

Determining Saturation Point in Swarm Robot

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Abstract— Swarm robotics is a new approach to the coordination of large numbers of relatively simple robots takes its inspiration from the system-level functioning of social insects which have three desired characteristics for multi-robot systems: robustness, flexibility and scalability. Since some of swarm robotics future applications require working in closed environment (e.g. Houses, Warehouses, etc), in this paper we tried to figure the ideal number of agents needed to perform mapping task in those kind of environments (saturation point), taking into account the relation between time and cost. We used Breve -3D Environment for the Simulation of Decentralized Systems- to build our simulation. Since many factors can affect the ideal number of agents, we studied selected important factors which we believe have the highest effects on the final result like task time, area, cost and map's capacity. In conclusion we find what it has to be the saturation point for swarm robotics mapping task. This research will lead to decrease the cost and improve the efficiency in swarm robotics' applications.

Keywords— swarm robotics; autonomous robots; network robotics; swarm intelligence, distributed robotics; collective robotics.

I. INTRODUCTION

Swarm robotics is a relatively new area of research and very diverse approaches are reported in the literature. However descriptions of everyday applications are as yet relatively rare. When we searched potential applications for swarm of robots, we found that industrial warehouses in the emergency accidents (e.g. Fire) are a major concern. Searching for victims will be dangerous, because of the combination of the warehouses' enormous dimensions and the expected low visibility when smoke develops. The mapping of an industrial warehouse in smoke was subsequently made the central application scenario of our project.

A major role of the robot swarm in this scenario is to support human beings searching the warehouse by providing fast, simple internal area map to enhance the human's navigation. Since no heavy physical task is assigned to the robots, the swarm may consist of small and even mini-robots. Whereas locomotion is not a problem, the smoke poses a problem for human beings as well as for robots. The low visibility causes a number of related problems: it hampers navigation as the sight on landmarks is lost and subsequently localization and mapping turn problematic. Swarm robots could be a great benefit in these applications. A question raises here, how many robots we need to use for this mapping application?

More robots will allow the swarm to perform mapping much faster, but there is always saturation point where adding more robots would be wasteful at best and could lead to efficiency reduction at worst case. Saturation point could be affected by many factors (e.g. Robot's speed and size, warehouse size, etc).

II. SWARM ROBOTICS BRIEF DEFINITION

Swarm robotics is a new approach to the coordination of large numbers of relatively simple robots takes its inspiration from the system-level functioning of social insects which have three desired characteristics for multi-robot systems: robustness, flexibility and scalability. Key terms are swarm aggregation, navigation, coordination and control. Certain approaches focus on basically autonomous individuals that can physically connect to for a larger 'organism', refer to the S-Bot project or the Replicator project. We also mention the Particle Swarm Optimisation PSO and Swarm Intelligence approaches which use swarm simulations to find problem solutions. Different simulation platforms are used in different places. Such as SWarm Experimentation and Evaluation Platform (*SWEEP*) is used in [1]. 3D dynamics simulator of a multi-agent system (*swarmbot3d*) is used in [2]. Other 3D dynamics simulation environment is *Breve* [3] which is used in this paper.

III. MODELLING

A. Environment

We used Breve [3] which is a 3D simulation environment designed for simulation of decentralized systems and artificial life. Since we are concerning about mapping only, we used very simple representation for the robots in the environment. Every robot is represented as simple cubic with size $(0.35 * 0.35 * 0.1)$ meter. And equipped with six IR sensors, the three front sensors are used to detect obstacles for mapping while all six sensors are used to communicate with other robots around. Sensor's detection distance is set to one meter and propagating distance is set to five meters. Performance result for model is presented here in terms of its Simulation Time Multiplier (STM) value (figure.1) which refers to how fast real time can be simulated. STM values were obtained running the tests on a dual 3.00 GHz hp PC with one Intel Graphic Media accelerator 3100 graphics card.



Figure 1. Simulation Time Multiplier vs. Agents number

B. Mapping Method

Robots are able to sense obstacles and other robots around (figure. 2). They are also able to make brief (25*25) binary maps of the surrounding environment and transmit them to neighbour robots. This allows robots to gather information about obscure areas which other robots already explored without the need to explore it again.

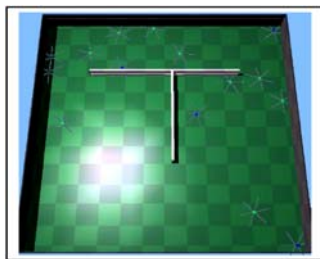


Figure 2. Simulation snapshot.

