CATFISH

An Environmental Initiative for
Flexible and Real-time Water Monitoring

Project Description

2020

Contact Information

Harvey Blanco
Alireza Esmaeilzadeh
Michael Forshlé

CatFish Team

Team members

Joakim Tell
Head of CatFish Project
Associate Professor at Halmstad University
https://www.linkedin.com/in/joakim-tell-a2062017/

Harvey Blanco
Project Leader
Universitetsadjunkt - School of business, innovation, and sustainability at Halmstad University
https://www.linkedin.com/in/harvey-blanco-616165ab/

Alireza Esmaeilzadeh
Project Leader
Universitetsadjunkt - School of business, innovation, and sustainability at Halmstad University
https://www.linkedin.com/in/alireza-esmaeilzadeh-44166677/

Michael Forschle
Embedded engineer
Master's Student in Embedded Engineering at Halmstad University
https://www.linkedin.com/in/michael-forschle-718b27193/

Julian Kaduk
Interaction Design Engineer
Master's Student in Embedded Engineering at Halmstad University
https://www.linkedin.com/in/julian-k-19b603166/

Hamad Farah Hamad
Electronic engineer
Master's in Energy Engineering at Halmstad University
https://www.linkedin.com/in/hamad-farah-316533141/

Executive Summary

Opportunities

Problem Summary

All the more, societies compel authorities to return water bodies to pristine in order to enhance the quality of life for the ecosystem, humans and other species. For this purpose, we need a good understanding of the patterns and behaviors of the ecosystem and the habitats. When it comes to water, collecting valid information is even more laborious. To summarize, an efficient water monitoring method should tackle three main challenges. First, the quality of water changes over time so we need real-time data to perceive accurately. Second, in most cases, water is not homogeneous, so we need a level of freedom to move in all three physical dimensions to reach the samples. Last, a variety of parameters (physical, chemical and biological) affect the quality of water. However, the current means of measurement are rather limited and costly. To reach an accurate result with this limited sensing ability, we might need a level of intelligence to extract the patterns and analyze the behavior and quality of an ecosystem.

Solution Summary

Catfish is a system of interconnected drones designed to improve the flexibility and accuracy of water monitoring while reducing the complexity and cost of technology and operation. In short, the system is able to capture real-time data from the ecosystem, has the ability to move in all physical dimensions to reach the representative samples, and has the ability to sense some characteristics of both water and air, to transfer the captured data to a cloud-based server, and to analyze the data in order to find the patterns. Moreover, the system is designed in a way to be less energy-dependent and autonomous in order to reach maximum efficiency and reliability.

The industry of drones for environmental monitoring is increasing at a rapid rate and is expected to surpass the 12 billion Euros barrier in 2024. Furthermore, the industry of IoT for water and air monitoring is expected to be over 18 billion Euros in the same year. IoT environmental monitoring devices are in early stage of development. Lots of researchers, startups, companies and institutions aim to reach a dominant design, some of which invested millions of Euros on product development. General Electric, Libelium, Trimble, Valarm, SenseGrow, Semtech, Bacsoft, and OceanAlpha are just some of the actors in IoT environmental monitoring sector. Regarding the fact that the sector is extensive, each of these companies covers a limited range of expertise.

CatFish team is formed by enthusiastic master's students of Halmstad University from different programs with sustainability concerns. We aim to utilize our knowledge and experience to solve an environmental problem as well as learning new skills during the process of product development. The project is leaded by Professor Joakim Tell, head of Industrial Management and Innovation program.

Halmstad University as the first sponsor of the project provided us with the required resources, knowledge, and networks. Regarding the fact that innovation and Smart Cities are the main field of research in the university, we possess a reliable infrastructure for development.

Region Halland with the ambition of being a smart city and sustainability concerns provides us with a network of professionals. Moreover, being close to Lund, Malmö and Gothenburg the region brings even more opportunities for the project.

Opportunity

Problem & Solution

Problem Worth Solving

Natural and man-made toxic substances and microorganisms in water bodies[1] can present a health hazard to wildlife and humankind. For instance, diarrhea, the most common cause of death among children, is mostly transmitted through water (Unicef, 2009). With greater reason, environmental awareness urges governments to return water bodies to pristine. Besides, environmental scientists focus on maintaining healthy ecosystems, protecting endangered species and improving human health standards. Meanwhile, constant monitoring of environmental quality parameters is crucial in order to manage and restore the environment. However, freshwaters are exceptionally challenging to sample; this since they are not homogeneous, and the quality differs during the day and the year. Although it seems easy to collect a bottle of the sample from a river, the taken sample represents the quality of that certain location at that point in time. Moreover, most of the representative sampling locations are often isolated and far from the shore which escalates the complexity of logistic (Wetzel, 2001).

