# Nonlinear Algorithm for Formation Control and Rendezvous

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# Problem Definition

- To achieve rendezvous and formation control for a multi agent system under the following conditions:
  - Single integrator dynamics
  - Non linear control strategy
  - Dynamic interaction topology represented by a $\Delta$ disk proximity graph.

# Challenges

- Linear control strategy given by:
  - $\dot{X} = -L(G)(X - \tau)$
- Works only if the graph is connected throughout the timeframe
- Limited sensing range can result in the graph getting disconnected.
- Higher weightage must be given to an edge that is about to be severed

# Rendezvous Case

- Consider the tension function:
  - $\mathcal{V}_{ij} = \frac{\|l_{ij}\|^2}{\delta - \|l_{ij}\|}$ $if\ \{v_i, v_j\} \in E$
- The value of the function and its derivatives is infinite if $\|l_{ij}\| = \delta$
- Hence a viable controller would be
  - $\dot{X}_i = \sum_{j\in\mathcal{N}(i)} \frac{\partial \mathcal{V}_{ij}}{\partial x_i} = \sum_{j\in\mathcal{N}(i)} \frac{2\delta - \|l_{ij}\|}{(\delta - \|l_{ij}\|)^2} \left(\mathrm{x_j} - \mathrm{x_i}\right)$

# Hysteresis

- When the inter-agent distance is $\delta$ the control input reaches infinity.
- Might cause problems for agents just entering the sensing radius
- Hysteresis to be introduced in forming a new link
- $A_{n+1}(i,j) = \begin{cases} 1, & if\ A_n = 1 \\ 1, & if\ d_{ij} < \delta - \epsilon \\ 0, & if\ d_{ij} > \delta \end{cases}$
- Thus a link which is formed will remain unbroken throughout the timeframe of simulation

# Formation Case

- The tension function needs to be modified
- Let $\tau_i$ be the formation specification
- $d_{ij} = \tau_i - \tau_j$ , $l_{ij} = x_i - x_j$, $\lambda_{ij} = l_{ij} - d_{ij}$
- $\mathcal{V}_{ij} = \dfrac{\|\lambda_{ij}\|^2}{\delta - \|d_{ij}\| - \|\lambda_{ij}\|}$

# The controller

- According to the edge function given above the controller is of the form:
  - $\dot{X}_i = \sum_{j \in \mathcal{N}(i)} \frac{2(\delta - \|d_{ij}\|) - \|\lambda_{ij}\|)}{(\delta - \|d_{ij}\| - \|\lambda_{ij}\|)^2} (x_i - x_j - d_{ij})$
- Thus once an formation distance is achieved the controller makes it difficult to break the edge.