1	1	1	-----	0	0	0	0
1	0	0	0	0	0	0	0
1	0	1	1	1	1	0	0
...	0	0	0	1	0	0	0
...	0	0	0	1	0	0	0
1	0	0	0	1	0	0	0
1	0	0	0	0	0	0	0
1	1	1	-----	0	0	0	0

Figure 3. Mapping the environment

We suggested the maps to be represented as binary matrices with 0, 1 Values (figure. 3). The value 1 represents an obstacle while 0 represents unknown or clear area. Every row in the matrix considered as one binary number and robots only save the corresponding decimal value, so the whole map

is saved as one vector. That is making it much easier to process or transmit to other robots. When map is transmitted to another robot, it's logically operated with the old saved map and the result will be a united map with more information about the unknown area.

IV. EXPERIMENTS AND RESULTS

A. Experiments

Experiments are done in three sized areas (100*100 / 200*200 / 300*300) meter. Those areas have the same scheme represented in figure 4, while every obstacle's length is multiplied by K (Area size multiplier). That means degree of complexity will not change while capacity will decrease. For every K= 1, 2, 3 we register mapping percentage for every robot every 50 simulation's time step. The result will appear as shown in Figure 5. By repeating the experiment with different number of robots we can get 3D-chart as the one shown in Figure 6.

