

Wireless Connectivity of Swarms in Presence of Obstacles



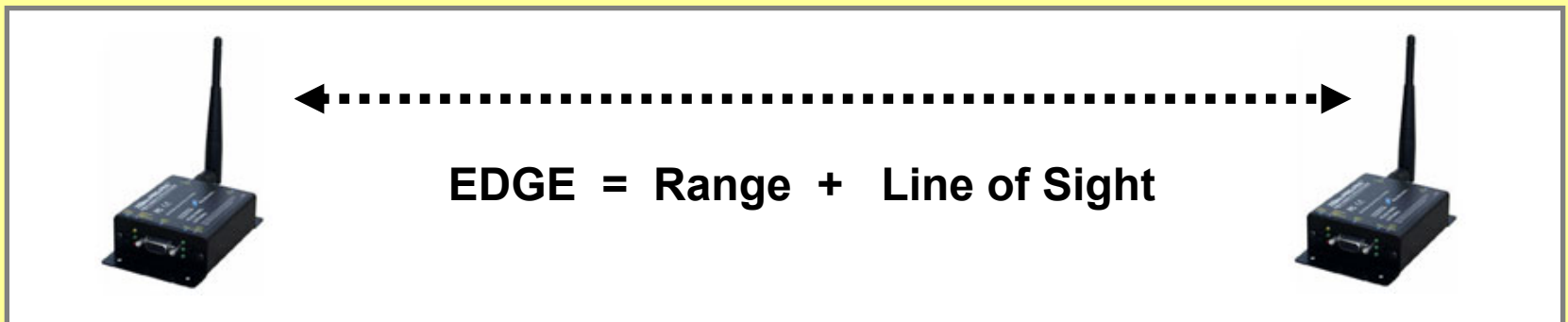
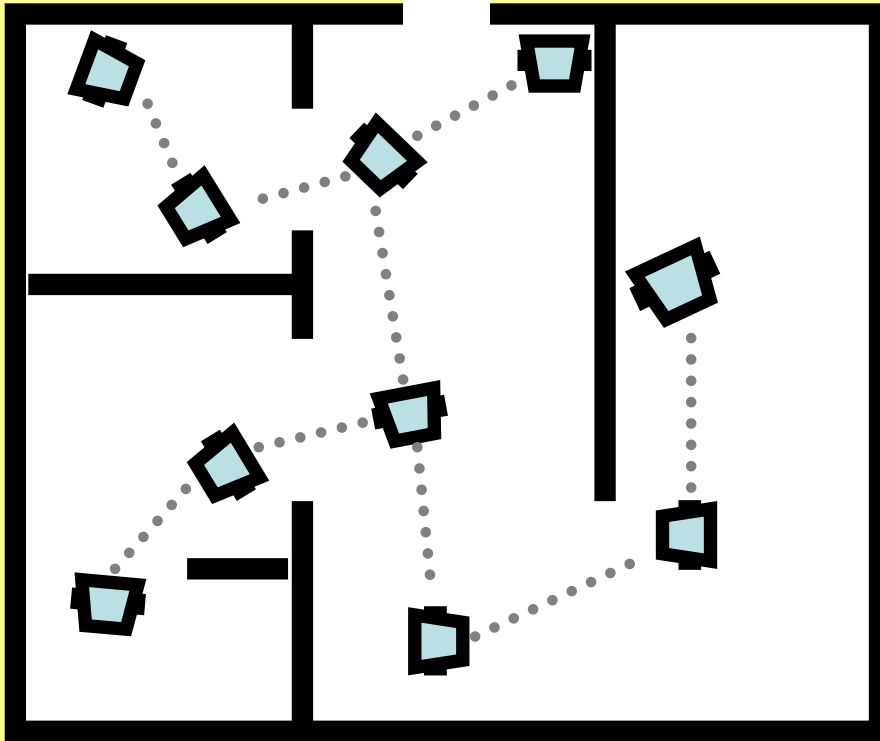
Joel Esposito

US Naval Academy

Thomas Dunbar

Naval Postgraduate School

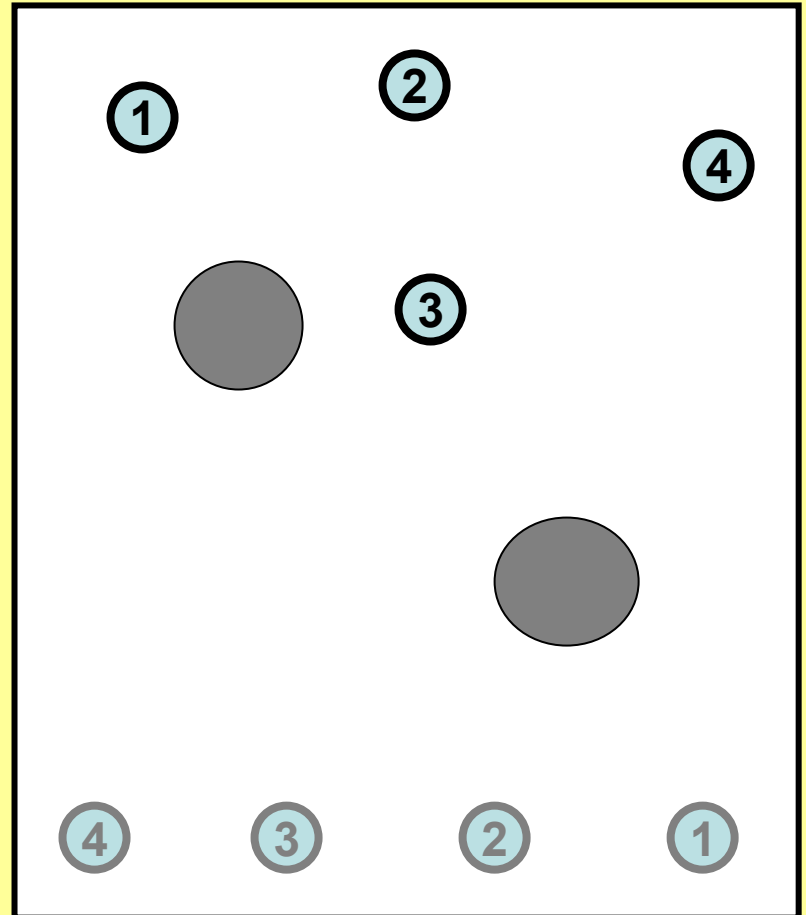
Motivation



Problem Statement

Given:

