UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

Team Aston Martin

<Team Leader>
<Mathijs Berkhout>

<Team Members>
<Jakub Stachurski>
<Denzel Hagen>
<Tim Schulpen>
<Mitchell van Poecke>
<Madelon Gorter>
< Yrjö Lagerweij>

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Chapter 0: Introduction

We are team Aston Martin! Our team consists of Mathijs Berkhout, Jakub Stachurski, Denzel Hagen, Tim Schulpen, Mitchell van Poecke, Madelon Gorter and Yrjö Lagerweij.

The problem we are tackling is the contamination of water by determining the pH value In the Netherlands. We have a lot of natural water like lakes and rivers in the Netherlands, which we would like to protect from contamination by finding the value of the pH to figure out if there is a need for more expensive research to find out which contamination it is.

Another reason to find the pH of water is to find out if the aquatic hierarchy is in danger. Because a difference in pH can make it so that certain aquatic life will be terminated, this will cause certain species to get extinct in the lake. This can have as follow-up that the lake gets deoxygenated because of an increase of algae growth when the pH gets lower, which endangers other species in the water.

Our solution consists of a boat, a pH-meter, a water sensor and gps sensor. Together they can measure the pH-level of water. The boat delivers the pH-meter to the right place and when the meter is long enough in the water he will start to measure the pH and the gps-sensor measures the exact coordinates of where the boat is.

We chose this solution because a boat can be used to measure the water in the middle of the lake in a cheaper way. Because the human controlling the boat can stay at the edge of the water instead of having to get a boat to go to the middle of the lake. We also chose this idea because our other idea became too heavy for a drone so we had to change our idea to be able to carry the weight.

In the end because of an expensive sensor the plan of measuring nitrogen was altered to measuring the pH in water. This made it so that this report is partially about measuring the nitrogen levels of water and partially about measuring the pH levels. This switch was made so that the research that was collected could still be used in the report because measuring the pH of water is to show that the water is contaminated and the next step would be to figure out what’s contaminating the water. This makes it so that the beginning is a little bit more focussed on a specific form of contamination while the last part of the report is focussed on if the water is contaminated.

Chapter 1: Literature Review

This chapter consists of 20 summaries of meaningful publications about climate change. This is part of our ideation phase where we gain a basic knowledge about climate change from which we can evolve to come up with new ideas.

1. Economic interactions between climate change and outdoor air pollution

Interactions between climate change and air pollution are acknowledged, however much less is known about how these will impact the economy in the coming decades.

There are 4 main interactions between climate change and outdoor air pollution.
1. The effects of economic damages on emission levels.
2. Greenhouse gasses have a polluting effect on the environment.
3. Changes in the ecosystems such as diminishing water resources.
4. Interaction inside of the economic system.

In the coming decades the damages will be relatively small because the consequences of air pollution will dominate. but overtime both air pollution and climate change will increase significantly. especially in low income countries. The agricultural sector will be hit the hardest as global wheat production will be significantly reduced. The model suggests that damages in emission will be small. The impact of the air pollution on the average global temperature is relatively small as well because of the fact that not only are there warmer pollutants (e.g. black carbon) but also cooling pollutants (aerosols). These roughly cancel eachother out. [1]

2. Extreme weather from climate change could overwhelm bird eggs

Climate change could leave bird eggs unprotected against the extreme heat. Bird eggs are resilient to diseases and the birds can breathe inside of the eggs. But they are less likely to survive against heavy rainfall or extreme temperatures.

Scientists have figured out how birds use water to their advantage in certain situations. The eggs can be either hydrophobic (repelling the water) or hydrophilic (letting the water stick more to the egg). It is common for a bird that generally lives more in drought climates to lay hydrophilic eggs and it is more common for birds that live in more dry and humid environments. It is also known that birds that take more time to hatch will most likely have a hydrophobic shell.

