H2BOT

Presented by: **Wild Chickens**

Team 4

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Table of Contents

H2BOT Underwater Robot

Wild Chickens

1. Introduction

The Challenge-Based Innovation (CBI) initiative, in collaboration with CERN and the Fusion Point comprising Esade, UPC, and IED Barcelona, is designed to harness the power of CERN's open science and technology in solving key societal challenges. Our program introduces the "Challenge-Based Innovation for Artificial Intelligence" (CBI4AI) course. Our goal is to merge advanced European technologies with deep AI expertise to address specific Sustainable Development Goals (SDGs). As participants, we are expected to conceptualize and develop AI-based solutions that leverage technologies from the ATTRACT project, aiming to fast-track the creation of impactful innovations tailored to these global challenges.

In the Challenge-Based Innovation for Artificial Intelligence (CBI4AI) course, our group has chosen to focus on Sustainable Development Goal 6.6, which aims to "protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes" by 2020. This goal aligns with our commitment to addressing urgent environmental challenges, emphasizing the preservation and rehabilitation of water ecosystems that are crucial for biodiversity, climate stability, and human well-being. By leveraging advanced AI technologies, we aim to propose innovative solutions that will help meet this essential environmental objective, contributing to the global effort to sustain and restore vital natural resources.

2. Understanding the problem

2.1 Desk Research

Our discovery process began with a comprehensive desk research phase aimed at addressing Sustainable Development Goal (SDG) 6.6, which focuses on protecting and restoring water-related ecosystems. Recognizing the importance of this goal, we embarked on a detailed exploration to identify specific water ecosystems where our efforts could be most effective. Our initial research aimed to understand the types of ecosystems we could target, eventually narrowing down our focus to smaller water bodies such as lakes and rivers. This choice was strategic, allowing us to gather detailed information and apply specific solutions that could potentially be scaled up later.

2.1.1 Targeting Specific Water Ecosystems

Selection of Focus Areas

We decided to concentrate on smaller water ecosystems rather than vast bodies like oceans and seas. This approach facilitated a more detailed and manageable scope for our research. Our objective was to identify specific problems within these ecosystems and develop targeted solutions.

Example of Studied Water Bodies

Marilao River, Philippines: The Marilao River is heavily polluted due to industrial waste from tanneries and gold refineries, as well as plastic dumping. The presence of heavy metals like lead poses severe health risks to residents and aquatic life.

Mississippi River, USA: Known for its brownish hue due to continuous industrial and agricultural waste discharge, the Mississippi River suffers from nitrogen-based fertilizer runoff, leading to eutrophication and decreased oxygen levels, which are detrimental to aquatic life.

Yangtze River, China: This river is polluted mainly by industrial wastewater and agricultural runoff. The pollution levels are so high that nearby towns are often called 'cancer villages' due to the high incidence of cancers among residents.

2.1.2 Focus on Lake Geneva

To further refine our research, we chose Lake Geneva as our primary case study. Lake Geneva, one of the largest freshwater lakes in Europe, faces unique environmental challenges, making it an ideal subject for developing and testing our restoration strategies.

Identifying the Problems

Our research into Lake Geneva revealed several pressing issues:

Pollution from Agricultural Runoff: Similar to many other lakes, Lake Geneva suffers from nutrient runoff, particularly nitrogen and phosphorus, from surrounding agricultural lands. This leads to eutrophication, causing algal blooms that deplete oxygen levels in the water.

Urbanization and Industrial Discharge: Urban development around the lake has increased pollution levels from sewage, industrial discharge, and stormwater runoff. These pollutants introduce harmful chemicals and heavy metals into the lake.

Urbanization and Industrial Solid Waste: Every year, approximately 50 tons of plastic end up in Lake Geneva, posing significant environmental risks due to its presence in the lake for an extended period.

2.1.3 Market Research on Water Cleaning Systems

Market Research

The focus on cleaning polluted water bodies has led to the development of various innovative technologies, mainly aimed at surface cleaning. However, there have been attempts to integrate waterbed cleaning with new technologies.

Jellyfish-Bot by MPI-IS: This underwater robot uses HASEL actuators as artificial muscles to navigate delicate environments and collect waste without contact. It preserves coral reefs and captures both litter and biological samples, addressing ocean cleanup needs, particularly plastic pollution on the seabed. https://www.openaccessgovernment.org/underwater-robot-remove-plastic-ocean/158143/#:~:text=While%20there%20are%20numerous%20strategies,the%20size%20of%20a%20hand.

Clearbot Neo by Open Ocean Engineering: An AI-enabled robotic boat that autonomously collects floating garbage in harbors and rivers. It prevents waste from reaching oceans and provides valuable data on marine waste using AI, cameras, and Azure cloud technology.

https://news.microsoft.com/source/asia/features/this-ai-enabled-robotic-boat-cleans-up-harbors-and-rivers-to-keep-trash-out-of-the-ocean/

SeaClear Project: Funded by Horizon 2020, this project uses a combination of Unmanned Underwater Vehicles (UUVs), Unmanned Surface Vehicles (USVs), and Unmanned Aerial Vehicles (UAVs) to detect and classify underwater litter, aiming for an 80% collection success rate. The project reduces costs compared to traditional diver methods by 70%.
https://projects.research-and-innovation.ec.europa.eu/en/horizon-magazine/how-robots-and-bubbles-could-soon-help-clean-underwater-litter

Traditional Technologies in Use

Water Treatment Technologies

Filtration Systems: Advanced filtration systems are used to remove pollutants from water, improving quality and restoring ecosystem functions.

Biological Treatment Processes: Biological methods like bioremediation use microorganisms or plants to degrade and remove pollutants.

Constructed Wetlands: These mimic natural wetlands to treat wastewater and restore ecosystem functions, providing habitat and aiding in nutrient cycling.

Remote Sensing and GIS

Remote Sensing: Utilizes satellite imagery and remote sensing technologies (e.g., Landsat, Sentinel) to monitor changes in land cover and water bodies, helping identify degradation and assess restoration efforts.

Geographic Information Systems (GIS): GIS software (e.g., ArcGIS, QGIS) analyzes spatial data related to water resources and ecosystems, aiding in planning and decision-making processes.

Data Analytics and Decision Support Systems

Data Analytics Tools: Integrate data from multiple sources to analyze complex environmental datasets and support ecosystem management decisions.

Decision Support Systems (DSS): Software like AQUATOOL and WEAP aid in prioritizing conservation actions, optimizing resource allocation, and evaluating intervention effectiveness.

Sensor Technologies

Water Quality Sensors: Devices like YSI's water quality sensors and EXO Water Quality Sondes monitor parameters such as pH, dissolved oxygen, and nutrient levels in real-time, helping assess ecological status and detect pollution.

Hydrological Modeling: Models like MODFLOW, HEC-HMS, and SWAT simulate water flow, predict changes in availability, and assess the impact of land use and climate variability.

Aquatic Habitat Restoration Technologies

Bioengineering Techniques: Methods like brush mattresses and coir rolls stabilize riverbanks and enhance habitats.

Artificial Reefs and Floating Islands: Structures like Reef Balls and BioHaven Floating Islands create suitable habitats for aquatic species and improve ecosystem resilience.

2.1.4 Researching SDG 6.6 Initiatives

To align our efforts with global standards and best practices, we explored various initiatives under SDG 6.6. These initiatives provided valuable insights and potential models for our work on Lake Geneva.

