Stephan Dörfler

Collective mapping and movement in a swarm of highly unreliable individuals in unknown environments

OTTO VON GUERICKE
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MAGDEBURG

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Collective mapping and movement in a swarm of highly unreliable individuals in unknown environments

Author: Stephan Dörfler

Professor: Prof. Dr.-Ing. habil. Sanaz Mostaghim

Examiner: Another Professor

Examiner: Someone from Industry

Advisor: Dipl.-Inform. Christoph Steup

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Abstract

Foo Bar Baz

this will be written at the very end of the project

Todo list

Contents

1 Introduction

write out the list below

- Importance of robotics
- Importance of swarm-robotics
- We can't measure *true/exact* values –> probabilistic approach
- Combination of "swarm" and "probabilistic" to find good solutions despite of the problems

1.1 Motivation

write out the list below

- simple individuals
  - cheap
  - robust
  - easy to use/initialize
  - very limited capabilities
  - highly inaccurate
- try to overcome the weaknesses
  - additional external sensors (camera tracking)
  - additional external computing (by commands via bluetooth)
  - probabilistically learn the inaccuracy and compensate accordingly
- combine multiple individuals in a swarm for better results
  - higher quality & quantity probabilistic data for learning
  - get the differences between multiple individuals

  - get a better/faster impression of the environment's effects
  - in most use-cases: single individual's minor inaccuracies are compensated for by the swarm

1.2 Goal

write out the list below

- Find an effective way to measure and quantify the error/inaccuracy
- From a single measurement differentiate the own error from the environment's error
- Publicly share the information about the measured inaccuracy
- As a swarm: continuously & collectively improve the knowledge about inaccuracy
- Find a way to use the knowledge of the inaccuracy to take countermeasures

1.3 Structured approach

write out the list below

- Figure out the required knowledge and technologies
- Draft the (measurable/verifiable) measure for success
- Related work: which similar problems are already (partly) solved?
- Design a concept
- Evaluate the concept theoretically
- Exemplary show the realization of the concept to confirm the theoretical evaluation

2 Background/Basics

write out the list below

- Basics to mobile robotics
- Basics to probabilistic robotics
- Basics to swarm behavior
- Basics to distributed mapping
- Basics to ROS as development framework

2.1 Spherical Robot: Orbotix Sphero

write out the list below

- Definition: spherical robot
- Sphero: specifics and limitations
  - Movement: differential drive
  - Sensors: accelerometer
  - sources of inaccuracy (slip, orientation through odometry)

In this work a special kind of mobile robot is used. As stated in the previous chapter one of the principles in swarm robotics is to be able to achive a relatively complex task with each individual being as simple as possible. In regards to this principle the kind of robot used in this work is one of the simpelest forms a robot can take: a spherical robot.

state in the prev. chap.

A spherical robot is a robot which outer hull is spherical and all the elements are contained within this spherical hull. Thus, collisions can be handeled extremely well and a lot of issues emerging from the direction the robot is currently facing are avoided. Also, for most use-cases the internal workings of the robot can be disregarded/abstracted to just a sphere rolling in it's

state some issues

wording

environment.

state more (beneficial) properties

footnotes & links

To be able to reproduce and verify the findings in this work, real-world robots were used. The robot best matching the properties stated above was found to be the "Sphero" made by the Company "Obortix" .

2.1.1 Orbotix Sphero: Specifics and Limitations

image

The Sphero (img.) is based on a spherical acrylic hull which contains the internal sensors and actors. It is originally sold as a toy to be remotely controlled via bluetooth from a smartphone. Based on the communities use-cases and suggestions more and more features regarding remote programming and automated controlling were officially added to the Sphero's capabilities.

Movement

explain & references

The movement is realized with a differiential drive, two wheels running against the acrylic hull from the inside. This special design has implication on the possible movements of the Sphero. In regards of the nautical/Cardan angles this renders the Sphero impossible to turn in a *roll* axis (bank-axis). Spinning around the *pitch* axis will result in movement and steering the direction of the movement relative to a two-dimensional world-frame is done by controlling the individuals wheels with different speeds and thus spinning around the *yaw* axis (bearing).

2.2 Probabilistic robot movement and perception

write out the list below

- uncertainty is inevitable in real-world use-cases
- instead of unrealistic simplifications use best-effort with probabilities
- approaches to minimize uncertainty

2.3 Requirements

write out the list below

- There is an error model to evaluate the error/inaccuracy by quantity and quality
- Each individual's movement is subject to a smaller error when it has *knowledge* vs. when it hasn't
- Each individual is able to use data from locations *any* individual has visited
- Statistically: increase in accuracy after a small amount of time/iterations

2.4 Related work

Topics:

write out the list below

- distributed mapping
- error-correction

3 Concept

write out the list below

- Error-data are collected
- Error-data get evaluated (statistically)
- Error-data are shared throughout the swarm
- Error-data are used to improve quality of movement
- New movements feed back into measurement-loop

3.1 Measurement of error

write out the list below

- Error is measured by error in position and error in movement
- Error is measured for each individual
- Error-data are scored by quality
- Error-data about environment and it's quality is fed into a centralized map
- Existing error-data are used to improve each individual's movement

3.2 Separation of environmental influences from inherent inaccuracy

write out the list below

- Error-data get separated by error from environment and error from individual

  - Constant/linear error *probably* originates from individual
  - Dynamic error *probably* originates from environment
  - Comparison with existing measurements to statistically improve separation
- Environmental influences are shared with every other individual
- Individual error is kept and continually improved

3.3 Continuous improvement

write out the list below

- Respect existing data
  - per individual
  - from environment
- generate new data from movement
- feed back new data into the map
- improve data (accuracy/quality) using *Kalman Filter*

3.4 Data-Distribution

write out the list below

- Error-data about the individual are not shared
- Error-data about the environment are shared
  - A single centralized map with error-data for each coordinate
  - Each update is used to statistically improve a single coordinate's quality of data (*Kalman-Filter*)

4 Exemplary implementation

write out the list below

- plan, goals, restrictions of implementation
- outline general structure of implementation
- used environment and tools

4.1 Ros Nodes

write out the list below

- existing ROS libs
  - camera tracking
  - bluetooth-control
  - ros-sphero-driver
  - simones error-correction
- newly developed nodes
  - centralized map
  - error-distinction (self vs. env)

5 Evaluation

write out the list below

- evaluation-approach
- formally evaluate math/statistics
  - probabilistic data increase in accuracy
  - time/effort needed single vs. swarm
- evaluate via real-world tests
  - explain setting/arena
  - raw data from multiple runs
  - processing of recorded data
  - insights obtained from experiment
- evaluate via simulation
  - diff. simulation vs. real-world
  - raw data from multiple runs
  - processing of recorded data
  - insights obtained from experiment
- explain results rl vs. sim

6 Future works

write out the list below

- unanswered questions –> unexplained experimental data?
- overcome simplifications used in this work
  - static vs. dynamic environments
- transfer this approach to different levels of reliability
- map to imaginable use-cases (firefighter...)