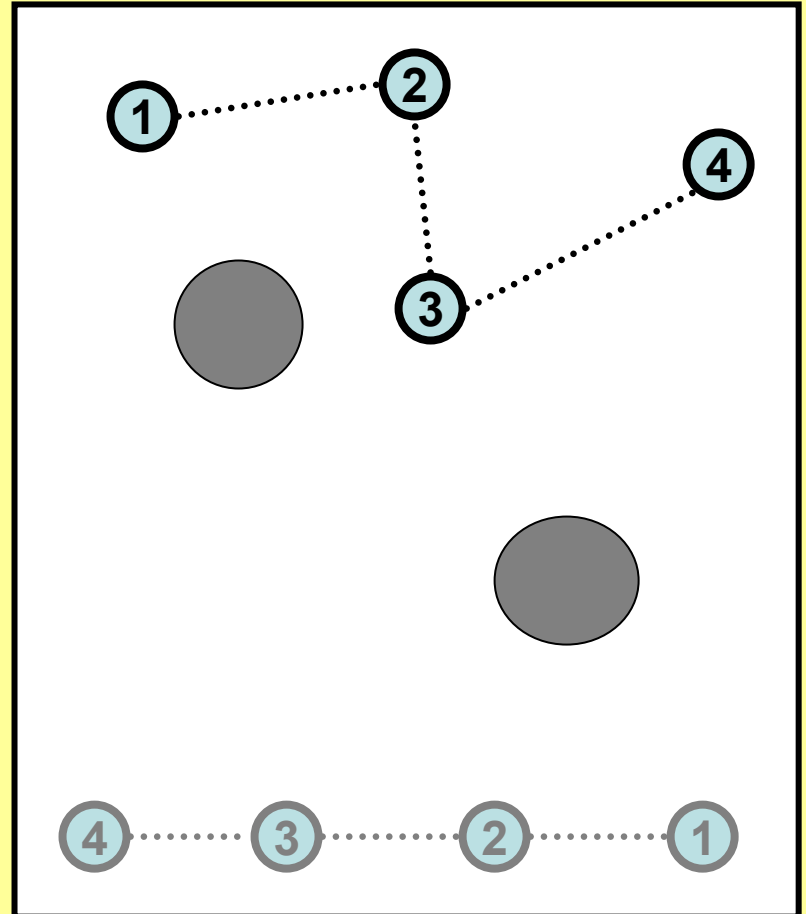
- N mobile holonomic robots
- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}



Problem Statement

Given:

- N mobile holonomic robots
- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}
- *Critical* communication graph, $C^* \subseteq G$
(EDGE = Range + Line-of-sight)



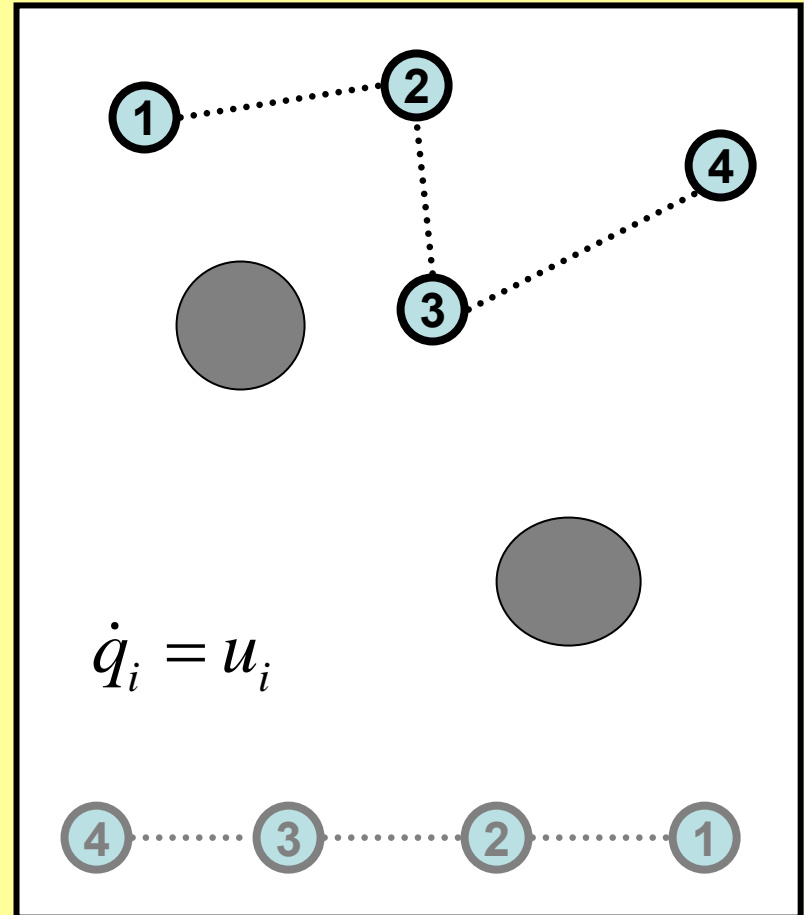
Problem Statement

Given:

- N mobile holonomic robots
- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}
- *Critical* communication graph, $C^* \subseteq G$
(EDGE = Range + Line-of-sight)

Problem:

Design a ***distributed*** control law which achieves final position ***while*** preserving all **critical** edges of G (i.e range and LOS)



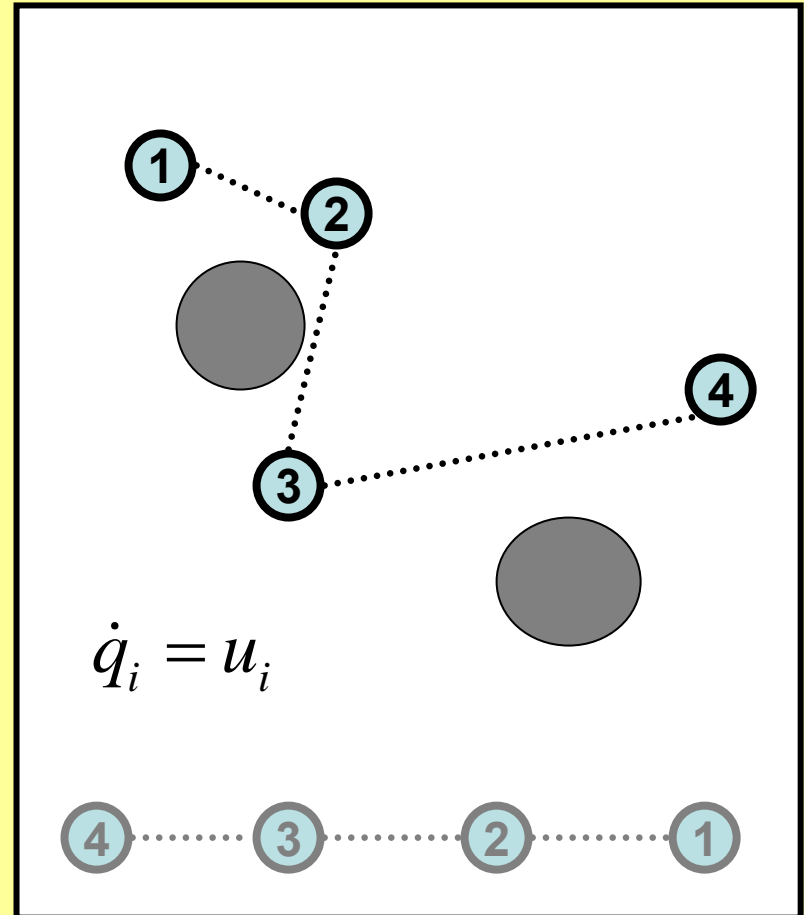
Problem Statement

Given:

- N mobile holonomic robots
- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}
- *Critical* communication graph, $C^* \subseteq G$
(EDGE = Range + Line-of-sight)

Problem:

Design a ***distributed*** control law which achieves final position ***while*** preserving all **critical** edges of G (i.e range and LOS)



