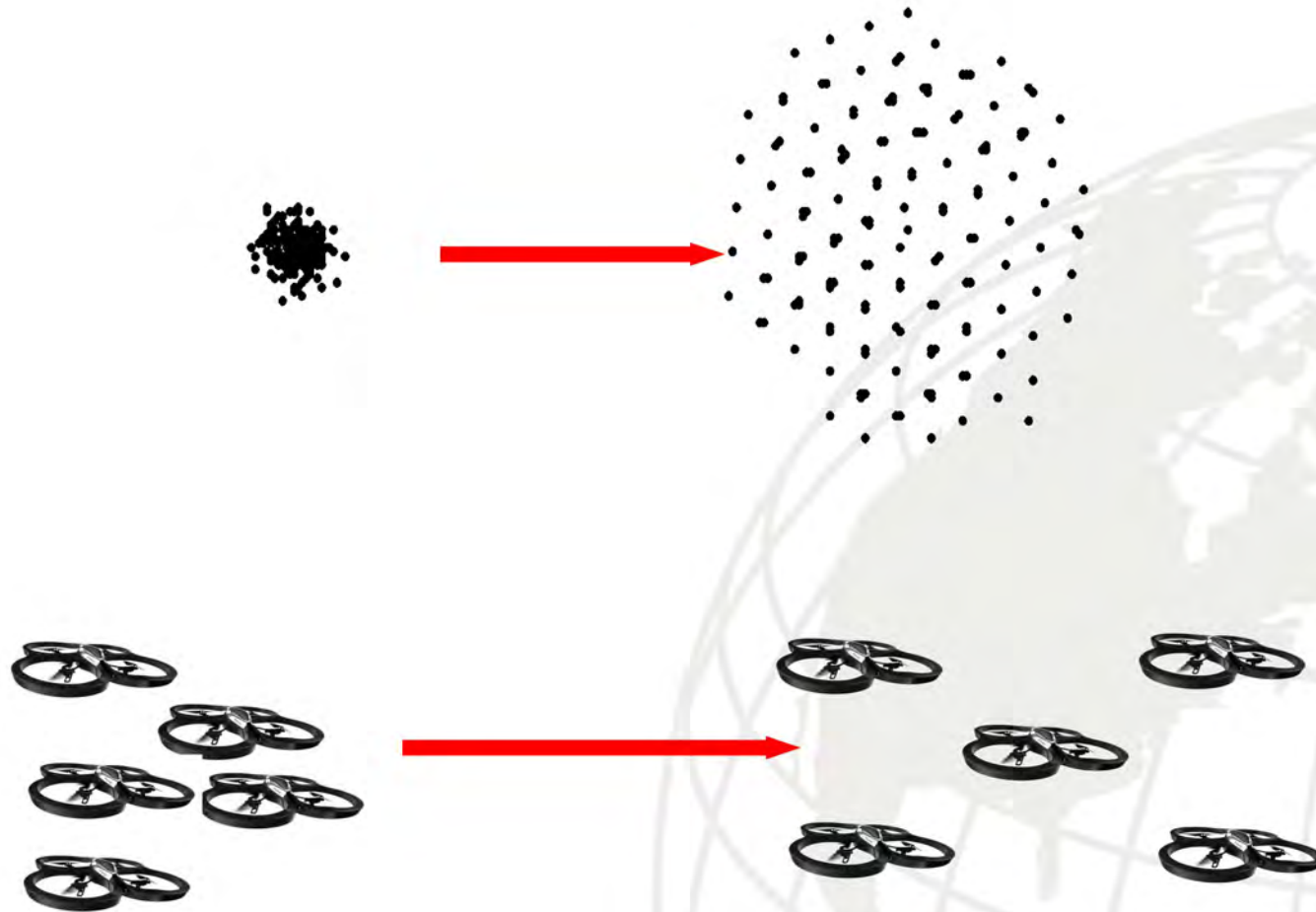


$$\mathbf{F}_{\text{agent}} = \frac{GMM}{(d_{m,n})^p} \hat{\mathbf{r}}_{m,n}$$

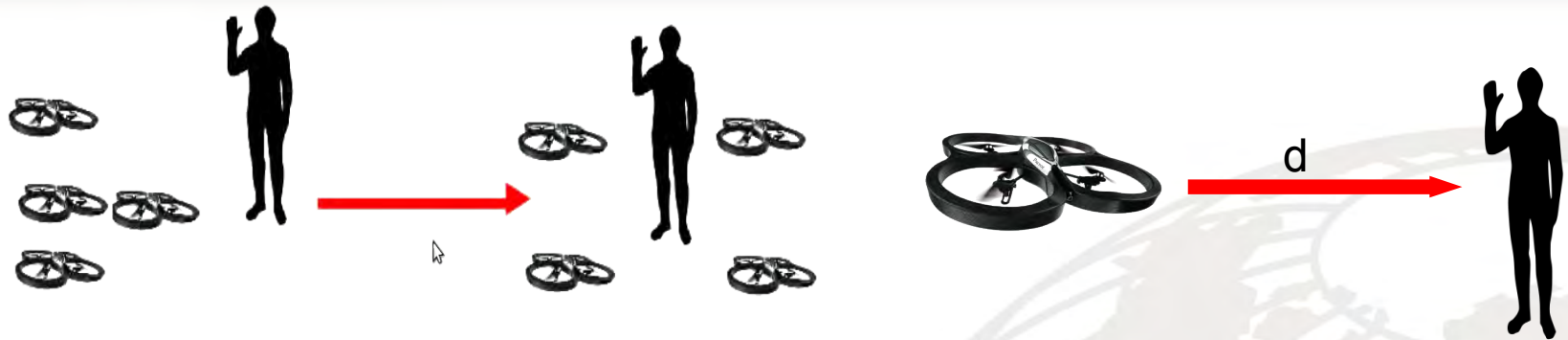
Using AP to Achieve Desired Agent Spacing



