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Wireless Connectivity of Swarms in Presence of Obstacles

Esposito, Joel; Dunbar, Thomas

Naval Academy

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Wireless Connectivity of Swarms in Presence of Obstacles

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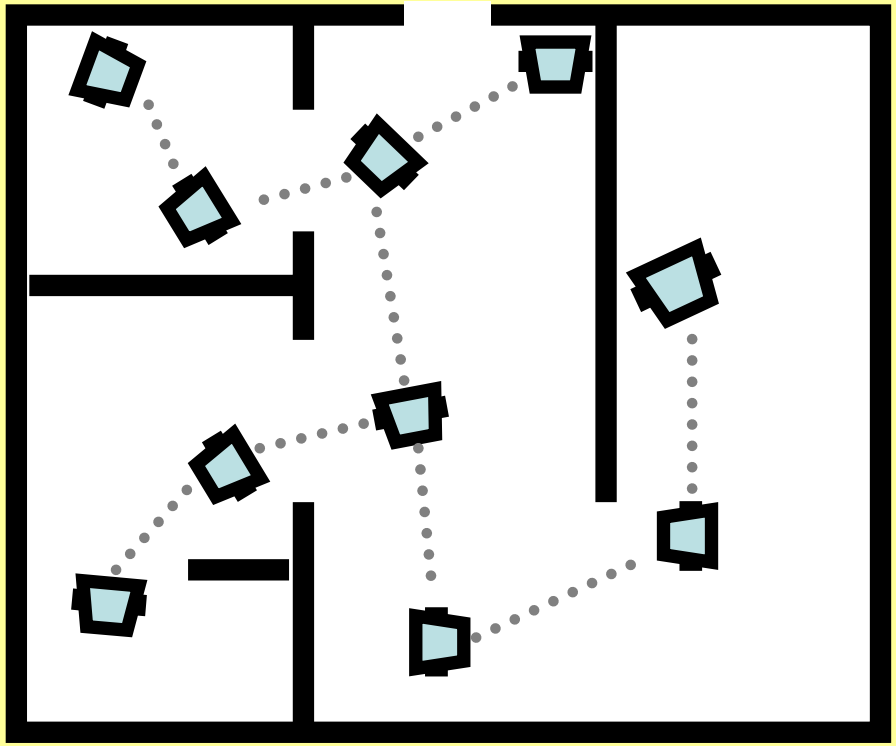
US Naval Academy

Thomas Dunbar
Naval Postgraduate School

Motivation

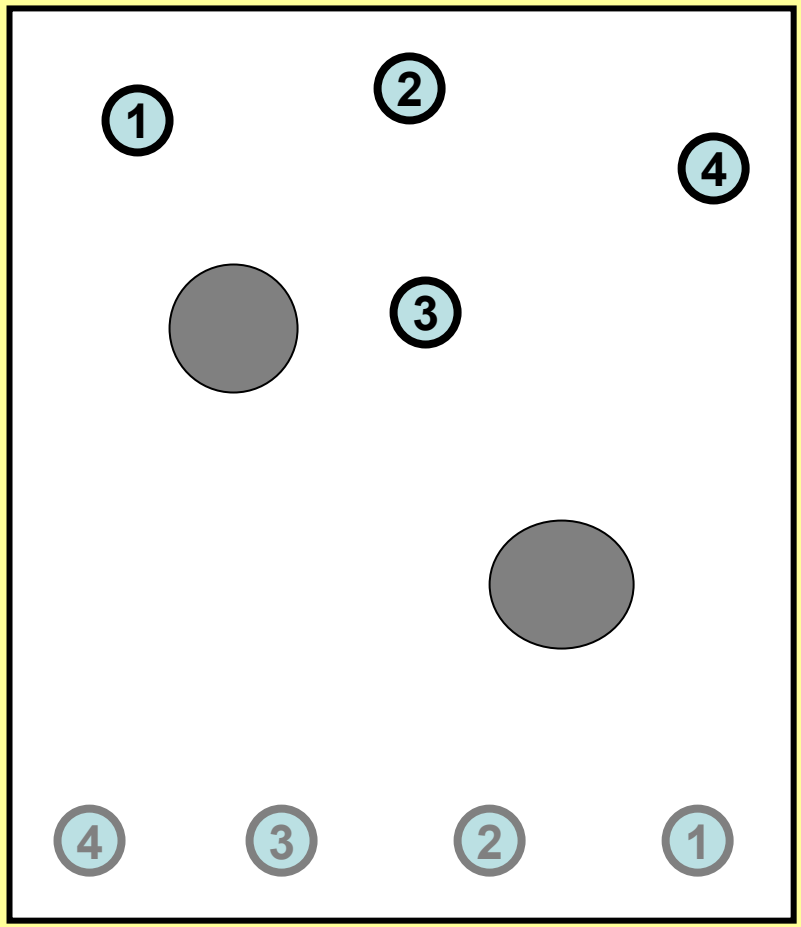


EDGE = Range + Line of Sight

Problem Statement

Given:

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



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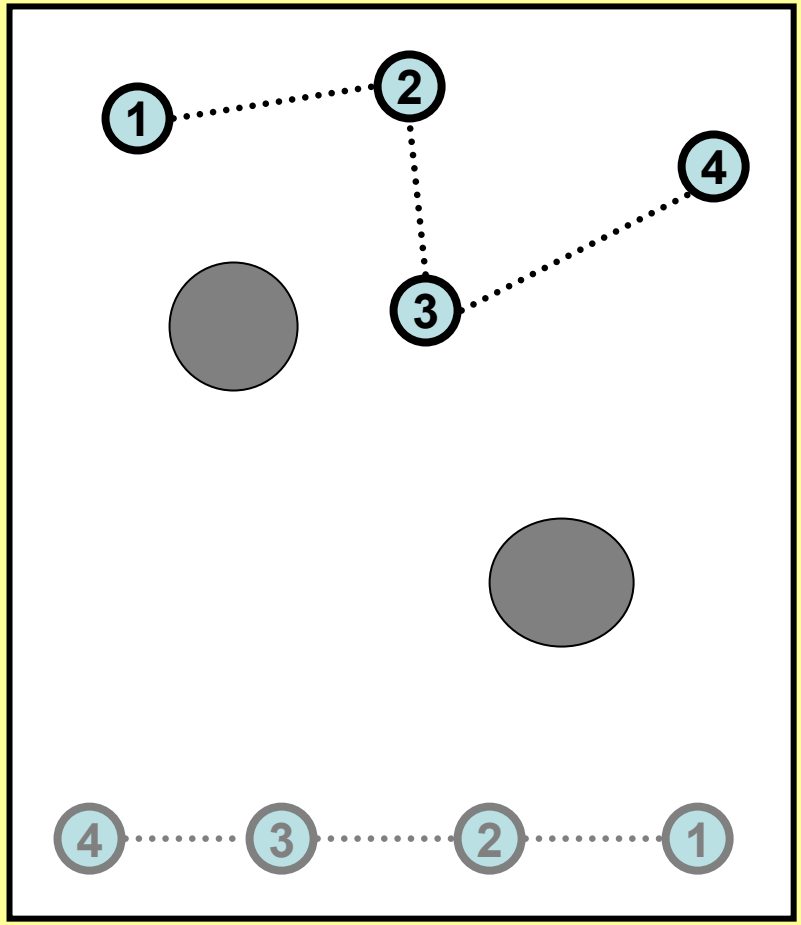