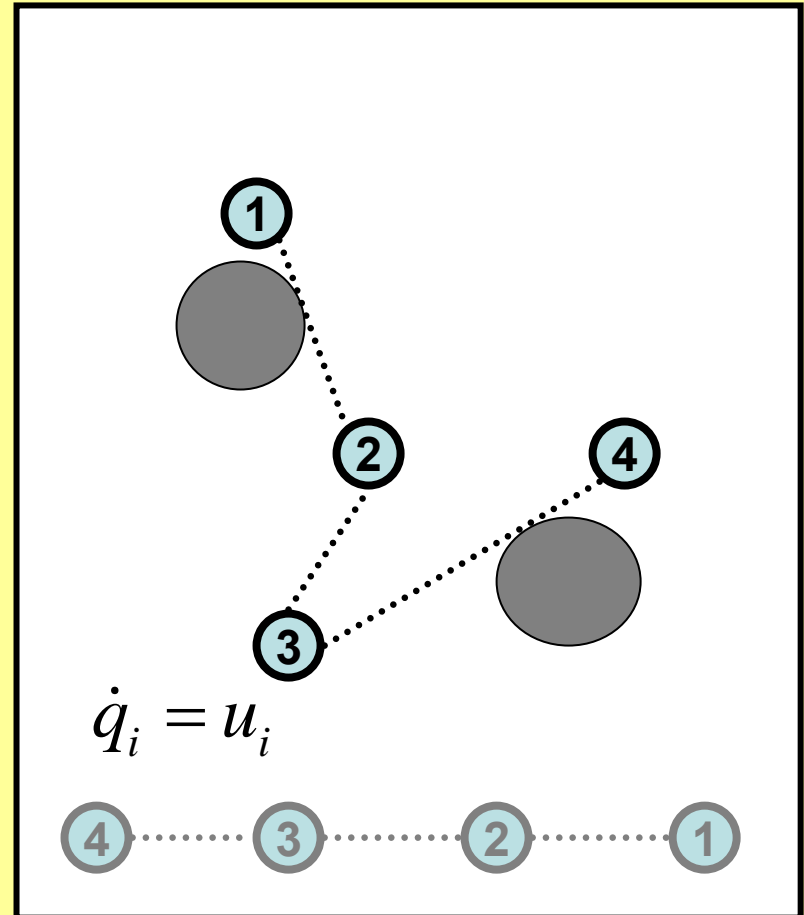
Problem Statement

Given:

- N mobile holonomic robots
- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}
- *Critical* communication graph, $C^* \subseteq G$
(EDGE = Range + Line-of-sight)

Problem:

Design a ***distributed*** control law which achieves final position ***while*** preserving all **critical** edges of G (i.e range and LOS)



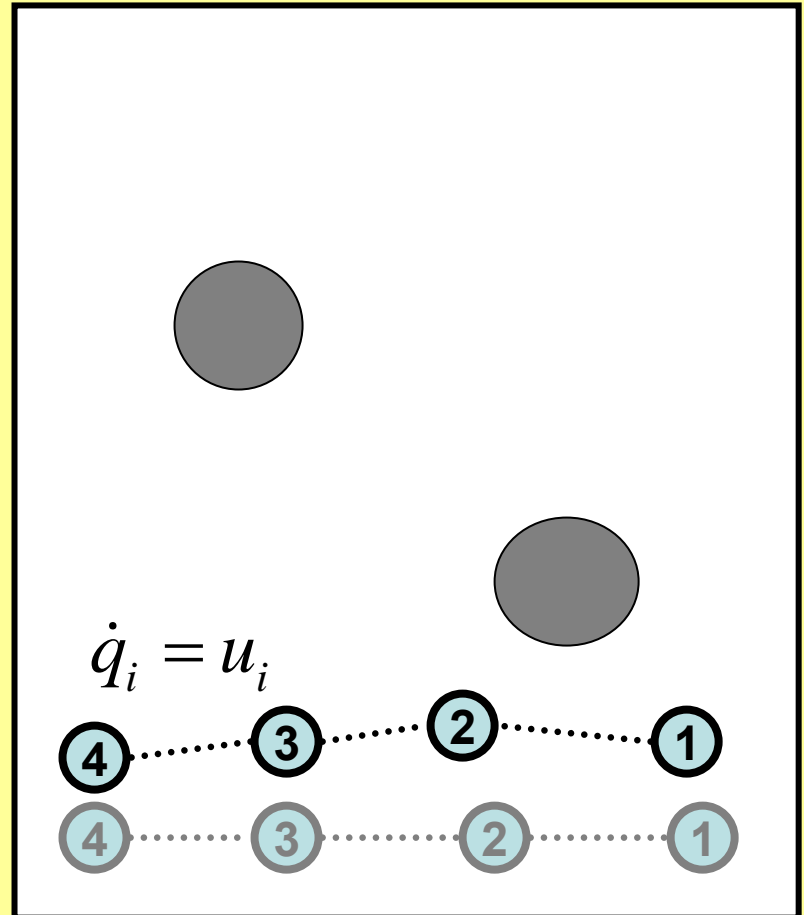
Problem Statement

Given:

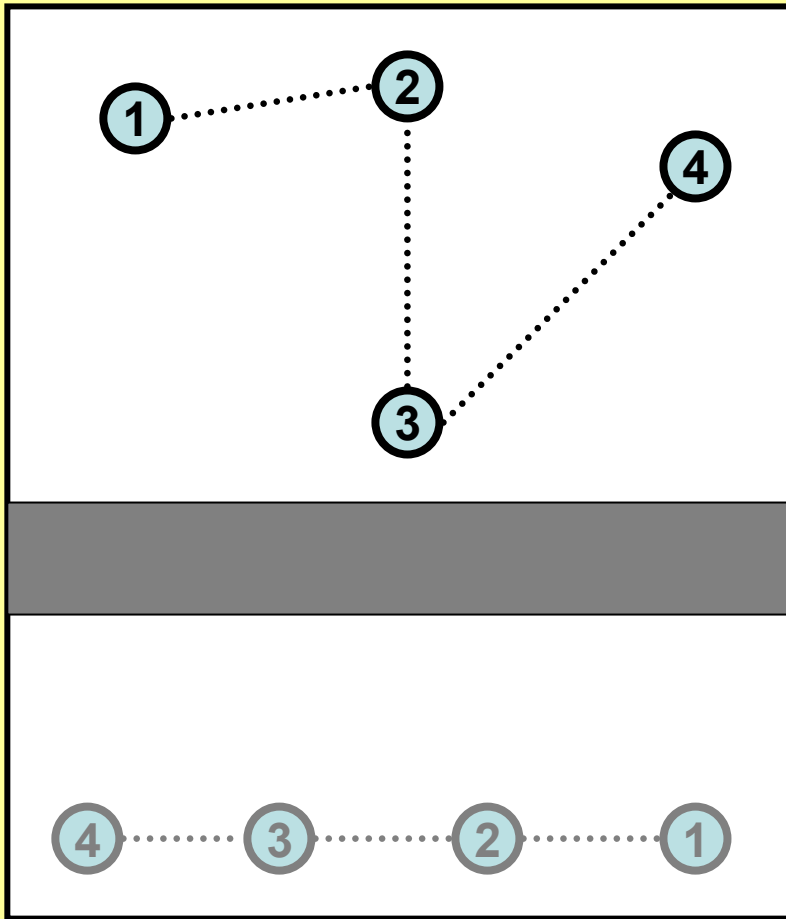
- N mobile holonomic robots
- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}
- *Critical* communication graph, $C^* \subseteq G$
(EDGE = Range + Line-of-sight)

Problem:

