

Wireless Connectivity of Swarms in Presence of Obstacles



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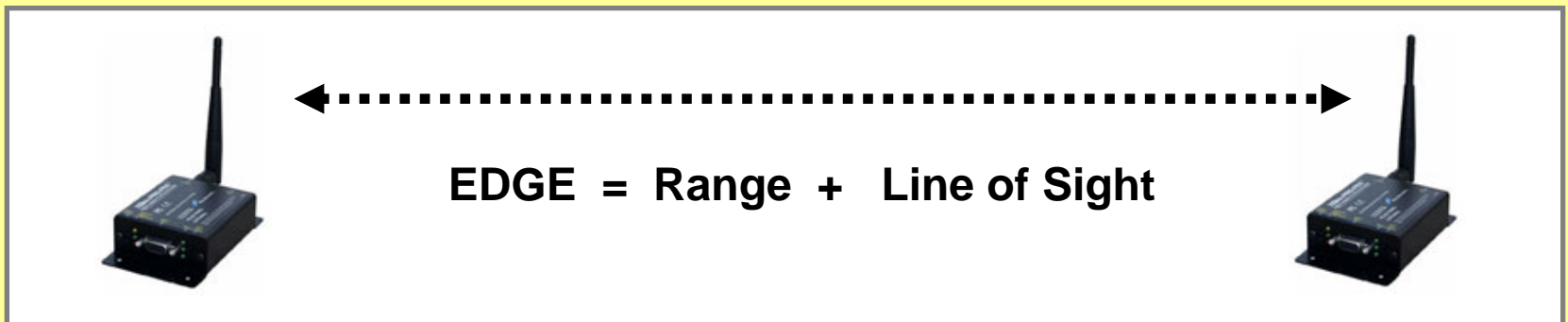
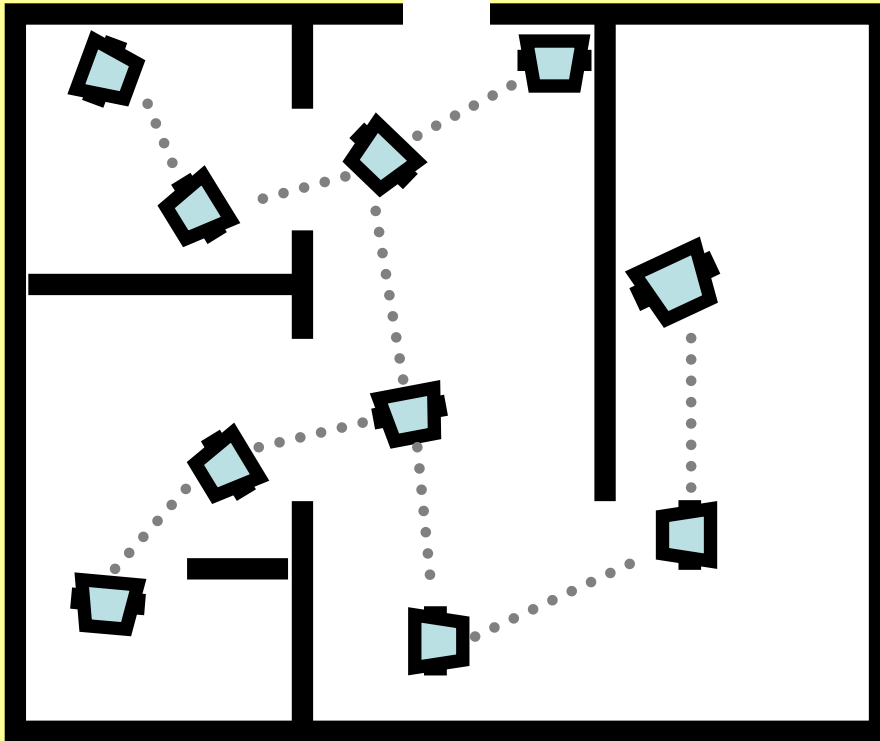
Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE MAY 2006		2. REPORT TYPE		3. DATES COVERED 00-00-2006 to 00-00-2006	
4. TITLE AND SUBTITLE Wireless Connectivity of Swarms in Presence of Obstacles				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) United States Naval Academy, Department of Weapons and Systems Engineering, Annapolis, MD, 21402				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES IEEE International Conference on Robotics and Automation, May 2006, p. 946-952					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	unclassified	unclassified	Same as Report (SAR)	22	

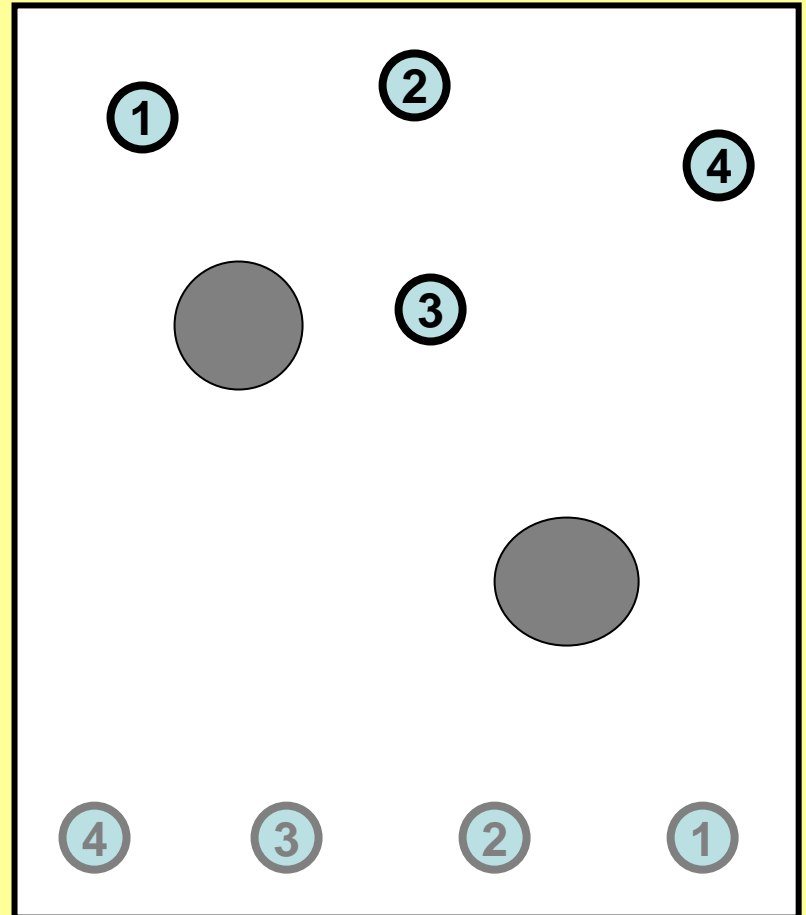
Motivation



Problem Statement

Given:

