DISTRIBUTED IDENTIFICATION OF LEADER AGENTS IN SEMI-AUTONOMOUS NETWORKS

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AUTONOMOUS NETWORK – INTRODUCTION

- SELF – ORGANIZED
- DECENTRALIZE – DISTRIBUTED
- COOPERATIVE MISSION

- LEADERS

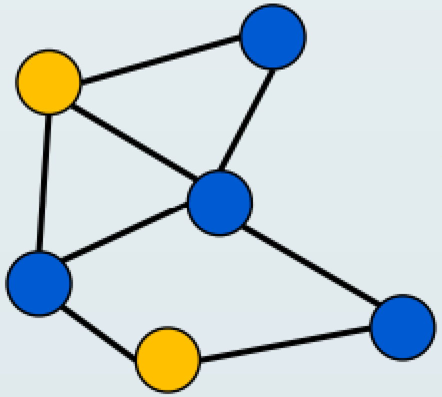
AUTONOMOUS NETWORK – FORMATION

- SELF – ORGANIZED
- DECENTRALIZE – DISTRIBUTED
- COOPERATIVE MISSION
- LEADERS
- V SHAPE FORMATION

GRAPH BASED – DEFINITION

<u>Agents</u>

Each agent modeled as simple kinematic point mass	$x_i(t) \in \mathbb{R}^d, \; i \in \mathcal{V}$
Leader nodes can receive external input	$u_\ell(t), \; \ell \in \mathcal{V}_\ell$
Leader indicator function	$b_{i\ell} = \begin{cases} 1, & i, \ell \in \mathcal{V}_\ell \\ 0, & i \notin \mathcal{V}_\ell, \ell \in \mathcal{V}_\ell \end{cases}$



$$\mathcal{G} = (\mathcal{V}, \mathcal{E}, \mathcal{W})$$

A (weighted) **graph** is a collection of vertices and weighted edges

$(\mathcal{V}_\ell)$ A **follower** node

NETWORK CONSENSUS IN SAN

- **CONSENSUS DYNAMIC -**

$$\dot{x}_i(t) = -\sum_{j \in \mathcal{N}_i} w_{ij}(x_i(t) - x_j(t)) - \sum_{l \in \mathcal{V}_\ell} b_{il}(x_i(t) - u_l)$$

- **CONSENSUS CONDITION**

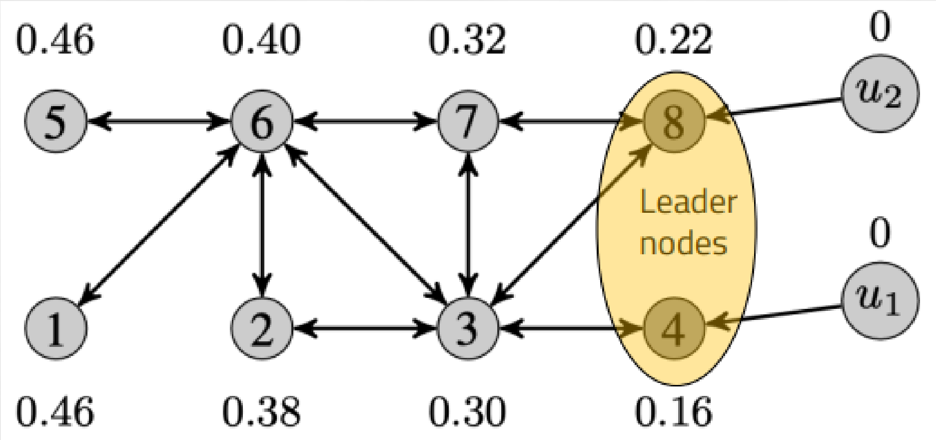
$$\lim_{t \to \infty} \|x_i(t) - x_j(t)\| = 0, \ \forall\, (i, j) \in \mathcal{E}$$

