Swarming

Research framework

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1 Problem analysis

Researcher have always been inspired by nature. When they looked at "social" insects like ants they discovered "swarming"[?] . The behaviour of one ant on its own seems illogical, but together they solve problems of great importance for the entire colony. These ants make us of the so called "trail laying" and "trail following" principle. Every ants lays a trail of pheromones, when a few ants walk back and forth to a food source. The one walking the shortest route will lay a more concentrated trail. The other ants will get attracted by the strongest trail, this way a positive feedback loop is created, which will make every ant walk the shortest route if given enough time. This is one example where relatively simple units, can achieve complex goals like path finding because they work together in a swarm. This principle is called "swarm intelligence"[?].

Swarming can have alot of up sides compared to the "classical" approach. A few are: quicker solution time, lower unit complexity and a greater fault tolerance[?]. When for example one of the units breaks down, then will the other units still be able to complete the task. When this happens to one, more complex unit, this wont be the case. For these reasons its interesting to researching the applications of swarming.

2 Context analysis

The Delft university of technology started a program to research the applications of swarming. In this program multiple universities work together to make this research possible. The idea of this program is that each project group contributes a small bit to reach the end result, which will be a working swarm of robots. The technology developed should be modular, so it can be easily used on other platforms.
The programs focus lies on researching the applications of swarming on Mars. Its preferable that the technologies developed also work on Mars, but in some cases other technologies can be used to cut the cost. For example, for a simple proximity sensor on earth, an ultrasonic sensor would do just fine. But in the Mars atmosphere the ultrasonic waves get heavily dampened to the point where the sensor just wont work[?]. The cheapest sensor that would work on Mars would be a lidar[?]. While the average ultrasonic sensor costs around $2e$ the cheapest lidar costs atleast $100e$. In this project the aim is to build one unit for around $200e$, just one lidar sensor would be half of the robots budget. To proof the concept of swarming the robots don't need to be "Mars proof", so costs will be cut where possible.

3 Problem definition

Swarming intelligent systems are typically made up of simple agents(robots) interacting locally with one another and their environment. The group of individuals acting in such manner is referred to as a swarm[?]. For a group of robots to qualify as a swarm-robotics the following criteria have to be met:

- Autonomy - It is required that the individuals that make up the swarm-robotic system are autonomous robots. They are able to physically interact with the environment and affect it.
- Large number - A large number of units is required as well, so the cooperative behavior (and swarm intelligence) may occur. The minimum number is hard to define and justify. The swarm-robotic system can be made of few homogeneous groups of robots consisted of large number of units. Highly heterogeneous robot groups tend to fall outside swarm robotics.
- Limited capabilities - The robots in a swarm should be relatively incapable or inefficien on their own with respect to the task at hand.
- Scalability and robustness - A swarm-robotic system needs to be scalable and robust. Adding the new units will improve the performance of the overall system and on the other hand, loosing some units will not cause the catastrophic failure.
- Distributed coordination - The robots in a swarm should only have local and limited sensing and communication abilities. The coordination between the robots is distributed. The use of a global channel for the coordination would influence the autonomy of the units.

These criteria are a good indication of what makes a system swarm-robotic. But should not be used to determine whether a system is swarm-robotic or not. This is because some criteria are still somewhat vague[?].Looking at these criteria we chose to define the problem into two sub-problems. This division is chosen because problem one will cover distributed coordination and scalability with what we call a "swarming module", which will provide communication and relative localization to the other units in the swarm. And problem two covers Autonomy, Large number and limited capabilities. Problem two will cover the platform that will provide movement and some basic autonomous functions. The projects focus will be the swarming module. The swarming module has to be completely modular so it can easily be used on other robotic platforms in future projects. Because of this the commissioning party stresses that this has to be a finished product. Resources(time) should be focused on the swarming module. For the sake of demonstration, problem two (the robot platform) will also need to be developed. This platform will have to provide some basic autonomous functions like movement and obstacle avoidance. One important requirement is that it should be easily replicated, so a swarm of these platforms can be created.

3.1 Goal

As previously discussed the problem is now divided in two sub-problems with the focus on the swarming module. In this paragraph will be discussed what will be expected from the swarming module and the robot platform.

3.1.1 Swarmingmodule

Distributed coordination is one of the swarming criteria. To achieve this, some form of (relative) localization is needed. This should keep units from moving to close or to far from each other. And could also be used to accomplish certain goals like; mapping, assembly of structures or inspections [?]. Communication is needed to share information about the environment and every units position. Requirements here are that the communication should not be depended on one host and should be scalable. This is so communication is not cut off when one of the units breaks down. The scale-ability is important so that units can be added or removed from the swarm [?]. Because this project is part of a running program the modules made should be modular so they can be used on future projects. Summed up, the swarming module has the following characteristics.