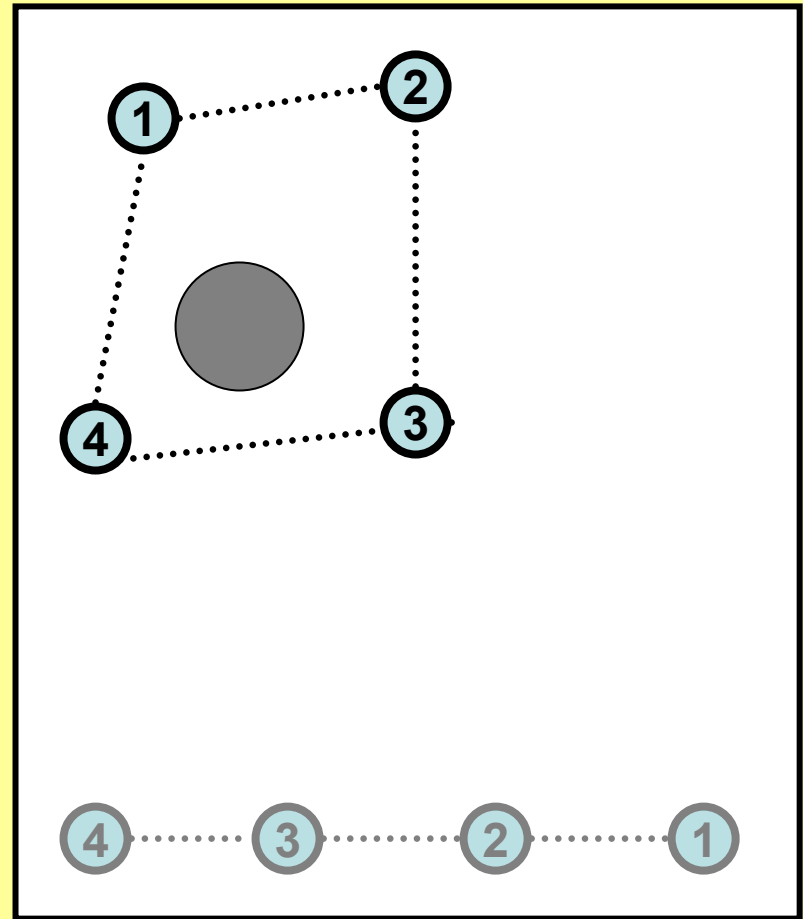
Design a ***distributed*** control law which achieves final position ***while*** preserving all **critical** edges of G (i.e range and LOS)



Obvious Infeasibility



Start and goal in different connected components of W



Cycles in different homotopic equivalence classes

Related work

Formations:

- Fixed relative pose
- Leader

Desai, Kumar, Fierro

Flocks:

- Constr. rel. pose
- Distributed
- Swarm-wide objective

*Reynolds, Reif, Bishop, Tanner,
Pappas, Moorse, Jadbabaie
Passiano, Olfati-Saber, Murray*

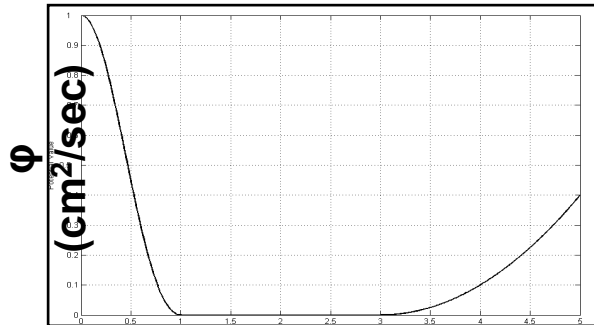
Closely Related Works:

- Maintaining network connectivity
- Multi-hops networks
- Obstacle free?

*Spanos, Murray; Zavlanos Pappas
Bullo, Cortes, Notarstefano*

Approach: Potential Functions

1. Range: 

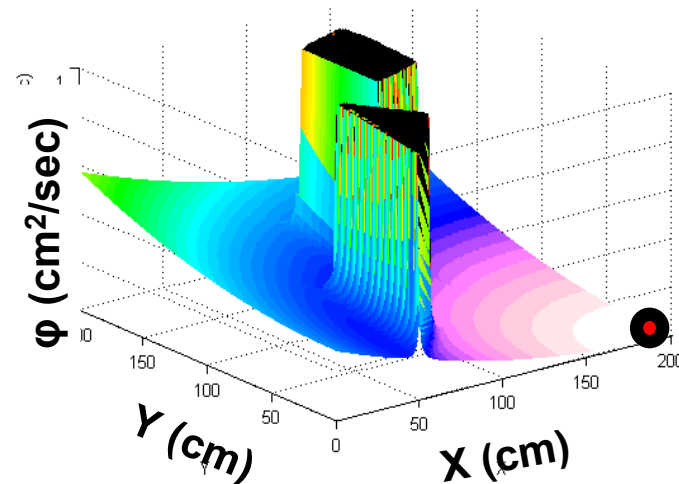


distance to other robot (cm)

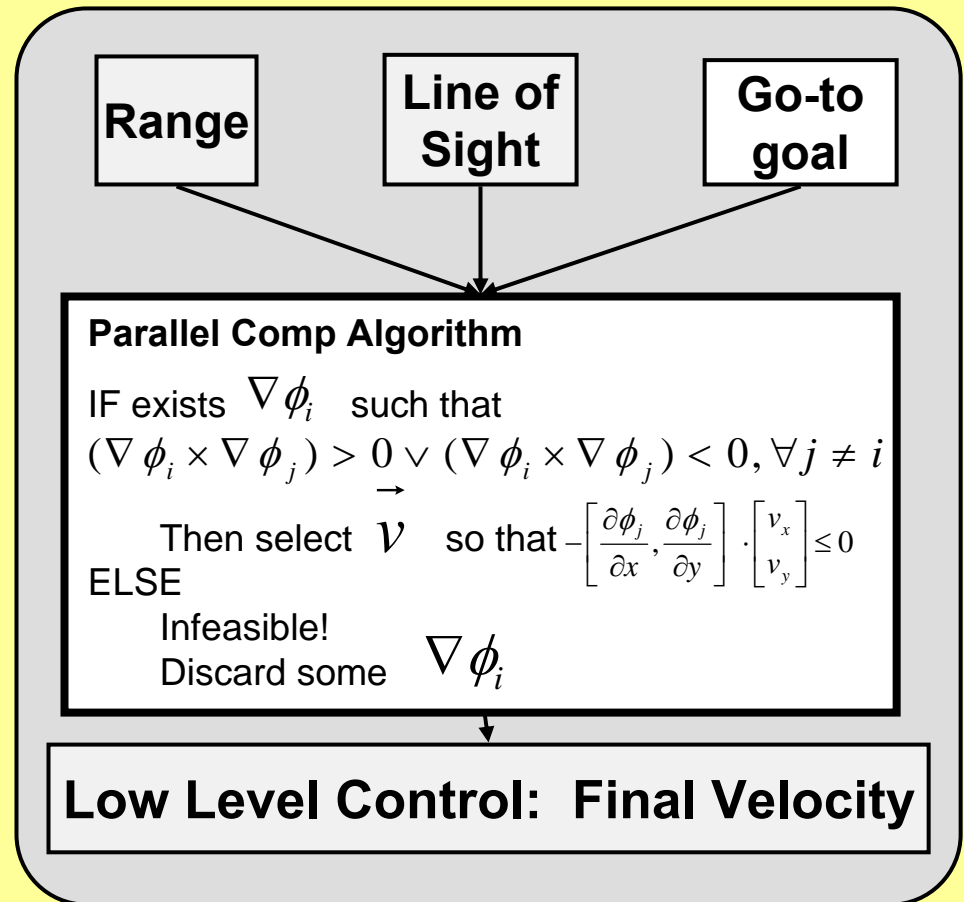
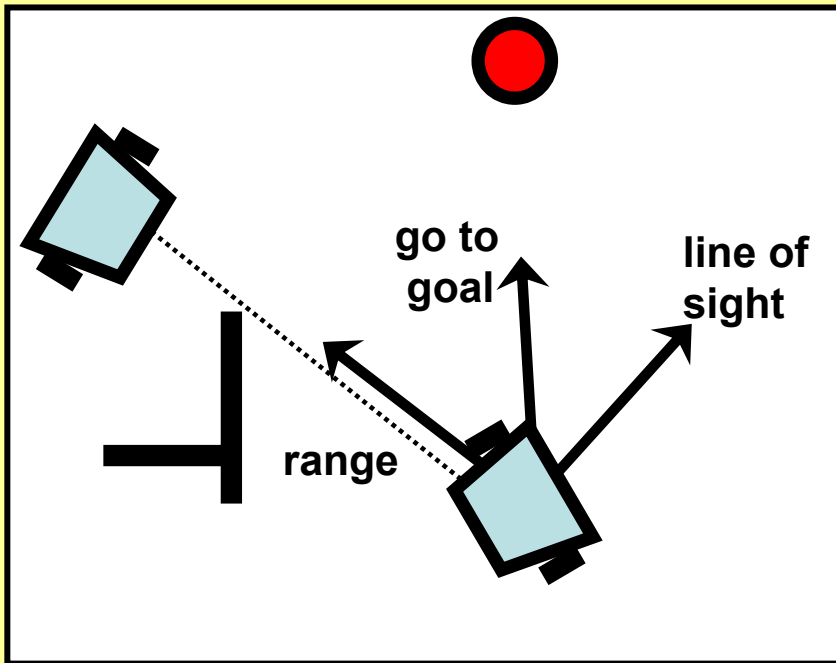
2. Line of Sight: 

