Robot Behavior Adaptation for Formation Maintenance

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Introduction

- Formation maintenance in motion
  - queue or column
  - inverted-V or wedge
  - rectangle or roman manipulus

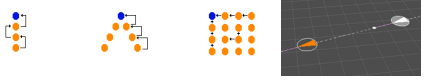
- Local information (behaviors)
- No notion about formation
- Simulation: OpenSteer C++ library

Basic behaviors

- 5 different basic behaviors:
  - Reference neighbor following
  - Reactivity
  - Reaching a target position
  - Waiting for the follower
  - Priority respect
  - Simple to guarantee formation robustness
  - Parameterized

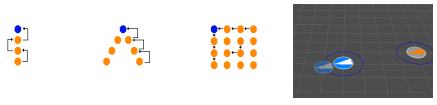
Basic behaviors I

- Reference neighbor following (RNF):
  - 1 or 2 reference robots to follow
  - keeping fixed angle α (formation property)
  - and fixed distance *d* (*separation distance*)
    - related to robot visibility range, speed or reaction capabilities



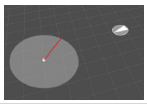
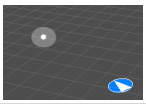
Basic behaviors II

- Reactivity (R):
  - Movement propagation along the formation
  - Filter noisy movements:
  - *Minimum movement distance* before reacting
    - small values do not filter properly
    - large values introduce delays



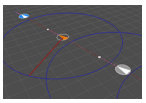
Basic behaviors III

- Reaching a target position (RTP):
  - Get to a target position and stop there
  - Reduce velocity at a certain *braking distance*
    - if too large then ***d*** is not accomplished (too slow)
    - if too small then trajectory loops to recover target positions (surpassed)
  - *Tolerance* for low accuracy robots

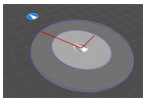
Basic behaviors IV

- Waiting for the follower (WF):
  - When not properly followed, reference robot reduces its velocity
  - *Maximum separation distance*
    - should be > d
  - Social courtesy



Basic behaviors V

- Priority respect (PR):
  - Loops force crossing trajectories
  - Avoid collisions
  - *critical stopping distance*
  - *critical braking distance*
    - angle of influence = 90º
    - order priorities to avoid waiting deadlocks



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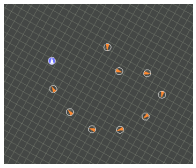
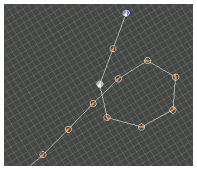
Formation maintenance

- From the combination of basic behaviors emerges complex formation behaviors.
  - Specify:
    - reference robots
    - angle α
  - Formations:
    - queue
    - inverted V
    - rectangle

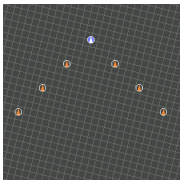
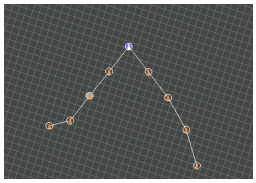
Formation maintenance

- Queue:
  - leader's trajectory, reference=foregoer, α = 0 º
  - local movement: RNF & RTP
  - stabilization & robustness: R & WF & PR

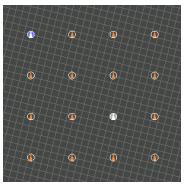
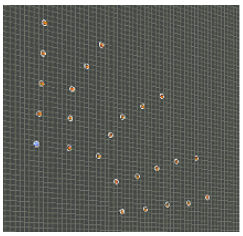
Formation maintenance II

- Inverted V
  - reference: foregoer, α = ±45 º
  - turning deformations

Formation maintenance III

- Rectangle
  - references: foregoer & left, α = 0 º & -90º
  - less flexible

Formation maintenance IV

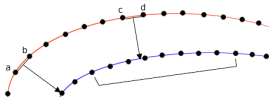
- Demo
  - video1_2.html
    - Conservative and Non-conservative Queue formation
    - Inverted-V and Rectangle formation

Formation maintenance V

- Local information only
- All three recover from deformations
  - when the leader moves straight forward
  - or stops
- But error propagates
  - accumulative effect

Performance evaluation

- Maximum distance between robot trajectories:
  - actual vs target.
  - time window



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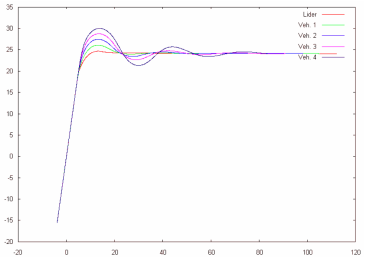
Results

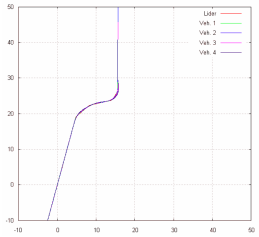
- Performance measured as error
- Queue
  - max error
    - 5.37
  - av. error:
    - 0.19
    - 0.50
    - 0.85
    - 1.5

(robot diameter = 1)



Results I

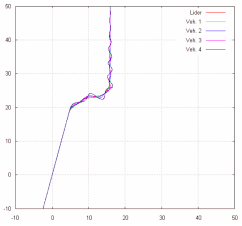
- Parameter adaptation to reduce errors
  - av. error:
    - 0.03
    - 0.04
    - 0.05
    - 0.07
  - param.:
    - d = 4 (RNF)
    - max sep = 4.5 (WF)
    - min mov = 2 (R)
    - **brak d=2**, tol = 0.1 (RTP)
    - crit stop=2, crit brak=3.5 (PR)



Results II

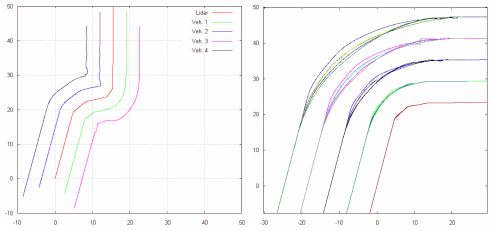
- 1 Parameter adaptation to reduce errors

	Braking distance		
	1	**2**	3
rob2	0.04	**0.03**	0.04
rob3	0.07	**0.04**	0.05
rob4	0.11	**0.05**	0.09
rob5	0.18	**0.07**	0.10



Results III

- Error measurement for other formations



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- Introduction
- Basic behaviors
- Formation maintenance
- Performance evaluation
- Results
- Conclusions, related & future work

Related work

- Multi-agent robotic systems (Brooks'90, Johnson'95)
- Formations:
  - Friend robots (Mataric'02)
  - Performance (Sutkame'03)
  - Mathematical stabilization (Yamaguchi'01)
  - Attraction/repulsion forces (Feddema'04)

Conclusions & Future Work

- Robot behavior adaptation for formation maintenance:
  - basic behaviors
  - parameterization
  - formation maintenance emerges
  - performance
- We plan to use GA to find best parameters