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A Graphical Interface for Specifying and Establishing Multi-Robot Formations

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Abstract

The user describes desired swarm formations → Through **digital sketches** → *Graphical Interface*

↓

The method leverages **computer vision** techniques to extract critical points from the user drawing, thus defining the number of robots needed

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Each "point" (a.k.a. desired formation node) is assigned to one robot

↓

The robots are deployed to **form** the initial user drawing

Introduction

- **Human-Swarm Interaction (HSI)** enables the user to **control** a swarm of robots' behaviors, posing a handful of technical challenges like real-time responsiveness and balancing decentralized robot autonomy with centralized human input. [1]
- Recent works propose user-centered interfaces and mediums such as Augmented Reality (AR) to **enhance human–swarm collaboration** in tasks like environmental monitoring and area coverage. [2]
- Traditional **formation control** approaches rely on pre-set parameters without real-time human interaction. Existing gesture-based methods improve HSI but remain constrained by pre-defined gestures. [3]
- This project advances HSI by **allowing users to sketch desired swarm formations**, enabling flexible, real-time, and robust control of multi-agent systems.

Select References

[1] A. Kolling, P. Walker, N. Chakraborty, K. Sycara, and M. Lewis, "Human interaction with robot swarms: A survey," IEEE Transactions on Human-Machine Systems, vol. 46, no. 1, pp. 9–26, 2015.
[2] S. O. Sachidanandam, S. Honarvar, and Y. Diaz-Mercado, "Effectiveness of augmented reality for human swarm interactions," in Proceedings of the International Conference on Robotics and Automation (ICRA). IEEE, 2022, pp. 11 258–11 264.
[3] A. Suresh and S. Martinez, "Human-swarm interactions for formation control using interpreters," International Journal of Control, Automation and Systems, vol. 18, no. 8, pp. 2131–2144, 2020.