Self Organization into a Lattice



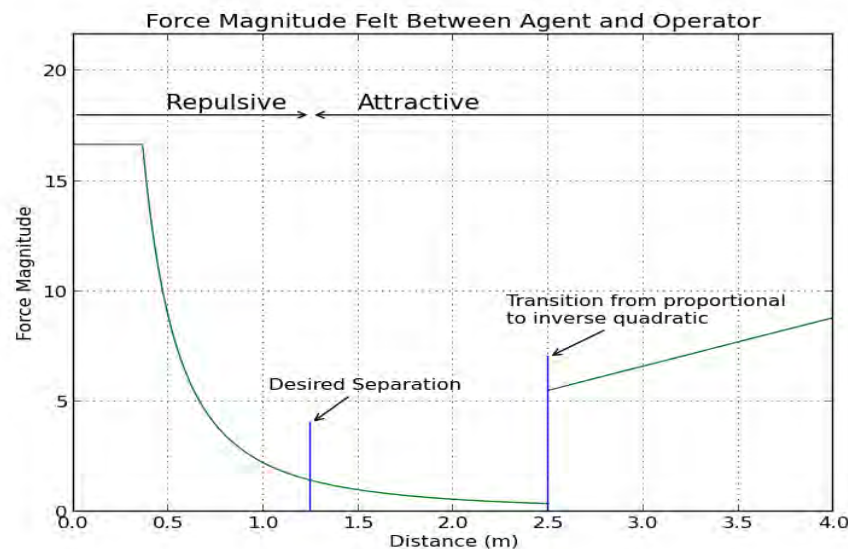
After many Δt



After many Δt but not too many Δt

$$\mathbf{F}_{\text{operator}} = \frac{CM}{(d_{m,op})^p} \hat{\mathbf{r}}_{m,op} \quad \text{where} \quad d_{m,op} < 2d_{\text{desired}}$$

$$\mathbf{F}_{\text{operator}} = -CMd_{m,op} \hat{\mathbf{r}}_{m,op} \quad \text{where} \quad d_{m,op} \geq 2d_{\text{desired}}$$



- Parrot AR.Drone™
 - 802.11b/g wifi self generated hotspot
 - 12 minutes of flight
 - Two cameras
 - Six Degrees of Freedom
 - Miniaturized IMUs track pitch, roll, and yaw
- Large open source base