FROM SAN TO FSN – PRINCIPLE

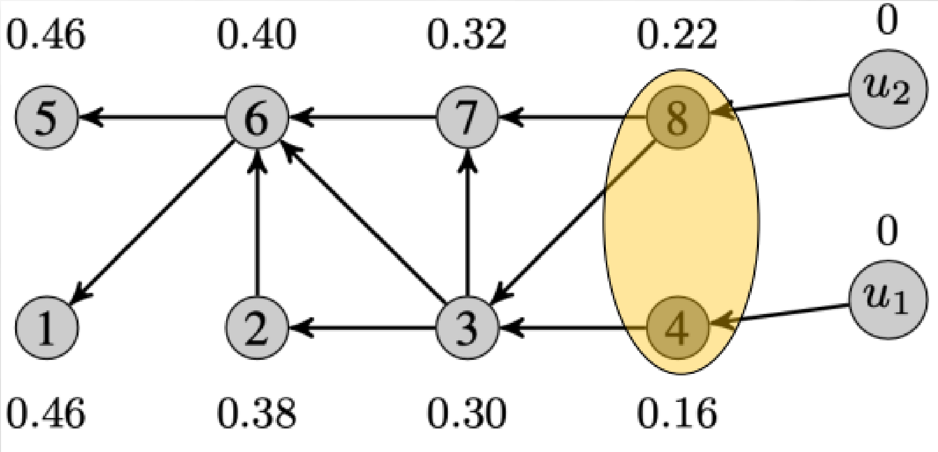
- FIND THE FIRST EIGEN VECTOR
- BUILD FSN NETWORK – FOLLOWING SLOWER NEIGHBOR

$L = EWE^{\top}$ weighted Laplacian matrix:

$$L_B = L + \mathrm{diag}(B\mathbf{1}_{n_L})$$



FSN graph obtained by pruning edges according to ordering of eigenvector elements



KNOWN RESULTS ON FSN FROM DNS

- **RELATIVE TEMPO**

$$g_{ij}(t) = \|\dot{x}_i(t)\| / \|\dot{x}_j(t)\|$$

$$\tau_{ij} = \lim_{t \to \infty} g_{ij}(t)$$

- **RELATIVE RATIO OF FIRST EIGEN VECTOR**

$$v_1(L_B)_{ij} = v_1(L_B)_i / v_1(L_B)_j$$

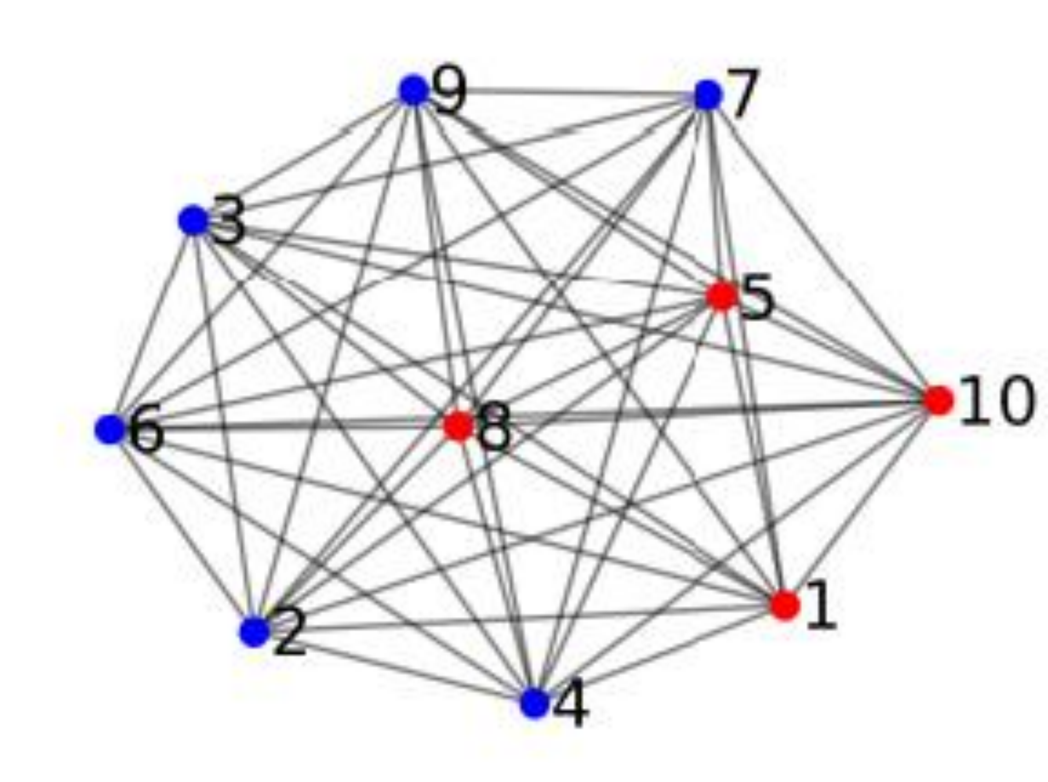
$$\tau_{ij} = v_1(L_B)_{ij}$$

LEADER IDENTIFICATION – ALGORITHM

- GIVEN THE NORMAL VELOCITIES $\|\dot{x}_i\|, \|\dot{x}_j\|$
- COMPUTE THE RELATIVE SPEED $g_{ij}=\|\dot{x}_i\|/\|\dot{x}_j\|$
- FIND THE GRAPH DIRECTIONS (FSN) $g_{ij}>1$
- SEARCH IN THE GRAPH
  UNTIL THE LEADER IS FOUND (MINIMAL NODE) $min\{v_1(L_B)\}$

