2022

Consensus-based Communication-aware Formation Control

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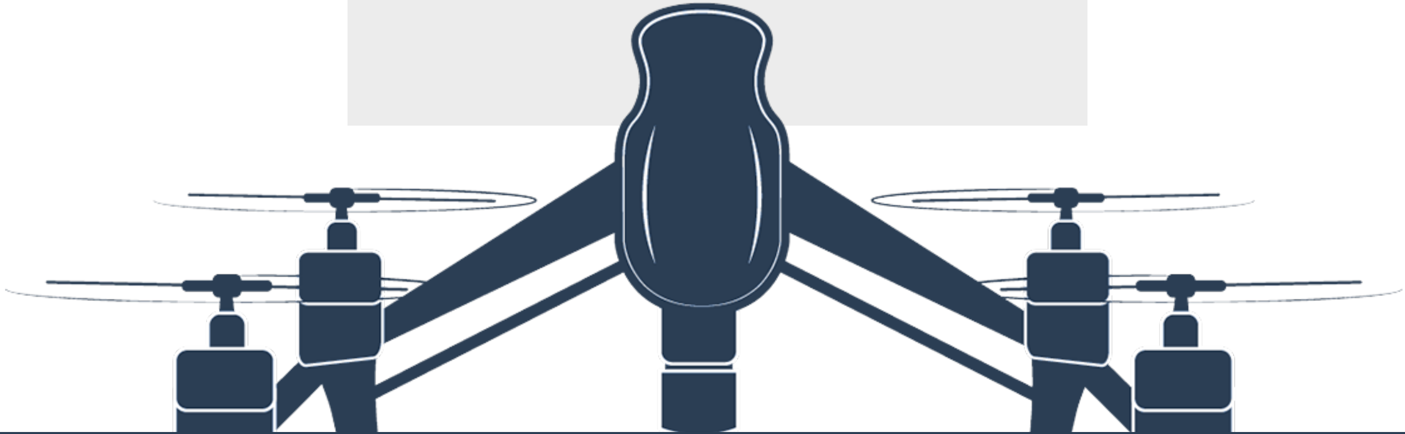
ERAU NSF REU



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Introduction

- ❑ Formation Control
- ❑ Preliminaries
- ❑ Schematic Diagram

Formation Control

Classical Formation Control

Agents typically perceive their absolute position relative to the global coordinate system and achieve their desired formation by actively controlling the absolute position.

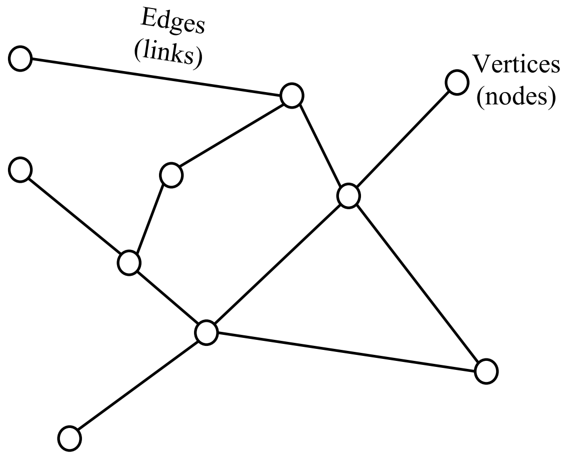
Communication-aware Formation Control

Wireless channel has been used in formation control since communications between agents are usually assumed to be ideal within a certain communication range.

Consensus-based Communication-aware Formation Control

In our research, we adopted ideas from [1], where author Li constructs a communication-aware formation controller that uses the communication channel quality, which is measured locally by agents to guide agents into a desired formation. Thus, it also optimizes the quality of communication of the formation system. Inspired by [2], We further constrains this formation control to reach a consensus between any pair of connected agents.

Preliminaries



Graph Theory

A **graph** G is a pair of $(\mathcal{V}, \mathcal{E})$ consisting of a set of **vertices** $\mathcal{V} = \{1,2, \dots, \mathrm{i}, \dots, j, \dots n\}$ and a set of ordered pairs of the vertices called **edges** $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$. I.e., $\mathcal{E} = \{(i,j) | i,j \in \mathcal{V},\ i \neq j\}$. Here, we assume that G has no **self-edges** and **undirected**.

Rigid Formation

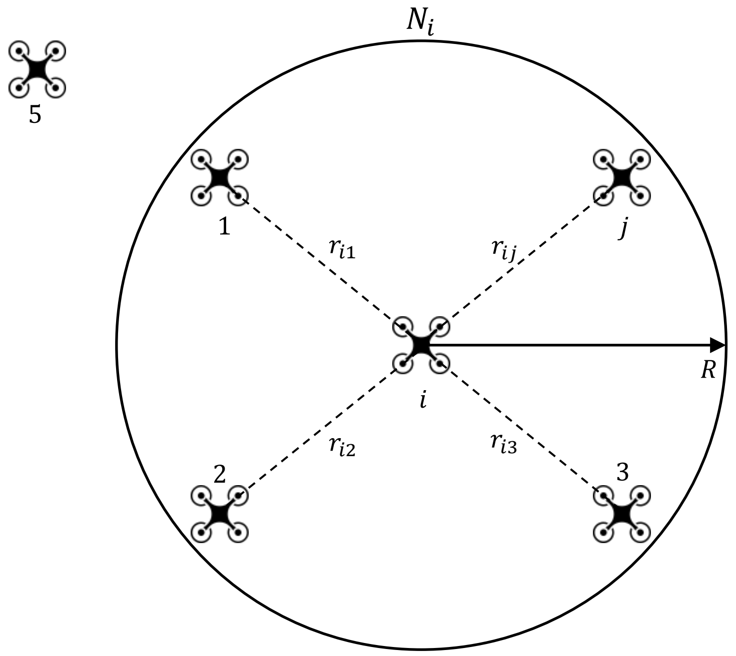
The formation of groups of mobile agents in which all inter-agent distances remain constant is called **rigid**.

The **relative distance** between agent i and agent j is denoted by

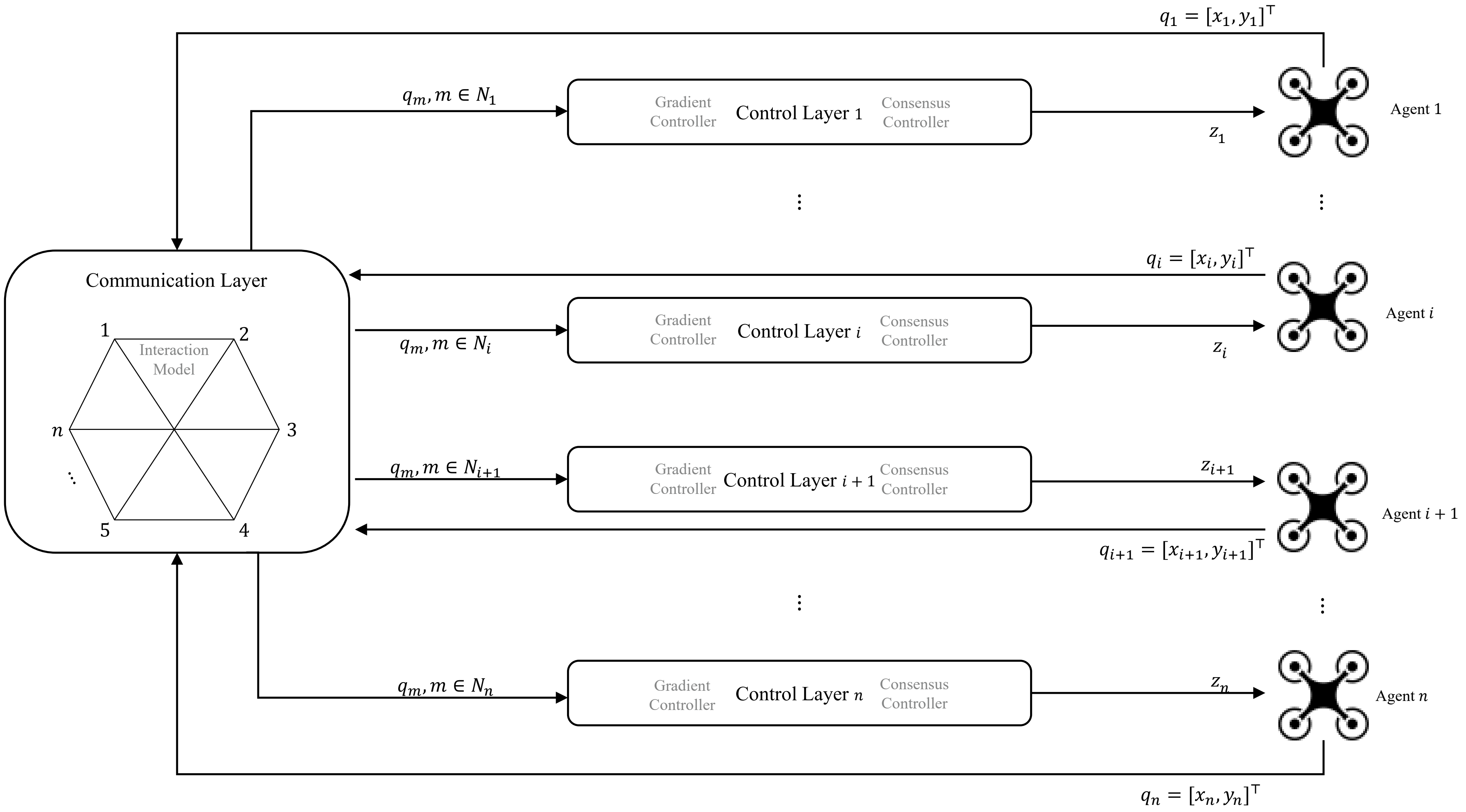
$$r_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} = \|q_i - q_j\|.$$

Let $R > 0$ denote the **communication range** between two agents. The neighboring set of agent i can be denoted by

$$N_i = \{j \in \mathcal{V} \mid r_{ij} \leq R\}.$$



Schematic Diagram



System Dynamics

The **dynamics** of this multi-agent system is denoted by

$$\dot{q}_i = z_i, \quad i = 1,2,\dots,n,$$

where

q: positions of agents,

z: controls of agents.

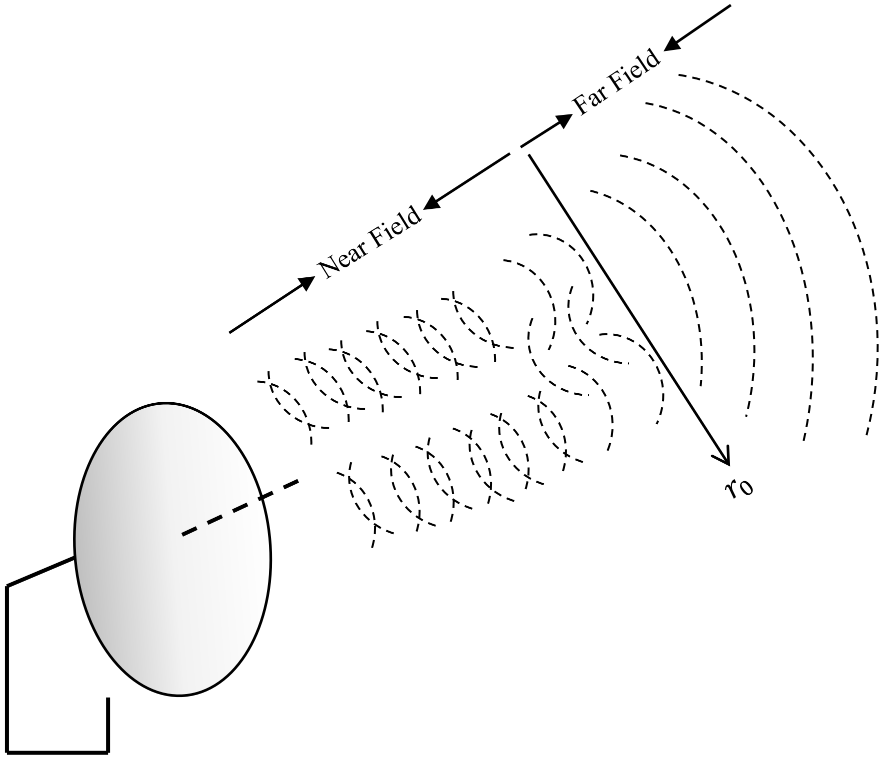
02

Communication Layer

- Antenna Near-field and Far-field
- Interaction Model

Antenna Near-field and Far-field

The antenna far field is the area away from the antenna. The boundary between antenna near-field and far-field is vaguely defined by the reference distance r_0 .



Far-field

The communication channel quality in antenna far-field is denoted by

$$f_{ij} = \exp\left(-\alpha\left(2^{\delta} - 1\right)\left(\frac{r_{ij}}{r_0}\right)^{\upsilon}\right),$$

where

r_0: reference distance for antenna near-field,

r_{ij}: Euclidean distance between agent i and agent j.

Near-field

A simple model of antenna near-field communication quality is:

$$n_{ij} = \frac{r_{ij}}{\sqrt{{r_{ij}}^2 + {r_0}^2}}$$

where

r_0: reference distance for antenna near-field,

r_{ij}: Euclidean distance between agent i and agent j.

Interaction Model

Signal Scattering Effect

When a traveling wave encounters a change in the wave impedance, it will reflect, at least partially. If the reflection is not total, it will also partially transmit into the new impedance.

Path Loss Effect

The reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. As a result, the received signal power level is several orders below the transmitted power level.

Interference Effect

When a signal is disrupted as it travels along the communication channel between its source and receiver. It may cause only a temporary loss of a signal and may affect the quality of the communication.

Interaction Model

The interaction model is denoted by

$$\phi(r_{ij}) = n_{ij} \cdot f_{ij} = \frac{r_{ij}}{\sqrt{{r_{ij}}^2 + {r_0}^2}} \cdot \exp\left(-\alpha\left(2^{\delta} - 1\right)\left(\frac{r_{ij}}{r_0}\right)^{v}\right).$$

03

Control Layer

- Gradient Controller
- Unicycle Kinematic Model
- Consensus Controller

Gradient Controller

In order to optimize the communication performance, the interaction model is designed to maximize its communication performance by taking the first-order derivative of interaction model we denote

$$\frac{d\phi}{dr_{ij}} = \varphi(r_{ij}) = \frac{-\beta v(r_{ij})^{v+2} - \beta v r_0^2 (r_{ij})^{v} + r_0^{v+2}}{\sqrt{(r_{ij}^2 + r_0^2)^3}} \cdot \exp\left(-\beta\left(\frac{r_{ij}}{r_0}\right)^{v}\right),$$

where $\beta = \alpha(2^{\delta} - 1)$.

We find that interaction model has the best communication performance ϕ^* at r_{ij}^*.

A gradient controller can be designed for agents converge in the formation with the maximized communication performance of function $\phi(r_{ij})$.

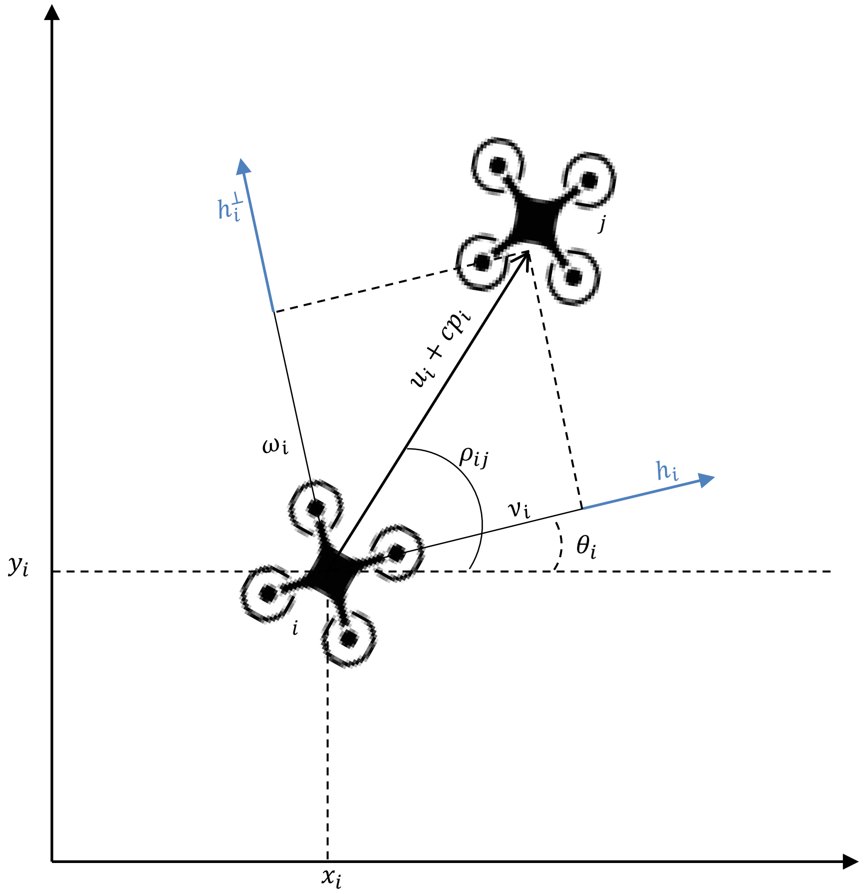
Gradient Control Model

The gradient control model of agent i is denoted by

$$\mathcal{G}_i = \sum_{j \in N_i} [\nabla_{q_i} \phi(r_{ij})] = \sum_{j \in N_i} [\varphi(r_{ij}) \cdot e_{ij}]$$

where $e_{ij} = (q_i - q_j)/\sqrt{r_{ij}}$.

