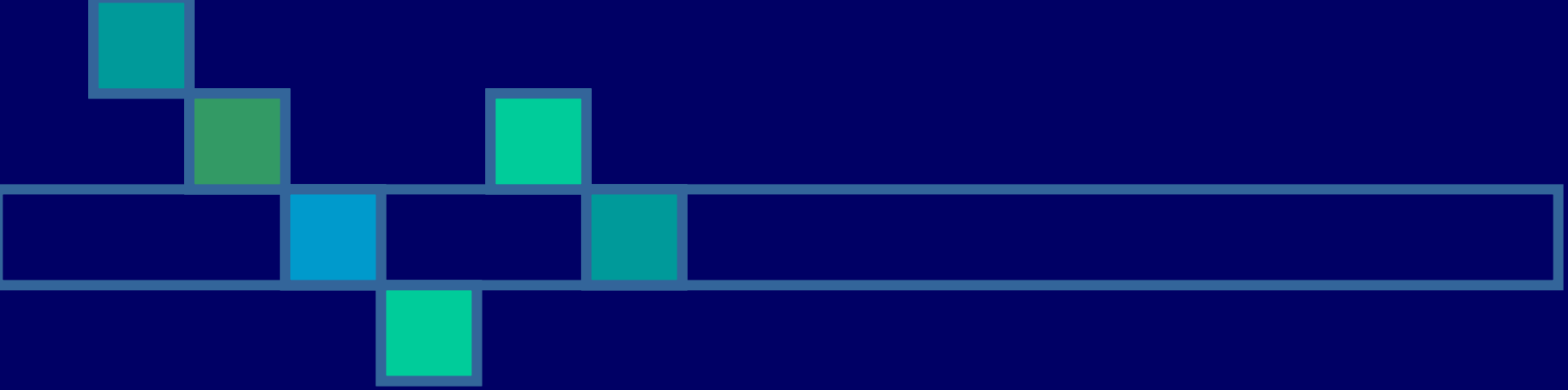

Behavior-based Formation Control for Multi-robot Teams

Presented by Fang Tang
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About this paper

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Agenda

- Introduction
- Approach
- Formation Results

Introduction (1)

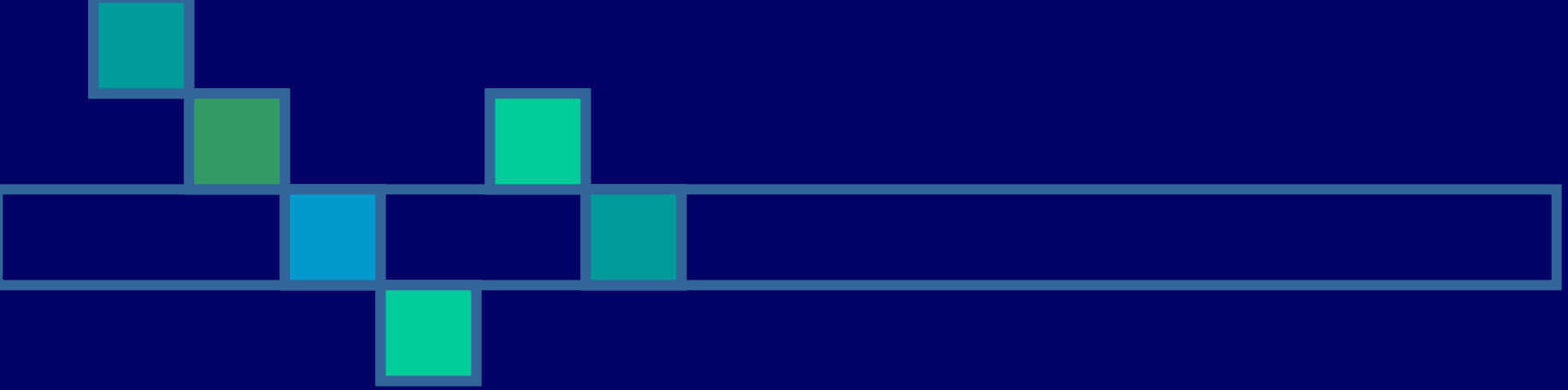
- Formation-keeping Objective: robots maintain specific formation while moving along path.
- This article presents a behavior-based approach to robot formation-keeping.

Introduction (2)

- It is important when sensor assets are limited.
- Widely used in military applications, like robot scout, and applicable to other domains like search and rescue, agricultural coverage tasks and security patrols.

Background

- Related work includes:
  - Craig Reynolds developed a simple behavior for flocking ("boids").
  - Mataric developed basic behaviors for emergent group behavior.
  - Parker studied line-formation using layered subsumption architecture. She concluded that local information combined with global information would be good for formation control.



