Oct. 23-25, 2020, Tianjin, China
ICGNC 2020 International Conference on Guidance, Navigation and Control

Differential Evolution based Multi-Agent Formation Fault Reconstruction

Authors: Zirui Liao, Shaoping Wang, Jian Shi, Qiwang Weng

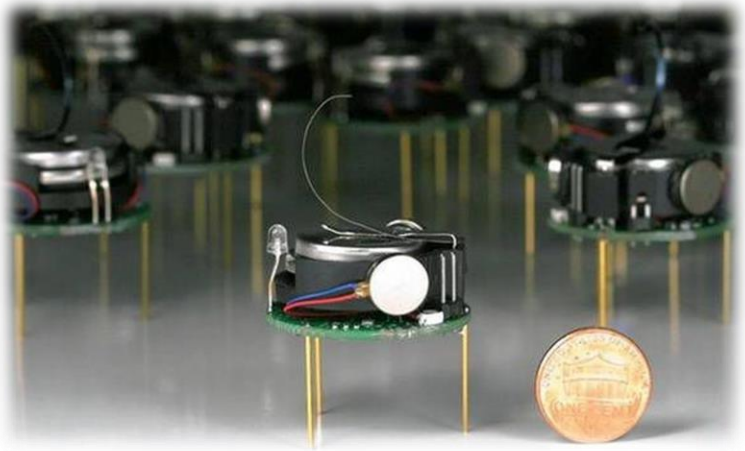
Organization: School of Automation Science and Electrical Engineering, Beihang University, Beijing, China