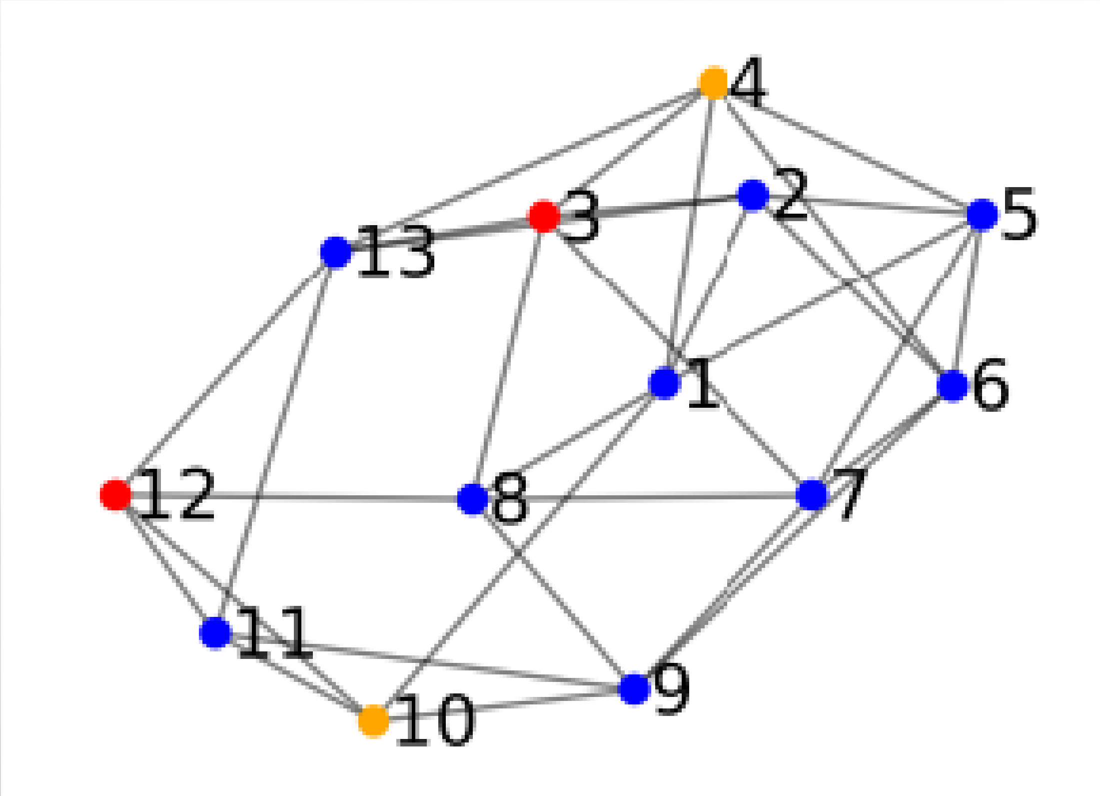
STATIC EXAMPLES

EXAMPLE 1 – ALL LEADERS ARE IDENTIFIED



ID	Leaders	EntryVB1	Identified
1	1	0.24438	4
2	0	0.35616	0
3	0	0.35616	0
4	0	0.35616	0
5	1	0.24438	1
6	0	0.35616	0
7	0	0.35616	0
8	1	0.24438	3
9	0	0.35616	0
10	1	0.24438	2

