

# AquaRobots Phase II: Oil Spillage Detection Using Swarm AquaBots

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**Abstract.** Applications of underwater and space exploration robots and those operating in hazardous environments can benefit from the use of multi-robot system. In challenging applications like these, multi-robot systems can deal with wide range of tasks, cope with environmental changes including the loss of robots, faster, and often relatively cheaper. The main aim of the project reported in this paper is to build autonomous marine robots (AquaBots), to deploy these AquaBots in group to form a swarm and assign them the task of searching the surrounding area for any oil spillage. In the prototypes, that spillage is simulated using target material. Finally optimize the number of robots in a swarm based on the time estimates to achieve this goal.

**Keywords** - *Aquarobots, swarms, search robots, spatial detection.*

## 1 Introduction

Swarm robots is the branch of robotics which deals with the study of how a large number of relatively simple agents can be designed and coordinated such that a desired collective behaviour emerges from their interactions among the agents and between the agents and the environment [11]. It was initially inspired by the emergent behaviours observed in insects, ants, termites, wasps and bees which stand as fascinating examples of how a large number of simple individuals can collectively interact to create intelligent systems. Social insects are well known to coordinate their actions to accomplish tasks that are beyond the capabilities of a single individual; for example termites build large and complex mounds, army of ants organize impressive foraging raids, and ants can collectively carry large preys [1].

Swarm robotics is one of the active areas of robotics research with enormous recent advances in this field [2]. This paper on swarm robotics presents the way in which how swarm intelligence can be implemented to address one of the major challenges that the world is facing today and demonstrates how this can be resolved.

Nowadays oil spills in oceans presents the potential for enormous harm to deep Ocean and coastal fishing and fisheries [3]. Therefore the aim of the project is to build water surface robots (Aquabots) extending on previous work in developing small scale aquarobots [10], and to deploy them in group to form a swarm and assign them the task of searching the surrounding area for any oil spill or exotic material. Finally optimize the swarm number by changing the team size for a give task i.e. to estimate the appropriate team size required to

achieve this goal by measuring the time taken.

## 2 BACKGROUND

Swarm robots find its theoretical roots in studies of animal societies such as bees and ants. Social insects are valuable source of inspiration for designing collectively intelligent systems comprising many agents [4].

### 2.1 Problem Domain

Oil pollution arising either from marine accidents or from routine ship operations is one of the major problems that threaten the equilibrium of the marine environment. They produce both economical and ecological damage. Wildlife including fish, sea creatures, mammals, reptiles, amphibians and birds that live in or near the ocean are also poisoned by oil waste. Oil waste that invades and pollutes these areas and negatively affects human activities can have devastating and long-term effects on the local economy and society [3].

The efforts in protecting the environment after an oil spill (through an anti-spill operation) could cost billions of dollars in cleanup and damage costs (sources ITOFF). Therefore marine oil pollution has attracted increasing research effort over past few decades to overcome this problem [5]. So, It is important for us to understand how overwhelm of modernisation has impacted the ecosystem. Today oil spills in water bodies is one of the major issues that we have to look upon acutely and take necessary measures to save the marine life.

In order to demonstrate the capabilities and potential of swarm robots to tackle this problem AquaBots where developed and tested in a pool of area 2.62 m<sup>2</sup>. AquaBots searched the surrounding area to locate the target/exotic material by avoiding any obstacle in their path. In each of the iteration the complexity of the problem (number of obstacles) was changed in order to check robustness of the control algorithm implemented. The experiments were carried out under certain test conditions like the robots were tested in an indoor environment since the sensors were calibrated for these conditions. Treating AquaBots as mobile sensors is the subject of another ongoing research [12].

