Paper Review

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Contents

ON SEGREGATIVE BEHAVIORS USING FLOCKING AND VELOCITY OBSTACLES [2012 DARS]

- Purpose
  - Swarm navigation combining **hierarchical abstractions**, **flocking** behaviors, and an **efficient** collision avoidance **mechanism**
- Methodology
  - Introducing penalty function to allow to select velocity belonging to VO.
  - Parameter triples (α， β， w)

$$\mathbf{v}_i^{\text{flock}} = \mathbf{v}_i^{\text{pref}} + \alpha(\mathbf{v}(\Phi_k) - \mathbf{v}_i) + \beta(\mathbf{p}(\Phi_k) - \mathbf{p}_i)$$

$$P_i(\mathbf{v}_i') = \frac{w}{c_i(\mathbf{v}_i')} + \|\mathbf{v}_i^{\text{flock}} - \mathbf{v}_i'\|,$$

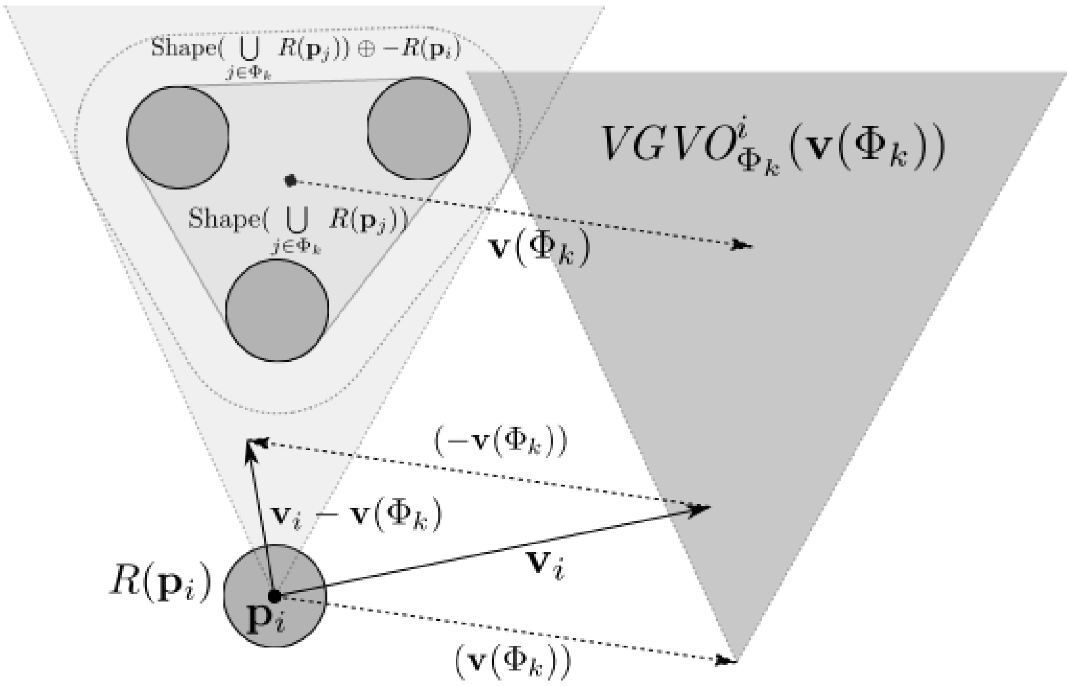
$$\mathbf{v}_i^{\text{new}} = \operatorname*{argmin}_{\mathbf{v}_i' \in S} P_i(\mathbf{v}_i')$$

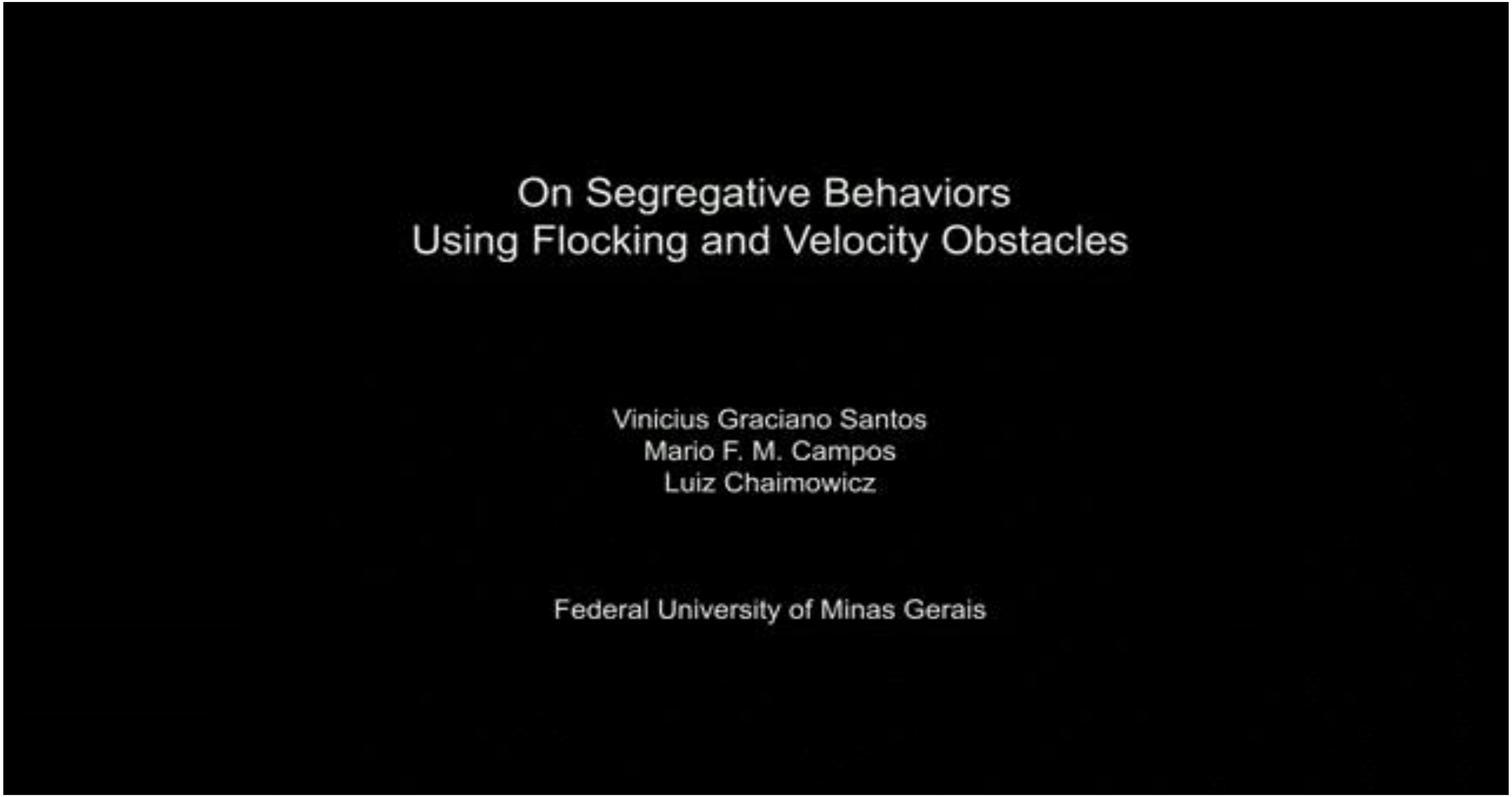
- **Drawback**
  - The same behavior cannot be guaranteed with small sensing neighborhood.
- **Improvement**
  - VGVO (virtual group)