Examples of SDG 6.6 Initiatives

The Bonn Challenge: This global effort aims to restore 350 million hectares of degraded land by 2030, with a focus on restoring forests and other ecosystems that contribute to water conservation and quality. https://www.bonnchallenge.org/

The Amazon Region Protected Areas Program (ARPA): This initiative aims to establish and expand protected areas in the Amazon rainforest, including wetlands and river basins, to conserve biodiversity and ecosystem services.
https://d3nehc6yl9qzo4.cloudfront.net/downloads/wwf_folder_ingles_paginas_2.pdf

The African Great Green Wall Initiative: This project involves planting trees and restoring vegetation across the Sahel region of Africa to combat desertification, improve soil fertility, and restore water resources, including rivers and aquifers. https://www.unccd.int/our-work/ggwi

The Danube River Basin Restoration Program: This collaborative effort among countries in the Danube River Basin aims to restore and maintain the ecological health of the river and its tributaries through measures such as wetland restoration, floodplain management, and pollution control. https://cordis.europa.eu/project/id/101093985

The Ramsar Convention's Wetland Conservation Projects: The Ramsar Convention on Wetlands supports numerous projects worldwide focused on conserving and restoring wetlands, including mangroves, marshes, and peatlands, which are critical for water purification, flood control, and habitat for aquatic species. https://www.ramsar.org/

The Global Forest and Water Action Plan: Led by the Food and Agriculture Organization (FAO) and partners, this initiative promotes integrated management of forests and water resources to enhance water supply, regulate flow, and improve water quality. https://www.fao.org/in-action/programme-forets-et-eau/actualites/news-detail/fr/c/386914/

Community-based River Restoration Projects: Many local communities and NGOs are involved in restoring degraded rivers and streams through activities such as removing invasive species, planting native vegetation, and implementing sustainable land management practices. https://www.fisheries.noaa.gov/national/habitat-conservation/current-and-past-community-based-restoration-projects

2.2 Interview Insights

Dr. Iakovos Tziortzis, Ministry of Agriculture, Rural Development, and Environment, Republic of Cyprus

In our interview with Dr. Iakovos Tziortzis, several key insights were gathered regarding the state of pollution in lakes compared to rivers. Dr. Tziortzis emphasized that lakes tend to be more polluted than rivers due to the accumulation of pollutants over time. This is attributed to the relatively stagnant nature of lake water compared to the flowing nature of rivers, which can disperse pollutants more effectively.
Dr. Tziortzis highlighted that urban lakes experience higher levels of pollution compared to rural lakes. This disparity is primarily due to the increased human activities and industrialization associated with urban areas. The main sources of pollution in lakes were identified as food and beverage containers made of plastic, paper, glass, and metals. These pollutants are predominantly the result of improper waste disposal practices by humans.

Furthermore, Dr. Tziortzis noted a worrying trend in the health of aquatic life in lakes. Over the past few years, there has been a noticeable decline in the populations and health of aquatic species, which has been inversely correlated with the rising levels of pollution. This correlation underscores the urgent need for effective pollution control and mitigation strategies to protect lake ecosystems.

Dr. David Smith, PhD & Director at Water, Environment and Business for Development

Additional insights were derived from our conversation with Dr. David Smith, who provided an overview of current practices in water pollution research and treatment. Dr. Smith pointed out that most research and treatment efforts are concentrated on surface trash. This focus is primarily because surface trash is more visible and its removal can create an immediate visual impact, which is often prioritized for aesthetic and public perception reasons.
Dr. Smith explained that the lack of attention to trash at the bottom of water bodies is due to its invisibility. The submerged trash is out of sight and, consequently, out of mind for most people, which leads to a significant gap in treatment efforts. This oversight highlights the need for innovative solutions and technologies to address underwater pollution, which remains largely neglected despite its detrimental impact on aquatic ecosystems.

The insights gathered from these interviews underscore the complexity and urgency of addressing lake pollution. The accumulation of pollutants, particularly in urban lakes, and the subsequent decline in aquatic life health highlight the need for comprehensive and innovative approaches to pollution control. The focus on surface trash to the neglect of underwater debris further suggests that new technologies, such as H2BOT, could play a crucial role in restoring and maintaining the health of aquatic ecosystems.

2.3 Problematic

Pollution in urban lakes is a widespread issue that poses significant environmental and health risks, particularly in densely populated regions. These lakes are vulnerable to various pollutants, which lead to water contamination and ecosystem degradation. The effects of such pollution are extremely impactful, reducing water quality, harming aquatic life, and limiting the water's usability for recreation and drinking purposes. The presence of pollutants disrupts the natural balance of these ecosystems, leading to problems such as toxic algae blooms and the accumulation of hazardous substances in the food chain.

Littering intensifies these environmental challenges, especially in popular urban and tourist areas such as Lake Geneva. Litter, primarily consisting of items like plastic bags, bottles, and other trash discarded improperly, accumulates in and around water bodies. This not only affects the aesthetic value of these areas but also poses direct threats to wildlife, which can ingest or become entangled in litter. In Lake Geneva, the litter problem is particularly pronounced due to the high visitor traffic and urban activity along its shores. Each year, large quantities of litter end up in the lake, degrading its natural beauty and harming its biodiversity. Plastics are especially problematic, as they break down into microplastics that persist in the environment, entering the food web and potentially impacting human health.

Underwater trash in lake beds represents a significant and often overlooked environmental challenge. When large items such as plastic containers, discarded fishing gear, and other trash items are abandoned in water bodies, they don't simply disappear. Over time, these materials begin to degrade and break down into smaller pieces known as microplastics. Unlike their original forms, microplastics are much more difficult to detect and remove, persisting in the aquatic environment where they pose a long-term threat to water quality and aquatic life.

The issue of underwater trash comes from the challenges regarding its retrieval. Removing trash from lake beds is not only technically difficult but also expensive. The costs are associated with specialized diving equipment, boats, and manpower required to locate and extract trash from underwater. These operations require careful planning to avoid further environmental disturbance and are often limited to shallower areas that are more accessible. Additionally, visibility and reachability are problems that make it challenging to ensure complete removal of trash, especially in deeper waters.

Moreover, the fact that underwater trash isn’t physically seen from the surface means it receives less attention and fewer resources than surface pollution, despite its severe consequences. Public awareness about this issue is minimal. This lack of visibility and the significant costs involved in cleanup efforts mean that much of this pollution remains underwater, continuously breaking down into microplastics and increasing the pollution of global waterways.

Important data points to consider:

- High Phosphorus Levels: The phosphorus concentration in the lake frequently surpasses the target limit of 20 micrograms per liter, often reaching 60 micrograms per liter.
- Microplastic Pollution: Annually, 55 tons of microplastic are spilled into the lake.
- Decline in Native Fish Population: Over the past few decades, there has been a 70% decline in the population of native fish species, such as the Arctic char.

2.4 Context Analysis

Lake Geneva, one of the largest lakes in Western Europe, is renowned for its clean water and picturesque location at the foot of the Alps. As the largest lake on the course of the Rhône, it plays a critical role in the region's ecology and economy. This section explores the biodiversity of Lake Geneva, the environmental challenges it faces, particularly from plastic pollution, and the conservation efforts aimed at protecting this vital freshwater ecosystem.

Lake Geneva is notable for its substantial depth, particularly in the broad portion between Évian-les-Bains and Lausanne, where it reaches 310 meters (1,020 feet). The lake's surface is the lowest point in the cantons of Valais and Vaud, with its bottom lying 62 meters (203 feet) above sea level. The drainage basin of Lake Geneva culminates at Monte Rosa, which stands 4,634 meters above sea level.

2.4.1 Stakeholders

The efforts to tackle pollution in Lake Geneva involve a various stakeholders, each playing a crucial role in the lake's environmental health. Municipalities are key, responsible for implementing and enforcing environmental policies and water treatment protocols that help mitigate pollution. Residents and tourists directly impact the lake's condition through their recreational activities and waste disposal habits, and they rely on the lake for drinking water, recreation, and its aesthetic value. Environmental NGOs are relevant in promoting stricter pollution control measures and raising public awareness about the state of the lake. Finally, local and tourist-related businesses are significantly influenced by the lake's health; they depend on it to sustain tourism, local food production, and water sports industries, and they are also potential sources of pollution if their wastes are not properly managed. Each stakeholder group has a strong interest in the sustainable management of Lake Geneva, making their cooperation essential for successful environmental conservation efforts.

