McMaster University

HydroSwarm

Software & Mechatronics Capstone

Requirements Document

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Date	**Revision**	**Comments**	**Author(s)**
Oct 28/2018	0	Basic template	All authors
Oct 29/2018	1	Functional Requirements Added	All authors
Oct 30/2018	2	Other sections added	All authors
Oct 31/2018	3	Final draft for Requirements Deadline	All authors

Figure 1: Revision History

1 Introduction

There are many applications for carrying out distributed measurements in large bodies of water. Weather tracking, oil spill tracking, and water toxicity measurements are among many. Unfortunately, it is both expensive and time-consuming to carry out such measurements over large regions. It typically requires many measurement stations, all placed in discrete locations, in order to provide accurate readings over large areas. We propose a fundamentally different approach.

1.1 Project Overview

HydroSwarm is a swarm of autonomous robotic boats meant to carry out measurements over large bodies of water. For our project, these boats will be measuring water temperature, but the idea can be expanded to any number of other quantifiable measurements. Central to our work will be two major components. First, a small motorized boat, attached with a water temperature sensor, as well as a control unit that allows it to communicate with – and be controlled by – a centralized control unit. Second, a software package that can control a large group (swarm) of these boats, with an algorithm focused on producing reliable, accurate, and fast measurements.

Our swarm will aim to cover large areas more quickly and cost-effectively than traditional products. To test the applicability of our project, we will demo it on a small scale body of water, such as a swimming pool, as well as develop a simulation to hypothetically prove the efficacy of the system on a larger scale.

Our project will be conducted between Fall 2018 – Winter 2019 for our Engineering Capstone project at McMaster University, under the guidance of Dr. Alan Wassyng. We have four Software Engineering students, and one Mechatronics Engineering student.

1.2 Naming Conventions and Terminology

- **System**: The entire software and hardware package - including the boats, boat hardware, control software, and server running the control software
- **Swarm**: A large group of objects (in our case, motorized boats) that can communicate and perform acts as a group
- **Insect**: A member of the swarm (in our case, a single motorized boat)
- **Simulation**: The simulation will be used for demo purposes, mainly to show that the system is valid with a large number of insects.
- **Researcher**: A user that is interested in the data that is returned from the survey.

- **System Administrator**: A user that controls the parameters of the **swarm**.
- **G.P.S.**: Global Positioning System

1.3 Relevant Facts and Assumptions

For demo purposes, our project will be conducted on a small scale. One major assumption is that this project can be effectively expanded to a much larger scale – that of lakes, rivers, or even oceans. There will likely be design challenges involved in a large-scale project, but due to the time and resources available to us, we must assume that such challenges could be overcome without compromising its fundamental goals. This assumption carries with it some implicit ones. Namely, we must assume that a large scale version of our project will be able to withstand the wind, water currents, and otherwise adverse weather conditions of real lakes and oceans. It will need to be able to communicate reliably over much larger distances.

Another assumption we must make is that there are no sensitive lifeforms or other objects that can be harmed by the system, in the near vicinity of the system. An object collision detection algorithm can certainly be implemented, most likely using cameras and computer vision, but due to time constraints, we may not be able to include one.

To simplify the development and testing process, we will assume that weather conditions are as follows:

- Water temperature between $10^o(C)$ and $30^o(C)$
- Air temperature between $10^o(C)$ and $30^o(C)$

- Water waves are at maximum ± 15mm$fromthebaseline$

2 Project Drivers

2.1 Purpose

The collection of water temperature data for the purpose of studying large bodies of water poses the following problems:

- Water conditions can vary substantially over the area of interest
- Water conditions vary with time

Therefore, it is optimal to survey multiple test points spanning the area of interest and to collect data regarding the change in water conditions at those test points over a given time interval. The typical solution to this is to place sensors on buoys and fix them to strategic locations in the water. There are two main drawbacks to this approach:

- The number of test points is limited to the number of buoys, which cannot be permanently placed in areas which will obstruct water traffic
- The measurement tools cannot be reused in other areas
- Placing buoys in fixed, arbitrary locations can be costly and time-consuming

A possible solution to these issues is a robot swarm of measurement boats. These could be reused in many different regions, and because they are not permanently fixed in the water they could potentially cover a wider range of test points. In addition, the mobility of the swarm allows test points to be measured in different parts of a region at different times, and as such more data can be collected with less equipment. Therefore, the purpose of this project is to build such a system.