CONTENTS

CONTENTS

1. Background

Application Scenarios



Bionic Ant Colony

Agriculture Protection

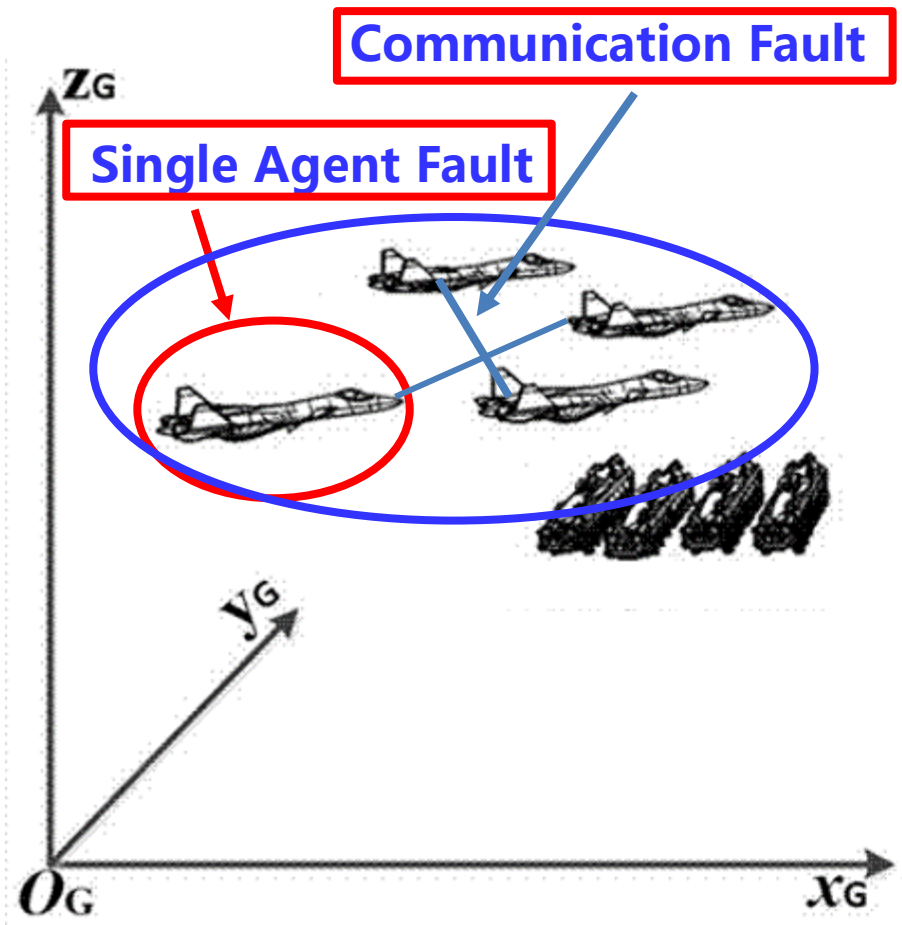
Widespread Applications

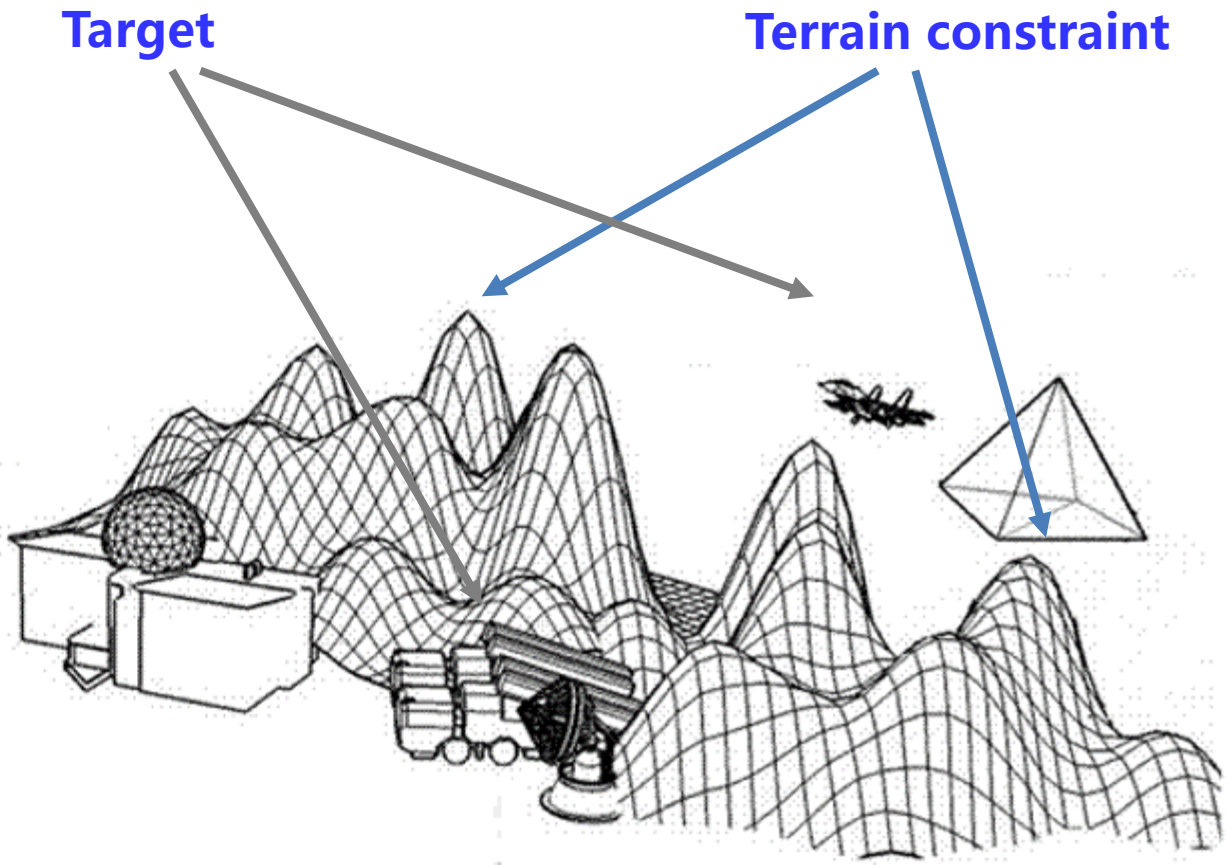
Cooperative Operations

Light Show

1. Background

Actual Influence Factors

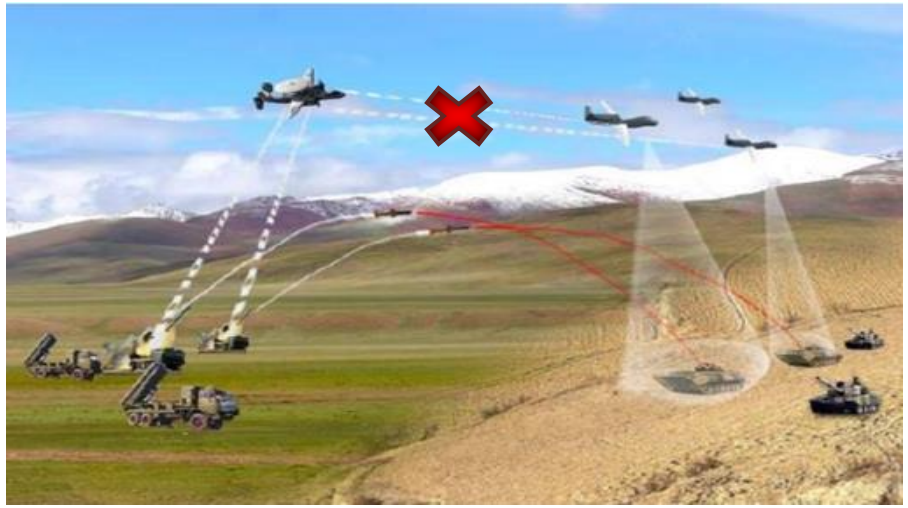


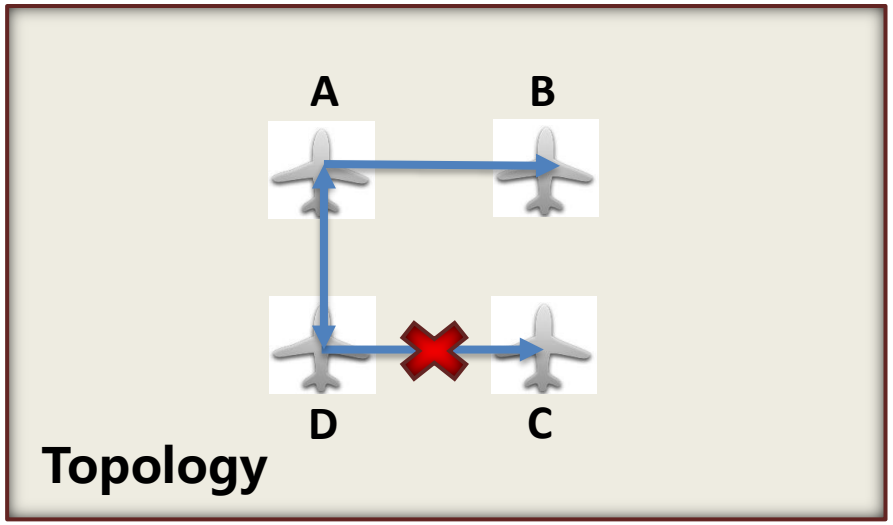


1. Background

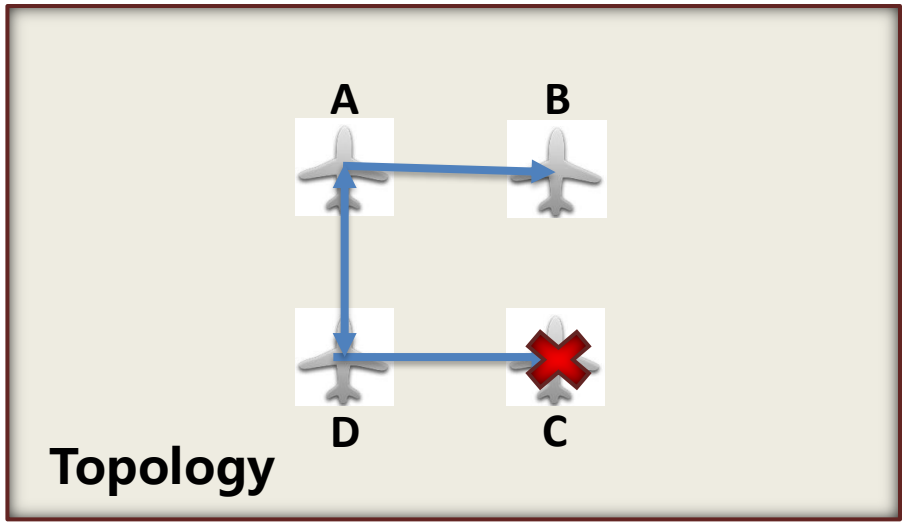
Challenges

- **Communication Fault:**





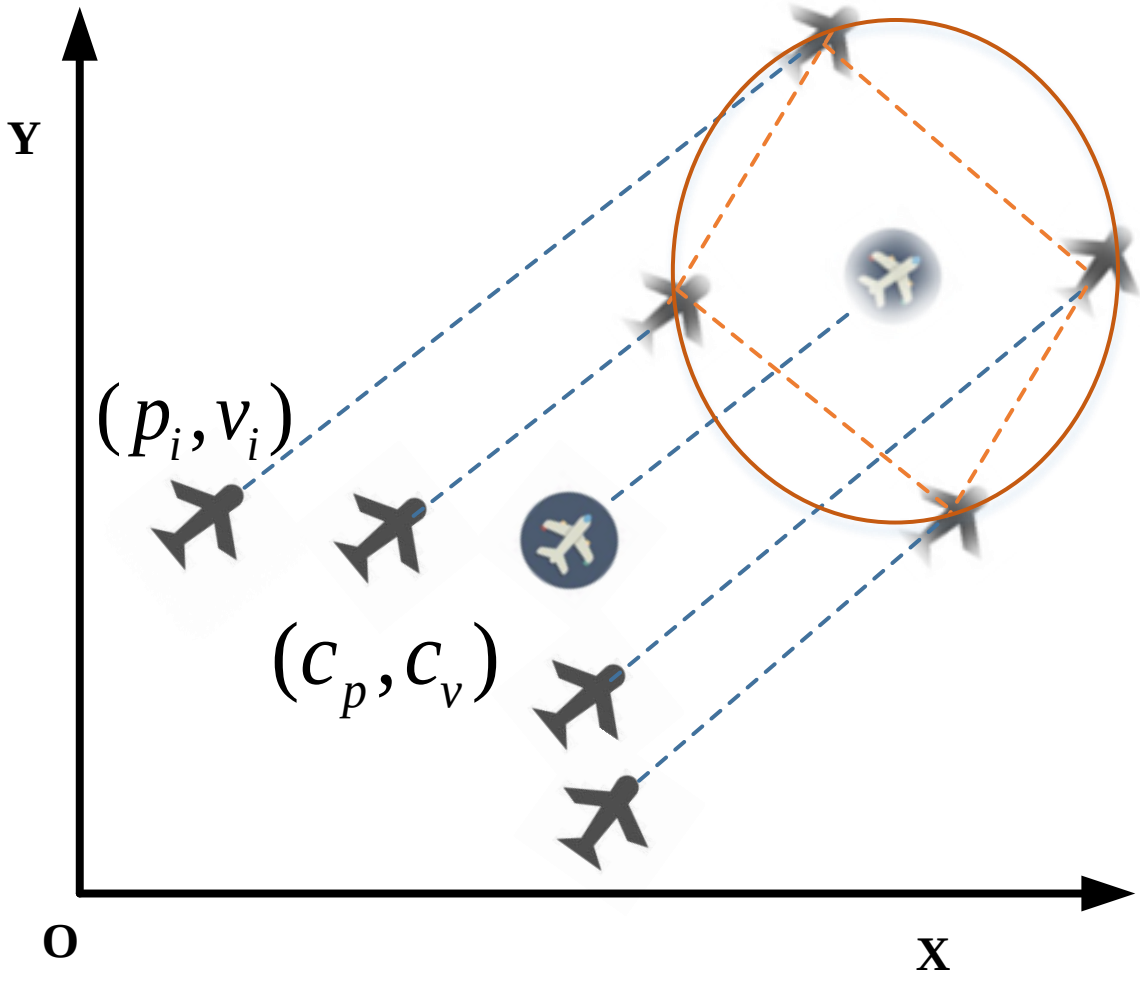
- **Single Agent Fault:**



CONTENTS

2. Problem Statement

Mission Description



Description of the Tracking Task

- **Relative Position Consistency:**

$$\lim_{t\to\infty}\frac{1}{N}\sum p_i(t)-c_p(t)=0$$

- **Relative Velocity Consistency:**