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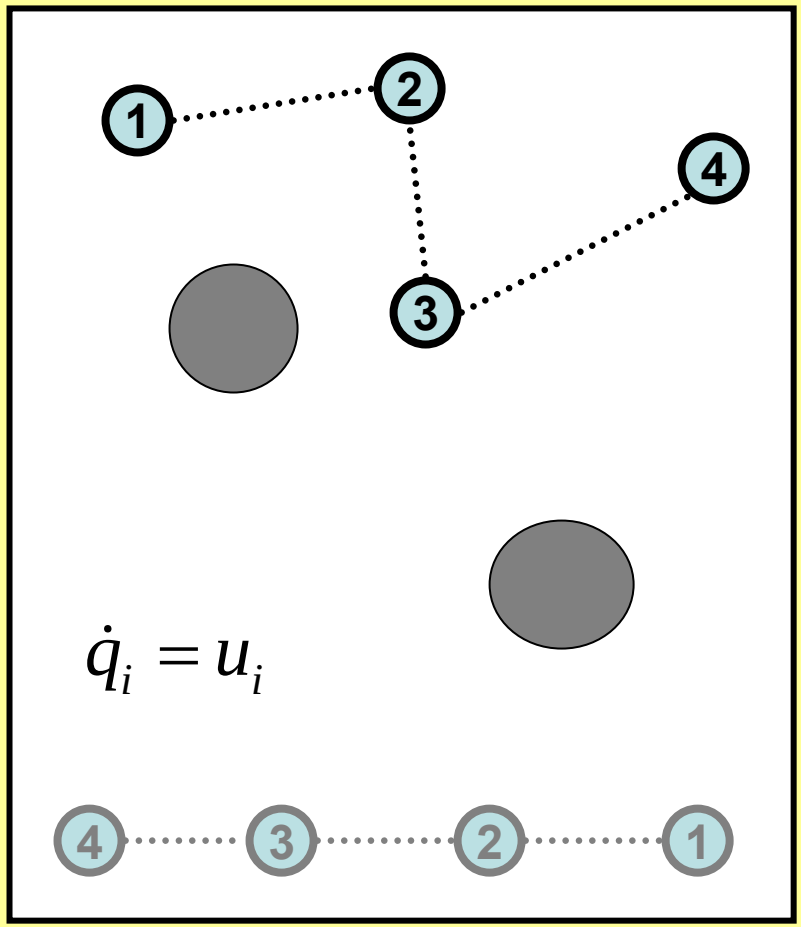

Problem:

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

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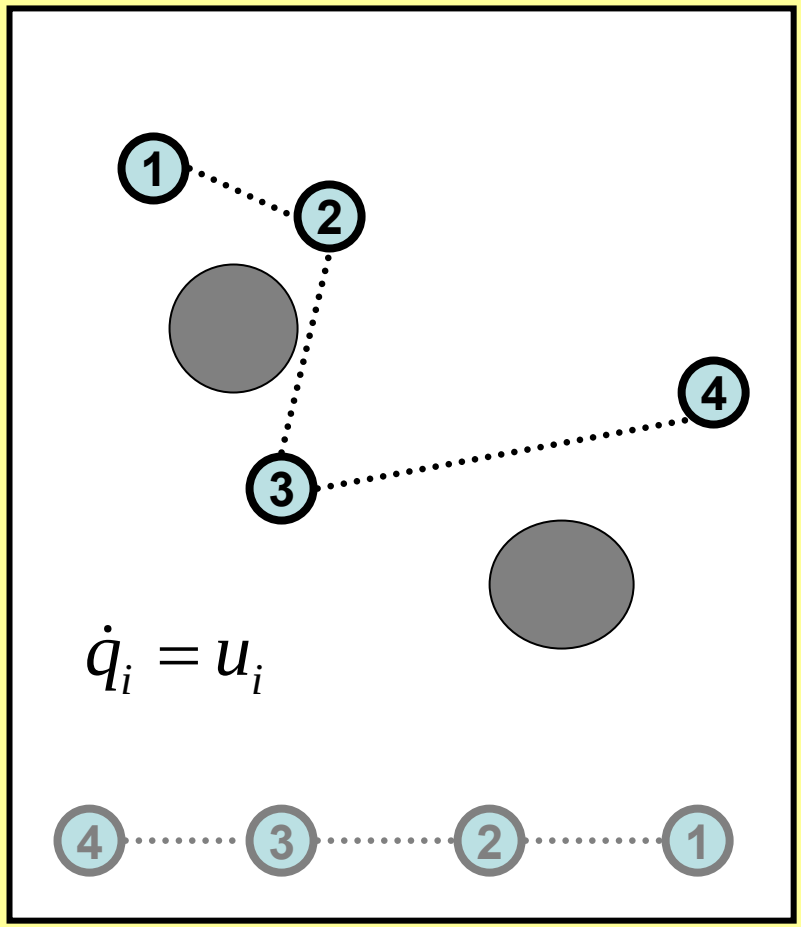

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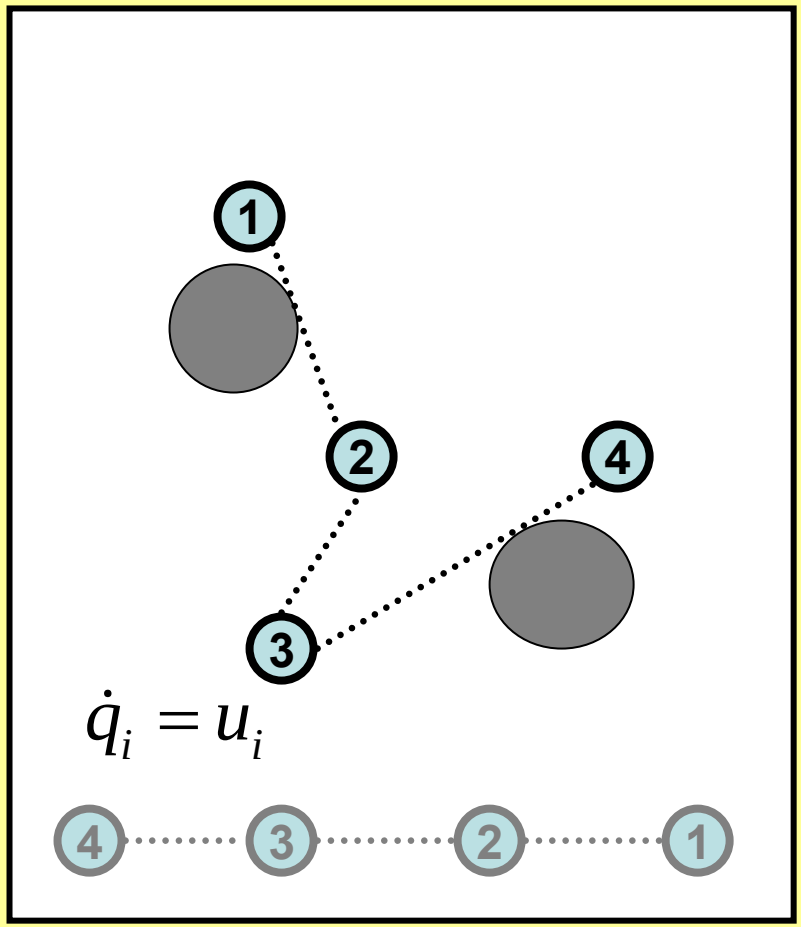