$$VGVO^i_{\Phi_k}(\mathbf{v}(\Phi_k)) = \{\mathbf{v}'_i \mid \lambda(\mathbf{p}_i, \mathbf{v}'_i - \mathbf{v}(\Phi_k)) \cap C(\mathbf{p}_i, \Phi_k) \neq \emptyset\},$$

$$C(\mathbf{p}_i, \Phi_k) = \text{Shape}(\bigcup_{j\in\Phi_k} R(\mathbf{p}_j)) \oplus -R(\mathbf{p}_i),$$

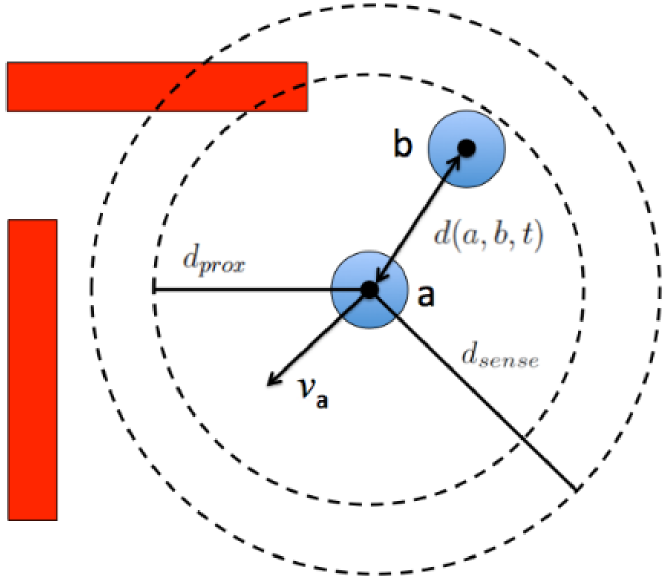
$$VGRVO^i_{\Phi_k}(\mathbf{v}(\Phi_k), \mathbf{v}_i) = \{\mathbf{v}''_i \mid 2\mathbf{v}''_i - \mathbf{v}_i \in VGVO^i_{\Phi_k}(\mathbf{v}(\Phi_k))\}.$$




On Segregative Behaviors
Using Flocking and Velocity Obstacles
Vinicius Graciano Santos
Mario F. M. Campos
Luiz Chaimowicz
Federal University of Minas Gerais

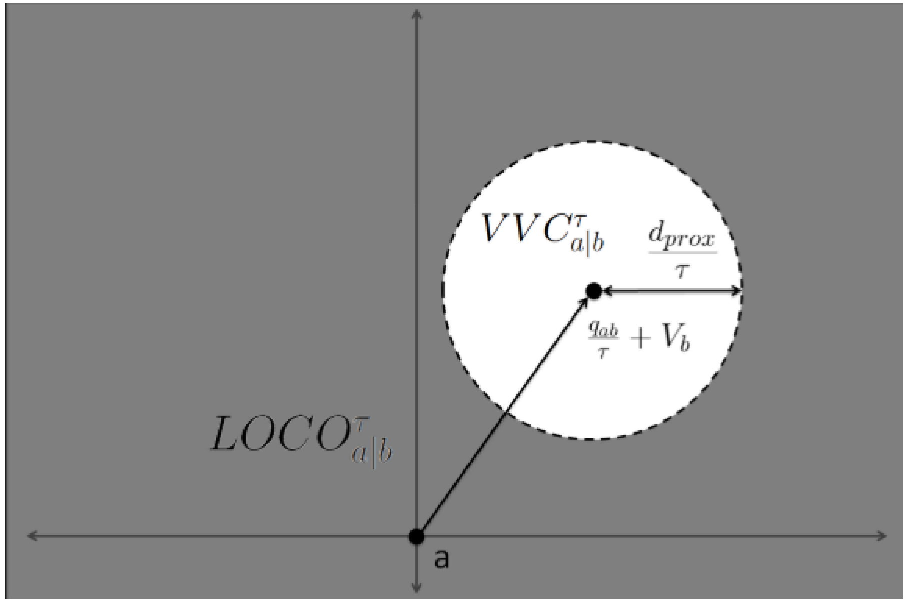
MAINTAINING TEAM COHERENCE UNDER THE VELOCITY OBSTACLE FRAMEWORK [2012 AAMAS]

- Purpose
  - Loss of Communication Obstacle, aiming to maintain proximity among agents by imposing constraints in the velocity space and restricting the set of feasible controls.