$$\lim_{t\to\infty}\frac{1}{N}\sum v_i(t)-c_v(t)=0$$

- **Ideal state:**

$$\lim_{t\to\infty}(\xi_i(t)-h_i(t)-c(t))=0(i=1,2,\ldots,N)$$

Variables	Meaning
p, v	Position and Velocity of UAV
c	Tracked Target
ξ	Actual state matrix of UAV
h	Ideal state matrix of UAV
N	The Number of UAV

2. Problem Statement

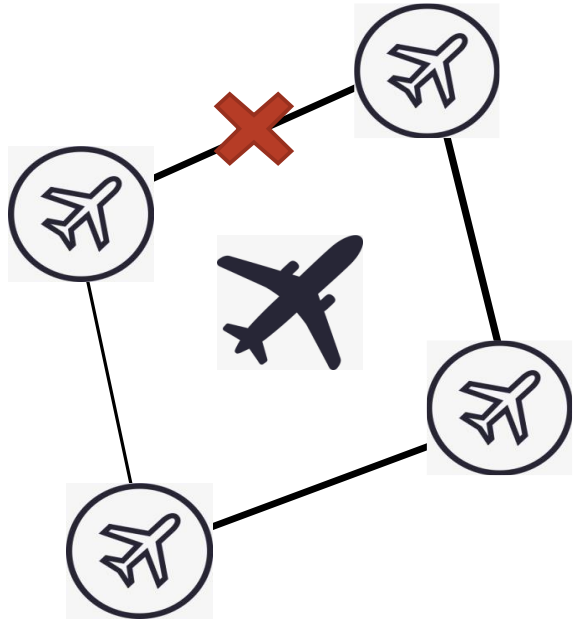
Fault Mode Analysis

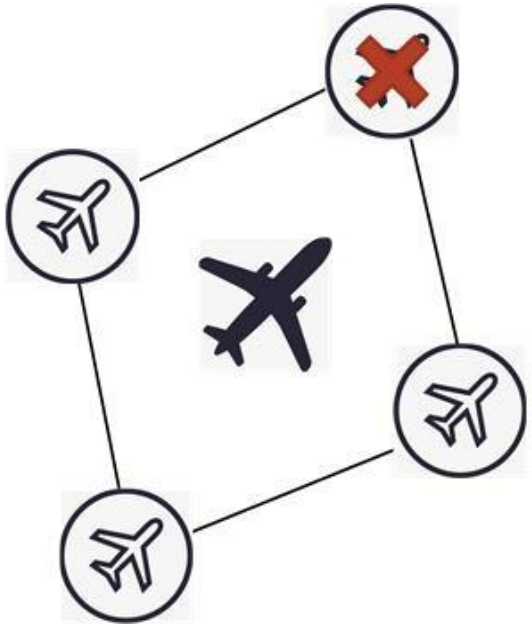
Communication Fault

➢ **State Equation of Formation:**

$$\dot{\xi}(t) = (I_N \otimes (BK_1 + A) - L \otimes (BK_2))\xi(t) + (I_N \otimes B)\dot{h}(t)$$
$$-(I_N \otimes (BK_1) - L \otimes (BK_2))h(t)$$

Single UAV Fault





CONTENTS

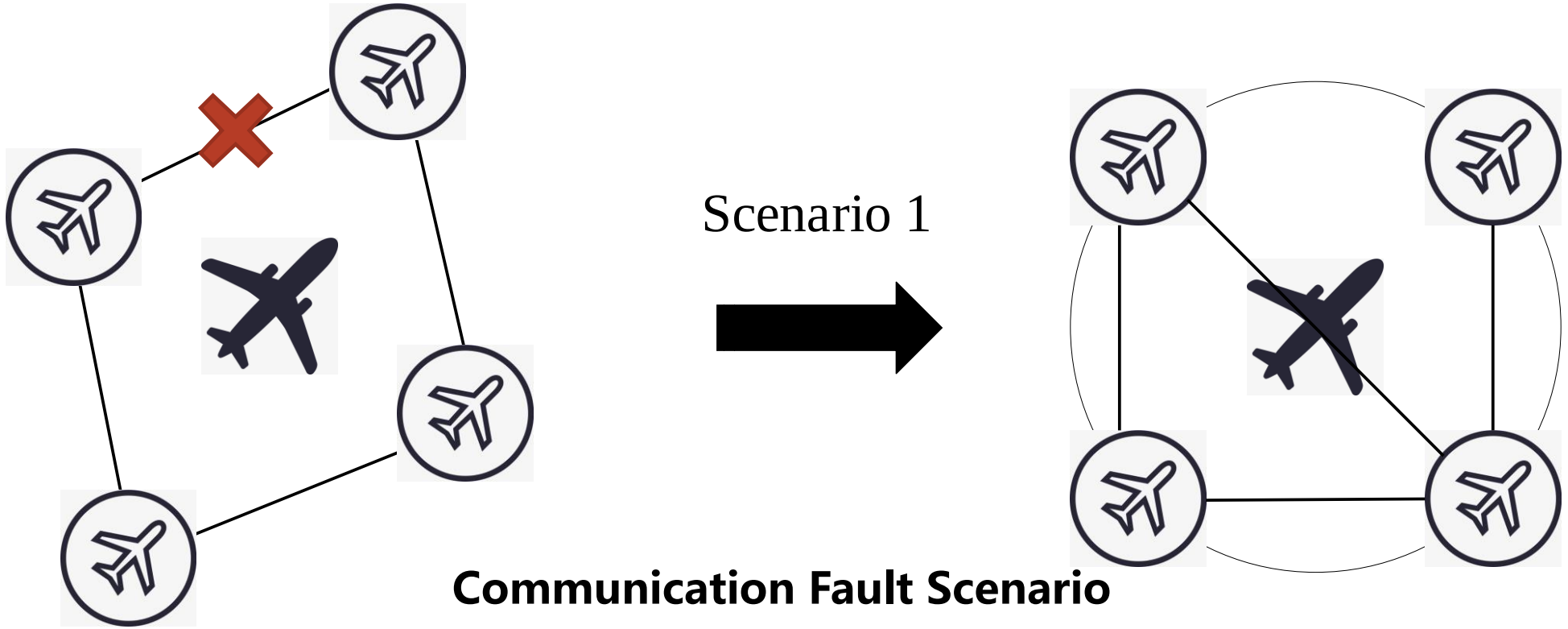
3. Differential Evolution Algorithm

Fault Scenario I

- Communication link is interrupted due to terrain and environmental.