2.2 Key Stakeholders

2.2.1 Users

The intended users of this system are primarily researchers requiring data for water body analysis. This includes meteorologists, environmental scientists, marine biologists, and oceanographers among many others.

2.2.2 Development Team

The development team is responsible for both the project concept and its implementation. This will be done with the guidance of Dr. Alan Wassyng and his teaching assistants.

2.2.3 Faculty

McMaster University - specifically, the Department of Computing and Software - is invested in the success of this project. Upon successful completion, it can be used to highlight the quality of the program, department, and institution.

3 Project Scope

3.1 The Scope of the product

Due to time and financial constraints, defining the project's scope is essential to ensure the project is feasible. One way we are scoping the project is the type of data we collect with each insect. We are only collecting temperature and location data. Another way we are scoping the project is restricting the area of the survey. Insects can travel only a maximum distance (approximately covering the size of a swimming pool) from the starting point. The type of water that the swarm will be deployed on is fresh water. We are using existing RC boats, and will not be building our own. We will also rely on other third-party components, such as embedded microcontrollers and transceivers.

3.1.1 Individual use case

The actors that interact with the system are the **researcher**, and the **system administrator**. The researcher is a primary actor, and the system administrator is a secondary actor. The researcher does not have to be present during the operation of the system.
The following are the primary use cases:

- Researcher requests a specific area to be surveyed
- Researcher requests time frame to retrieve data
- Researcher analyzes the returned data
- Researcher requests to end surveying session
- Researcher checks the progress of the survey

The following are secondary use cases:

- System Administrator adjusts the speed of an insect
- System Administrator sets the constraints of the survey
- System Administrator deploys the swarm
- System Administrator ends the session