EXAMPLE 2 – PART OF THE LEADERS ARE IDENTIFIED

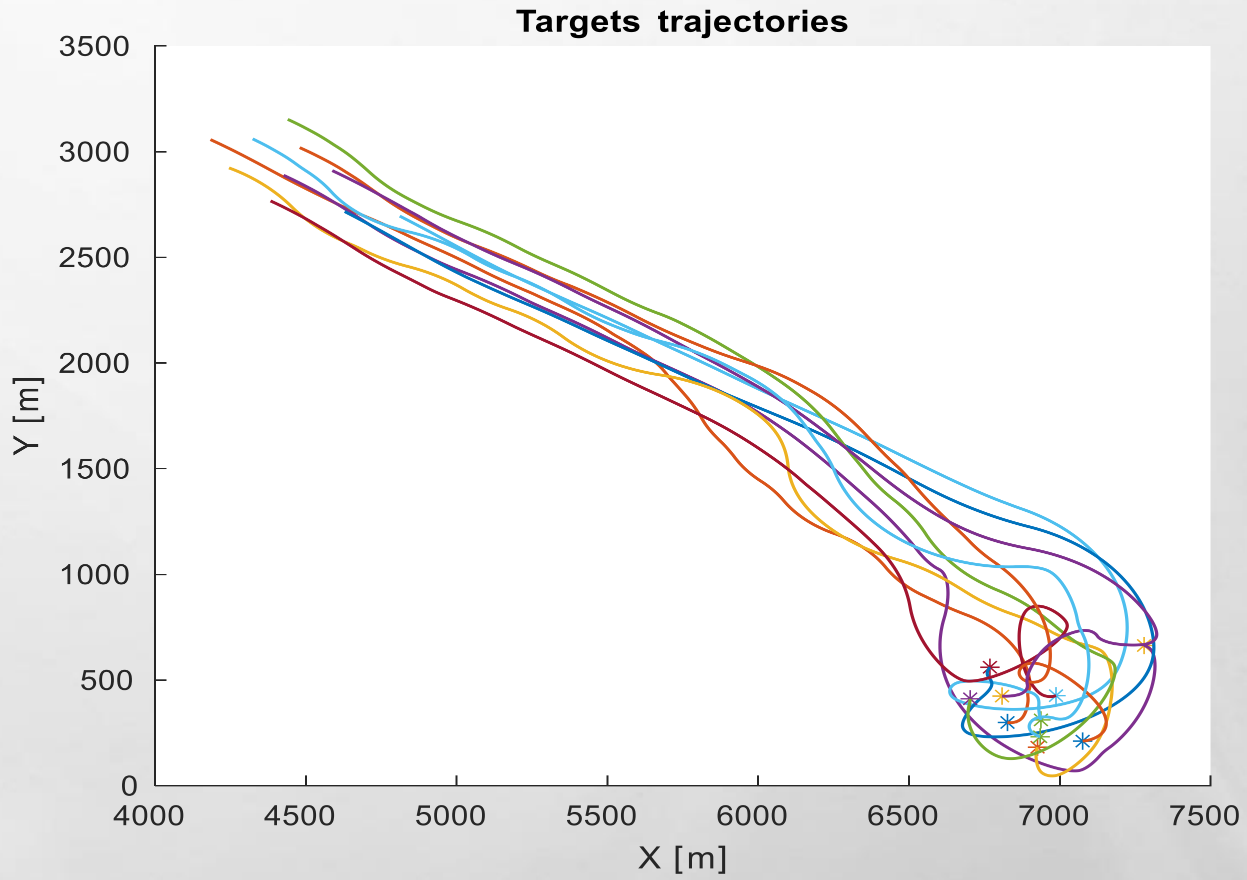


ID	Leaders	EntryVB1	Identified
1	0	0.30289	0
2	0	0.33414	0
3	1	0.16947	2
4	1	0.17292	0
5	0	0.35449	0
6	0	0.35915	0
7	0	0.35177	0
8	0	0.29855	0
9	0	0.32755	0
10	1	0.13937	0
11	0	0.25642	0
12	1	0.1292	1
13	0	0.24757	0