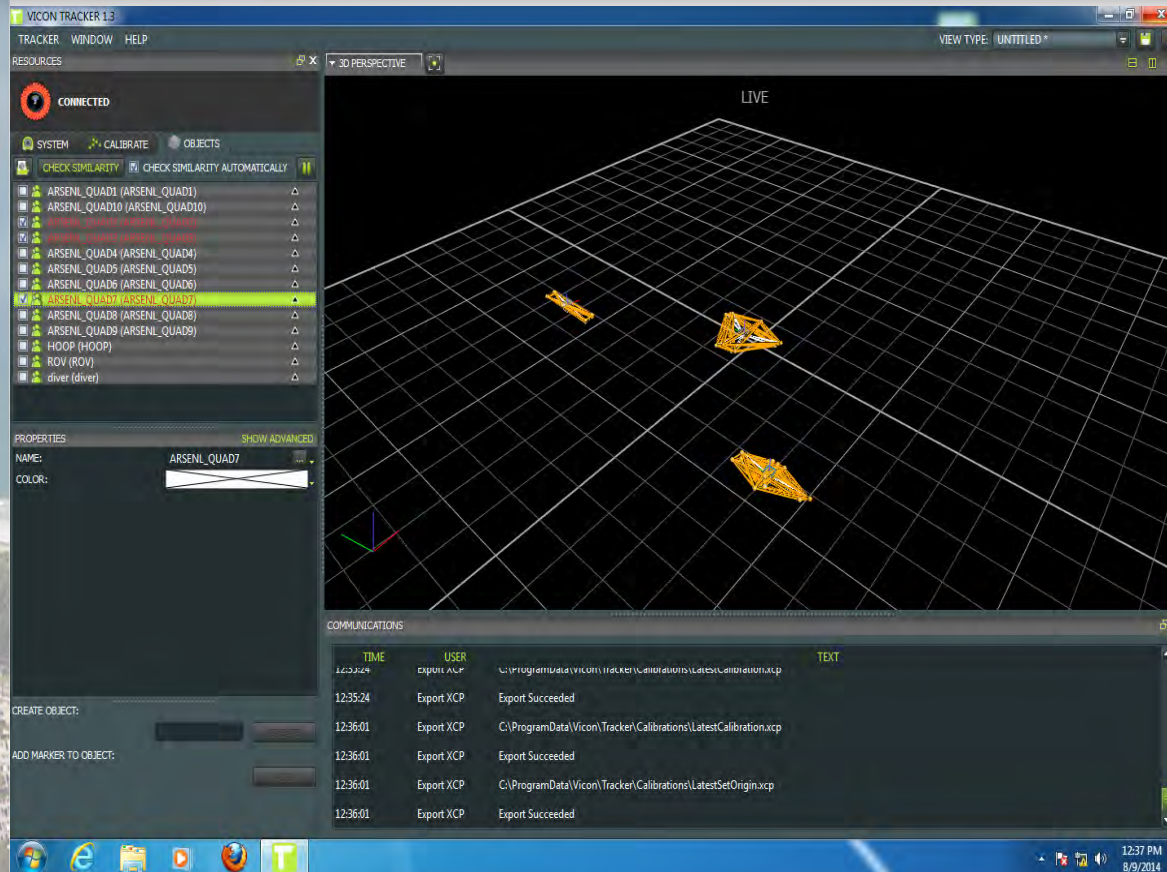


- VICON™
- 10 Cameras (and growing)
- Sub 1 cm accuracy
- x,y,z position and pitch,roll, yaw orientation





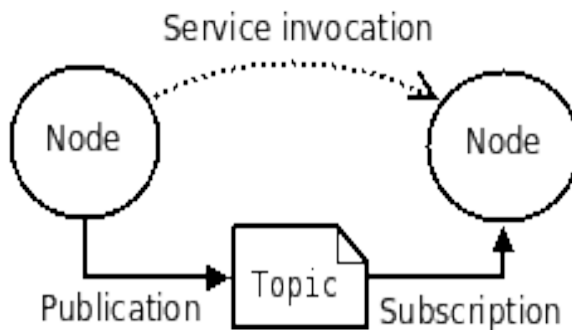
Constellation Identification and Tracking

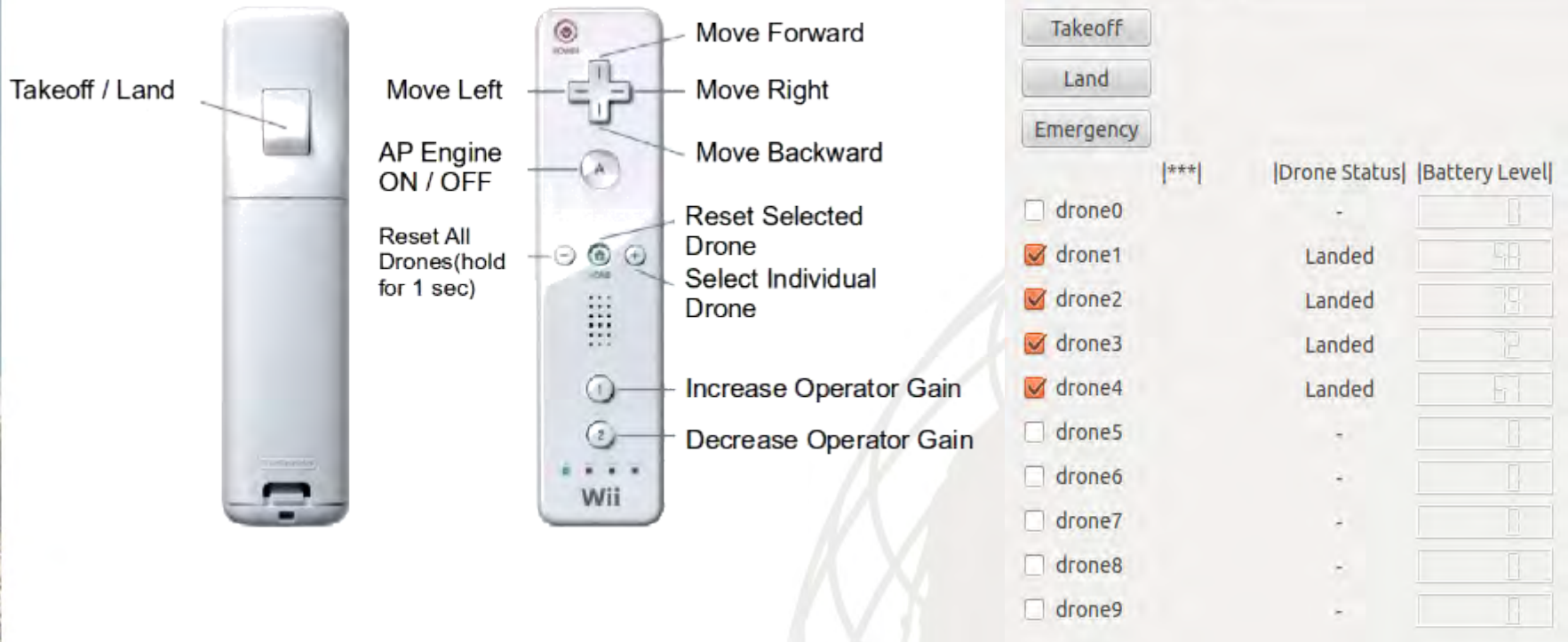


- IR reflectors, or markers, glued to objects
- Each object has a unique constellation
- Quaternions used to track orientation