Unicycle Kinematic Model



Unicycle Kinematic Model

The unicycle kinematic model of agent i is denoted by

$$\dot{x}_i = v_i \cos(\theta_i)$$
$$\dot{y}_i = v_i \sin(\theta_i)$$
$$\dot{\theta}_i = \omega_i,$$

h_i: Heading vector, defined as $\begin{bmatrix} \cos(\theta_i) \\ \sin(\theta_i) \end{bmatrix}$

$h_i^{\perp}$: Perpendicular heading vector, defined as $\begin{bmatrix} -\sin(\theta_i) \\ \cos(\theta_i) \end{bmatrix}$

θ_i: Heading angle

v_i: Linear velocity vector

ω_i : Angular velocity vector

ρ_{ij}: Line of sight, defined as $\arctan2(q_i - q_j)$

$u + cp_i$: consensus control vector

Dubins Constraints

Due to its physical capabilities, the airspeed and heading angle of the UAV are limited. These physical limits can be represented by the constraints

$$v_{min} \leq v_i \leq v_{\max},$$
$$|\omega_i| \leq \omega_{max},$$

Consensus Controller

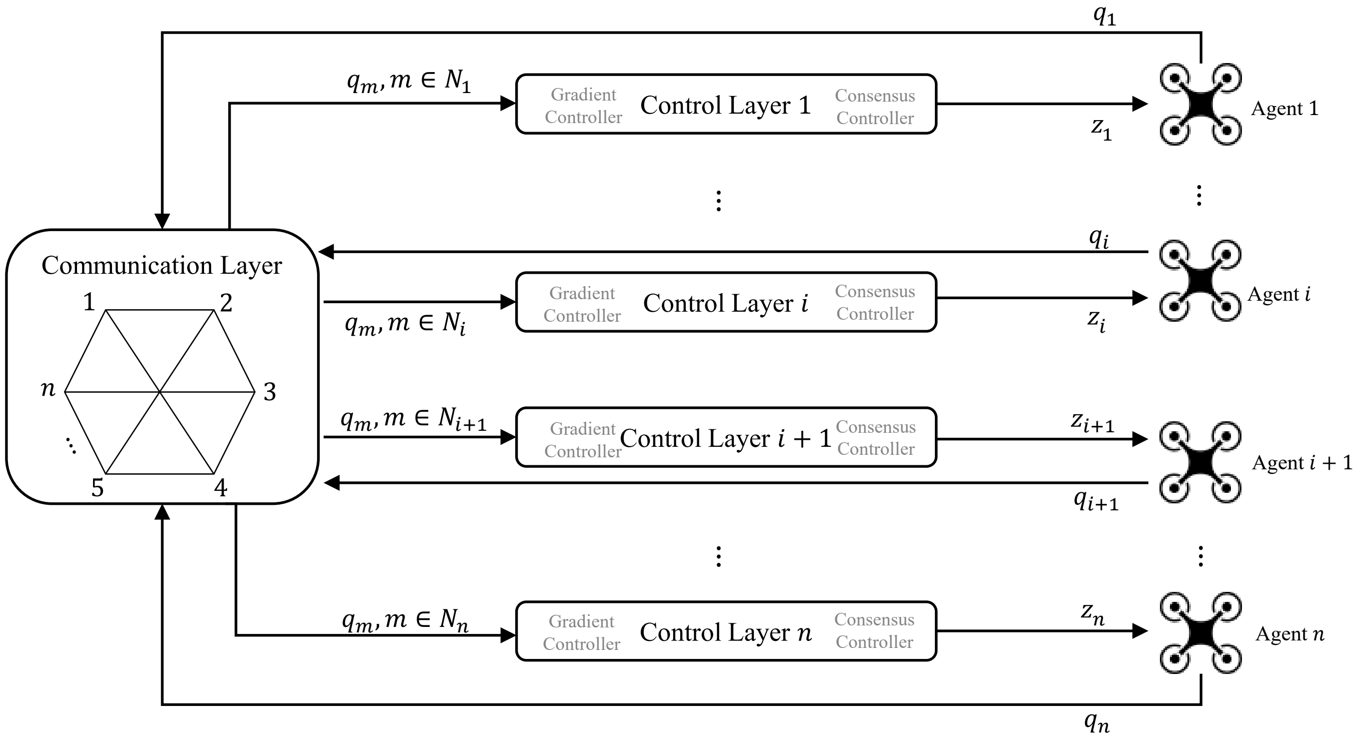
Consensus Control Model

The projections of consensus control vector $u + cp_i$ along the heading direction h_i and its perpendicular vector $h_i^{\perp}$ are then calculated and used as the linear and angular velocity vectors, respectively. Specifically, the linear and angular velocity controls are given by

$$\nu_i = h_i^{\top}(u + cp_i)\cos(\rho_{ij} - \theta_i)$$
$$\omega_i = h_i^{\perp\top}(u + cp_i)\sin(\rho_{ij} - \theta_i).$$

And the consensus motion of agents i can be collectively expressed as

$$\mathcal{C}_i = h_i h_i^{\top}(u + cp_i)\cos(\rho_{ij} - \theta_i).$$



Final Formation Controller

$$z_i = \mathcal{G}_i + \mathcal{C}_i$$

$$= \sum_{j \in N_i} [\varphi(r_{ij}) \cdot e_{ij}] + \sum_{j \in N_i} [h_i h_i^{\top}(u + cp_i)\cos(\rho_{ij} - \theta_i)]$$

Dynamics

The dynamics of this multi-agent system is denoted by

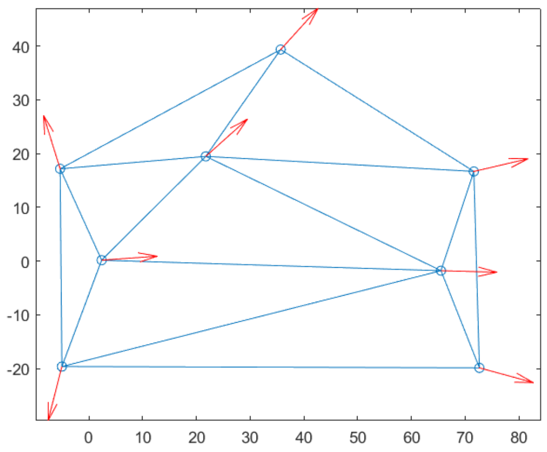
$$\dot{q}_i = z_i, \quad i = 1,2,\ldots,n,$$

where

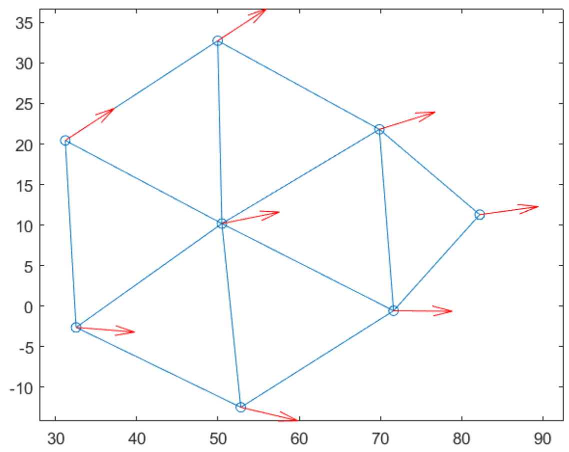
q: position input of agents,
z: control input of agents.

04

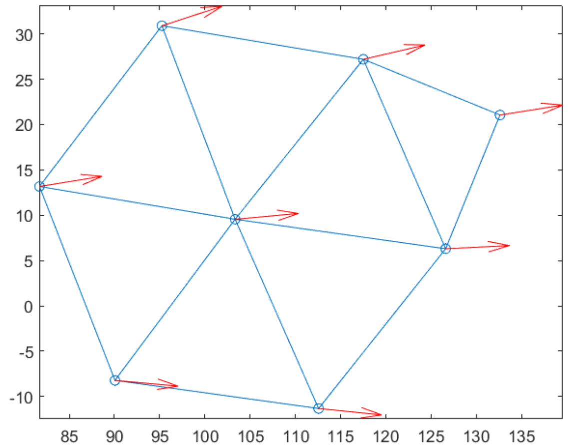
Simulations



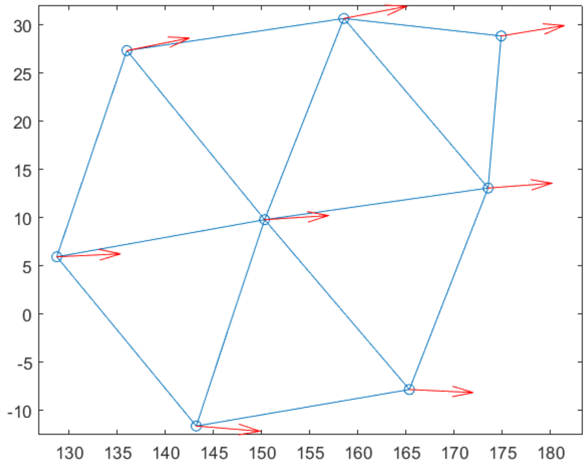
$t = 0s$



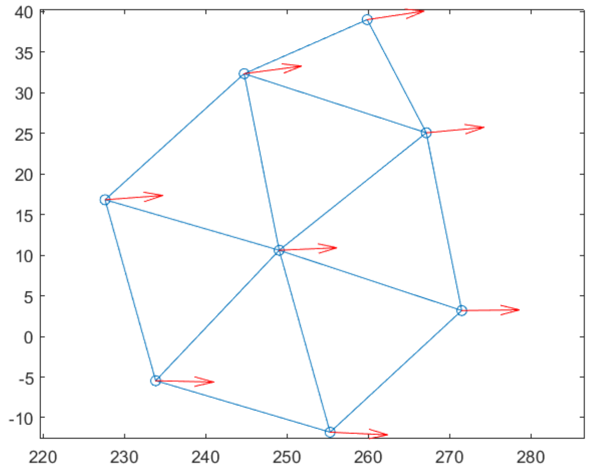
$t = 10s$



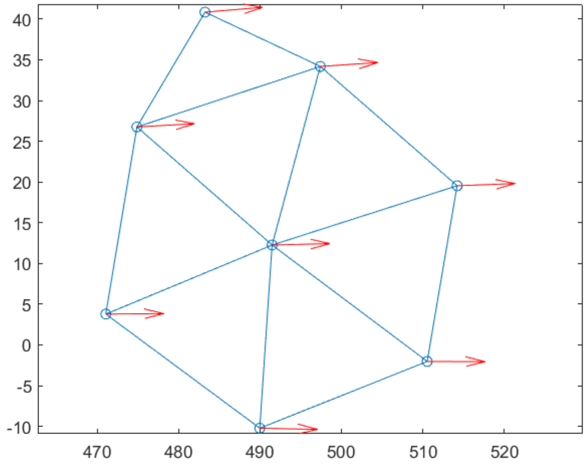
$t = 30s$



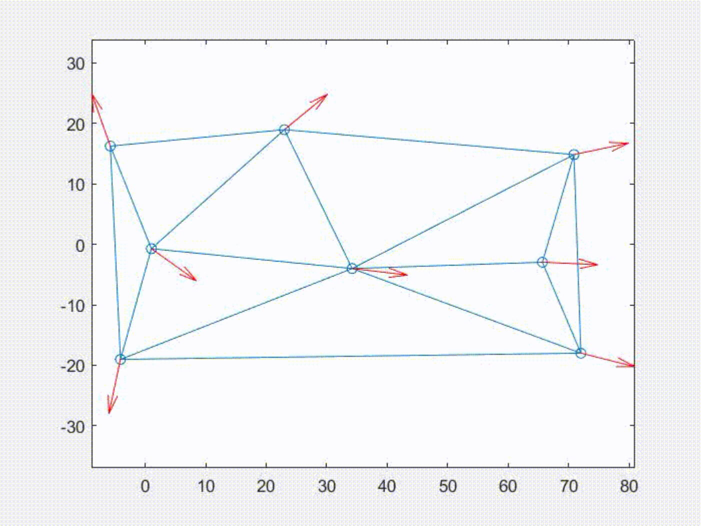
$t = 60s$



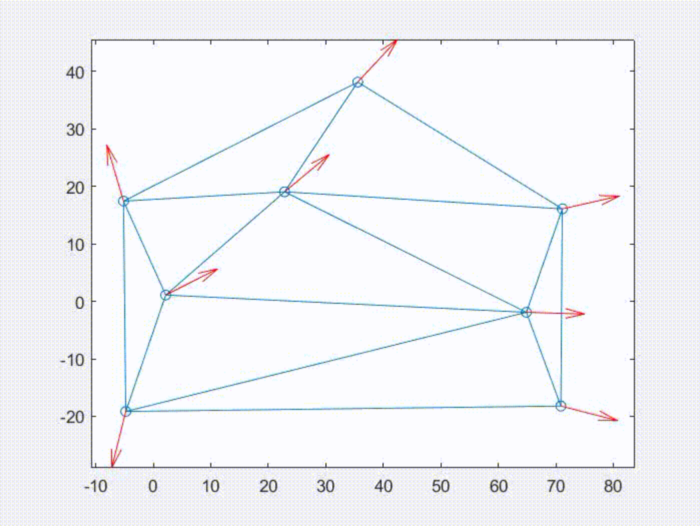
$t = 90s$



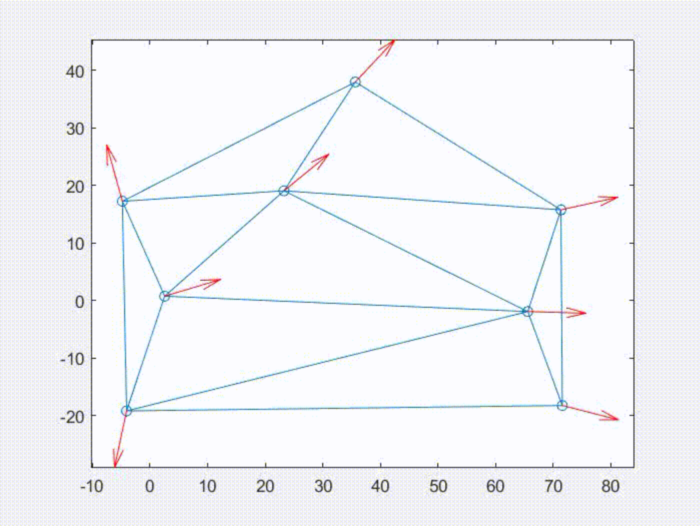
$t = 180s$



Before proposed



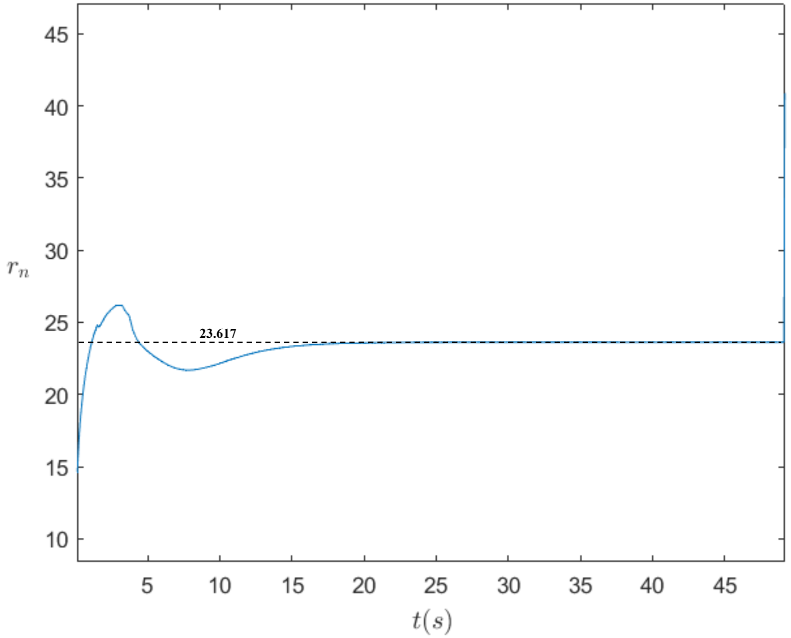
After Proposed
Traveling in NE direction

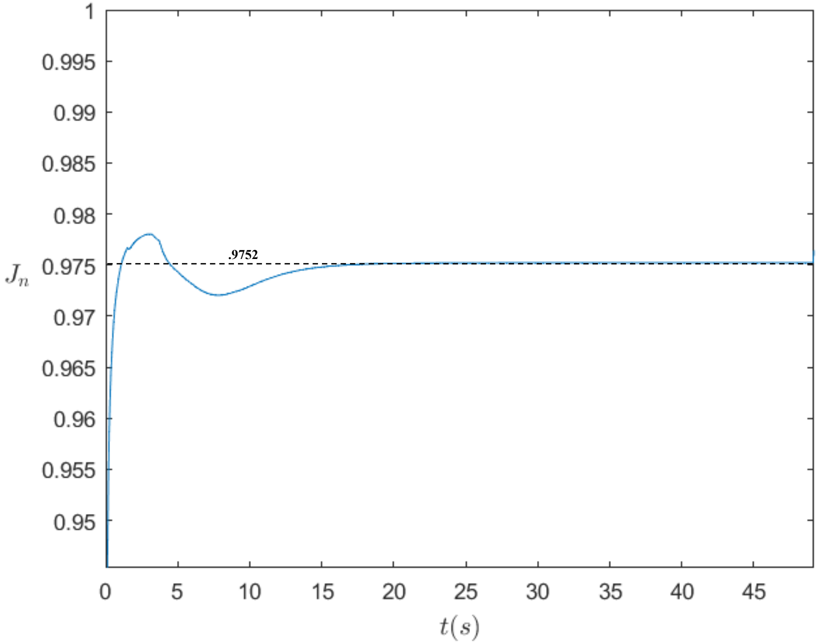


After Proposed
Traveling in in E direction

Agents Traveling in NE Direction

Before Proposed





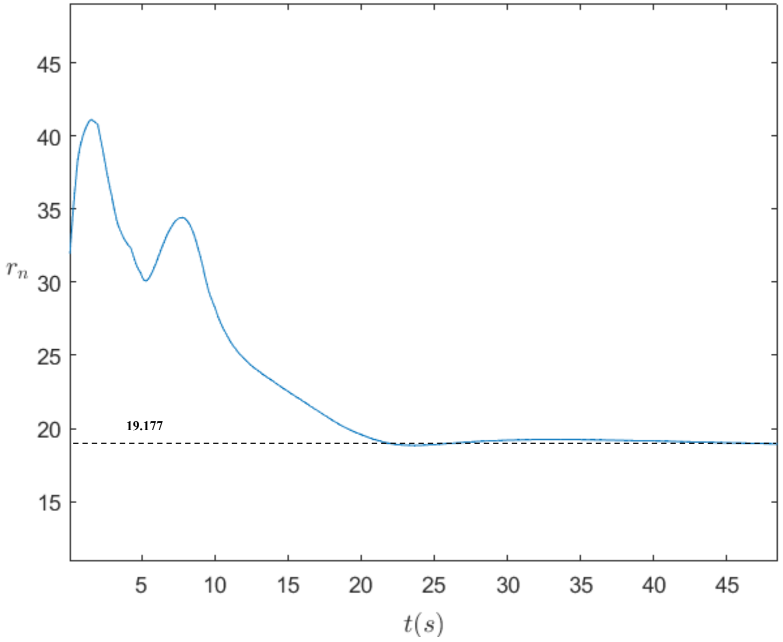
J_n: Average Communication Performance Indicator

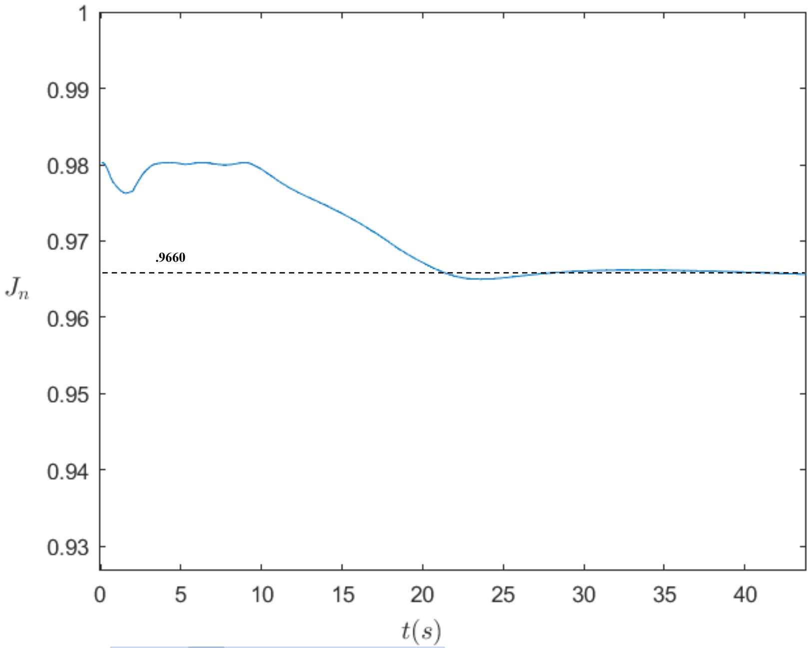
$$J_n = \frac{\sum_{i=1}^{n} \sum_{j \in N_i} \phi(r_{ij})}{2n|N_i|}$$