LOCO CONSTRUCTION

- To be noted, τ is tuned through comparison between V_{valid} and $V_{threshold}$
  - norm(V_{valid}) < norm($V_{threshold}$)， time horizon τ decreased;
  - Otherwise.



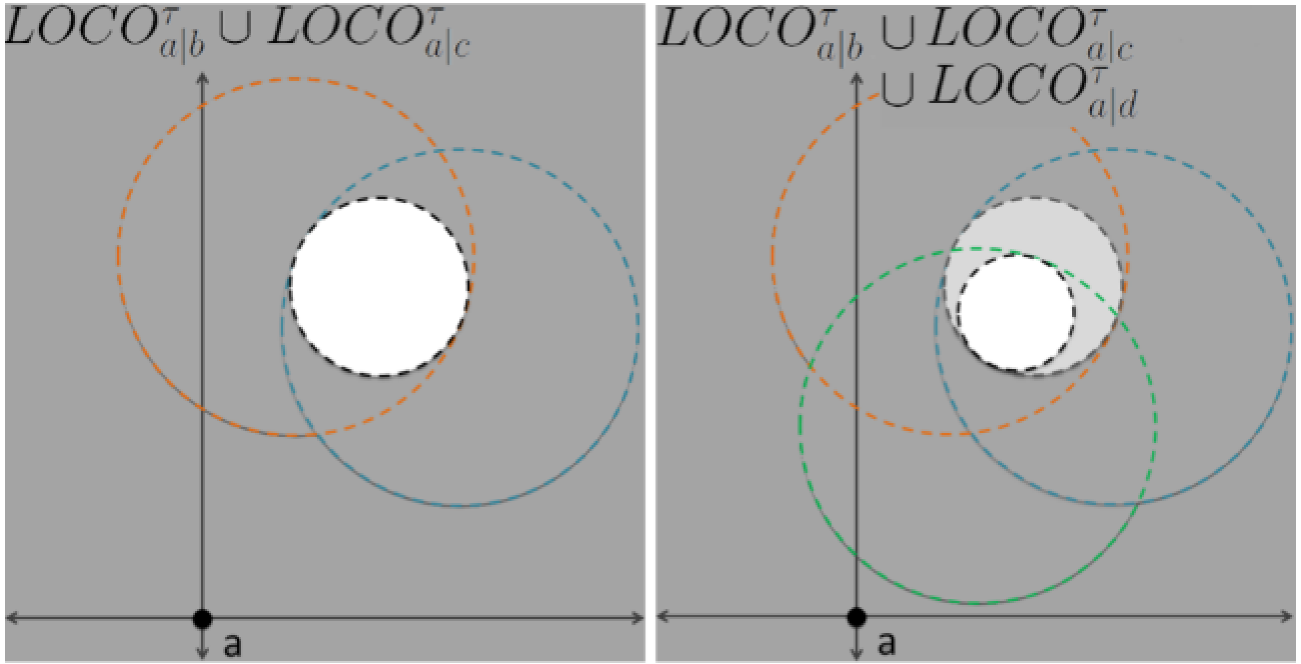
$$(q^X_{ab}(t+\tau))^2 + (q^Y_{ab}(t+\tau))^2 \leq d^2_{prox} \Rightarrow$$

$$(q^X_{ab}(t)+\tau*(V^X_b - V^X_a))^2+(q^Y_{ab}(t)+\tau*(V^Y_b - V^Y_a))^2 \leq d^2_{prox} \Rightarrow$$

$$(\frac{q^X_{ab}(t)}{\tau} + V^X_b - V^X_a)^2 + (\frac{q^Y_{ab}(t)}{\tau} + V^Y_b - V^Y_a)^2 \leq \frac{d^{prox^2}}{\tau^2} \Rightarrow$$

$$(V^X_a - \frac{q^X_{ab}(t)}{\tau} - V^X_b)^2 + (V^Y_a - \frac{q^Y_{ab}(t)}{\tau} - V^Y_b)^2 \leq (\frac{d_{prox}}{\tau})^2$$