Lakes, on the other hand, can be extremely complex ecosystems in which the parameters vary in time and all three physical dimensions (Wetzel, 2001). For example, in summer the higher layers of lakes are richer in oxygen, however, in autumn the water is more homogeneous because of the wind (Kumar, 2005). Not only the oxygen but also the other parameters like iron, phosphate, and manganese change in their chemical form by the redox[2] potential of the environment. Water from different sources and qualities (like storm water and wastewater) also are disposed to rivers and lakes and with them some different substances. Some of these particles float over the surface, some sink beneath, and the others rapidly mix with water. Furthermore, geological, atmospheric, and anthropogenic[3] inputs affect the quality of water. Each of these chemicals favors some organisms and harms the others that might result in a huge change in the ecosystem (Wetzel, 2001). In spite of the fact that the parameters and the relationship between them are really complicated, there are some physical, chemical and biological indicators which might lead us to some patterns, including:

- Color and turbidity,
- Organic constituents,
- Metals (Iron, Zinc, and Heavy metals),
- Nitrogen,
- Phosphorus,
- Arsenic,
- Solids,
- Bacterial, viral and parasite inputs, and

[1] Rivers, Lakes, and Ground-water
[2] A type of chemical reaction in which the oxidation state of atoms are changed
[3] Originating in human activity

- pH.

The number of indicators affecting the quality of water leads to a range of measurement techniques.

Sample collection:

For more complex measurements, collected samples should be analyzed in a laboratory. In this case, samples are collected, preserved, transported and analyzed at another location which leads to two serious issues. First, since the sample is collected from a certain location at a certain time, it might not be a good representative of the water source. In the best case, we might be able to suffice an average value. Second, the sample is removed from its surroundings and transferred to a new environment in which it begins a new equilibrium with its new surroundings. For this problem, sample preservation methods (like keeping the samples cold) might slow the rate of reactions but still it minimizes the changes not eliminating them (Goldman & Horne, 1983).

Testing in response to natural disasters and other emergencies

Right after natural disasters such as tsunamis and earthquakes, portable water test kits are widely used to measure some critical characteristics in order to prevent diseases. However, it might take a long time (in some cases up to one and a half years) until the quality of water returns to pre-disaster level (Hanaor & Sorrell, 2014).

Chemical analysis

This method basically relies on measuring chemical elements without respect to their form which is very costly and time-consuming. This method is mainly conducted by government agencies and some volunteer programs.

Real-time monitoring

Since the late 20^{th,} public interest in the quality of drinking water provided by municipalities has been raised. Accordingly, a lot of water utilities have invested in real-time monitoring systems. In the early 21st century, a number of remote monitoring sensors have been developed for measuring some parameters. Nowadays, these systems in form of IoT are being used for environmental water monitoring in rivers, lakes and coastal water bodies (Stanfield, 2018). These systems can be found in forms of stationary sensors, buoys, drones, and underwater robots. However, most of them lack the proper response to at least one of the main three complexity aspects that are mentioned in problem section.

Accordingly, we assume that for monitoring the quality of water bodies in an accurate way, we might need to deal with complexity in these aspects:

1. Time: the quality of water changes by time,
2. Location: water is not homogeneous in three dimensions and exists in equilibrium[1] with its surroundings,
3. Measurement: different parameters affect the quality of water in a complex way.

[1] A state in which opposing forces or influences are balanced

Our Solution

The Catfish project is a system of interconnected drones designed to improve the flexibility and accuracy of water monitoring while reducing the complexity and cost of technology and operation. The Catfish project is also an IoT experimentation developed at Halmstad University with the aim of tackling environmental issues on water bodies. The Catfish system provides real-time water quality control and monitoring, with a flexible and efficient water sampling approach. The system also can be used as a unit for inspecting freshwater and saline water bodies in low and medium depth. Figure 1 illustrates the concept of CatFish.

