Experimental Improvements to Event-Triggered Indirect Herding Control of a Cooperative Agent

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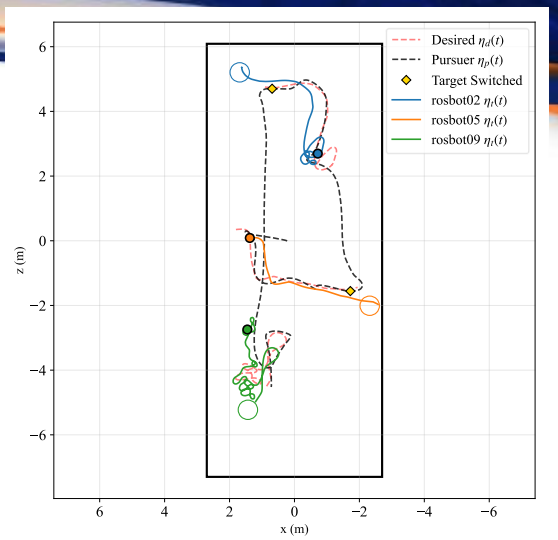
Honors Thesis Presentation | April 6, 2026



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- Systems often operate in environments that include:
  - Unknown terrain
  - Complex environments (extreme weather, marine, etc.)

- Limitations
  - Sensing
  - Energy usage

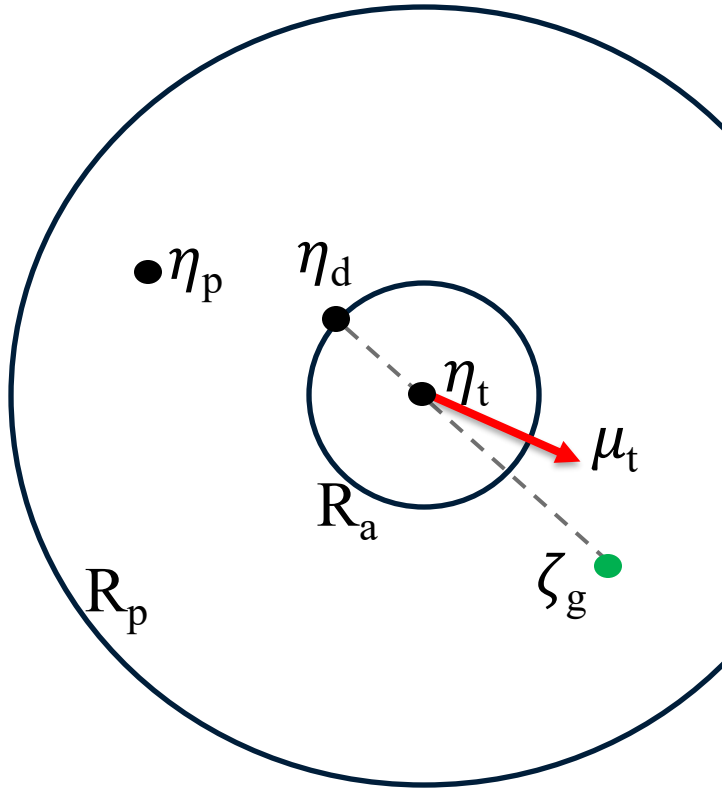
- An event triggered herding control framework was developed by Amy et al. (2026)

- Pursuer Agent:

$$\dot{\eta}_p(t) \triangleq \mu_p(t)$$
$$\eta_d(t) \triangleq \eta_t(t) + R_a S_0$$
$$S_0 \triangleq e_t(t)/||e_t(t)||$$
$$\mu_p(t) \triangleq \dot{\eta}_d(t) + (\beta+1)e_p(t)$$

Error systems:

$$e_t(t) \triangleq \eta_t(t) - \zeta_g$$
$$e_p(t) \triangleq \eta_d(t) - \eta_p(t)$$



- Target Agent:

$$\dot{\eta}_t(t) \triangleq f(\eta_t(t)) + \mu_t(\eta_t(t_k), \eta_p(t_k))$$

  - Influence:

$$\mu_t(\eta_t(t_k), \eta_p(t_k)) \triangleq \begin{cases} \nu_t \left(\frac{\eta_t(t_k) - \eta_p(t_k)}{\|\eta_t(t_k) - \eta_p(t_k)\|} \right), & \text{if } \|\eta_t(t_k) - \eta_p(t_k)\| \leq R_p \\ 0, & \text{otherwise,} \end{cases}$$

  - Drift: $f(\eta_t(t)) = \tanh(\eta_t(t))$

P. M. Amy, B. C. Fallin, J. N. Philor, and W. E. Dixon, "Event-triggered indirect herding control of a cooperative agent," IEEE Robotics and Automation Letters, vol. 11, no. 3, pp.3828–3835, 2026

1. Stochastic Drift
2. Multi-agent Switching
3. Experimental Safety in the Indoor Lab

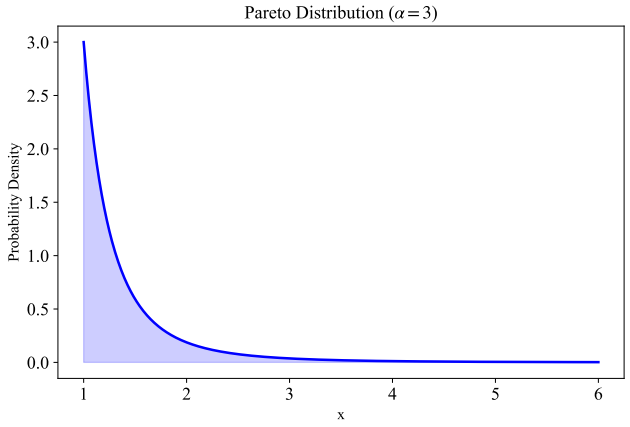
- Random step vector

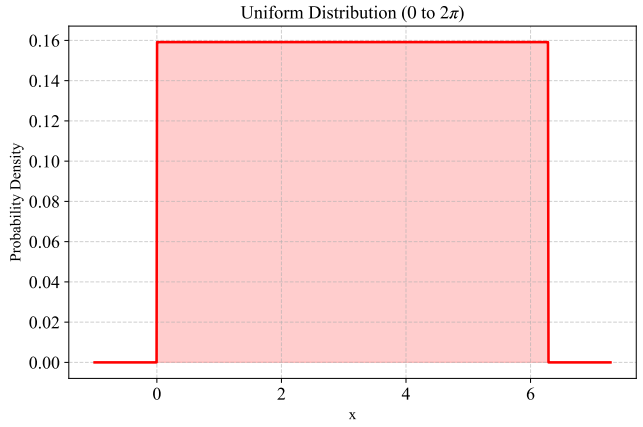
$$\eta_t(t_{k+1}) = \eta_t(t_k) + \Delta\eta_t(t_k)$$