DYNAMIC EXAMPLES

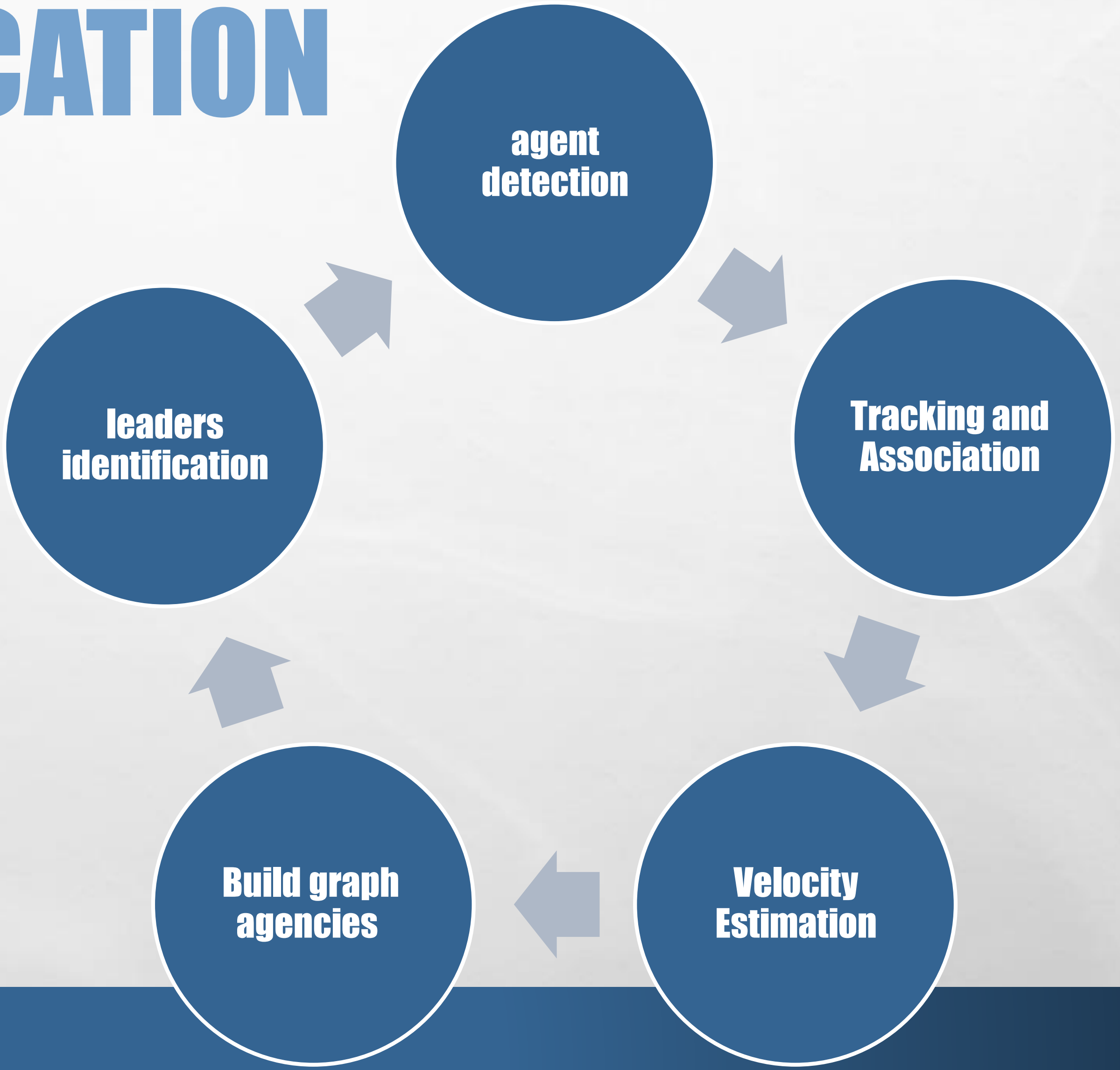
SWARM BASED ON CONSENSUS NETWORK

- ONE LEADER (OR MORE)
- SELF – ORGANIZED
- DISTRIBUTED
- COOPERATIVE MISSION – CONTROL COMMAND
- GATHER TOGETHER – MIN/MAX DISTANCE
- AVOID COLLISION