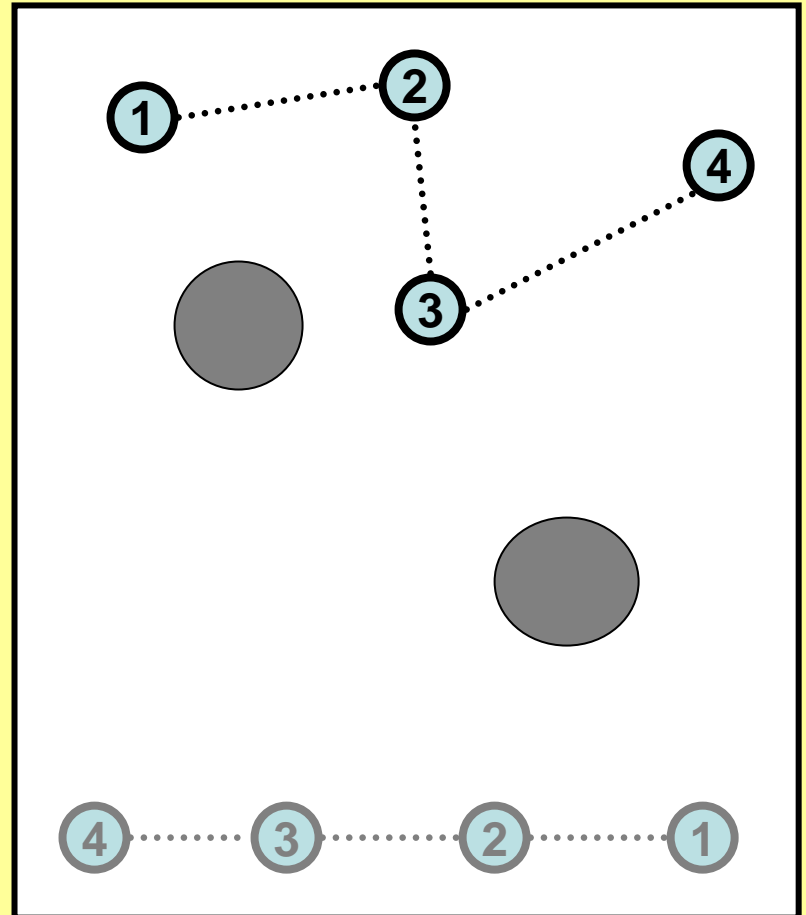
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- Workspace, W
- Initial positions, q^{init}
- Final Positions, q^{final}



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Given:

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- *Critical* communication graph, $C^* \subseteq G$
(EDGE = Range + Line-of-sight)



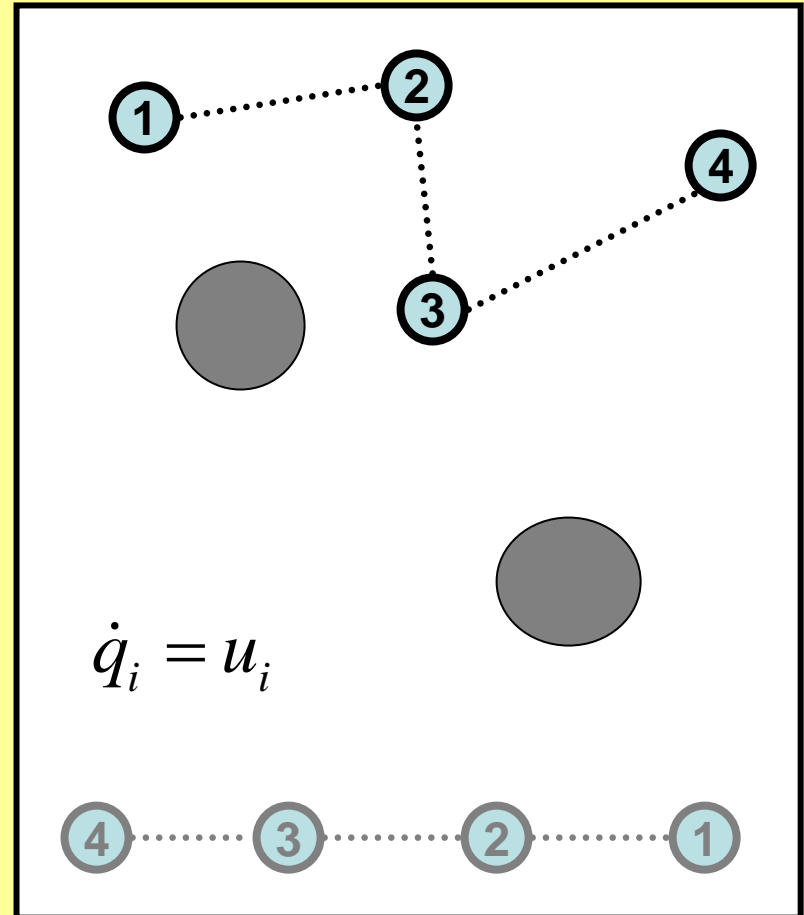
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Problem:

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



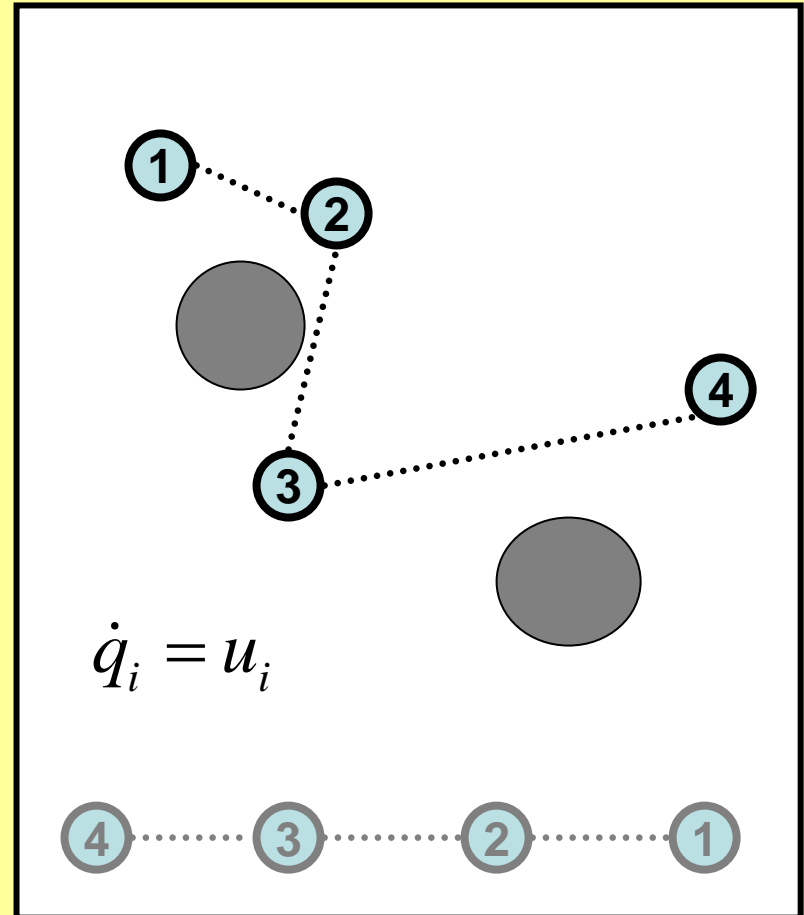
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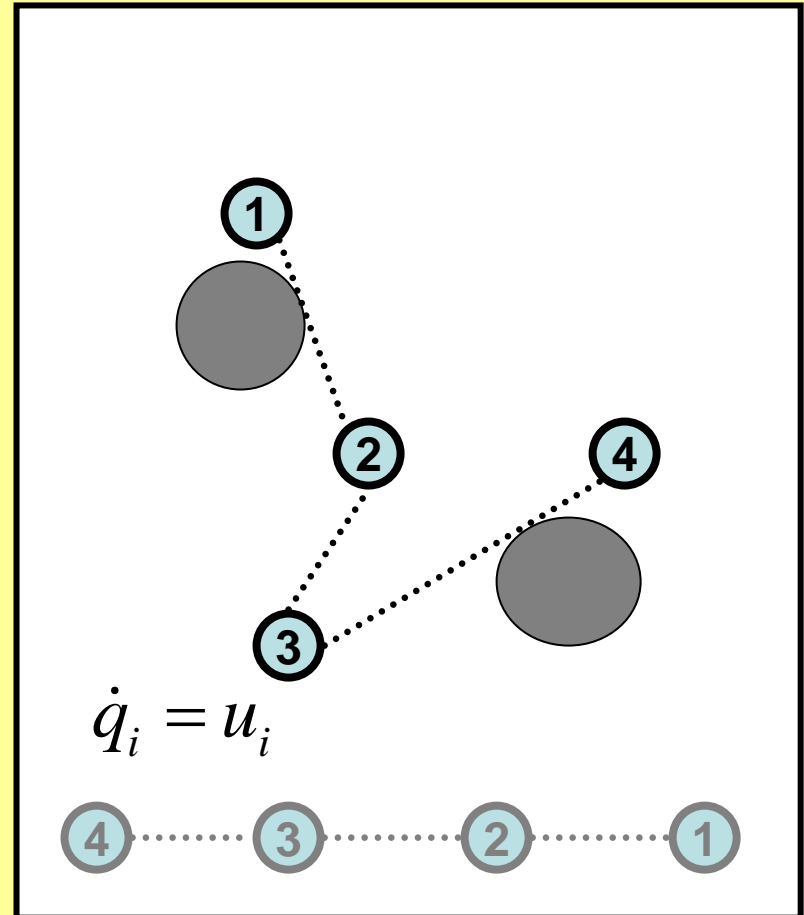
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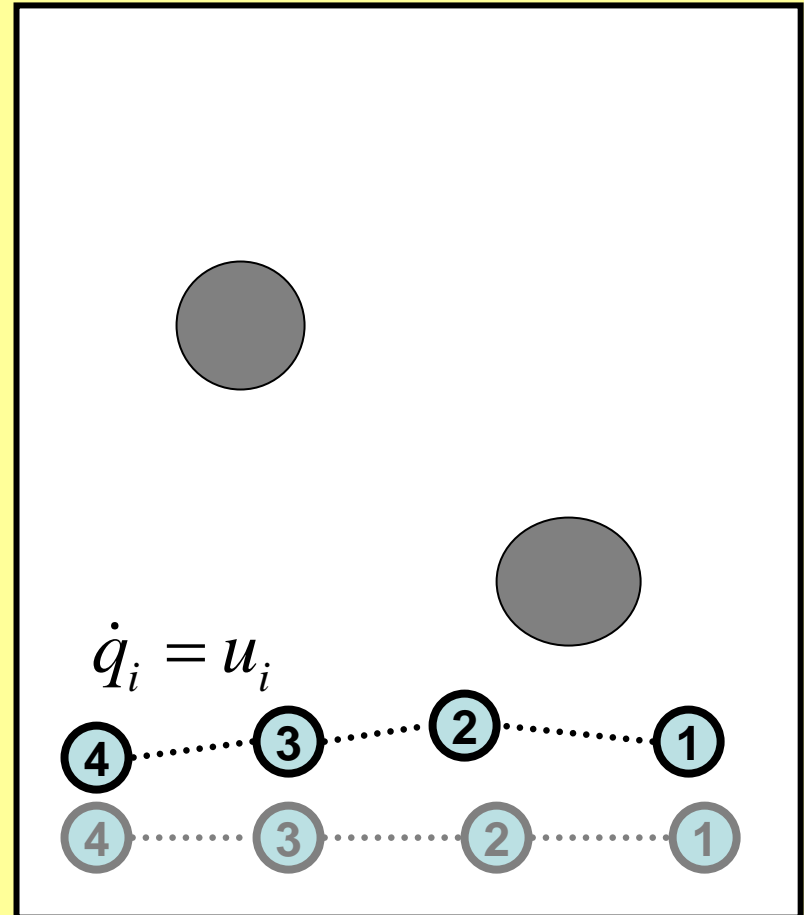
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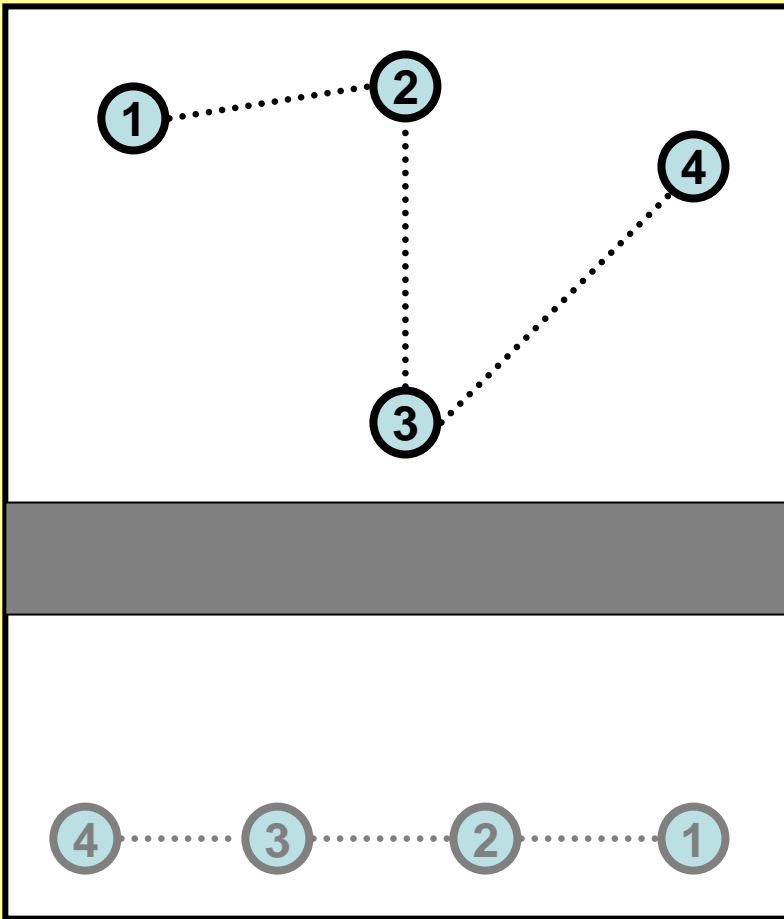
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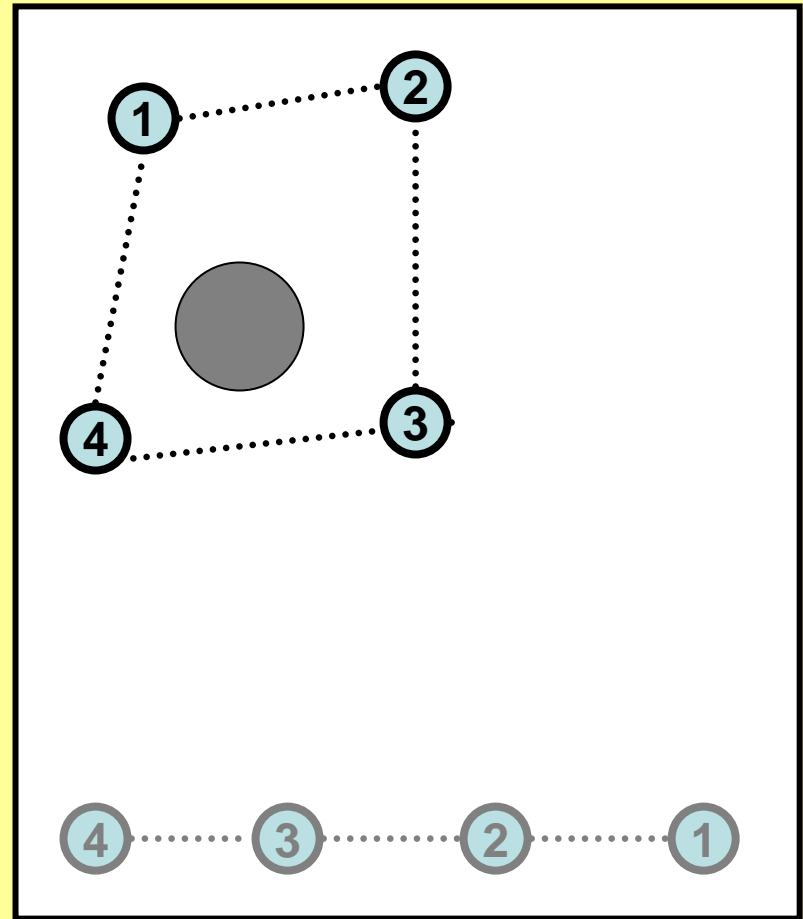
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Obvious Infeasibility