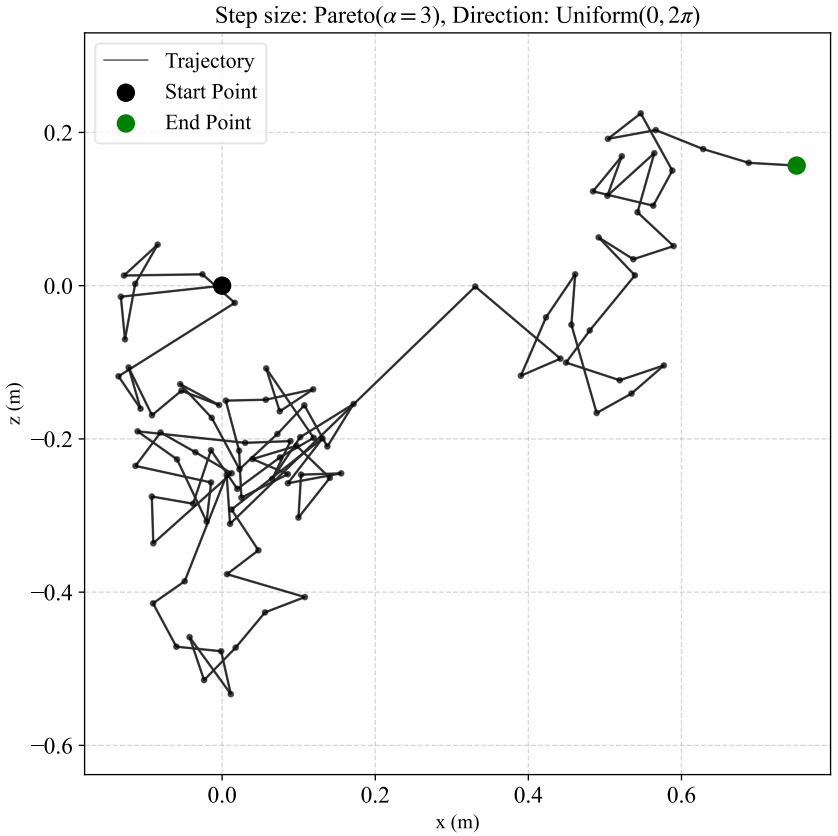
$$\Delta\eta_t(t_k) = \begin{bmatrix} s_k \cos\theta_k \\ s_k \sin\theta_k \end{bmatrix}$$

- Step size and heading

$$s_k \sim \text{Pareto}(\alpha_{Pareto}), \quad \theta_k \sim \text{Uniform}(0, 2\pi)$$