3. Go To Goal:

Navigation function
[Rimon & Kodischek]

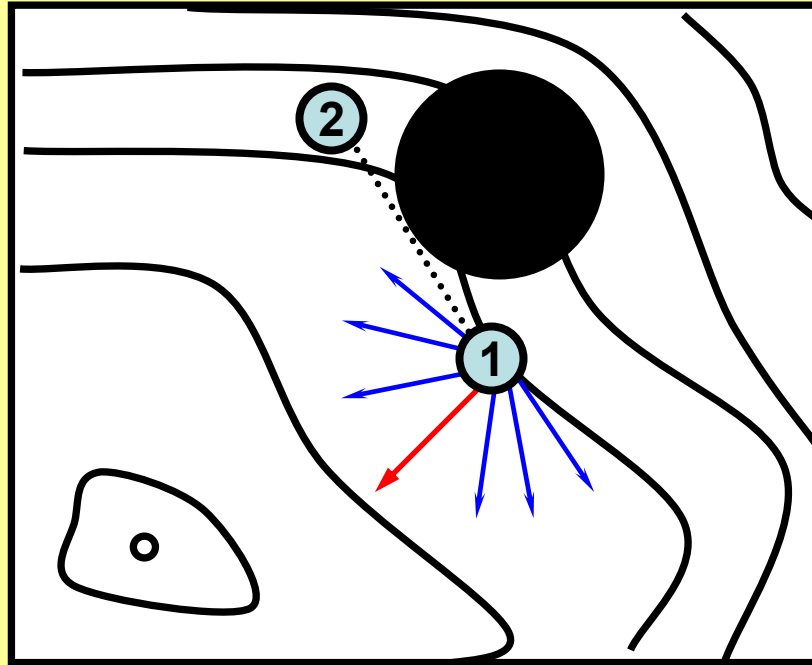


Addition of Potentials is Dangerous!