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*

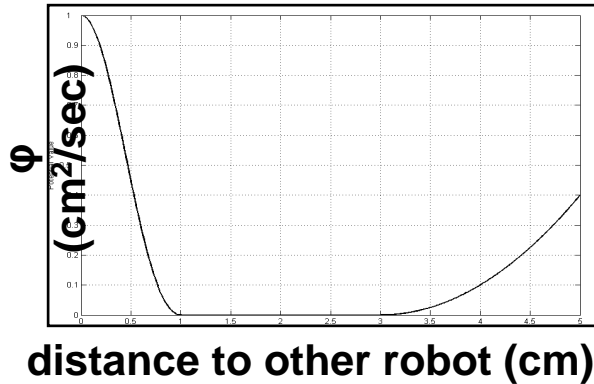
Closely Related Works:

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

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

Approach: Potential Functions

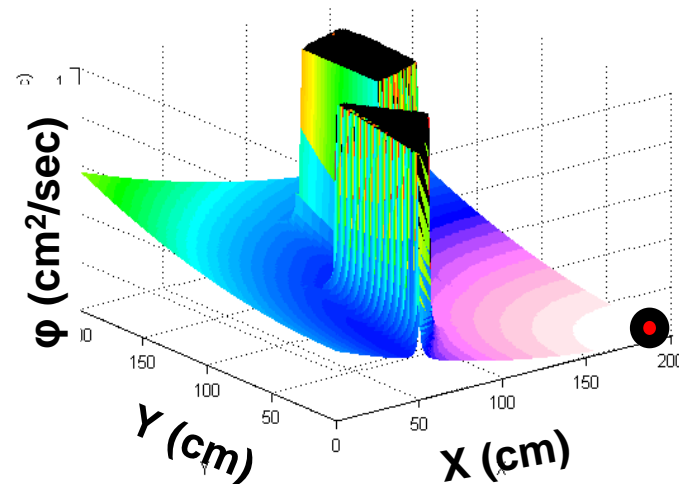
1. Range: 



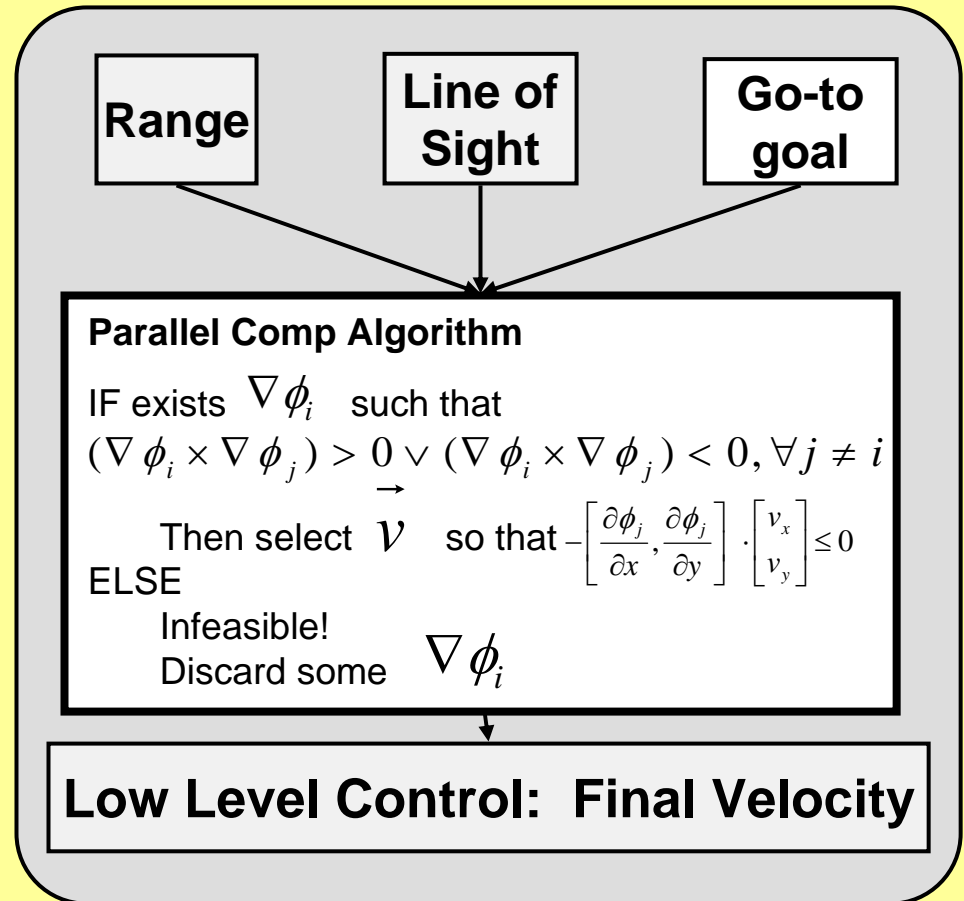
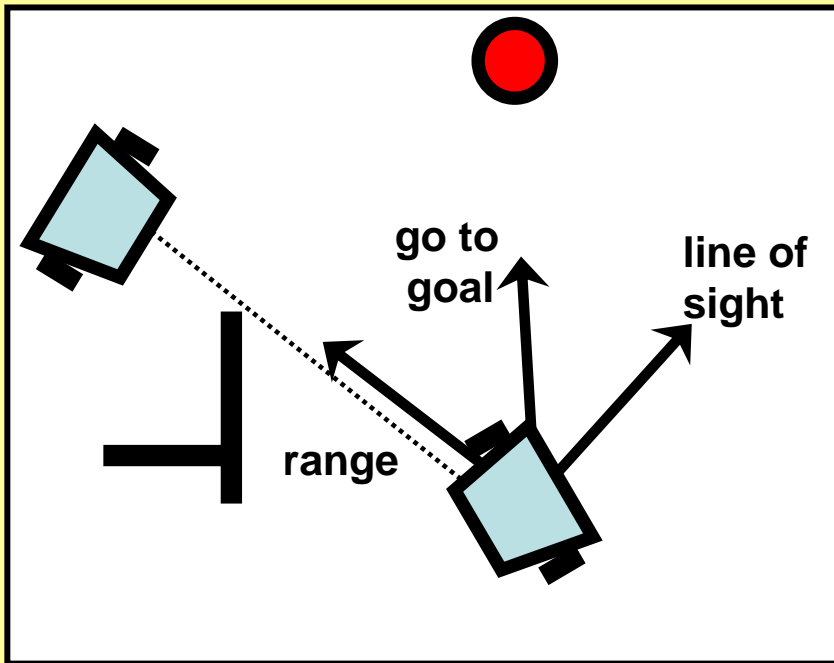
2. Line of Sight: 