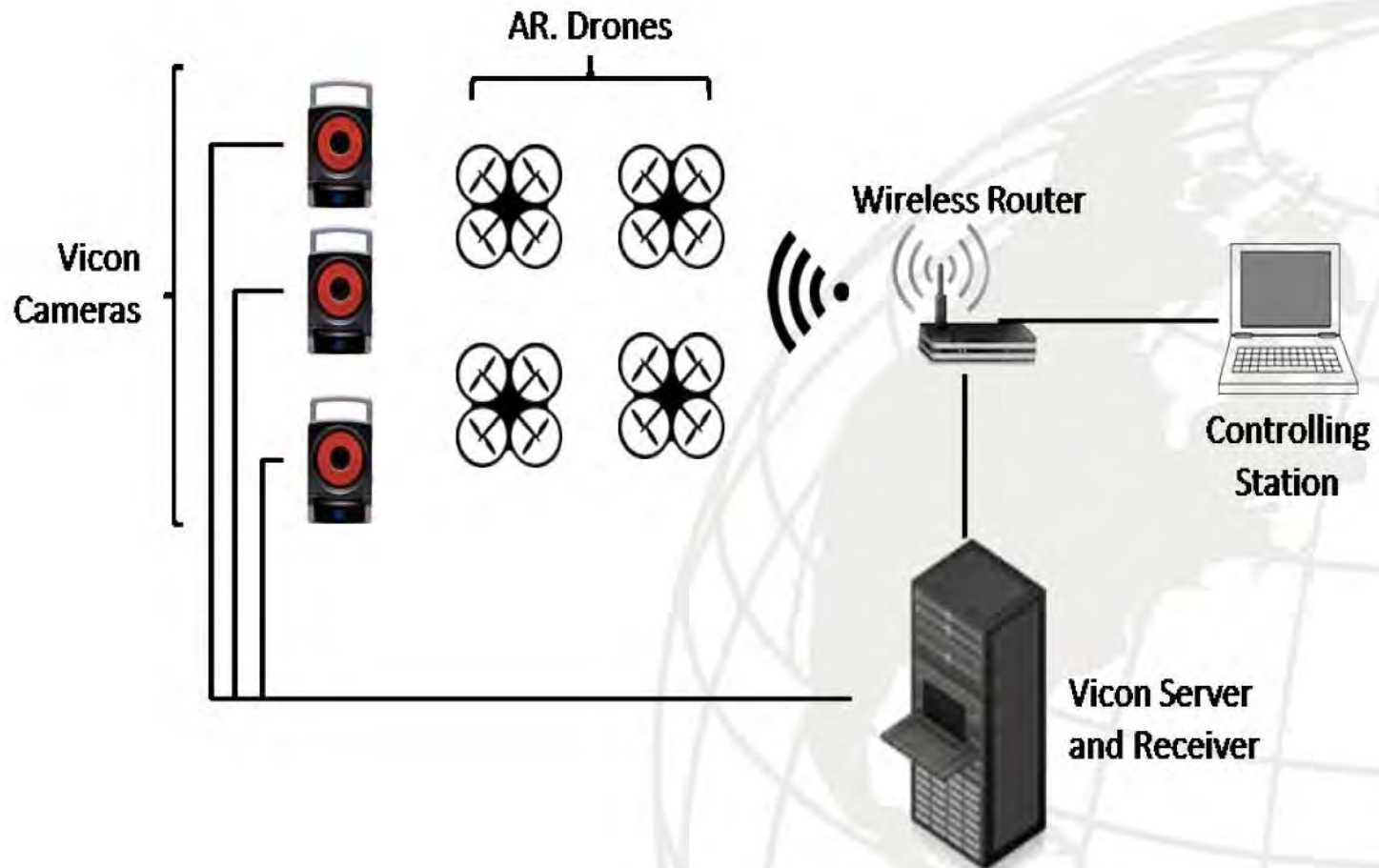
- Robotics Middleware
 - Hardware abstraction
 - Low-level device control
 - Implementation of commonly used functionality
 - Message-passing between processes
 - Package management
- Packages available for commonly available research and hobby grade sensors, controllers, and platforms
- Open Source