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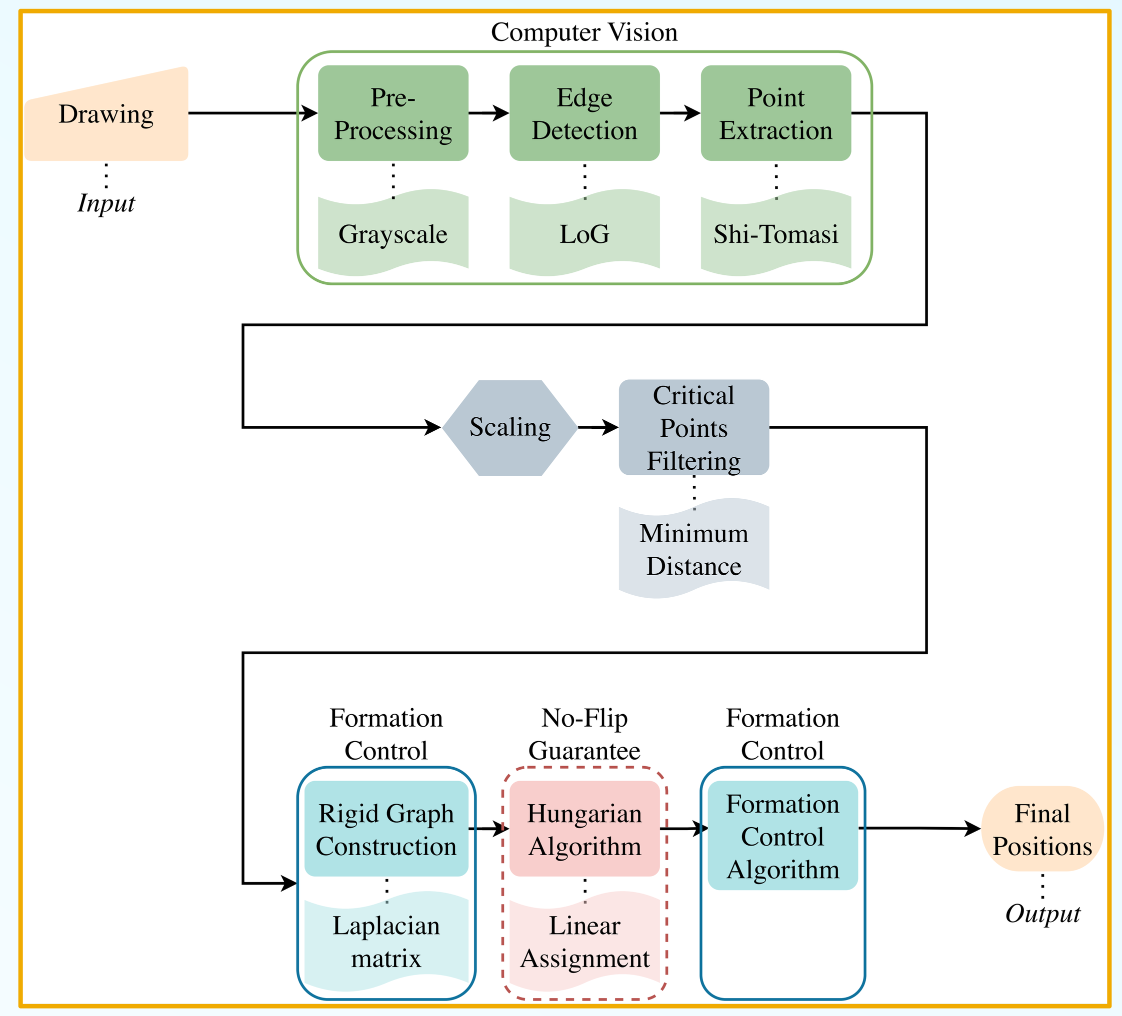
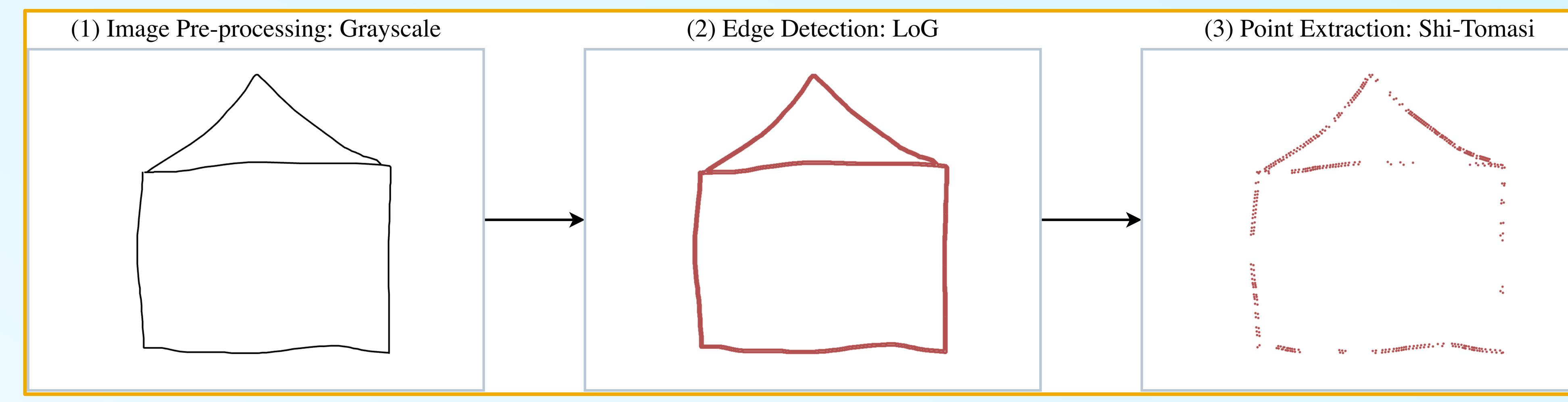
Methodology