LEADER IDENTIFICATION

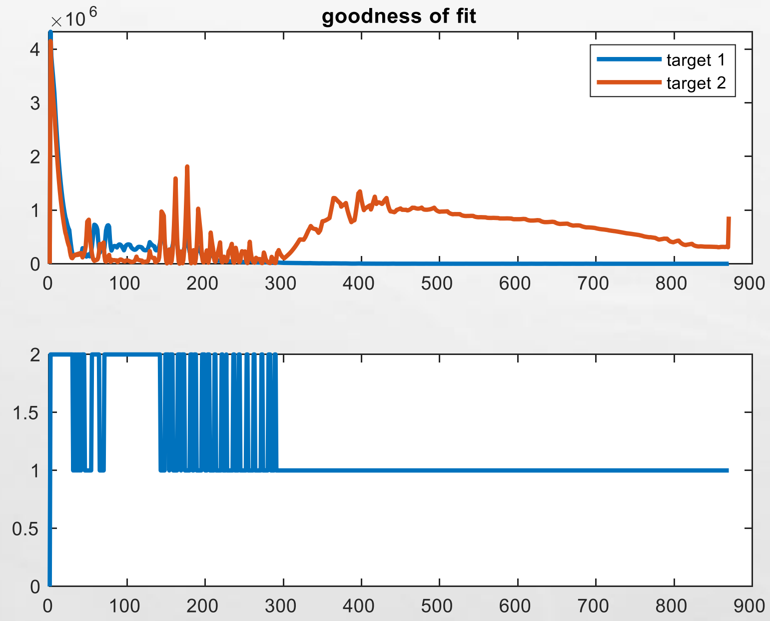
- ELECTRO-MAGNETIC/OPTIC OBSERVER



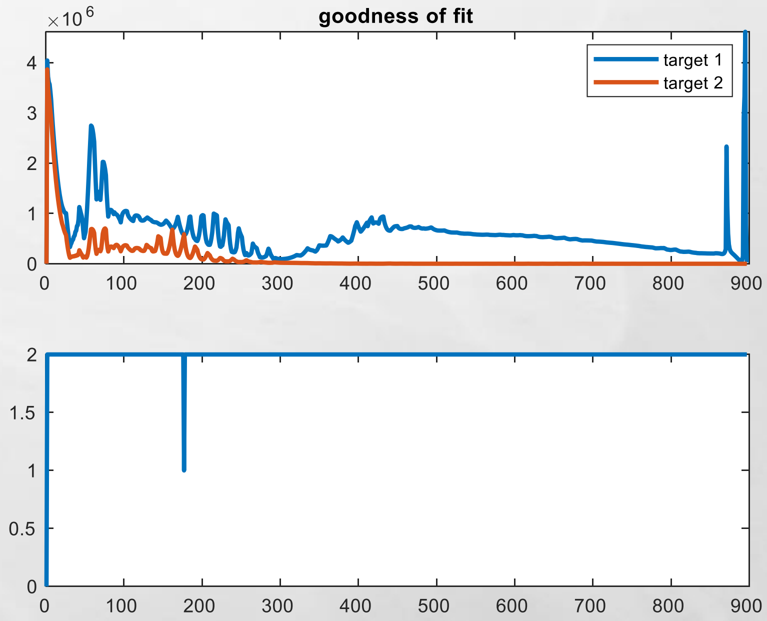
ASSOCIATION – PRINCIPLE

- **TRACKING AND ASSOCIATION**
  - **GOODNESS OF FIT**

$$J = (\tilde{z} - \hat{z})^T (HPH^T + R)^{-1} (\tilde{z} - \hat{z})$$



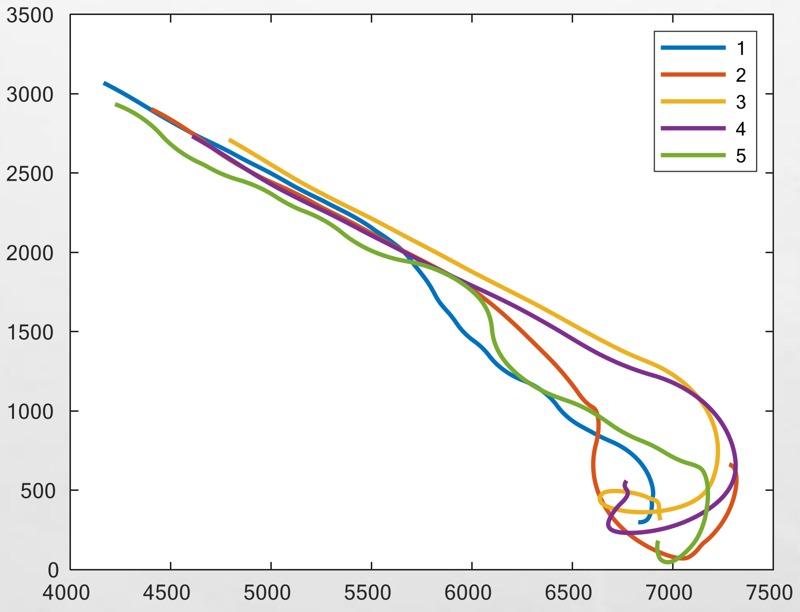
Choose target 1



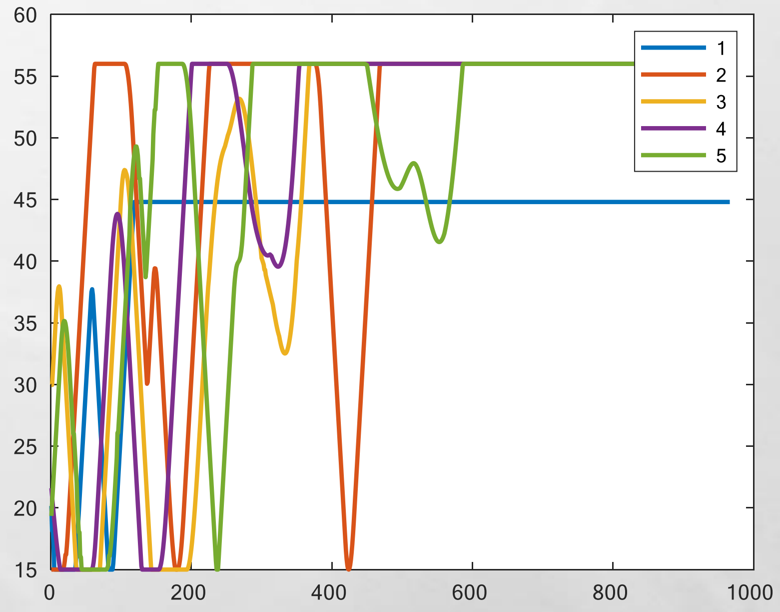
Choose target 2

VELOCITY ESTIMATION – PRINCIPLE

- TRACKING AND ASSOCIATION
- VELOCITY ESTIMATION



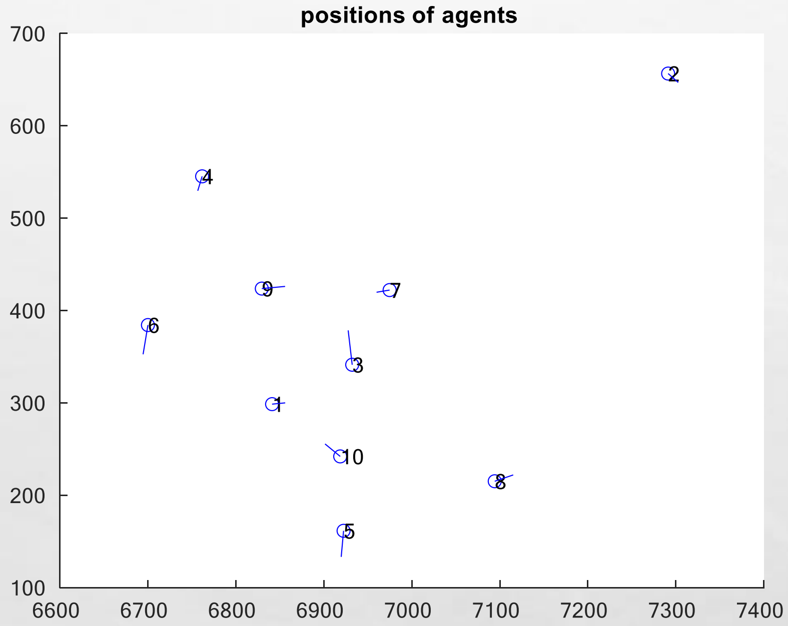
target positions