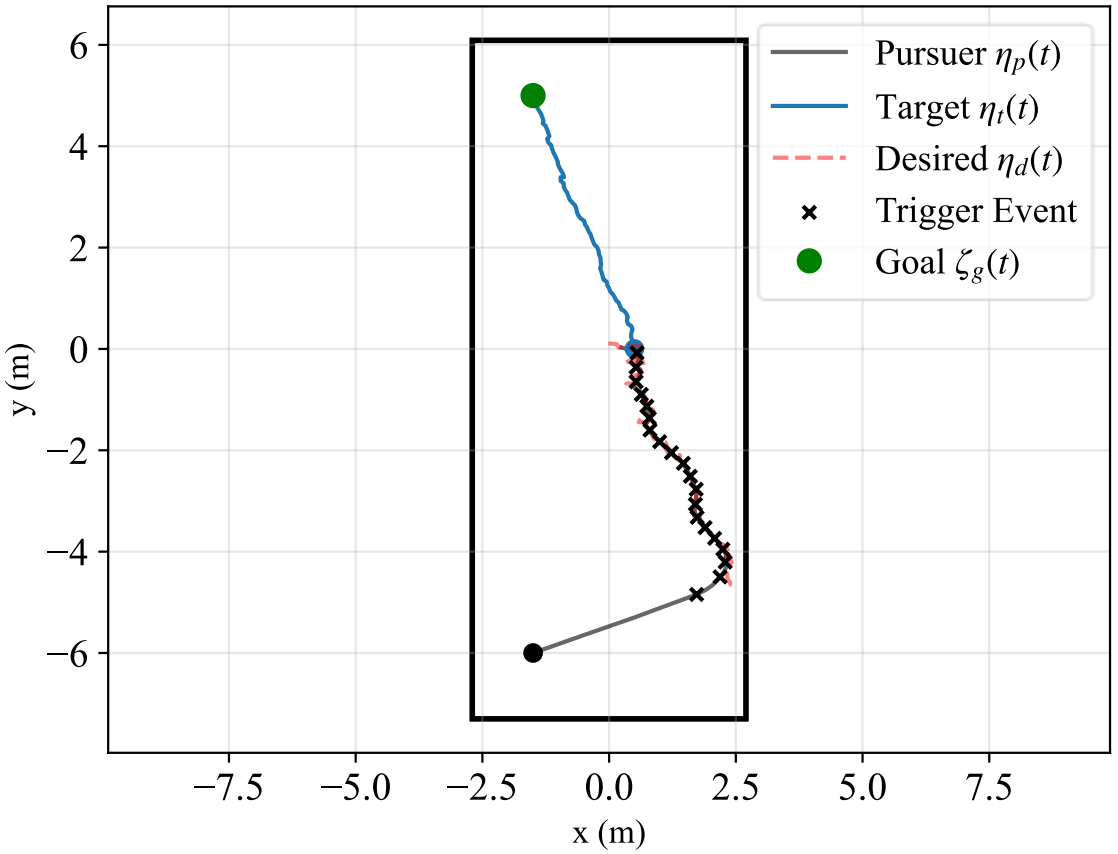


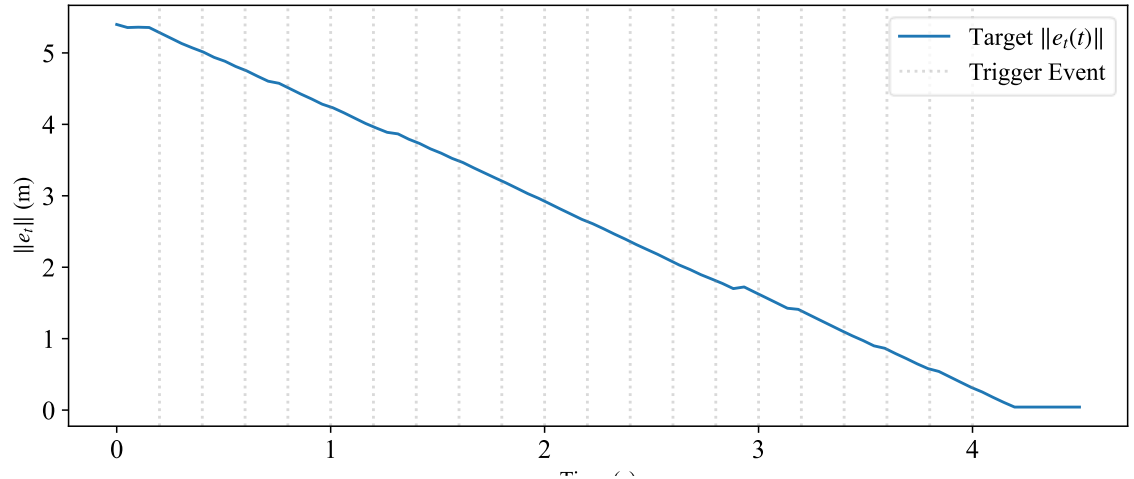
- Individually herd targets before switching to the next target with greatest goal error

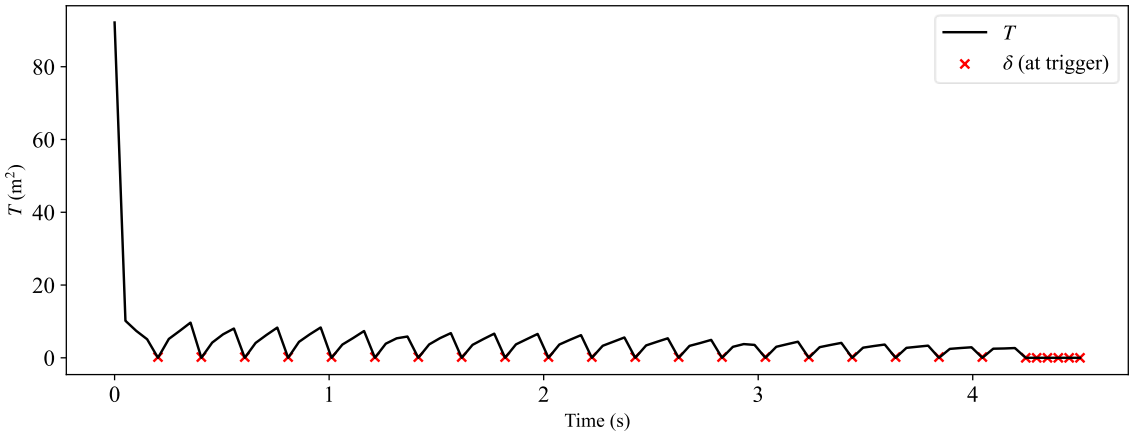
- Target drift is bounded by kinematic limits
- Target goal error is bounded by goal radius ε
- Global error is practically bounded

- Operating Modes
  - **Chased mode**: target agent will be herded to goal location
  - **Unchased mode**: target agent will drift and receive no pursuer influence commands
    - Targets were configured to stop at their goal locations