### 2.2 Methodologies adopted in overcoming this Problem.

The Elimination Unit for Marine Oil Pollution (EU-MOP) project uses this multi-robot system to respond to oil spills in oceans [6]. According [6] the operation of the working of the multi robots system is divided into different phases, after the detection of oil and initial phase, the robots and support vessel the so called mother ship

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will be ready for cleaning operation. Later the robots will start the oil recovery operation with the help of skimmers. As every unit has only limited energy supply and limited storage capacities onboard, they have to move back to the mother ship in the case its energy is running low or its oil storage is full. As soon as the whole oil spill is eliminated the units will move back to the mother ship. In another similar project by [7] uses autonomous multi-robot system for confinement of spilled oil. In this case, a simulation study was made, initially with two ships towing the boom and later on extended to swarm of robots which navigate through and confine the oil spill. But the robots are not capable of removing spills; they would only confine the spills by not allowing the oil to spread. In the project presented in this paper the ultimate focus was locating the object in a confined search area and identify whether the object is target material or not. When the target material was found the AquaBot stops immediately. In other words, our focus is the speed and consistency of time needed in finding the spillage spots in the infected area.

### 3 GENERALISED MODEL OF SYSTEM

While the aquabots perform the search operation, the interaction between the aquabots or between the aquabots and environment is reactive behaviour. The control is decentralised i.e. the aquabots are not in network. The advantage of having this type of controller is that any number of aquabots can be appended to the team at any point of time without re-synchronising the entire system [8].

The whole search operation of aquabot is based on set of pre-defined rules. So, the aquabots just follows the rules based on their priorities. The aquabots during the search operation should be capable avoiding obstacles, if any, in their path. The threshold value for the boats to change their direction in case of obstacle was determined by experimentation and ultrasonic range sensor was used for this purpose.

The Aquabots consisted of light sensor pointing downward as shown in figure1. Two ultrasonic sensors and one infrared sensor were used for changing the direction in case any obstacle in their path. RCX microcontrollers consisting of three input ports to read the sensors value and three output ports for the actuators were used. Lego motors with internal gearing were used to propel the boats [9].

The light sensor continuously searches the target object based on the light intensity. If the target object is found the boats stop immediately and helps in locating the target substance but if the object doesnt match the template (light intensity), the search operation is continued. The infra-red sensor and ultrasonic sensors mounted at the front measures the distance from nearest obstacle and compares it with threshold value, if the distance is less than the threshold value the boat changes the direction or it continues to move in straight path. The boat turns right if left ultrasonic sensor reading is greater or turns left if right ultrasonic sensor reading is greater. This process is looped until the target object is found.

The Aquabots were implemented in swarm, initially with one aquabot and gradually the number was increased to four to determine the appropriate size of team required to locate the target object in a test area of 2.62 m<sup>2</sup>. It was found that the search time decreased as the team size was increased but after certain critical value the time again increased due to interference between the aquabots. The experiments revealed that three aquabots were appropriate and resulted in minimal search time.