r_n: Average Neighboring Distance Indicator

$$r_n = \frac{\sum_{i=1}^{n} \sum_{j \in N_i} r_{ij}}{2n|N_i|}$$

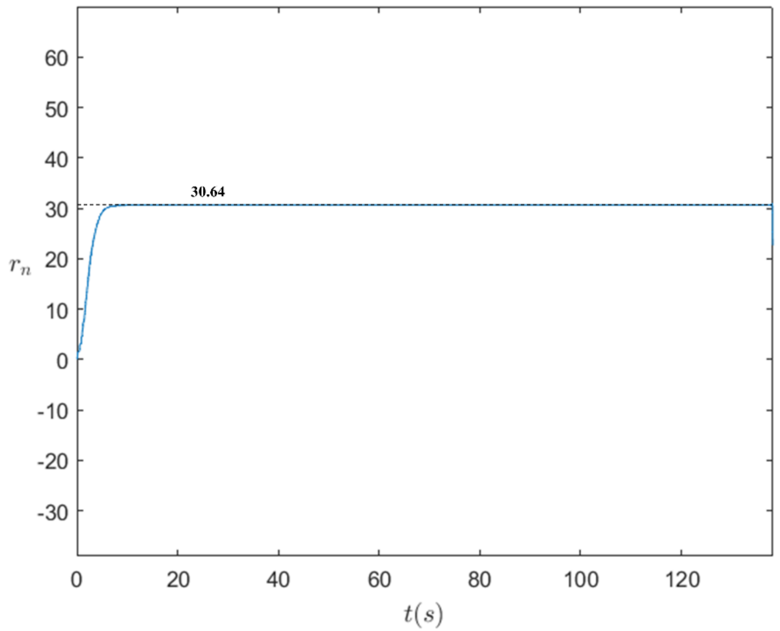
After Proposed

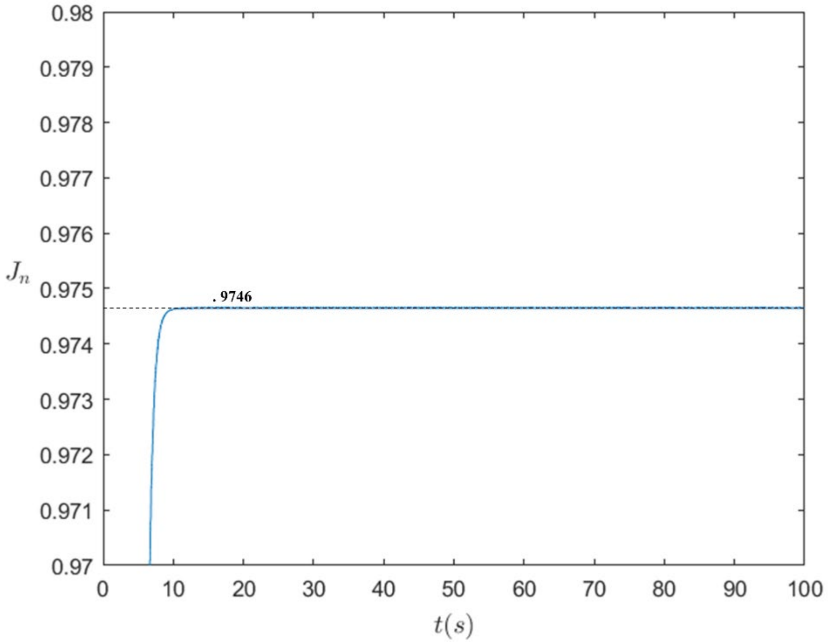




Agents Traveling in E Direction

Before Proposed





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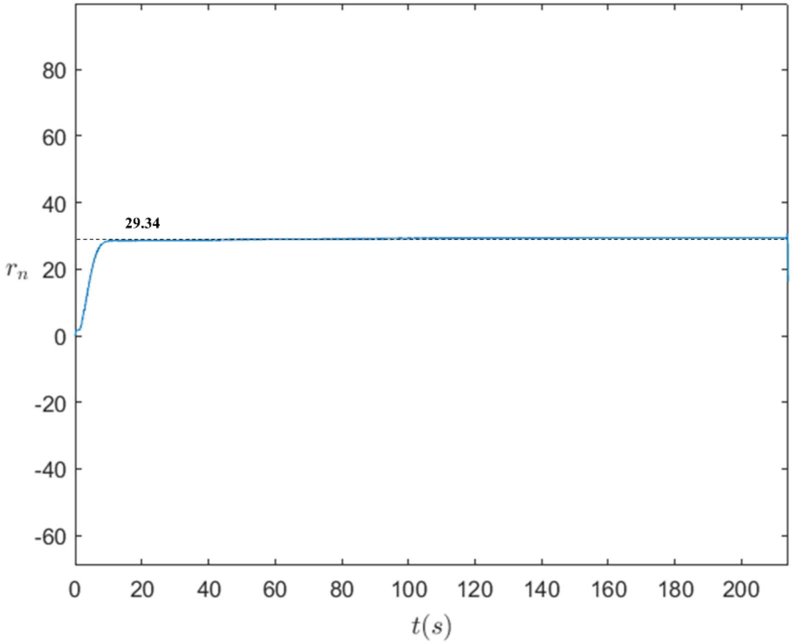
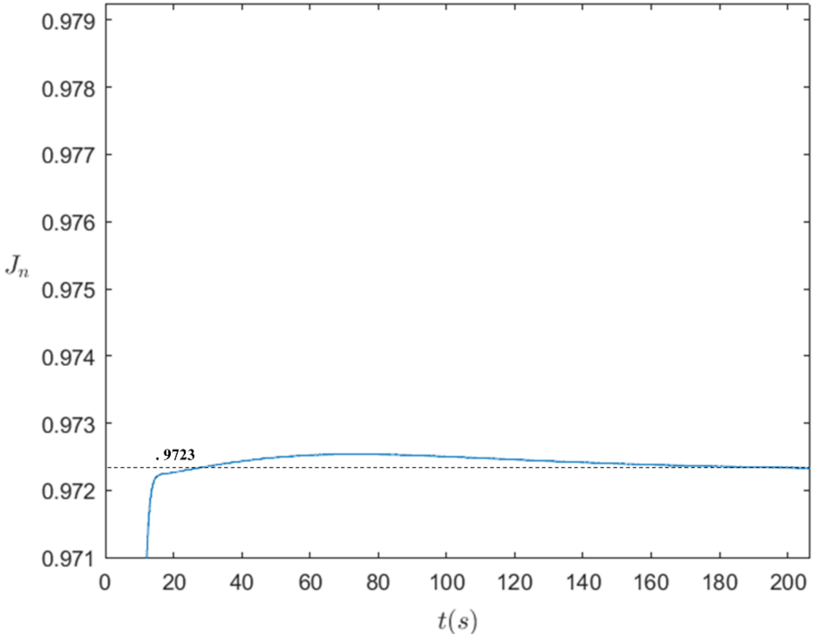




05

Conclusion

Outline

Intro

Preliminaries

- Graph Theory
- Rigid Formation
- System Dynamics

Communication Layer

- Antenna Far-field Model
- Antenna Near-field Model
- Interaction Model

Control Layer

- Gradient Controller
- Unicycle Kinematic Model
- Consensus Control

Simulation

- Average Communication Performance J_n
- Average neighboring Distance r_n

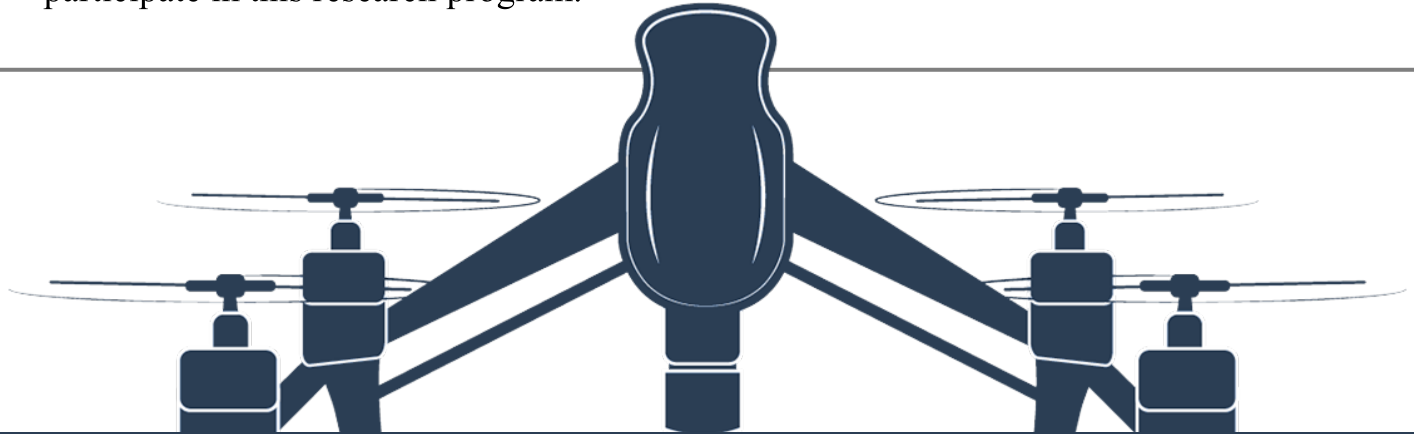
Outro

Significance

- Formation control is communication-aware.
- Formation control is consensus-based.
- Maintained a similar average neighboring distance.
- Achieved sufficient average communication performance.

Acknowledgements

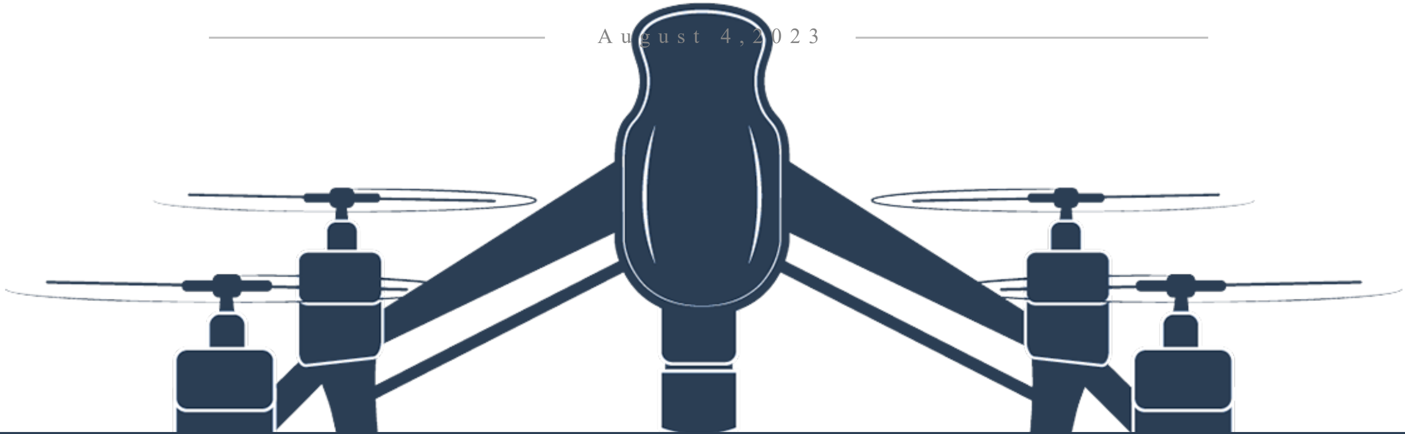
- This research was supported by the National Science Foundation under Grant No. 2150213.
- I'd like to thank you Dr. Song and Dr. Stansbury for considering me into this research program.
- I'd also like to thank you Dr. Yang's guidance throughout the project.
- Last but not the least, I would thank to Dr. Jayasena Dr. Ofori-Boateng, and Dr. Taylor-Rodriguez for taking the time to write me a letter of recommendation which allowed me to participate in this research program.



THANKS

Questions?

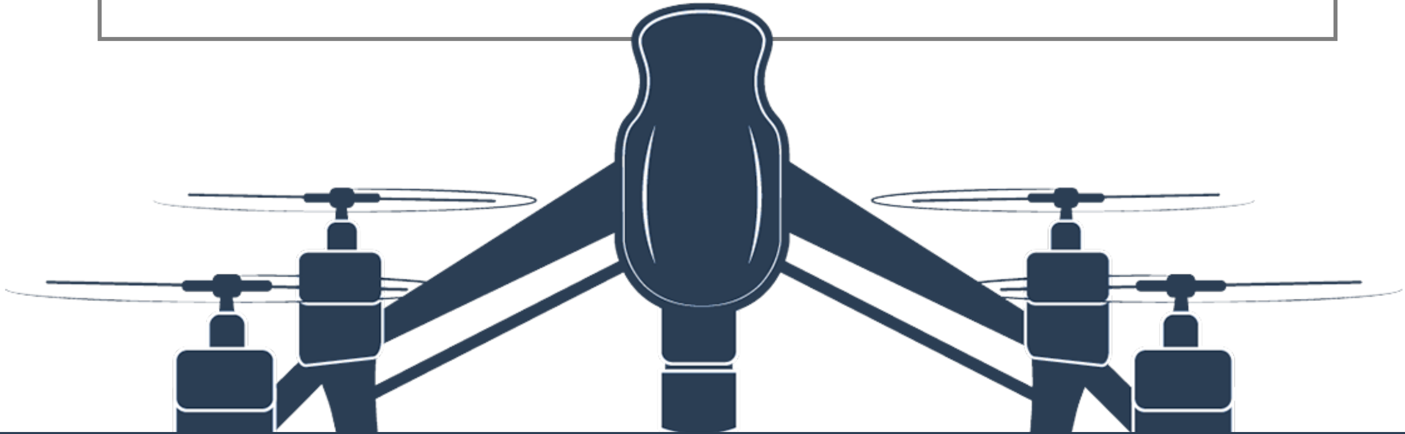
August 4, 2023



Reference

[1]: H. Li, J. Peng, W. Liu, K. Gao, Z. Huang, "A novel communication aware formation control strategy for dynamical multi-agent systems", Journal of the Franklin Institute 352 (2015), 3701-3715.

[2]: K. Fathian, T. H. Summers, and N. R. Gans, "Distributed formation control and navigation of fixed-wing UAVs at constant altitude," in 2018 International Conference on Unmanned Aircraft Systems (ICUAS), 2018.



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- ❑ Preliminaries
- ❑ Schematic Diagram

Formation Control

Tasks

1. How to navigate a swarm towards a destination?
2. How to avoid a jamming area without prior knowledge of its position?
3. How to achieve the above 2 tasks while maximizing communication quality?

Formation Control

Classical Formation Control

Agents typically perceive their absolute position relative to the global coordinate system and achieve their desired formation by actively controlling the absolute position.

Communication-aware Formation Control

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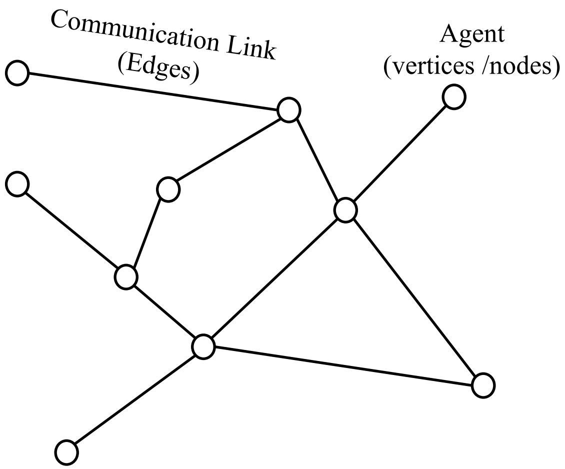
Preliminaries



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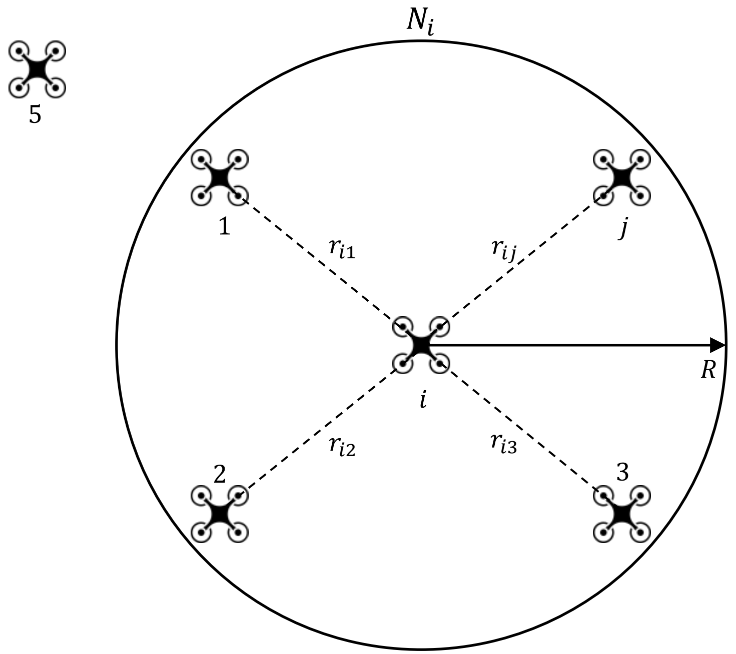

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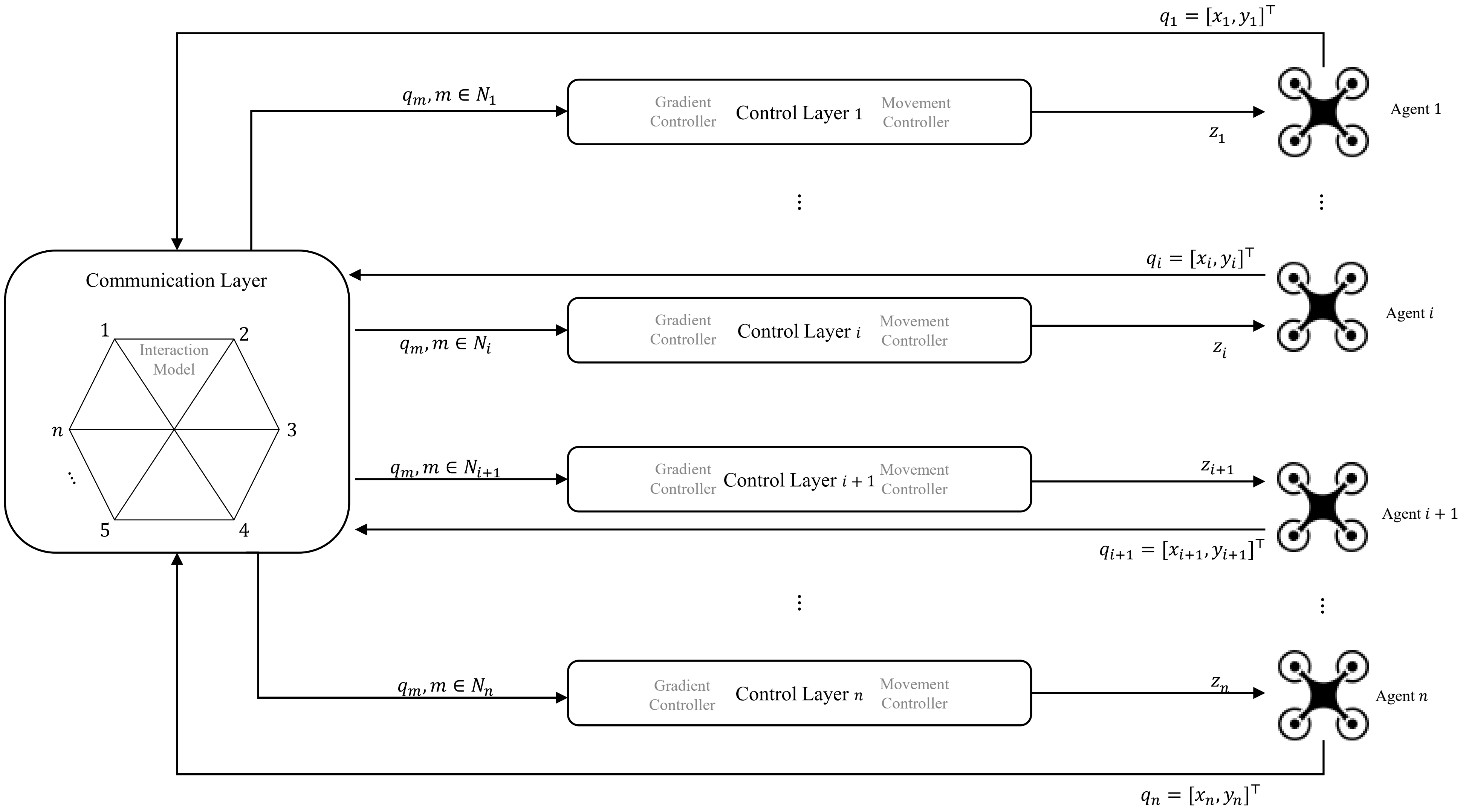

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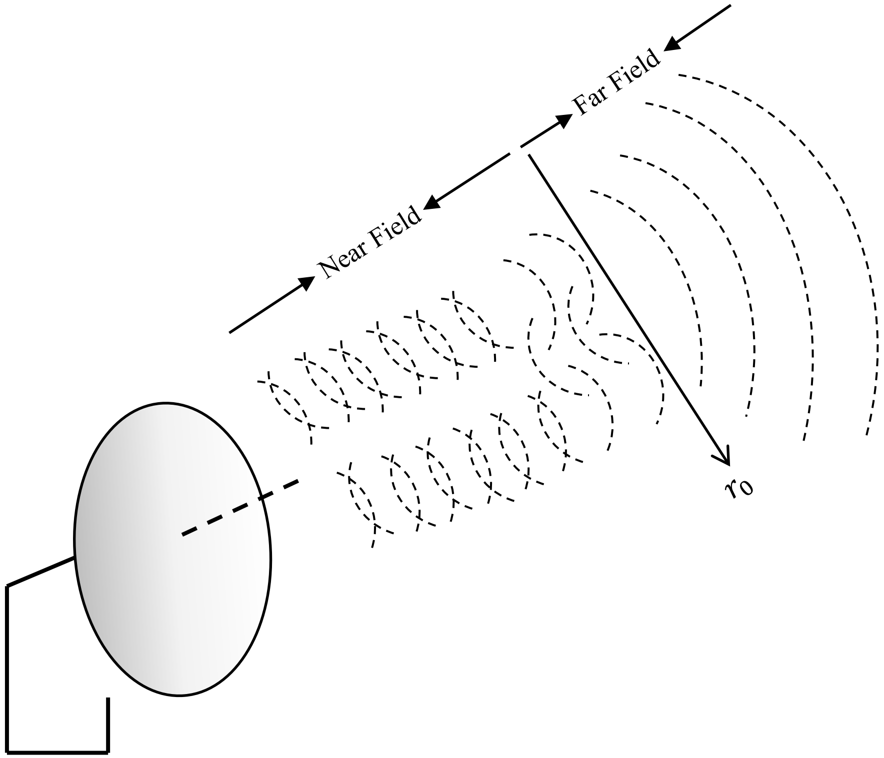

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A simple model of antenna near-field communication quality is:

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03

Control Layer

- ❑ Gradient Controller
- ❑ Movement Controller
  - Reach Goal Behavior
  - Jamming Avoidance Behavior
  - Edge Following Behavior

Gradient Controller

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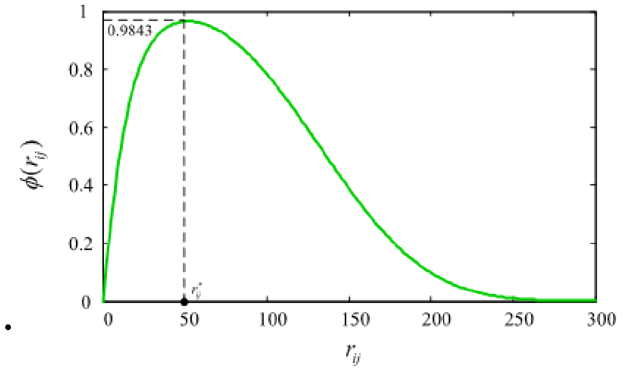
$$\frac{d\phi}{dr_{ij}} = \varphi(r_{ij}) = \frac{-\beta v(r_{ij})^{v+2} - \beta v r_0^2 (r_{ij})^{v} + r_0^{v+2}}{\sqrt{(r_{ij}^2 + r_0^2)^3}} \cdot \exp\left(-\beta\left(\frac{r_{ij}}{r_0}\right)^{v}\right),$$

where $\beta = \alpha(2^{\delta} - 1)$.