2.4.2 Implications and Consequences

Biodiversity in Lake Geneva

Lake Geneva and the adjacent banks of the Rhône River host a diverse array of habitats, each supporting various species of flora and fauna:

- **Reed Beds**: These habitats are home to species like the great crested grebe, marsh harrier, reed warbler, pike, tench, and roach. Reed beds provide essential cover and feeding grounds for many birds and fish.
- **River Mouths**: The areas where rivers meet the lake create ephemeral islands of stones and sand, which serve as habitats for small wading birds, sculpins, lake trout, great crested grebes, kingfishers, and common terns.
- **Alluvial Forests**: These forests are shaped by flooding and consist of pools, sandy islands, gravel bars, tall grass, and dense bushes. They support beavers, goosanders, willows, alders, poplars, and various hardwood trees such as oaks, elms, maples, and spruces.
- **Aquatic Meadows**: Home to many birds and fishlike perch and pike, these meadows are also indicators of good water quality, with aquatic plants such as the shiny pondweed and Characeae.
- **Pebble Beaches**: These serve as stopovers for migratory water birds like small waders, scaups, grackles, and ring-necked turnstones, especially in spring when water levels are low.

The biodiversity of Lake Geneva is threatened by the artificialization of its banks through the construction of riprap, walls, dikes, and quays. These modifications disrupt natural habitats and affect the ecological balance of the lake.

The International Commission for the Protection of the Waters of Lake Geneva (CIPEL) has highlighted these issues through exhibitions and educational initiatives to raise awareness about the lake's rich and fragile biodiversity.

Impact on Biodiversity

The biodiversity of Lake Geneva is undergoing significant changes due to pollution from various sources such as agricultural runoff, urban waste, and industrial discharges. Our research has focused on how these pollutants are affecting the lake's ecological balance, particularly in terms of fish populations and invasive species. The findings indicate a concerning shift in fish community structures, seen as a decline in native species and a rise in invasive species. This shift is due to altered habitats and the increasing competition for resources, both consequences of pollution. These changes in ecosystem dynamics underscore the urgent need for targeted conservation efforts to restore and protect the biodiversity of Lake Geneva.

Reference: Studies from local biological stations and regional environmental science journals detail these shifts, emphasizing the need for targeted conservation efforts.

Trash and Solid Waste Pollution in Lake Geneva

Our research into solid waste pollution in Lake Geneva has shown a worrying accumulation of plastics and other trash, which results in significant risks to the aquatic environment. The study specifically highlighted a high number of plastic bags, bottles, and microplastics, which are hazardous to aquatic life due to risks of ingestion and bioaccumulation. These microplastics arise from the breakdown of larger plastic items and have been increasing in quantity in the lake's ecosystem, with potential long-term ecological impacts. Additionally, waste from boating and fishing activities has been identified as a major contributor to the lake's pollution. This type of trash affects water quality and poses threats to the ecosystem's biodiversity.

Researchers from the University of Geneva and the University of Plymouth conducted a groundbreaking study on plastic pollution in Lake Geneva. This study, published in *Frontiers in Environmental Science*, is the first to chemically analyze plastic debris collected from the lake's beaches. The findings reveal significant levels of harmful chemicals, including cadmium, mercury, lead, and bromine, in the plastic samples. These toxic elements pose serious environmental risks and suggest that the plastic has been in the lake for a considerable time.

The study highlights the overlooked issue of plastic pollution in freshwater systems, like marine ecosystems. Plastics pose threats through entanglement and ingestion by wildlife. The numbers reveal a rate of 129g/km^2 of plastic waste 1-20mm in size, with a total of 14 million such particles floating in the lake. This puts Lake Geneva in the same category as heavily polluted bodies of water like the Mediterranean, where the global average for sea pollution is 160g/km^2.

Conservation and Cleaning Efforts

Net' Léman and other local initiatives have made significant efforts to address the pollution. For example, nearly 4 tons of rubbish were removed from Lake Geneva during a recent clean-up operation.

Lake Geneva has implemented several effective methods to maintain its pristine condition and address the issue of floating debris. One of the primary methods used is netting operations. Boats equipped with nets regularly patrol the lake to collect floating debris from the surface. These operations are a common sight on Lake Geneva, ensuring that visible pollutants are promptly removed.

In addition to netting, specialized trash skimmers are employed. These skimmers use technology similar to models developed by Aquarius Systems, which are known for their efficiency in removing surface pollutants. The skimmers are designed to capture a wide range of debris, including small plastic particles that nets might miss, thus enhancing the effectiveness of the cleaning efforts.

2.5 Research Objective

This research's main objective is to develop and implement effective strategies for cleaning urban lakes near inhabited areas from large solid waste residing in lakebeds, while preserving the biodiversity of these ecosystems.

2.5.1 How Might We (HMW) Statement

How might we clean urban lakes close to inhabited areas from large solid waste residing in lake beds while preserving biodiversity?

2.5.2 Detailed Explanation

Urban lakes are frequently plagued by pollution, especially from large solid wastes that accumulate on lakebeds. These wastes not only degrade water quality but also disrupt the natural habitats of various aquatic species, posing significant threats to biodiversity. Given the proximity of these lakes to densely populated areas, it is crucial to devise solutions that can efficiently remove the solid waste from lakebeds, without harming the existing flora and fauna.

Our goal is to explore and implement innovative and advanced technologies to address the pollution problem. By utilizing advanced techniques such as robotic waste collection, remote sensing, image processing, and classification, along with centralized AI systems, we aim to create sustainable and environmentally friendly methods for waste disposal.

Our goal is to restore the ecological balance of urban lakes, ensuring they remain valuable natural resources for both human communities and wildlife. This initiative aligns with Sustainable Development Goal (SDG) 6.6, which focuses on protecting and restoring water-related ecosystems.

3. Technical Ideation Process

In this section, we explain the different steps and alternatives we considered before settling on the final H2BOT design, detailed in the next section. The purpose is also to justify certain design decisions and present other viable routes to solve the same problem.

Our goal was to conceive a robot capable of collecting trash from the bottom of shallow water bodies and bringing it to shore for it to be recycled or properly disposed of. The robot would also need to have minimal impact on the natural environment.

The process was more or less sequential, with a constant narrowing and refinement of the design, in which we would compare (by researching, analyzing and debating) two or more different alternative approaches to overcome a problem, until finally deciding on what we considered to be the best one.

Decision 1: Autonomous Robot vs Human-Operated

The autonomous household vacuum cleaner robots were the original inspiration for H2BOT, so we were very inclined, from the beginning, to go for that approach. However, other existing (yet still in experimental status) technologies, rely on a close real-time human control of the robot, possibly to overcome technical difficulties with navigation and object detection.

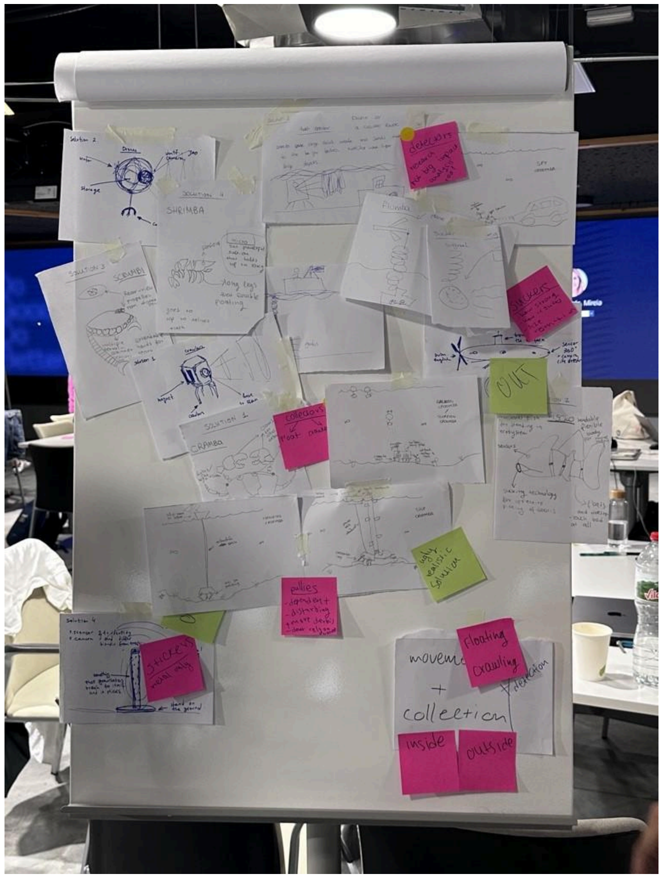
However, human control is also technically challenging because it requires a low-latency communication channel with a high transmission rate and a trained operator to be constantly maneuvering the device.