3. Go To Goal:

Navigation function
[Rimon & Kodischek]

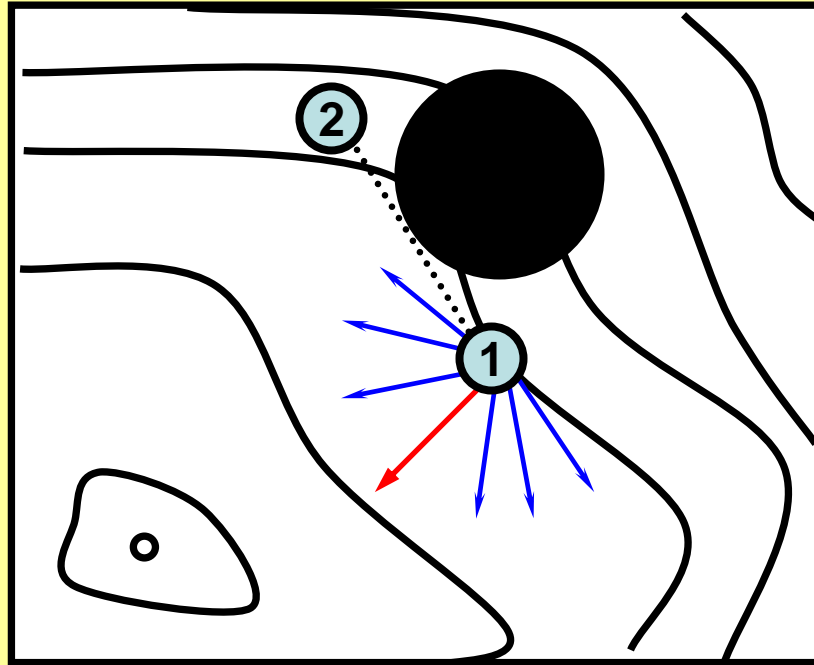


Addition of Potentials is Dangerous!