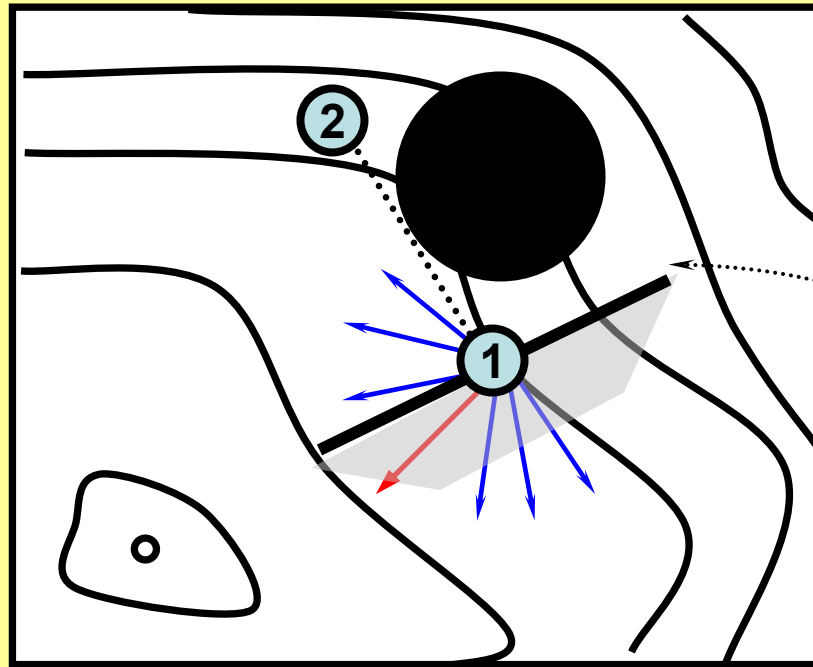


Parallel Composition controller: concept

Goal Potential

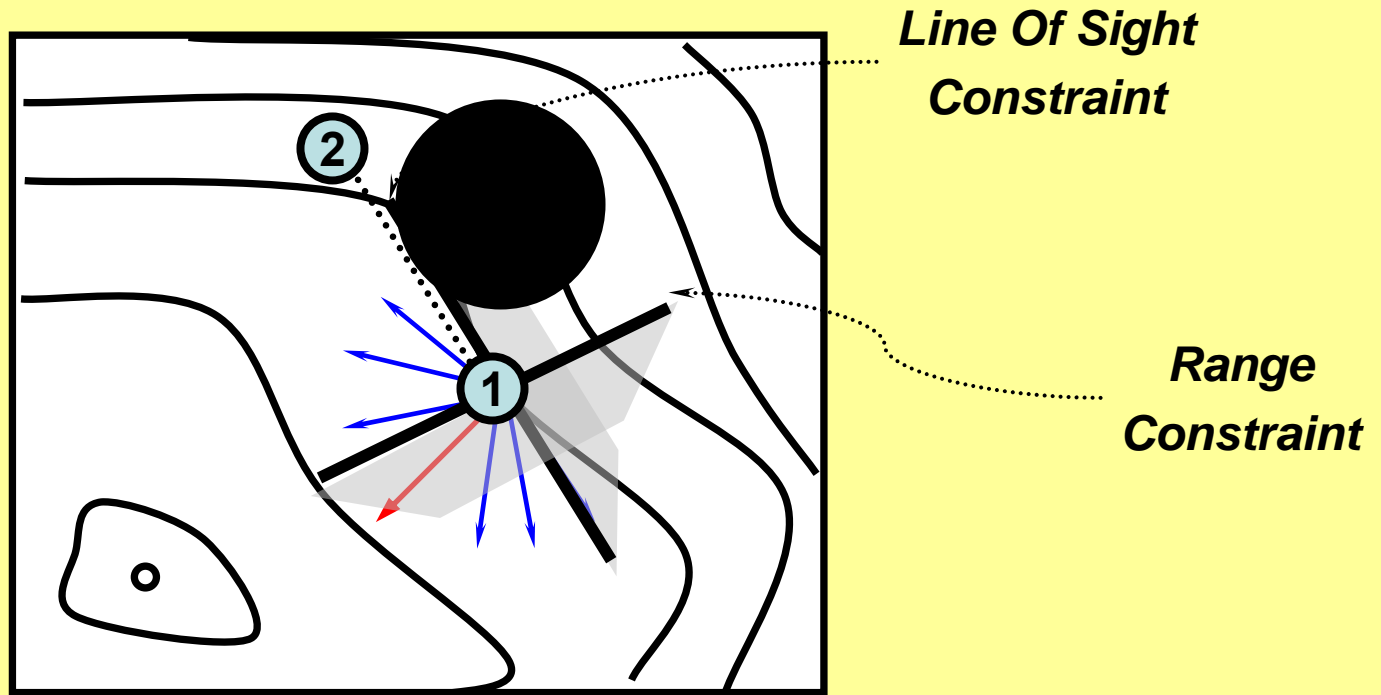


Parallel Composition controller: concept

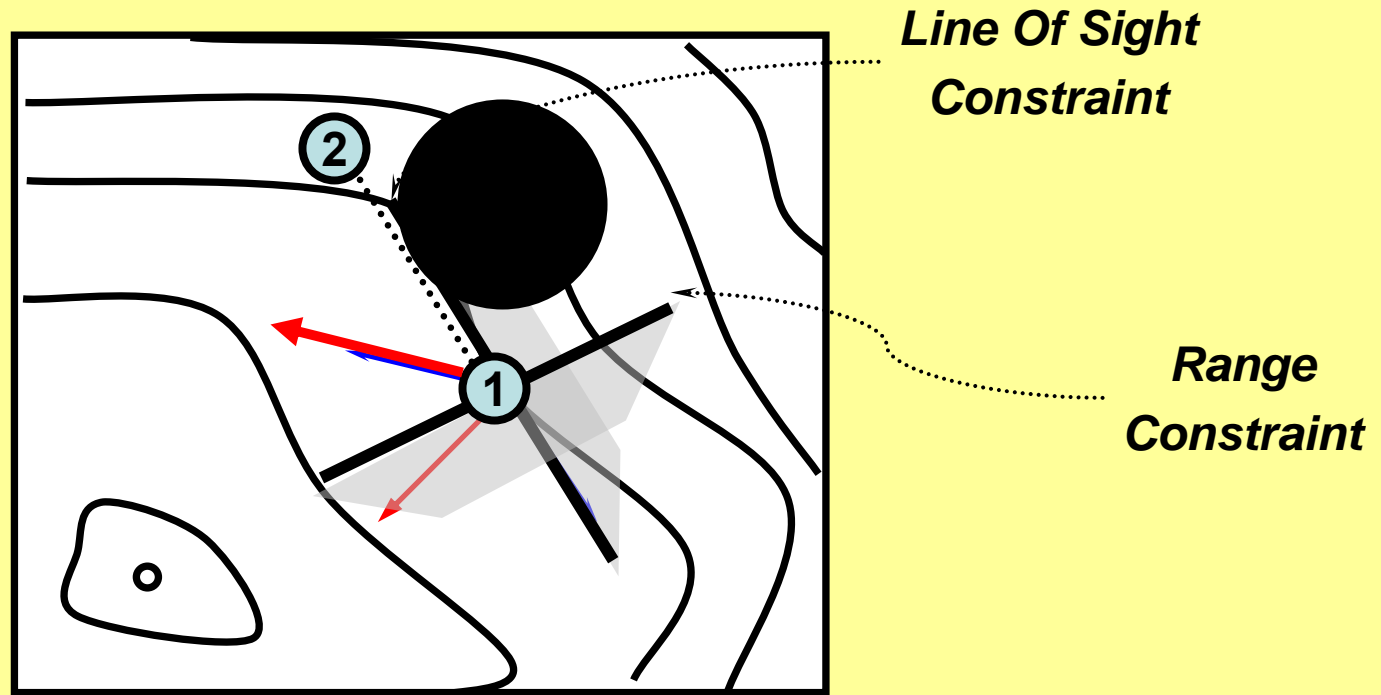


*Range
Constraint*

Parallel Composition controller: concept



Parallel Composition controller: concept

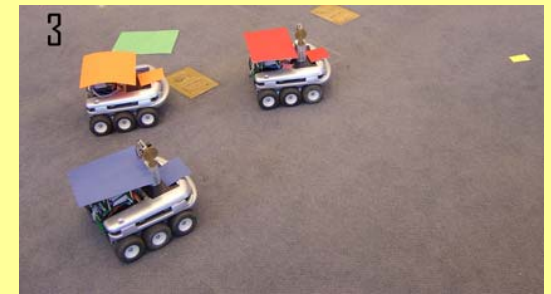
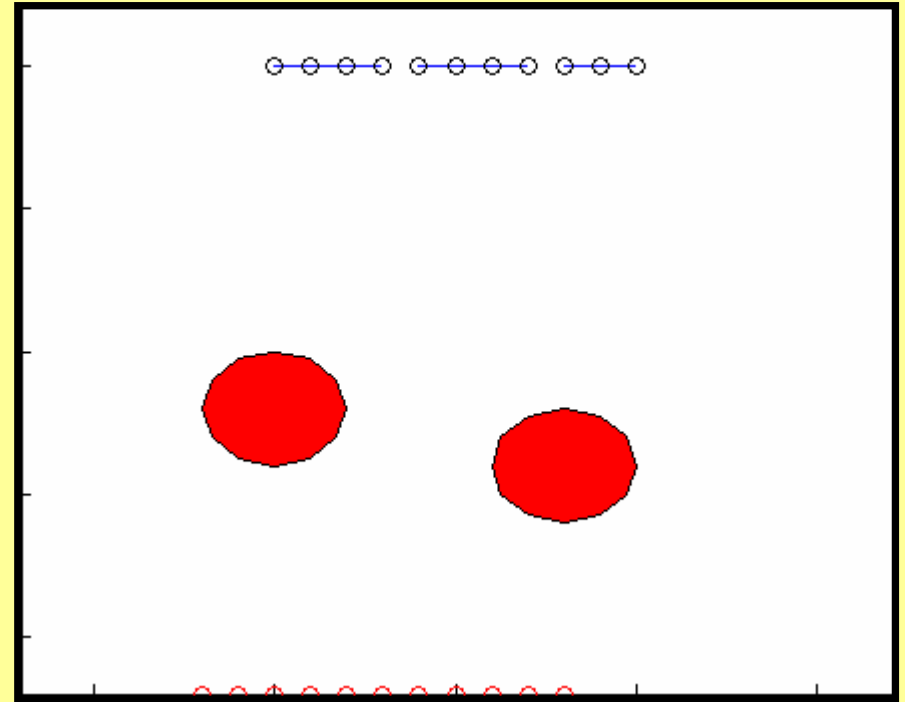
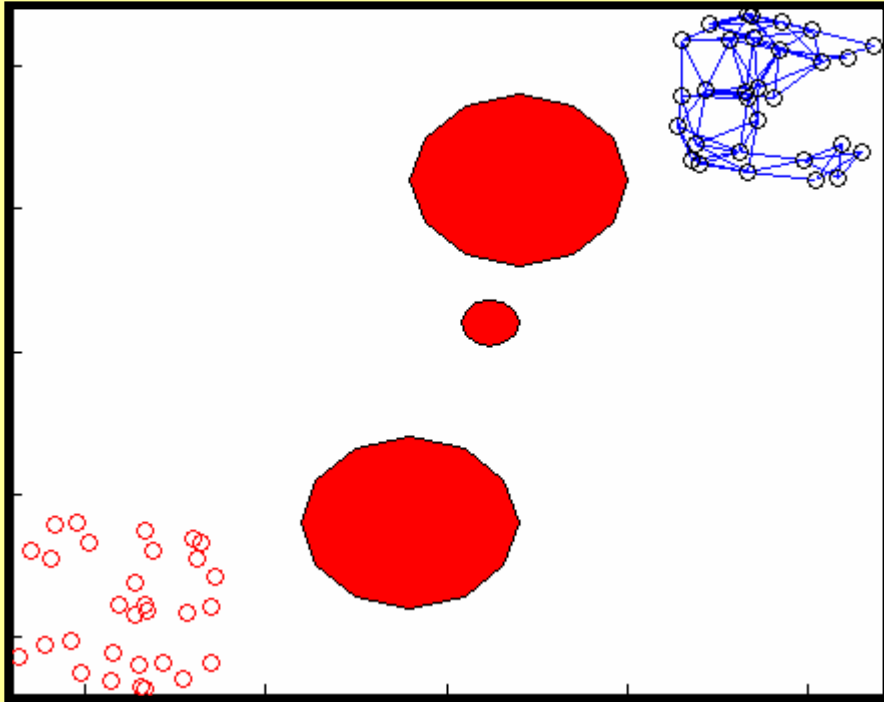