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where $e_{ij} = (q_i - q_j)/\sqrt{r_{ij}}$.

Movement Controller: Reach Goal Behavior

Description

Navigating the agents towards the destination.

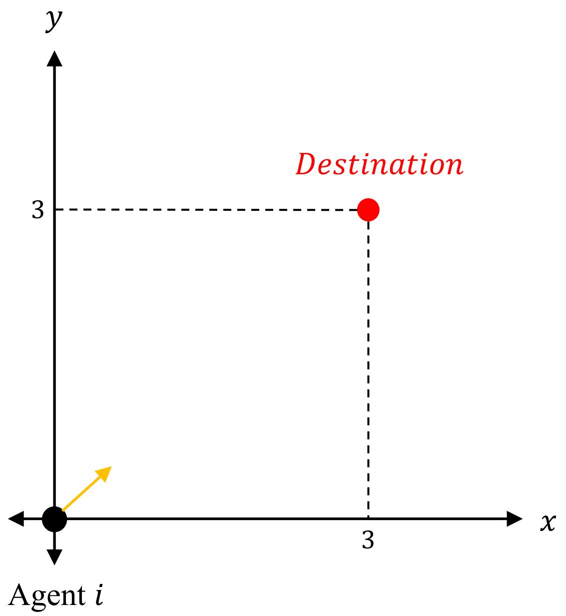
The behavior vector is calculated based on the current agent's coordinates and the destination coordinates.

The controlling parameter adjusts the agent's movement speed based on the distance between the agent and the target point.

Formula

$$V_{navigation} = \frac{1}{\sqrt{(x_{dest} - x_i)^2 + (y_{dest} - y_i)^2}} \begin{bmatrix} x_{dest} - x_i \\ y_{dest} - y_i \end{bmatrix}$$

$$f_1(d) = \begin{cases} a_m, & d > b_m \\ a_m \dfrac{d}{b_m}, & d \in [0, b_m] \end{cases}$$



$$V_{navigation} = \frac{1}{\sqrt{(x_{dest} - x_i)^2 + (y_{dest} - y_i)^2}} \begin{bmatrix} x_{dest} - x_i \\ y_{dest} - y_i \end{bmatrix}$$

$$= \frac{1}{\sqrt{(3-0)^2 + (3-0)^2}} \begin{bmatrix} 3 - 0 \\ 3 - 0 \end{bmatrix} = \frac{1}{\sqrt{18}} \begin{bmatrix} 3 \\ 3 \end{bmatrix} = \begin{bmatrix} 3/\sqrt{18} \\ 3/\sqrt{18} \end{bmatrix} = \begin{bmatrix} 0.707 \\ 0.707 \end{bmatrix}$$

Movement Controller: Reach Goal Behavior

Description

Navigating the agents towards the destination.

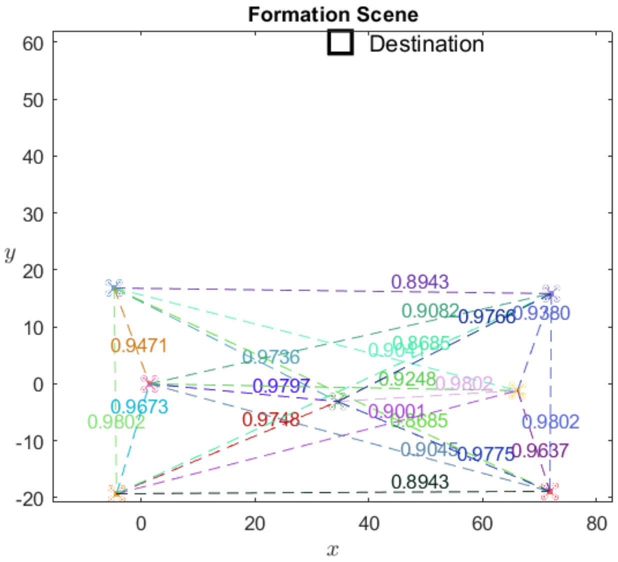
The behavior vector is calculated based on the current agent's coordinates and the destination coordinates.

The controlling parameter adjusts the agent's movement speed based on the distance between the agent and the target point.

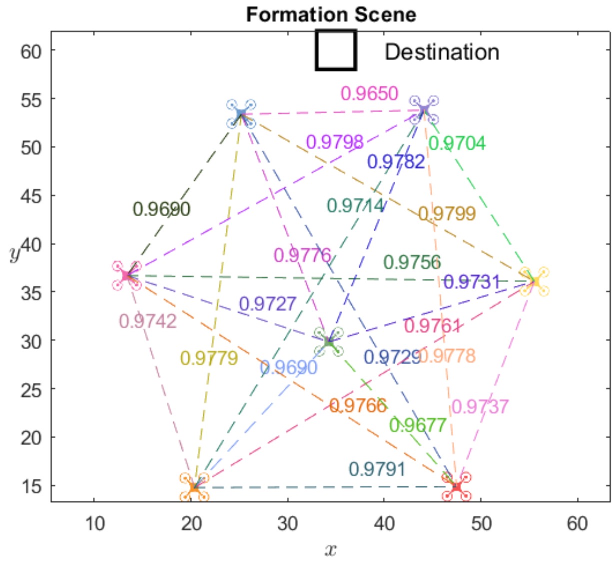
Formula

$$V_{navigation} = \frac{1}{\sqrt{(x_{dest} - x_i)^2 + (y_{dest} - y_i)^2}} \begin{bmatrix} x_{dest} - x_i \\ y_{dest} - y_i \end{bmatrix}$$

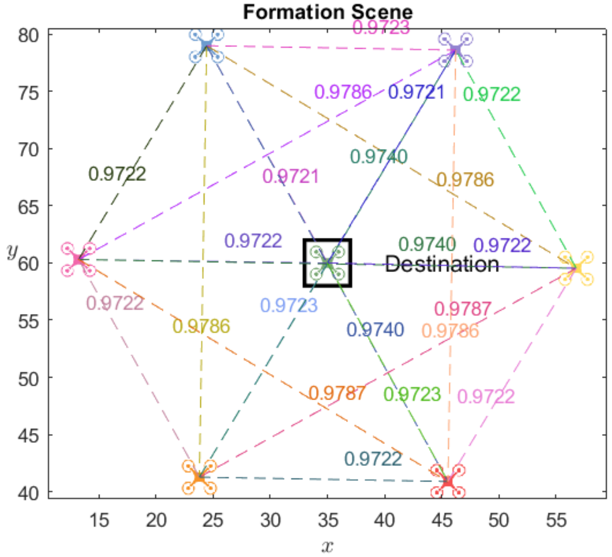
$$f_1(d) = \begin{cases} a_m, & d > b_m \\ a_m \dfrac{d}{b_m}, & d \in [0, b_m] \end{cases}$$



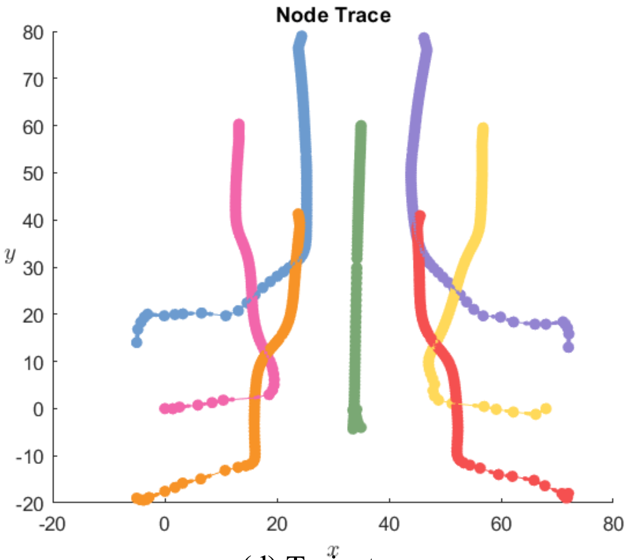
(a) Initial



(b) Halfway



(c) Final



(d) Trajectory

Movement Controller: Jamming Avoidance Behavior

Description

Enables agents to avoid jamming area in its path.

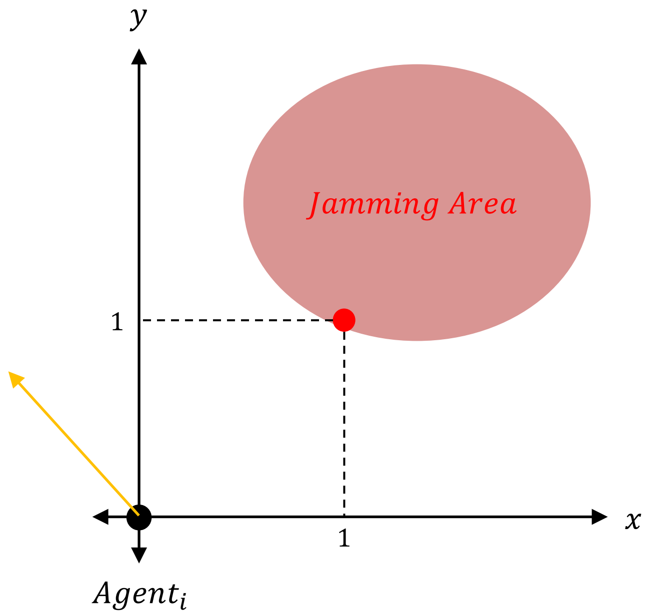
The behavior vector is determined by the distance between the agent and the nearest obstacle.

The controlling parameter adjusts the behavior to steer the agent away from the obstacle, with the sign of the vector determined by the obstacle's position relative to the agent.

Formula

$$V_{avoidance} = \frac{1}{\sqrt{\left(x_{jam} - x_i\right)^2 + \left(y_{jam} - y_i\right)^2}} \begin{bmatrix} \pm y_{jam} - y_i \\ \mp x_{jam} - x_i \end{bmatrix}$$

$$f_2(d) = \begin{cases} a_0 \left(\dfrac{d}{b_f - b_0} + \dfrac{b_0}{b_0 - b_f} \right), & d \in [b_f, b_0] \\ 0, & otherwise \end{cases}$$



$$V_{avoidance} = \frac{1}{\sqrt{\left(x_{jam} - x_i\right)^2 + \left(y_{jam} - y_i\right)^2}} \begin{bmatrix} \pm y_{jam} - y_i \\ \mp x_{jam} - x_i \end{bmatrix}$$

$$= \frac{1}{\sqrt{(1-0)^2 + (1-0)^2}} \begin{bmatrix} +(1-0) \\ -(1-0) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix} = \begin{bmatrix} 0.707 \\ -0.707 \end{bmatrix}$$

Movement Controller: Jamming Avoidance Behavior

Description

Enables agents to avoid jamming area in its path.

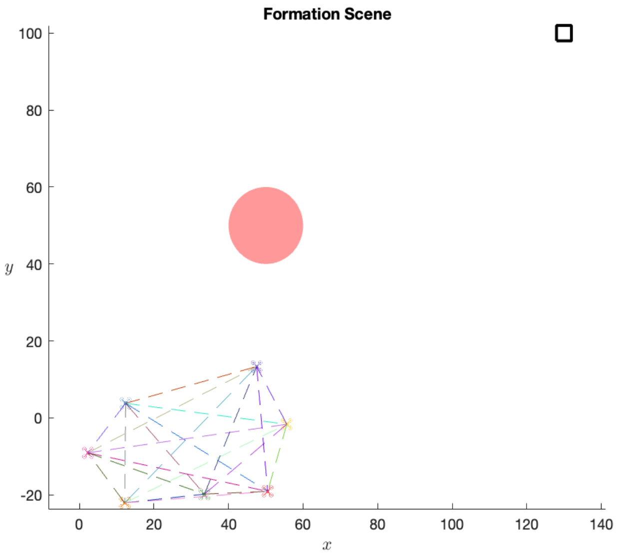
The behavior vector is determined by the distance between the agent and the nearest obstacle.

The controlling parameter adjusts the behavior to steer the agent away from the obstacle, with the sign of the vector determined by the obstacle's position relative to the agent.

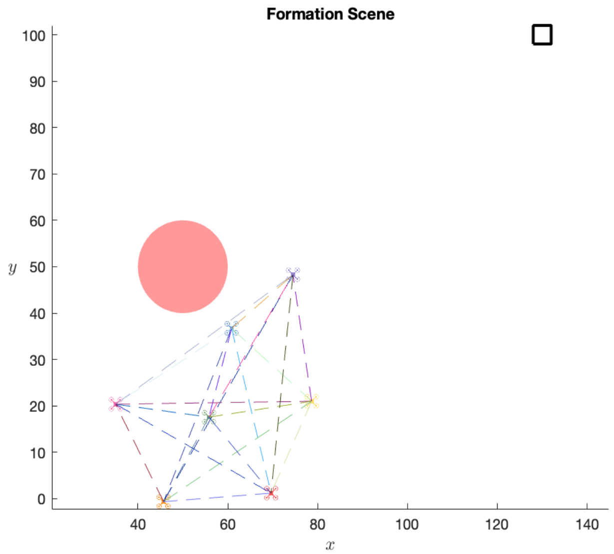
Formula

$$V_{avoidance} = \frac{1}{\sqrt{(x_{jam} - x_i)^2 + (y_{jam} - y_i)^2}} \begin{bmatrix} \pm y_{jam} - y_i \\ \mp x_{jam} - x_i \end{bmatrix}$$

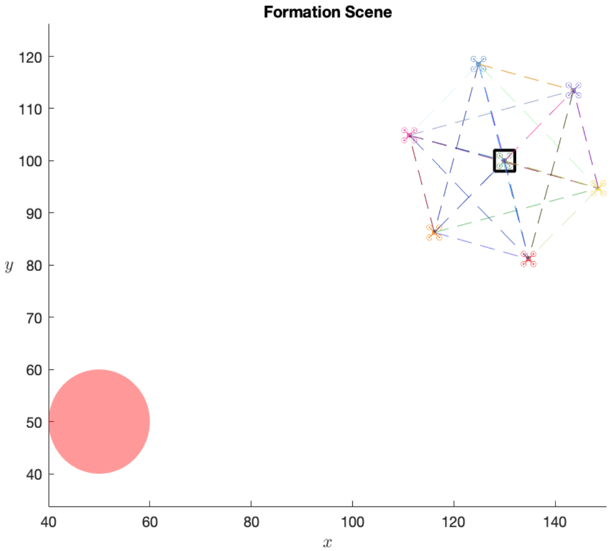
$$f_2(d) = \begin{cases} a_0 \left(\dfrac{d}{b_f - b_0} + \dfrac{b_0}{b_0 - b_f} \right), & d \in [b_f, b_0] \\ 0, & otherwise \end{cases}$$



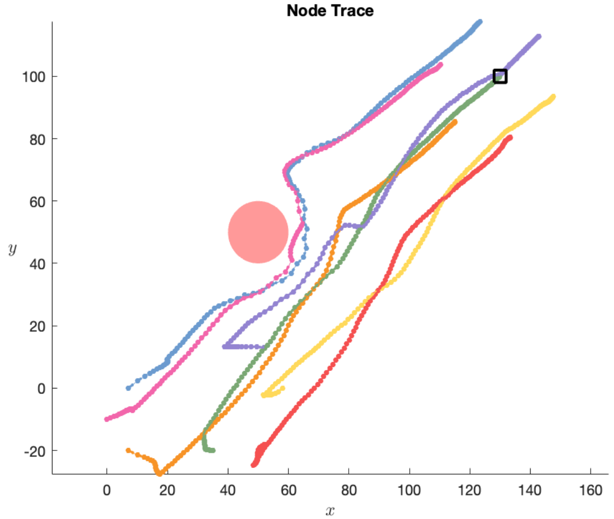
(a) Initial



(b) Halfway



(c) Final



(d) Trajectory

Movement Controller: Edge Following Behavior

Description

Helps the agents navigate by following jamming area edges.