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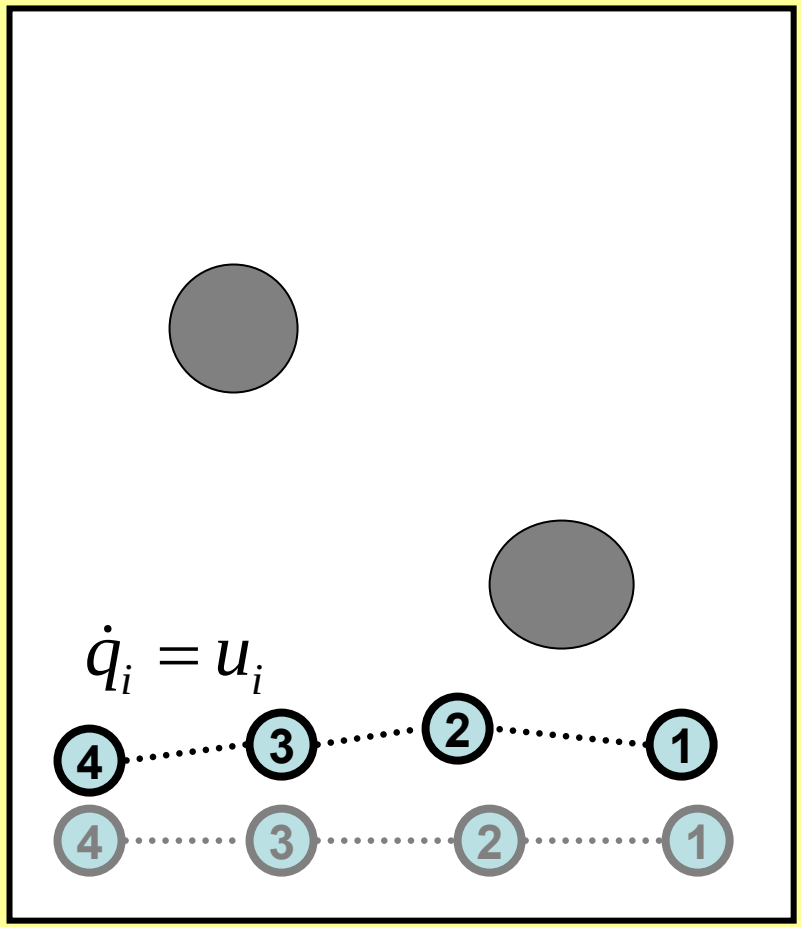

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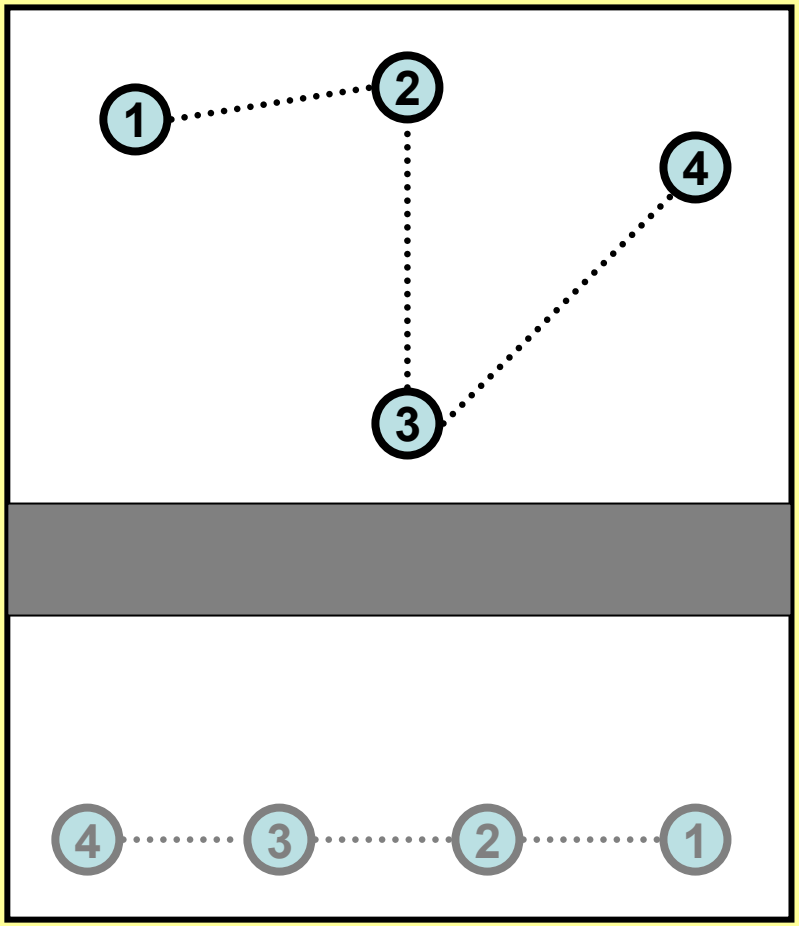
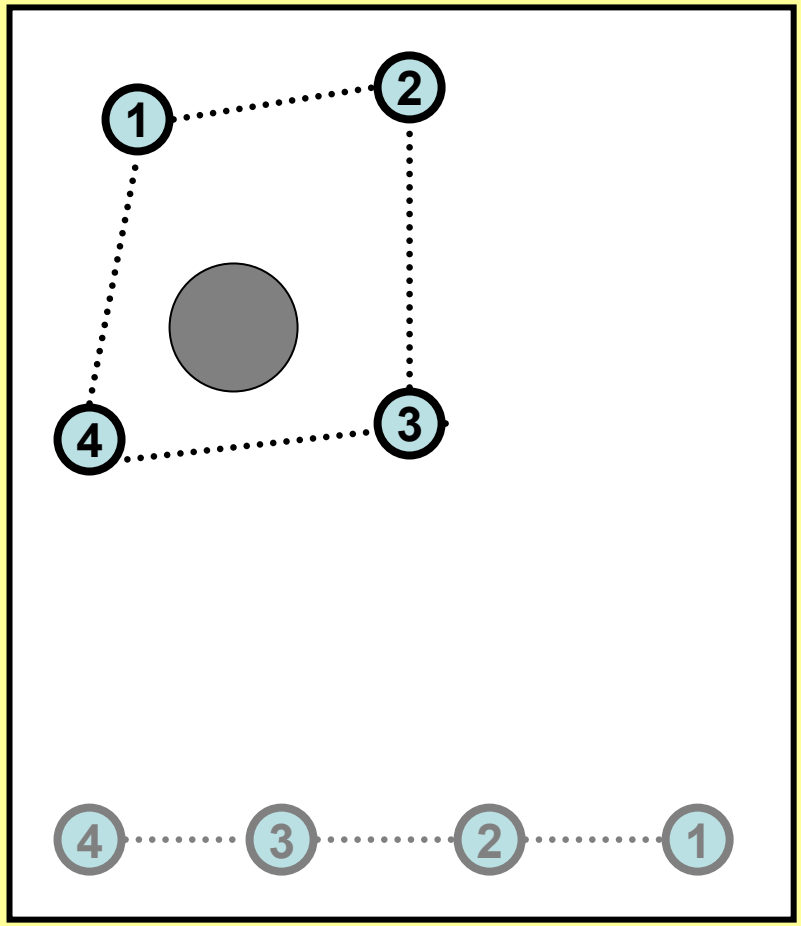
Obvious Infeasibility