Reconstruction Strategy

- Communicate another agent to construct the new topology.



Communication Fault Scenario

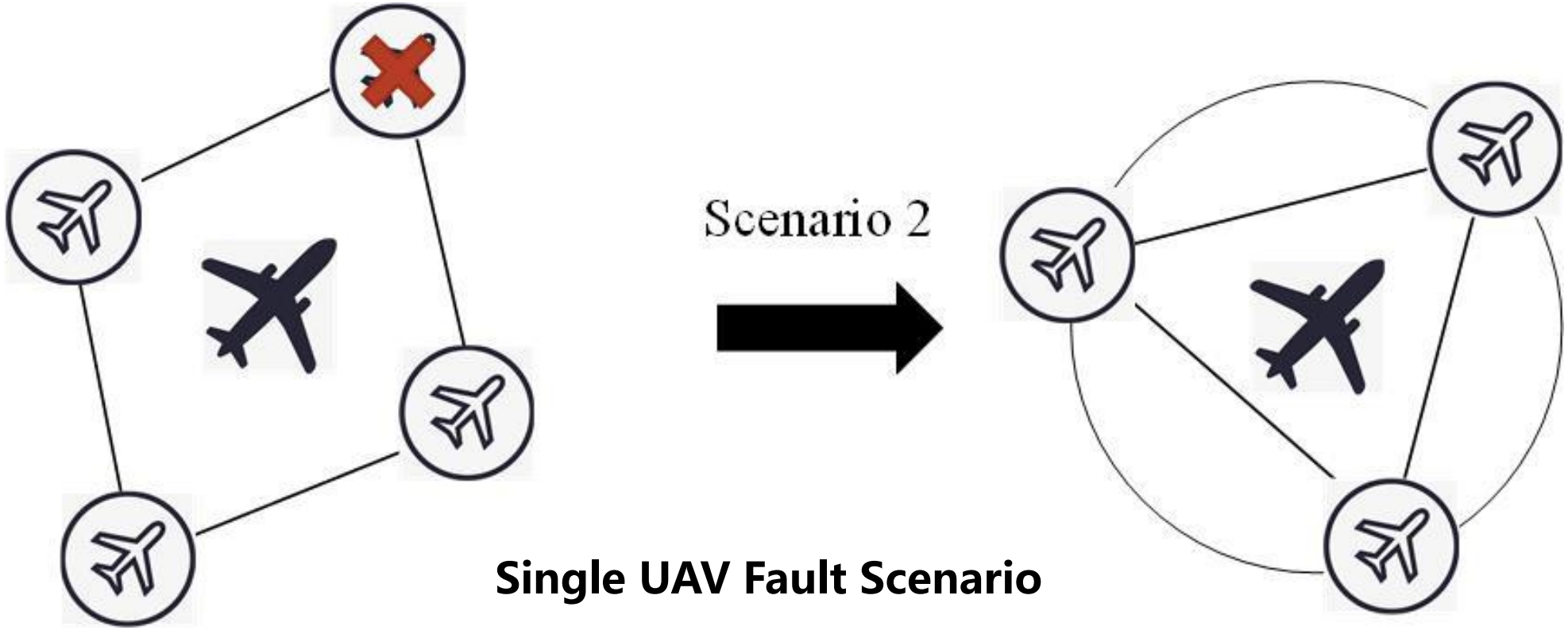
3. Differential Evolution Algorithm

Fault Scenario II

- An agent fails and is unable to keep the formation.

Reconstruction Strategy

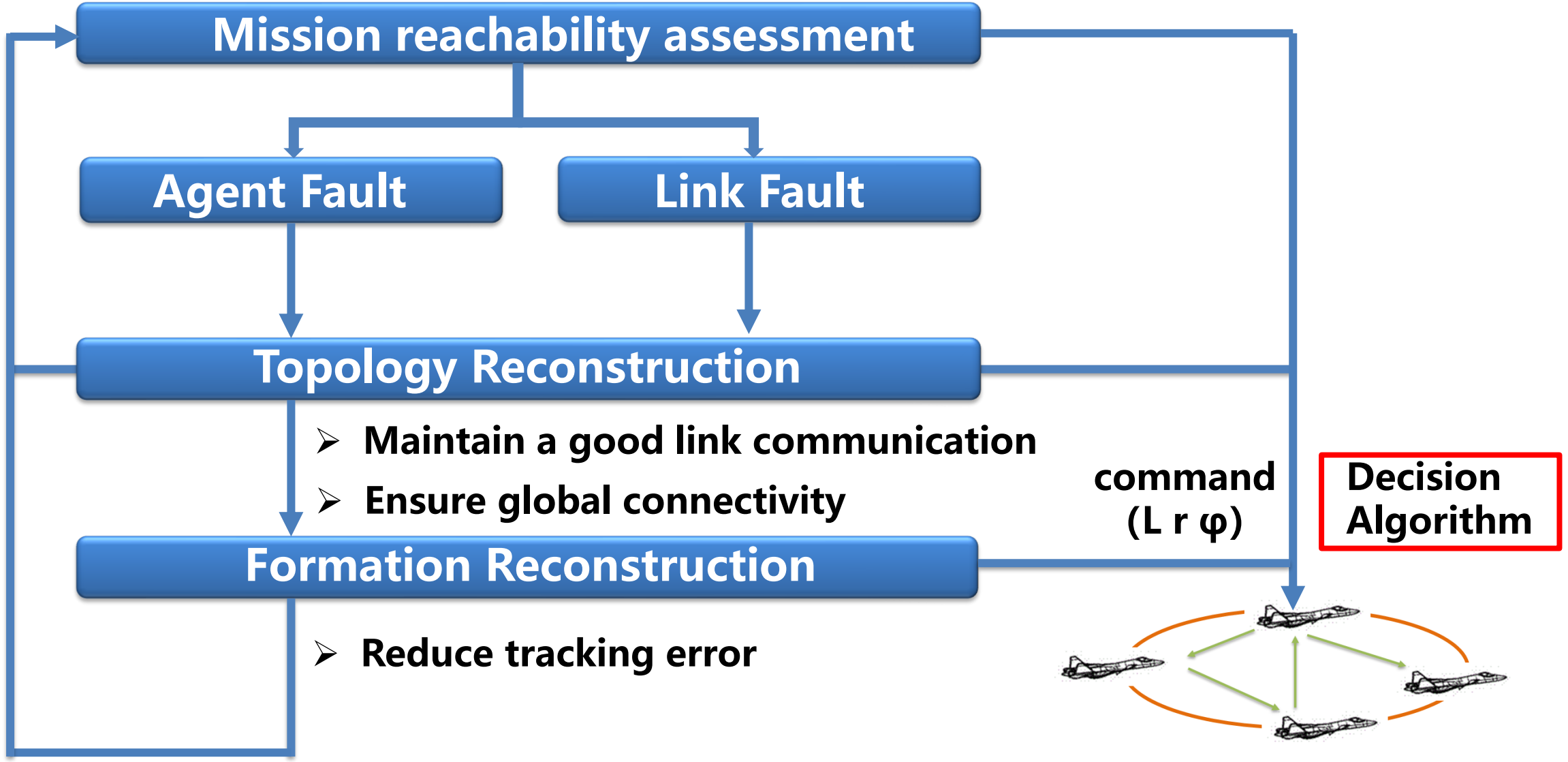
- Abandon this agent and adjust the remaining formation shape.



