Collective and Swarm Robotics –III

Frank Mletzko

Creating Emergent Behavior in a Group of Micro-robots
Overview

1. Introduction
2. Problem and goal of this work
3. Introduction of approaches
4. Selection of approaches
5. Implementation of scenarios
6. Discuss results
Introduction

• How can such emergent behavior be created on micro-robots?
Problem

• How to proceed to create swarm behavior?
• Many physically interacting systems
• Very very complex
• Ways to create swarm behavior:
  - Top-down approach
  - Evolutionary algorithms
  - Bio-inspired approach
  - Bottom-up approach
• Still no solution despite many research
Goal of this work

• Analyse, how those four approaches can be used to create swarm behavior
• Select the two most promising approaches
• Implement scenarios with both approaches
• Discuss results
Top-down Approach

- Define behavior robots shall show
- Stepwise refinement of behavior
- Implement those sub-behaviors
- Compose these functions then
Top-down Approach

• Programming starts far away from robots 
  feedback is missing at the beginning

• Problem: Swarm layer 
  Robotic layer

• Missing methodology to split up behavior from swarm to robotic layer

• Not very promising at the moment
Evolutionary Algorithms

Evolution of program code:
- Starting population
- Select elements
- Recombine/Mutate

- Calculate next population with fitness function
Evolutionary Algorithms

- Offer interesting solutions
- High requirements to programming environment
- Realization on robots can get very complex and needs high effort
- Should be kept in mind for future work
Bio-inspired Approach

- Nature offers good/perfect algorithms
- Find an example in nature
- Analyze behavior
- Try to extract simple rules
- Embody capabilities on robots
- Implement those rules on robots
Bio-inspired Approach

• If scenario can be found, this approach can be a simple solution
• How can embodiment (for example of pheromone) be solved?
• Many scenarios can‘t be found in nature
• Rules often not easy to extract
Bottom-up Approach

• Start with primitive functions
• Compose swarm behavior
Bottom-up Approach

- Reusability
- Not steerable
  Many adjustments necessary
- But we get results immediately
Selection of Approaches

- **Evolutionary Algorithms**
  - High effort necessary for realization
  - Behind the scope of this work
- **Top-down approach**
  - Missing methodology
  - Results will appear late
  - Not very promising at the moment
- **Bottom-up approach**
  - Produces results immediately
  - Promising for complex scenarios
  - We can try to apply this scenario
- **Bio-inspired approach**
  - Promising, if scenario is simple
  - We can try to apply this scenario
Clustering Scenario

• Can be found in nature (bees/ants)
• Useful for transportation or exploring in swarm robotics
• Implementation with bio-inspired approach
Implementation of Clustering

- Cluster by light or by beacon robot
- Stop or slow down speed/collision avoiding

- Random movement
- Light sensor exceeds threshold
- Light sensor under-runs threshold
- Slow down speed and collision avoiding
Results for Bio-inspired Approach
Results for bio-inspired Approach

- After extraction of rules, implementation was possible fast
- If we want to implement more complex scenarios we won’t find examples in nature or rules may be hard to extract
Communication-Street Scenario

- Necessary if robots want to stay in contact
- Complex scenario
- Examples for bio-inspired approach hard to find
- Composable implementation bottom-up
Communication-Street Scenario

- Composing behavior bottom-up out of two sub-scenarios
- Building line + walk along scenario

Communication Street scenario
Results

Frank Mletzko – 'Creating emergent behavior in a group of micro-robots'
Results

- Applicable to complex scenarios
- But implementation took lots of time
- Despite structured proceeding many tries and adjustments were necessary (ca. 100 tries including different sub-scenarios)
Results

Result often differs from desired behavior, often intuitive adjustments are necessary until desired behavior is reached.

How to get there?

Achieved Swarm behavior

Desired Swarm behavior

Swarm Movement | Other Functions
Collision Avoiding | Communication | Other Functions
Locomotion | Odometry | Touch sensor | Other Functions
Summary

• We showed that Bottom-up is applicable for complex situations but problems can occur. Many tries necessary.
• Implementation took lots of time for bottom-up.
• Bio-inspired is applicable if good example in nature exists and capabilities can be modelled on robots, Implementation is fast then.
• Bio-inspired approaches can be used for implementing primitive functions for Bottom-up approach.
Summary

• Apply bio-inspired approach to simple scenarios if possible
• Apply bottom-up approach to complex scenarios and use as many primitive functions that have already been implemented
The End

• Thanks for your attention
• Are there any questions left?