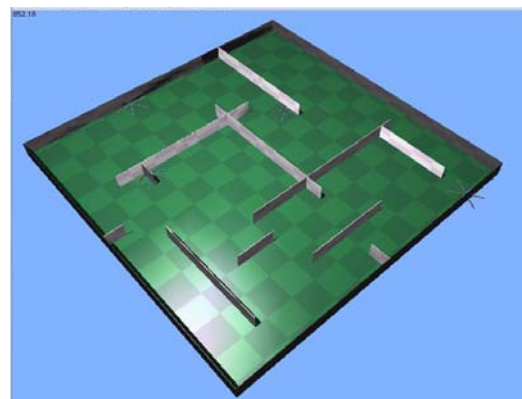


Figure 4. Environment

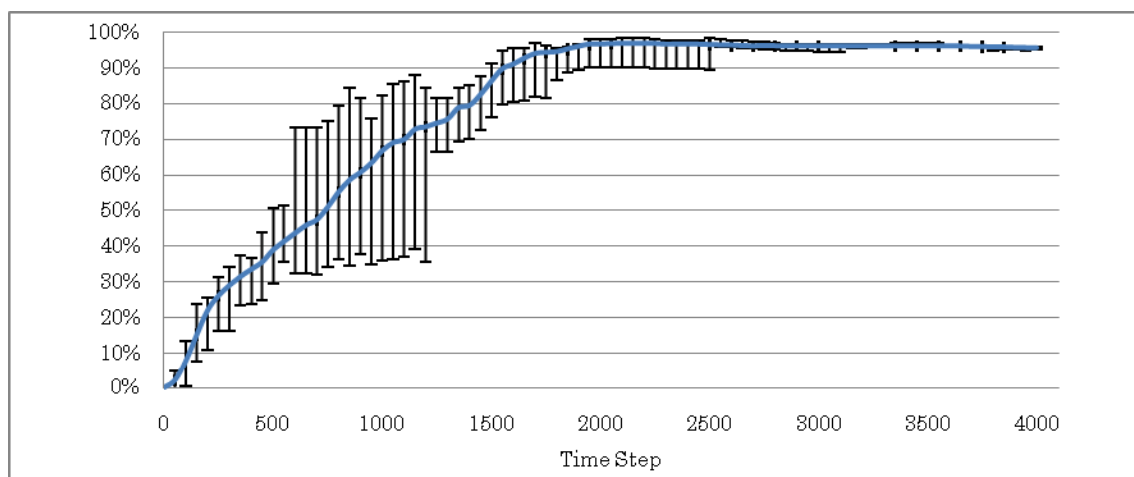


Figure 5. 25 Robots mapping vs. time, Area size 200 * 200 m

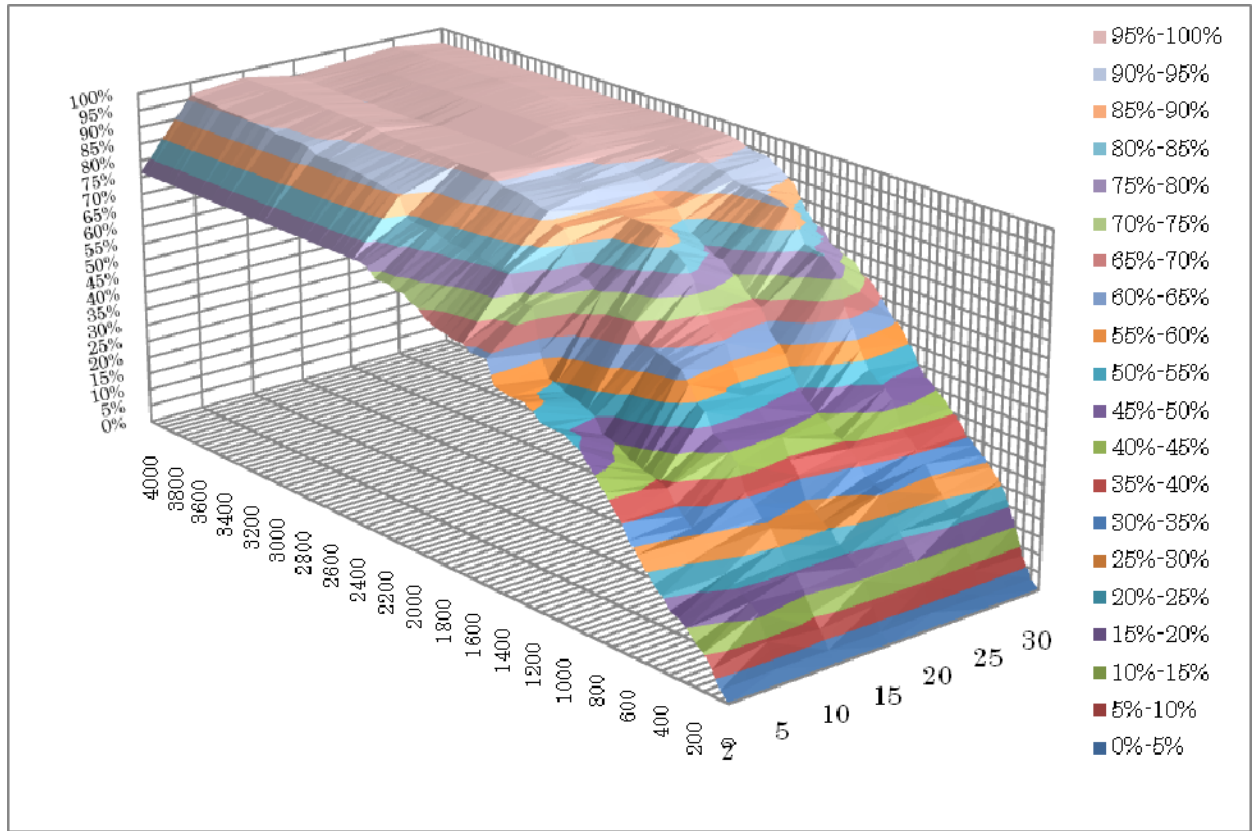


Figure 6. Robots Mapping vs. time and robots number, Area size 200 * 200 m

B. Calculating the optimum number of swarm robot agents

Differentiation must be done between several variables to get the optimum number of Agents (e.g. Time, Cost, Goal approach). The final cost equation could be given as following:

$$C_{tot} = (T.C_t + R.C_r).M_{per}$$

C_{tot} : Total cost.

T : Time needed to approach goal.

R : Number of swarm robot agents needed to approach goal.

C_t : Time valuation Coefficient.

C_r : Robot valuation Coefficient.

M_{per} : Desired mapping percentage.

$$T_R = \frac{C_r}{C_t} \Rightarrow C_{tot} = C_r \left(\frac{T}{T_R} + R \right) . M_{per}$$

$$C_{tot} = C_r (R_T + R) . M_{per} \Rightarrow$$

$$C_{tot} = C_r . R_{tot} . M_{per}$$

T_R : Constant represents the time equivalent to the value of one robot.

R_{tot} : Total agents' number.