So, birds already have some protection against the extreme weather conditions, but with climate change there will be more heavy rainfall and longer droughts. This could leave the chicks unprepared for these situations. [2]

3. Pests and diseases and climate change: Is there a connection?

Climate change can affect pests in multiple ways, such as survival rate, population size and geographical distribution of pests. Temperature and rainfall is one of the main factors for the spread of pests. The increase in temperature increases the living conditions for these pests, giving them a humid environment and it provides sufficient moisture for their growth. Although if the temperature gets too high this could impact the growth, by washing away the eggs and larvae from the host plants. Pests populations grow if temperatures increase up to a certain point. [3]

4. Will the ocean really be dead in 50 years?

The ocean is facing down three huge threats: overfishing, pollution and climate change. Most of these are caused by human mismanagement. Nature is stretching to breaking point. If we don’t stop, the ocean could be drastically changed within our lifetimes.

What will the ocean look like in 50 years if we don’t do anything?

- There will be more plastic than fish
- A jellyfish take-over
- The water will be warmer and it will hold less oxygen
- Our fish and chips will get smaller
- Coastlines will change
- Water will become more acidic
- Farming the sea

So what's the outlook?

Dead zones in the ocean remain a threat. Protecting this precious resource isn't an easy matter. The goal is making the whole ecosystem more resilient, more able to cope with change.

Lots of these problems are far bigger than any individual choice. Only collective action can solve them, which requires commitments from governments and business.

However, we can all make a difference by recycling our plastic waste, buying sustainable seafood, and reducing our own carbon emissions. [4]

5. 5 ways to make buildings climate change resilient

The evidence is clear. We are in a race against time to adapt to a rapidly changing climate – one of the three planetary crisis we face along with biodiversity loss, pollution and waste.

The construction industry accounts for 38 per cent of total global energy-related CO2 emissions. It plays a big role in global warming. Through investing in more resilient infrastructure humanity could save $4.2 trillion from climate change damages.

How can building and community spaces be constructed to increase resilience?

1. Building resilience to heatwaves
    - Create urban forests and green spaces to reduce heat waves in cities
    - Structural designs that help reduce heat inside buildings such as green roofs and reflective surfaces
2. Building resilience to drought
    - Rainwater harvesting and recharge systems that capture water on the roofs of buildings
    - Plant trees or other vegetation around buildings
3. Building resilience to coastal flooding and sea-level rise
    - Buildings elevated 2 meters above the ground
4. Building resilience to cyclones and strong winds
    - Build round-shaped houses
    - Consider optimum aerodynamic orientation
    - Strong connections between foundations and the roof
    - Consider the design of the roof
5. Building resilience to cold
    - Insulation in roof, walls, ceilings and double-glazed windows
    - Trombe walls
    - Water walls
    - Buildings oriented to maximize sun exposure
    - External surfaces of walls should be painted dark
    - Green roofs

[5]

6. Could Climate Change Make Food Less Nutritious?

Research that looks at the way climate change will impact our food.
Climate change will cause crop yields, or the amount of food we can produce on the planet , to fall. This could cause increased spikes in food prices, deepening food insecurity and micronutrient deficiencies.

Already, over 2 billion people, or 30 percent of the global population, suffer from micronutrient deficiencies, a major cause of death and disease, and that this will likely worsen.

Micronutrient deficiencies come with far-reaching public health consequences. Zinc deficiency for example can make you a lot more susceptible to severe cases or dying from respiratory infections. Iron deficiency can cause anemia, lower IQ and cognitive ability, reduce work capacity and increase mortality for mothers and their children.[6]

7. Energy use in buildings in a long-term perspective

In 2010, energy services related to buildings were responsible for 33% of the total global energy use. The quantity and quality of energy related to buildings is dependent on the human demands and the factors surrounding those buildings. The amount of energy for satisfaction of human activities depends on the personal situations and requirements; access to modern energy services, thermal comfort, increasing (wealthy) population, building poverty (inability to afford efficient energy services), household size, services/ devices provided by electrical energy and amount of equipment ownership. The population that has no access to modern energy services (3 billion) or electricity rely on solid biomass fuels, which produce more air pollution and deforestation. That is why diversification and resilience of energy supply is important.