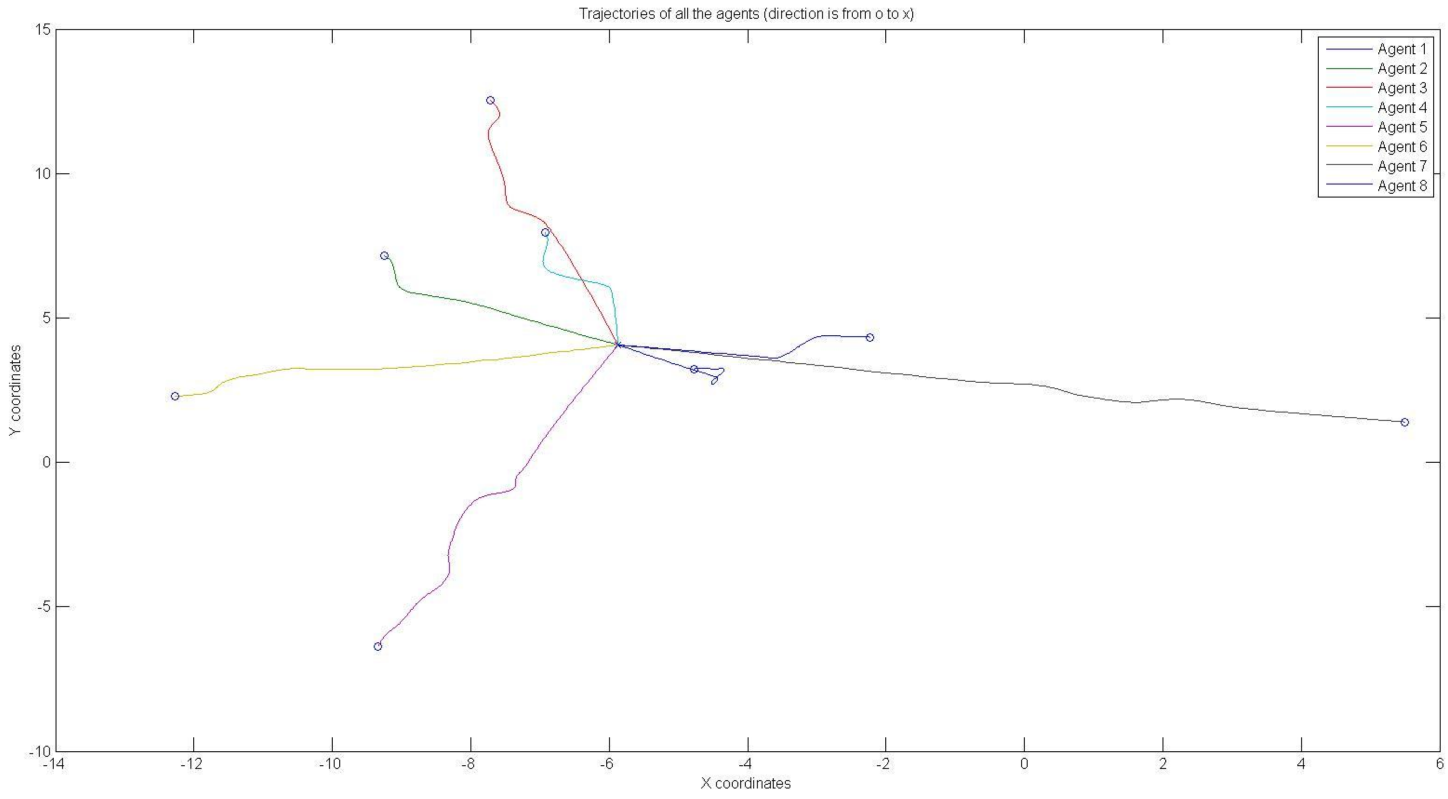
# Restrictions

- Both methods require the initial graph to be connected to achieve the objective.
- For the formation strategy the entire formation must be contained within a circle of diameter equal to the sensing radius.
- Cannot handle larger formations with inter-agent distances greater than the sensing radius