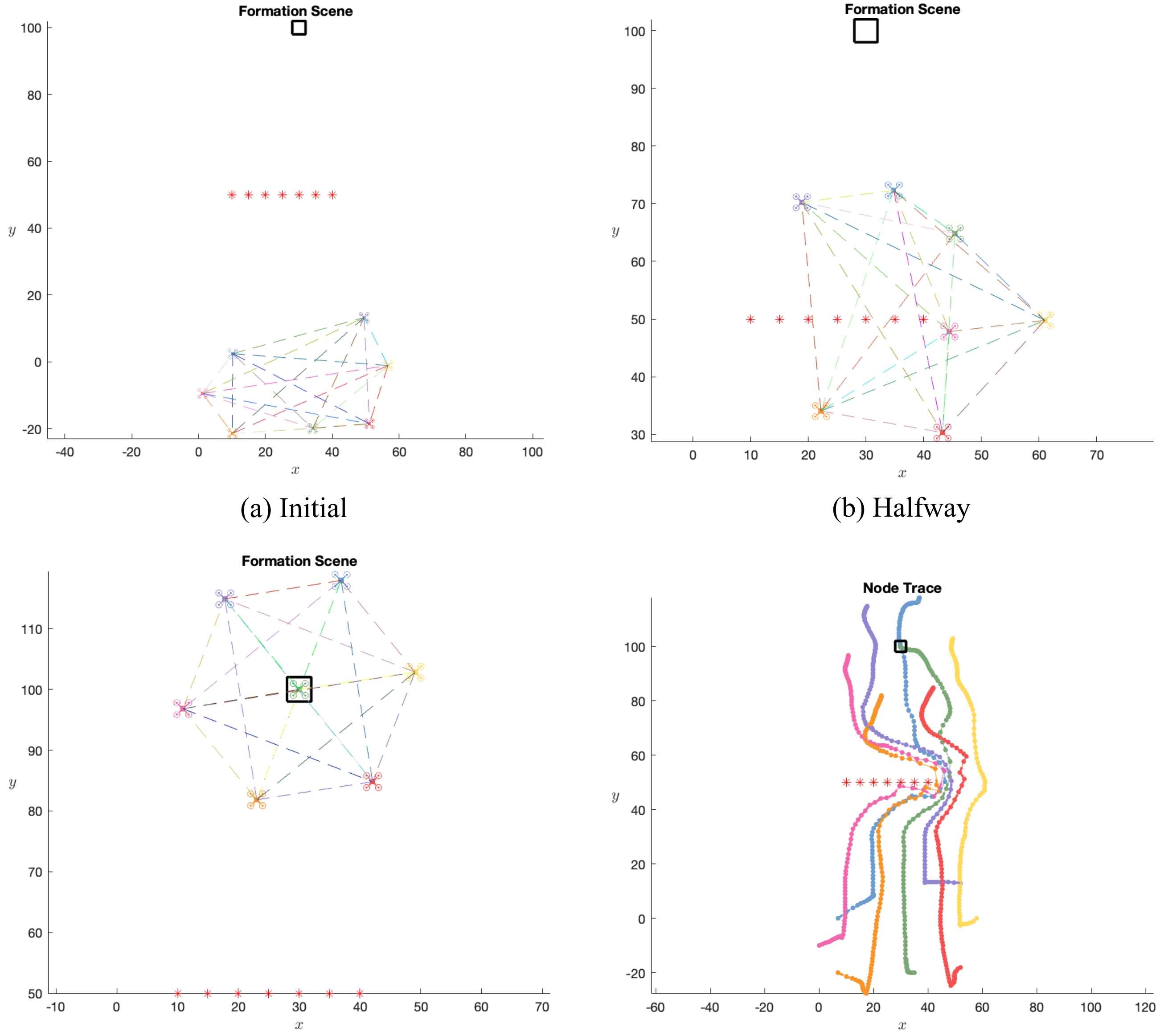
The behavior vector is calculated based on the coordinates of the nearest obstacle and the agent's current position.

The controlling parameter activates the behavior and determines the direction of edge following based on the obstacle's position relative to the agent.

Formula

$$V_{edge-following} = \frac{1}{\sqrt{\left(x_{jam} - x_i\right)^2 + \left(y_{jam} - y_i\right)^2}} \begin{bmatrix} \pm y_{jam} - y_i \\ \mp x_{jam} - x_i \end{bmatrix}$$

$$f_3(d) = \begin{cases} a_f, & d \in [0, e_f] \\ 0, & otherwise \end{cases}$$



(a) Initial (b) Halfway (c) Final (d) Trajectory

Final Controller

System Dynamics

The dynamics of this multi-agent system is denoted by

$$\dot{q}_i = z_i, \quad i = 1,2,\dots,n,$$

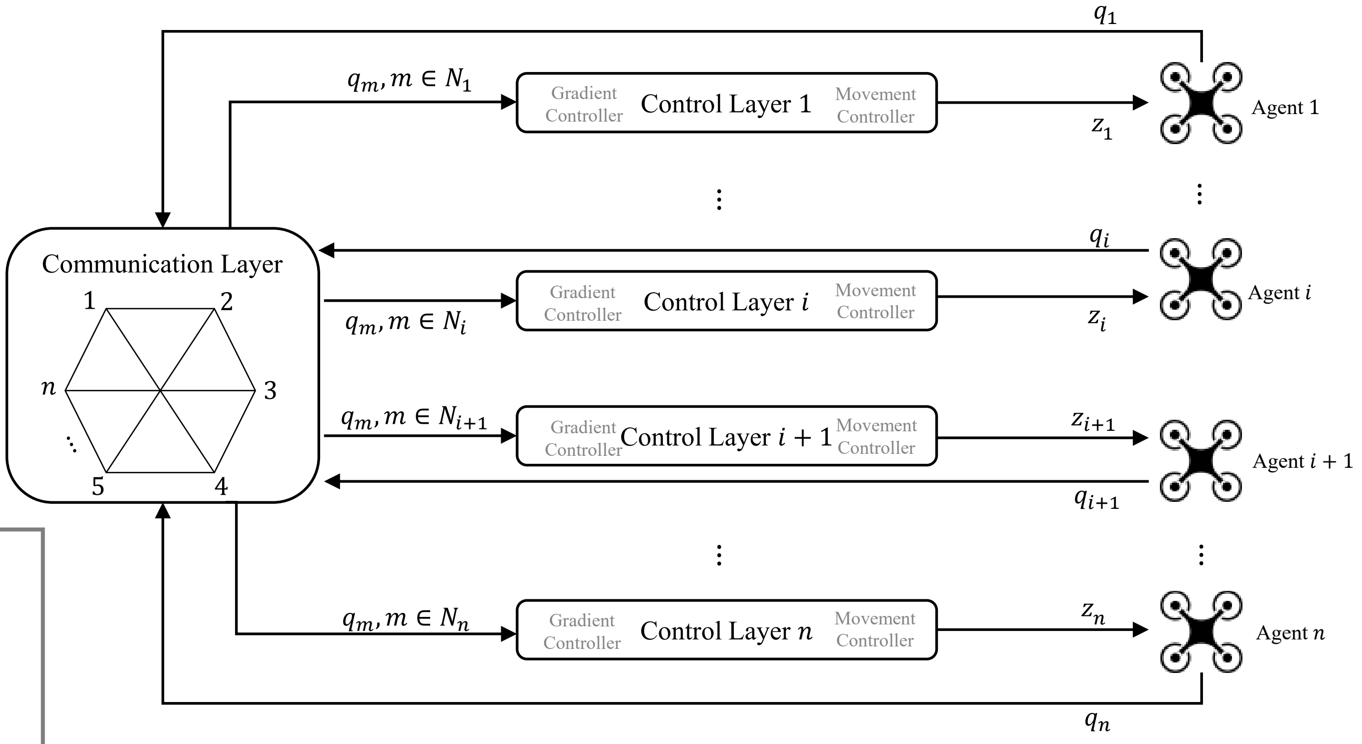
where

q: position input of agents,
z: control input of agents.

Final Formation Controller

$$z_i = \mathcal{G}_i + \mathcal{M}_i$$

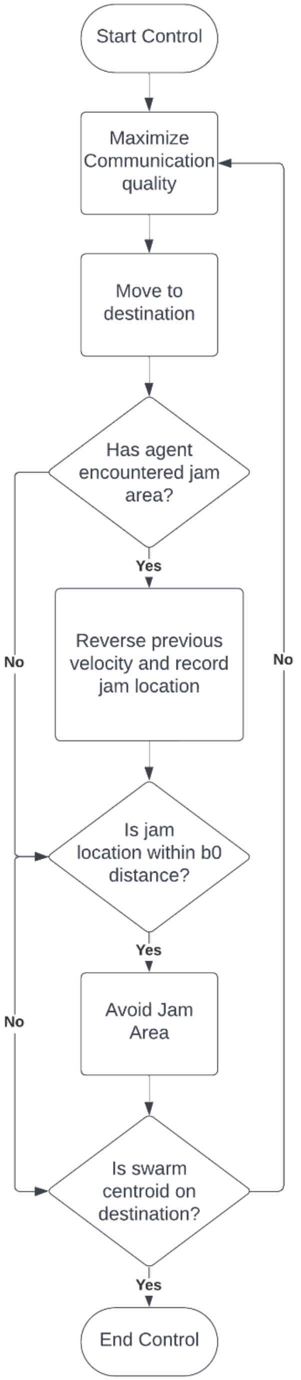
$$= \sum_{j \in N_i} \left[\varphi(r_{ij}) \cdot e_{ij} \right] + \left[f_1(\cdot) \quad f_2(\cdot) \quad f_3(\cdot) \right] \begin{bmatrix} V_{navigation} \\ V_{avoidance} \\ V_{edge-following} \end{bmatrix}$$

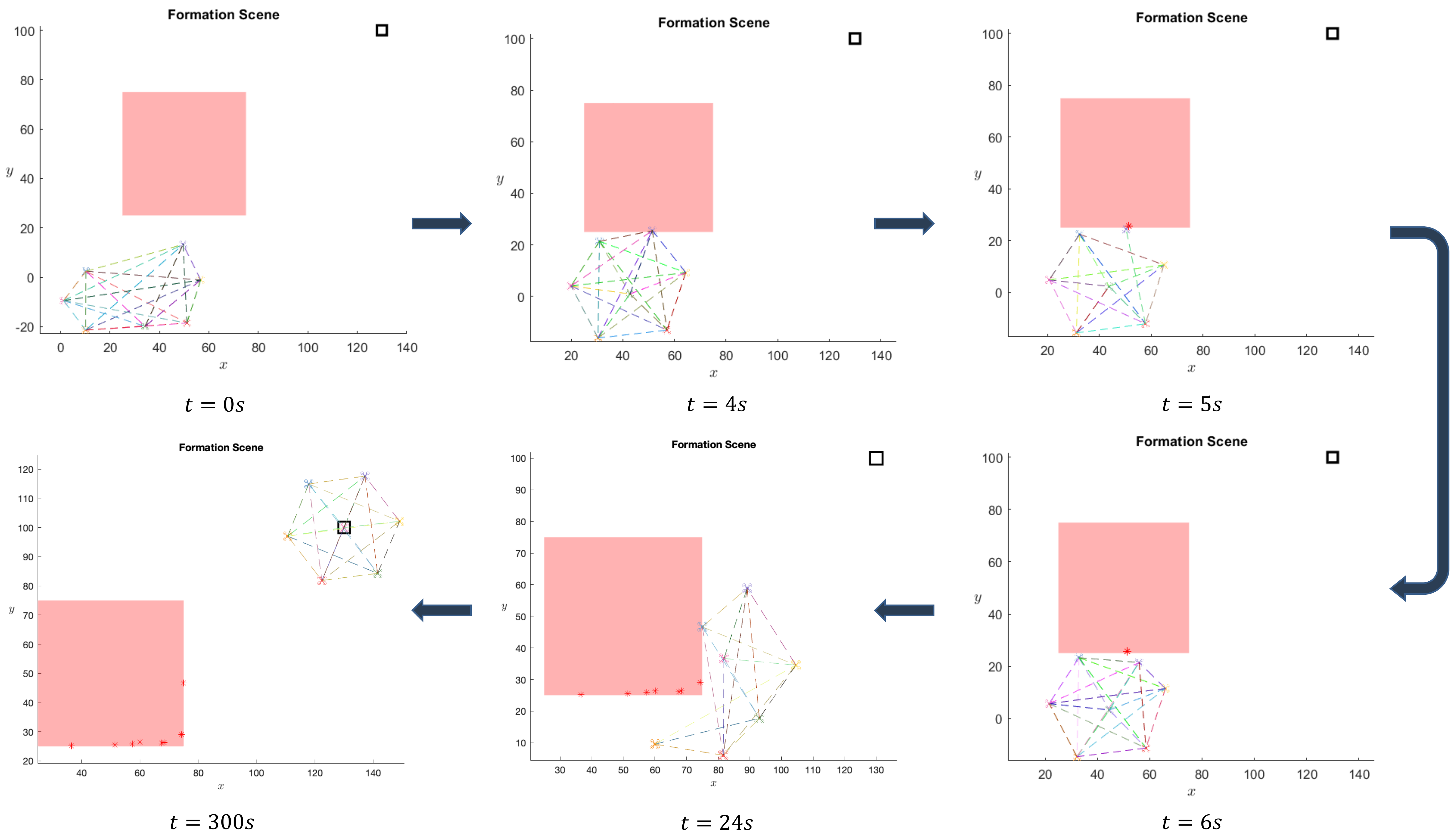


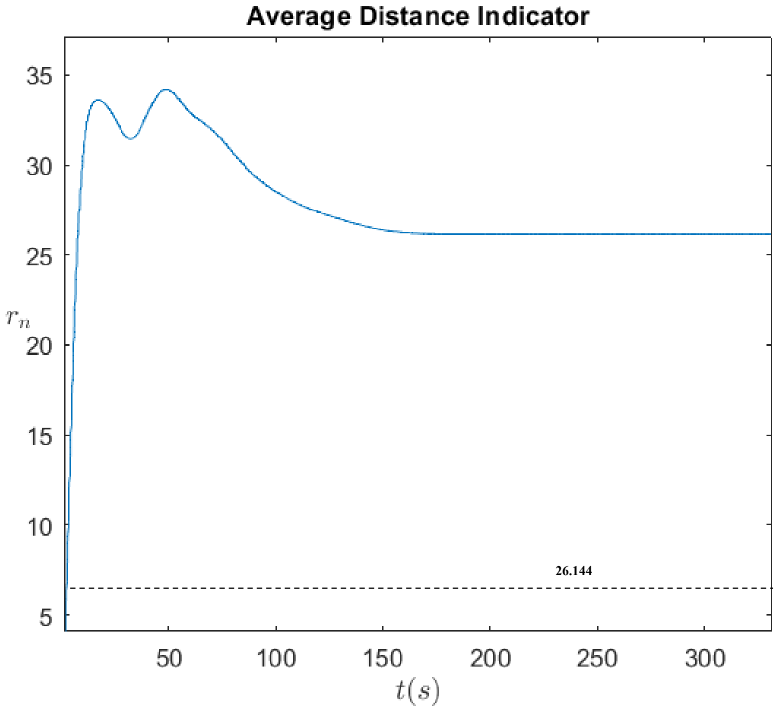
04

Simulations

Workflow


Start Control
Maximize Communication quality
Move to destination
Has agent encountered jam area?
Yes
No
Reverse previous velocity and record jam location
Is jam location within b0 distance?
Yes
No
Avoid Jam Area
Is swarm centroid on destination?
No
Yes
End Control


Formation Scene
$t = 0s$
Formation Scene
$t = 4s$
Formation Scene
$t = 5s$
Formation Scene
$t = 300s$
Formation Scene
$t = 24s$
Formation Scene
$t = 6s$

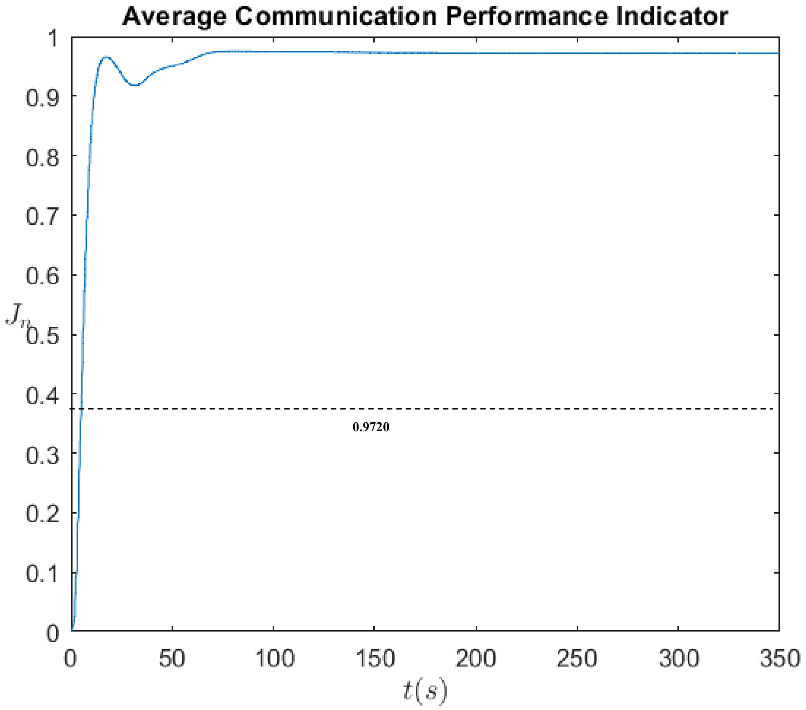


J_n: Average Communication Performance Indicator

$$J_n = \frac{\sum_{i=1}^{n} \sum_{j \in N_i} \phi(r_{ij})}{2n|N_i|}$$

r_n: Average Neighboring Distance Indicator

$$r_n = \frac{\sum_{i=1}^{n} \sum_{j \in N_i} r_{ij}}{2n|N_i|}$$



05

Conclusion

Review

Intro

Preliminaries

- Graph Theory
- Rigid Formation
- System Dynamics

Communication Layer

- Antenna Far-field Model
- Antenna Near-field Model
- Interaction Model

Control Layer

- Gradient Controller
- Movement Control

Simulation

- Average Communication Performance J_n
- Average neighboring Distance r_n

Outro

Results

- Formation control is communication-aware and behavior-based.
- Maintained a similar average neighboring distance. Achieved sufficient average communication performance.
- Enhanced resilience in complex environments, such as jamming area.

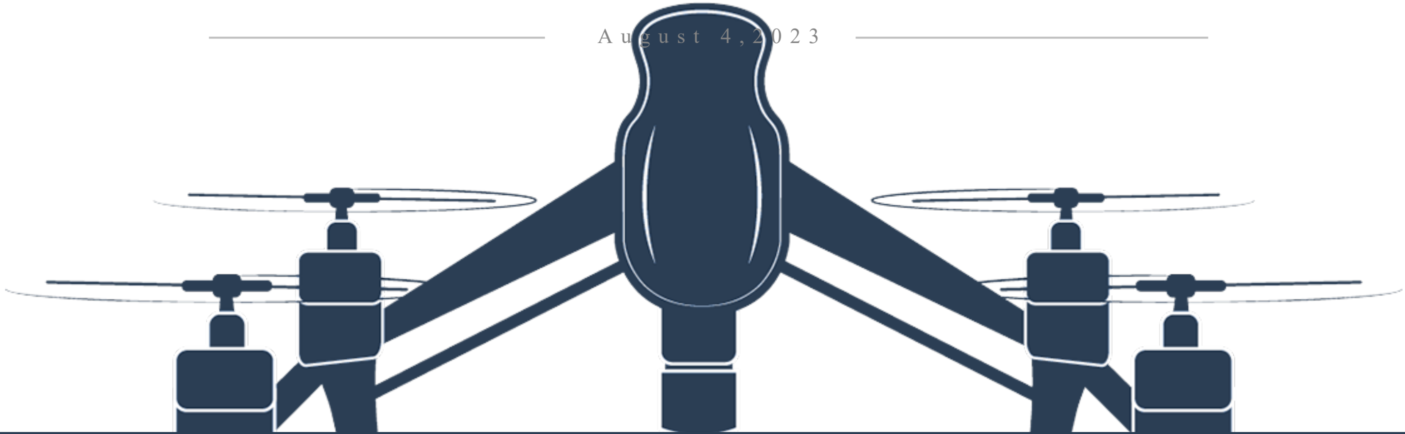
Acknowledgement

- This research was supported by the National Science Foundation under Grant No. 2150213.
- We'd like to thank you Dr. Stansbury for considering us into this research program.
- We'd like to thank you Dr. Yang's guidance throughout this research project.

THANKS

Questions?

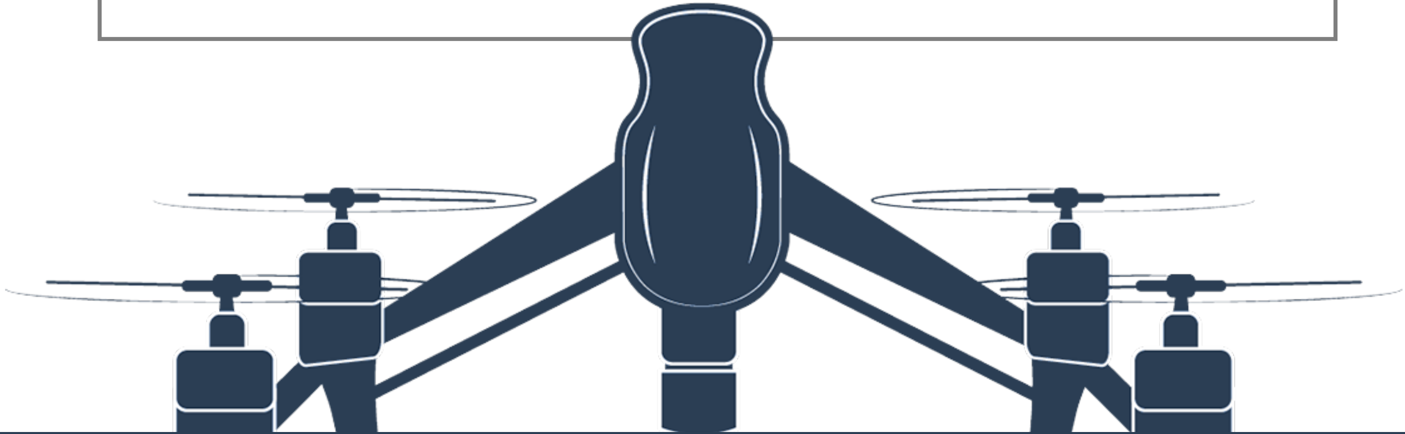
August 4, 2023



Reference

[1]: H. Li, J. Peng, W. Liu, K. Gao, Z. Huang, "A novel communication aware formation control strategy for dynamical multi-agent systems", Journal of the Franklin Institute 352 (2015), 3701-3715.