While technologies for autonomous navigation, underwater object detection and trash collection are not still very reliable nowadays, they are already being used successfully in experimental setups, and we expect them to be production-ready within the next decade.

We decided on the autonomous approach to avoid relying on the constant monitoring and control by humans, which would greatly increase the cost of using H2BOT and its future scalability if used alongside multiple others

Decision 2: Trash - Inside or Outside

While storing the collected objects within the body of the robot avoids the need of a channel for constantly extracting them to the surface, it would require a very large storage compartment. Such a space would greatly limit the minimum dimensions that the robot could have and present several navigation issues.



Brainstorming board during one of the first early design discussions.

Moreover, the possible objects to be collected would be very limited in size; the solution being to simply mark the position of large pieces of debris in order to be extracted with other conventional and expensive methods.

We agreed that a method of trash extraction to the outside was necessary, since the alternative was very technically challenging and severely limited H2BOT's trash-collecting possibilities.

Decision 3: Attached Boat vs Independent Submarine

One of the key decisions in the robot design was whether to make it be connected to a floating device in the surface, or not.

Such a device would be in the form of a small boat, attached to an underwater robot through cables. It would not even require motors, since it could rely on the underwater robot's thrust for movement. Some kind of pulley system would help raise the collected trash to the surface, where it would be stored in the boat. Having an attached floating boat could also help with H2BOT's autonomy, since it could rely on solar power for energy generation, as well as over-the-air communication with antennas on the shore. However, the main the disadvantages we considered were the added complexity to the system, that would no longer be a standalone underwater robot; the force needed to pull the floating boat, especially in the presence of strong winds or surface currents; and its effect on boat traffic, that is non-negligible in urban lakes.

On the other hand, having the robot move independently underwater offers much more flexibility for navigation and scalability to other environments. However, it requires an alternative way of extracting the collected trash; the only way we devised of accomplishing this was through the use of air balloons, inflated underwater and rising to the surface due to buoyancy forces. We liked this idea due to its originality and simplicity, but also to its capacity to extract large pieces of debris, that alternative methods were not able to.

In the end, we concluded that attaching a boat, to which we informally referred to as the "*realistic but ugly*" approach, might be a better idea in order to build a feasible working solution in a very short term, but having it roam independently aligned more with our project goals and futuristic (i.e. feasible within the next decade) mindset.

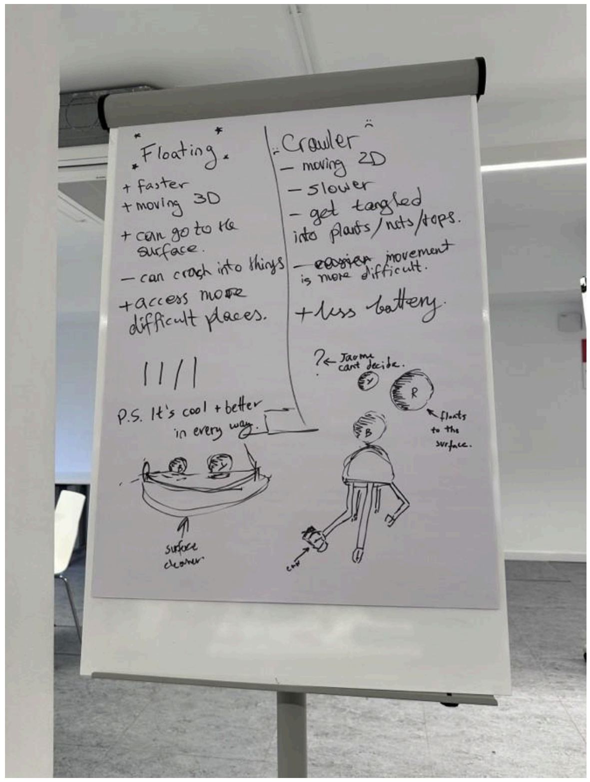
Decision 4: Gas Generation

The original design of H2BOT did not rely on compressed air tanks to inflate the balloons, but instead used electrolysis processes to generate the necessary gas in-place. Such an idea is very inefficient in terms of recharging time and energy consumption, rendering the idea of using balloons very unattractive. Afterwards, we realized that using compressed air tanks was a much simpler and cheaper alternative, and we opted for this path.

Note that this decision was taken while still deciding on the previous ones, since before we had the idea of using compressed air, we did not consider the balloon system a viable possibility.

Decision 5: Crawling vs Floating

The original design of H2BOT was inspired by a crab, that would crawl the lakebed in search of solid waste to collect. Later in the design process, inspired by other existing underwater robots, we considered making it float (i.e. move like a submarine).



Brainstorming board during the *crawling vs floating* discussion.

Floating presents the clear advantages of a faster top moving speed, which in turn can be dangerous if the navigation is not robust and the robot crashes, and full movement in 3 dimensions, which is not very relevant when we are only interested in the lakebed but can facilitate the access to some places. If needed, it can also rise to the surface easily.

A crawling robot has the advantage of a more stable movement, which is convenient to improve the robustness of object detection through the camera. However, programming the navigation with coordinated moving legs can be challenging. One of the critical disadvantages of this design, however, was the impossibility to move in certain terrains: while sandy and smooth lake beds are ideal for a crawling mechanism, a rocky terrain full of crevices can be tricky to navigate; moreover, the possibility of entanglement with seaweed and algae, that through our research we found to be abundant in lake Geneva, was a big downside to the crawling argument.

We thus decided that a floating robot would be the most suitable option for our current problem.

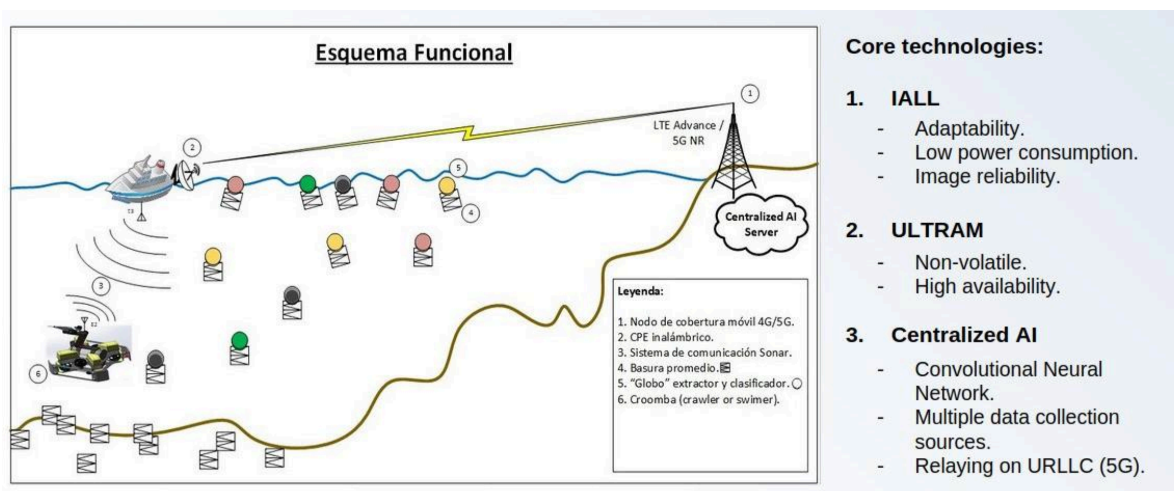
Decision 6: Balloon Collection

We considered the necessity of collecting balloons in the surface after having been released by H2BOT. One of the ideas considered was to have them all attached with a single string so that surface collection would simply need pulling the continuous string. We discontinued this idea mainly because we foresaw a high risk of entanglement with external objects in the lake, especially considering that a large part of the cleanup tasks would need to take place around areas such as piers or beaches with high levels of human activity.

Decision 7: Processing - Inside vs Outside

A question that was raised during our coaching sessions was the issue of performing complex computational tasks, such as navigation and running machine learning models for real-time object detection, within the robot, that had to depend on its own internal battery.