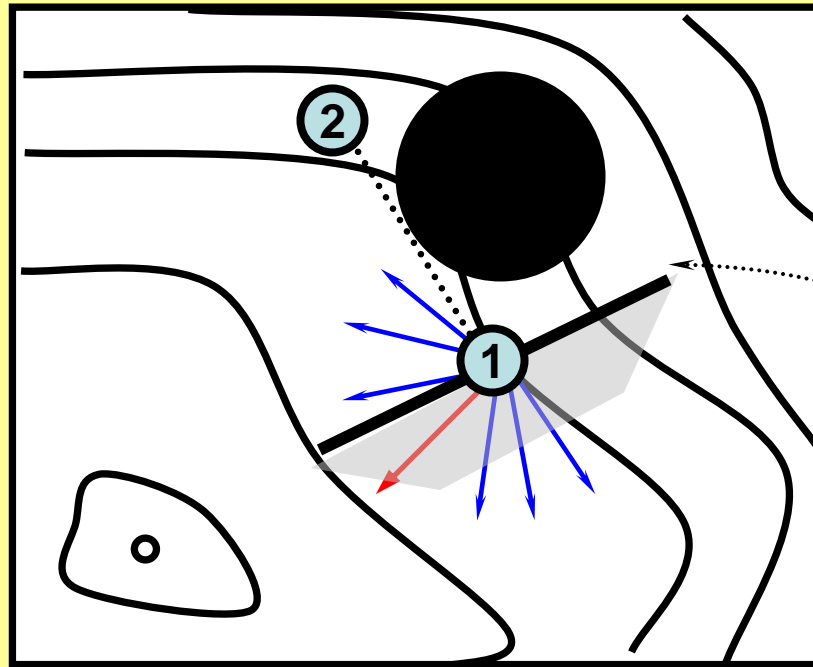


Parallel Composition controller: concept

Goal Potential

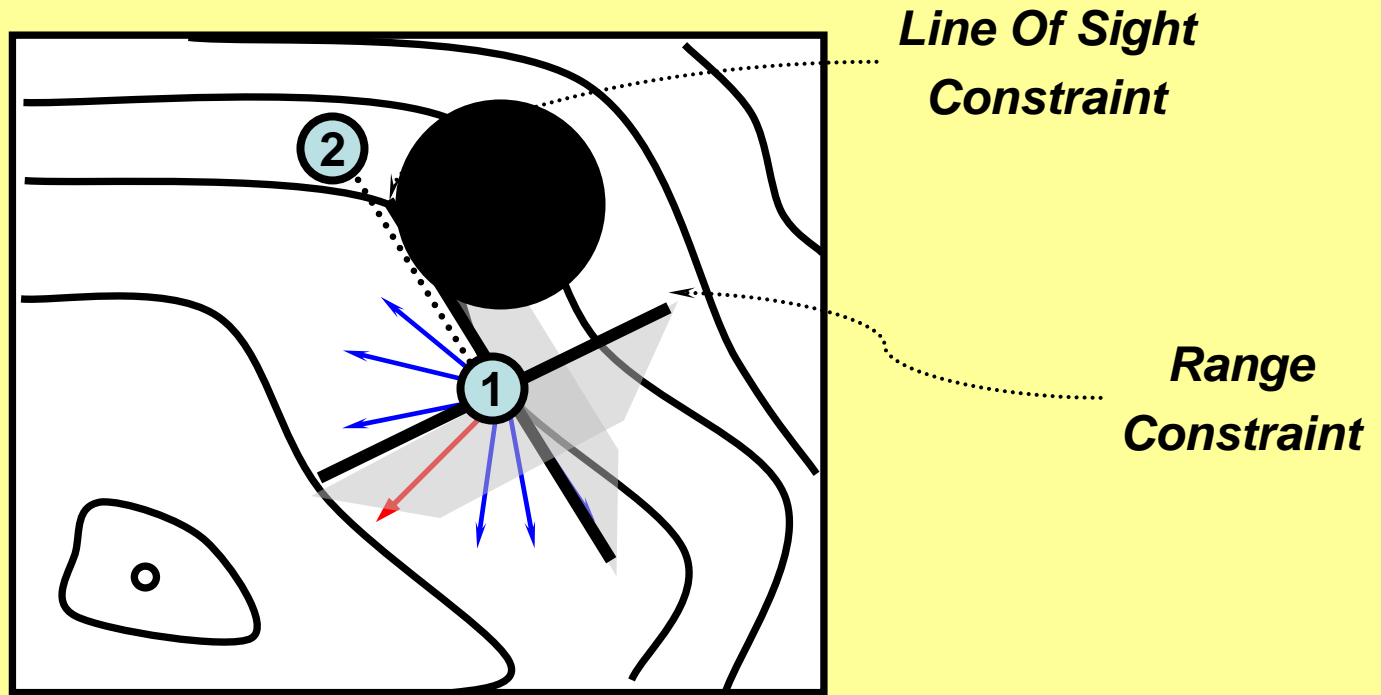


Parallel Composition controller: concept

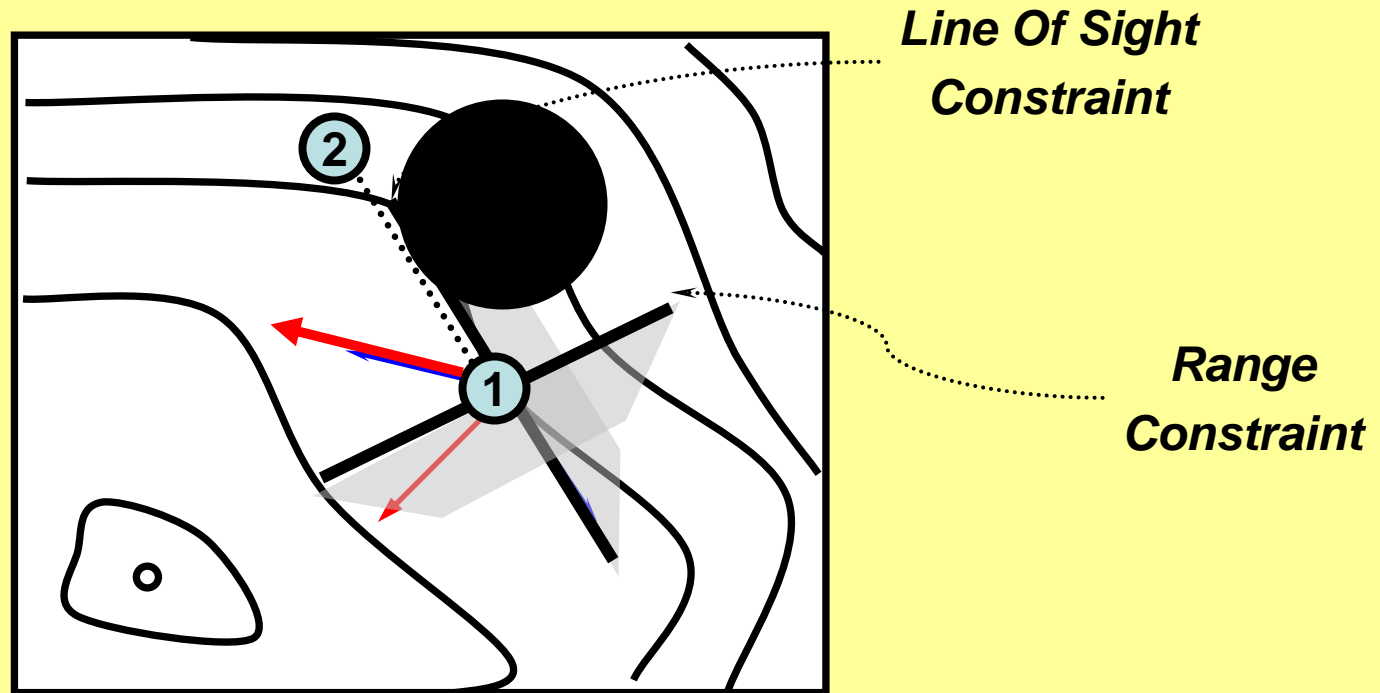


*Range
Constraint*

Parallel Composition controller: concept



Parallel Composition controller: concept

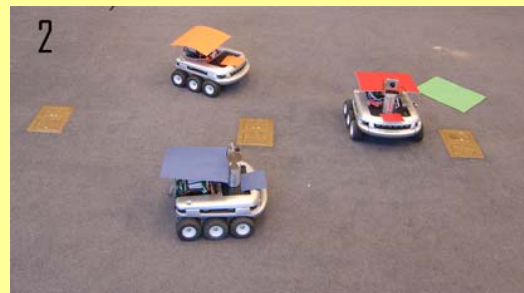
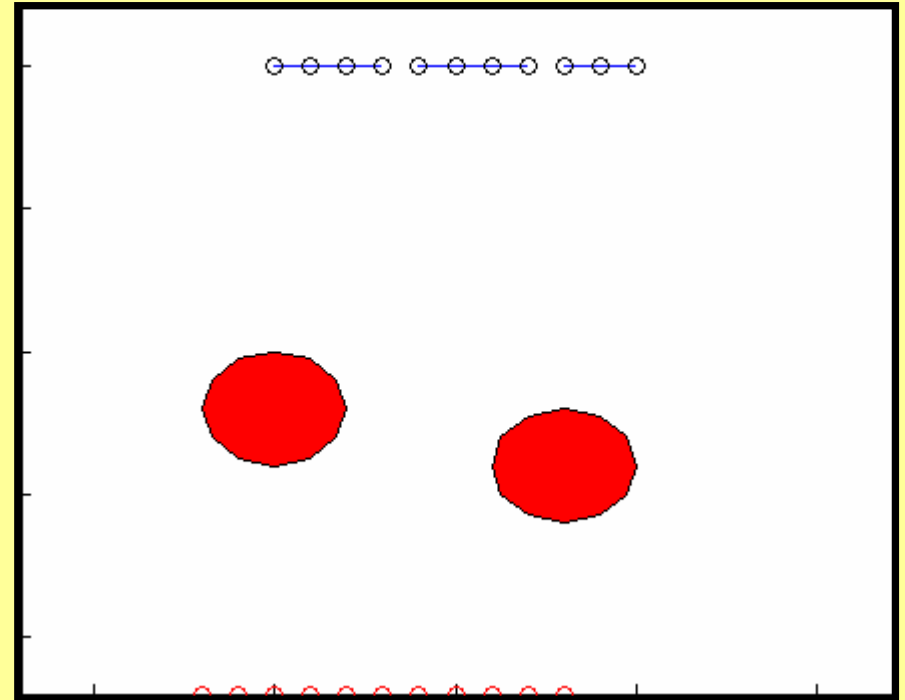
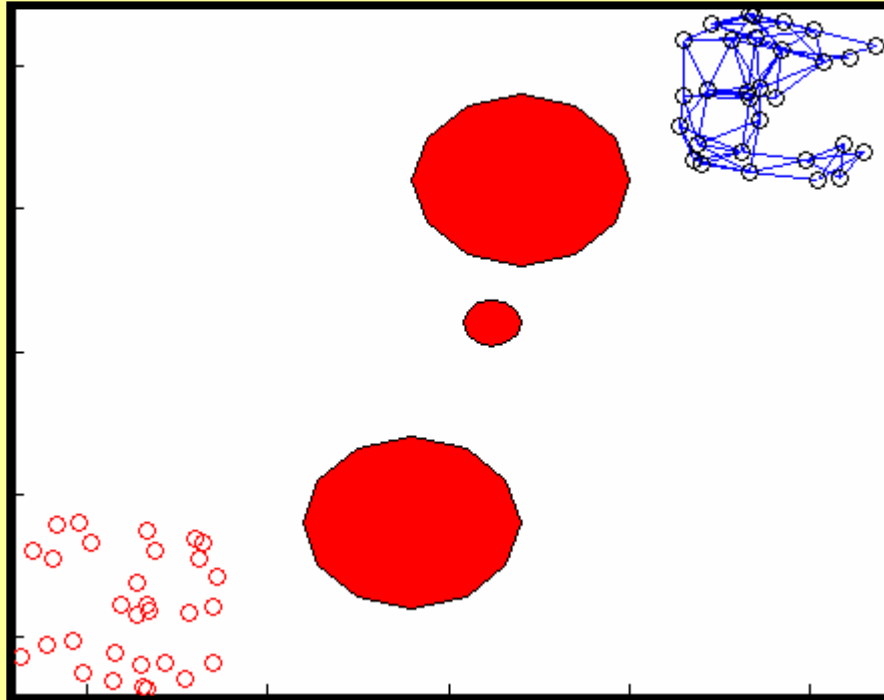