Start and goal in different connected components of W



Cycles in different homoptic equivalence classes

Related work

Formations:
- Fixed relative pose
- Leader

Desai, Kumar, Fierro

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

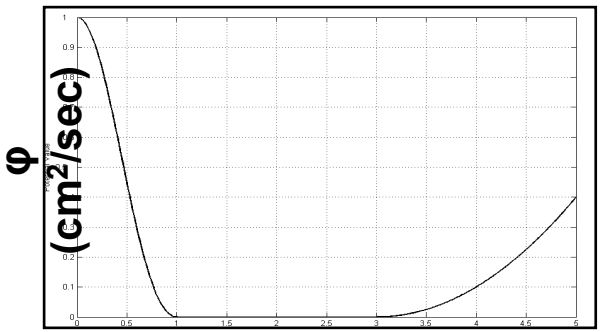
Reynolds, Reif, Bishop, Tanner, Pappas, Moorse, Jadbabaie Passiano,Olfati-Saber, Murray

Closely Related Works:
- Maintaining network connectivity
- Multi-hops networks
- Obstacle free?

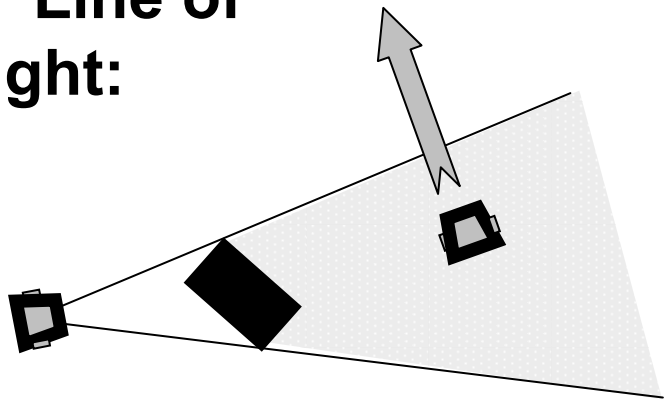
Spanos, Murray; Zavlanos Pappas Bullo, Cortes, Notarstefano

Approach: Potential Functions

1. Range:

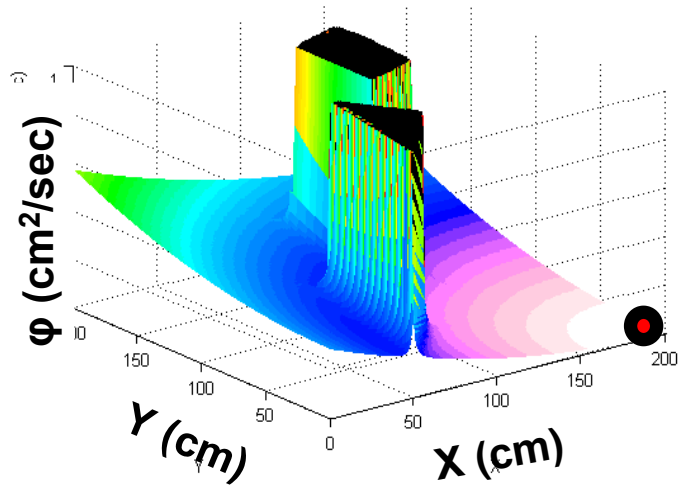


2. Line of Sight:

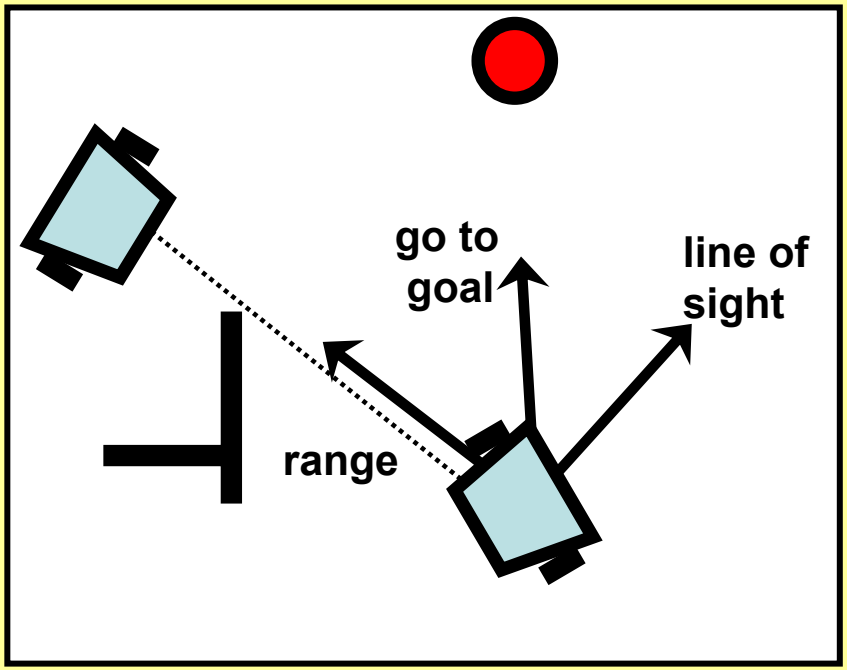


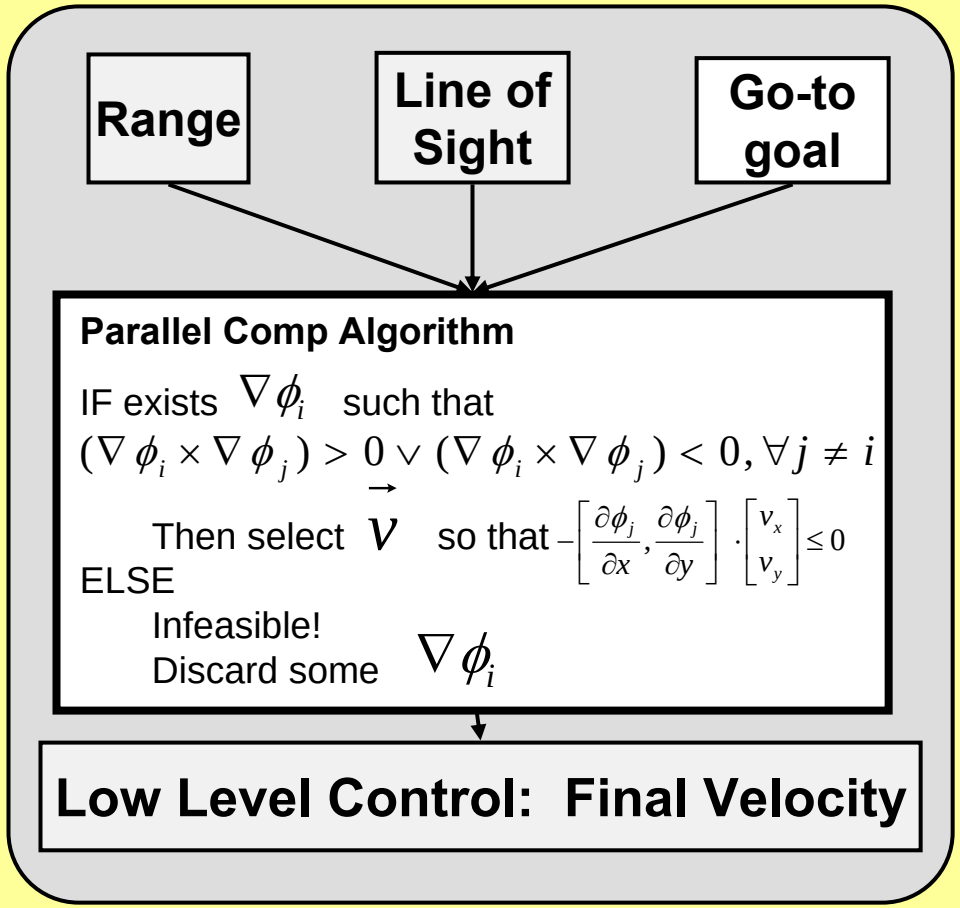
3. Go To Goal:

Navigation function
[Rimon & Kodischek]

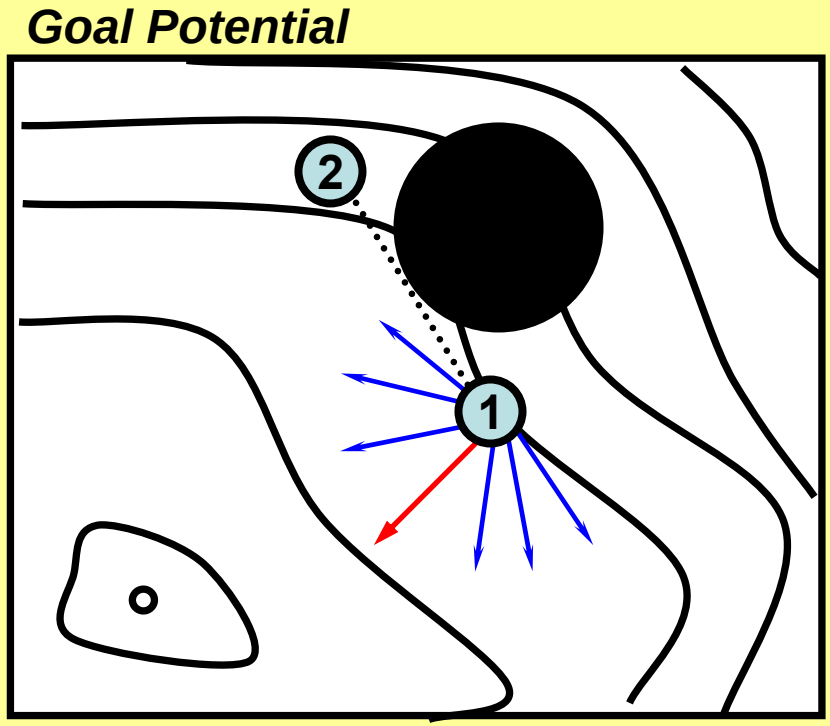


Addition of Potentials is Dangerous!





Parallel Composition controller: concept



[Esposito Kumar 2002]

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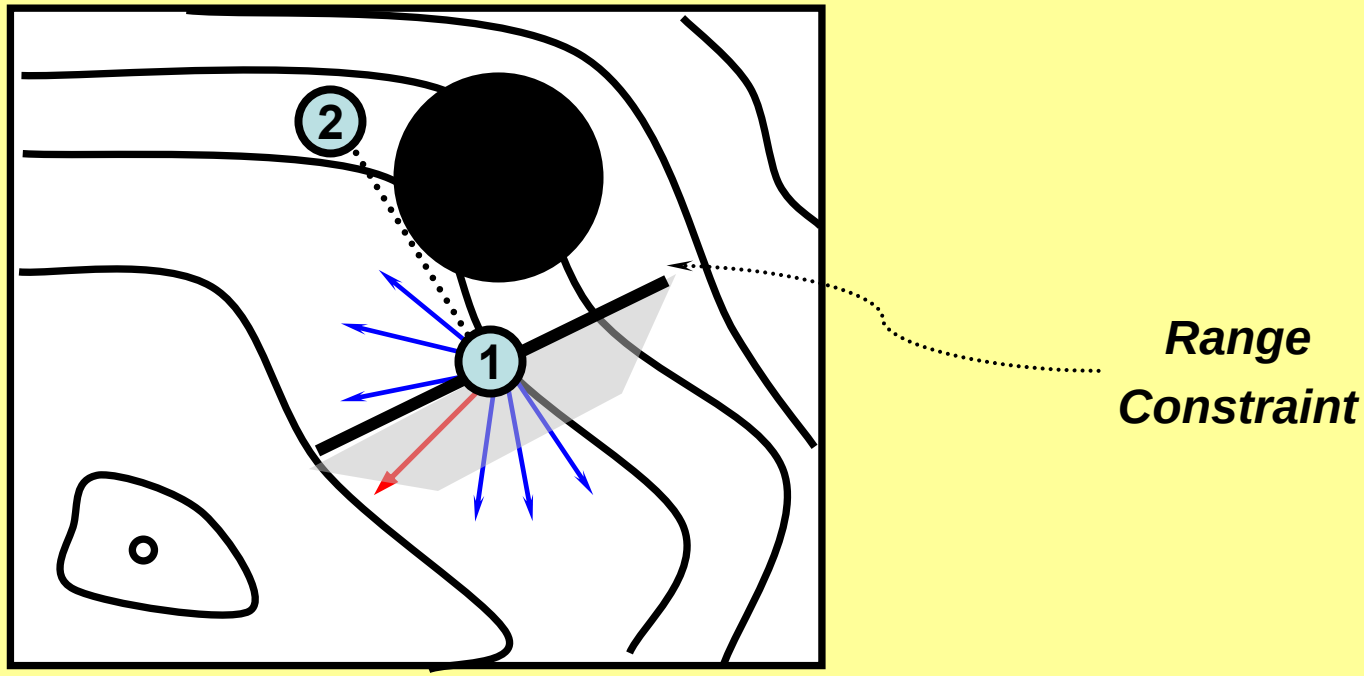