Efficient: Computing directions is $O(P^2)$ (all pairs of cross products)

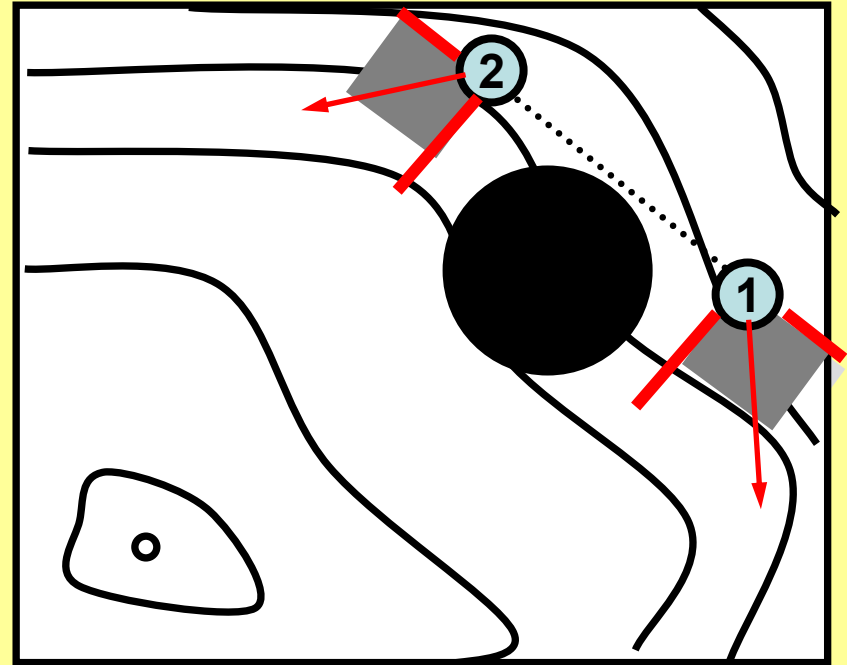
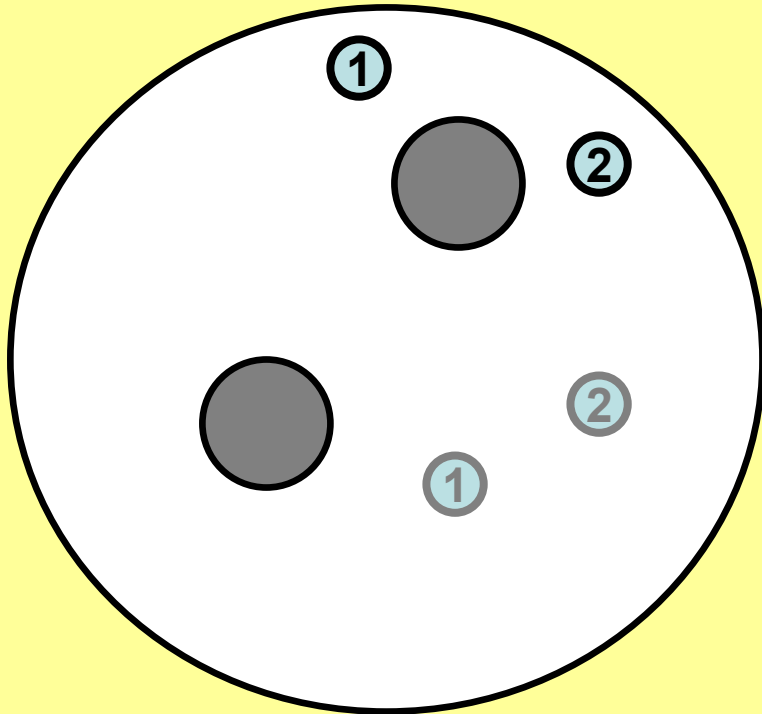
Complete: Generates solution if feasible. If infeasible, algorithm is conclusive.

Stability: Common Lyapunov function.