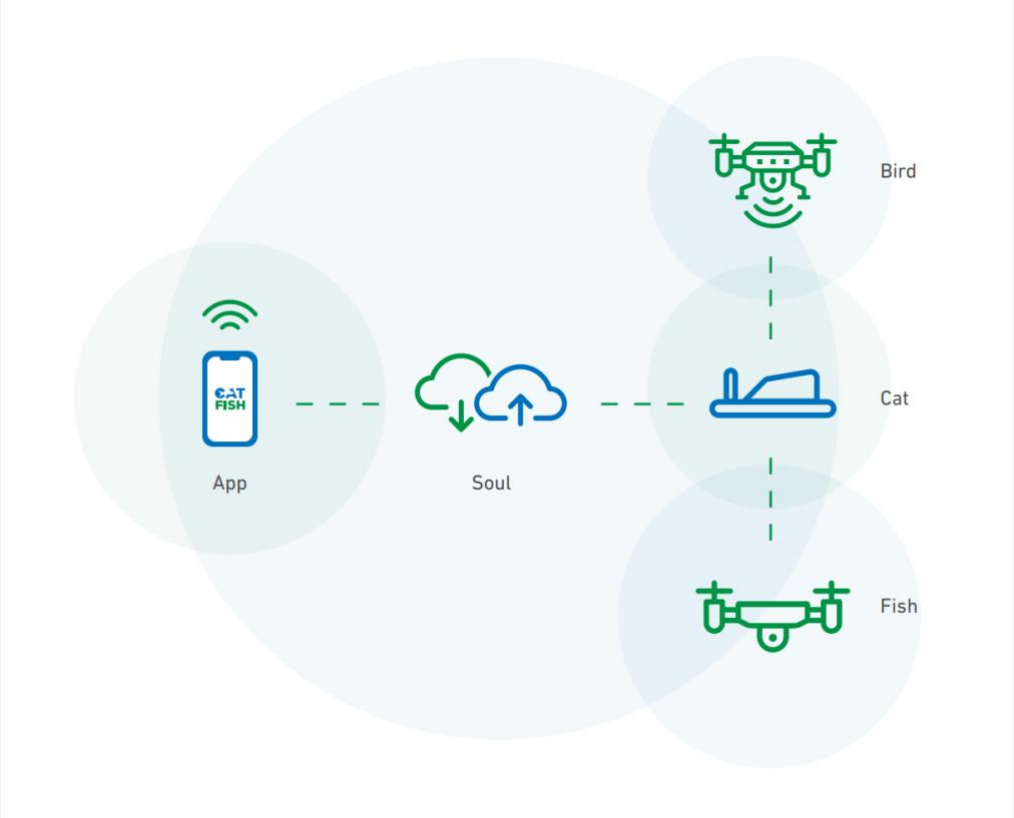


Figure 1 CatFish Concept

The system is formed by three drones, modular sensor box, and software which work together to perform water monitoring operations in a low and medium depth, in fresh and saline water.

The components of the system include:

The Fish

The fish is an underwater drone capable of sensing, perceiving, sampling, navigating and moving in marine and fresh bodies of water such as springs, rivers, lakes, and dams.

- The fish senses water temperature, depth, and qualities that need to be measured locally. The modular design of the drone allows different sensors to be adapted to the system.
- The fish perceives the environment for inspection and control through a set of cameras and sensors.
- The fish moves in all three dimensions autonomously to navigate to specific points.

The Cat

The cat is a drone placed on the surface of a marine or a fresh body of water. It carries out functions as to perceiving, sensing and measuring, navigating and moving, communicating, producing and storing energy.

- The cat senses the quality of the surface of the water and the quality of the air. The modular design of the drone allows different sensors to be adapted to the system.
- The cat moves in two dimensions autonomously to navigate to specific points.
- The cat communicates with its commander through the use of the internet and with the fish through cable.
- The cat uses a combination of cameras and sonar technologies to perceive the environment.
- The cat distributes power to the whole system.

The Bird

The bird is an aerial drone that senses and measures the air quality, navigate and move, perceive and transport water samples.