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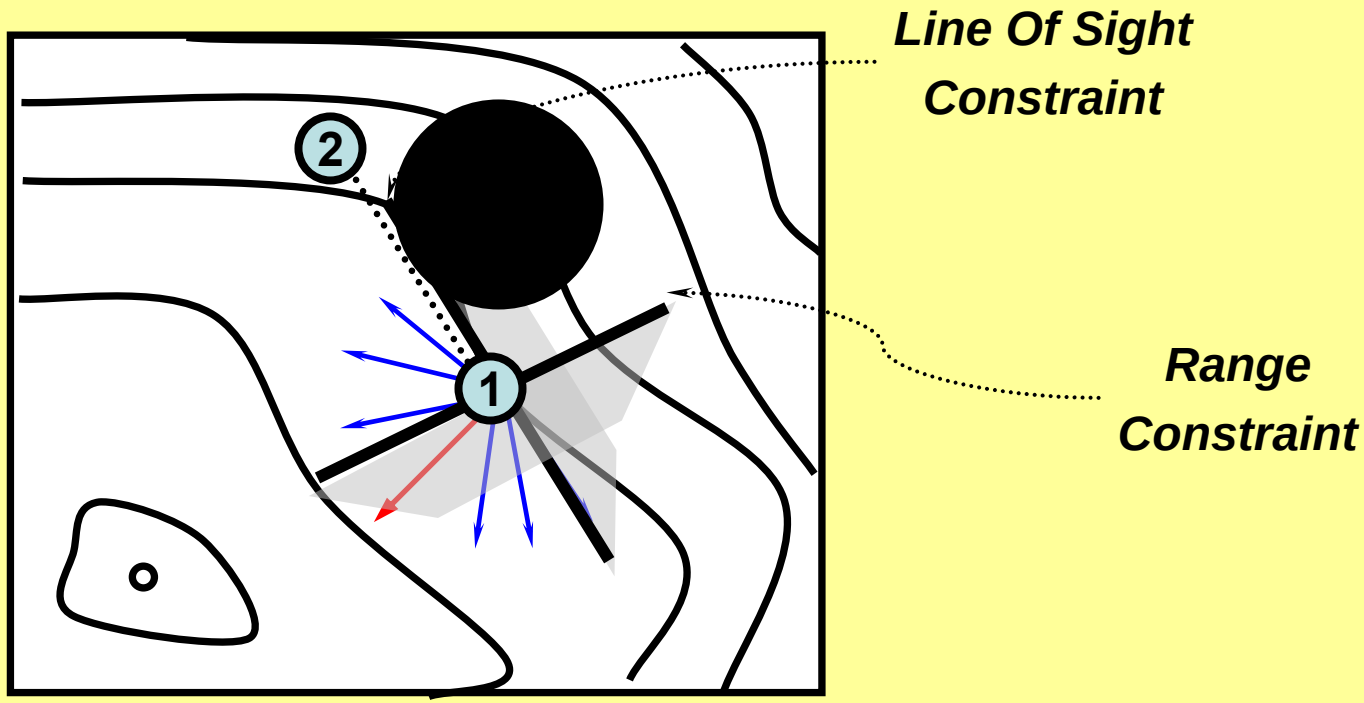

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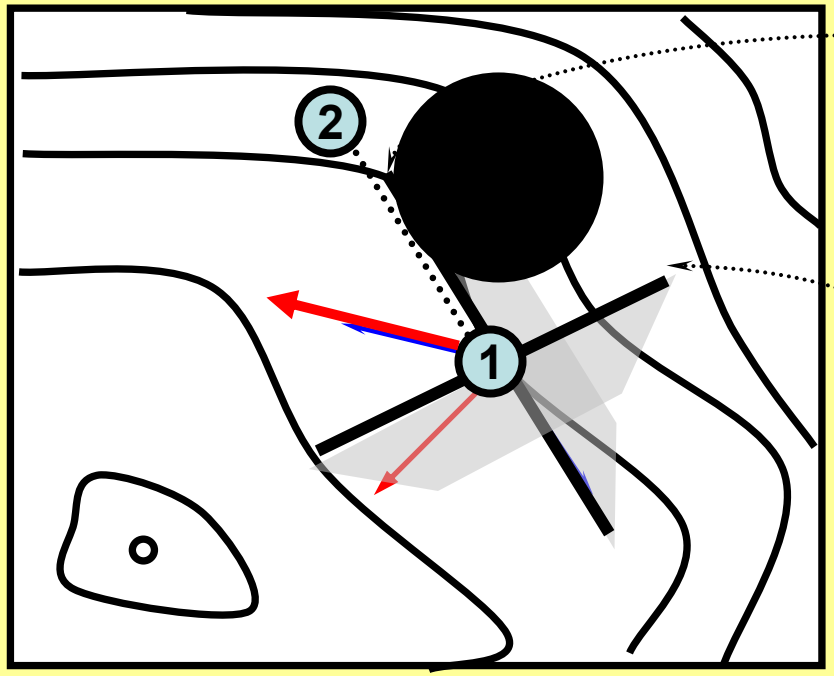


Line Of Sight Constraint

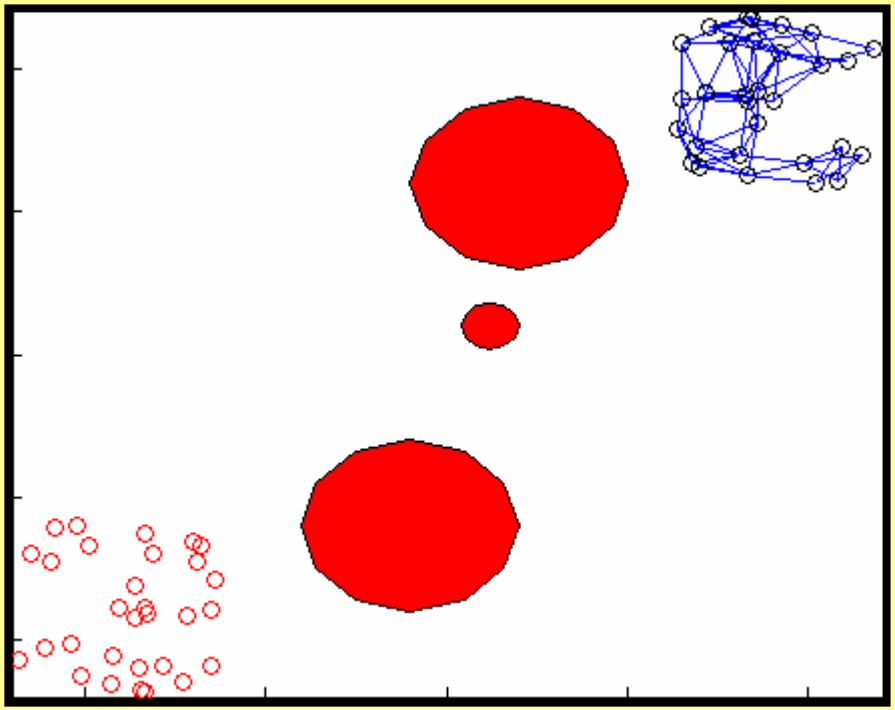
Range Constraint

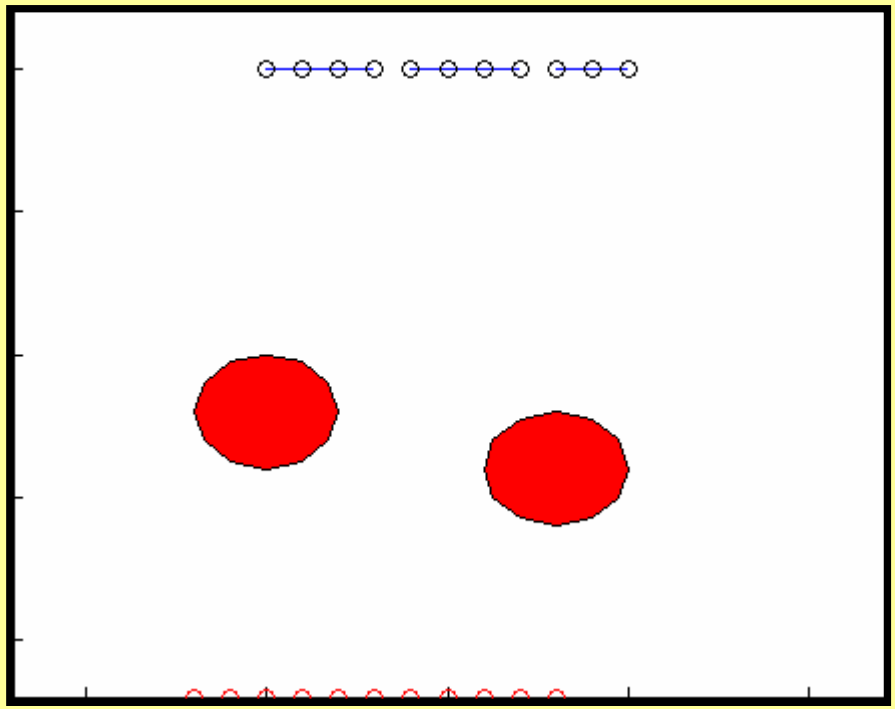
Efficient: Computing directions is $O(P^2)$ (all pairs of cross products)