CONSERVATIVE APPROXIMATION

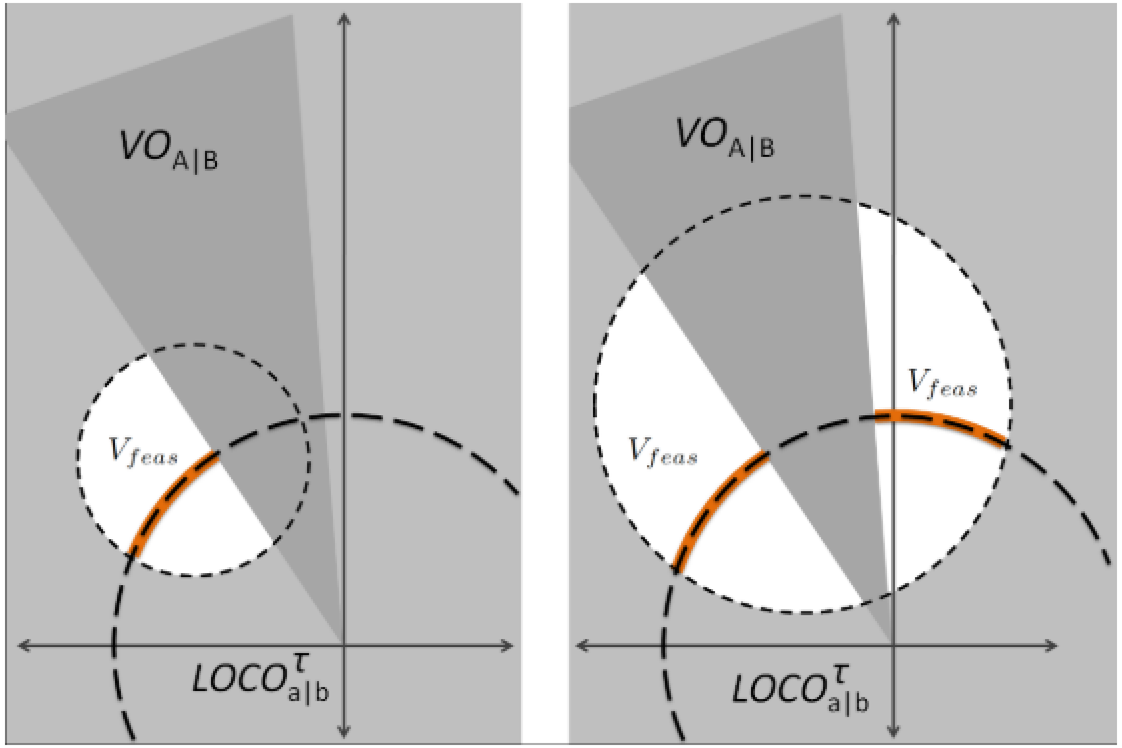


INTEGRATION

- Weighted velocity selection

$$q_{avg} = \frac{\sum_i^n \frac{d_i}{d_{prox}} q_i}{\sum_i^n \frac{d_i}{d_{prox}}}$$

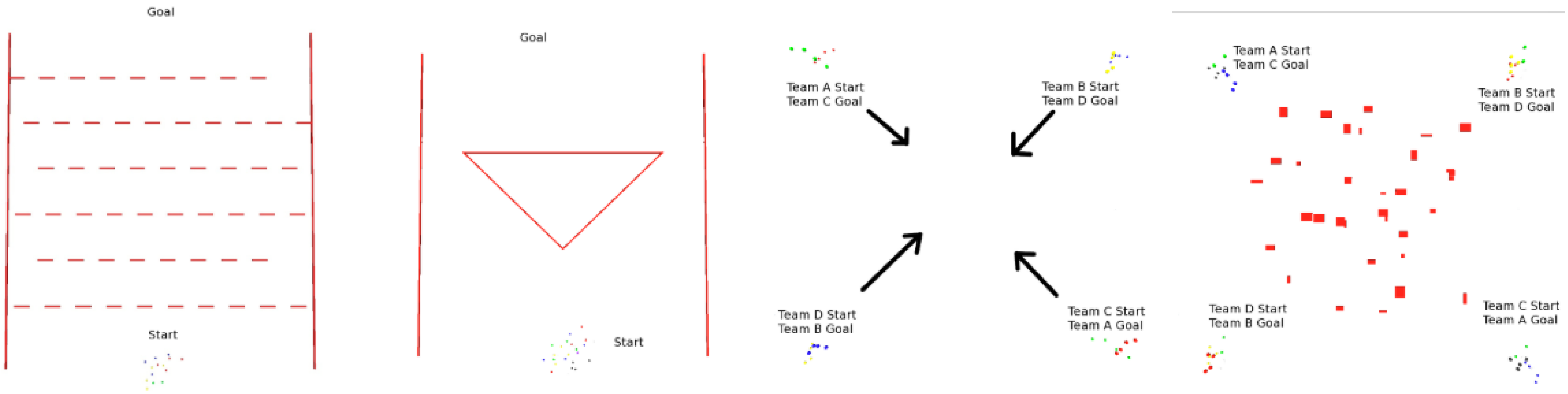
$$v_a^{pref} = \frac{d_{avg}}{d_{prox}} v_{avg} + \frac{d_{prox} - d_{avg}}{d_{prox}} v_{goal}$$



- To be noted: when there's no valid velocity, agent remains its current velocity

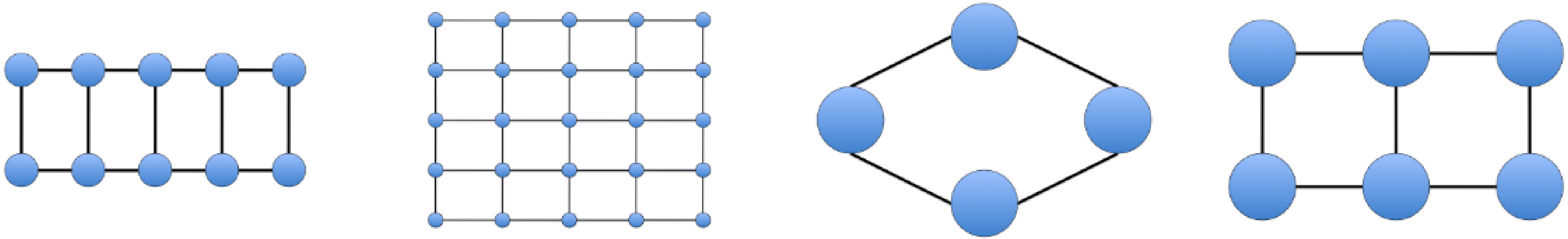
METRICS

- total number of collisions during the entire experiment
- computation time per frame,
- total time to solve the problem,
- average ratio of respected proximity links per frame,
- and number of successful runs.