- 1 pursuer, 1 target

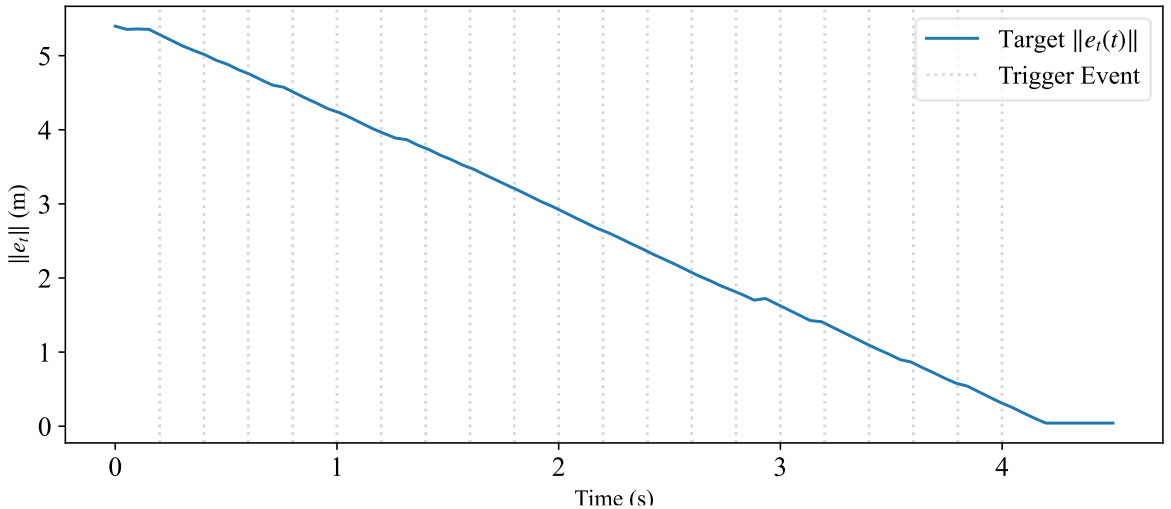






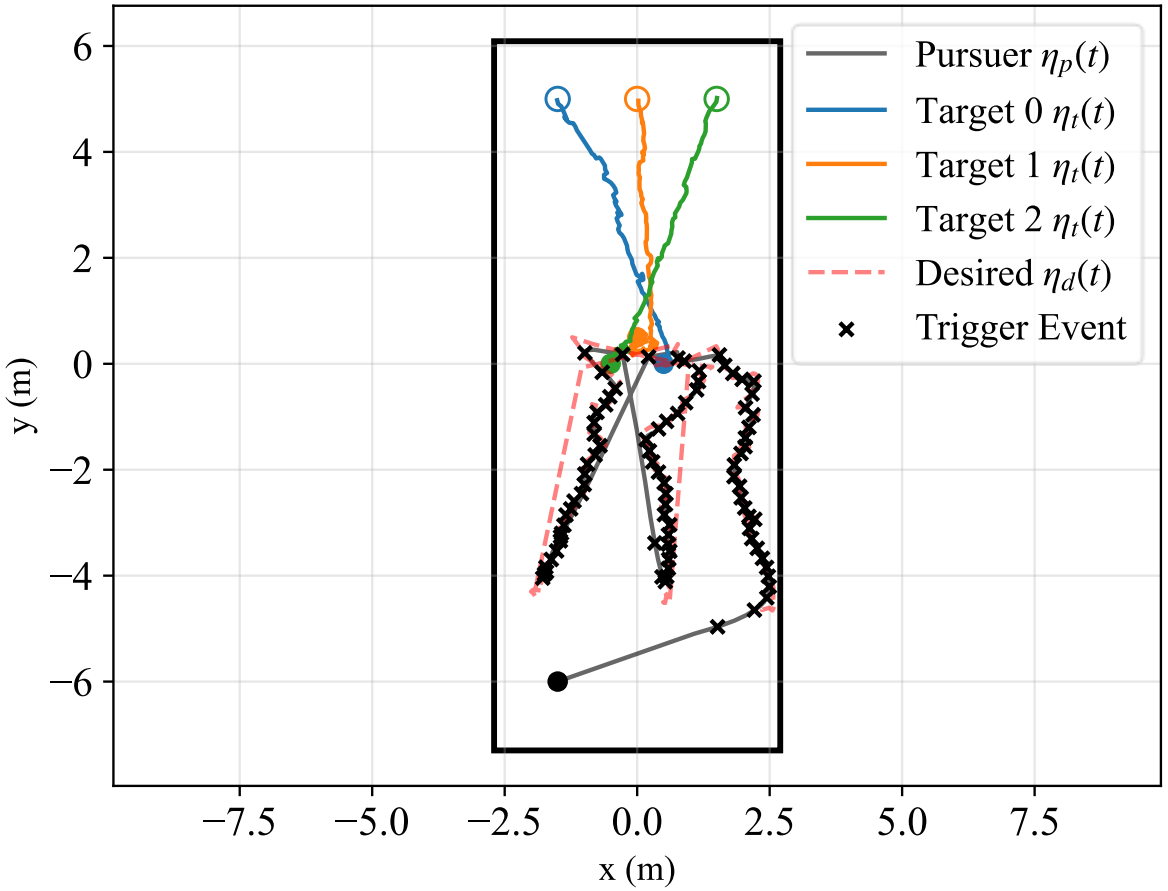
- Upper IET bound, $\delta_{max} = 0.178$ (~6 Hz)
- Lower IET bound, $\delta_{min} = 0.0178$ (~60 Hz)

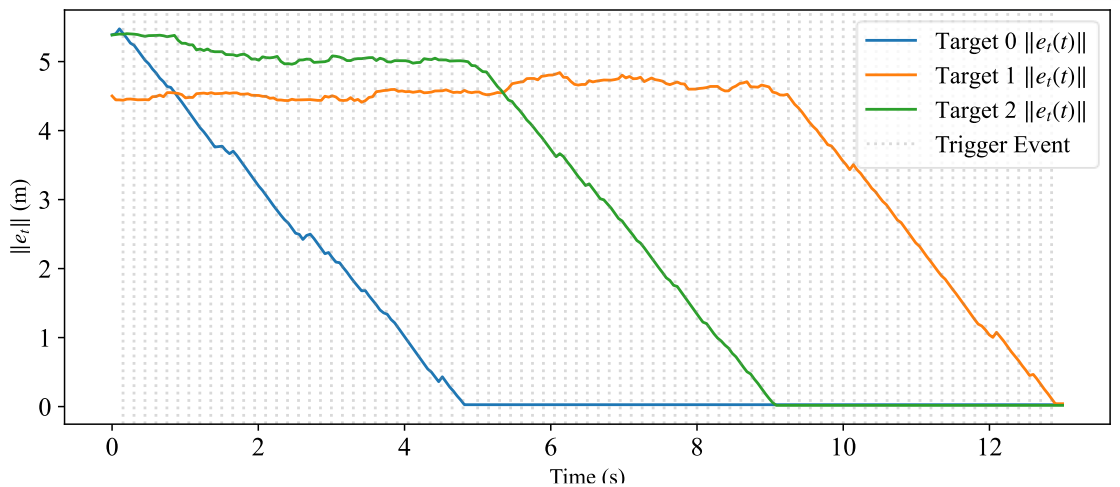
- $\delta_{min} = 0.1\ \delta_{max}$
- δ_{max} found using stability analysis

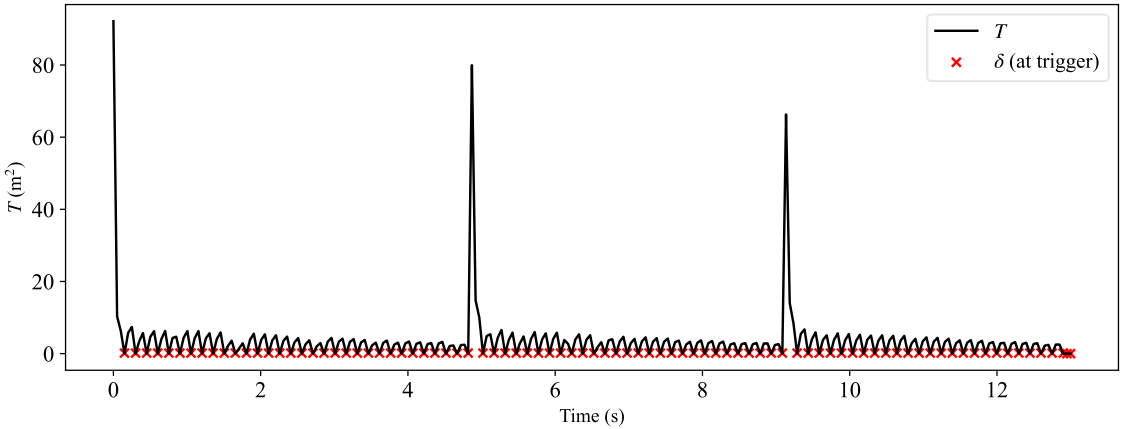


- Trigger configured to allow higher frequency updates, but will default to timer