Existing projects rely on wired communication to a surface computational unit, that is floating on an attached boat, which is not our case. The two alternatives we considered were to fit all the necessary hardware inside H2BOT's body and perform all the processing locally (with some communication to the outside, but very minimal and merely for reporting purposes), or transmit the data in real time to a processing unit placed in the shore.



Schema of a possible communication system for the real-time transmission of video data for external processing.

The first approach suffers from the well-known problem of battery drainage when using high-end GPUs at full capacity, required to run state-of-the-art computer vision models. While the latter would need to rely on sonar, which can be challenging in shallow waters and can struggle to transmit high data rates reliably and with low latency.

However, this is not crucial to the concept of H2BOT, and we expect technology to advance enough in the next few years so that both of these approaches can become feasible in the near future. The choice of one over the other would depend on the state of the technology at that particular moment. We elaborate more on this in the next section.

Decision 8: Grabbing Mechanism

The last design decision taken with regards to the technical design of the robot is the grabbing mechanism, used to attach balloons to trash objects. This issue was also raised during the coaching sessions, and we again have not found a definite answer. We have come up with several alternatives to attach balloons to different types of objects:

- Nail gun: perforate the object with a metal nail. Useful for thin, plastic objects.
- Hook: a very simple but versatile grabbing shape. It works well with certain shapes but would require more complex image processing to identify where to grab the object.
- Tighten a string around the object: versatile with the type of material, and somewhat with the shape and size, but, again, requires analyzing the object in more detail to spot the best place to attach.
- Inflate the balloon inside of object: useful for closed objects such as bottles but would require either spotting an existing hole or creating one.
- Put the balloon around the object: surround the object and inflate the balloon with the object inside. Very versatile as to the shape and material, but limited to small sizes.
- Use a sticky material: very versatile to the material, shape and size, but most standard sticky substances do not work well underwater. Additionally, government regulations are very strict on the use of chemicals in such environments.

All the different proposed approaches have pros and cons, and most of them work well for a specific type of object, but not with others. In the end, we concluded that it would be convenient to make H2BOT versatile in having it be able to use several of these options. This can be as in it having multiple mechanical arms, each with a different mechanism; allowing this mechanism to be replaced in the shore, so that on different runs the robot can collect different types of trash; or in having multiple robots running in parallel, each specializing in a type of trash.

4. Technical Description

H2BOT is equipped with advanced navigation and multiple specialized systems that enable it to perform trash collection autonomously and efficiently. At its core, the device employs a sophisticated image processing and classification system, leveraging high-resolution cameras and machine learning algorithms to detect and categorize various types of trash in real time. This capability is crucial for identifying debris that is often camouflaged within the lake's natural environment, ensuring thorough and effective cleaning operations.

Visibility underwater can be a significant challenge due to low light conditions and murky waters. To overcome this, H2BOT is outfitted with a powerful illumination system featuring high-intensity LED lights panel that can be dynamically adjusted based on the ambient lighting conditions. This ensures that the cameras can capture clear images, enabling precise detection and classification of trash; and considering the usage of new IALL lens technology for accurate imagine sampling, quality of image collection is highly guaranteed.

One particular but possible scenario is when H2BOT will have to proceed with operations entirely isolated due to the non-availability of the communications channel, this scenario highlights the importance of the proposed storage system based on UltraRAM technology which will store critical information until time is proper to transmit again or play as backup server for data.

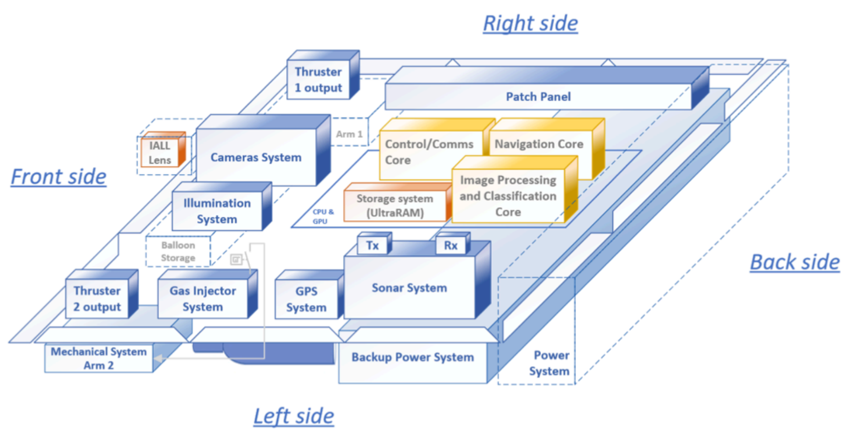
The material handling system, with its articulated robotic arms and versatile grippers, enables H2BOT to collect a wide range of debris types, from lightweight plastics to heavier metal objects. This system is supported by a mechanism that efficiently attaches a floating device to the selected debris and proceeds to its respective inflation.

The device's GPS system, combined with underwater navigation aids such as dead reckoning and inertial navigation systems, provides precise localization, ensuring navigation effectively even when GPS signals are weak or unavailable. This capability is crucial for maintaining operational accuracy in the complex underwater environment of Lake Geneva.

Powering these advanced systems is a robust energy management setup, utilizing high-capacity lithium-ion polymer batteries that ensure extended operation times. The smart power distribution mechanism prioritizes essential functions, optimizing battery life and ensuring uninterrupted performance.

An artificial intelligence system enhances autonomy, enabling it to navigate and perform tasks with minimal human intervention. This system is a centralized and previously trained server that will allow H2BOT to make real-time decisions and continuously improves its performance through reinforcement learning algorithms.

Communication is facilitated through a dual-channel system, combining 5G New Radio technology for high-speed, low-latency data transmission with sonar-based backhaul for reliable underwater communication. This ensures that H2BOT remains connected to the control station, enabling real-time monitoring.



The H2BOT designed for trash collection in Lake Geneva is a comprehensive and technologically advanced solution. It integrates multiple cutting-edge systems to ensure efficient and autonomous operations, addressing the critical issue of underwater pollution and contributing significantly to the preservation and restoration of Lake Geneva's natural environment, now let's take a more detailed review of its systems:

4.1 Navigation System

The underwater vehicle's design integrates sophisticated propulsion and control systems to facilitate vertical and horizontal movements. The dual thrusters manage vertical motion effectively and horizontal maneuvers. The control system, powered by an array of microprocessors enhanced with reliable sensors and communication modules, offers robust operational capabilities. The host computer module provides an accessible and comprehensive interface for independent navigation and, when necessary, real-time monitoring and control, ensuring the vehicle's effective deployment and operation. This design balances technical complexity with user-friendly controls, making it a versatile tool for underwater exploration and tasks.

a. **Navigation Core**

The computer interface serves as the primary control interface for the underwater vehicle. This module provides independent navigation and real-time monitoring and control capabilities through an intuitive interface.

- **Real-Time Monitoring:** The interface displays the vehicle's motion state using both images and data. A camera, coupled with the vehicle's communications system, captures and transmits live footage, while sensors on the vehicle collect data such as water pressure.
- **User Control:** Users can initiate or halt the vehicle's operations and control its movements directly from the interface. This allows for precise maneuvering and immediate response to changing conditions whenever the independent navigation will enter a degraded stage.
- **Emergency Response:** In the event of an emergency, the system can send an interrupt signal to the host computer, prompting floating base station staff to provide manual assistance.

b. **Vertical Propulsion Design**

The underwater vehicle is equipped with two thrusters dedicated to vertical propulsion. These thrusters are powered by DC motors, supported by lithium batteries, and regulated by a brushless electric regulator. The propulsion mechanism enables three types of vertical movements: ascending, descending, and hovering.

- **Ascending:** This motion is achieved when the combined lift force and water generated by the two propellers exceed the vehicle's gravitational force. By increasing the rotation speed of both propellers equally, the lift is enhanced, allowing the vehicle to rise.
- **Descending:** Conversely, descending occurs when the sum of the lift and buoyancy is less than the vehicle's gravity. This is managed by reducing the propellers' speed, thus decreasing the lift and allowing the vehicle to sink.
- **Hovering:** To hover, the lift force and buoyancy need to precisely counterbalance the vehicle's weight. The propellers' speed is adjusted to maintain this balance, resulting in a stable position within the water column.

c. **Horizontal Thruster Design**

To facilitate smooth horizontal motion, the vehicle depends on the modification of the axis of the two thrusters previously presented. Each thruster's operation can be independently controlled to produce linear and steering movements.