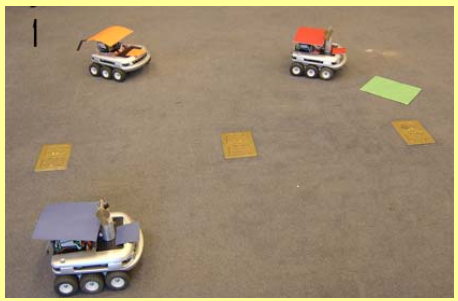
Complete: Generates solution if feasible. If infeasible, algorithm is conclusive.

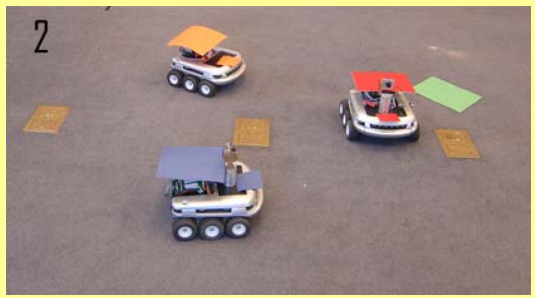
Stability: Common Lyapunov function.

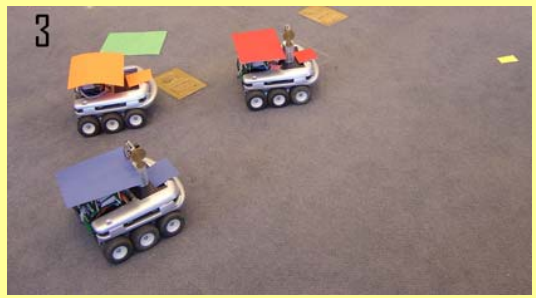
Validation



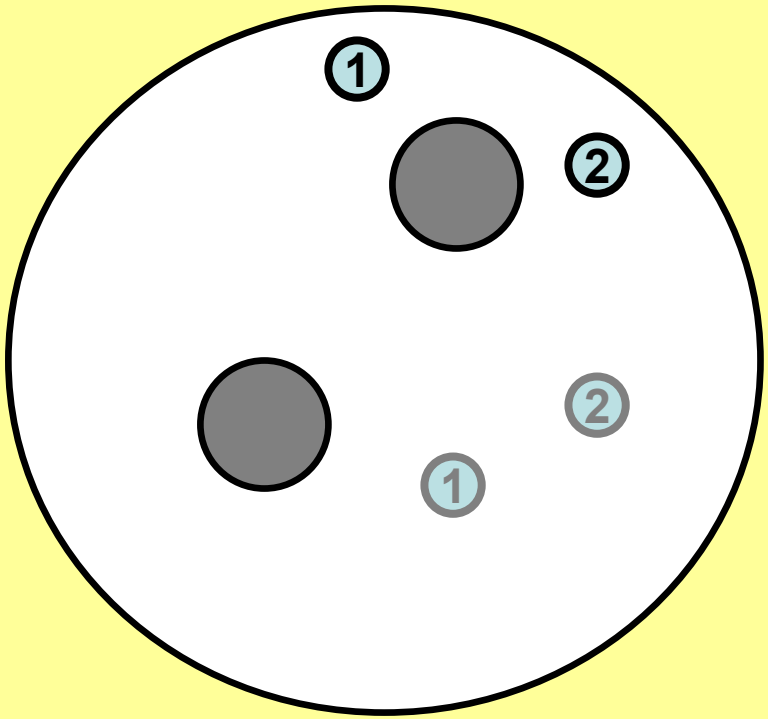


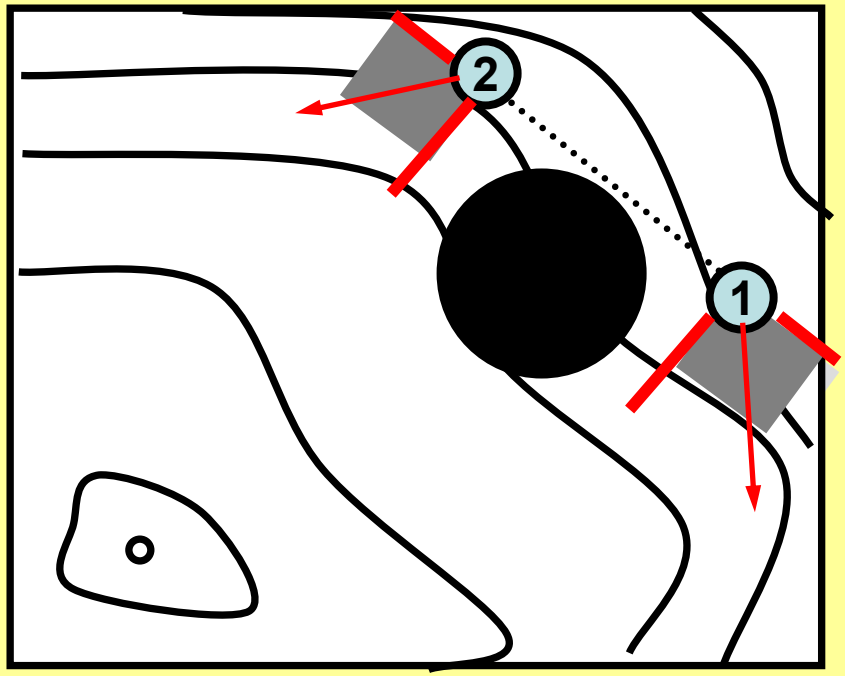




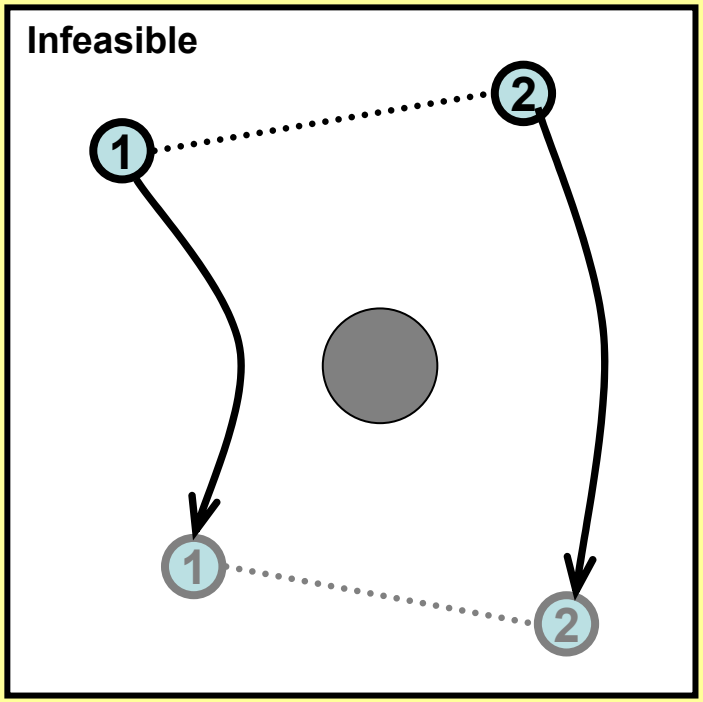


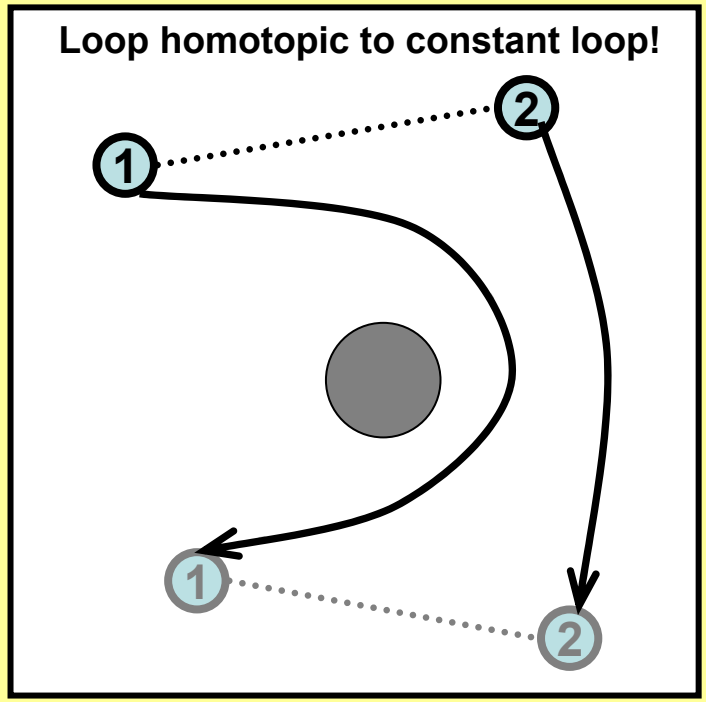
Completeness: Is the composition always feasible?





A Necessary Condition





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

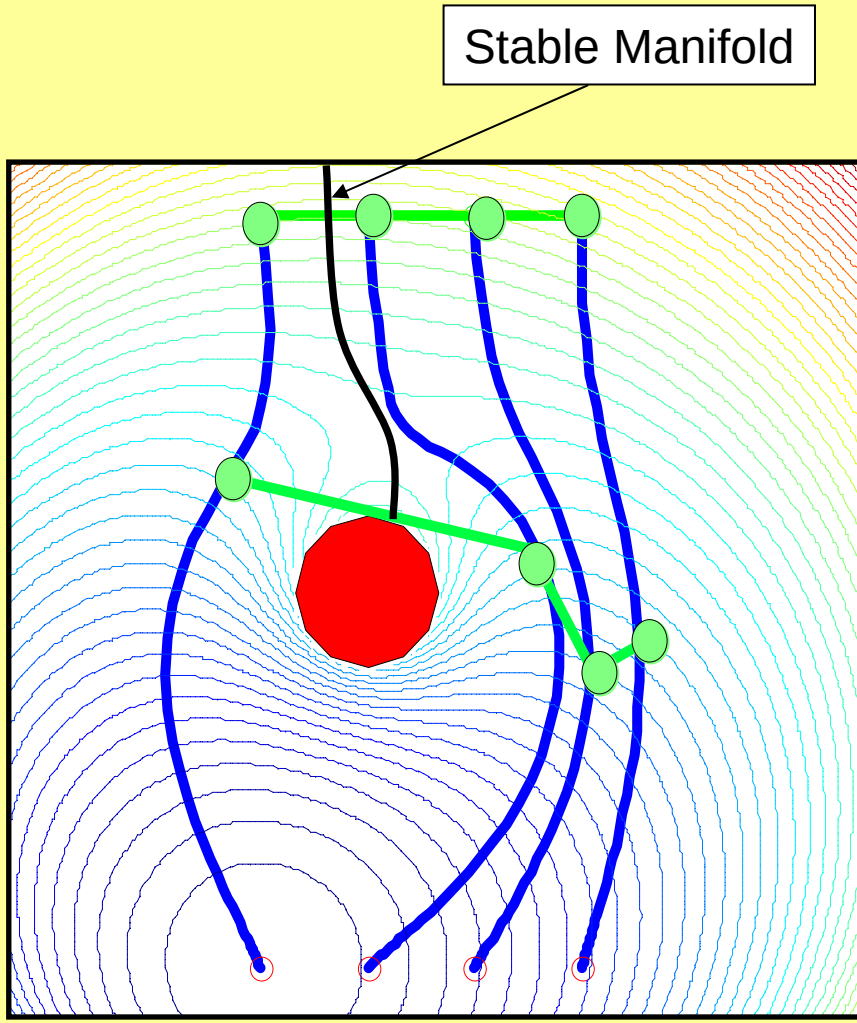
⟹