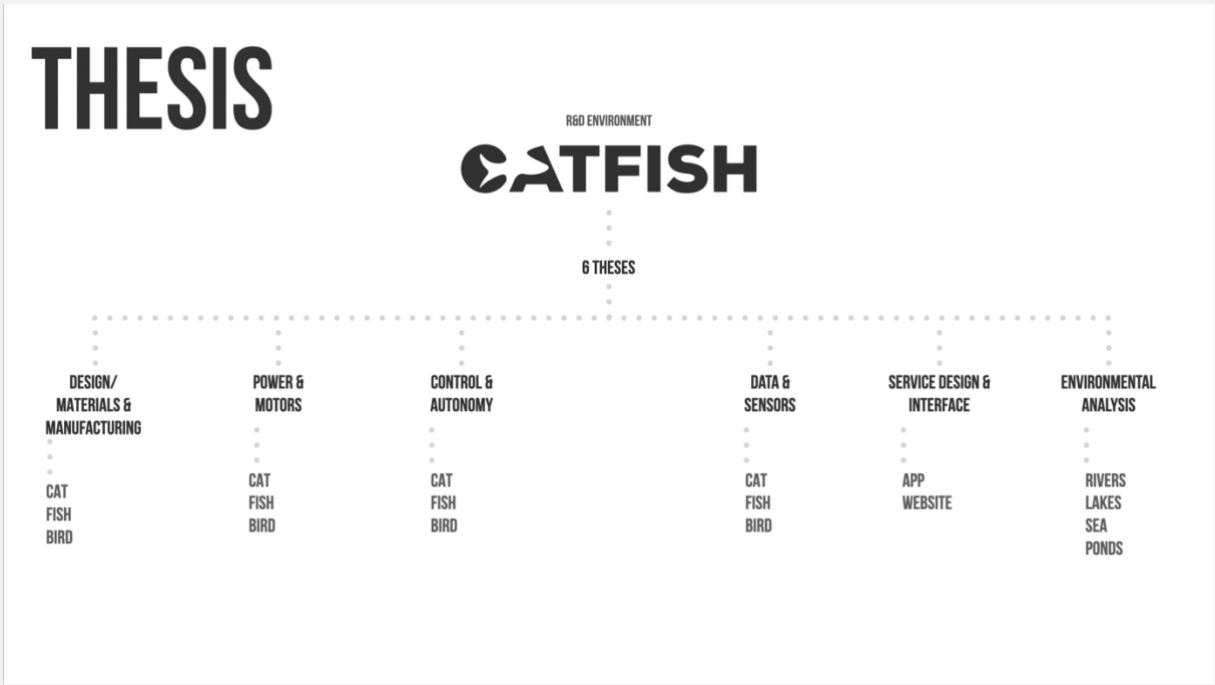
- The bird senses and measures air quality that need to be measured locally.
- The bird moves in all three dimensions autonomously to navigate to specific points.
- The bird lands, takes-off and recharges its power from the cat.
- The bird perceives the environment from above to navigate the system.

The Soul

The soul is an intelligent platform that includes data processing, data storing, monitoring and controlling systems.

- The soul captures, processes, stores and reports the data collected from the cat.
- The soul allows for the system to be controlled, monitored and updated.
- The soul uses external databases to enrich reports.
- The soul is the source for the development of future applications.

In summary, CatFish project is designed to tackle the complexity of time, location and measurement of water monitoring. The solution provides real-time monitoring with flexibility in all three dimensions in underwater and above water and also two dimensions of surface water. Due its modular design, it also provides a range of monitoring/measurement possibilities from sensors to cameras. The data captured from the environment is later processed, stored, analyzed and reported by an integrated database, software and artificial intelligence in order to find possible patterns. Current solutions both traditional and modern methods lack the proper response for at least one of the three major complexities of water monitoring mentioned in problem section.



Students will have the opportunity to experience a multidisciplinary research and development environment in a real setup. The project is divided within six teams (2 people per team); each team writes an individual thesis according to their specialty or subject of interest. Teams must work cross-functional in order to reach the ultimate goal of building CatFish 2.0. The prototype must be built and functioning by the first week of March 2021, so that it can be deployed in the Nissan River and in the Baltic sea.

Innovation-Lab makes sure of the synergy of the teams and provides the required support, equipment and materials for the development of the project. Besides writing a thesis, at the end of the project, students will be certified by the innovation-lab for this research and development experience.

If you are interested on writing your thesis with CatFish project 2.0, please send us an email to innovation.lab@hh.se with the following information:

Name(s)
program
Subject of interest (ie. Power & motors, data & sensors etc.)
Supervisor(s) name

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