Single UAV Fault Scenario

3. Differential Evolution Algorithm

Reconstruction Flow Chart



3. Differential Evolution Algorithm

Topology

Optimization Problems

Name	Meaning	Formula
Objective Functions	**Highest network connectivity**	$\max(R)$
	Highest Communication Quality	$\max(\mathrm{Q})$
	Lowest Conversion Cost	$\min(C)$
Decision Variables	**Status Between Two Nodes**	a_{ij}
Constraint Equations	**Network Connectivity Equation**	$R = g(a_{ij})$
	Link Attenuation Constraint	$Q = f(\sqrt{\Delta S_x^{\,2} + \Delta S_y^{\,2}})$
	Maximum Distance Constraint	$\sqrt{\Delta S_x^{\,2} + \Delta S_y^{\,2}} < d_{\max}$
	Conversion Cost Formula	$C = k \times \sum \Delta a_{ij}$

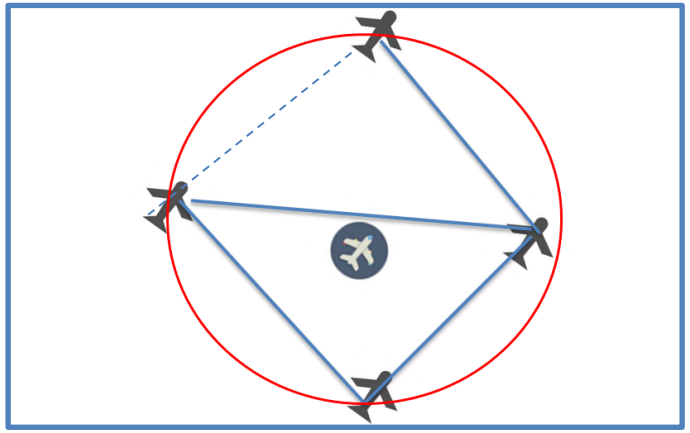
S_x S_y : Flight position, m

V_x V_y : Flight velocity, m/s

a_{ij} : Connection status

$d_{\max}$: Maximum distance, m

k : Topology cost, m



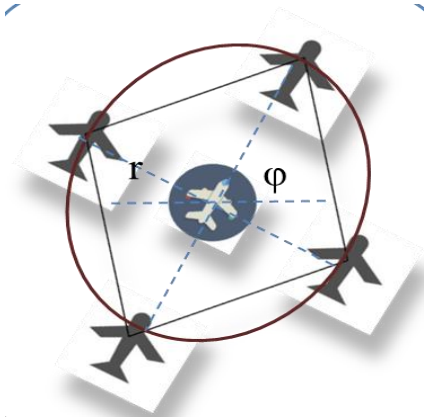
3. Differential Evolution Algorithm

Formation

Optimization Problems

Name	Meaning	Formula
Objective Function	**Minimal Enclosure Error**	$\min(E)$
Decision Variables	**Circle Radius**	r
	Round Phase Angle	θ
	Tangential Velocity	V_{i_t}
Constraint Equations	**1 Error Calculation**	$E = f(\theta, d, V_{i_t})$
	2 Speed Constraint	$V_{\max} < M_v$
	3 Safety Constraint	$\sqrt{\Delta S_x^{\,2} + \Delta S_y^{\,2}} < M_S$

S_x S_y : Flight Position, m
V_x V_y : Flight Velocity, m/s
r : Circle Radius, m
θ : Round Phase Angle, rad
M_S: Safe Distance, m
M_v: Maximum Velocity, m/s

