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

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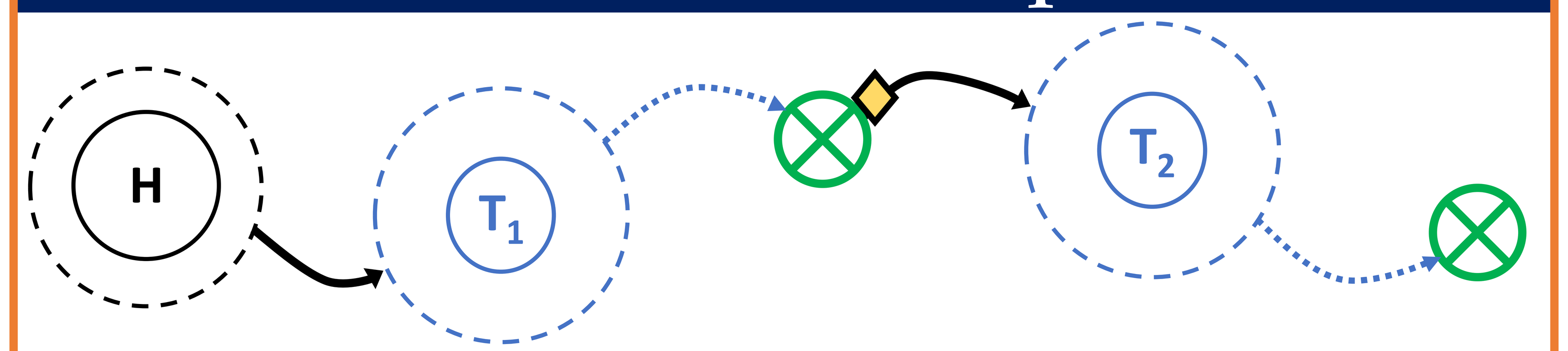
Motivation

- Inspired by natural shepherding behaviors, a single pursuer can indirectly guide multiple targets to desired goal locations by exploiting interaction dynamics rather than direct control.
- Applications include Crowd Management, Environmental Monitoring, and Defense.
- Consider scenarios where a pursuer cannot directly control a target, we derive a robust controller that incorporates uncertainty (stochastic drift) and sequential agent switching in multi-target scenarios.

Control Setup



Objective:

Regulate a target agent to a goal location known only to the pursuer agent by leveraging an uncertain influence before switching to the next target with greatest goal error. The pursuer agent is assumed to be directly controllable and to have complete state observability of target agents.

Dynamics

Pursuer agent

$$\dot{\eta}_p(t) \triangleq \mu_p$$

Target agent

$$\dot{\eta}_t(t) \triangleq f(\eta_d(t)) + \mu_t$$

Target drift

$$f(\eta_d(t)) \triangleq \text{Pareto}(\alpha)\begin{bmatrix}\cos\theta_k \\ \sin\theta_k\end{bmatrix}, \theta_k = \mathcal{U}(0, 2\pi)$$

Error system

Pursuer tracking error

$$e_p \triangleq \eta_d(t) - \eta_p(t)$$

Target goal error

$$e_t(t) \triangleq \eta_t(t) - \zeta_g$$

Pursuer desired trajectory

$$\eta_d(t) \triangleq \eta_t(t) + R_a \frac{e_t(t)}{\|e_t(t)\|}$$

Pursuer Controller

$$\mu_p \triangleq \dot{\eta}_d(t) + (\beta + 1)e_p(t) \qquad \beta \in \mathbb{R}_{>0}$$

Target Controller

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

Lyapunov Stability

$$V(\xi) = \frac{1}{2}\left(e_p^\top e_p + e_t^\top e_t\right)$$

Theorem 1. For the dynamical system under the proposed control law, the state ξ converges exponentially to a bounded set $\mathcal{B}$. The trigger function and control law guarantee that the state ξ remains bounded for all $t \in \mathbb{R}_{\geq 0}$ provided the inter-event time δ_k satisfies

$$\delta_k \leq \frac{1}{2}\ln\left[\frac{\xi_s + \gamma_u}{\xi_u}\right].$$

Where the error norms at the start of the stable and unstable subsystems are:

$$\xi_s \triangleq \left\|\xi(t_k^s)\right\|^2, \qquad \xi_u \triangleq \left\|\xi(t_k^u)\right\|^2,$$

and the constant γ_u which is determined by the drift dynamics of the target is defined as:

$$\gamma_u \triangleq \frac{1}{2}\bar{f}^2 + \frac{1}{2}v_t^2.$$

Simulated Results

Case: 1 pursuer, 1 target

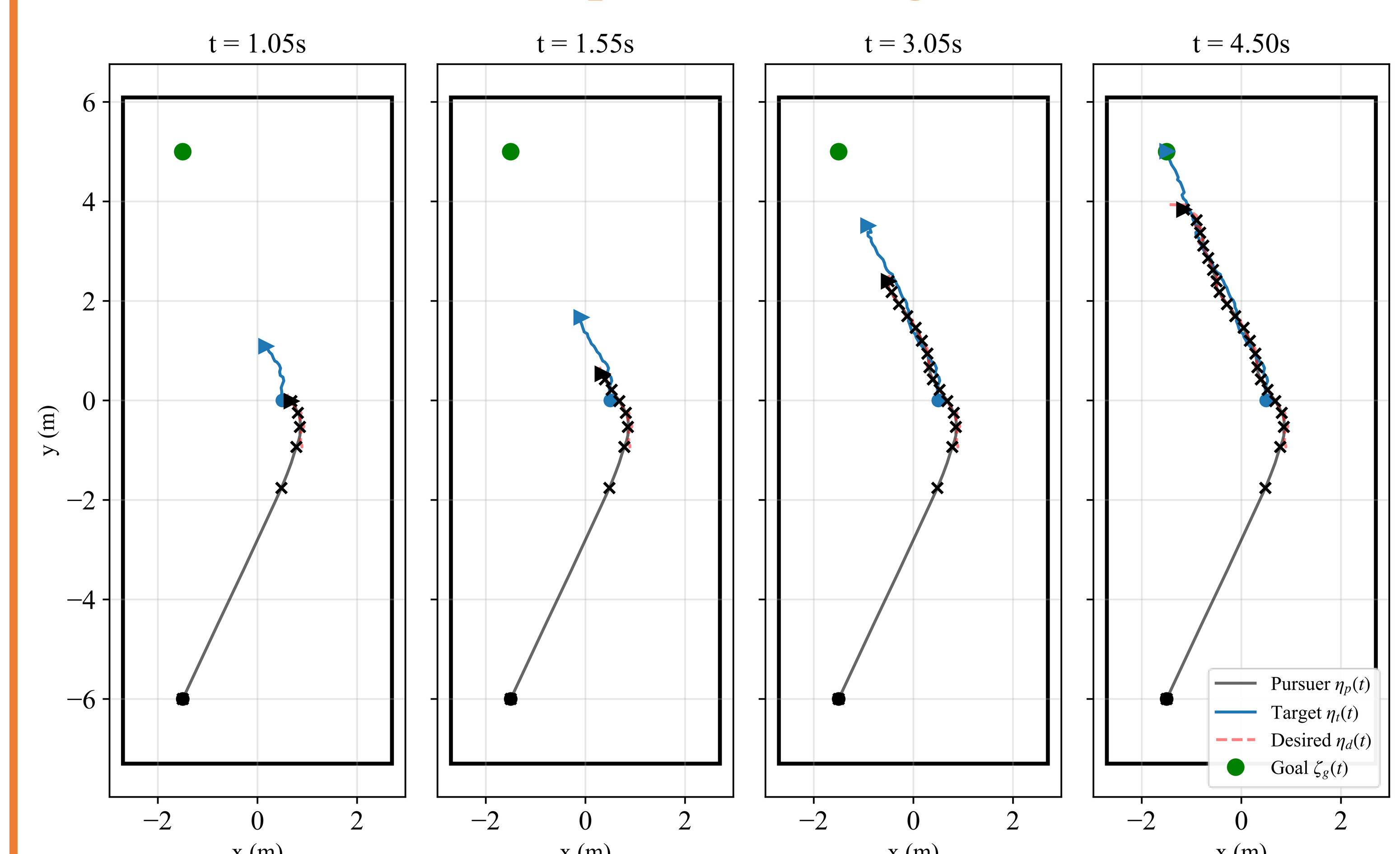


Fig. 1: Trajectories of a single pursuer agent and single target agent as a series of snapshots in time progressing from left to right. The initial positions are depicted by circles, and current positions of the respective agents are depicted by the triangles. Controller trigger function activations are depicted by ×'s.

