Work-plan for Master's thesis

Multi-Robot Formations for Area Coverage in Space Applications

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1. MAIN IDEA & OBJECTIVES

My Research will be in the field of swarm robotics where I will try to investigate algorithms for area coverage problems. The solution should be general enough to cover applications for satellites (for ISSL research) as well as rovers (for TKK research). At the beginning the goal will be to cover an area with simple shapes (most likely circles), later on, depending on progress, difficulty, and time availability, more difficult (also non-convex) shapes and areas (e.g. representing obstacles in the line of sight) will be added. Of interest is to measure of how optimal the coverage is and optimizing the positioning (i.e. various ways to do this should be investigated), this could be in terms of overlap, fluctuation (e.g. changing coverage areas of each unit) or limited resources (e.g. rover energy/movement, satellite fuel).

Another possibility for extension is a time varying target area, which would represent e.g. a continues ground scan by the satellites with changing scan widths. Implementation of the algorithm will also be part of the thesis project. This might take some time especially with coordinating all the needed (software) packages as well as trying to understand (and use) the tools used both at TKK and ISSL.

2. IMPORTANT DATES

These dates shown in the tables are important deadlines or milestones for the thesis project. Table 1 shows the planned (before the project started) timeline, whereas the actual dates, when important events and/or milestones happened throughout the project, are shown in Table 2. This should make it easier to see if the project is on time or not.

3. DELIVERABLES

The first main focus is on being able to simulate the robot movement/behaviour/placement for the coverage of a an area. It is planned to do an actual robotic implementation with the Marsupians at TKK's lab *(this is also depending on availability)*.

TODO: this needs to be discuss with the supervisors/tutors to clearly define the deliverables and also the boundaries (see below)

4. THINGS TO DO

4.1 Thesis Applications - DONE

Applications for the Master's thesis have to be submitted to TKK and LTU. The forms with the (preliminary) title "Multi-Robot Formations for Area Coverage in Space Applications" were handed in to Anja on December 18 and e-mailed to LTU on December 31. The LTU mail also included a preliminary topic description[1] (about 1 page). The LTU documents were also e-mailed to Tomi since TKK needs copies.

4.2 SpaceMaster Seminar

According to last year's schedule the Seminar was planned to run from January to February. My guess is that it will be at about the same time this year. During this time I am still at the ISSL. Some possibilities for my participation were discussed with Tomi before leaving (just paper, presentation when I come back, tele-presentation via Skype,...).

This still needs to be cleared out.

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[1] date taken from last year's schedule, needs to be confirmed by TKK for this year

[1] `http://Juxi.net/studies/SpaceMaster/Thesis/ProjectDescription.pdf`

Table 1: Planned Timeline of Milestones

Dec 20	finalize prelim. thesis topic
Dec 25	going to Japan
Dec 31	Thesis Application LTU and TKK
Jan 5	start of work in Japan
Jan 15	send work-plan and TOC to TKK
(February	*visit of Prof. Kalevi Hyyppä)*
(End of February	*SpaceMaster seminar)*
Feb 15	finish Literature Review
Apr 5	return to Helsinki
Apr 9-15	Easter holidays at TKK
Jun 1[1]	mid-term presentation
Jun 10[1]	release thesis draft to Professors
July	Tomi, Aarne Holidays
Aug 4[1]	final deadline
Aug 18[1]	presentation
Sep 3[1]	Graduation TKK

Table 2: Actual Timeline of Tasks done

Dec 15	started with Literature Review
Dec 18	TKK form handed in
Dec 26	arriving in Tokyo
Dec 31	LTU form mailed
Jan 5	started at ISSL
Jan 14	started Japanese Language course
Jan 15	work-plan and TOC sent to TKK

4.3 Literature Review

Planned: Dec 15 - Feb 15 *(duration: 5-6 weeks)*
This is part of the seminar and part of every scientific work, since comprehensive knowledge of the literature of the field is necessary to start research. It tries to review the current state and critical points of research in a particular area of interest and provide a solid background for further investigation, especially in the ever growing amount of papers published. Part of the Literature Review will be to look at old SpaceMaster master's theses. I am also trying to so some investigation into multi satellite formation flying and related topics that are done here at ISSL. *Deadline is to be determined by Tomi and the SpaceMaster seminar.*

4.4 Define Boundary Conditions

Planned: Jan 13 - Jan 30 *duration: 2-3 weeks*
The project and thesis should clearly define the requirements and assumptions about the robots, the environment, the software and all other interfaces and connection points. The Deliverables defined in Section 3 are closely coupled with the boundary conditions defined here. These will be very strict at the beginning and may be loosened later if there is enough progress and if time permits.