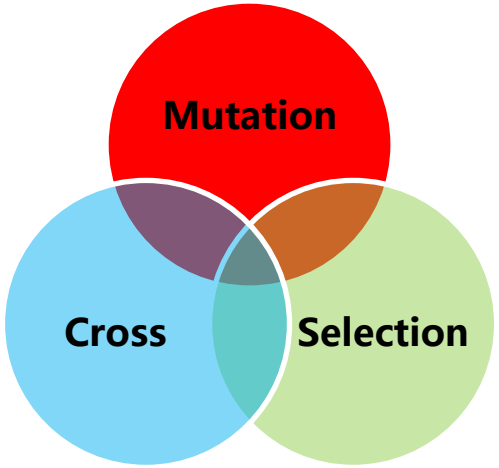


3. Differential Evolution Algorithm

DE (Differential Evolution) Algorithm

Biological Evolution

Optimization

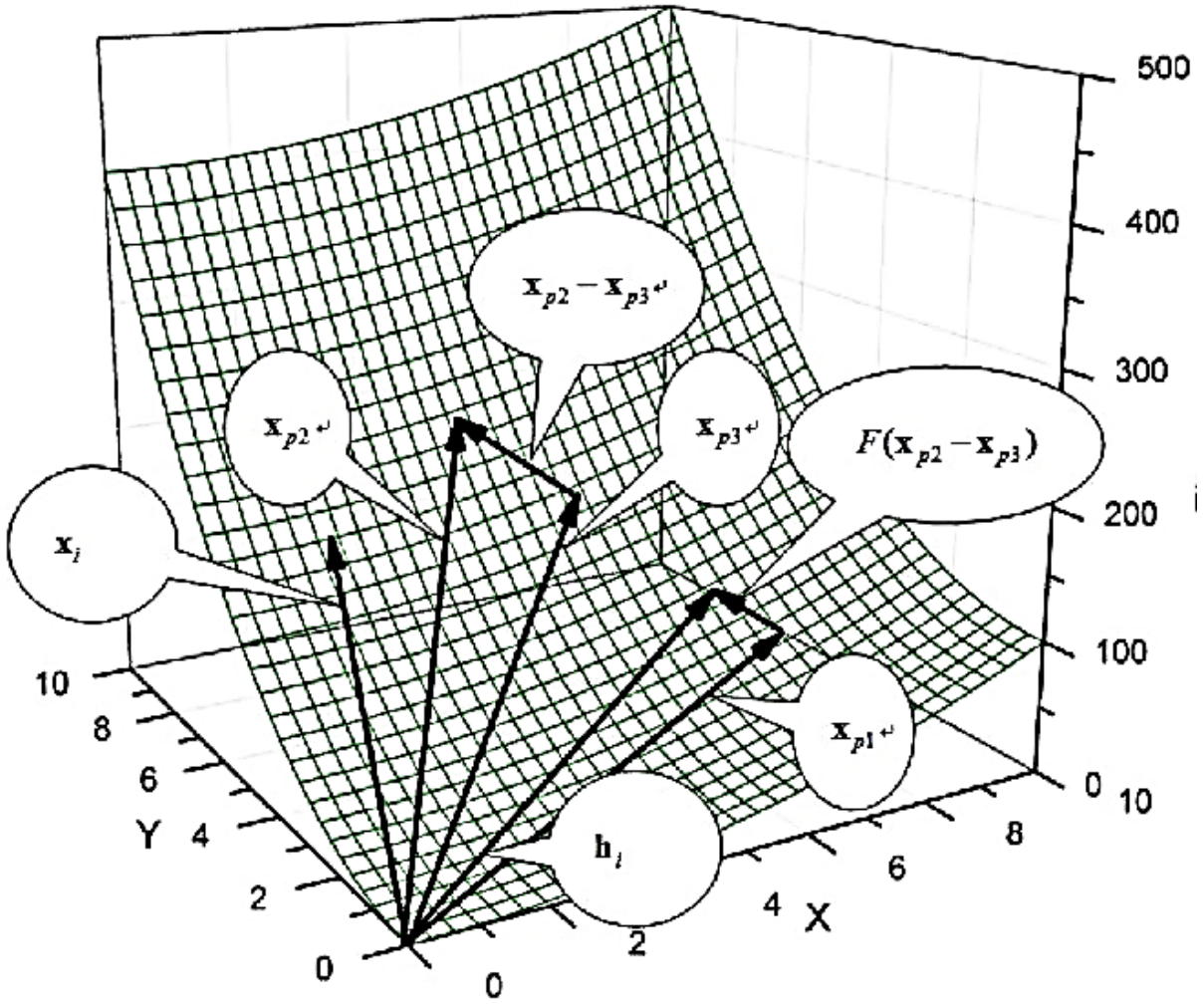


1 Optimization problems characterized by continuous variables

→ **Formation Parameters** $r\ \varphi$

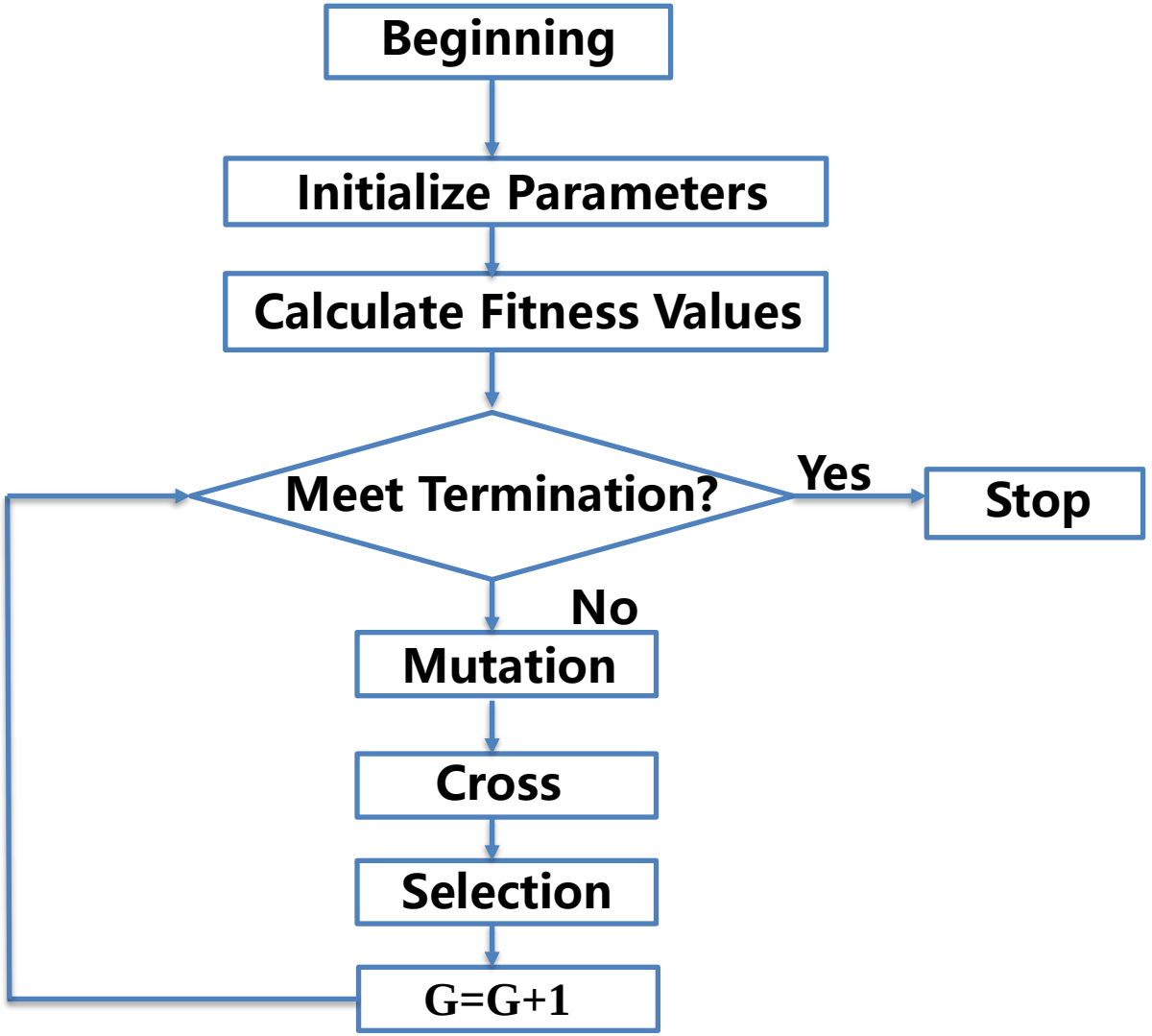
2 Optimization problems based on discrete variable characteristics