Experiment Setup

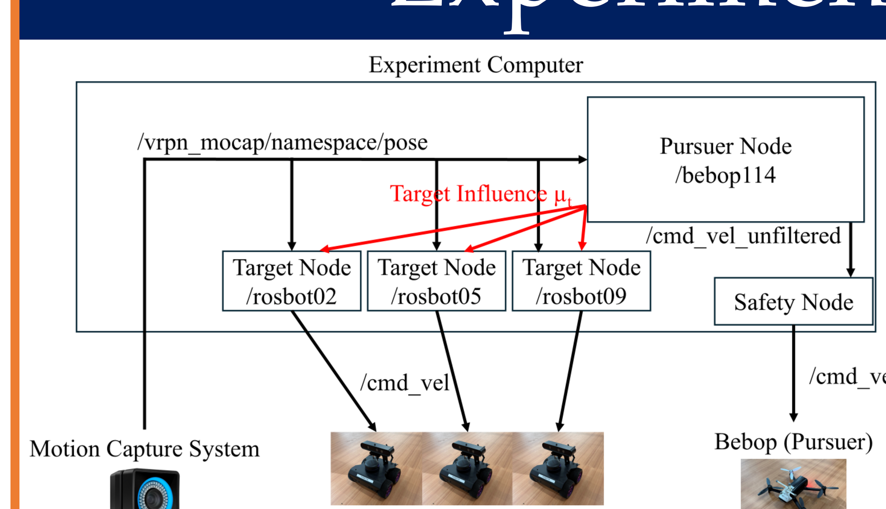


Fig. 2: Robot Operating System 2 architecture in the experiment. The pursuer can access all target poses. Pursuer commands are filtered through the safety node to prevent the Bebop quadcopter from exiting a safe region defined in the lab workspace.