Efficient: Computing directions is $O(P^2)$ (all pairs of cross products)

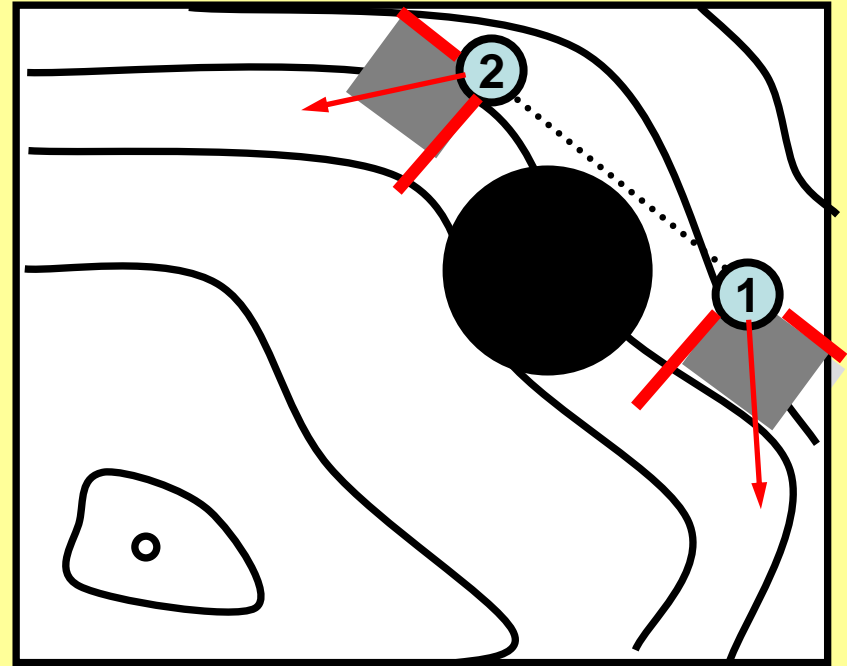
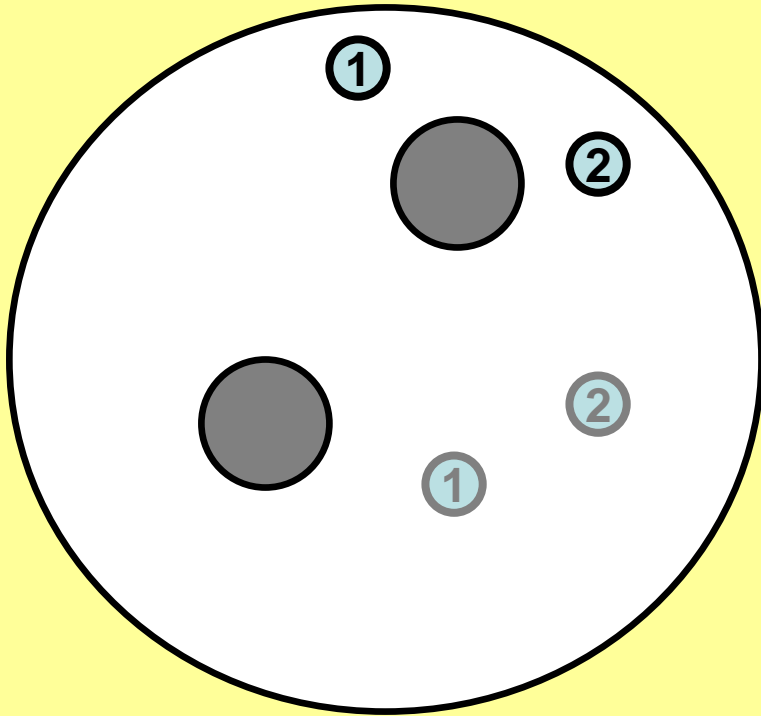
Complete: Generates solution if feasible. If infeasible, algorithm is conclusive.

Stability: Common Lyapunov function.