→ **Topology** L

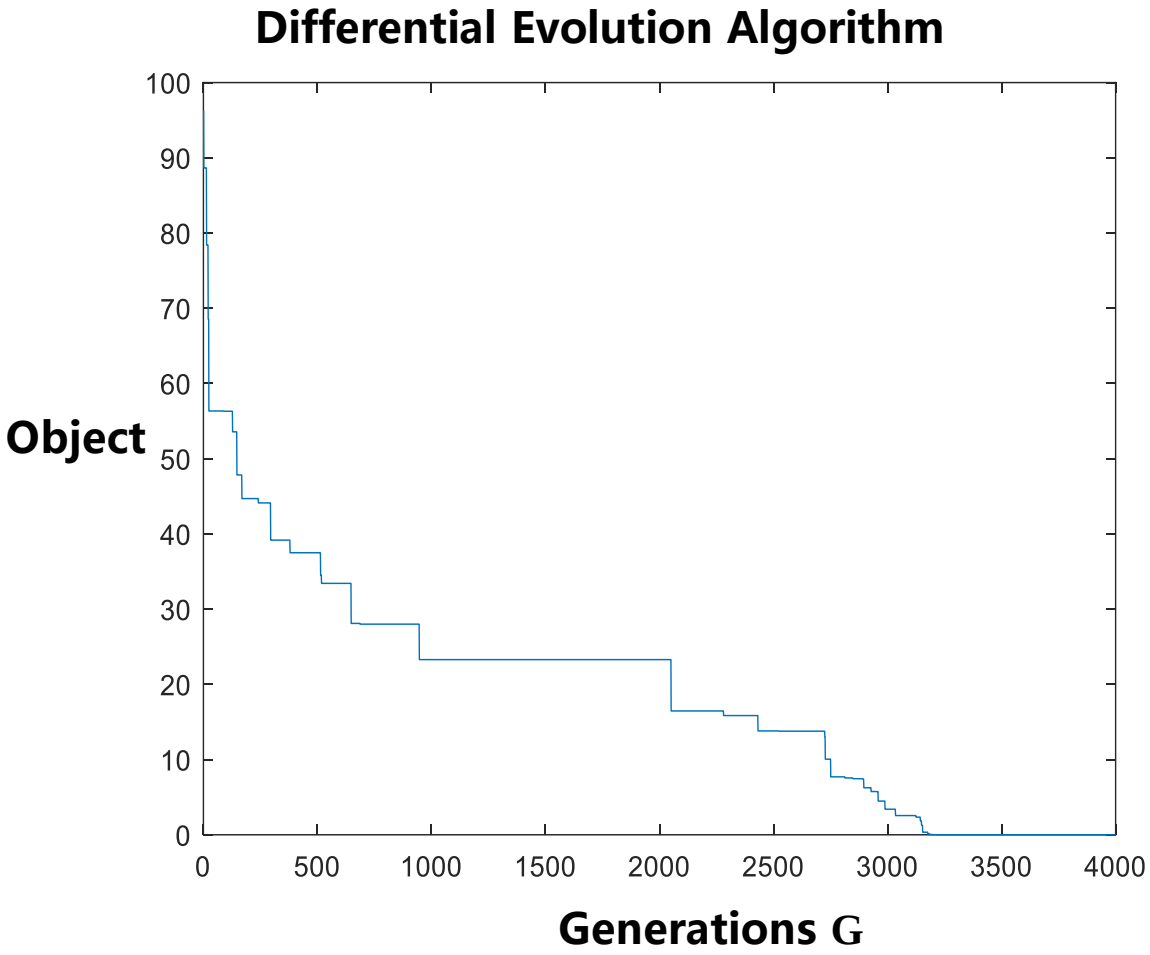


3. Differential Evolution Algorithm

DE Flow Chart



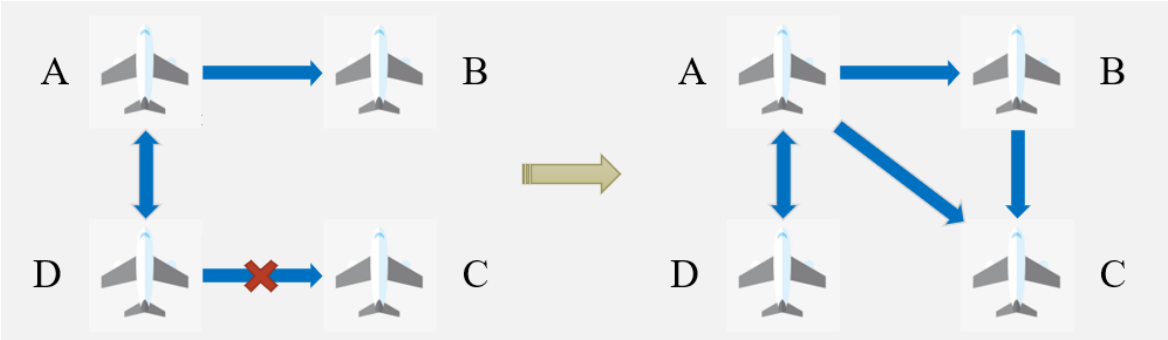
DE Example

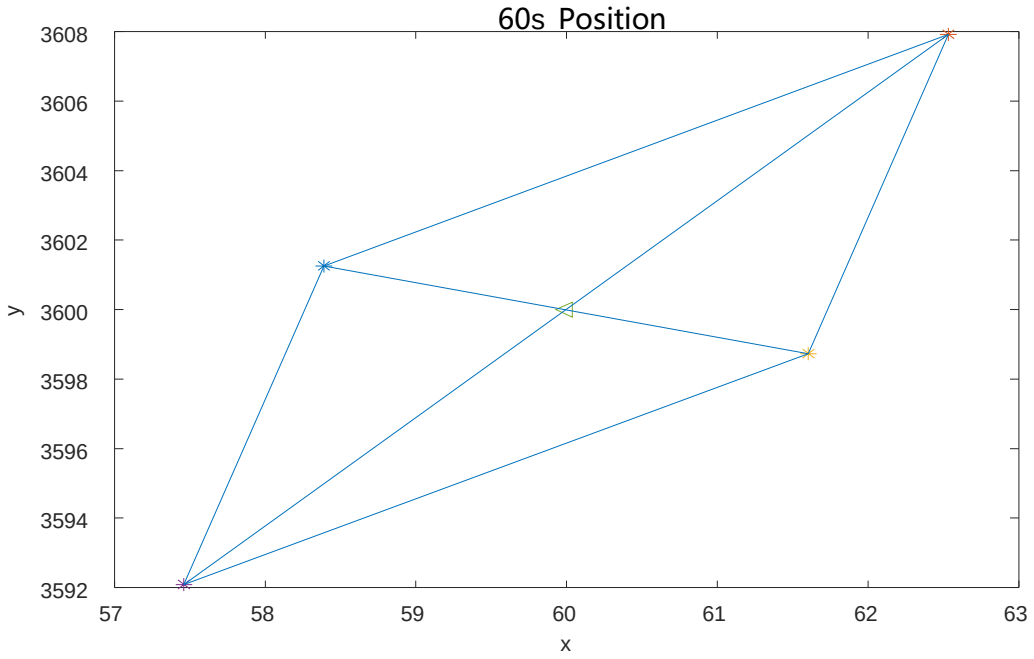


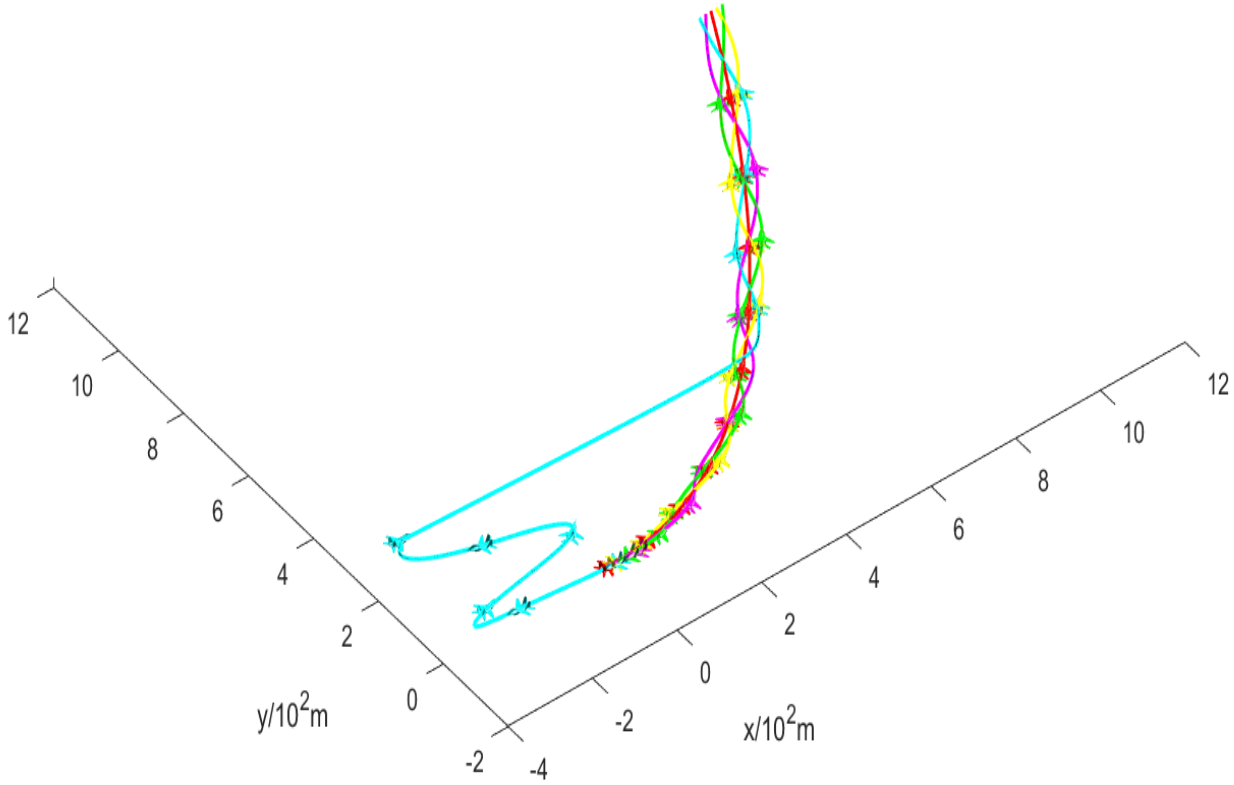
CONTENTS

4. Simulation and Discussion

Scenario 1： Link Fading

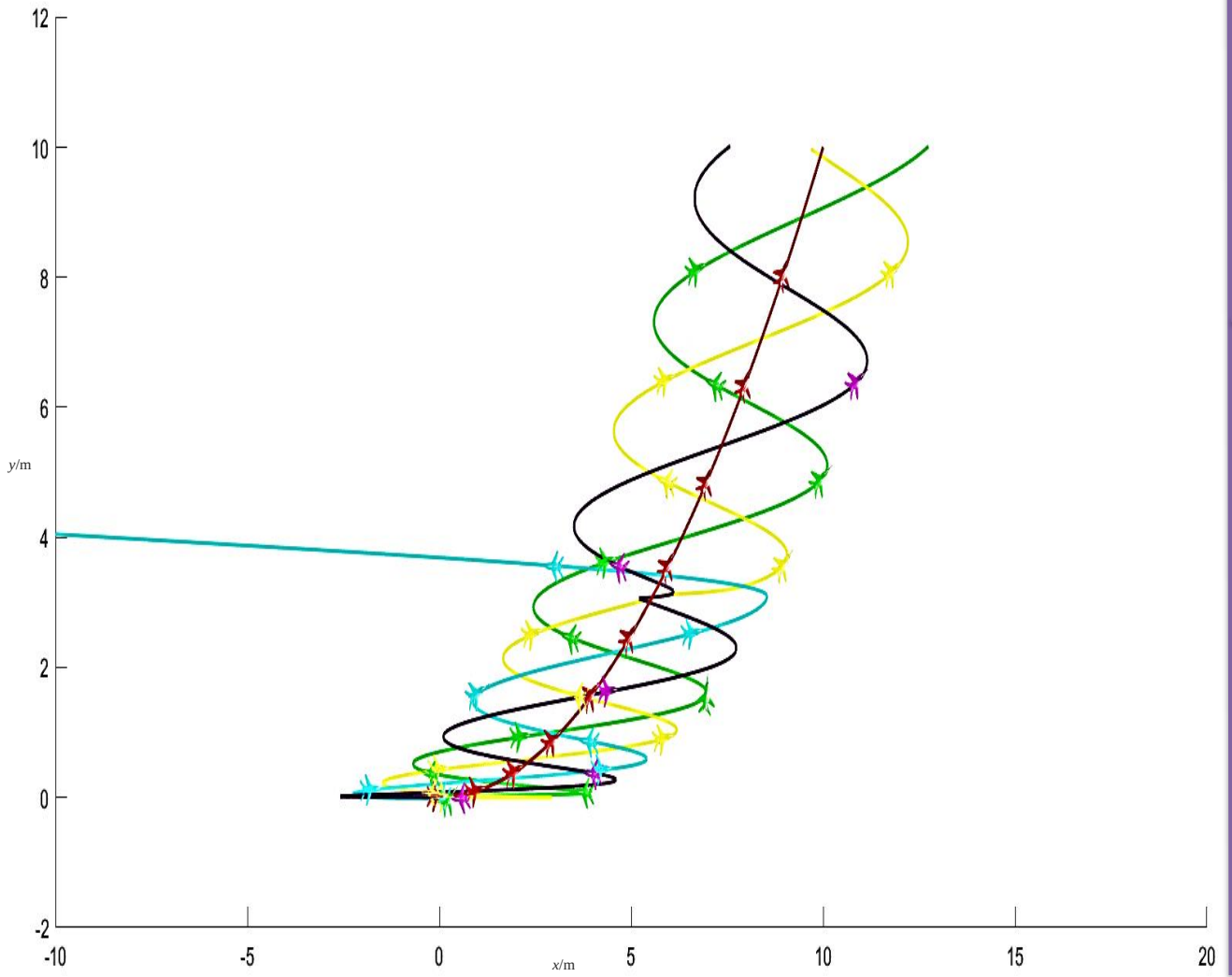


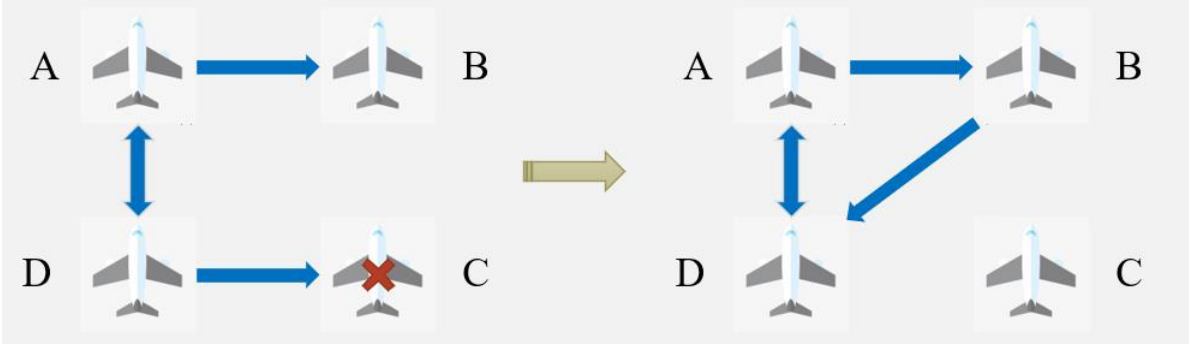