(a) PACHINKO environment (b) WEDGE environment (c) CROSSROADS environment (d) Random environment

Figure 7: The environments on which the experiments were executed



(a) (b) (c) (d)

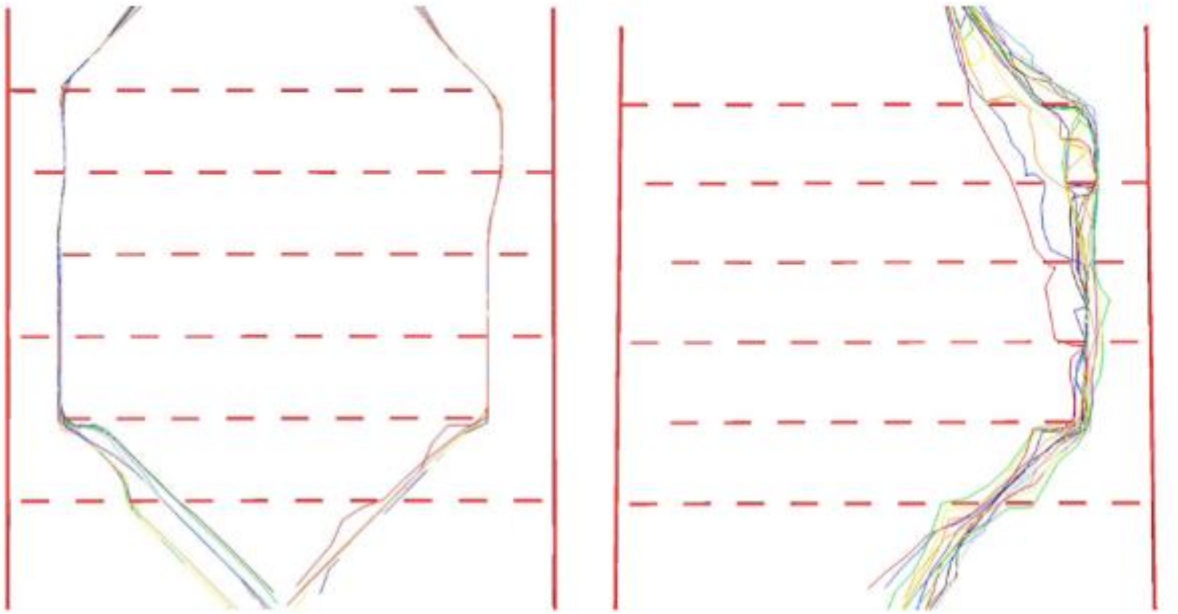


Figure 10: An example of the paths taken by 24 agents in the PACHINKO environment for the RVO (left) and LOCO (right) approach.

PRIORITIZED GROUP NAVIGATION WITH FORMATION VELOCITY OBSTACLES [2015 ICRA]

- Purpose
  - navigating a group of robots having prioritized formations amidst static and dynamic obstacles. At each planning cycle, we compute a **new** formation which accounts for both these **priority** values and the **safe** progress of the robots towards their goals.
- Methodology
  - Group planning* (main discussion, novelty)
    - To find F* which balances between user's input and collision-free progress
  - Individual planning
    - Slightly discussed

INFERENCE

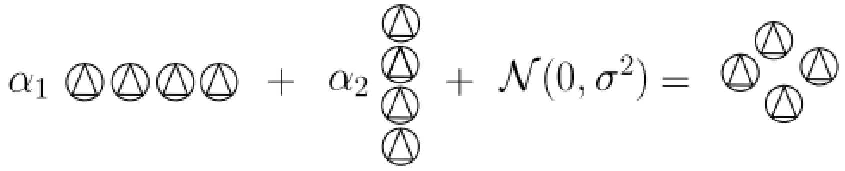


Fig. 1. **Defining Arbitrary Formations** We can decompose any arbitrary formation into a linear combination of the user provided template formations T plus some noise. For example, the staggered formation on the far right is a combination of the line-abreast and column formations with $a_1 = 0.56$ and $a_2 = 0.43$, respectively, and $\sigma = 0.08$.

- Given a formation F, cost function is defined as: $E(F) = p_F\left(\mathbf{v}_F \cdot \hat{\mathbf{v}}^{\text{pref}}\right)$
- To obtain a formation F* from set of Fs, it's assumed to be a convex combination of k provided templates with noise.

$$F = a_1 T_1 + \cdots + a_k T_k + \mathcal{N}(0, \sigma^2), \text{ s.t} \sum_{i=1}^{k} a_i = 1,$$

- Infer the value of priority of formation F.

$$p_F = a_1 p_1 + a_2 p_2 + \cdots + a_k p_k - \gamma\sigma,$$

- Infer the value set given the formation F.

$$\underset{a_1,\ldots,a_k,\sigma}{\operatorname{argmax}} P(a_1, \ldots, a_k, \sigma | F) \quad (7)$$

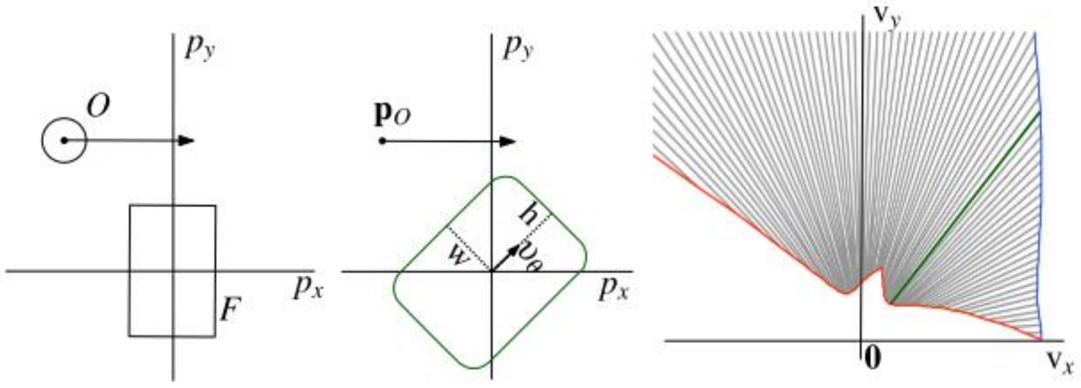
$$= \underset{a_1,\ldots,a_k,\sigma}{\operatorname{argmax}} \mathcal{L}(F | a_1, \ldots, a_k, \sigma) + \mathcal{L}(a_1, \ldots, a_k) + \mathcal{L}(\sigma),$$

$$\underset{a_1,\ldots,a_k,\sigma}{\operatorname{argmax}} \frac{-[D(F, a_1 T_1 + \ldots + a_k T_k)]^2}{\sigma^2}.$$