Experimental Results

Case: 1 pursuer, 3 targets

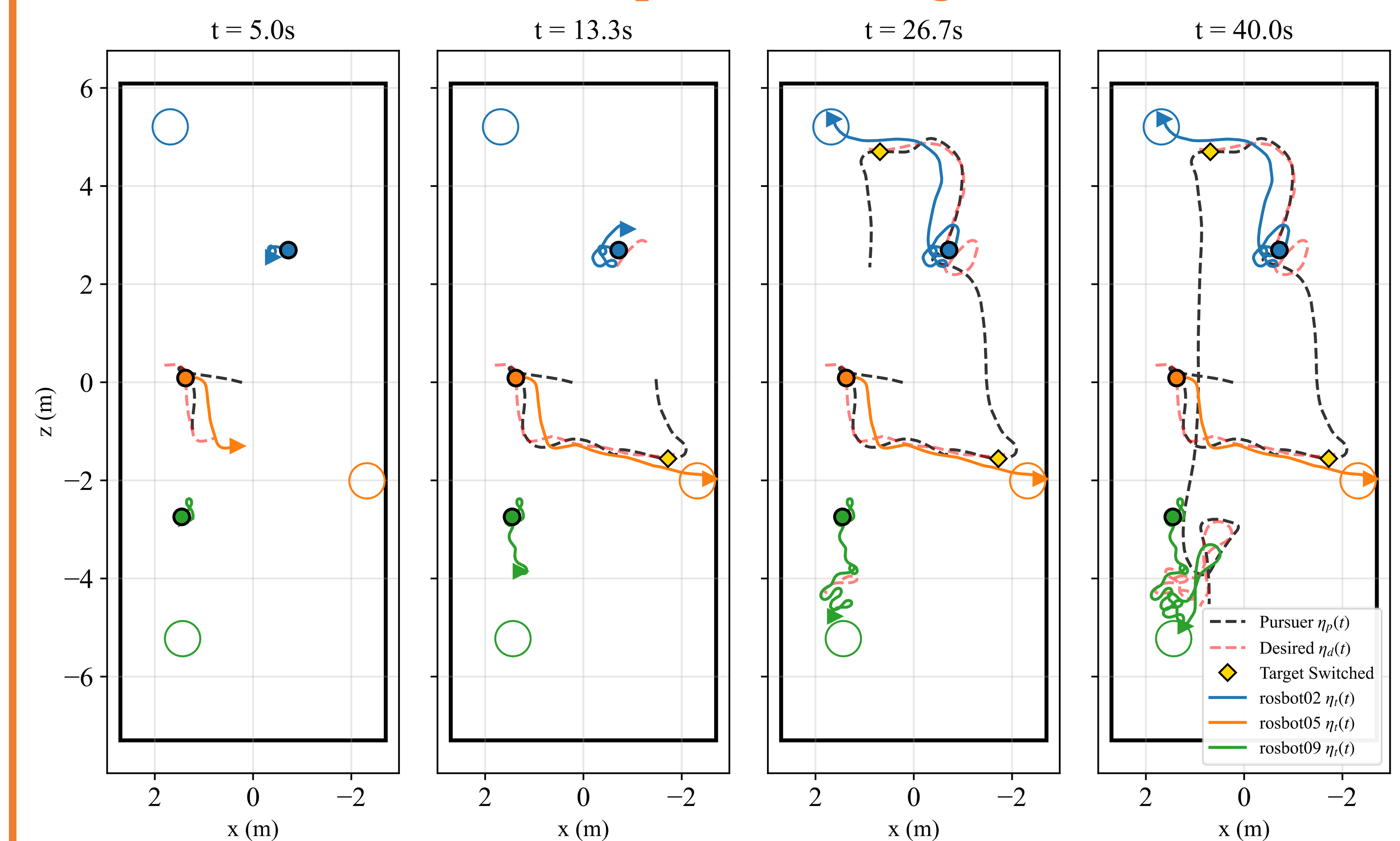


Fig. 3: Trajectories of a single pursuer agent (dashed line) and three target agents as a series of snapshots in time progressing from left to right. Current target positions are represented with triangles, starting positions are indicated with solid circles, and goal locations are denoted with open circles. Switching events are marked with diamonds.

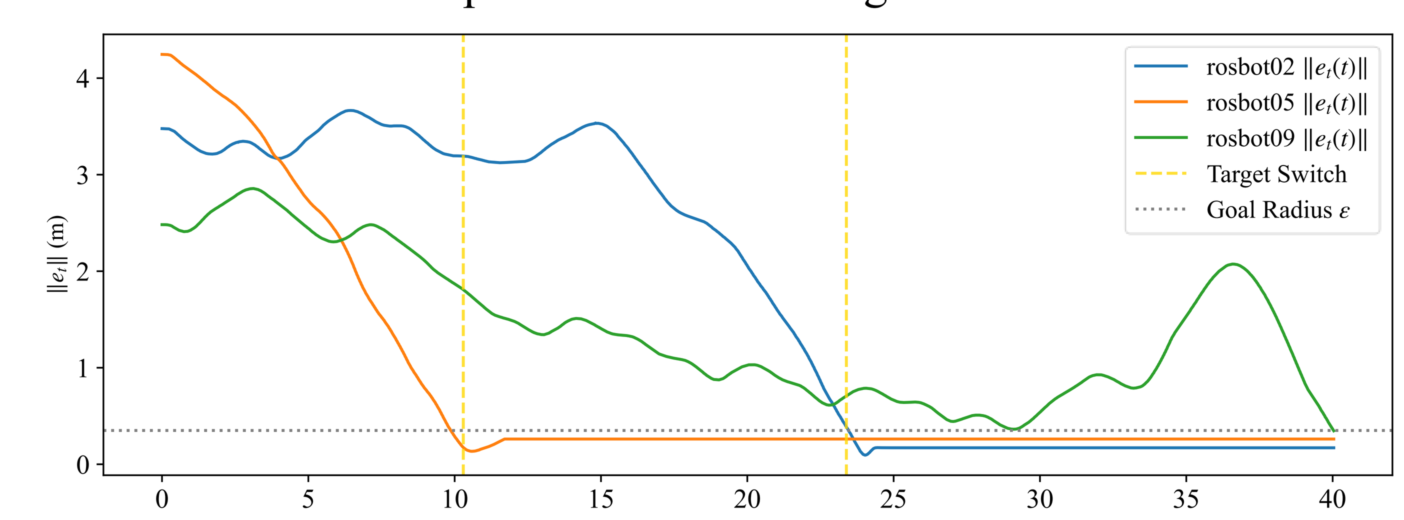


Fig. 4: The tracking errors for each target are shown to converge to ϵ. The tracking error of the initial target, rosbot05 (orange) and subsequent targets rosbot02 (blue) and rosbot09 (green) are displayed. Target switching events are marked (yellow), and herding is successful if the target goal error falls within the goal radius ϵ (grey).

Experiment Video

youtube.com/watch?v=sWcg1zkc75E

NCR Lab

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