Development of an Outdoor Multi Agent Robot Toolkit at the UF Autonomy Park

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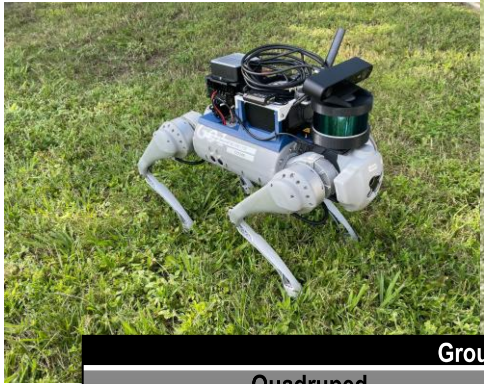
University of Florida Autonomy Park

- Support multi-agent outdoor robotics development
- 75x27x18 meter netted enclosure



Ground Robots		Aerial Robots
Quadruped	Wheeled	
(3) Unitree Go1	(2) Clearpath Jackal	(1) Freefly Alta-X
(1) Unitree B1	(2) Clearpath Husky	(3) Freefly Astro
		(20) Custom[1] Multirotor

[1] "Custom" refers to lab-built quadcopters assembled using a variety of off-the-shelf parts.

Research Objectives

- Research group standardization for working with 30+ robots
- Develop a toolkit for common functions
- Prove out the toolkit with a representative experiment

Project Goals

- Build confidence in state feedback information
  - Justify RTK-GPS
  - Multirotor aircraft altitude challenges
- Toolkit development
  - Automatic frame conversion in ROS2
  - Nonholonomic to holonomic command conversion
  - Visualization and data logging
  - Prove out a workflow to run herding experiments

Outdoor Localization

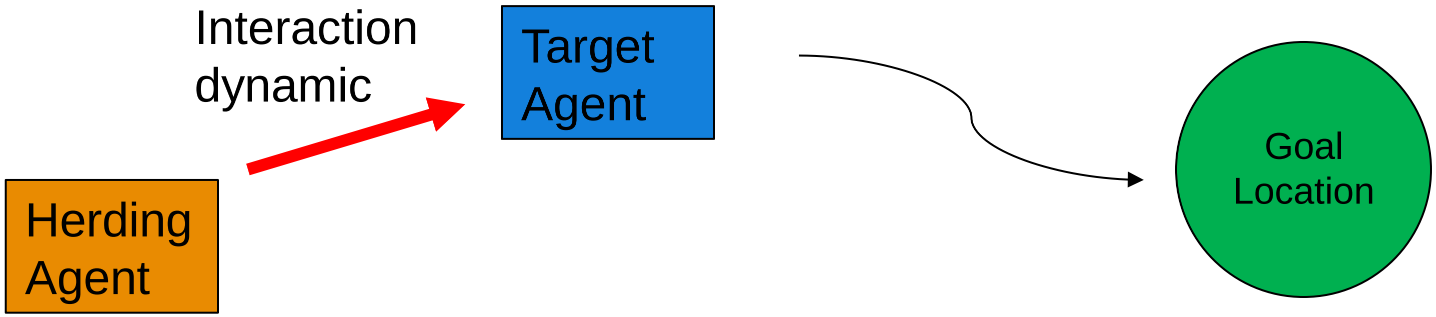
- Motion capture systems are unsuitable
- RTK-GPS (Real-Time Kinematic Global Positioning System)
  - A base station at a surveyed point broadcasts GPS corrections
  - CSRS-PPP used to survey
  - Emlid Reach RS3 (950g) & M2 (35g)

RTK-GPS Receiver Location	$\sigma_{E,avg}$ (m)	$\sigma_{N,avg}$ (m)	$\sigma_{U,avg}$ (m)
Base Station (RS3)	0.100	0.120	0.280
Clearpath Husky (RS3)	0.014	0.025	0.029
Unitree GO1 (M2)	0.071	0.066	0.162

Localization Challenges

- UAV Altitude Control
  - RTK-GPS unsuitable for direct altitude measurement (even fused with IMU data)
  - Inconsistent behavior as weather changes
  - AMSL pressure and local barometric pressure discrepancy
  - Downwards facing single-beam LIDAR
  - Barometer corrections (planned)

