Distributed Intelligent Systems Project:
Multi-Robot Navigation in Cluttered and Dynamic Environments

Chiara Ercolani, Johann Franziskakis, Benjamin Leis and Jean-Baptiste Magnin
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Overview

- Introduction
- Objectives
- Simulation
  - Implementation
  - Results
- Real World
  - Implementation
  - Results
- Conclusions

Introduction

- Flocking behaviour vastly observed in nature
- Useful strategy for distributed robotics [1]
- Dedicated robots built to achieve flocking behaviour [2]

Objectives

1. Implement a navigation strategy with multiple robots.

2. Two scenarios:
   a. Static environment: static obstacles
   b. Dynamic environment: obstacles are robots belonging to another flock
Implementation

- Flocking Behaviour → Reynolds’ rules (Cohesion, Dispersion, Consistency)
- Obstacle Avoidance → Braitenberg vehicle
- Migratory urge in the forward direction
- Finite State Machine to transition between the two behaviours
Simulation Supervisor

● Five metrics used to evaluate simulation:
  ○ Orientation
  ○ Cohesion
  ○ Velocity
  ○ Instant Performance
  ○ Overall Performance

● Constraint: Supervisor cannot share information between the robots
Simulation Controller

- Range and bearing → IR sensors
- Migratory urge → odometry
- Reynolds and Braitenberg weights calibrated manually
- Small noise added to obstacle avoidance to escape deadlocks

➢ Same controller for both worlds
Results - Static Obstacles

- Metrics for the static world

<table>
<thead>
<tr>
<th>Metrics</th>
<th>No Obstacle</th>
<th>Obstacle World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time [s]</td>
<td>58</td>
<td>64.5</td>
</tr>
<tr>
<td>Orientation</td>
<td>0.999</td>
<td>0.998</td>
</tr>
<tr>
<td>Cohesion</td>
<td>0.88</td>
<td>0.88</td>
</tr>
<tr>
<td>Velocity</td>
<td>0.87</td>
<td>0.85</td>
</tr>
<tr>
<td>Instant Performance</td>
<td>0.77</td>
<td>0.75</td>
</tr>
<tr>
<td>Overall Performance</td>
<td>0.67</td>
<td>0.58</td>
</tr>
</tbody>
</table>

speed x6
Results - Dynamic world

- Metrics for the dynamic environment

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Flock One</th>
<th>Flock Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time [s]</td>
<td>16.64</td>
<td>16.64</td>
</tr>
<tr>
<td>Orientation</td>
<td>0.998</td>
<td>0.997</td>
</tr>
<tr>
<td>Cohesion</td>
<td>0.890</td>
<td>0.888</td>
</tr>
<tr>
<td>Velocity</td>
<td>0.871</td>
<td>0.853</td>
</tr>
<tr>
<td>Instant Performance</td>
<td>0.774</td>
<td>0.756</td>
</tr>
<tr>
<td>Overall Performance</td>
<td>0.572</td>
<td>0.566</td>
</tr>
</tbody>
</table>
Results - Scalability

- Metrics of the scalability experiments

<table>
<thead>
<tr>
<th>Metrics</th>
<th>8 Robots</th>
<th>9 Robots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time [s]</td>
<td>70.08</td>
<td>67.84</td>
</tr>
<tr>
<td>Orientation</td>
<td>0.947</td>
<td>0.996</td>
</tr>
<tr>
<td>Cohesion</td>
<td>0.801</td>
<td>0.800</td>
</tr>
<tr>
<td>Velocity</td>
<td>0.548</td>
<td>0.852</td>
</tr>
<tr>
<td>Instant Performance</td>
<td>0.416</td>
<td>0.679</td>
</tr>
<tr>
<td>Overall Performance</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

- Metrics for 5 robots in the static world

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</tbody>
</table>
Real World Adaptation

● Translation to hardware
  ○ Code translation to e-pucks libraries
  ○ Selection of robots' IDs
  ○ Retuning of weights and thresholds
  ○ Slower speeds
Real World Adaptation

- Architectural changes
  - Frequency of communication
  - Reynolds’ speeds computed only when ping received
  - Memory of previous Reynolds’ speeds
  - Consistency rule not implemented

➢ Effort to transfer to hardware was significant
Results - Real World

- Dynamic obstacles
- Static obstacles

speed x2
Results - Real World

- **Goals fulfilled**
  - ✓ Flocking
  - ✓ Obstacle avoidance
  - ✓ Migration

However…

- ➔ Flocking hard to observe due to migration urge
- ➔ Communication issues
- ➔ Obstacle avoidance not smooth
Conclusion

- Controller fulfills the project’s goals
- Improvements can be made
- Tradeoff between rules

Lesson learned:

- Simplicity
- Simulation ≠ Hardware
Questions ?