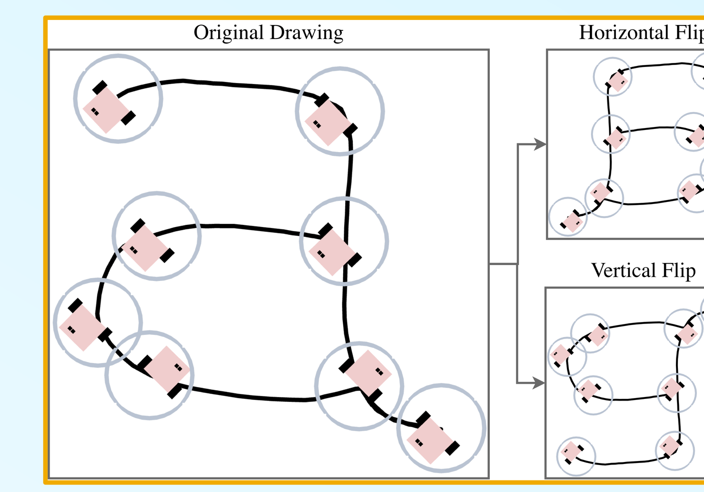
Algorithm



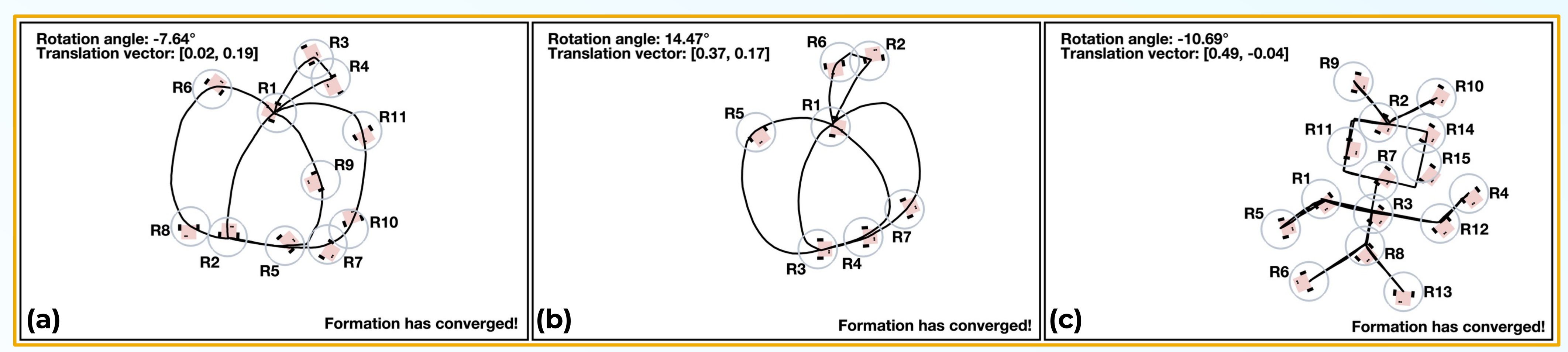
Computer Vision Process Example



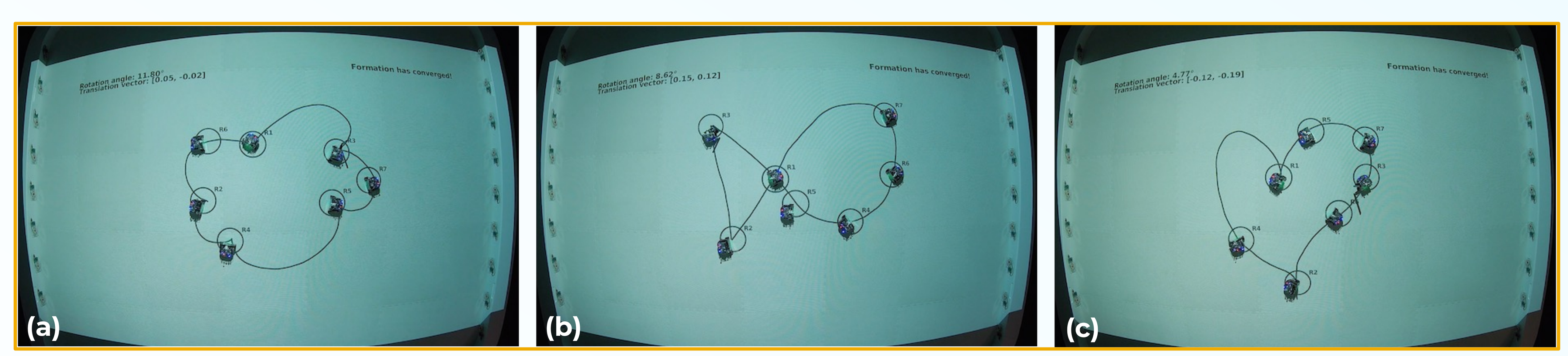
Definition:
A flip of a formation occurs when a formation is either mirrored horizontally or vertically due to robot assignments crossing paths, resulting in misalignment.