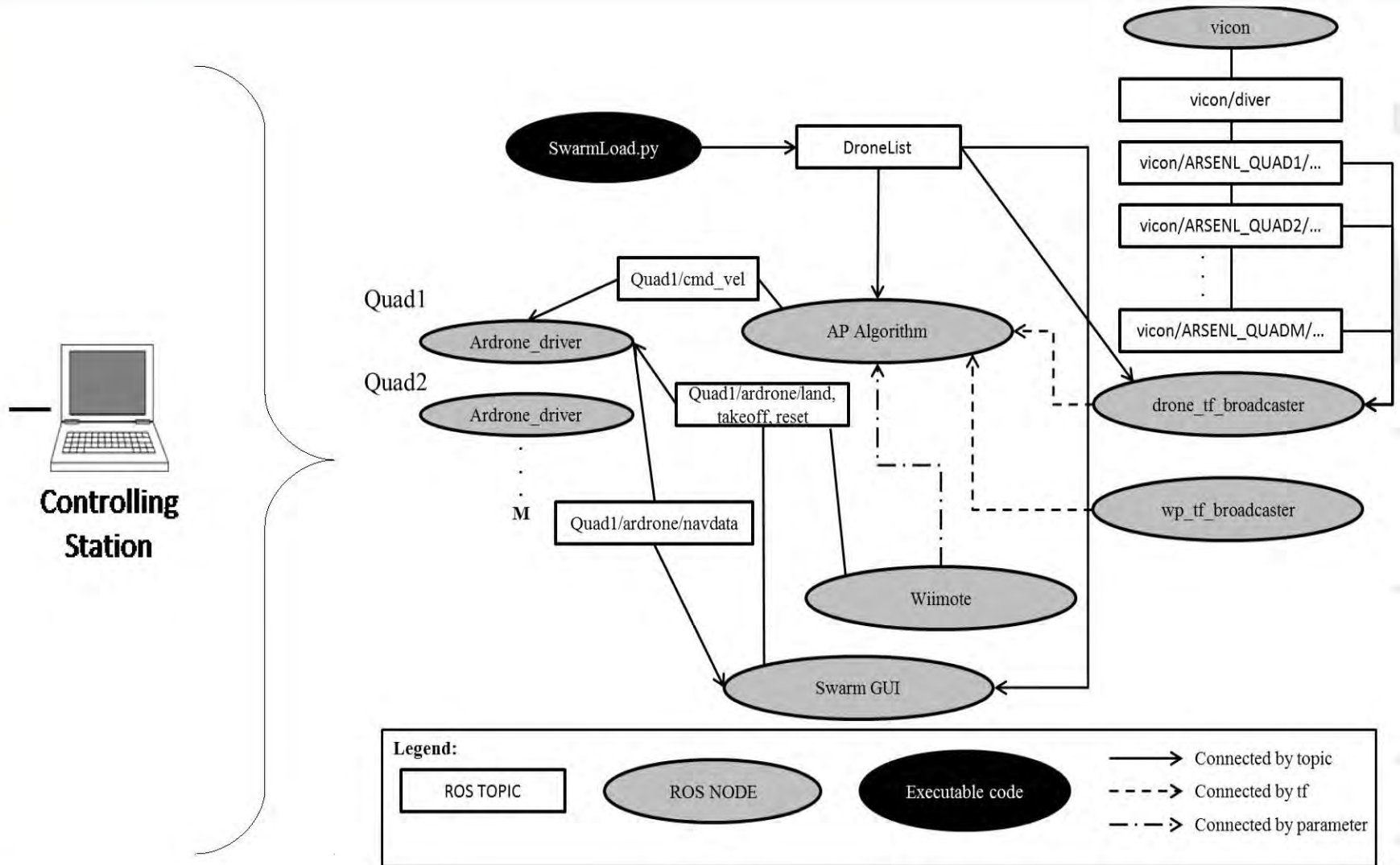




- Hand-held controller, Nintendo Wiimote, used for takeoff, landing, reset, parameter adjustment, and AP engine control
- Graphical User Interface used for group or single drone takeoff, landing, reset, and monitoring