- 1 pursuer, 3 targets

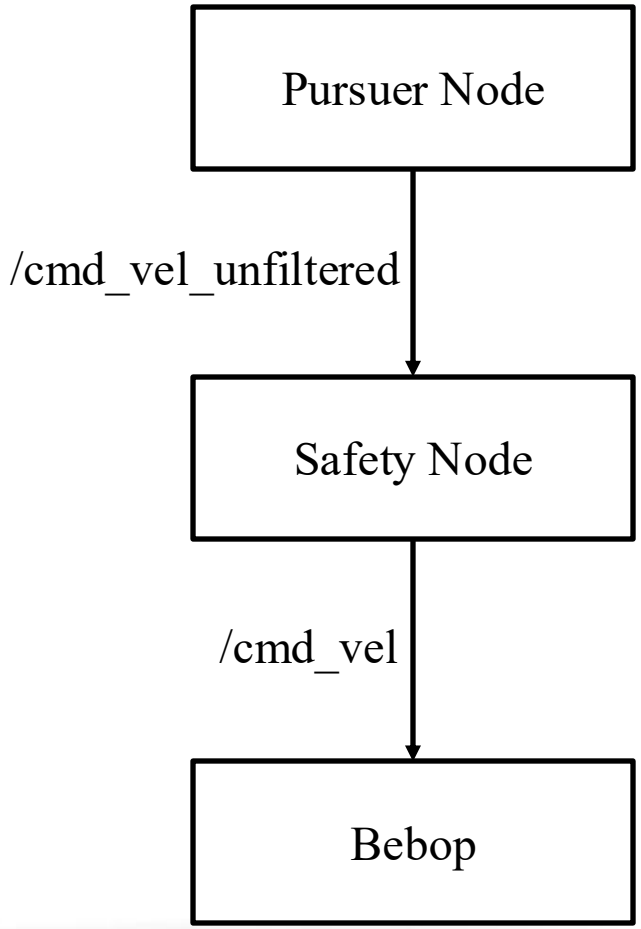






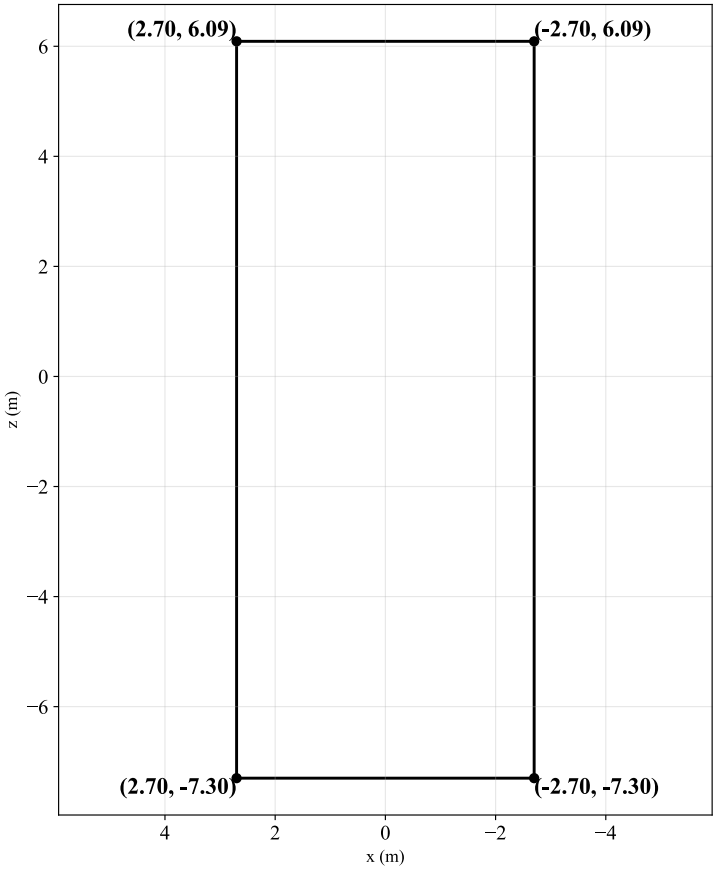
- Goal: prevent quadcopters from exiting a defined boundary
- Distance to nearest boundary, d