- **Forward and Backward Movement:** For forward motion, the propellers rotate at the same speed, generating forward thrust. The thrust perpendicular to the vehicle's longitudinal direction cancels out, resulting in a straightforward motion. For backward movement, the propellers will be required to modify their orientation by 180 degrees.

- **Left and Right Movement:** Leftward motion is achieved by rotating the propellers, which generate a leftward thrust. For rightward movement, the propellers rotate, producing a rightward thrust.

4.2 Image Processing and Classification System

The image processing and classification system is the cornerstone of the device's ability to detect and categorize underwater debris. This system is expected to rely on a dedicated GPU for onboard image processing which is well-suited for handling the intensive computational requirements of real-time image analysis. Utilizing deep learning frameworks, this system is specifically optimized for underwater imagery and allows the system to accurately differentiate between various types of trash and natural underwater elements.

One of the key capabilities of this system is its use of convolutional neural networks (CNNs) for object detection. These neural networks are adept at identifying and localizing trash items within H2BOT's field of view, even in challenging underwater conditions (supported by the enhanced camera system). The classification accuracy of this system is expected to be accurate, ensuring reliable differentiation between plastics, metals, and organic matter. This high level of accuracy is crucial for effective trash collection, as it allows us to prioritize targets based on material type and size. Furthermore, and considering the capabilities of new GPUs (such as NVIDIA or AMD), the system's processing speed is capable of handling high rates in frames per second (FPS), which is essential for maintaining real-time analysis and decision-making during H2BOT's operation. This speed ensures that the device can continuously monitor its environment and adapt its actions swiftly, enhancing its overall efficiency and effectiveness in underwater trash collection.

- **Capabilities:**
  - **Object Detection:** Employs convolutional neural networks (CNNs) to identify and localize trash items in real-time.
  - **Classification Accuracy:** Achieves high accuracy in differentiating between various types of trash, such as plastics, metals, and organic matter due to the enhancement in the camera system (IALL – High resolution).
  - **Processing Speed:** Capable of processing high rates in frames per second (FPS) to ensure real-time analysis.

4.3 Camera System

The camera system of H2BOT is designed to provide high-quality visual input necessary for navigation and trash detection. The primary camera features an IALL lens for high resolution, known for its high-detail imagery and excellent performance in various lighting conditions. This main camera captures detailed images, enabling the image processing system to identify and classify underwater trash accurately. In addition to the primary camera, the device is equipped with multiple secondary cameras that provide a 360-degree view. This comprehensive coverage ensures that no area around goes unmonitored, which is crucial for thorough trash collection and navigation.

To enhance low light performance, the cameras are fitted with large-aperture lenses and high ISO sensitivity settings. These features allow the cameras to capture clear images even in the dimly lit environments typical of underwater settings. Moreover, the cameras are encased in titanium housings rated for pressures at depths of up to 50 meters, ensuring durability and consistent performance under harsh conditions. This robust design protects the sensitive electronics from water damage and pressure-related failures, thereby extending the operational lifespan. Overall, the camera system's combination of high resolution, wide coverage and durability significantly enhances the capability to perform effective underwater trash collection.

The camera system provides the visual input required for navigation and trash detection:

- **Types of Cameras:**
  - Main Camera: High resolution guaranteed by the IALL technology lens for high-detail imagery.
  - Secondary Cameras: Multiple cameras dedicated to navigation purposes.
- **Features:**
  - Low Light Performance: Enhanced with large-nonmechanical aperture lenses and high ISO sensitivity to operate in dark underwater conditions.
  - Durability: Encased in titanium housing rated for pressures at depths of up to 50 meters to ensure longevity and performance.

4.4 Illumination System

The illumination system is integral to ensuring that the camera system operates effectively in the low-light conditions often found underwater. The system utilizes high-intensity LED panel array to provide bright and consistent lighting. These LEDs can output up to 10,000 lumens, with adjustable intensity to suit varying environmental conditions (and according to power availability). The color temperature of the lights is tunable between 5000K and 6500K, which mimics natural sunlight and improve the visibility and color accuracy of the captured images.

Smart control technology integrates the illumination system with the image processing unit, allowing dynamic adjustments based on ambient light conditions. This adaptive lighting ensures optimal visibility at all times, reducing shadows and glare that can obscure trash items. By maintaining consistent and adequate lighting, the illumination system enhances the performance of the camera system and ensures that the image processing algorithms receive high-quality input. This synergy between lighting and imaging components is crucial for the accurate detection and classification of underwater debris, thereby improving the overall efficiency and effectiveness of H2BOT's operations.

This system ensures adequate lighting for camera operation and visibility.

- **Light Sources:** High-intensity LED panel array.
- **Specifications:**
  - **Brightness:** Up to 10,000 lumens with adjustable intensity.
  - **Color Temperature:** Tunable between 5000K to 6500K to mimic natural sunlight.
- **Smart Control:** Control core integrated with the image processing system to dynamically adjust brightness based on ambient light conditions

4.5 Gas Injection System

The gas injection system is a crucial component designed to aid in the flotation and retrieval of collected underwater trash. This system inflates a balloon, which is part of a specialized flotation device, allowing the trash to be buoyantly lifted to the surface. The system is equipped with several interconnected gas tanks, ensuring a steady supply of compressed air or gas for inflation purposes.

The system includes multiple high-capacity compressed air tanks, electronically controlled valves, precision nozzles, and durable gas lines. These tanks, mounted on H2BOT, are interconnected to provide redundancy and consistent pressure, ensuring a continuous supply of gas for inflation. The electronically controlled valves and precision nozzles regulate the flow of gas to the flotation device, allowing for rapid response and efficient inflation. Durable gas lines, running from the tanks to the left robotic arm, ensure reliable gas delivery while withstanding underwater pressure.

When trash is collected, the right robotic arm holds and secures the trash to the flotation device. Simultaneously, the left arm, equipped with the gas lines, inflates the balloon attached to the flotation device. This inflation process is precisely controlled to ensure the correct amount of buoyancy for the specific trash load, lifting the trash to the surface. The system's design ensures that H2BOT can perform multiple retrievals during a single dive. The interconnected gas tanks and efficient gas management allow for the inflation of several flotation devices, enabling continuous operation without frequent surfacing to replace or refill gas supplies. This enhanced gas injection system significantly improves the efficiency and effectiveness of the underwater trash collection process maximizing the impact of each mission in cleaning up Lake Geneva.

4.6 Material Handling System

The material handling system is designed to collect trash effectively, it features two articulated robotic arms with wide degrees of freedom (DoF) each, providing a high level of dexterity and precision. These arms are equipped with interchangeable grippers tailored for different types of trash. For instance, claw-like grippers are used for grabbing plastic debris. Each arm has a payload capacity of up to 15 kg, allowing to lift and manipulate a wide range of objects.

The collected items are secured by the right arm, which also attaches a flotation device, later the left arm proceeds with the inflation of it. This comprehensive material handling system and procedure ensures that H2BOT can efficiently collect and handle underwater debris, maximizing the effectiveness of each mission and contributing significantly to the cleanup efforts in Lake Geneva.

This system is responsible for collecting and storing trash.

- **Robotic Arms:** Two articulated arms with wide degrees of freedom (DoF) each.
- **Grippers:** Interchangeable gripper designs for different types of trash (e.g., claws for plastics).

4.7 GPS System

The GPS system provides precise localization and navigation support, which is crucial for H2BOT's operation in underwater environments. It employs dual GPS receivers for redundancy and enhanced accuracy, ensuring reliable position data even if one receiver fails. These GPS receivers work in conjunction with dead reckoning and inertial navigation systems (INS) to provide continuous and precise positioning, and it is backed up by the communication’s system in order to provide a non-interruptions scenario. The integration of these systems allows H2BOT to maintain accurate navigation and positioning even when GPS signals are weak or unavailable, such as in deeper waters or areas with obstructions.