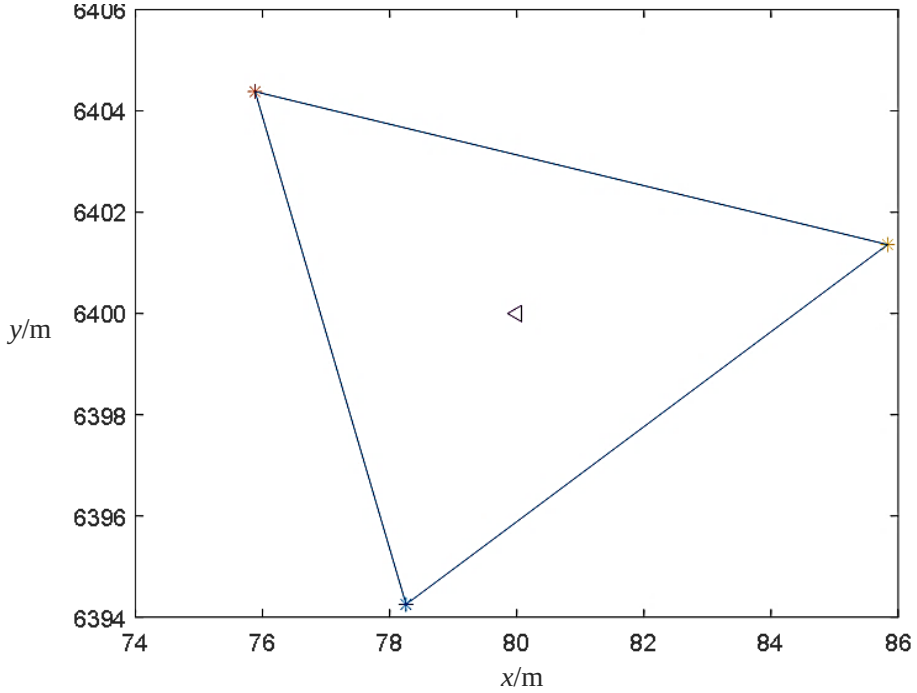


4. Simulation and Discussion

Scenario 2: Single UAV fault







CONTENTS

5. Summary

1. Two specific scenarios of fault in dynamic tracking mission are considered;

2. Differential evolution algorithm is introduced to solve the reconstruction problems;

3. Simulation results are given to verify the effectiveness of the method.

Thank you so much for your listening!

Reporter: Zirui Liao