Human Robotic Swarm Interaction Using An Artificial Physics Approach

LT Brenton Campbell

ADVISORS:
Asst Professor Dr. Timothy Chung
Senior Lecturer Richard Harkins
**Human Robotic Swarm Interaction Using An Artificial Physics Approach**
(Briefing Charts)

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<th>Performing Organization Name(s) and Address(es)</th>
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<td>Naval Postgraduate School, Monterey, CA, 93943</td>
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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
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
  \[
  \Delta x = \vec{v} \Delta t \\
  \Delta v = \frac{\vec{F} \Delta t}{m}
  \]
Calculated Force

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

\[ F_{\text{agent}} = \frac{Gm_1m_2\hat{r}_{m,n}}{(d_{m,n})^p} \]

\[ F = \frac{k|q|Q}{r^2} \]
Using AP to Achieve Desired Agent Spacing

![Diagram showing force magnitude felt between agents as a function of distance. The graph indicates that force magnitude decreases exponentially with distance, with a desired separation marked at a specific distance.]
Self Organization into a Lattice

After many $\Delta t$

After many $\Delta t$
Adding an Operator

After many $\Delta t$ but not too many $\Delta t$

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

\[
F_{\text{operator}} = -CMd_{m,op}\hat{r}_{m,op} \quad \text{where} \quad d_{m,op} \geq 2d_{\text{desired}}
\]
Test Platform

• 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
Motion Capture

- **VICON™**
- 10 Cameras (and growing)
- Sub 1 cm accuracy
- x,y,z position and pitch, roll, yaw orientation
• IR reflectors, or markers, glued to objects
• Each object has a unique constellation
• Quaternions used to track orientation
Robotic Operating System

- **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
Force Vector Evolution

- **time = 0.0 s**
- **time = 2.0 s**
- **time = 4.0 s**
- **time = 6.0 s**

- Operator
- Drone 2
- Drone 5
- Drone 6

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Stationary Operator

- After ~10 sec, drones achieve tight formation around operator.
- Stable formation with low separation error (<20%).
Moving Operator

- Drones follow operator during movement
- Difficulty in recreating formation after operator stops
• 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
Questions?
References