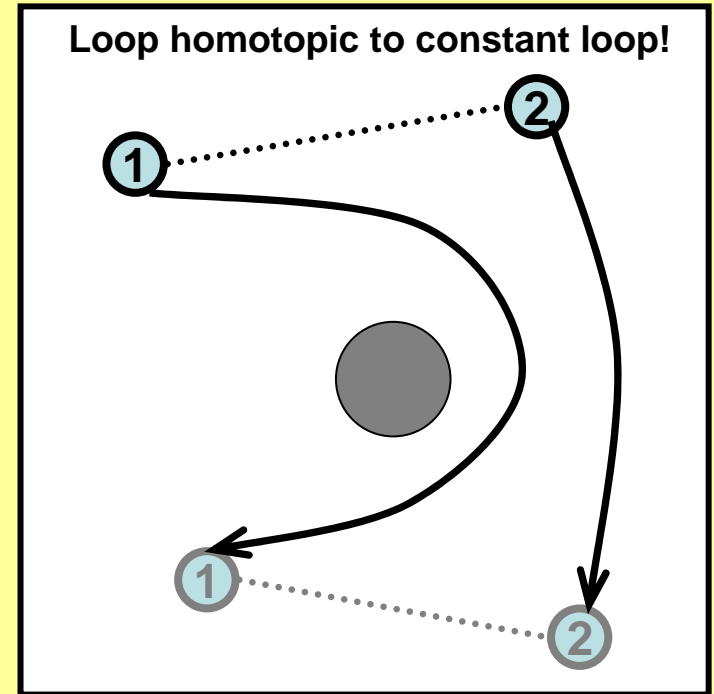
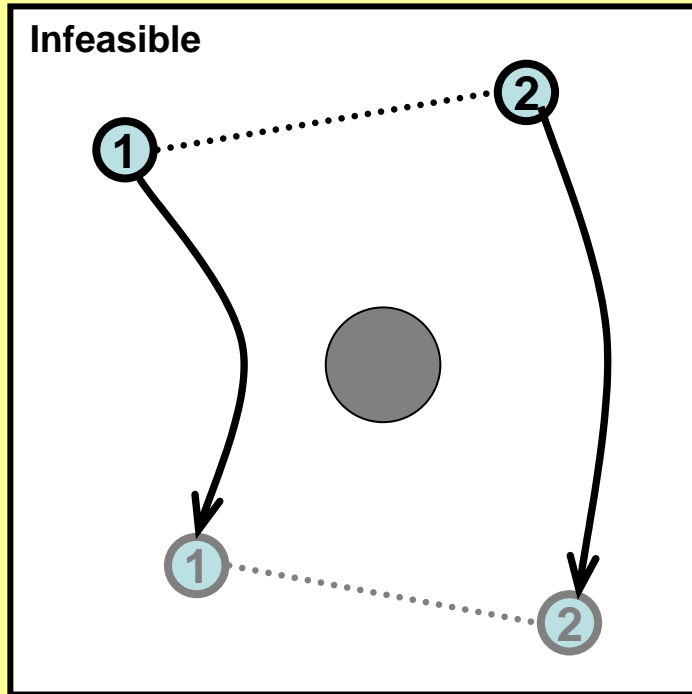
Validation



Completeness: Is the composition always feasible?



A Necessary Condition



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

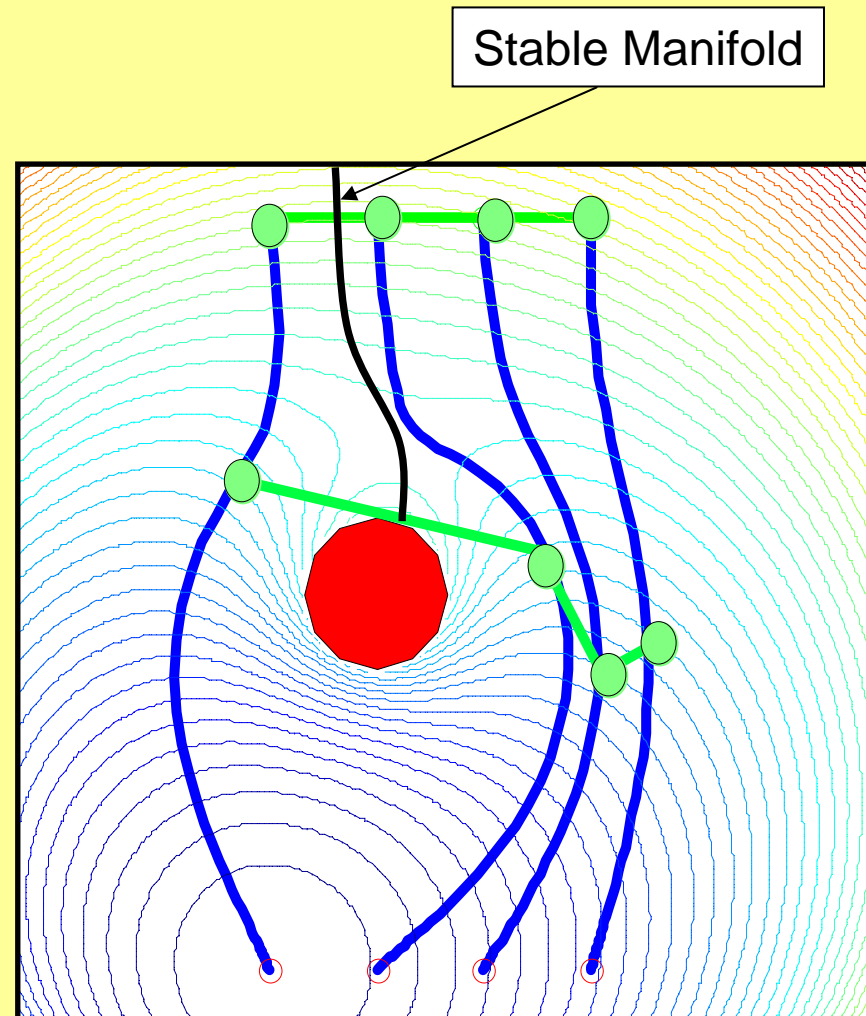


- A connected swarm cannot “split” an obstacle
- ***No distributed, global solution !!!***

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

manifold \Rightarrow infeasibility

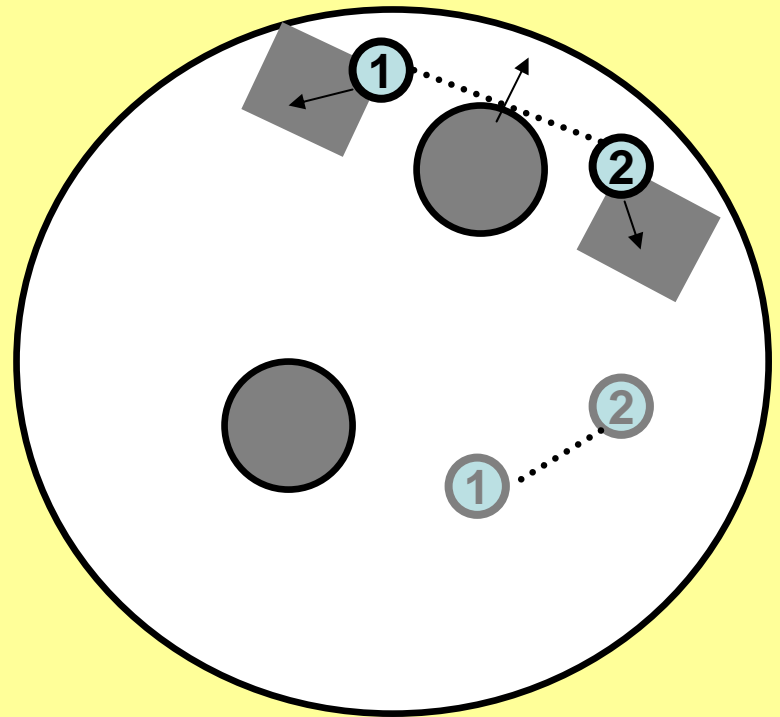
1. Any feasible path is a loop homotopic to trivial loop
2. must cross stable manifold an even number of times,
3. requires increasing potential function



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....**



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