- (Relative) Localization
- Communication
- Scalable
- Modular

3.1.2 Robot platform

To properly demonstrate and test the swarming module, a robotic platform will be needed. This platform will need to meet the swarming criteria of autonomy, large numbers and limited capabilities. The autonomy of the robot should stay simple and robust, the key features are movement, obstacle avoidance and power supply. The robot has to be easily duplicated so multiple units can be produced for the swarm. Also it should be able to house the swarming module.

4 Research-question

The main question of this research is as following: *"How can communication and relative localization be achieved in a swarm or robots?"*. To give an answer to this question there are multiple sub-questions to research first.

4.1 Sub-questions

The following questions need to be answered to come to a good conclusion to our research:

- "What is swarming?"
  - "What is the definition of swarming?"
  - "How many robots are needed to create a swarm?"
  - "How do the units communicate within the swarm?"
  - "How do robots in the swarm know their location?"
- "Swarming communication"
  - "What software protocol should be used?"
  - "What hardware protocol should be used?"
  - "What is de minimal required communication speed?"
  - "What hardware is needed to implement the communication?"
- "Communication between modules"
  - "What software protocol should be used?"
  - "What hardware protocol should be used?"
  - "What is de minimal required communication speed?"
  - "What hardware is needed to implement the communication?"

  - "How can the energy supply be managed?"
  - "Is it possible to implement a recharge point?"
  - "How can the energy supply be handled safely?"
- "How will autonomous obstacle avoidance be achieved?"
  - "What types of sensor technigues are there?"

5 Specifications

In this chapter the functional requirements for building a robot which can perform a task in cooperation with other robots will be defined. The specifications are divided into several features. The specifications to be achieved for swarming will be classified according to the MoSCoW-method. The corresponding specifications are further illustrated in this chapter. In the block diagram shown in Figure 1, the various modules are connected to each other.

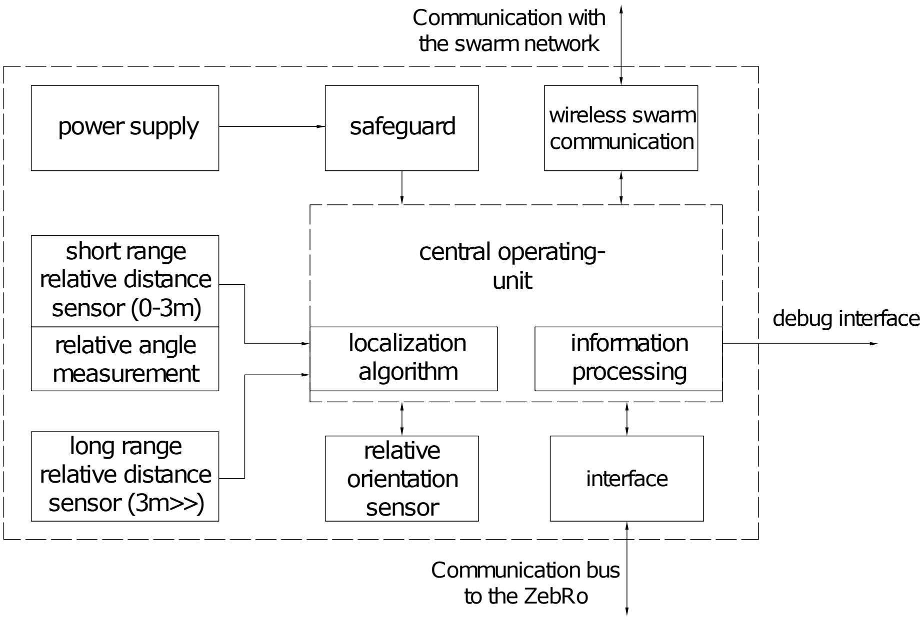

Figure 1: simplified block diagram of the connection of the different subsystems within the robot

5.1 Must haves

M1 - Modular system architecture - Modules developed during this project must be modular so they can be used in future projects.

M2 - Units must be able to communicate with each other - The units in the swarm must be able to exchange information to properly funtion as a swarm. This is discussed in the problem defention[**?**].

M3 - Relative localization to other units - Localization is needed for robots to properly function in a swarm. This is discussed in the problem defention[**?**]

M4 - The communication needs to be wireless - The robots cant be restrained by wires, they need to be able to move freely trough their environment.