[2]: D. Xu, X. Zhang, Z. Zhu, C. Chen, and P. Yang, "Behavior-based formation control of Swarm Robots," Mathematical Problems in Engineering, vol. 2014, pp. 1–13, 2014. doi:10.1155/2014/205759



2023

Robust Communication-aware Jamming Detection and Avoidance

Samuel Peccoud (CSU)

Sang Xing (PSU)

Dr. Yang (ERAU)

ERAU NSF REU

Table of Contents

01

Introduction

- ❑ Research Questions
- ❑ Background
- ❑ Preliminaries
- ❑ Schematic Diagram

Research Questions

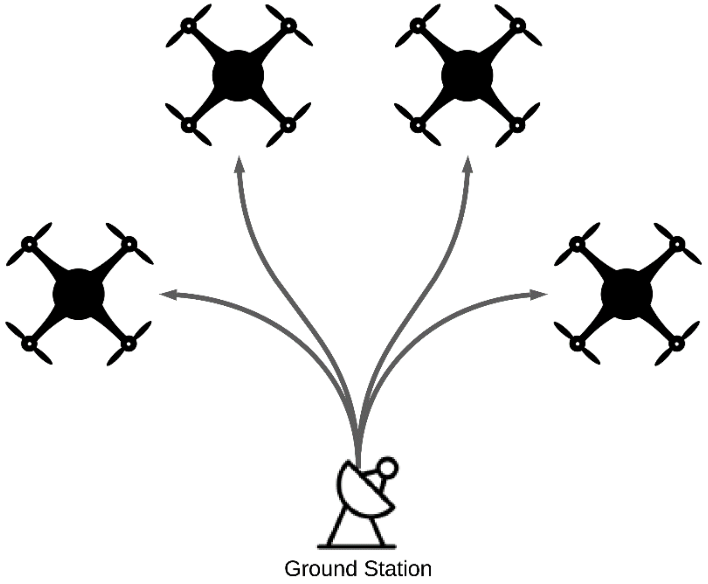
1. How to navigate a swarm around jamming areas?
   - Particle Swarm Optimization (PSO) Algorithm + Path Planning Algorithm

2. How to maximizing communication quality between agents?
   - Communication-aware formation control

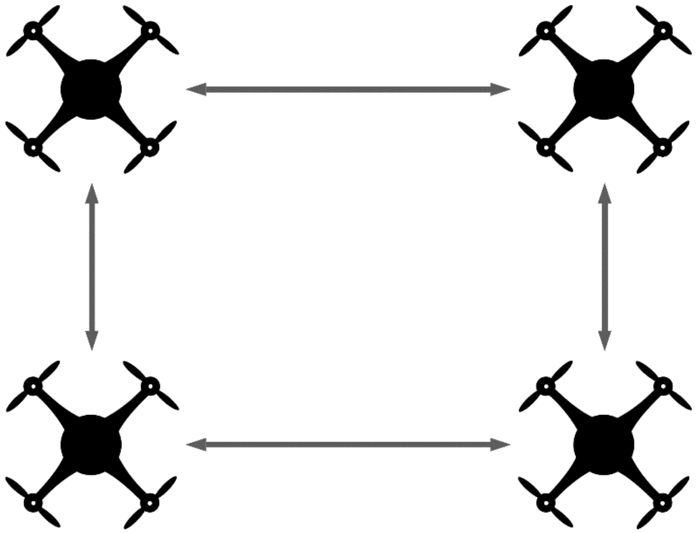
Background

Formation Control

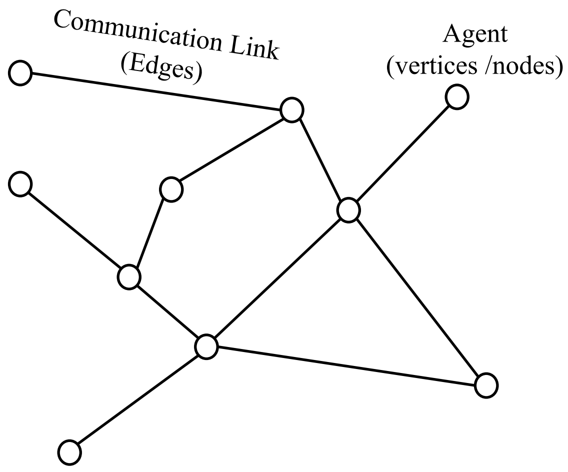
Centralized Control



Distributed Control



Preliminaries



Graph Theory

A **graph** G is a pair of $(\mathcal{V}, \mathcal{E})$ consisting of a set of **vertices** $\mathcal{V} = \{1,2, \ldots, \mathrm{i}, \ldots, j, \ldots n\}$ and a set of ordered pairs of the vertices called **edges** $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$. I.e., $\mathcal{E} = \{(i,j) | i,j \in \mathcal{V},\ i \neq j\}$. Here, we assume that G has no **self-edges** and **undirected**.

Rigid Formation

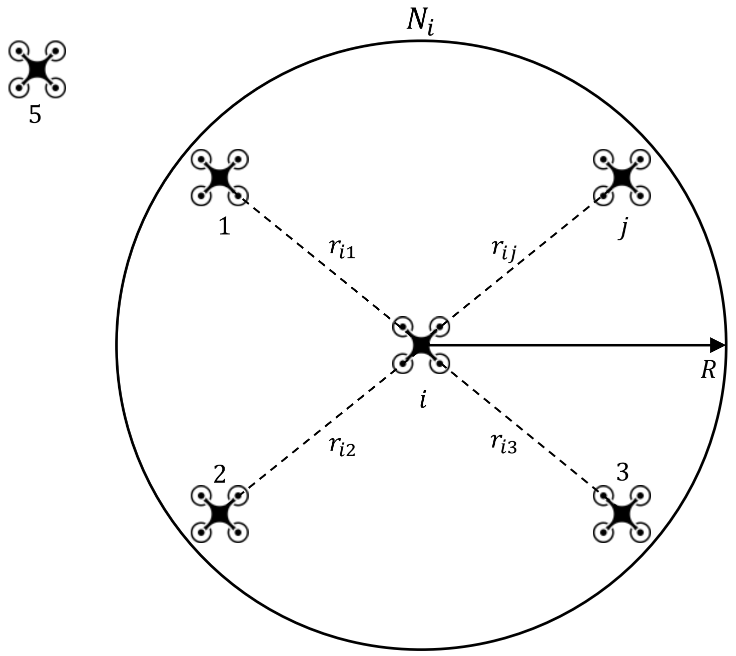
The formation of groups of mobile agents in which all inter-agent distances remain constant is called **rigid**.

The **relative distance** between agent i and agent j is denoted by

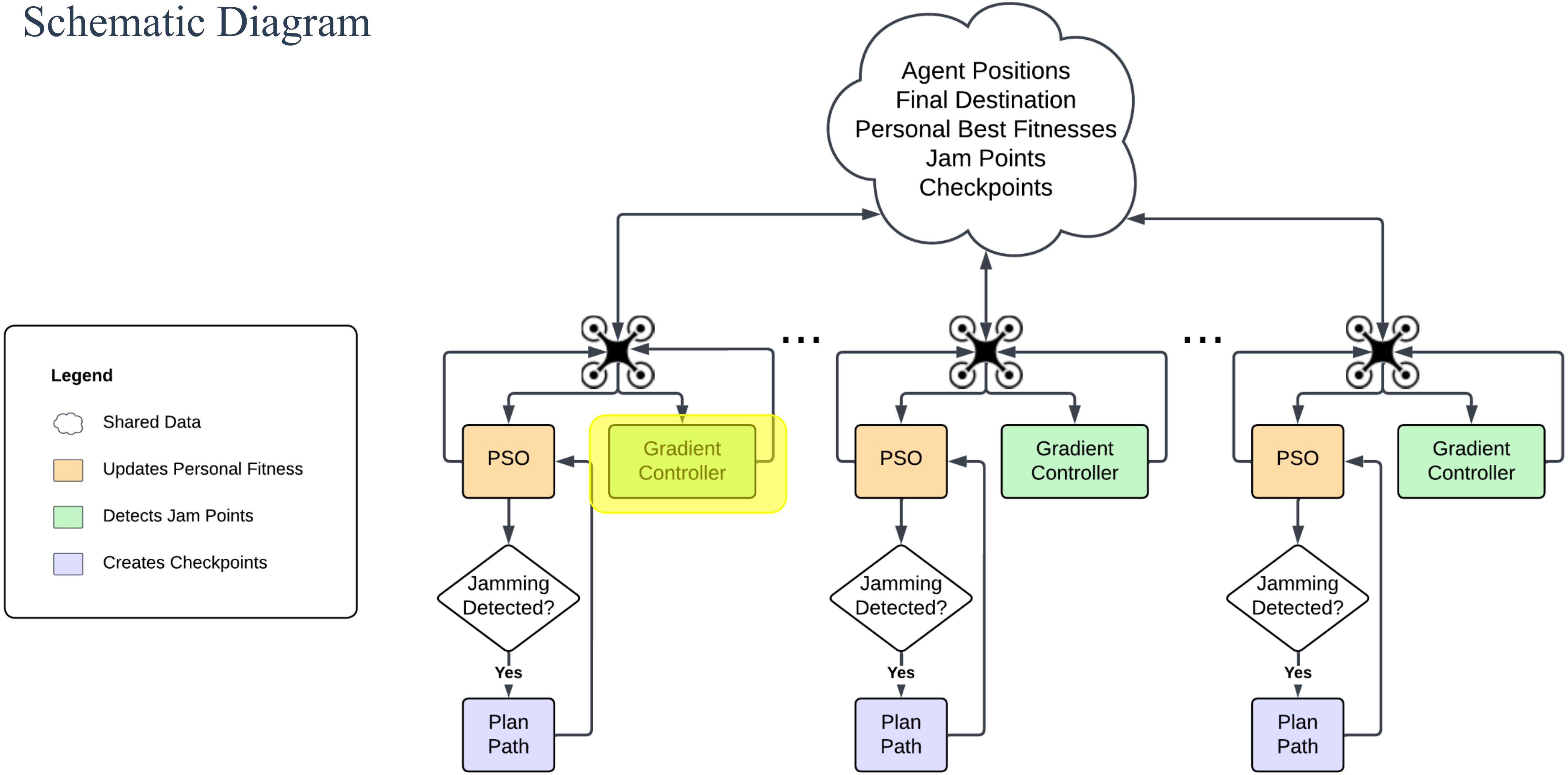
$$r_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} = \|q_i - q_j\|.$$

Let $R > 0$ denote the **communication range** between two agents. The neighboring set of agent i can be denoted by

$$N_i = \{j \in \mathcal{V} \mid r_{ij} \leq R\}.$$



Schematic Diagram

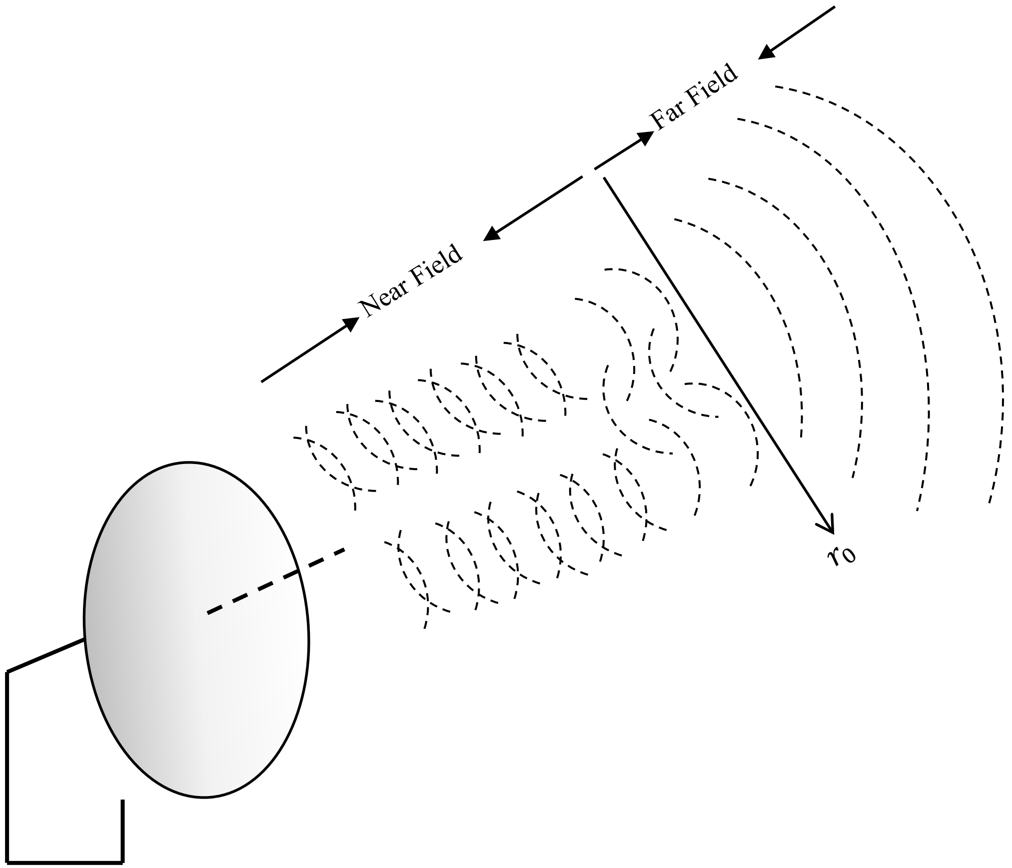


02

Communication Model

- Antenna Near-field and Far-field
- Interaction Model

Antenna Near-field and Far-field



Far-field

The communication channel quality in antenna far-field is:

$$f_{ij} = \exp\left(-\alpha\left(2^{\delta}-1\right)\left(\frac{r_{ij}}{r_0}\right)^{v}\right).$$

Near-field

A simple model of antenna near-field communication quality is:

$$n_{ij} = \frac{r_{ij}}{\sqrt{{r_{ij}}^2+{r_0}^2}}$$

where

r_0: antenna field separator,

r_{ij}: distance between agent i and agent j.

Interaction Model

Signal Scattering Effect

When a traveling wave encounters a change in the wave impedance, it will reflect, at least partially. If the reflection is not total, it will also partially transmit into the new impedance.

Path Loss Effect

The reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. As a result, the received signal power level is several orders below the transmitted power level.

Interference Effect

When a signal is disrupted as it travels along the communication channel between its source and receiver. It may cause only a temporary loss of a signal and may affect the quality of the communication.

Interaction Model

The interaction model is denoted by

$$\phi(r_{ij}) = n_{ij} \cdot f_{ij} = \frac{r_{ij}}{\sqrt{{r_{ij}}^2 + {r_0}^2}} \cdot \exp\left(-\alpha\left(2^{\delta} - 1\right)\left(\frac{r_{ij}}{r_0}\right)^{v}\right).$$

03

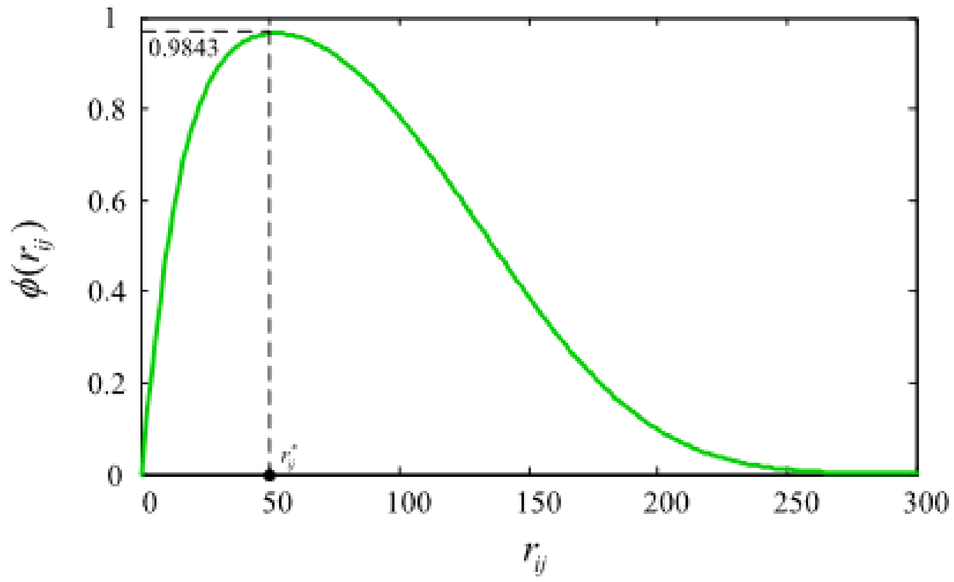
Control Layer

- ❑ Gradient Controller
- ❑ Movement Controller
  - Particle Swarm Optimization (PSO)
  - Path Planning

Gradient Controller

To maximizes the communication performance, we take the first-order derivative of the interaction model,

$$\frac{d\phi}{dr_{ij}} = \varphi(r_{ij}) = \frac{-\beta v (r_{ij})^{v+2} - \beta v r_0^2 (r_{ij})^{v} + r_0^{v+2}}{\sqrt{(r_{ij}^2 + r_0^2)^3}} \cdot \exp\left(-\beta \left(\frac{r_{ij}}{r_0}\right)^{v}\right).$$



A gradient controller moves agents to maximize communication performance.

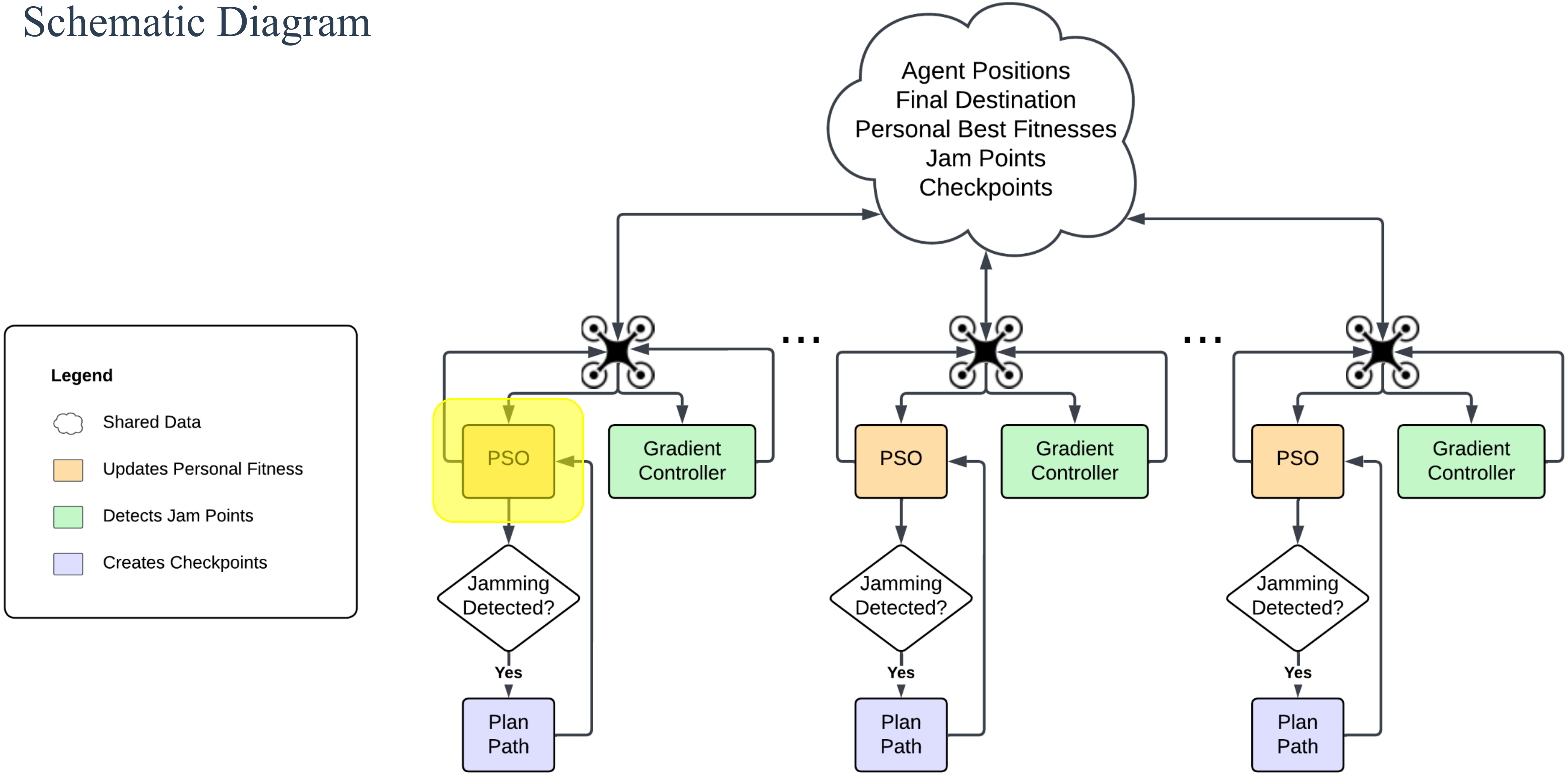
Gradient Control Model

The gradient control model of agent i is denoted by

$$\mathcal{G}_i = \sum_{j \in N_i} [\nabla_{q_i} \phi(r_{ij})] = \sum_{j \in N_i} [\varphi(r_{ij}) \cdot e_{ij}]$$

where $e_{ij} = (q_i - q_j)/\sqrt{r_{ij}}$.