The factors to reduce heating and cooling energy in buildings are to improve the air tightness in a building, deal with the urban heat island effect by improving city planning and infrastructure, have less extreme climate change around the building and deal with less outdoor and indoor air pollution. [7]

8. Road transport technology and climate change mitigation

To decrease the emission from transportation you need to look at technology, behavior and intelligent transport systems. Combustion engines affect the health and air quality of the environment due to air pollution of GHG emissions and mostly CO_2. Travel distance plays a big role; 3% of the total car trips in the UK had a travel distance of more than 40 km, which caused 22% of the CO_2 transport emissions in the UK.

For low-carbon engine technologies like hybrid and electric engines, efficient low-carbon production lines, new infrastructure of the spread of zero-carbon facilities and decarbonisation of the electricity production are needed. For a change in driving behavior, awareness and a decrease in drive-demand is important; smaller cars, eco-driving or increase the fuel price as a government. [8]

9. Impact of open burning of crop residues on air pollution and climate change in Indonesia

The agricultural purpose for biomass burning is to clear land of harvest residues, change land use, soil enrichments and pest control. Globally at annual, 45 million tons of crops are burned, which emits 90% CO_2 and the rest of GHG emissions (other gasses). These burnings affect air quality, causing disruptions in rainfall patterns and can cause hazes in combination with tropospheric ozone. These hazes create brown clouds that can be fatal for the health of nearby cities. Farmers stick to burning, because they lack access to modern energy and efficient farming practices. Alternatives used for dealing with harvest residues are: composting materials, building materials (roofs), animal food and home-fuels. The amount of burning needed also depends on the type of crop and the percentage of usability, each crop has their own amounts of certain emission gasses if they are burned down. [9]

10. Personal experience with climate change predicts intentions to act

In this study[6], the researchers have looked into the willingness to contribute to adaptation or mitigation to climate change and how it relates to their experience with the effects of the changing climate. The research also split with general intentions to mitigate climate change and the will to do certain actions to mitigate climate change.

In the research a survey was posted in 25 countries gathering 11 614 valid responses. The survey consisted of questions about endorsing various mitigation measures and personal experience with climate change and other metrics:
'We collected responses on an inventory of scales designed to measure (a) belief in GW, (b) environmental worldview, (c) self-efficacy, (d) personal experience with GW, (e) belief in the free-market system, and (f) knowledge about causes of GW. Our dependent measures of intention to act are (a) a 4-item scale of general endorsement of action and (b) endorsement of 3 specific actions.' [6, pp.69]

The results revealed a link between personal experience of climate change and direct action to make a change. It also showed that individual measures are less endorsed than the mitigation in general and also vary more from person to person. [10]

11. Climate change mitigation and transport in developing nations.

This study highlights the importance of growing personal transport markets to future carbon emissions. The issue addressed in the publication is the potential amount of carbon emissions that could be caused by increased share of personal motor vehicles, like cars and motorcycles in transportation amongst populations of countries like India where the amount of people that can afford a car is growing, while the technology to reduce the emission of motorized vehicles cannot compensate for this growth.

This raise of emissions caused by motor vehicles could extremely hamper the current climate change mitigation efforts. And have to be mitigated themselves.
This can be done by promoting less polluting alternatives like bicycles and public transport. Although the paper admits that these alternatives lack in some aspects and those weaknesses have to be addressed to be successful. [11]

12. Extreme Makeover: Human Activities Are Making Some Extreme Events More Frequent or Intense

The article[12] is about the major events that happened in the past year like the floods in the Netherlands or the heatwaves in the United States. In the article it's explained that a lot of these events happened because of the ecosystem deterioration by humans. The problem central in the article is that the human population is emitting too much greenhouse gasses which are destroying the ecosystems and because of that the major crises follow, for example they explain that the major rainfall can be explained by an increase in the atmospheric water vapor attributable to human-produced warming.