4.5 Simulator Investigation

Planned: Jan 15 - Jan 27 *duration: 1-2 weeks*
The main task here is to find out which simulators are used at TKK and ISSL respectively (and maybe other ones). This should be a look at what is currently in use not really a review of papers, although it will be part of it when the solutions used at both labs are not sufficient for the multi-robot/satellite research I am planning to do. In that case other simulators will have to be investigated and evaluated for usefulness in respect to this thesis' area. TODO: (put in the sim investig pdf - ISSL their own attitude control simulator in Java, not much use for me ... :/)

4.6 Japanese Language Learning

Planned: while in Tokyo *(course: Jan 14 - Feb 4)*
The OICE at the School of Engineering, Tokyo Daigaku, has a semester long Japanese course which started already in October 2008. I am able to join the group for the last few courses and will have to do some self study to be able to follow. Classes are held Monday and Wednesdays. The aim is to get very basic proficiency in Japanese ("survival phrases").

4.7 Mathematical Formulation of the Coverage Problem

Planned: Jan 16 - ongoing
Depending on the complexity chosen at the end this might be a more than trivial job. It will run parallel to the other parts of research and hopefully influence or simplify the simulation and implementation tasks at hand. An effort will be taken to formalize the problem as much as possible (and useful!). The Literature Review will help in figuring out how much of this has already be done by others.

4.8 Heuristics for the Coverage Problem

Start: Feb 9 *(will be running for almost the full project)*
TODO: define this here a bit more
TODO: Genetic/self-learning ... something like this ...
The Literature Review will help to spot feasible heuristics to solve the problem of area coverage. The improvement and testing of the heuristic will most likely run parallel to the whole project until the experiments are finished. **TODO: Needs to be more defined!**

4.9 Multi-Agent Frameworks Research

Planned: Feb 25 - Mar 13 *(duration: 2-3 weeks)*
A thorough check-up on the frameworks which TKK currently uses, investigate which ones were implemented before and which ones will work best for this project. Start implementing/integrating them into the project and work on the simulation with the full framework used (for easier transition to live system later). Time-wise this will start with (or parallel to) the Literature Review, although it will concentrate on which systems are used and not which ones are proposed.

4.10 Simulator Implementation

Start: Feb 12 *(will be running for almost the full project)*
A simulator for visualizing the results of the coverage problem solution (mainly coming from the heuristic) and allow to simulate the robot behaviour. The simulator will be used to test the algorithms for the best coverage, its results will also be compared to the actual implementation, to see if the assumptions also work in real applications.
A rough timeline starts with the implementation of the simulator in mid February and hopes to have some tangible solutions to present with the simulator by the time I return to Europe (April). The simulator could also be extended to allow a more realistic simulation with real data inputs (e.g. lunar surface data or closer simulation of the robot (including movement)).

4.11 Robot Implementation and Experiments

Planned: not before Apr 6 *(duration: 5-10 weeks)*
The implementation of the algorithms to work for the real robots is (hopefully) going to be part of the thesis project. This depends of course on the availability of the Marsupians in the lab. Currently I hope to have something (very basic problem) run on the robots by the end of April or mid May. The problem is then going to increase and the data will constantly be checked with the simulated version of the problem. Another thing to think is how to design and quantify the results of experiments done with the real robots. (e.g. how to simulate the sensor coverage area in real robots?)

4.12 Evaluation of the Results

Planned: tbd *(duration: 2-3 weeks)*
Comparing the real world results with the simulated results and maybe different versions of the heuristics will give an evaluation of the system which can be used to write the conclusion of the thesis. Also here real world test (astronaut support mission of multiple rovers (like initial ideas) with real data (of surface of moon for example and marsupians data)) data would be very good and useful.

5. CALENDAR

This is the preliminary work plan for the Master's thesis at TKK and ISSL.