Results

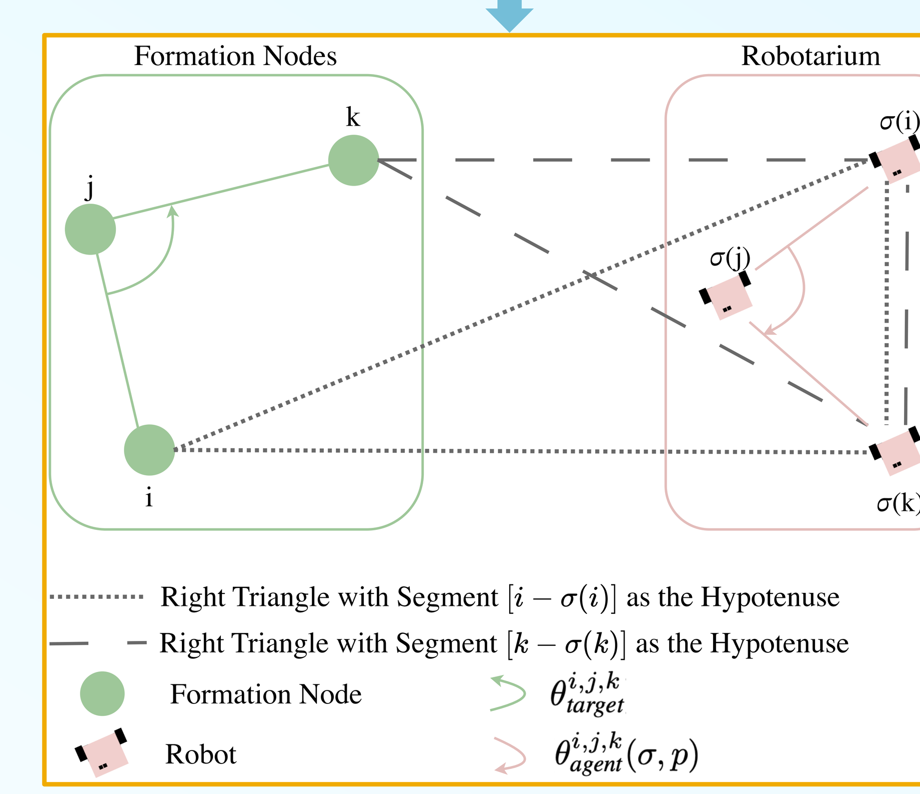


Simulation of robots representing user-drawn:
(a) pumpkin (unconstrained), (b) pumpkin (7 robots), (c) robot (unconstrained).



Robotarium experiments of 7 robots representing user-drawn:
(a) cloud, (b) fish, (c) heart.

Theorem:
If $\phi(\sigma, p) \le \phi(\sigma', p)$ *for all* $\sigma' \in \mathcal{P}$, *then* $sign[\theta^{i,j,k}_{agent}(\sigma, p)] = sign[\theta^{i,j,k}_{target}]$



Visualization of the theorem

Check out cool videos of this algorithm in action on real robots!