Herding


Interaction dynamic
Target Agent
Goal Location
Herding Agent

Who can Benefit

- Aerospace – UAV control [1]
- Defense – Missile Intercept Problems [2]
- Agriculture – Herding Livestock [3]

- Many problems benefit from Heterogenous Robotic Systems
  - Offer sensing and coordination advantages
  - Aerial and ground robots are well suited to help one another

Herding Controller

$$u \triangleq k_2 e_y - \left(\frac{k_1^2}{g} + g\right) e_x \quad (1)$$

$$e_x \triangleq x - x_g \quad (2)$$

$$e_y \triangleq y_d - y \quad (3)$$

[2]

Herding Controller

Herding Agent Control Output

Gains

Interaction Dynamic

$$u \triangleq k_2 e_y - \left(\frac{k_1^2}{g} + g\right) e_x \qquad (1)$$

Target Agent Error

Goal Location

$$e_x \triangleq x - x_g \qquad (2)$$

$$e_y \triangleq y_d - y \qquad (3)$$

Herding Agent Error

[2]

Herding Agent Desired Trajectory

Toolkit Development

Automatic Frame Conversion	Command Conversion	Common Experiment Functions
• Robot Operating System 2 (ROS2) TF library • Convert GPS data in world frame {*G*} to Autonomy Park frame {*L*} • Attach frame information to ROS2 *pose* messages	• Nonholonomic to holonomic command conversion • Allows ground and air robots to receive one type of command message (ROS2 *cmd_vel*)	• Simple integration function for coarse robot simulation • Real time visualization • Data logging to .csv files • Distance between every agent (Euclidian norm) • Interaction dynamics (fear-based) • Levy Walk (pareto distribution)

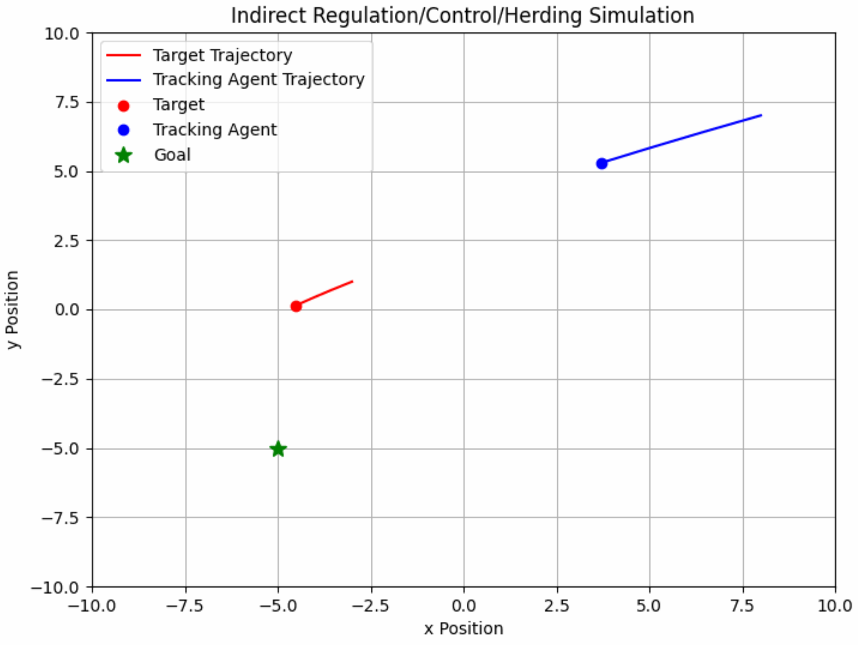
$$[v_{xG}, v_{yG}] \Longrightarrow [v_{xL}, v_{yL}]$$