Schematic Diagram

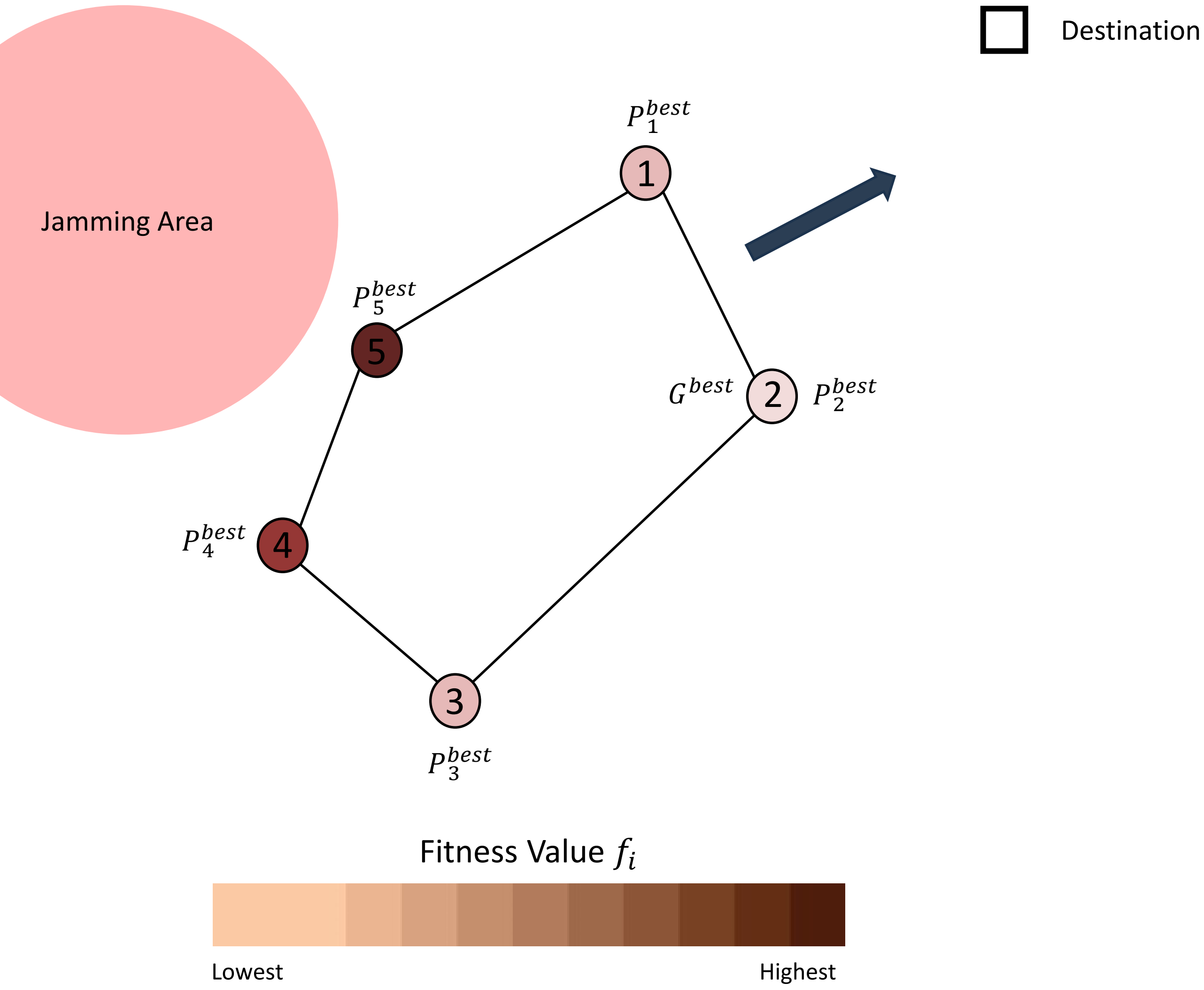


Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a biology inspired algorithm.

It is commonly used in multi-robot path planning.

Particle Swarm Optimization



Fitness Function

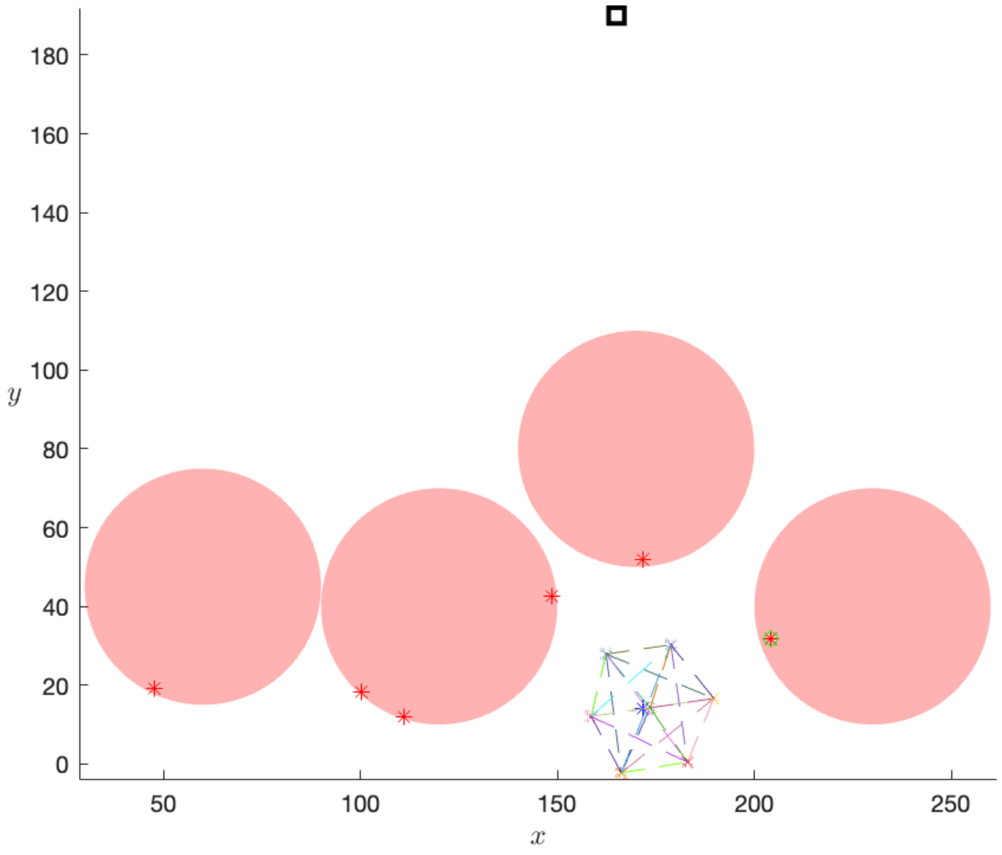
The fitness value of agent i is:

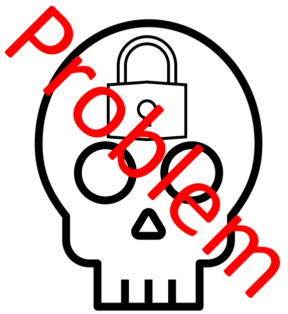
$$f_i = d_{\text{dest}} \cdot w_{\text{dest}} - \log_{10}\left(h_{\text{jam}}\right) \cdot w_{\text{jam}},$$

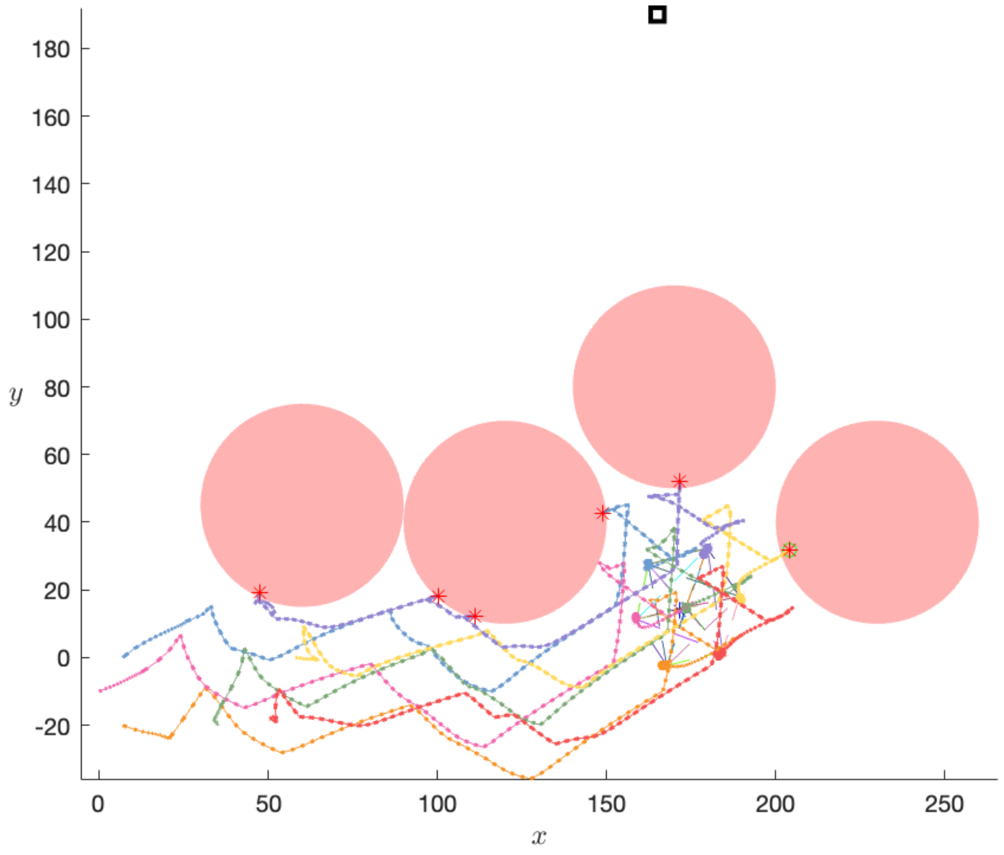
where

- d_{dest} is the distance from agent to destination.
- h_{jam} is the distance from agent to jam point.
- w_{dest} and w_{jam} are adjustable weight to the distance vector.