For surface communication, the GPS system interfaces with a surface pivot (which can be a boat or any available vehicle) equipped with GPS. They help to triangulate the position underwater, providing an additional layer of accuracy and reliability. This capability ensures that H2BOT can navigate effectively along predetermined paths or autonomously explore areas with detected trash. The GPS system's precise localization support is critical for ensuring that the device can perform its tasks accurately and efficiently, contributing to effective underwater trash collection and environmental cleanup

4.8 Storage System

The storage system for H2BOT is designed to provide robust and reliable data storage, ensuring that critical information is preserved even when communication with the surface is interrupted. This system serves as a local hard drive, acting as a redundancy storage solution to guarantee data integrity and availability.

The storage system leverages UltraRAM, a cutting-edge memory technology that combines the advantages of both DRAM and flash memory without their associated drawbacks. UltraRAM offers several key benefits that make it ideal for the demanding underwater environment of H2BOT's operations. It provides a non-volatile storage time of at least 1000 years, ensuring that data remains intact and retrievable over extensive periods. This feature is crucial for long-term environmental monitoring and data logging.

This high endurance ensures the storage system can handle frequent data writing and erasing without degradation, supporting continuous data recording during extended missions. The memory also features non-destructive read capabilities, meaning that the data can be read multiple times without affecting its integrity.

One of the standout characteristics of UltraRAM is its very low switching energy, which is 100 times lower per unit area than DRAM. This energy efficiency is vital for the power-constrained environment of an underwater device, allowing the system to operate effectively without excessive power consumption. Additionally, the intrinsic sub-nanosecond switching speeds enable rapid data access and storage, facilitating real-time image processing and logging of other systems and operational data.

The storage system is designed to store various types of data, including the system’s readings, navigational data, video feeds and, most importantly, image collection and processing results for later feedback to the AI system. In scenarios where the communication system is unavailable, the storage system ensures that all collected data is securely stored and can be transmitted once connectivity is restored. This redundancy is essential for maintaining data integrity and continuity, especially during long-duration or deep-water missions where communication interruptions may occur.

Overall, the storage system's integration of UltraRAM technology provides H2BOT with a highly reliable, efficient and durable data storage solution. This system ensures that all critical data is preserved and accessible, supporting H2BOT’s mission to clean up underwater trash in Lake Geneva while maintaining comprehensive records of its operations.

4.9 Power System

The power system is essential for ensuring reliable operation of all H2BOT’s systems, it is expected to utilize high-capacity Lithium-Ion Polymer (Li-Po) batteries, which provide a high energy density and long-lasting power. The battery capacity is expected to allow H2BOT to operate continuously for up to 10 hours on a single charge, this extended operational time is crucial for covering large areas and collecting significant amounts of trash during each mission. Also, in order to prevent a situation of degradation in the main power supply, the system is equipped with a redundant power module responsible for backing it up.

The power management system is designed to distribute energy smartly, prioritizing essential functions to optimize battery life. It monitors the power consumption of different systems and adjusts the power distribution to ensure that critical components, such as the navigation, imaging, and material handling systems, receive sufficient power. This intelligent power management ensures that H2BOT can maintain optimal performance throughout its operation. The reliability and efficiency of the power system are vital for enabling devices to perform long-duration missions and contribute effectively to underwater trash collection.

4.10 Centralized AI System

The artificial intelligence (AI) system enhances the autonomy and efficiency of H2BOT. At the core of this system, there is a centralized processing server which provides the computational power needed for complex AI tasks. The AI system employs deep reinforcement learning algorithms to navigate complex underwater environments autonomously, that enable the device to learn from its experience and adapt its strategies for better future performance.

The AI system’s adaptive learning capability continuously improves its performance based on collected data and past missions. This feature allows H2BOT to refine its navigation paths, optimize trash collection strategies, and enhance overall efficiency. Real-time decision-making is another critical function of the AI system. It processes sensory input from cameras, sensors and other systems, allowing the device to make immediate adjustments to its actions whenever the communications system is available (otherwise, H2BOT relies entirely on its previous training). This capability is crucial for responding to dynamic underwater conditions and ensuring successful trash collection.

The AI system's ability to operate autonomously reduces the need for human intervention, allows to perform tasks independently and efficiently. This autonomy enhances the overall effectiveness of the device, making it a powerful tool for underwater environmental cleanup.

4.11 Communications System

The communications system of the underwater H2BOT is designed to ensure seamless and reliable data transmission and remote control of systems whenever necessary. This system leverages the latest advancements in 5G technology and sonar-based communication to provide robust connectivity, crucial for real-time operations and data processing.

Backbone (5G NR)

The backbone of the communication system is based on 5G New Radio (NR) technology, offering ultra-high-speed connectivity and low-latency performance. The 5G NR link supports data rates of up to 1 Gbps, enabling real-time video and data streaming, which is essential for H2BOT's operation. The 5G NR backbone is critical for several functions:

- **Live Communications**: Facilitates real-time communication between the device and the control station, ensuring instant feedback and control adjustments.
- **Live AI Training**: Supports the continuous training and updating of the AI server by transmitting large datasets and receiving processed results almost instantaneously whenever necessary.
- **Real-Time Control**: Ensures low-latency control inputs from operators, allowing for precise maneuvering and immediate response to environmental changes.

The URLLC capability of 5G NR is particularly valuable, providing the reliability and low latency necessary for mission-critical communications. This ensures that the operations remain uninterrupted and efficient, even in challenging conditions.

Backhaul (Sonar)

The sonar-based backhaul communication system complements the 5G NR backbone by providing reliable underwater connectivity. Operating at 25 kHz frequency, 20 kHz carrier bandwidth and OFDM modulation schemes, this system ensures that data can be transmitted effectively over distances of up to 1 kilometer. The sonar system is designed to handle varying water conditions, ensuring robust performance regardless of salinity, temperature, or turbidity.

The sonar backhaul is essential for maintaining communication when the device is submerged and out of direct range of the 5G NR network. This redundancy ensures that critical data, including navigational information, sensor readings and collected images, can still be transmitted to the control station.

Edge Computing Integration

The integration of edge computing further enhances the functionality and efficiency of the communications system. Edge computing allows for local data processing and analysis at the point of collection, reducing the need for constant high-bandwidth data transmission to the central AI server. By processing data locally, H2BOT can make real-time decisions and adjustments, improving its operational autonomy and response time.

Edge computing also supports the live training of the AI system by enabling on-the-fly analysis and learning from collected data. This capability allows the device to adapt to new situations and environments more quickly, enhancing its performance and effectiveness in underwater trash collection.

In summary, the communications system of H2BOT, featuring a combination of 5G NR and sonar technology, provides a robust and reliable connectivity framework. The integration of edge computing further enhances this system, ensuring efficient data processing, real-time decision-making, and continuous AI training. This comprehensive communication strategy is vital for the successful operation of the device in cleaning up underwater trash in Lake Geneva.

5. Social Impact

Our advanced underwater automated robot system is expected to make an important social impact by addressing the strong issue of water pollution in Lake Geneva. This innovative solution holds immense importance for several key reasons:

Environmental Preservation and Biodiversity Protection:

Lake Geneva is home to a diverse range of aquatic life. By efficiently removing various types of trash from the lake, our system helps to protect the delicate ecosystems that thrive within these waters. Cleaner habitats lead to healthier fish populations, which in turn supports a balanced and biodiverse environment.

Public Health and Safety:

Water pollution has a significant health risk to local communities. Large amounts of trash in the lake can lead to waterborne diseases and impact the quality of drinking water sourced from the lake due to the microplastics. By collecting and removing underwater trash, our robot system helps to avoid more microplastics being developed and thus providing cleaner water for the community and reducing the risk of water-related illnesses.

Economic Benefits:

Lake Geneva is a very important resource for the local economy, supporting industries such as fishing and tourism. A cleaner lake increases the attractiveness of the area for tourists, boosting local businesses and creating job opportunities. By maintaining the cleanliness of the lake, our system contributes to the sustainable economic growth of the region.