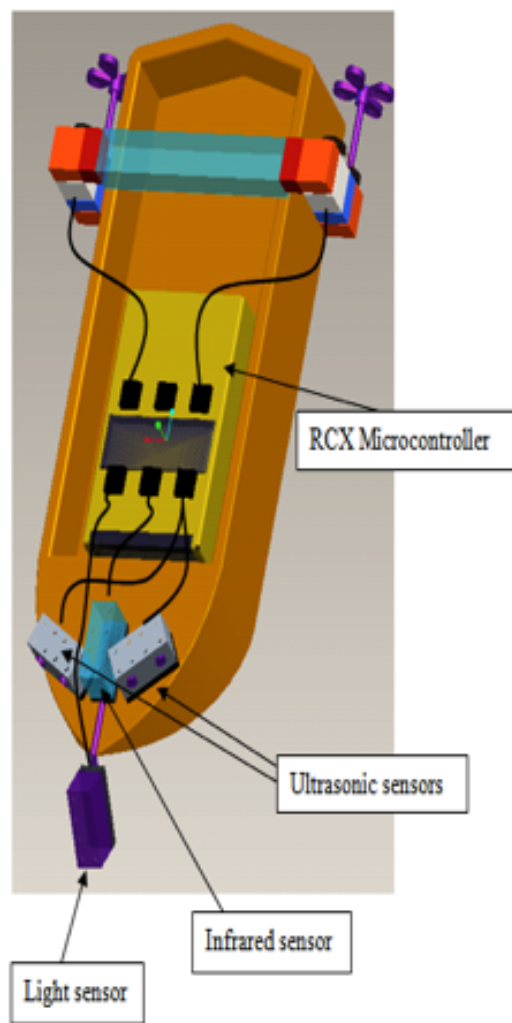


Figure 1. CAD model of Aquabot

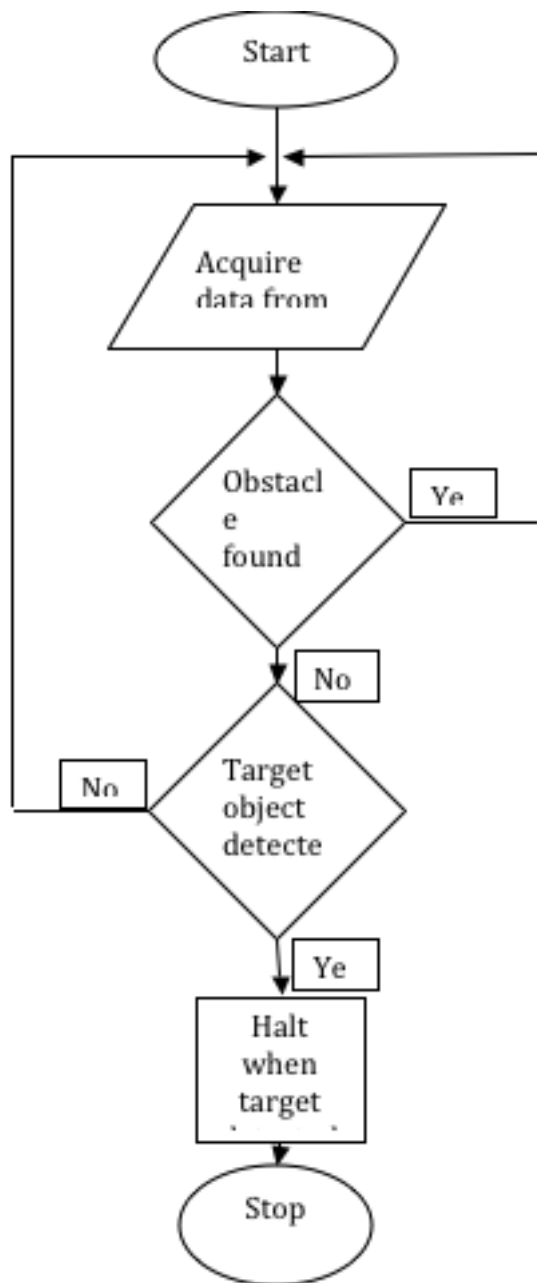


Figure 2. Flow chart of Aquabot control

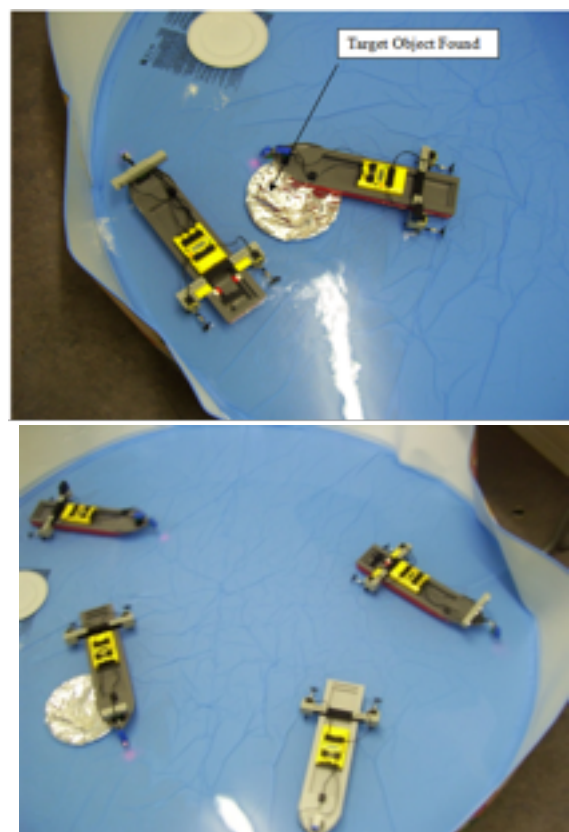


Figure 3. Robots Swarm searching for the target object in teams of two and four respectively.