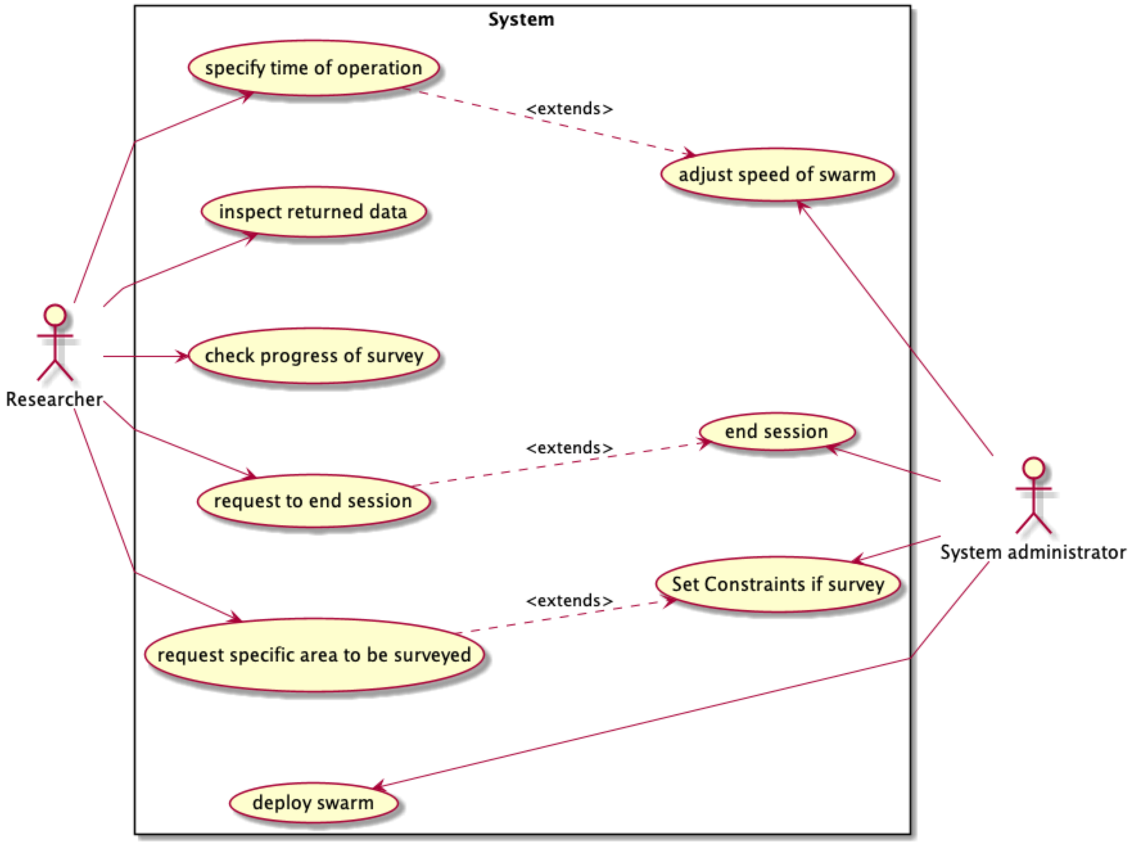

Figure 2: Use Case Diagram

3.2 Mandated Constraints

There are 2 constraints put on the project. The first being time, since the project is due at the end of April 2019. The second constraint is money. There is a $750 budget for this project.

3.3 Undesired Behavior

An insect should not lose connection to the server during the survey. An insect should not be hit or come in the path on any object including other insects. The power supply of an insect should not explode. The water should not interfere with the operations of an insect. Other network signals should not interfere with the server and the swarm.

3.4 Variables

Variable Name	**Type**	**Value**	**Description**
Area of survey	Fixed	X in m^2	The total surface area of water in a survey
Perimeter of survey	Fixed	X in m	The region that bounds the survey on a body of water
Insect location	Monitored	(X, Y) representing lat/lon values, respectively	The perceived location of an insect at any given time
Temperature	Monitored	X in °C	The measurement an insect takes at a specific point
Speed of Insect	Controlled	X in m/s	The speed relative to the water of an insect
Number of Insect	Controlled	X amount of insects	The number insects currently deployed in a swarm
Battery life	Monitored	X in $minutes$	The amount of battery left in a specific insect
Range of communication	Fixed	X in m	The range in which server can communicate with each insect
Max Time for survey	Fixed	X in minutes	The maximum time the survey will run for
Min Time for survey	Fixed	X in minutes	The minimum time the survey will run for
Start Point	Fixed	(X, Y) representing lat/lon values, respectively	The Starting point from where an insect is deployed