M5 - Scalable swarm population - This is one of the criteria of swarming discussed in the problem definition

5.2 Should haves

S1 - The localization technique should be able to work in any kind of noisy environment and therefore is immune to interference sound noise

5.3 Could haves

C1 - Localization also works with heights. Could be able to identify its' surroundings with an additional z-axis. C2 - Shows signs of intelligence - Could learn how to behave on specific (environment) situations

5.4 Won't haves

- A master in the swarm network. There won't be a swarm master controlling the swarm.

6 Sub-specifications

Table 1: Sensors

Module	Sensors
Input	Communication with the system
Output	Communication with the system
Functions	measuring the distance between itself and the environment To communicate the measured value to the controller

The sensors on the robot must create awareness of its surroundings so that he can anticipate. See Table 1

Table 2: Power supply

Module	Power supply
Input	Power supply
Output	Communication with the system
Functions	measuring the voltage/ current of the Power supply To send the measured value to the controller

It is important to measure the battery level to ensure that the robots will not be able malfunction.
The measured value is send to the controller. See Table 2

Table 3: Wireless communication mudule

Module	Wireless communication mudule
Input	Communication with the system Communication with the other robots in the swarm
Output	Communication with the system Communication with the other robots in the swarm
Functions	establishes the communication between the modules swarm Obtains information regarding the distance between the different robots

To communicate between different units a communication network should be set up with a common protocol . In addition, the protocol must be able to provide additional information such as localization. See Table 3

Table 4: Central control unit

Module	Central control unit
Input	All information from the system
Output	All control of the modules in the robot
Functions	All the communication comes together and controls the inputs and outputs

The central control unit handles all communication between the various modules that are present on the robot. See Table 4

6.1 Excising swarming Modules

In this chapter existing swarming modules will be researched and reviewed.

6.1.1 Nanotron

Nanotron is a German company that makes swarm modules. The swarm bee LE is their second swarming module. It communicates on 2.4 GHz radio signal with a speed of 155 kbps. Beside the communication it also contains a localisation module, temperature sensor, a RF amplifier, MEMS, and a microcontroller unit. The communication is trough UART and the API (Application Programming Interface) is controlled by special API commands. To implement self-made application the development board is needed to program the device. This device uses serial communication.

The localisation of Swarmbee has an accuracy of one to two meters. The localisation works better outdoor then indoor. For demonstration the modules should work indoor as well. [?]

Nantron announced there newest module on 25 February 2016. This module has a localisation accuracy of +/- 10 cm. Which is an huge improvement compared to the second generation of the module. It also has an larger range within the different modules can be detected. It will be released soon, and the price will be the same as the second generation. So this would definitely be worth waiting for. [?]

6.1.2 NXP Jennic

Jennic has made a Wireless Microcontroller. Which could operate as a swarm module. Time of flight is implemented in this device, and communication is trough the 2.4Ghz Communication is realised with Zigbee Pro network. Since it is not specifically made for swarming some specification which are defined by Nanotron is not specified here. The accuracy of the localisation is not specified. Expectation is that it is the same as the Nanotron or worse. [?]

Other then these two modules, there are no specific swarm modules that could be found. But there are a lot of research that have made there own localisation in a swarm, and/or their own communication.

7 Conclusion

Since this project is still in the early stages of research the specifications are still limited and not fully substantiated. Parallel to writing this document a lot of research has been done into different implementations of localization and communication in swarming networks. This research can be found in the project folder. When the research is concluded precise specifications can be composed.

7.1 Design approach

To give guidance to this project, a design approach is needed. We will use the V-model to give structure to the design approach. The V-model uses multiple phases to make this project successful. The first three phases are:

- User requirement specification
- Functional specification
- Design specification

At the end of these phases the design stage has ended with all corresponding documents. For each stage that is mentioned above a test phase is present. This is to justify the specifications and decisions that have been made. The test plan can be found the qualification document. When all these stages have been carried out correctly a well tested product will be the result. In the first phase the wishes of the customer will be mapped. From these a research framework will be set up, including a research questions and multiple sub questions. These questions needs to be researched and written down. This will be done in a separate research document. From this document specifications will be made with well supported arguments explaining why. And test conditions for these specifications If everything is complete the next stage will begin: "the Functional specification". From the specification that have been set up the functional specifications will be made. The design is orthogonalised so that is easier to design the separate functions. At the end the separate functions can be added together to make one big flowchart. Again at the end of the stage new test conditions should be made. In the third stage: "the Design specifications" the previous specifications and functional designs will be implemented. All design specifications should be as detailed as possible. For example the dimensions of the components need to be written down. If this phase is completed the next step is the "system build". During the system build the functions of the product will be build separately so that every group member can continue to work. When all separate functions are build they will be tested. If all separate blocks work fine, they can be added to each other so that one product will remain. Thereafter the complete system will be tested. As noted before the test plan will be written down in the qualification document.

8 Bibliography