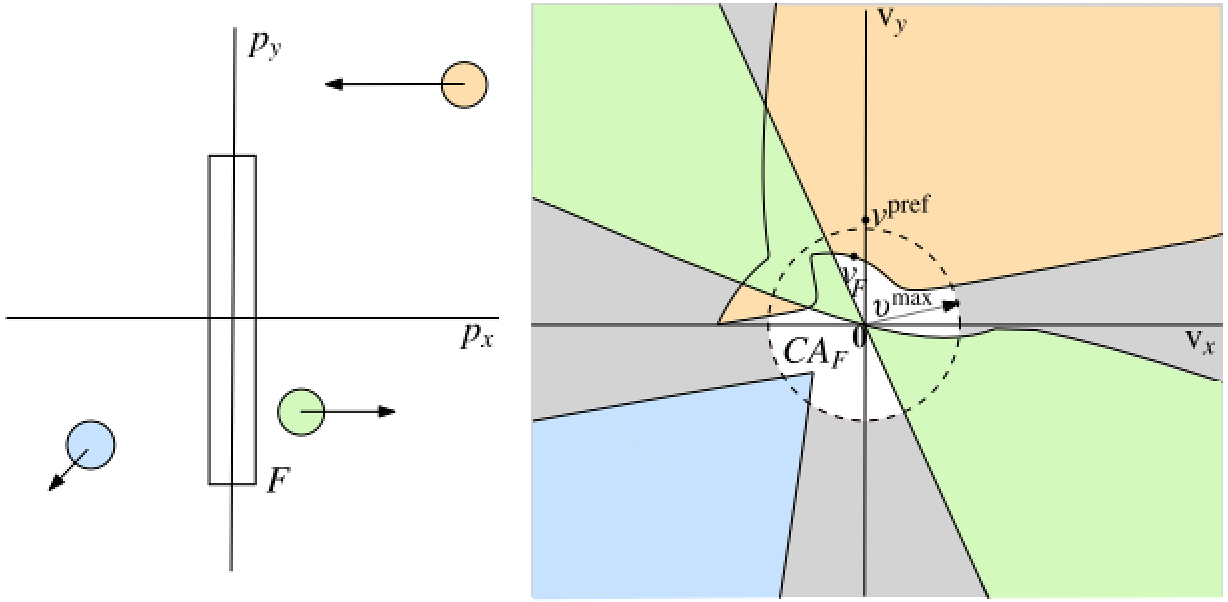
where $\mathcal{L}(\cdot)$ denotes the *log likelihood* function.

FORMATION VELOCITY OBSTACLE

- Treat formation as a bounding box with w and h.

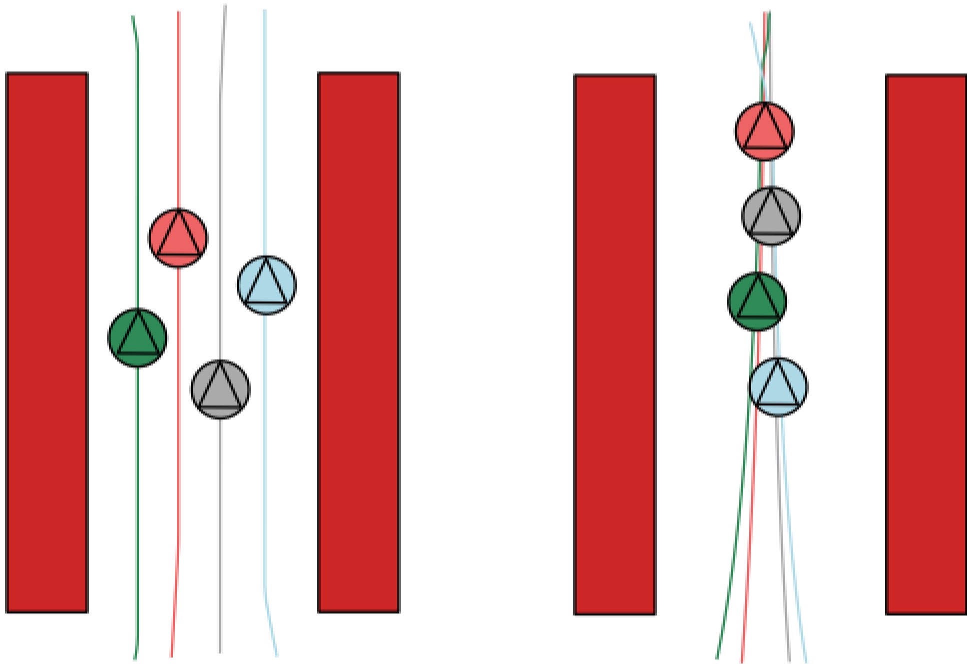


(a) (b) (c)



(a) (b)