Figure 3: List of Variables

3.5 Context Diagram

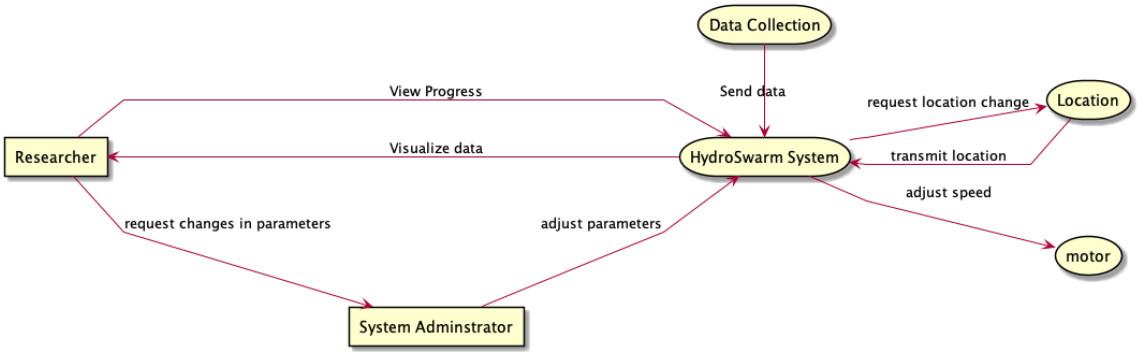

Figure 4: Context Diagram

4 Functional Decomposition Diagram

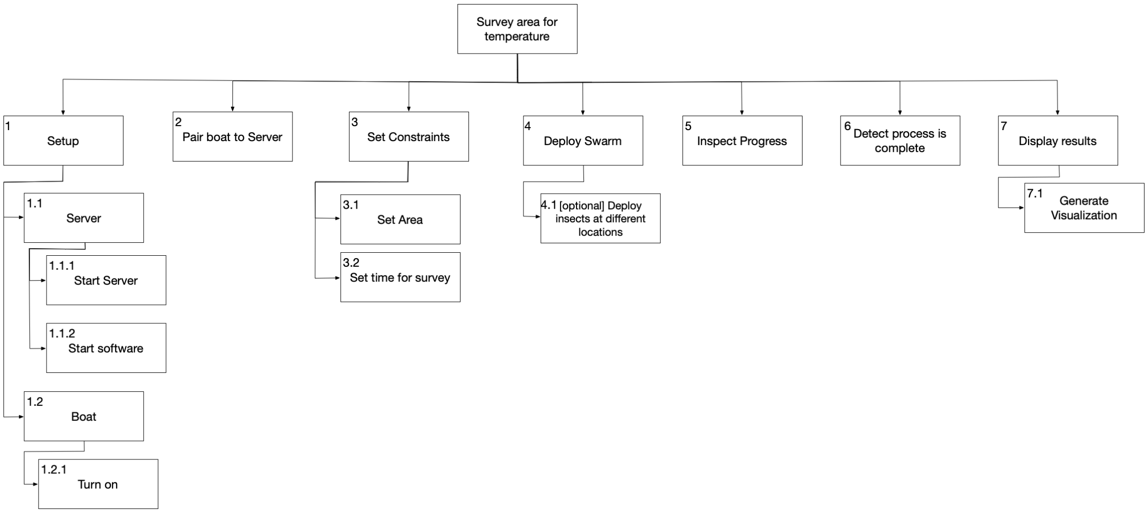

Figure 5: Functional Decomposition Diagram

5 Functional Requirements

Requirement ID: F1 **Requirement Type**: F

Description: Each insect in the swarm must be able to measure the water temperature at its current location
Rationale: Accurate water temperature measurements have many applications in academic or professional work
Fit Criterion: Each insect must be able to measure the water accuracy at its location to within ± 1^oC at all times
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 28, 2018

Requirement ID: F2 **Requirement Type**: F

Description: Each insect in the swarm must be able to provide its current location
Rationale: Water temperature measurements must be combined with the location at which they are measured
Fit Criterion: Each insect's location must be known to within $1m$ accuracy at all times
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 28, 2018

Requirement ID: F3 **Requirement Type**: F

Description: The system must be able to produce temperature measurements, specified in Requirement F1, at many different locations in a body of water
Rationale: Producing many data points provides a more accurate representation of the underlying property (in our case, the temperature of the water)
Fit Criterion: The system must produce at least 5 different measurements for each insect that is available
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 28, 2018

Requirement ID: F4 **Requirement Type**: F

Description: The system must be able to produce a Water Temperature Map of a swimming pool-sized body of water
Rationale: Producing a visual temperature map of a body of water is a useful tool for analyzing measurement data
Fit Criterion: The swarm must be able to produce a visualization that displays a representation of the temperature measurement data
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 28, 2018

Requirement ID: F5 **Requirement Type**: F

Description: Each insect in the system shall be maneuverable such that it can move to any position (x, y) on the surface of the water
Rationale: Allows proper coverage of the area of interest
Fit Criterion: The insect is able to move to a specified position
Originator: Gabriel Potter
Priority: High
History: Created Oct. 31, 2018