13. Energy and climate change

The article[13] is about the goals of the EU to reduce the amount of greenhouse gasses in the upcoming years and the plan they set out for the reduction of greenhouse gasses until 2020. It highlights the problem of the energy consumption in Europa and their goal to reduce the energy consumption by 20% and an improvement of 20% in the energy efficiency sector and this will be increased to 275 for both sectors after 2020. Another section that will be regulated are power stations and industrial plants, when the plans were announced they were responsible for 45 % of the greenhouse gasses in the EU and the emission of these factories have to be reduced by 43% in 2030 compared to 2005. The changes they propose are: opting for cleaner energy sources, using more non-combustible renewable energy sources instead of fossil fuels and by reducing the total amount of energy consumption by energy savings and energy efficiency.

14. Deforestation and its effect on the planet

The article[14] is about deforestation, the importance of forests and the effects humans have on them. At the moment too many forests are being cut by humans for supplies and fuels and lost because of human interference, for example because of urbanization. This matters because deforestation helps some species get extinct and because trees are a factor for the removal of carbon dioxide it helps the climate deteriorate even more. In the article they say they're trying to stop deforestation by focusing on making sure forests aren't being cut illegally, but this alone won't be enough to stop deforestation, consumers of products also should be aware of what they're buying.

15. The Psychology of Climate Change

This paper[15] is about the psychological reasons of "what has to be done and why has nobody done it yet." The final conclusion is that it is a combination of various psychological effects, and it will take new ideas to solve the problem. These new ideas should come in the form of alternative energy sources, and only then are people in a likely position to convince the general public that actions need to --and CAN-- be taken.

16. The Psychological Impacts of Global Climate Change

This article[16] goes into the psychological effects global climate change has on the humans experiencing it. It divides the psychological effects into three classes: Direct (IE trauma and stress from the increased number of extreme weather events), indirect (IE stress from seeing the effects that occur already and insecurity about whether the future will be livable) and psychosocial (IE effects that the changed climate will have on society by virtue of being a different climate). It also goes into what needs to change in the general populace's ideas, such as increasing knowledge on ecology and changes in how responsible people feel.

17. Plant Phenology and Global Climate Change: Current Progresses and Challenges

This research[17] investigates the yearly cycle of leaves opening and falling in the context of recent changes in the ecosystem caused by global climate change. It found that the leaves would open earlier and earlier and fall later and later. Oddly enough, though, in recent years this increase has slowed down and, in some cases, even reversed. It also goes into the feedback this cycle itself has on CO2 levels and climate change in general.

18. Limited potential of no-till agriculture for climate change mitigation

In this article weighs the positive and the negative effects of no-till, which is the practice of not tilling the field before planting, saving fuel from not having to plow by mechanized means, absorbing more carbon into the top layers soil and in turn presumably mitigating CO_2 buildup and improving soil quality. The retention of more carbon in the soil is the primary benefit of no-till that is discussed in the article. The researchers point out that the additional carbon does not come primarily at the cost of the atmospheric carbon but from the lower layers of soil. This means that the potential for this technique to mitigate climate change directly is minimal at best. In addition to that the additional emissions of nitrous oxide that may come from no-till can completely negate any greenhouse gas reductions. The paper concludes that managing nitrogen and fertilizer is a better way to mitigate climate change in agriculture. Although the articles say that no-till is beneficial in some environments because of the other effects on crop growth. [18]

19. The impacts of melting sea ice

The Arctic and Antarctic make sure the earth stays cooler. They are covered with snow and ice which reflects the sunlight back into the atmosphere. If the ice melts there is less reflection and the earth will be warmer which makes more ice melt and even less reflection.

If the sea ice melts there is less space for animals that need it for survival. If one species would get instinct because of the melting ice it could change entire ecosystems for the worst. [19]

20. The results of rising sea levels

In the last 250 years the sea levels have risen 21-24 cm about one third of that has happened in the last 25 years. The rising water is a combination of the melting sea ice and the expanding of the water because of the higher temperatures.

Even if the entire world all of the sudden would switch to green electricity the sea levels would still rise another 30 cm by 2100.

If we continue the current rate with high emissions, the worst case scenario would mean that the sea levels would rise by about 2.5 meters by 2100. [20]

Chapter 2: Identification of General Problems and Challenges

From the summaries that were written, we came up with some problems and related challenges that we found interesting and could be usable for the future.