We can realize that C_r is a constant can be calculated easily depending on the total cost for one robot. C_t is another constant which define the value of time unit. Time can be considered much valuable in sever applications. For example mapping the environment in case of fire fighting [4] where's moments can be crucial for the survival of people tapped in fire. Time could be less valuable in case of mapping under usual conditions. To find optimum agents' number we investigate the minimum cost.

$$\min C_{tot} \equiv \min R_{tot}$$

We considered mapping 90% of the area is a sufficient goal. We applied the former equations to find saturation point for two types of applications: In first one, time factor is very curial ($T_R = 10$) for the success of the mission (e.g. Search for survivors in disaster situations). In the second type, time factor is less important ($T_R = 100$). In Figure 7 we can get saturation point (Ideal robot number) for the least cost in every experiment. Figure 8 shows how saturation point changed when K (Area size multiplier) changed.

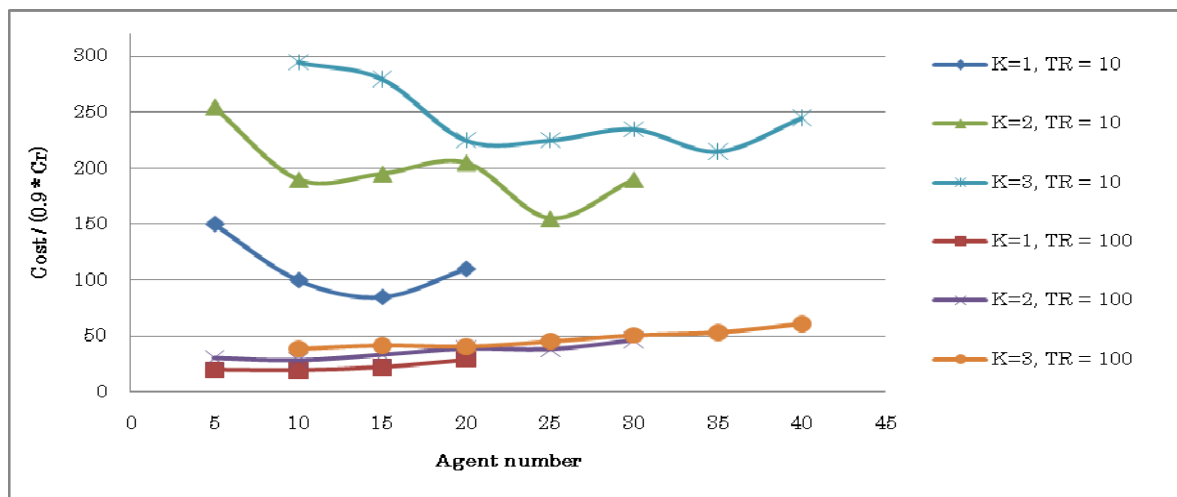


Figure 7. Optimum Agent Number for 90% mapping goal

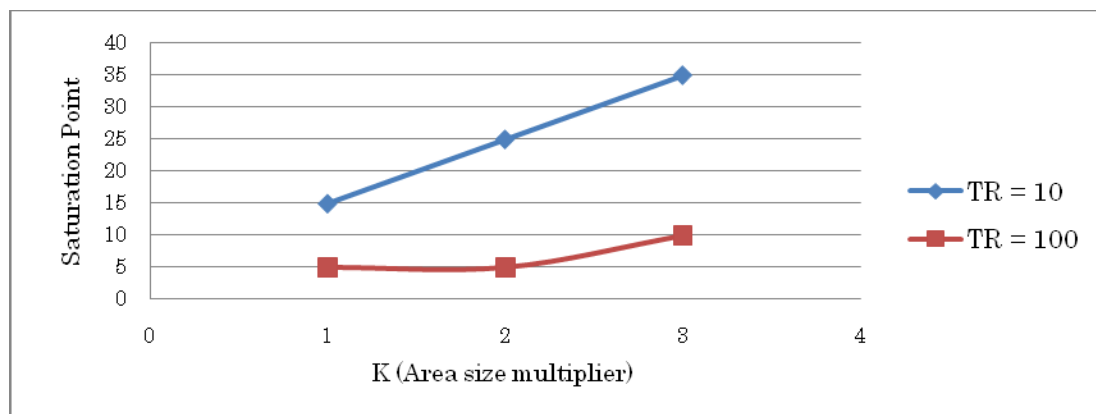


Figure 8. Saturation point vs. Area

V. CONCLUSIONS

This paper concerned about finding saturate point in swarm robotics' mapping applications. This issue had not been mentioned adequately in swarm robotics publications. There are many factors affect saturate point and these factors can be varied from one application to another. Using the right number of robots is crucial to reduce cost and increase efficiency in swarm robotics applications. I have also to mention that research in this paper was restricted to simulation study, more practical studies is needed in future to validate the results.

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