Requirement ID: F6 **Requirement Type**: F

Description: The system shall be able to plan and control the paths of insects such that redundant measurements are not made and there are no collisions
Rationale: Efficiency
Fit Criterion: There are no collisions (between insects) or redundant measurements
Originator: Gabriel Potter
Priority: High
History: Created Oct. 31, 2018

Requirement ID: F7 **Requirement Type**: F

Description: The insects shall return to the start point when data collection is complete
Rationale: Ease of use, cost effectiveness
Fit Criterion: All insects return when collection is complete

Originator: Gabriel Potter
Priority: High
History: Created Oct. 31, 2018

Requirement ID: F8 **Requirement Type**: F

Description: The insects shall move in an autonomous manner
Rationale: Swarms should move based on collective intelligence
Fit Criterion: All insects should move without control input from users
Originator: Nishanth Balamohan
Priority: High
History: Created Oct. 31, 2018

Requirement ID: F9 **Requirement Type**: F

Description: If an insect loses a critical function for autonomous operation (i.e. location) it shall have the ability to be manually overridden and controlled by the user
Rationale: Allow the insect to be easily returned to the start point
Fit Criterion: Each insect has the ability to be manually controlled if the circumstances require it
Originator: Gabriel Potter
Priority: Medium
History: Created Oct. 31, 2018

Requirement ID: F10 **Requirement Type**: F

Description: If an insect loses critical functionality such as communication, sensing, or movement, the remaining operational insects should operate as if that insect is no longer part of the swarm
Rationale: A non-functional insect provides no use to the swarm
Fit Criterion: If an insect fails to communicate or notifies the swarm of an error, the algorithm must recompute the paths based on the new number of insects
Originator: Nishanth Balamohan
Priority: High
History: Created Oct. 31, 2018

6 Non-Functional Requirements

6.1 Look and Feel Requirements

Requirement ID: NF1 **Requirement Type**: NF

Description: The system's interface must look simple
Rationale: Users want to use a simple interface
Fit Criterion: Users should be able to see all interface elements clearly and easily
Originator: Nishanth Balamohan
Priority: Low
History: Created Oct. 31, 2018

6.2 Usability and Humanity Requirements

Requirement ID: NF2 **Requirement Type**: NF

Description: The system shall have an interface with high learnability
Rationale: Users want to interpret the data as fast as possible
Fit Criterion: Users should be able to understand the data that swarm provide
Originator: Nishanth Balamohan
Priority: Low
History: Created Oct. 31, 2018

6.3 Performance Requirements

Requirement ID: NF3 **Requirement Type**: NF

Description: The system must collect data within a reasonable maximum amount of time
Rationale: Users do not want to wait too long for their results
Fit Criterion: The swarm must provide the measurement data with a latency (relative to the time of measurement) of no more than $20s$
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 28, 2018

Requirement ID: NF4 **Requirement Type**: NF

Description: The system must collect data for a long enough amount of time without failing
Rationale: Users want the system to collect data for long enough to produce enough data points
Fit Criterion: The system must collect temperature measurements reliably for a minimum of 20m
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 28, 2018

6.4 Operational and Environmental Requirements

Requirement ID: NF5 **Requirement Type**: NF

Description: The swarm must be able to work with an arbitrary number of insects
Rationale: The number of boats in the swarm should be easily configurable
Fit Criterion: The swarm must work correctly with 3-30 insects
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 29, 2018

Requirement ID: NF6 **Requirement Type**: NF

Description: The server software will run on Linux
Rationale: Linux is a popular, efficient and well-supported operating system
Fit Criterion: The server software will run on Linux
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 30, 2018

Requirement ID: NF7 **Requirement Type**: NF

Description: The user shall be able to pair insects to the server

Rationale: Users should be able to pair as many insects as they want
Fit Criterion: Pairing must be easy to do
Originator: Victor Velechovsky
Priority: High
History: Created Oct. 30, 2018