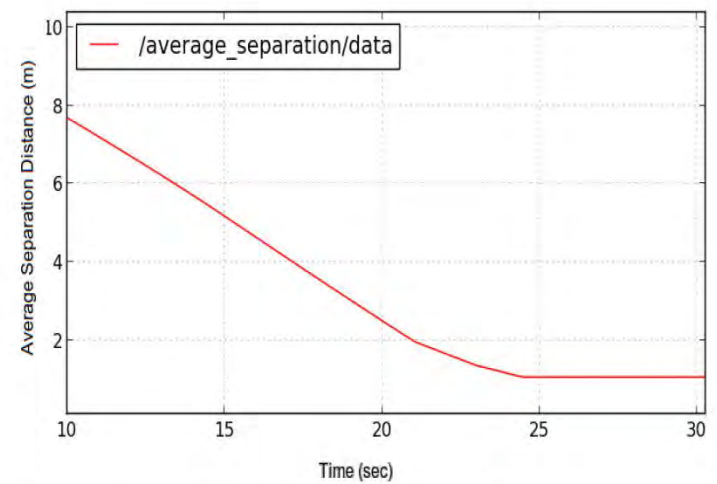
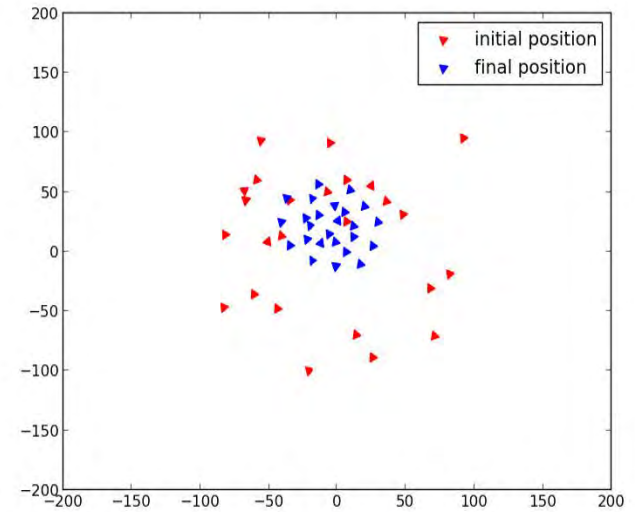
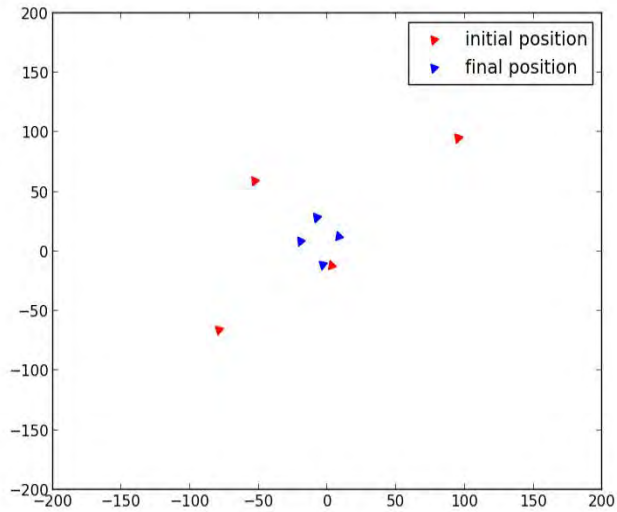
Hardware Integration