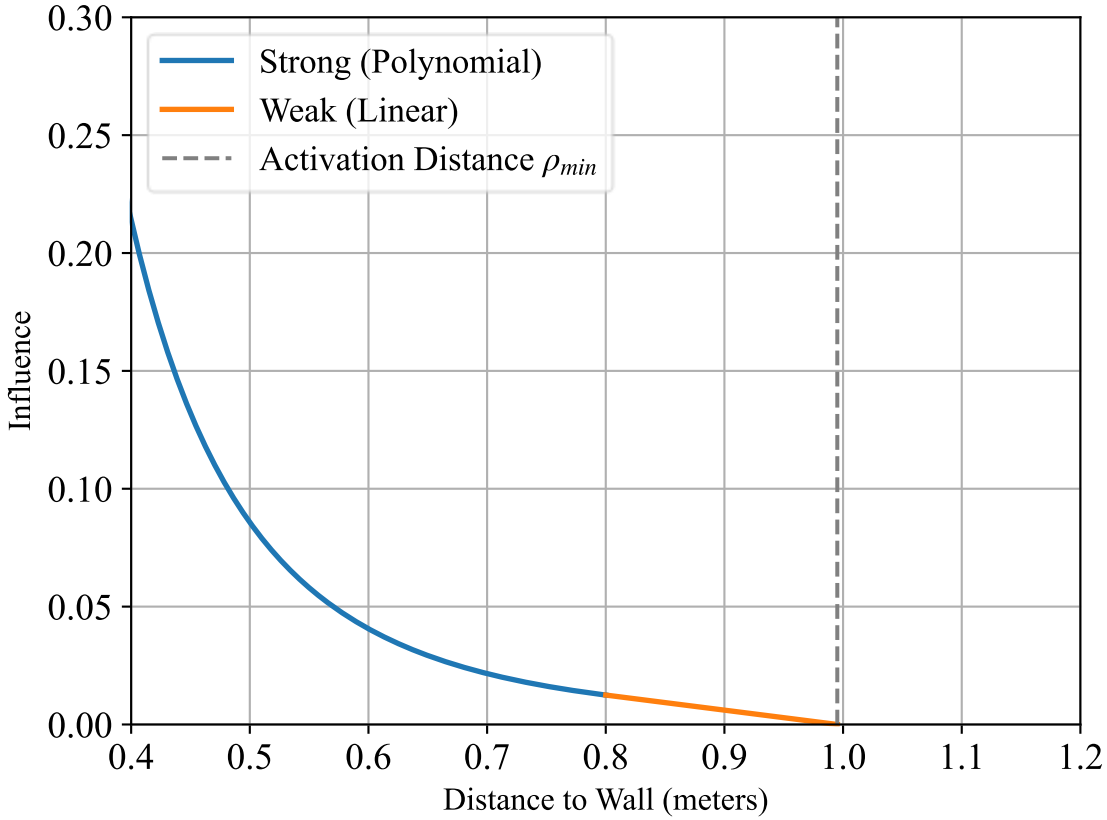
- Repulsive velocity command: $\phi(d) = \begin{cases} ad^{-b}, & 0 < d \leq p \\ -abp^{-(b+1)}d + ap^{-b}(1+b), & p < d \leq \rho_{\min} \\ 0, & d > \rho_{\min} \end{cases}$
- Activation distance: $\rho_{\min} = p\frac{1+b}{b}$