- Tuning γ

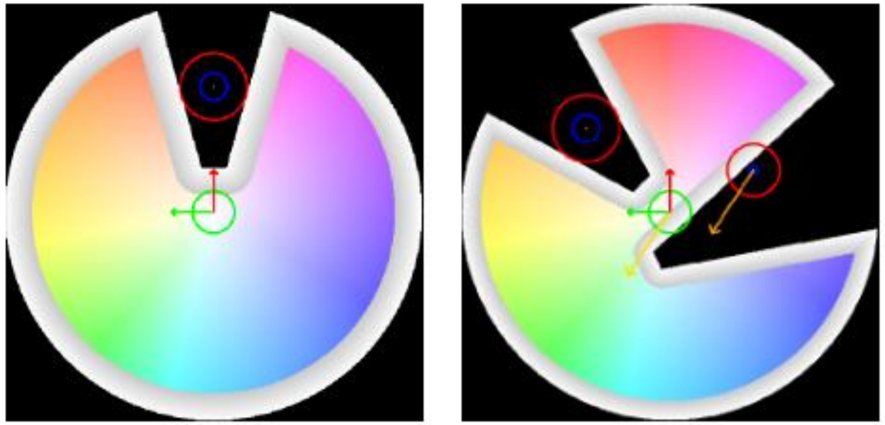


(a) (b)

Fig. 6. **Effect of γ parameter.** Agents navigate through a passage given two formations: line abreast and single column. (a) With a small value of γ agents adopt an ad-hoc formation which fits the obstacle. (b) With a larger value of γ agents follow very closely the single column formation.

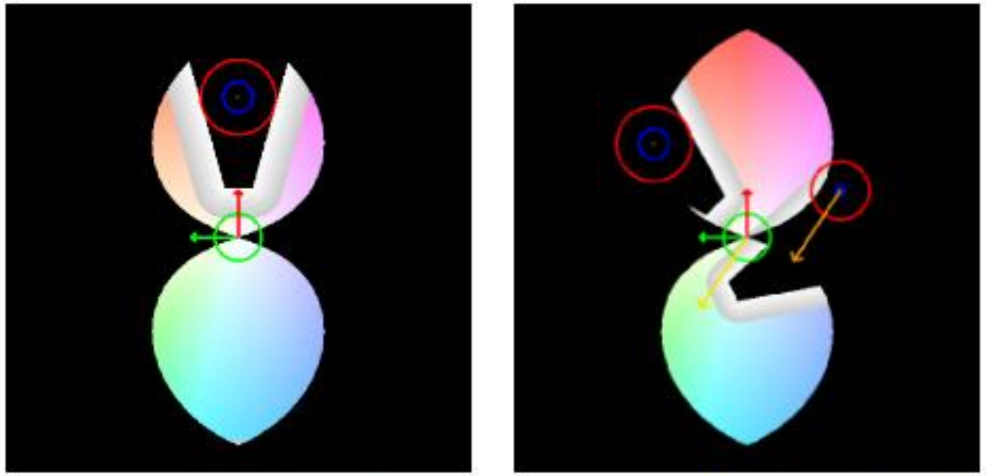
AN ADAPTIVE VELOCITY OBSTACLE AVOIDANCE ALGORITHM FOR AUTONOMOUS SURFACE VEHICLES [2019 IROS]

- Purpose
  - A real-time obstacle avoidance for surface vehicle with protective zone concept, using particle swarm optimization to minimize a multicriteria evaluation metric(danger, deviation and cross distance)
- Methodology
  - Protective Zone



(a) Single static obstacle. (b) Static and dynamic obstacles.

Kinematics constraint



(a) Single static obstacle. (b) Static and dynamic obstacles.

VELOCITY SELECTION

- Multicriteria optimization object function h(V)

$$\min_{\Delta v_d, \Delta\theta_d, \nabla_i} \quad h(V_i)$$

$$h(V_i) = \varepsilon^{\intercal} \cdot \psi$$

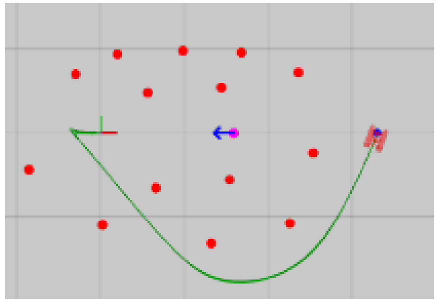
→ PSO

$$V_i = \varphi_1 \cdot V_{i-1} + \varphi_2 \cdot r_1 \cdot (pBest - P_{i-1}) + \varphi_3 \cdot r_2 \cdot (gBest - P_{i-1}) + \varphi_4 \cdot \tau$$

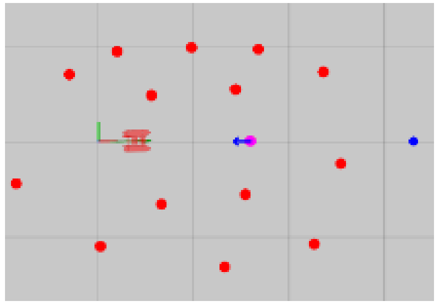
$$P_i = P_{i-1} + V$$

$$\varepsilon = \begin{bmatrix} |\Delta v_d| \\ |\Delta\theta_d| \\ \nabla_i \end{bmatrix}, \ \Delta v_d, \Delta\theta_d \in [-1, 1], \ \nabla_i \in [0, 1]$$

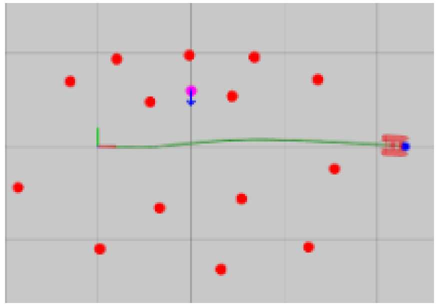
RESULT



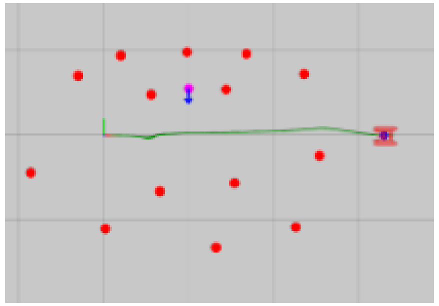
(a) *AVOA* (Scenario A).