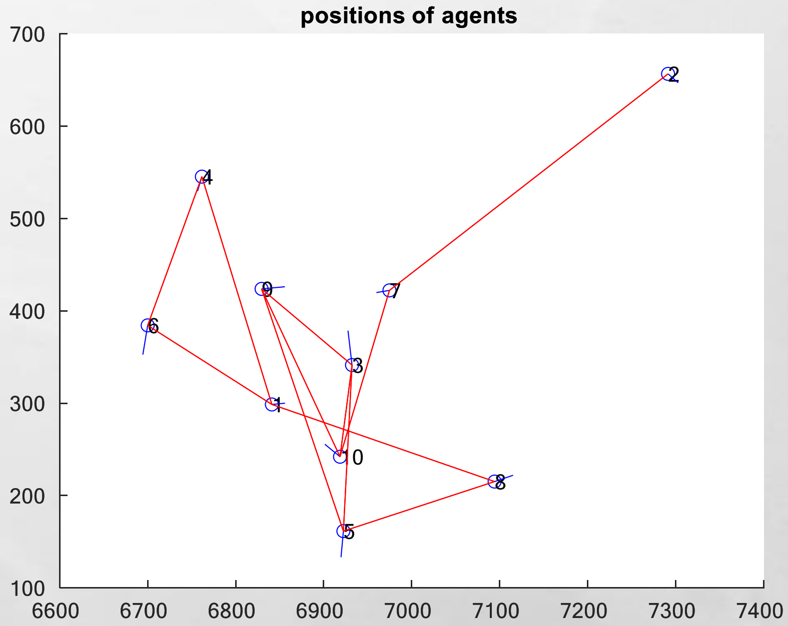


Target norm velocity

GRAPH BUILDING – PRINCIPLE

- TRACKING AND ASSOCIATION
- VELOCITY ESTIMATION
- BUILD GRAPH ADJACENCY





FINDING LEADER – PRINCIPLE

- ADJACENCY MATRIX E
- WEIGHT MATRIX W

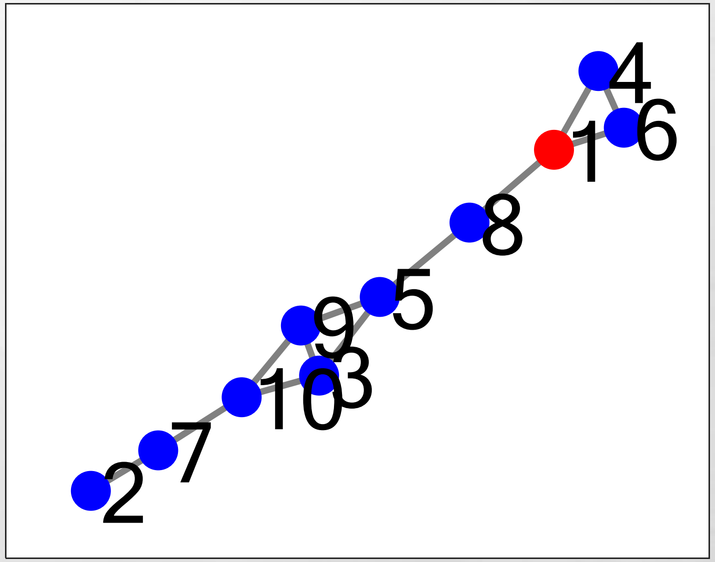
  COMPUTE THE RELATIVE TEMPO $g_{ij} = \|\dot{x}_i\| / \|\dot{x}_j\|$
- SEARCH THE MINIMAL NODE IN THE GRAPH

  $$min\{v_1(L_B)\}$$

EndNodes		Weight	Dir
1	4	1.0937	-1
1	6	2.1443	-1
1	8	1.4731	-1
2	7	1	1
3	5	1.3218	1
3	9	1.4112	1
3	10	1.7112	1
4	6	1.9606	-1
5	8	1.2831	1
5	9	1.0676	1
7	10	1.4601	-1
9	10	1.2125	1