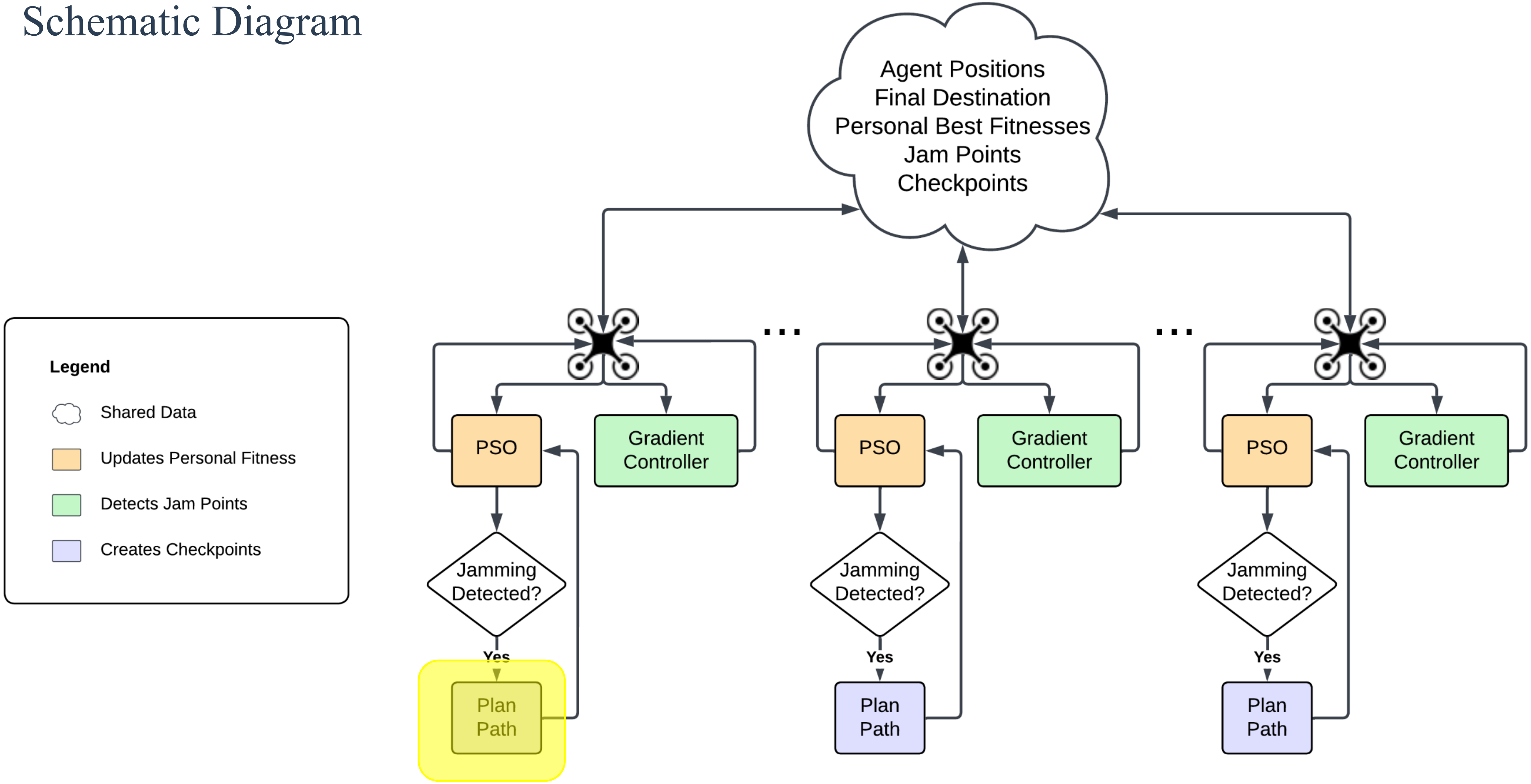
Particle Swarm Optimization



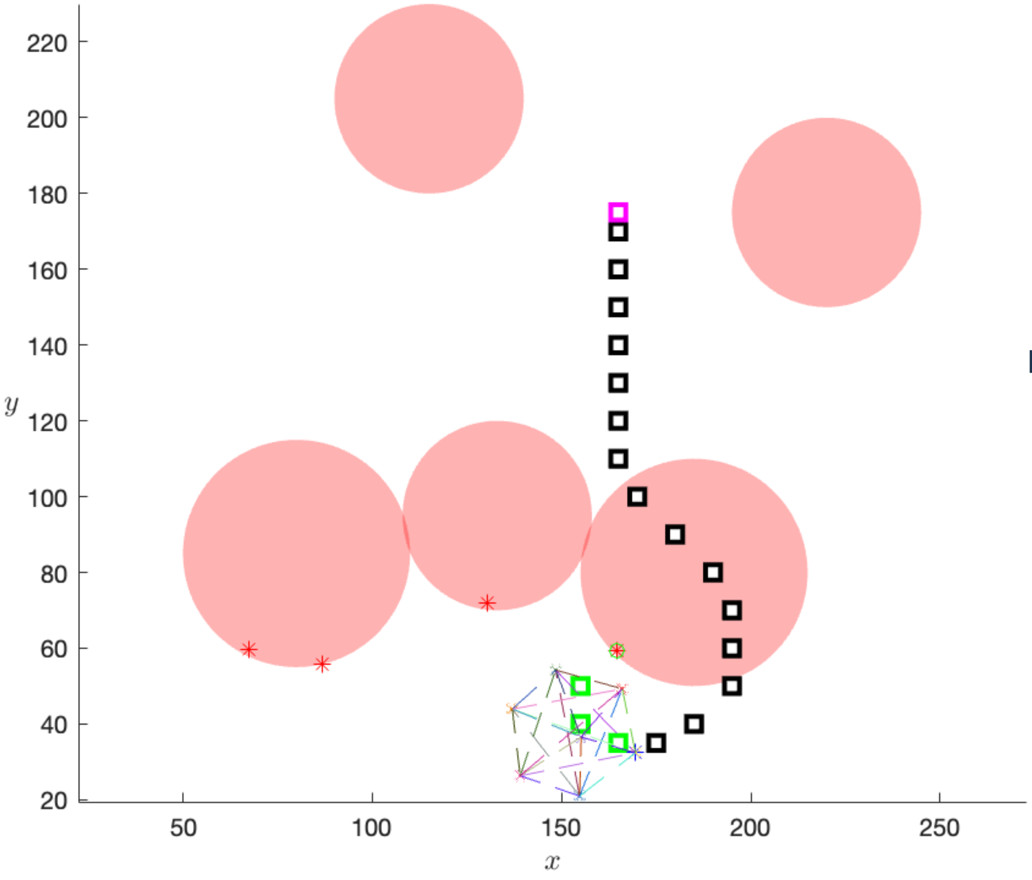




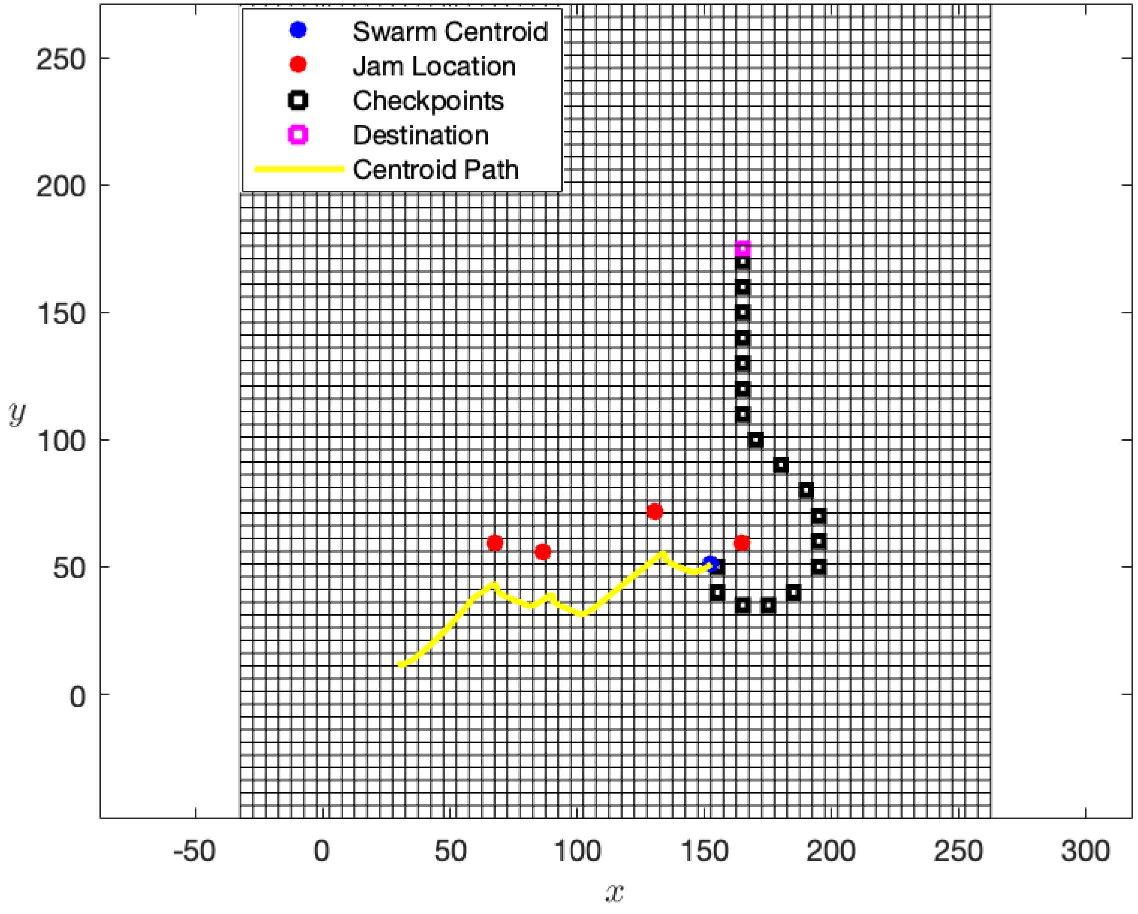
Schematic Diagram



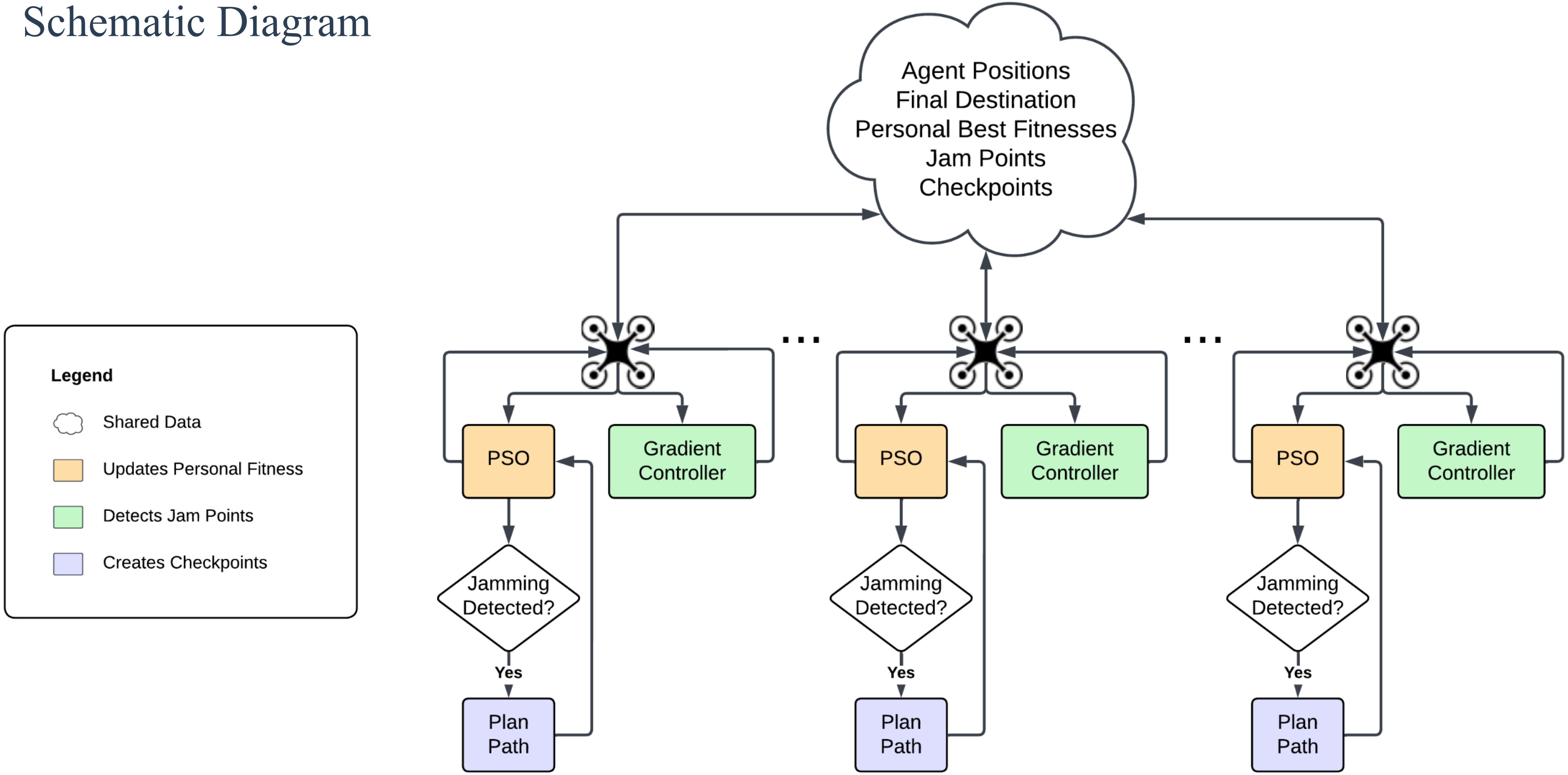
Path Planning Algorithm



Discretized Environment



Schematic Diagram

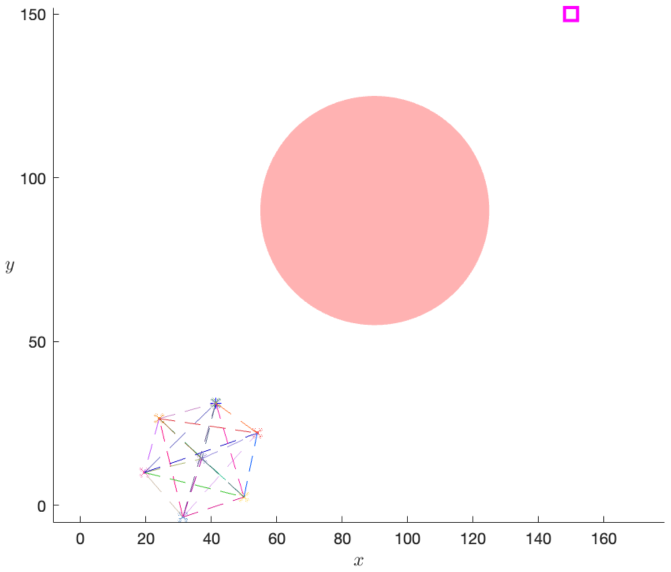


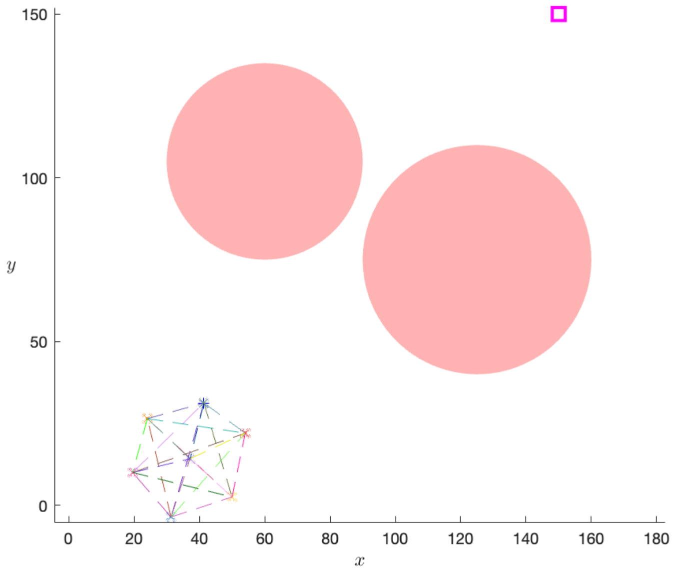
04

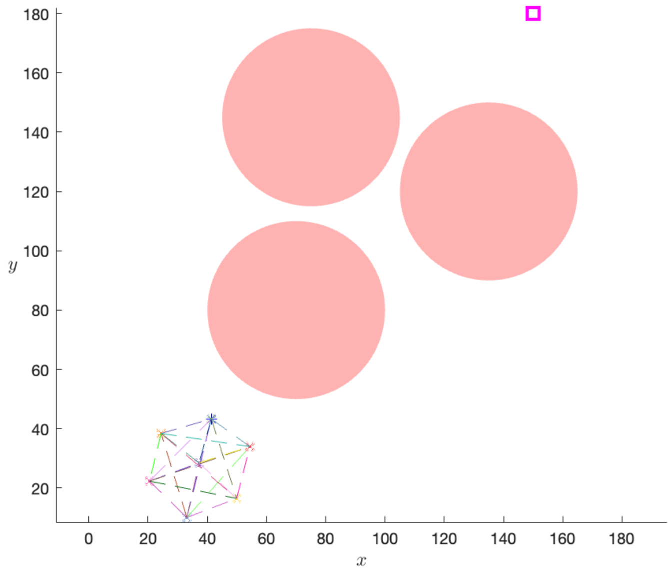
Simulations

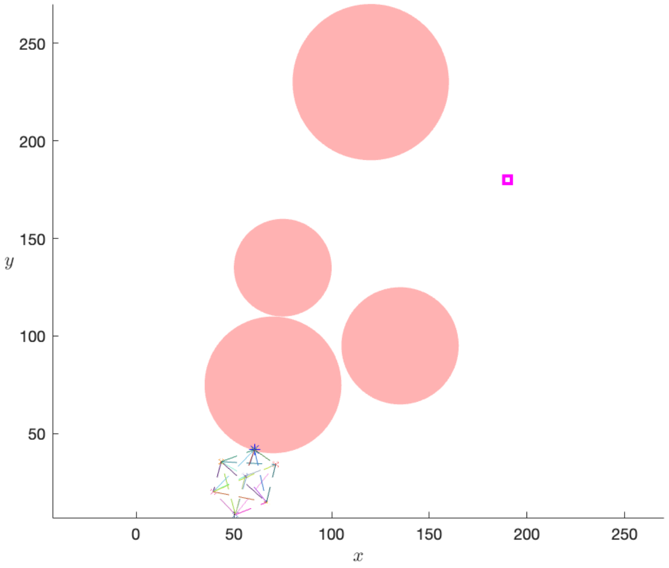
- Simulation Environments
- Simulation Results
- Simulation Evaluation

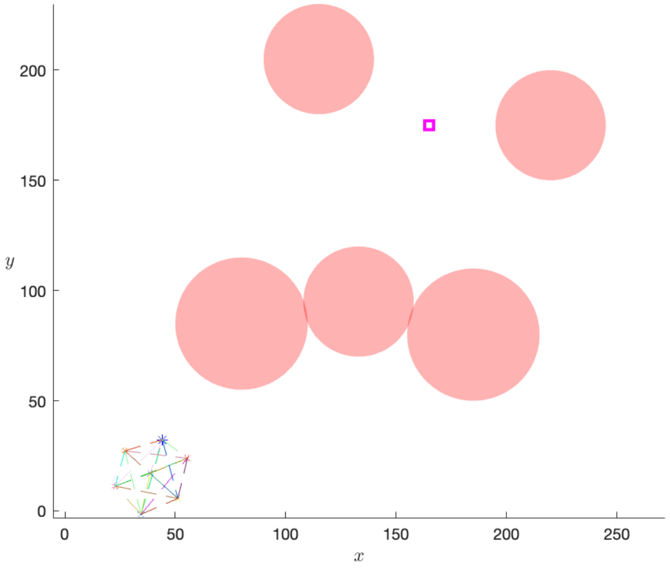
Simulation Environments







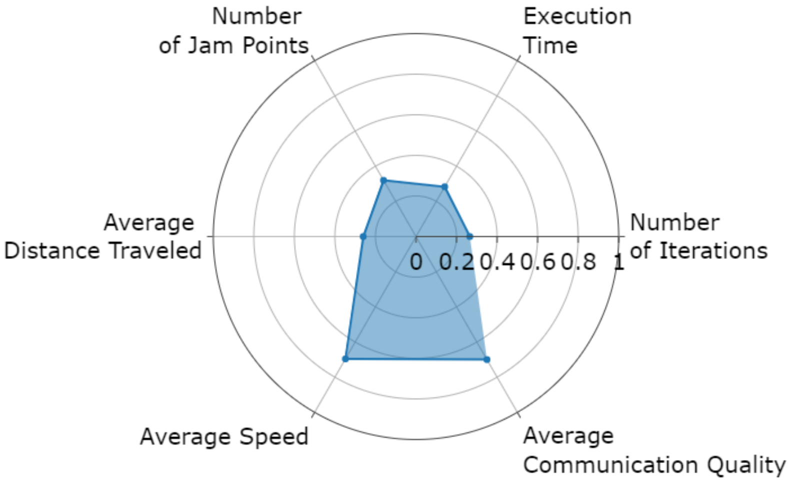




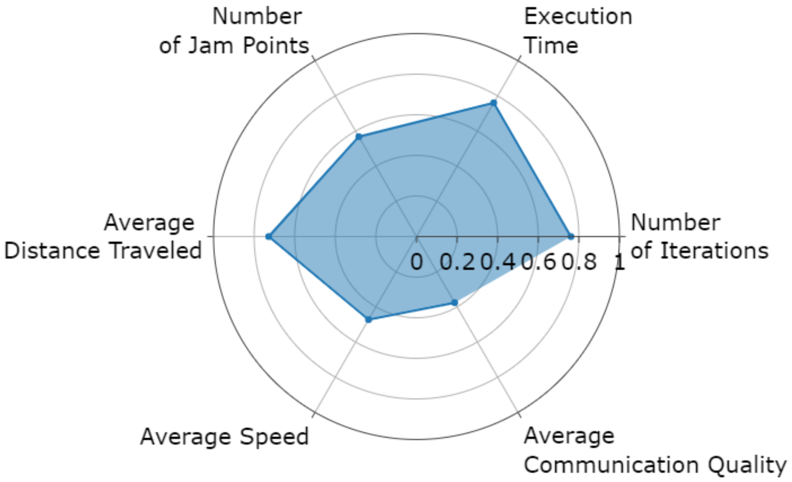
Simulation Results

Simulation Evaluation

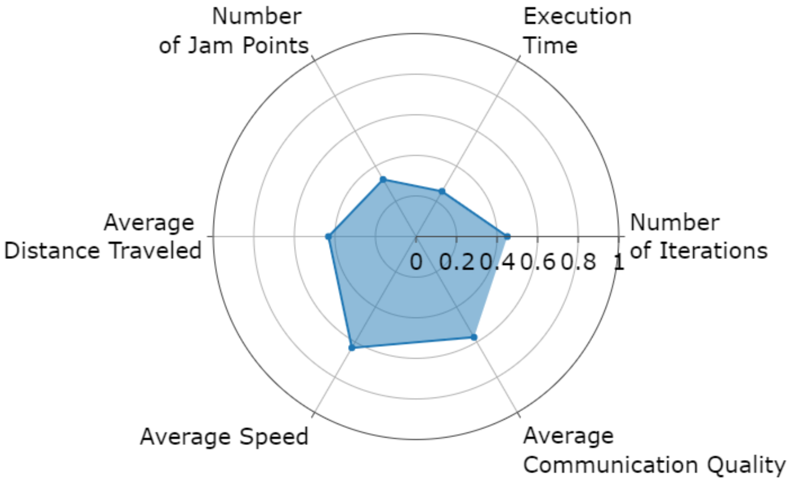
Theta*



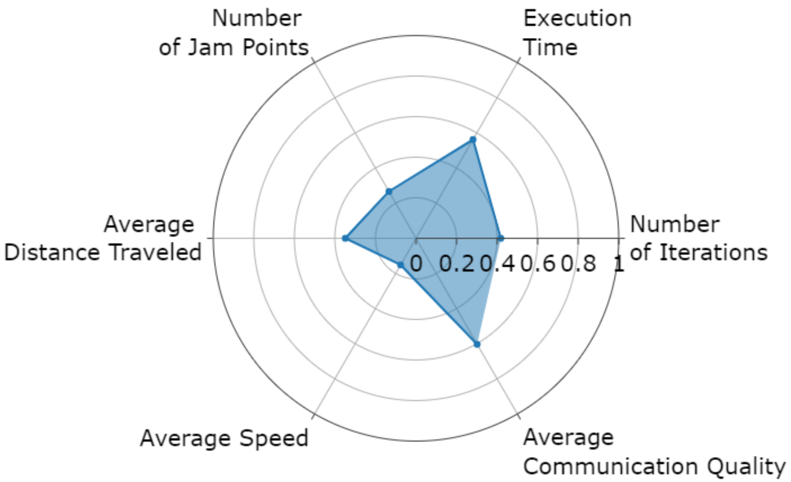
Jump Point Search



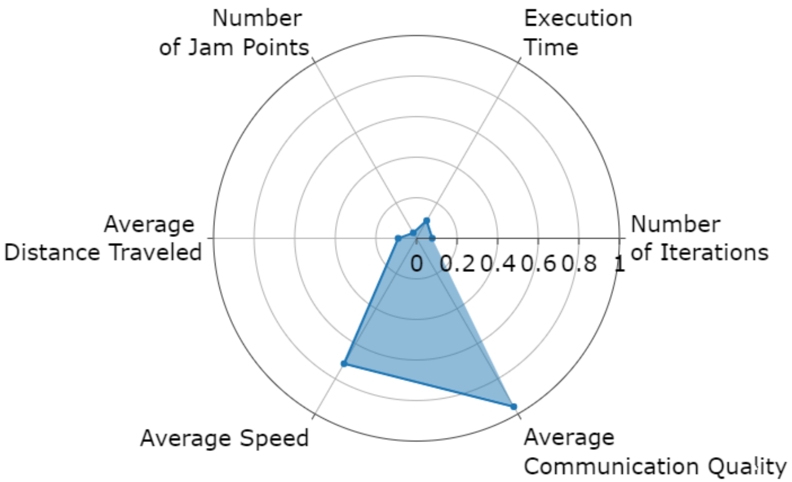
Breadth First Search



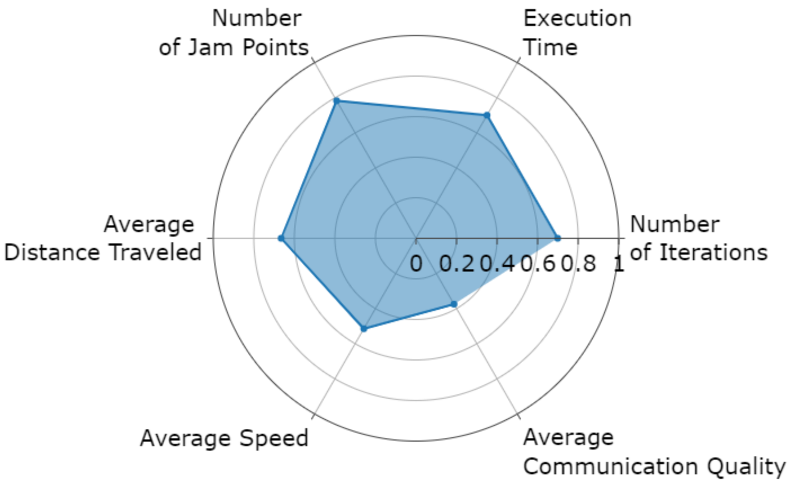
Greedy Best First Search



A*



Dijkstra



05

Conclusion

Result

- A* is identified as the most effective approach.
- Proposed a novel control strategy for swarm navigation in the presence of unknown jamming areas.
- Ensures efficient navigation, formation maintenance, and robust communication through extensive simulations in all 30 simulations.

Review

Intro

Preliminaries

- System Dynamics
- Graph Theory
- Rigid Formation

Communication Layer

- Antenna Far-field Model
- Antenna Near-field Model
- Interaction Model

Control Layer

- Gradient Controller
- PSO
- Path Planning

Simulation

- Performance Metrics

Outro

Acknowledgement

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THANKS

Questions?

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