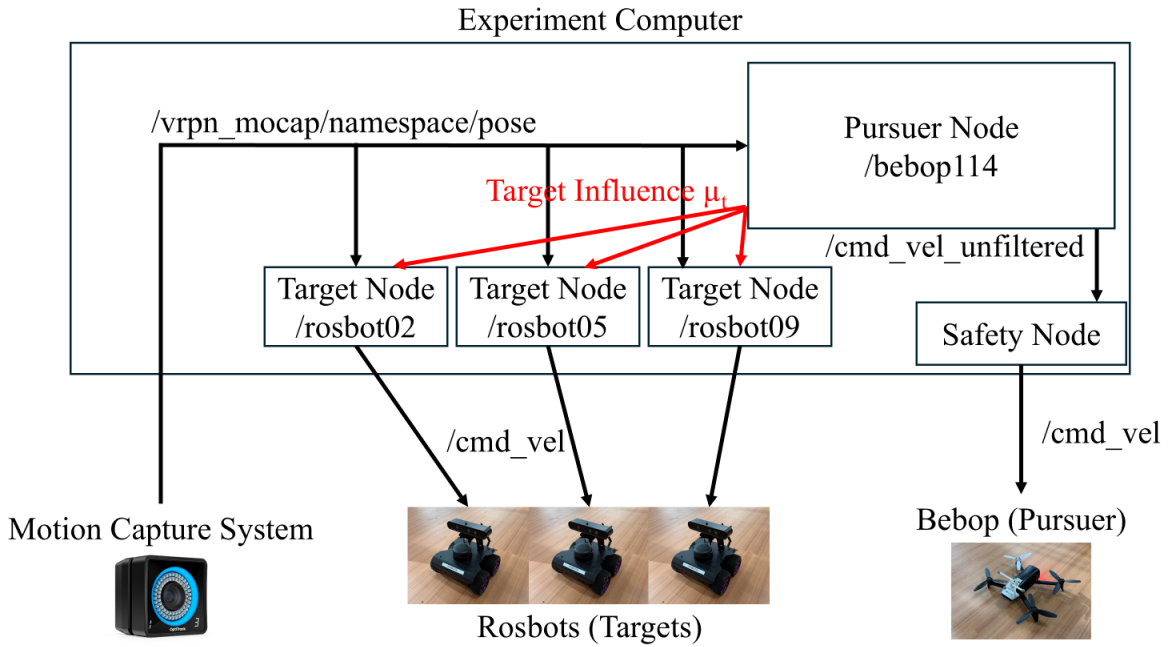
- Safety calibration

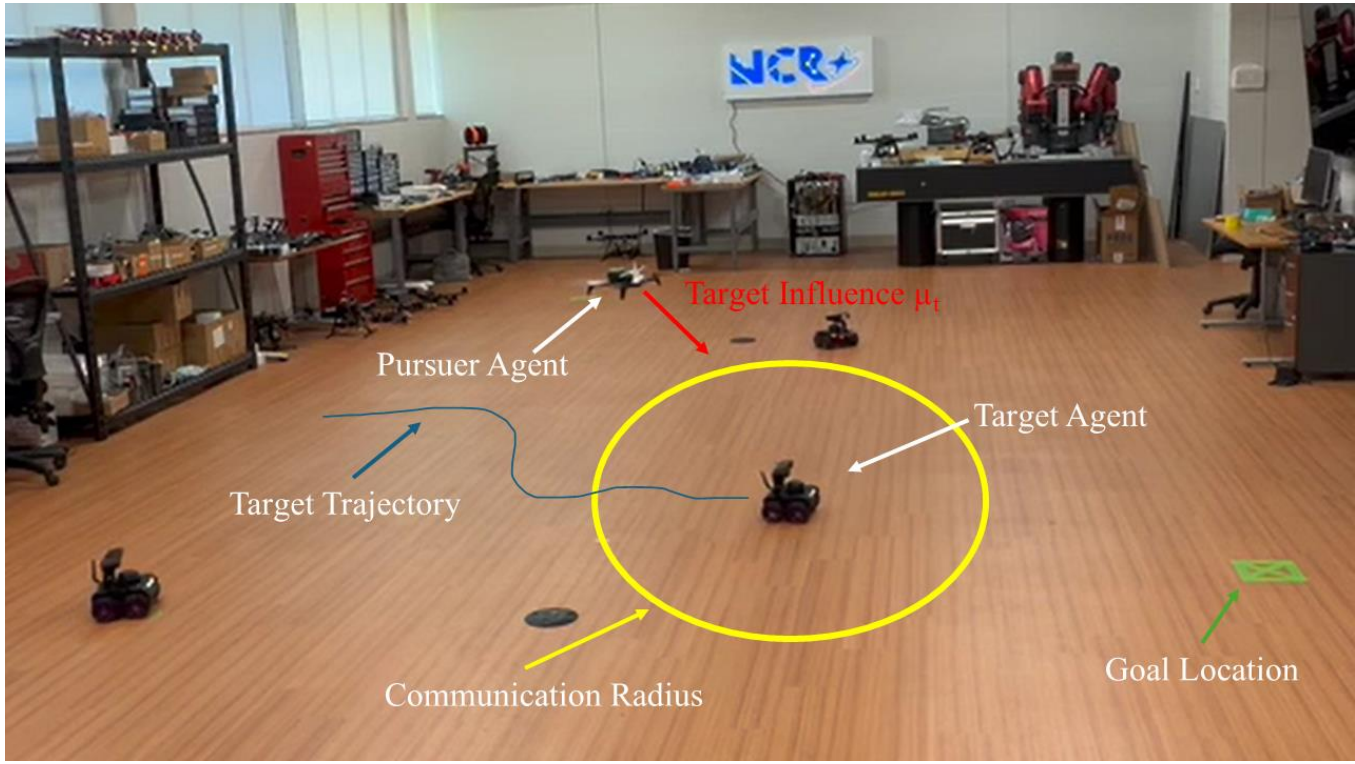
Parameter	Value
a	0.005
b	4.1
p	0.8
$\rho_{\min}$ (calculated)	0.9951 m