- A lack of access to modern technology. This ensures that people are still using energy inefficient energy services like fossil or primary biofuels, inefficient farming technology which will not replace crop-burning and a lack of availability of low-carbon energy facilities like charging stations.
- Heatwaves through the city cause a high demand of heating energy in buildings, which is indirectly responsible for CO_2 emissions. The urban heat island effect is also a part of it, which can have to do with poor city planning. There is a lack of green spaces in the city and buildings lack effective structural designs and reflectiveness.
- Outdoor air pollution can cause changes in ecosystems which will diminish water resources. This can cause harvest problems in the agricultural sector, which can lead to an decrease in food resources in low income countries. Together with pollution, overfishing and climate change, water will hold less oxygen and become more acidic.
- There is too much deforestation happening which has the effect that certain animal species are going extinct and more gasses like CO_2, greenhouse gasses and water vapors keep building up in the atmosphere.
- Too much energy is used and energy isn’t used efficiently enough. A lot of the time people use extra energy while it isn’t necessary. For example turning on the light while it’s still bright enough in the room.
- Eggs of birds won't survive and can no longer keep up with the conditions of climate change; more heavy rainfall and longer droughts. This could leave the chicks unprepared in these situations.
- People don’t directly experience climate change enough to think of mitigation behaviors. There is a lack of willingness and awareness of individuals to adapt and change their behavior towards global warming. This can have to do with psychological reasons, like the mindset that actions need and can be taken.
- Nitrogen management in agriculture is not seen as a big enough problem, even if it plays a big role in climate change. The management of fertilizer can be improved.

Chapter 3: Identification of Relevant Problems

1. Unnecessary energy consumption

People forget to turn their appliances off when they are done using them. An example for this is that some people leave their house and leave the light on for when they come back, meaning that the light was on for nothing. Another example is that people use their pc or laptop during the day and when they will do something else, like have dinner, they don’t turn their device off or on sleep mode. These small things don’t look like a big problem but if a lot of people do this it will eventually cost a loss of extra energy which will cause a bigger effect on the climate. A solution to this could be making people more aware of what leaving their appliances on will do to the climate and another solution would be using other devices to help stimulate the use of the appliance.

2. Ocean acidification due to the absorption of CO_2

The ocean gets more acidic because more CO_2 gets dissolved in water due to increased CO_2 levels in the atmosphere, because the ocean needs to regulate its balance. This affects marine life and the coastal ecosystems; less aragonite saturation levels make it hard for marinelife to build their shells and the production of carbonic acid changes the amount of minerals [21]. This problem will impact ocean biodiversity, physical capabilities of some fish and the fisheries, because of the food security that needs to be maintained. Solutions could be related to the manipulation of planetary systems, fertilizers, iron that will absorb CO_2 from the atmosphere and sink down to the bottom of the sea, phytoplankton[22], algae or seagrasses. Regulating seaweed farms can slow down ocean acidification and it both fights overfishing by providing an alternative foodsource [23].

3. People do not prioritize sustainable living

People do not care about climate change until it affects them or their direct descendants. This problem is the prime culprit of slowing the public efforts in mitigating climate change, because the interest of the voters directly affects what the government is planning to do. This effect is due to how people prioritize things that directly affect them to improve their condition, which is a valid strategy for the short term, but lacks the long term perspective we need to alleviate the problems with the climate. Bringing awareness to climate change is something that should be done by actually affecting the individual to some degree to put this issue on their priorities list.

4. Contamination of nitrogen in soil and groundwater

Farms use too much nitrogen which causes nitrogen contamination of soil and groundwater. Nitrogen is mainly used for the food industry as fertilizers and for the preservation of food. The way nitrogen is used for preservation of food is that it drives out the oxygen and all the moisture in the inside the food packaging, if there is less moisture it takes longer before bacteria can spoil the food. The nitrogen found in fertilizers is essential to keep the plants healthy. The nitrogen that gets absorbed by plants is used to make protein and let the plants grow faster but the nitrogen that does not get absorbed by plants contaminates the soil and groundwater. If there gets too much nitrogen in a lake or drinking reservoir it could cause an overgrowth of water plants and algae. This can block sunlight and oxygen from getting into the water which could kill all the other organisms in the water. A possible solution to this problem could be planting nitrogen fixing legumes which absorb the excessive nitrogen and keeping them in check with smart sensors.[24] [25]