- A connected swarm cannot "split" an obstacle
- ***No <u>distributed,</u> <u>global</u> solution !!!***

Conjecture: **Feasible, iff initial conditions are not "split" by saddle stable manifolds**

manifold ⇒ infeasibility

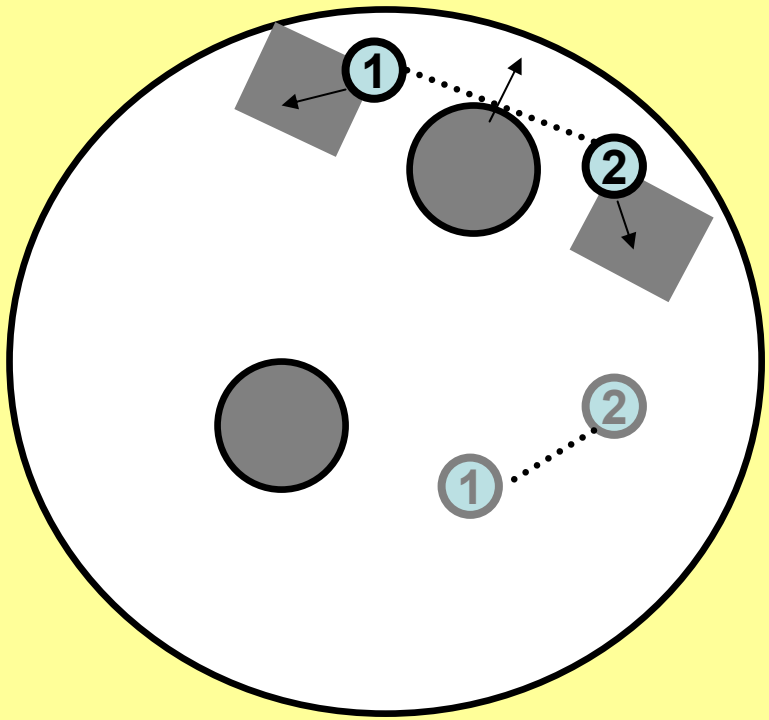
1. Any feasible path is a loop homotopic to trivial loop
2. must cross stable manifold an even number of times,
3. requires increasing potential function



Conjecture: **Feasible, iff initial conditions are not "split" by saddle stable manifolds**

manifold ⇐ 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….**



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