6.5 Maintainability and Support Requirements

Requirement ID: NF8 **Requirement Type**: NF

Description: The insects will be waterproof in the areas that hold critical electronics
Rationale: The electronics will fail and require replacement if they get wet
Fit Criterion: All critical areas are sufficiently waterproof
Originator: Gabriel Potter
Priority: High
History: Created Oct. 31, 2018

6.6 Security Requirements

Requirement ID: NF9 **Requirement Type**: NF

Description: The project shall not allow unauthorized access of data
Rationale: The user's data must be protected from unauthorized users
Fit Criterion: No unauthorized users should be granted access to user data
Originator: Nishanth Balamohan
Priority: Medium
History: Created Oct. 31, 2018

6.7 Political Requirements

Requirement ID: NF10 **Requirement Type**: NF

Description: The project shall not use any text, images, or media that will offend the users that purchase it
Rationale: This project must not offend any users or cause any political conflicts
Fit Criterion: Any text, image, or media used should not cause offence to any user

Originator: Nishanth Balamohan
Priority: Medium
History: Created Oct. 31, 2018

6.8 Legal & Compliance Requirements

Requirement ID: NF11 **Requirement Type**: NF

Description: The project must comply with ethical standards
Rationale: The project must be ethically responsible
Fit Criterion: The project must comply with the guidelines set by the Members Business & Engineering Student Research Ethics Committee
Originator: Nishanth Balamohan
Priority: Medium
History: Created Oct. 31, 2018

6.9 Health and Safety Requirements

Requirement ID: NF12 **Requirement Type**: NF

Description: The insects will not travel too quickly
Rationale: Fast moving boats may present a danger to the nearby environment
Fit Criterion: The boats will not travel faster than $10km/h$
Originator: Victor Velechovsky
Priority: Medium
History: Created Oct. 29, 2018

Requirement ID: NF13 **Requirement Type**: NF

Description: The insects will not have exposed wiring
Rationale: Expired wiring could be a safety concern to the nearby environment
Fit Criterion: The boats will not have any visible wiring under normal operation
Originator: Victor Velechovsky
Priority: Medium
History: Created Oct. 30, 2018

7 Project Issues

7.1 Open Issues

Due to the complexity of the project, there are some open issues that our group might have to overcome to be successful. One of the open issues that we have is an error in data and how to check the validity of the temperature data received from the boats. For example, one of the insects in the swarm could potentially have a faulty reading and skew the data resulting in an invalid survey. Since our group has not chosen the temperature sensor yet, we do not have concrete information about the severity of this issue. Another open issue we have is the battery life for the insect. If it dies midway through the survey, it will result in missing data. In addition, if the insect battery dies, an issue that might arise is how to retrieve the insect and supplement the missing data. Path correction is also an open issue that might be difficult to solve since we do not have any information on direction or about the water current speed and location.

7.2 Off The Shelf Solutions

In order to solve the open issues, some off-the-shelf solutions must be incorporated into the project. The error in temperature data, for example, can be solved by buying a more accurate temperature. However, the more accurate the temperature sensor, the higher the price, which is one of the constraints in this project. Another open issue that can be solved with Off The Shelf Solutions is the battery life. Again buying a larger battery will increase the life of the insect but will increase weight and costs which might affect other requirements. In addition, path correction might be solved by an accurate G.P.S. system but the price might force the solution to be too expensive to pursue.

7.3 New Problems

As of October 30^{th} 2018, no new problems exist.

7.4 Risk

The largest risk that the group has is potentially going over budget. The cost will mainly be based on the number of insects we decide to build for the swarm. In addition, the precision of the sensors and motors used will also be correlated with price, which might increase as development progresses.

7.5 User Documentation & Training

The users will be informed of the following items in order to use the system efficiently:

- Creating a boundary or area to survey

- Pairing insects with the server
- Limiting survey time
- Setting the number of insects in the swarm
- Deploying insects
- How to read/interpret the resultant data