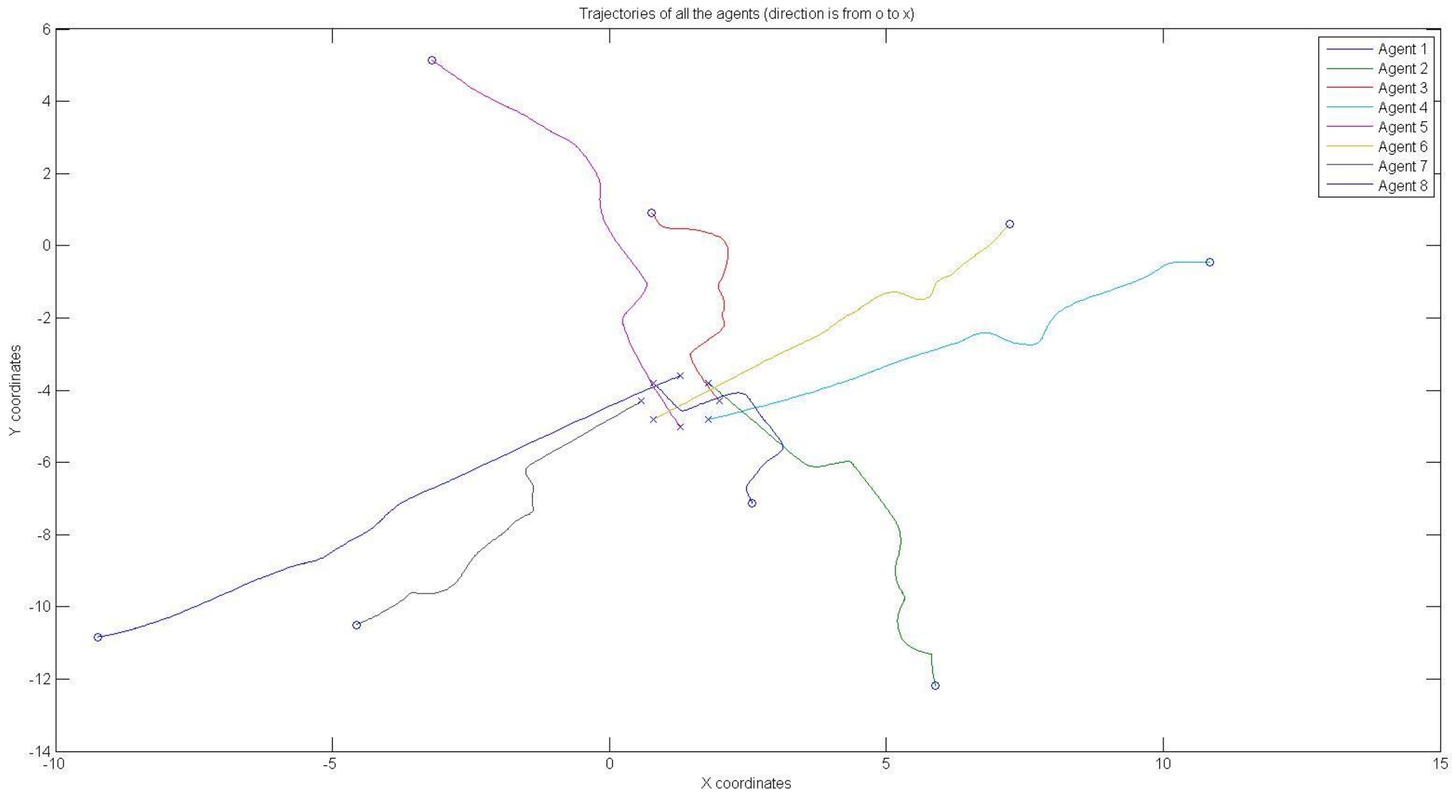
# Features of the code

- Both the codes can accept any specified number of identical agents
- Starting positions are generated randomly.
- Initial graph connectivity is ensured before starting the controller.
- The default formation specification is a regular polygon of agents with a circumcentre of radius $\sqrt{2}$.
- The results are plotted as a trajectory with the initial and the final points marked

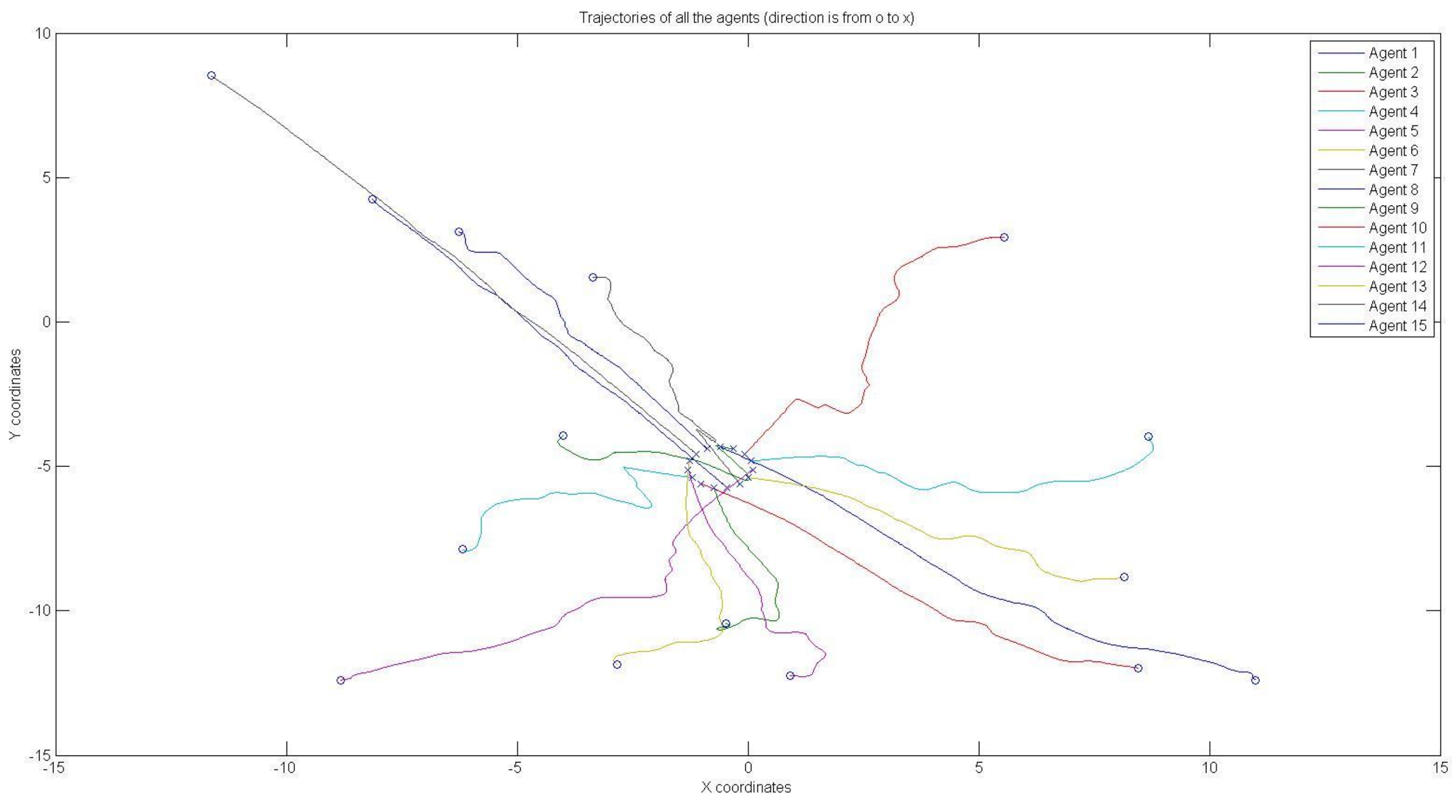
# Results: Rendezvous (N = 8)