## 4 Experiment and Analysis of Results

Several experiments were conducted to estimate the time required to locate the target object and the results are tabulated as shown below<sup>3</sup>. Initially the experiment was conducted with one Aquabot to locate the target object.

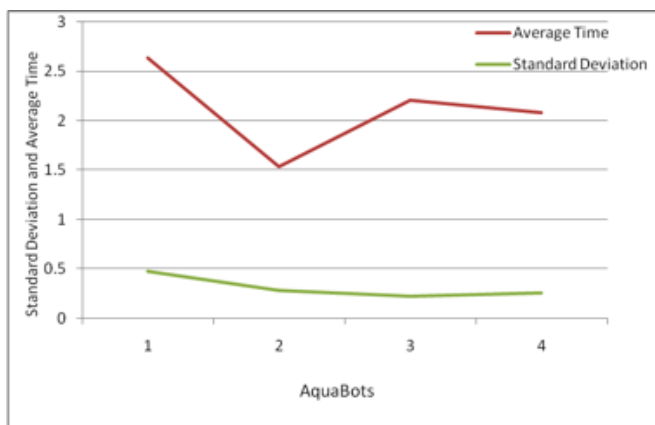
Experiment No.	No. of Robots	Time Required to Locate Target (mins)
1	1	3.12
2	1	2.29
3	1	2.54
4	1	3.24
5	1	2.01

**Table 1.** Time taken for one AquaBot to search the target material

From table 1 we can calculate the average time using one AquaBot is 2.642 minutes and the standard deviation was found to be 0.475. The experiment was repeated by varying the team size in order to determine optimum number of AquaBots required to achieve this task at best consistent time duration. The timings are presented in table 2.

Experiment No.	No. of Robots	TRLT (mins)	Standard deviation
1	1	2.64	0.475
2	2	1.54	0.286
3	3	2.21	0.229
4	4	2.09	0.263

**Table 2.** Time taken for one AquaBot to search the target material



**Figure 4.** Variation of time and standard deviation in relation to AquaBots number

From Table 2 Standard deviation seems to decrease greatly once a second AquaBot is introduced but the difference in standard deviation between second and fourth AquaBot is small.

From the above experiments it is clearly evident that the average time taken to achieve the goal decreases when the team size increases to two but the time taken again increases. This is because when the

<sup>3</sup> Video clips from the experiments are available at: <http://www.youtube.com/aayesh15>

team size is larger than that is required the AquaBots interfere with each other and slow down the search operation. Another critical issue that was noted during the experiment was, when the boats located the target object they moved a little from their location due to inertia of the boat even after the motors were turned off and there was collision among the members at times due to inefficiency of the sensors.

## 5 Conclusion

Taking all constrains into account, the outcomes of the project was reasonably good. The project clearly demonstrated the development process of Aquabots and their implementation in swarm to accomplish the task of search operation. The Aquabots were capable of manoeuvring independently and all the aim and objectives mention in this project were achieved. Several experiments were conducted to demonstrate the capabilities of Aquabots to locate the target object by avoiding the obstacles in their path. When the Aquabots were implemented in Swarm to optimize the group size, it was found that three Aquabots were appropriate and resulted in minimal time to locate the target object for a test area of 2.62 m<sup>2</sup>.

Since Lego mindstorm robotic kit was used in development of Aquabots, it resulted in some of the limitations like the inability of the microcontroller to take more than three inputs and give out only three outputs. The absence of Bluetooth module in microcontroller hindered the ability of members of swarm to communicate effectively. The use of vision based camera could result in better object recognition capabilities of Aquabots.

During the search operation, the sensors used in Aquabots for obstacle avoidance like ultrasonic sensors were not fully efficient because when the transmitter of ultrasonic sensor sends signal and if the reflecting surface is not even the Aquabots could not detect the presence of obstacle as result they collided with the obstacle.

Since the inertia of the Aquabot was the hindrance in term of achieving the dynamic stability of the system, review of mechanical design could lead to much better dynamic stability of the Aquabots. This can be achieved by changing the positions of motors and other components in the system.

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