LEADER-FOLLOWER CONTROL USING DIRECTED GRAPHS

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MOTIVATION

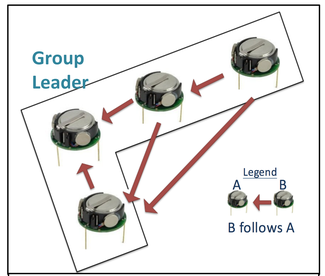
Abstract: Multi-robot formations can perform large-scale tasks and are inspired by swarm intelligence in animals; for example, rigid robot formations can aid in transportation during search-and-rescue missions. We optimize collaboration using a leader-follower model. Some leader-follower interactions can be modeled by body-and-pin structures and their associated rigid directed graphs.

Leader-follower formation of geese for efficient communication.

Image Courtesy: http://www.cloudjock.com/blog/2012/12/31/the-power-of-v.html

Multi-robot formation of quadrotors to carry a rigid structure.

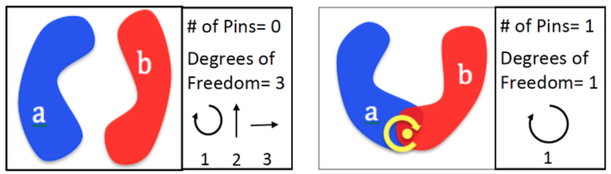
Image Courtesy: D. Mellinger, M. Shomin, N. Michael, and V. Kumar, Cooperative grasping and transport using multiple quadrotors, Proceedings of the international symposium on distributed autonomous robotic systems, 2010.



Communication and movement constraints can be modeled using directed graphs.

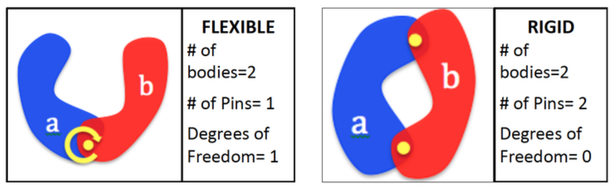
BODY-AND-PIN FRAMEWORK

DEGREES OF FREEDOM (given a fixed position for structure a)

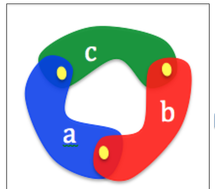


Adding one pin removed 2 degrees of freedom. Thus, a pin represents the addition of 2 possible constraints on a framework.

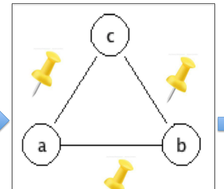
RIGID BODY-AND-PIN STRUCTURES



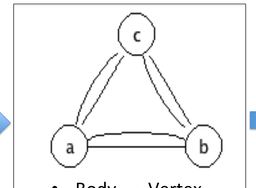
COMBINATORIAL MODEL FOR BODY-AND-PIN FRAMEWORK



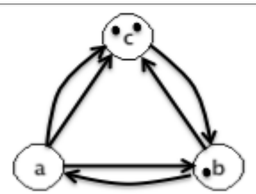
Body and pin structure



- Body ⟶ Vertex
- Pin ⟶ Edge



- Body ⟶ Vertex
- Constraints underlying pins ⟶ Edges



Pebble Game Directed Graph

- Directed subgraph
- Edges ⟷ minimal constraints required for rigidity

Pebble Game Algorithm

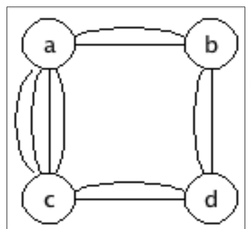
- Detects rigidity
- Outputs pebble game graph

RESEARCH QUESTION: DIRECTIONALLY CONSISTENT PEBBLE GAME GRAPHS

Given: Rigid body-and-pin structure with minimum number of pins.

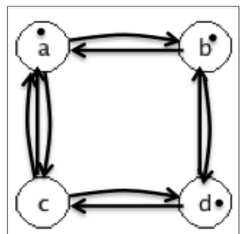
Question: Can we flip the edges to get a *directionally consistent* pebble game graph? (i.e. edges corresponding to the same pin point in the same direction)

Example of directionally consistent graph



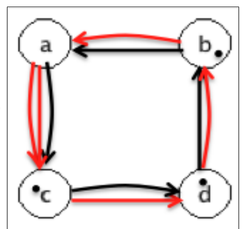
Underlying constraints of a rigid body-and-pin structure with minimum number of pins.

Pebble Game



Pebble game graph

Flip edges

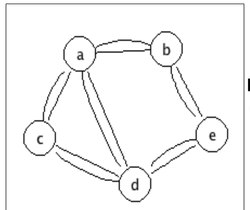


Edges successfully redirected, graph is directionally consistent

GRAPHS THAT CANNOT BE MADE DIRECTIONALLY CONSISTENT

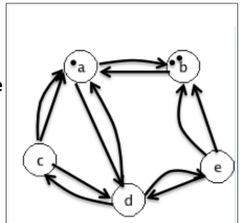
Theorem: For rigid body-and-pin structures with the minimum number of pins, it is possible to have directionally consistent pebble game graphs if and only if there are less than 5 bodies.

Counterexample of directionally consistent graph



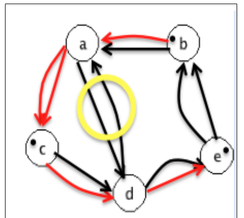
Underlying constraints of rigid body-and-pin structure with minimum number of pins.

Pebble Game



Pebble game graph

Flip edges



Edges **CANNOT** be redirected so that the output is directionally consistent.

FUTURE WORK

- Consider cases that are not restricted to the minimum number of pins.
- Develop an algorithm to flip edges to get directionally consistent pebble game graphs.

Example of directionally consistent pebble game graph