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

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Master's Thesis

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

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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

Robots and automation are topics that more then ever take place in the average everyday life. Not only are robots well-established in industrial surroundings but also personal appliances are getting common, like autonomous vacuum-robtos or self-driving cars. It's obvious that robots can assist humans on their tasks or even replace the need for humans, sometimes even surpassing human performance or accuracy.

In the recent years robots became so common that due tue improvements in their manufacturing and pricing it is now possible to get elaborated robots as toys for personal usage. This again opened up new posibilies in regards of swarm-robotics.

The field of swarm-intelligence traditionally was inspired by nature itself, seeing large numbers of individual animals like fish or birds behave in such an manner that the combined actions of all the single individuals result in an action none of the individuals could have accomplished on it's own. Many of the theories on swarm-behavior are well known for years. Now with the emerging possibilities introduced by cheap, simple robots these theories can be put to test by experimenting in real-world setups with adjustable individuals. The first results of this research can lately be observed in the form of .

find some popular, demonstrative examples

One persisting problem in the field of real-world robotics is the inherent inaccuracy of the robots actions, it's sensorics and even their surrounding. The models used to define the behavior of the robots often times assumed exact values and for most simple scenarios the observed real-world results were close enough or the deviation could be explained and accounted for. But with increasing complexity of the use-cases the robots are applied in this inaccuracy becomes a bigger problem.

As a solution for this, the models defining the behaviour of the robots tried not to calculate with exact values, as these were known to be unrealistic. Instead a probabilistic apporach was chosen. In that, the varying confidence in the percieved values is accounted for and all the possible results of the possible values are computed each with a probability. This is results not in a single value which might or might not be fitting, but instead in a distribution of possible values and their respective probability to be true. Future iterations of usage or perception of that value then are used to improve and adjust that distribution of probability.

Any usage of these probabilistic data is subject to uncertainty. As a result it is a key factor to improve the probabilistic data to their maximum possible quality. The iterative approach of constantly improving the data indicates a correlation between the number of samples used and the overall quality of the estimate. Here is where Swarm-robotics enters the stage . One of swarm-robotic's key features is a high number of individuals. These individuals are able to cross-check each other's perception and when feeding into a shared estimation can easily outperform a greater number of autarkic individuals, each only acting on it's own.

wording

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).

Sensors

Inaccuracy

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...)