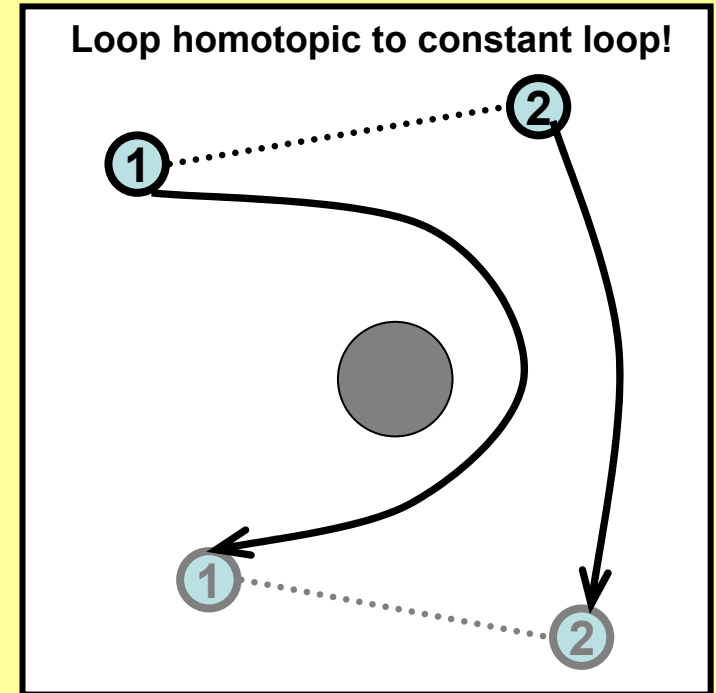
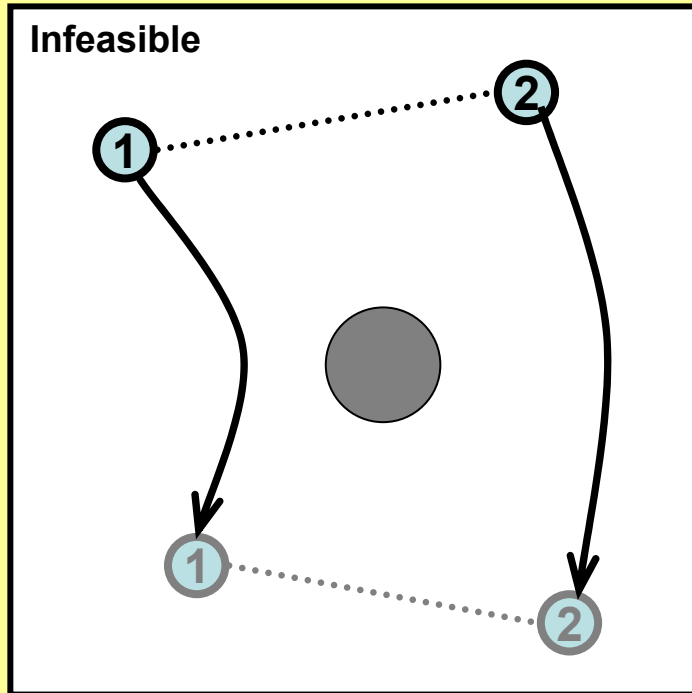
Validation



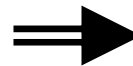
Completeness: Is the composition always feasible?



A Necessary Condition



Neighbors must select paths
in same (straight line)
homotopy class!

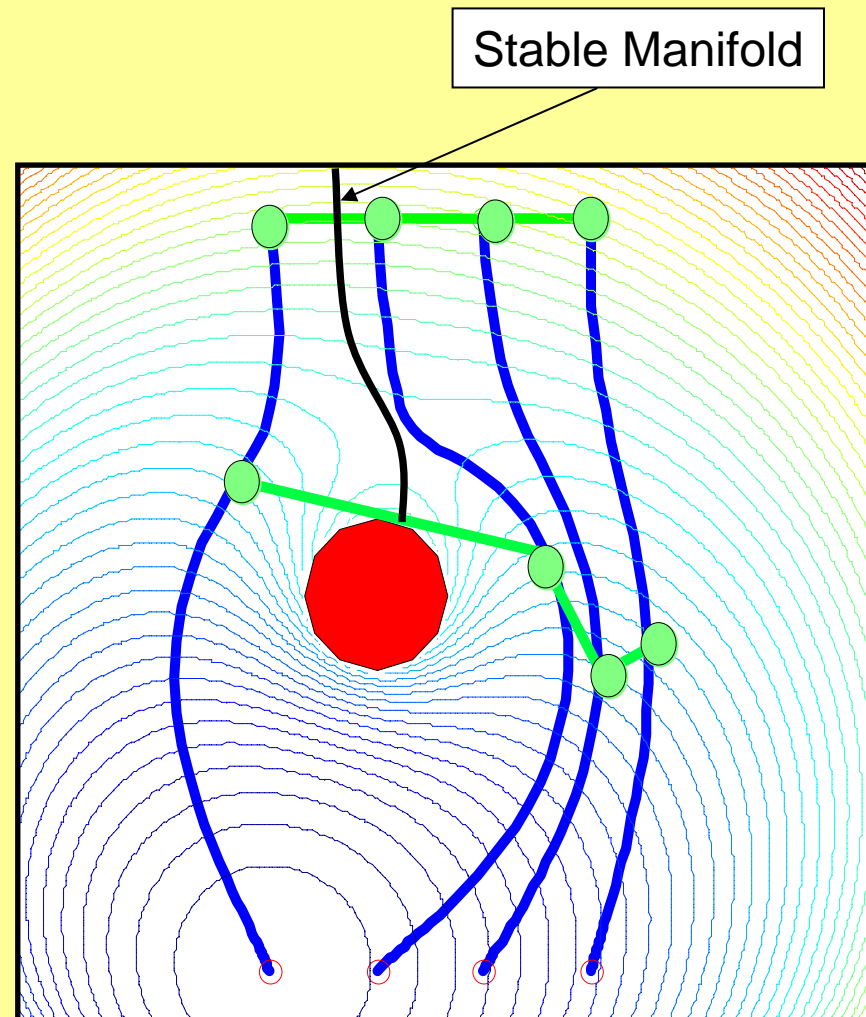


- A connected swarm cannot “split” an obstacle
- ***No distributed, global solution !!!***

Conjecture: Feasible, iff initial conditions are not “split” by saddle stable manifolds

manifold \Rightarrow infeasibility

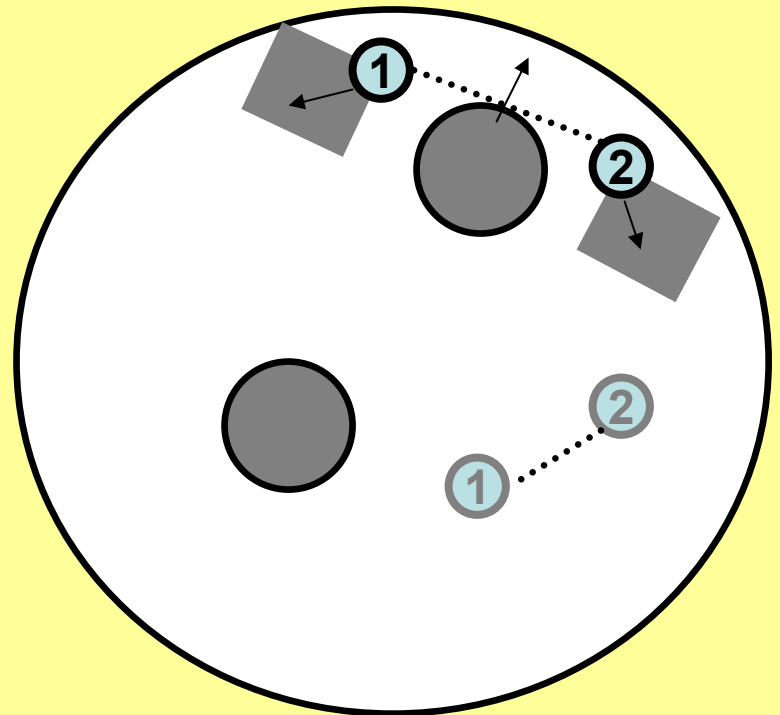
1. Any feasible path is a loop homotopic to trivial loop
2. must cross stable manifold an even number of times,
3. requires increasing potential function



Conjecture: Feasible, iff initial conditions are not “split” by saddle stable manifolds

manifold \leftarrow infeasibility

1. Potential peaks in dimension along edge (**range violated**)
2. Sign of derivative transverse to edge changes ≥ 2 times (**LOS violated**)
3. Turns out there is no local condition for a stable manifold? **Future work....**



Swarm Wireless Connectivity w/ Obstacles

Joel Esposito

US Naval Academy

Thomas Dunbar

Naval Postgraduate School