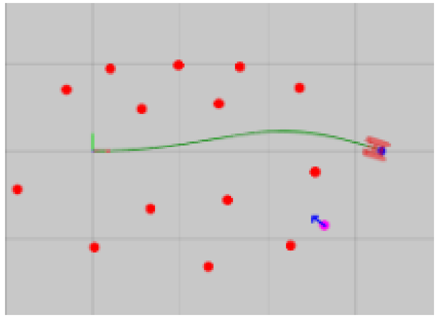
(b) TEB (Scenario A).



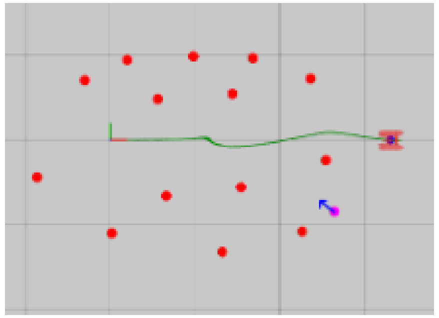
(c) *AVOA* (Scenario B).



(d) TEB (Scenario B).



(e) *AVOA* (Scenario C).



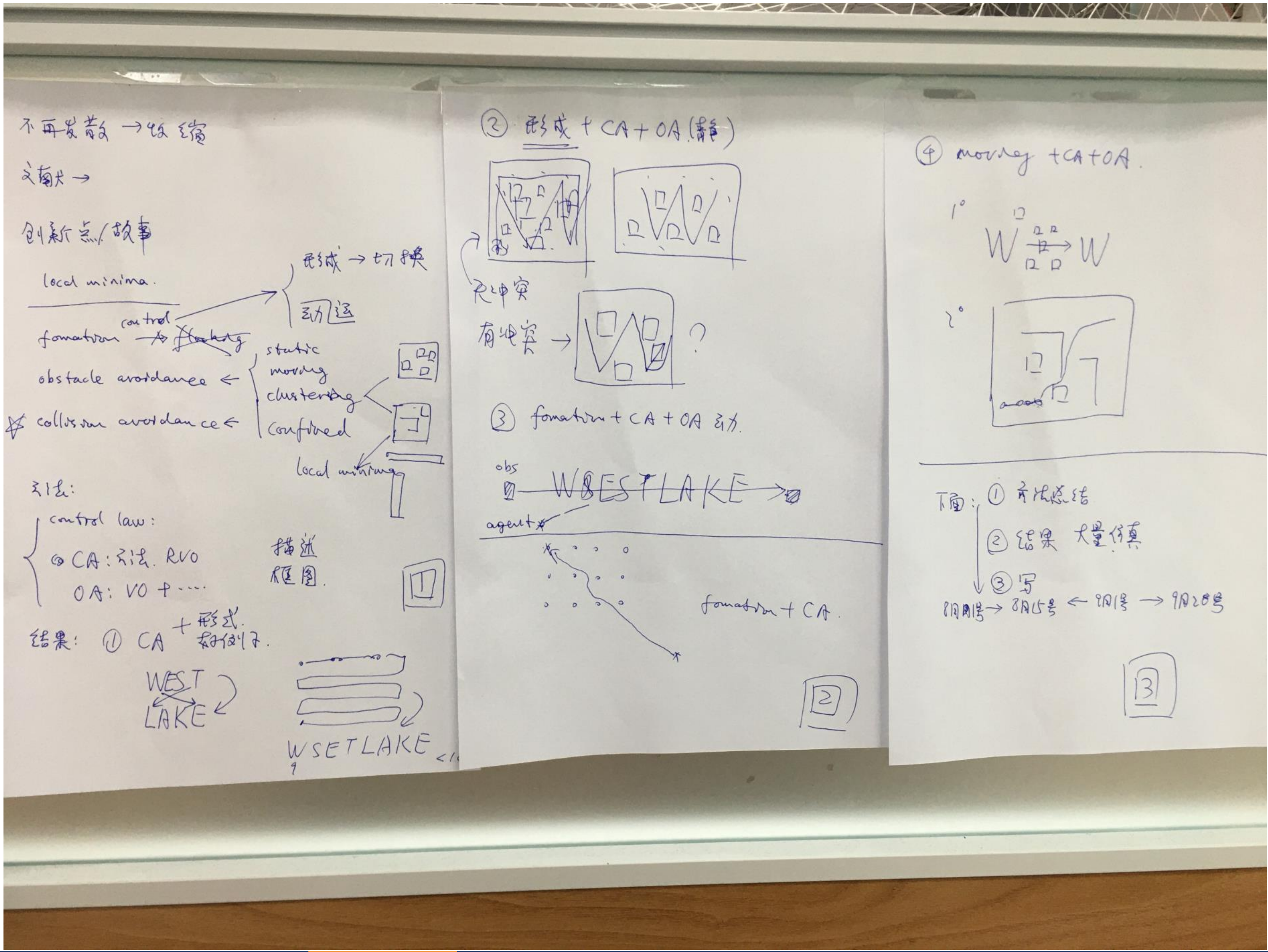
(f) TEB (Scenario C).

DISTRIBUTED LYAPUNOV-BASED MODEL PREDICTIVE CONTROL FOR COLLISION AVOIDANCE OF MULTI-AGENT FORMATION

- Navigate groups of robots in a shared environment while maintaining segregation among groups.
  - Extended concept of RVO with flocking behaviors and hierarchical abstractions.

ARRANGEMENT

Q&A



THANK YOU

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