5. Unnecessary trash costs a lot of energy

People use way too many products only once. There are way too many products that have non-recyclable or non-reusable packaging that is one-use and is then thrown out. This means that a lot of energy has to be put into creating new packaging. It also creates a lot of rubbish, which will most likely be burned, releasing toxic substances and more CO_2 into the atmosphere. Recycling still costs more energy than just creating reusable packaging, so making reusable items would be the best solution. Examples of already reusable packaging are soda bottles. What might also help is making biodegradable packaging that doesn’t pollute as much as plastic does.

- Sustainable alternatives
- Discouraging use of one-use products

6. Underutilization of sustainable energy sources

We need other reliable energy sources. Right now we are using a lot of unsustainable energy sources like fossil fuels and gasses. Around 11% of our energy comes from sustainable alternatives. Most of this is from biomass and wind energy and a little comes from solar, hydropower, geothermal and aerothermal energy. We need to increase the amount of sustainable energy by using more renewable and reliable energy sources, like either nuclear energy or wave energy. [26]

Chapter 4: Problem Selection and Motivation

Nitrogen Contamination in Soil and Groundwater

We want to prevent the overgrowth of water plants and algae and prevent other water plants and aquatic life from dying out. In the Netherlands, we have a LOT of agriculture, and thus a lot of nitrogen contamination. We also have a lot of natural water like lakes and rivers in the Netherlands, which we would like to protect from contamination by nitrogen based compounds that chemical fertilizers bring with them.

Another reason to reduce nitrogen compounds we put into the soil is the nitrous oxide that the soil emits when oversaturated with nitrogen. This gas has the global warming potential of almost 300 fold of that of carbon dioxide and it can deflect ozone in the atmosphere. An increase of nitrogen and fertilization in the soil gives the opportunity for plants that absorb more nitrogen to overgrow the plants that need less nitrogen. This can cause a shift in the amount of insects and animal species which rely on the balance of the amount of plants in the ecosystem. This can result in imbalances in ecosystems [27].

The ones in control of release of additional nitrogen compounds into the soil, the farmers are not financially incentivised enough to invest in the current methods of measuring nitrogen species on their field as those are prohibitively expensive. Although if the measurements could be done cheaply by the farmer themselves, they would pay for themselves as they could give the farmer an indication to use less of the expensive chemical fertilizers.

Chapter 5: Potential Solutions

Solution 1

A fast way of measuring so vital but so lethal nitrogen base compounds in both water and soils necessary to reduce those compounds effectively. The measurements can be used to identify overuse of fertilizers that are the biggest human source of nitrogen based compounds in the soil and in turn in the ground waters that connect to lakes and other surface-layer aquatic environments. Or narrow down the search for the aforementioned or other, miscellaneous nitrogen contamination. The measurements need to be made over large swaths of land, which requires the measuring device to be mounted on a swift and autonomous platform. Those requirements are met by drones capable of moving autonomously, which can be bought off the shelf. But to measure the soil in that way, the drone would need to lower the apparatus into the ground to take a sample, or ideally measure the composition of the soil in-situ. The second option can be realized using spectrophotometry as seen in this article. [28] And although proper sensors for this kind of measurement are expensive, a DIY solution is possible for our prototype. The problem with this solution is that a drone cannot land everywhere, so the measurement apparatus would have to hang on a long, unwieldy stick to clear any plants that might be in the way of the measurement zone. But if executed properly, this measuring drone could measure large areas in one pass, send the information to a ground station and leave minimal trace on the measured terrain or water body. And because drones are commercially available, the only thing left to develop is the sensor cluster on a stick that can penetrate the ground or the water surface to make the measurement and software to manage the stick and the drone. If the drone can be made autonomous, there is minimal human involvement in the measurement outside taking care of the drone.