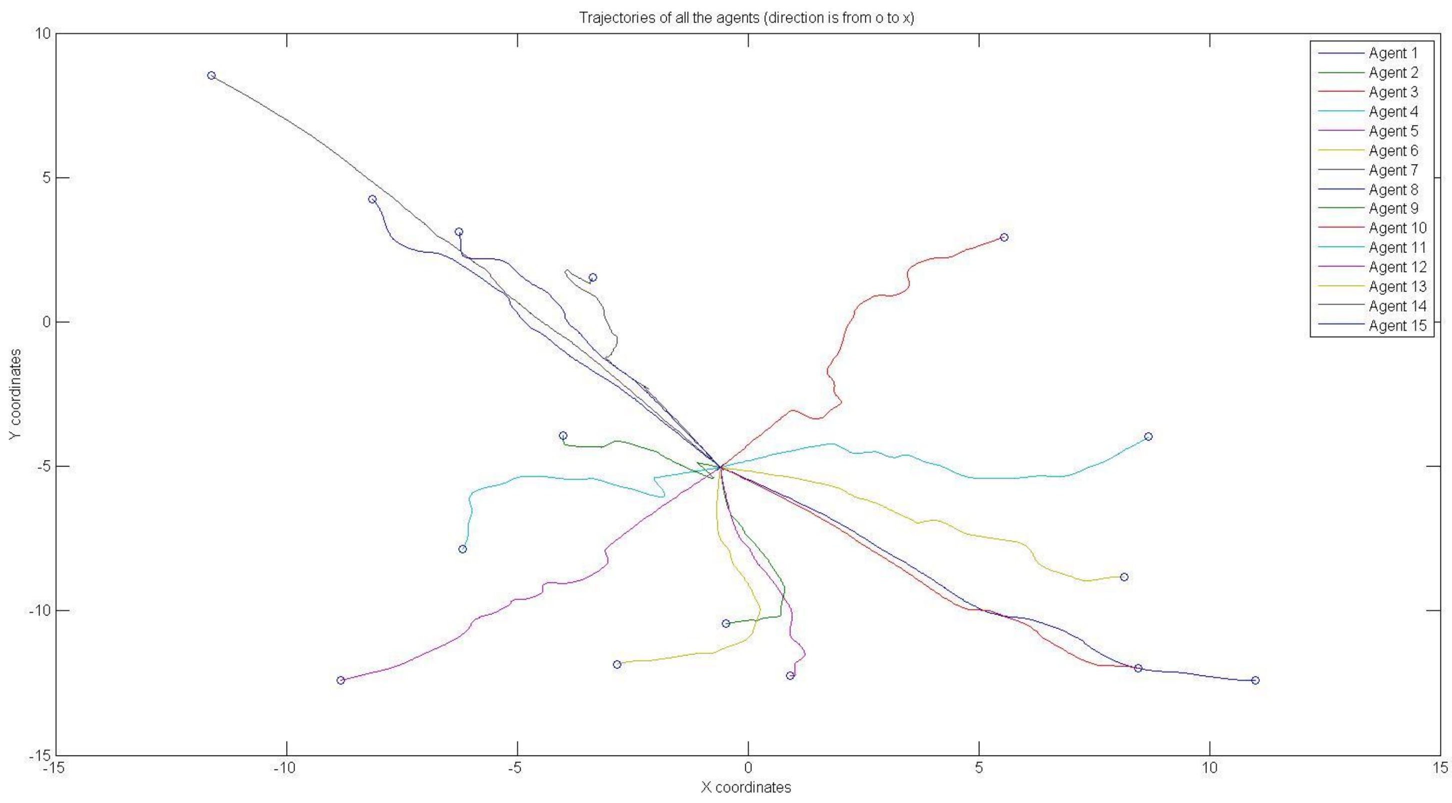
# Results: Formation control (N=8)



# Results: Formation control (N=15)



# Results: Rendezvous (N=15)



# Thank you