Community Engagement and Awareness:

The deployment of our robot serves as a demonstration of technological innovation being used for environmental purposes. This can inspire and engage the community, creating a sense of responsibility and awareness about the importance of maintaining natural resources. Educational programs and public awareness campaigns can be built around this initiative, encouraging active participation from the community.

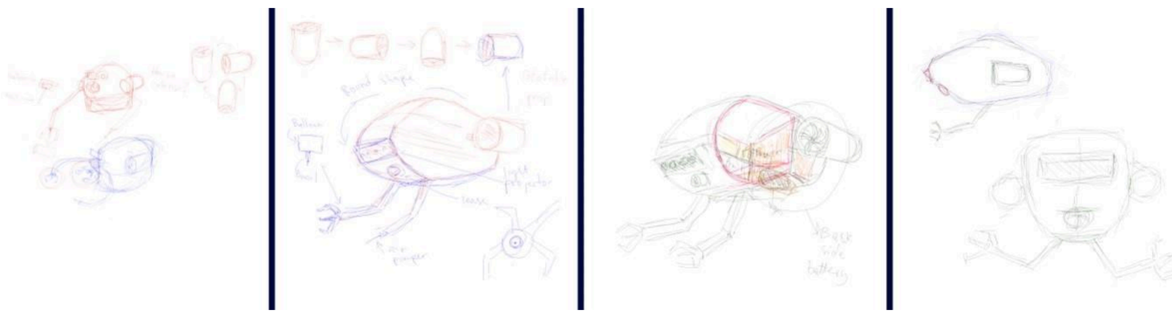
Long-term Sustainability:

Traditional methods of trash collection are very labor-intensive and not as efficient. Our automated system, with its advanced AI capabilities, offers a sustainable solution that can operate continuously and with greater precision. This ensures the long-term maintenance of Lake Geneva's cleanliness by maintaining and restoring it from pollution.

6. Prototyping Description

6.1 Ideation

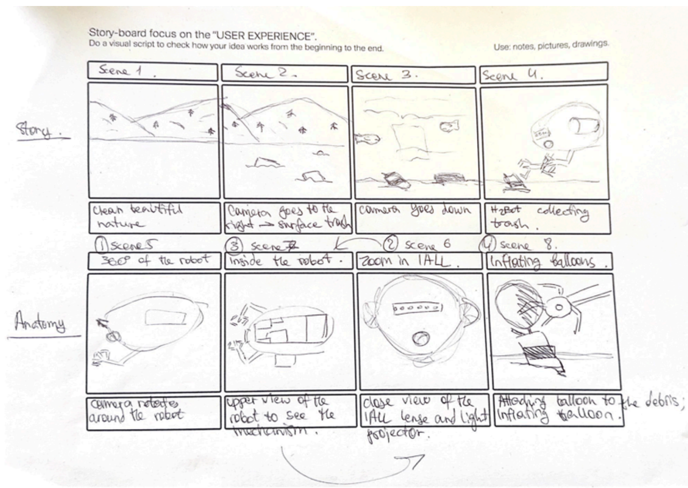
The design process for our product, H2BOT, was extensive and involved numerous iterations. Initially, we focused on sketching the robot's outline, paying close attention to its features and characteristics. Our primary goal was to integrate the robot seamlessly into biodiversity, ensuring it would not disrupt its habitats. Therefore, we selected the robot's shape based on the lake environment, opting for a smooth form and rotatable thrusters to allow for unobtrusive and fluid movement in the water. To begin, we brainstormed various ideas and, with the assistance of Generative AI, tested different shapes. This approach helped us identify the optimal external shape that could house all the necessary mechanical technologies while maintaining functionality and aesthetics.



The color scheme was chosen to mimic the deep-water environment, with added orange lines to ensure easy detection by humans in case of any inconveniences.

6.2 Story Boards

Upon finalizing the sketches and defining the robot's outline, we proceeded to create storyboards for the video prototype. These storyboards served as a visual guide to demonstrate the robot's functionalities and its interaction with the environment.

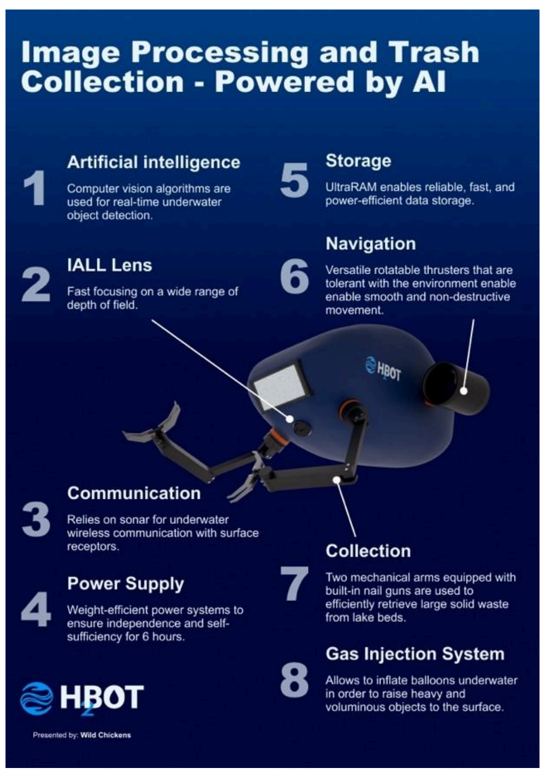


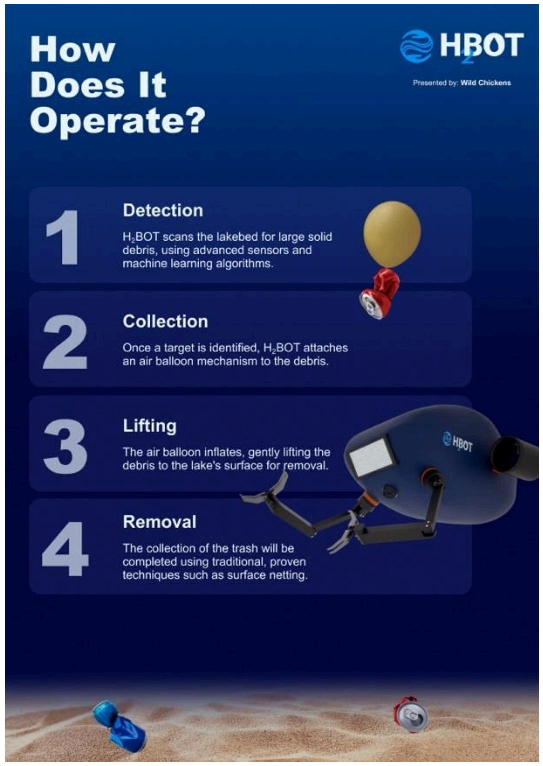
6.3 3D Model

Following the storyboarding phase, we transitioned to 3D modeling. This step involved creating precise models suitable for 3D printing, which allowed us to produce a tangible prototype of the robot.

6.4 Posters

Concurrently, we developed posters to highlight the main functionalities and purpose of H2BOT, providing a clear and concise overview of its capabilities and intended impact.





6.5 Video

To further illustrate the robot's workings, we created a detailed video. This video explains H2BOT's operation, showcasing its design features, technology integration, and its role in protecting and restoring water-related ecosystems. The video serves as an informative resource, conveying the innovative solutions our AI-based robot offers in contributing to Sustainable Development Goal 6.6.

It can be found on YouTube: https://youtu.be/2Z6Vr5oOvMQ

7. Branding

For our visual communication, we designed a distinctive logotype that effectively represents our brand. We chose to create combination marks, which include both a wordmark and an abstract logo. Our abstract logo is inspired by the fluid shape and movement of water, capturing its essence visually

Logo Variations

The name of our robot, "H2BOT," cleverly combines the chemical formula for water (H2O) with the word "robot." This fusion not only reflects the fundamental nature of water but also emphasizes the technological aspect of our product. Our design goal was to seamlessly merge these two elements, creating a logo that is both meaningful and visually appealing. The flowing lines and dynamic curves of the logo symbolize water's adaptability and vitality, mirroring the innovative and versatile nature of our robot.

Color scheme

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