Formation-keeping Approach

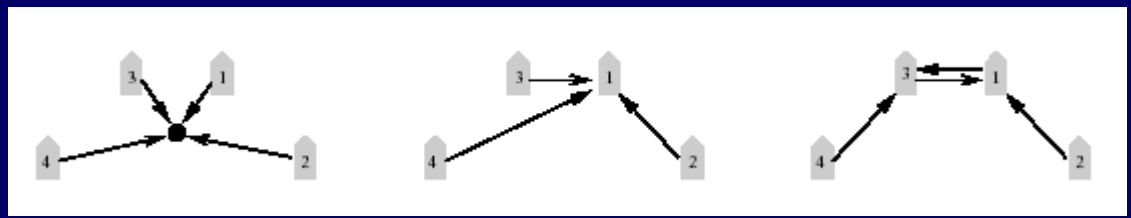
Formation Types
Motor Schema-Based Formation Control

Formation Type

- Formations considered in this paper include:
- Line, column, diamond, and wedge.

Position Determination

- How to determine the correct position?
  - Unit-center-referenced
  - Leader-referenced
  - Neighbor-referenced
- For example, considering wedge formation.



Basic Behaviors

- move-to-goal
- avoid-static-obstacle
- avoid-robot
- maintain-formation
- Above behaviors generate the overall behavior for a robot to move to a goal location while avoiding obstacles, collisions with other robots and remaining in formation.

Maintain-formation (1)

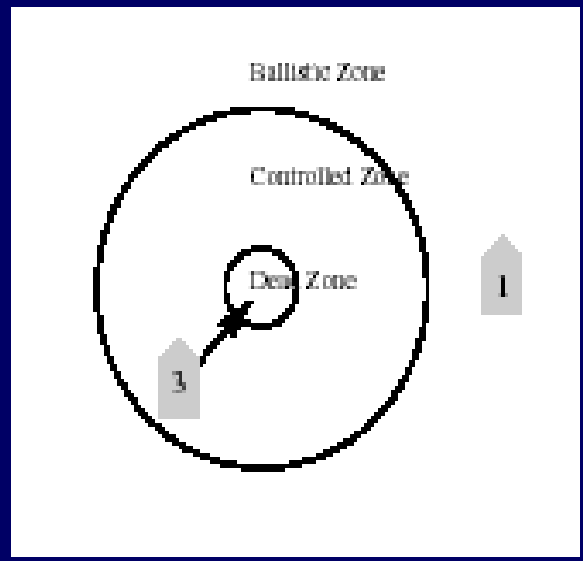
- Perceptual Schema: detect-formation-position
  - Determine robot's desired location of a certain type
  - Determine robot's relative position in the overall formation
  - Determine other robot's position

Maintain-formation (2)

- Motor Schema generates a movement vector.
  - Direction: always in the direction of the desired formation position.
  - Magnitude: depends on how far the robot is away from the desired position.

Computation of magnitude

- Ballistic zone: the magnitude is set at its maximum.
- Controlled zone: the magnitude varies linearly, 0 at inner edge, maximum at the furthest edge.
- Dead zone: always zero. Position reporting error and communication delay.



When there are obstacles…

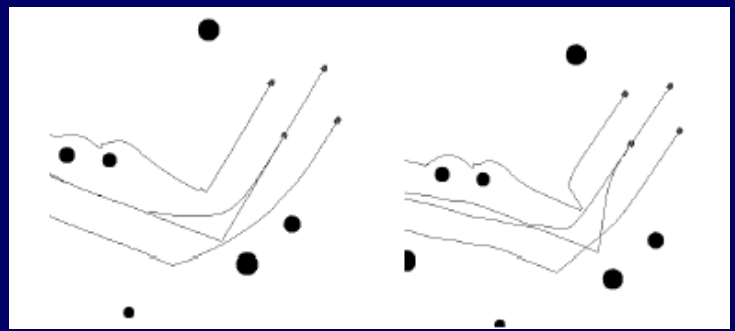
- To avoid obstacles like barriers, choices are:
  - Move as an unit around the barrier
  - Divide into subgroups
  - Depends on the relative strengths of behaviors (gain)

So, what's the result?

Qualitative/Quantitative view

A Qualitative Analysis

- For a 90 degree left turn.
- Left: leader-referenced, any turn by the leader causes the entire formation to shift accordingly.
- Right: unit-center-referenced, any robot move or turn impacts the entire formation.



A Quantitative Analysis

- To evaluate the performance of various formation types and references, two experiments were conducted:
  - performance in 90 degree turn
  - performance across an obstacle field

Formation Results

- For 90 degree turn:
  - Diamond formation best with unit-center-ref.
  - Wedge, line formations best with leader-ref.
- For avoiding obstacle:
  - Column formation best with either unit-center-ref. or leader-ref.
- Most of the time:

  - Unit-center-ref. formations performs better than leader-ref formations.

But…

- Unit-center-ref. formations are not used widely for the following reasons:
  - If using human leader, no reason to use unit-center-ref., leader-ref. is better.
  - For communications restricted applications, the unit-center-ref. requires a transmitter and receiver for each robot and a protocol.
  - Passive sensors are difficult to use for unit-center-ref.

Conclusion

- This paper presents a behavior-based approach to implement formation-keeping, several different formation types are implemented and compared.
- But there are some issues that are not mentioned in this paper, like scalability and implementation of other formation types.

Thank you!