- ROS2 Architecture

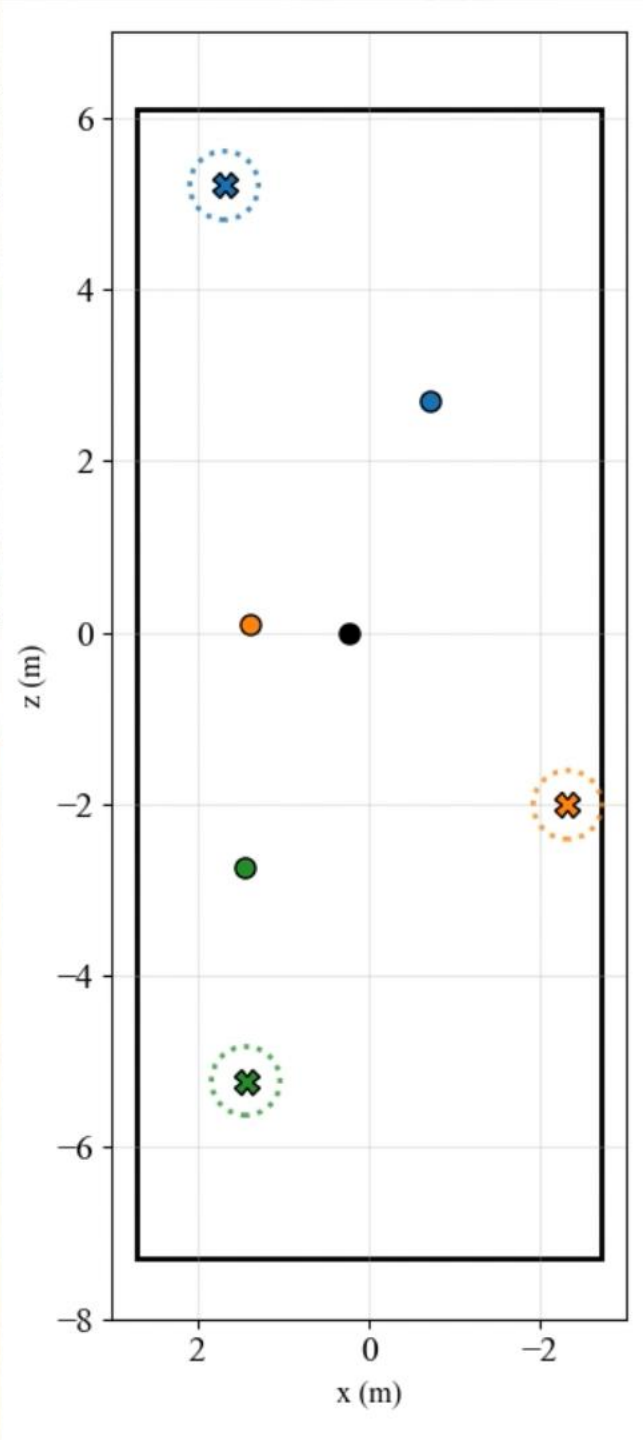




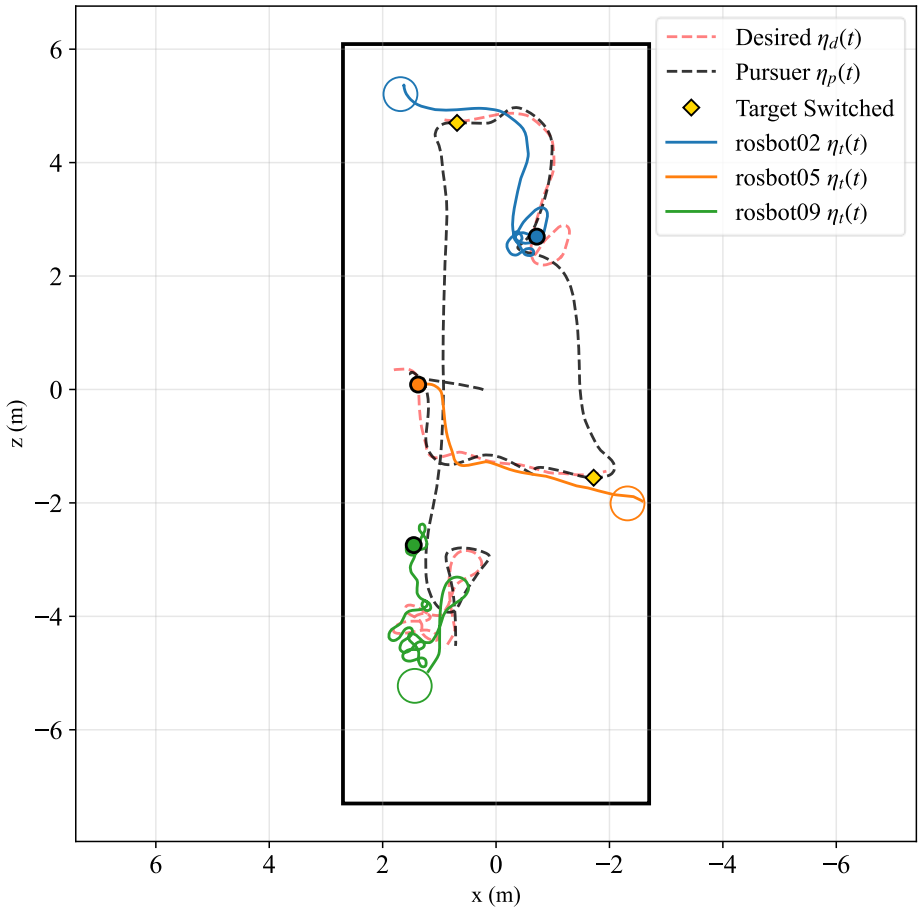
- Configuration Parameters

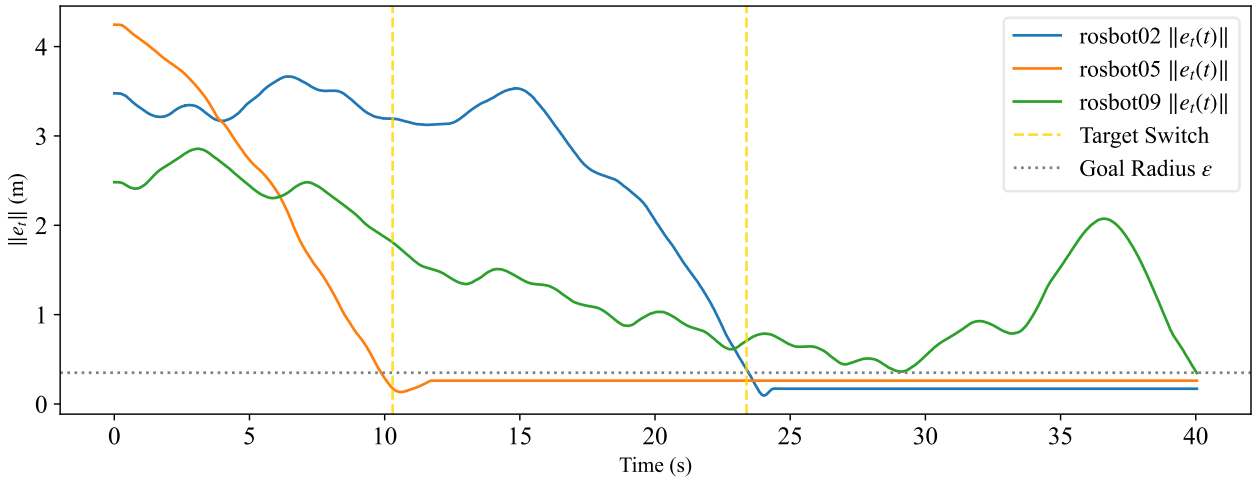
Parameter	Value
Time Step (dt)	0.005s (200 Hz)
Target Constant Speed (v_t)	0.25 m/s
Goal Radius (ε)	0.4 m
Target Sight Range (R_p)	1.5 m
Desired Influence Radius (R_a)	0.5 m
α	2.1
β	4.0
Pursuer Max Speed (v_{max})	1.0 m/s
α_{Pareto}	3.0

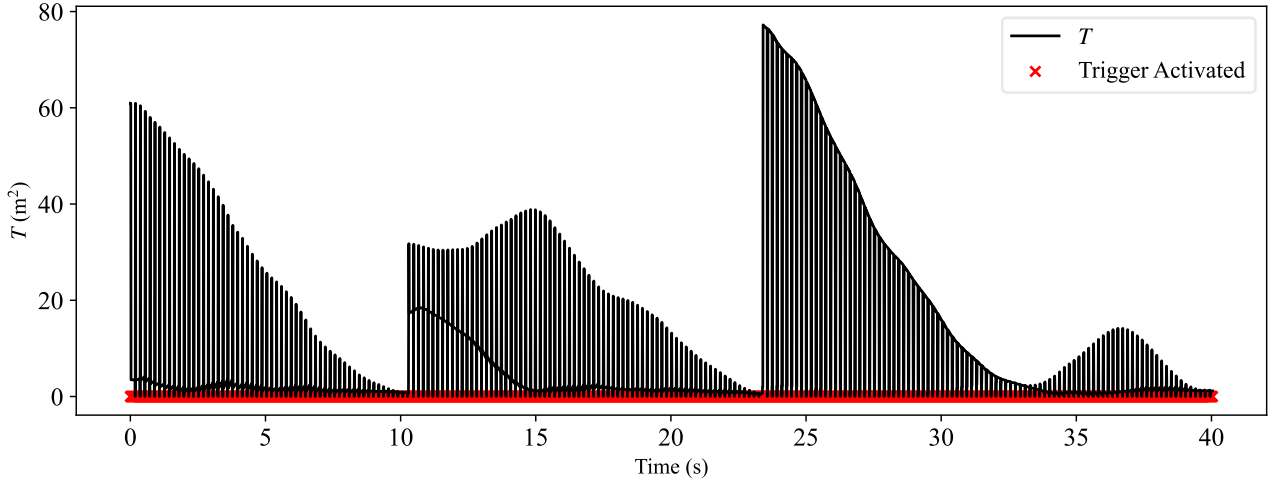
Parameter	Value
Bebop altitude proportional gain	1.0
Bebop heading proportional gain	1.0
Rosbot heading proportional gain	5.4


6
4
2
0
−2
−4
−6
−8
z (m)
2
0
−2
x (m)

Experiment Results







- Event trigger refinement
- Simultaneous multi-target influence

Thank you!

Contact:

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