Simulation Results



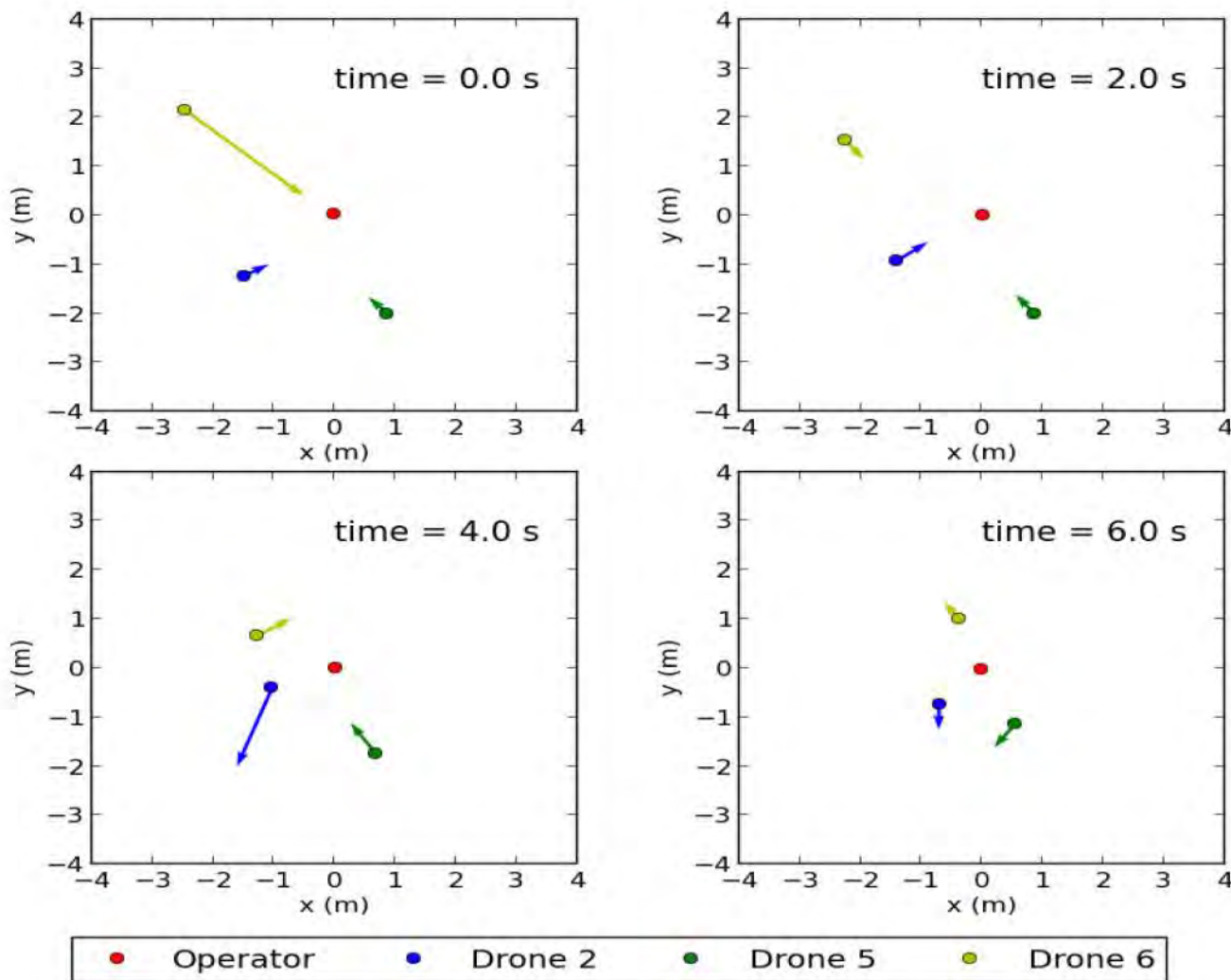


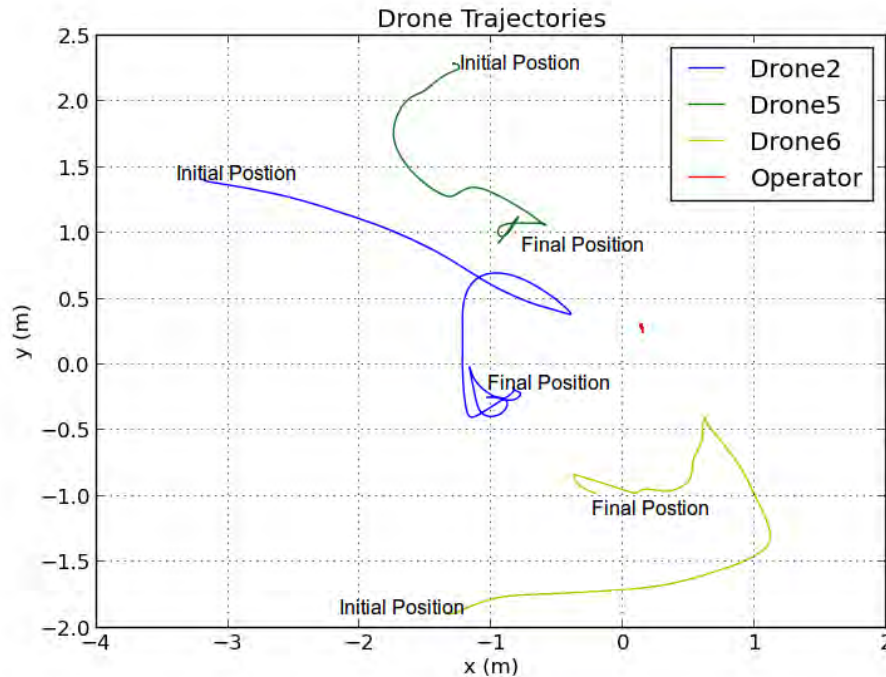
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Physical Experimentation