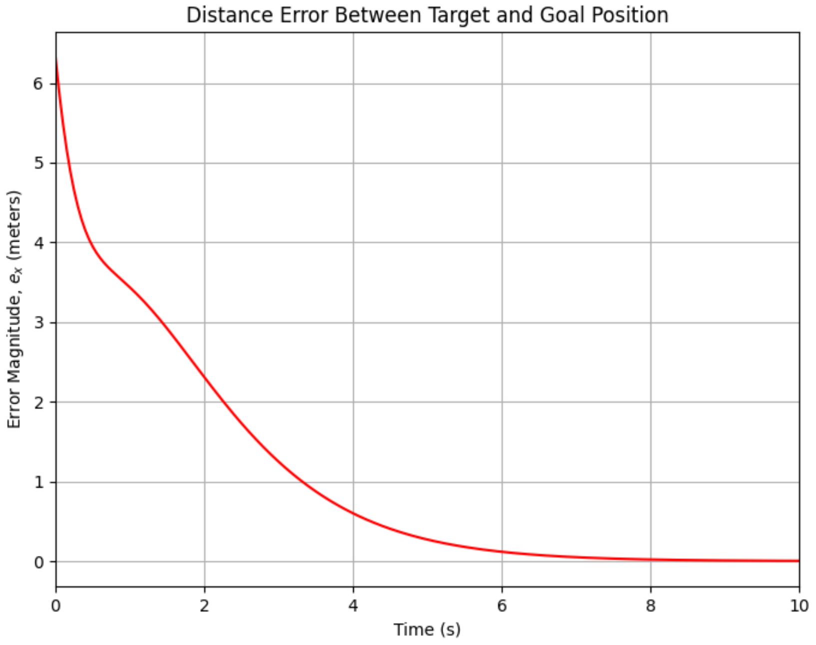
$$[v_x, v_y] \Longrightarrow [v, \omega]$$

Herding Toolkit Benefits

- Separates development and test hardware
- Standardizes the group’s convention when implementing experiments
- Included visualization tools help monitor controller performance