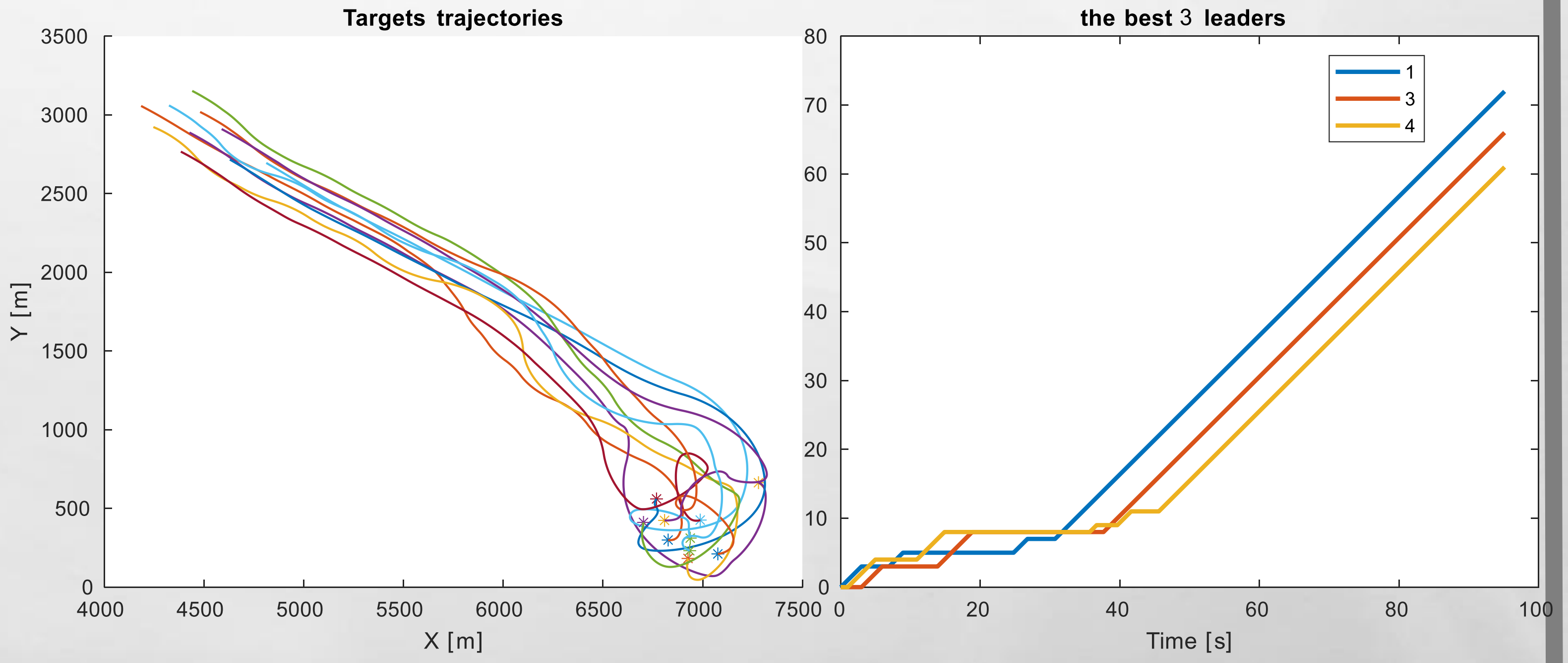
ID	Leaders	EntryVB1	Identified
1	1	0.1211	1
2	0	0.44513	3
3	0	0.36417	0
4	0	0.12635	0
5	0	0.32281	0
6	0	0.12635	0
7	0	0.42663	2
8	0	0.22667	0
9	0	0.36417	0
10	0	0.3904	0

ACTUAL



LEADER IDENTIFICATION – OVERVIEW

- AGENTS DETECTION
- TRACKING AND ASSOCIATION
- VELOCITY ESTIMATION
- BUILD GRAPH ADJACENCY
- LEADER IDENTIFICATION
  - GRAPH SEARCH FOR A MINIMAL NODE $min\{v_1(L_B)\}$



SUMMARY

- SAN – SEMI AUTONOMOUS NETWORK – LEADERS AND FOLLOWERS
- FSN NETWORK – FOLLOWING THE SLOWER NEIGHBOR – DIRECTED NETWORK
- LEADER IDENTIFICATION
- STATIC NETWORK EXAMPLES
- LEADER IDENTIFICATION IN A DYNAMIC NETWORK

THANKS

QUESTIONS?