January 2009

Monday	Tuesday	Wednesday	Thursday	Friday
29	30	31	1	2
5 — 10:00 AM start at ISSL	6 Literature Review	7 ■ 5:00 PM presentation about myself ISSL	8	9
12 Coming-of-Age Day	13 define boundary conditions / Literature Review: Coverage	14 finish initial Work Plan / ■ 1:30 PM Japanese Course	15 investigate simulation software systems used / finish prelim TOC	16 start: formali...tical problem
19 Literature Review: Multi Agent/Robot / define boundary conditions / investigate simulation software systems used / ■ 1:30 PM Japanse Course	20	21 PRISM launch / ■ 1:30 PM Japanese Course	22	23
26 Literature Review: Satellites / define boundary conditions / investigate simulation software systems used / ■ 1:30 PM Japanse Course	27	28 ■ 1:30 PM Japanse Course	29	30

February 2009

Monday	Tuesday	Wednesday	Thursday	Friday
26 define boundary conditions / Literature Review: Satellites / investigate simulation software systems used / ■ 1:30 PM Japanse Course	27	28 ■ 1:30 PM Japanse Course	29	30
2 Literature Review / ■ 1:30 PM Japanse Course	3	4 ■ 1:30 PM Japanese Course	5	6
9 Heuristics Investigation and Implementation / Literature Review	10	11 National Foundation Day	12 Literature Review / Simulation Implementation	13
16 Heuristics Investigation and Implementation / Simulation Implementation	17	18	19	20
23 Heuristics Investigation and Implementation / Simulation Implementation	24	25 Multi Robot Framework Investigation	26	27

March 2009

Monday	Tuesday	Wednesday	Thursday	Friday
23 Heuristics Investigation and Implementation / Simulation Implementation	24	25 Multi Robot Framework Investigation	26	27
2 Simulation Implementation / Multi Robot Framework Investigation / Heuristics Investigation and Implementation	3	4	5 LAST YEAR S...Presentations	6
9 Heuristics Investigation and Implementation / Multi Robot Framework Investigation / Simulation Implementation	10	11	12	13
16 Simulation Implementation / Heuristics Investigation and Implementation	17	18	19	20
23 Simulation Implementation / Heuristics Investigation and Implementation	24	25	26	27
30 Simulation Implementation / Heuristics Investigation and Implementation	31	1	2	3

April 2009

Monday	Tuesday	Wednesday	Thursday	Friday
30 Simulation Implementation / Heuristics Investigation and Implementation	31	1	2	3
6 back at TKK	7 Robot Implementation and Experiments / Simulation Implementation	8	9 Easter Holidays	10
13 Easter Holidays	14	15	16 Robot Implementation and Experiments / Simulation Implementation	17
20 Simulation Implementation / Robot Implementation and Experiments	21	22	23	24
27 Robot Implementation and Experiments	28	29	30	1 May Day

June 2009

Monday	Tuesday	Wednesday	Thursday	Friday
1 Robot Implementation and Experiments	2	3	4	5
8 Robot Implementation and Experiments / Evaluation of the Results	9	10 LAST YEAR ...d presentation / LAST YEAR r...t to professor	11	12
15 Robot Implementation and Experiments / Evaluation of the Results	16	17	18	19
22 Robot Implementation and Experiments / Evaluation of the Results	23	24	25	26
29	30	1	2	3

July 2009

Monday	Tuesday	Wednesday	Thursday	Friday
29	30	1	2	3
6	7	8	9	10
13	14	15	16	17
20	21	22	23	24
27	28	29	30	31

August 2009

	Monday	Tuesday	Wednesday	Thursday	Friday
	27	28	29	30	31
	3	4 LAST YEAR final deadline	5	6	7
	10	11	12	13	14
	17	18 LAST YEAR presentations	19	20	21
	24	25	26	27	28
	31	1	2 LAST YEAR G...eremony TKK	3	4

Holidays
Thesis

6. PRELIMINARY TOC

1. Introduction and Motivation

2. Problem Formulation

    (a) Mathematical formulation of coverage
    (b) some more maths and coverage topics?
    (c) maybe also multi-robot stuff in here?

3. Algorithmic Solutions/Strategies/Heuristics

    (a) (Evolutionary?)
    (b) (Machine Learning?)
    (c) Formalized?

4. Simulation

    (a) Results

5. Experiments

    (a) Results

6. Conclusion

    (a) compare results
    (b) possible future research...