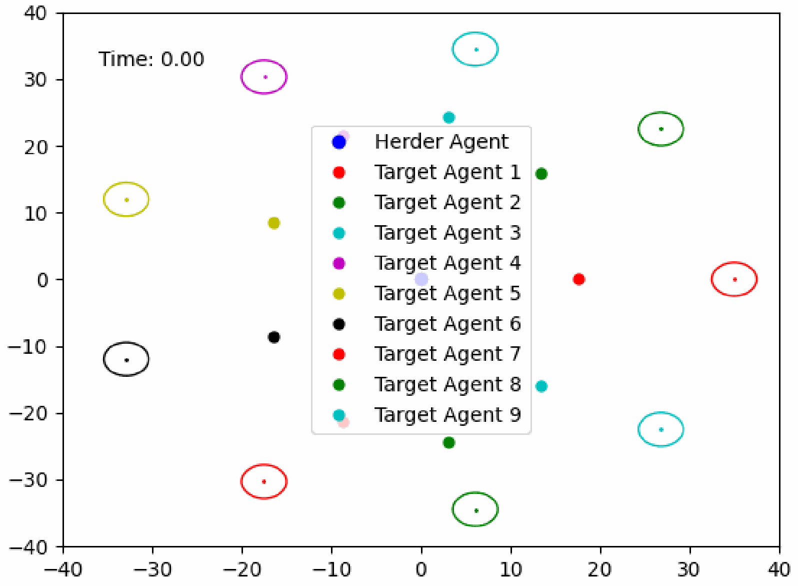
Simulated Results

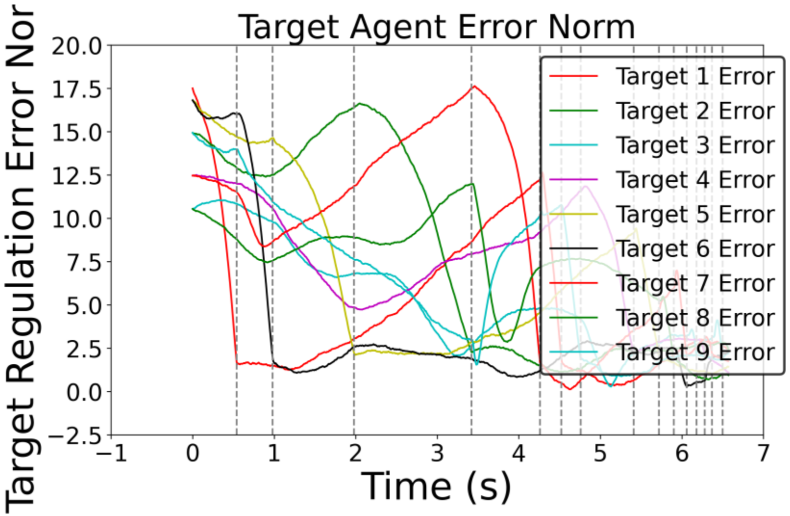




N-agent compatible

Implementation based on Adaptive Control work by C. Nino [4]





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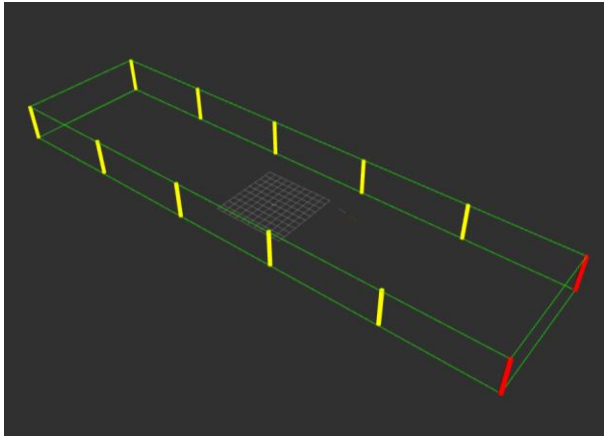
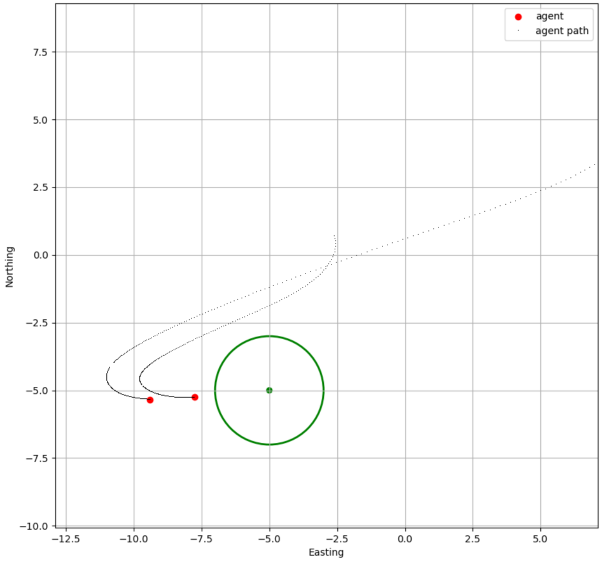
ROS2-in-the-loop Simulation

- Euler integration for position updates
- RVIZ environment to verify trajectories





Limitations and Next Steps

- Only compatible with 2D problems, projected cylinders
- Multirotor aircraft have limited control in flight

- Run an experiment
- Incorporate additional robots

References

[1] Chipade, Vishnu S, and Panagou, D. “Aerial Swarm Defense Using Interception and Herding Strategies.” IEEE Transactions on Robotics, Vol. 39, 2023, pp. 3821–3837. https://doi.org/10.1109/TRO.2023.3292514.

[2] Licitra, R. A., Neale, A. J., Doucette, E. A., and Curtis, J. W. Adversarial Aircraft Diversion and Interception Using Missile Herding Techniques. No. 10982, 2019, pp. 335–343. https://doi.org/10.1117/12.2519148.

[3] Long, N. K., Sammut, K., Sgarioto, D., Garratt, M., and Abbass, H. A. “A Comprehensive Review of Shepherding as a Bio Inspired Swarm-Robotics Guidance Approach.” IEEE Transactions on Emerging Topics in Computational Intelligence, Vol. 4, 2020, pp. 523–537. https://doi.org/10.1109/TETCI.2020.2992778.

[4] Nino, C. F., Patil, O. S., Philor, J. N., Bell, Z. I., and Dixon, W. E. Deep Adaptive Indirect Herding of Multiple Target Agents with Unknown Interaction Dynamics.

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