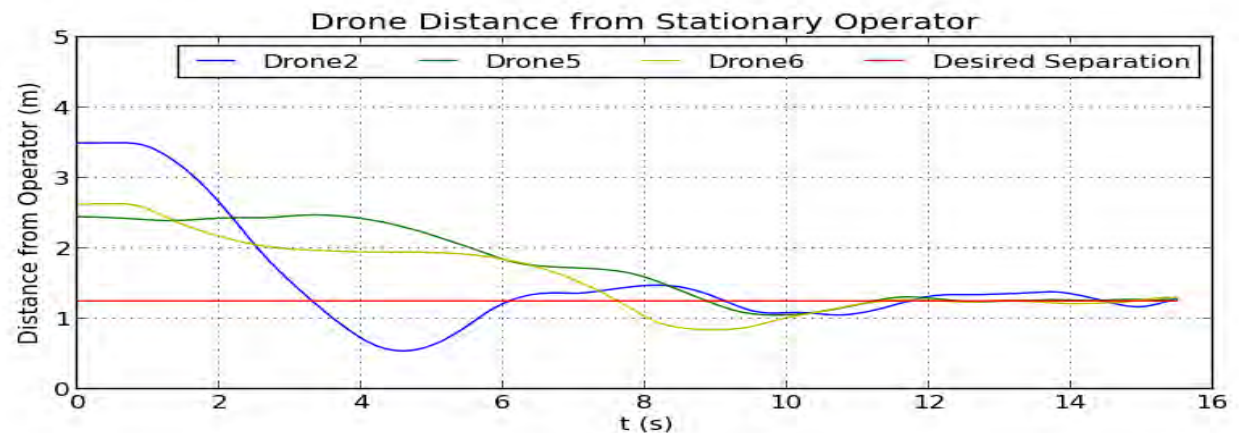


Force Vector Evolution

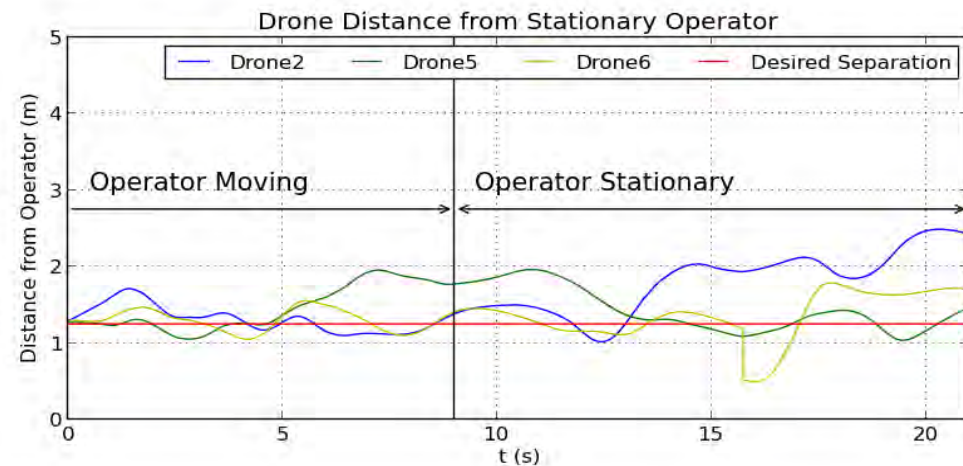
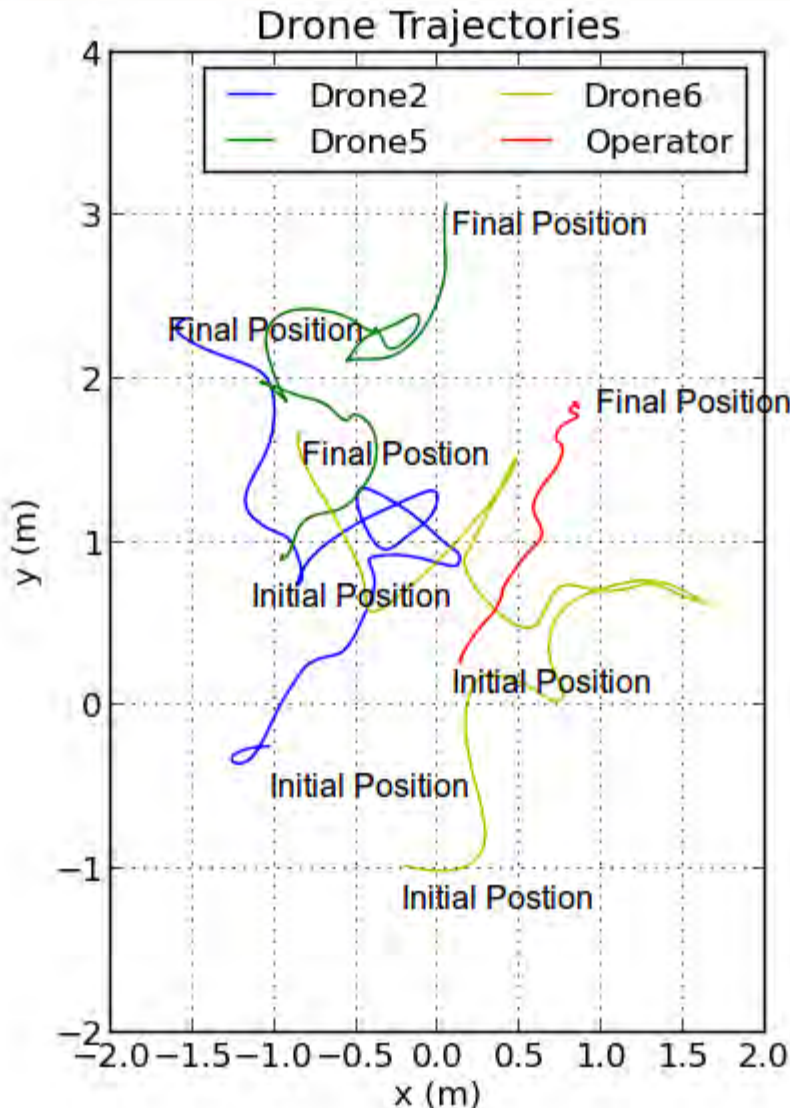




- After ~10 sec
drones achieve tight
formation around
operator
- Stable formation
with low separation
error ($< 20\%$)



- Drones follow operator during movement
- Difficulty in recreating formation after operator stops





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RVIZ Playback



- Demonstrated that an AP based framework allows a group of UAVs to autonomously follow a human operator
 - 2D and 3D simulations
 - Drone communication
 - Interface development: GUI and Wiimote
 - Hardware and software integration
 - Flight data playback
- Future work
 - Outdoor flight
 - More agent
 - Threat detection
 - Mission based testing





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Questions?



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