Major Project outline specification

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Project Title: Map building using swarm intelligence

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1 Project Description

The goal of my project is to be able to use swarm intelligence to map a target area. Some of the key points of this task are:

- networking between nodes(robots)

- finding a good deployment solution for the swarm

- mapping the area (including obstacle avoidance)

- moving the swarm in unison while covering the largest possible area with the sensors

- finding a mapping solution for rooms/corridors

Each of this tasks has to be completed in order of getting a reasonably good solution with might be used to map unknown areas,however it does not need to be limited to mapping. The underlying key features: networking between the robots, deployment and obstacle avoidance techniques etc. can be used in all kind of applications which require robot flocking. One example could be to use robots equipped with cameras to get an inside view of potential dangerous buildings to asses the area before sending in humans. In my project however the solution will be limited to range finder and communication sensors to simply map the target area. I believe this is a worthwhile project as robot applications can gain greatly when used correctly in flocks.

The main aspect of my project is to find a good deployment and communication solution for the flock, to assure that no units loose communication with the other and to be able to move the flock in unison while covering the largest possible area.
As I said above I am going to use the flock to map the area but theoretically a user can configure the robots to hold any kind of sensor e.g cameras. Given this and my plan to assure maximum area coverage while not having the need of a previous map or location information like GPS a user can then use the flock and their sensors for what ever task which requires wide area coverage.
In my project I am going to use a limited number of robots however the flocking solution should be scalable enough for a flock of any size.

The mapping part of my project is going to use simple obstacle recognition and avoidance techniques which in the same time is going to be mapped. The problem with this is that I have to find a solution for map sharing between the robots as well as how to improve map accuracy. Each unit can easily map an area using distance sensors however to able to compare the map fragments with each other a global reference point(or a number of reference points) will be needed.
As my project is going to be simulator only this should not be a problem however as my indention is to make it program as applicable for the real world as possible as solution needs to be found. In one of the research papers I am using a solution using a millimetre wave radar was used to keep track of the global reference points while acquiring new obstacles[DNC+01]. As I planed to make my solution suitable for E-puck robots I will have to find a suitable solution using simpler techniques, however I do not have a clear idea how to do this as of this moment.

My project is as stated before simulator based, this is for a sake of simplicity and the limited timespan we have to complete the project. I am going to use the Webots^{TM}robotic simulator and programs which work in the simulator should also work problem less on the E-puck robots (assuming real world restrictions are fulfilled i.e. the robots have the same sensor equipment).
The programming language I am going to use is C.
As this is a very research heavy project the information in this section is the outline as to date however I might have to change some aspects of it once I acquire new information and find newer, better solutions to a problem.

2   Proposed Tasks

The simulator I am going to use is the Webots^{TM}simulator which I will use to simulate a flock of
E-puck robots. The programming language I am going to use is C.
My project is very research heavy and will perform research throughout the entire project. So far I have
looked at research papers concerning SLAM (Simultaneous Localization and Map building)[DNC⁺01],
flock intelligence[Rey87] and networking between robots[PS04]. Theses gave me a general idea for a
solution, however I have to look more into similar papers.

The robots need to be able to deploy effectively while still staying in communication range to each
other, as well covering the largest possible area. In a scenario where a number of different rooms exist a
solution must be found to keep up communication, assuming that communication through walls is not
possible.
For this kind of scenario it would be essential to assign roles to the different robots e.g. scout and
communicator roles. Where the communicator stays in range of other communicators while the scouts
map the area inside their communication range. This would mean that a room can be mapped by the
scouts while the communicators stays inside the doorway and keeps contact with the rest of the flock.
I am at this moment not sure how to define scout and communicator roles as I image that it would be
more useful to have all robots scouting in the beginning of a session and change then up into smaller
"groups" which stay in contact through the communicators once the flock spreads out into
corridor/room areas. I am not yet sure how to handle this problem yet and I am doing research on this
matter.

For the mapping part of the area I am going to use distances sensors for the simulated robots. I will
also use this range data for obstacle avoidance techniques. The main problem here is to be able to
define global reference points which will allow me to piece together the different map fragments I get
from the different robots. As I for realism sake do not have GPS information I will have to use the data
from the range finders. I am not sure how to deal with the global reference point problem as of yet.
One possible solution would be to build the map dynamically on a central robot which would mean that
all map data need to be transferred to it the moment it is acquired, this could lead to networking
problems on larger flocks and I am doing research on to tackle this problem.

3   Project Deliverables

3.1   Final Program

A working program which holds solutions to the deployment, communication and mapping problems.
The solution should be scalable for a flock of any size and a demonstration will show that the flock is
able to deploy effectively and map the area as accurately as possible.

3.2   Source Code and Testing

The complete, commented source code as well as any testing data which have been acquired.
The testing data will be part of the final documentation while the code can be delivered separately.
This also includes any world and robot files I created and used for the Webots^{TM}simulator.

3.3   Final Report

The full report detailing the process as well as any changes to the design. This will include the design of
the system and my reasoning for this design, the output data and detailed, analysed testing data. The
testing analyse will hold all information I gather, problems I found during the testing and how I solved
them.
It will hold a reference section of all sources I used for my research and the report will hold information
about what information I gathered from them. This will including dates of access for web pages.

References

[DNC+01] M. W. M. G. Dissanayake, P. Newman, S. Clark, H. F. Durrant-Whyte, and M. Csorba. A solution to the simultaneous localization and map building (SLAM) problem. *Robotics and Automation, IEEE Transactions on*, 17(3):229–241, June 2001.

This paper proves that SLAM is possible and gives a solution using global referance points for map building. The solution in this paper however was used on only a single car rather than a flock and using a millimeter wave radar for localising different obstacles and referance points. This makes this solution not applicable for my project, however it gave me some ideas concerning referance points.

[PS04] S. Poduri and G. Sukhatme. Constrained coverage for mobile sensor networks. In *Robotics and Automation, 2004. Proceedings. ICRA '04. 2004 IEEE International Conference on*, volume 1, pages 165–171 Vol.1. IEEE, April 2004.

This paper gives a good solution to the flock deployment and communication problem using a nearest-neighbor approach. This approach is scalable for a flock of any size and is my base idea for the deployment I will implement in my program.

[Rey87] Craig W. Reynolds. Flocks, Herds and Schools: A Distributed Behavioral Model. In *Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques*, volume 21 of *SIGGRAPH '87*, pages 25–34, New York, NY, USA, July 1987. ACM.

While not entirely relevant to my problem it rises a few important points about flock behavior. These include collision avoidance between members of the flock and the reduced perceptance of members whic hare moving in the middle of the flock. Collision avoidance between members will play a big role when trying to navigate the flock through a tight environment.