Solution 2

The idea of a tiny toy boat that floats on a lake and makes measurements of the nitrogen levels in this lake. The boat can take samples of the lake water on different locations of the lake(the locations can be controlled by sending coördinates to the boat). With these samples there can be done research on the boat or information can be collected and sent to a different place where it can be researched. With this collected information the amount of nitrogen in the lake can be calculated.
If the amount of nitrogen is measured it can be used to compare different lakes or different locations of the same lake to each other. When compared it would be possible to make a map of the lake which shows the amounts of nitrogen in each place. This information could be used to locate the main source of nitrogen pollution in the lake.
The boat can be powered by solar energy to be as energy sustainable as possible.

Solution 3

An idea similar to those automatic lawnmowers you see driving around yards might work to combat the water plants that cover ponds and lakes with too much nitrogen. It would be a simple automatic boat that propels itself around on solar energy (with a small battery for emergencies). It also has two motors rotating in opposite directions, working similar to paper shredders, to pull plants that get caught in it out of the ground. Preferably, the boat will also catch the plants and pull them along. When it reaches a bank, it turns around semi-randomly and releases the plants it collected.
Possibly, it could also procedurally map out a lake so it kind of knows where the edges are, like a roomba.
If the boat cannot catch the weeds and pull them along, a secondary boat could be used instead. This boat would push the loose plants before it, and turn around when it reached a bank, leaving the plants near the side.
With either solution, the plants would still have to be collected occasionally by humans. Since the plants use large amounts of nitrogen to grow, they basically already remove the nitrogen by growing and store it within themselves. This means that if you remove the plants, you also remove the nitrogen from the water, although this is probably not a quick process.
Downsides to this solution are that such drones are not that fast, but thankfully plants don't grow at the speed the drone moves.
A second problem is that this only solves the problem of the plants covering the lakes and ponds, and only slightly helps with the nitrogen. It would not help if the water becomes completely toxic by nitrogen, nor does it directly remove the nitrogen from the lake.
If a lake has active boating in it, the little cleaner drones might be in danger, as they probably won't survive being hit by a boat. A fine might cause boaters to try and steer clear of the little cleaners.
Upsides are that the boats should work autonomously, and thus only needs a human to pick up the plants from time to time, which can then also be recycled. A human could be hired to take care of a couple of lakes, visit them every few days and collect the plants.
Once designed, the drones shouldn't be too hard to produce and thus could be released en masse on bigger lakes, since lakes are usually larger than the average lawn. They could also garner a similar affection to roombas, as little friendly robots that help clean up our lakes.

Solution 4

An analytical system of various sensors that the farmer can use on his own farm to decrease the amount of nitrogen needed for farming. With these sensors and data about the optimal growth of a crop the system can calculate the amount of fertilizer that needs to be added. In this way the amount of nitrogen not absorbed by the crops and the amount of fertilizer farmers need to use is reduced. Using less nitrogen makes sure the pollution is minimized which is better for the environment and using less fertilizer means less costs for the farmer and optimal growth of the crops.

The toolset can have a database of proper amounts of fertilizers and other growth factors for various crops, which would help the farmer to break up the monoculture by encouraging planting diverse crops. The tool could also serve to establish synergy between different plant types. This would diversificate the income of the farmer as not all crops do as well every year, add biodiversity to the area, and help restore pollinator populations that would increase the yield of the crops and the income of the farmer.

The negatives to this solution would be that there are a lot of things that are influencing crop growth, measuring all of these things would take a lot of time and sensors to develop. Not every sensor works in the same way, so you can't make a small one that does all of it.

The measurements could be made both by analysis of the soil the plants grow on, or by looking at the biomarkers on some part of the crop.

Solution 5

A possible solution is to make a device that could work 24/7 to remove the surface plants from lakes. There exists a seabin, which is used to collect trash from the ocean, by just being barely below the surface level of the ocean. All of the nearby trash flows to the seabin and falls inside the bin. This could also work with duckweed, this is a plant type that covers lakes and ditches. The growth of duckweed gets amplified by nitrogen. So to remove this you could use the seabin to remove the surface duckweed from the lakes. This is a way to fight the effects but not the cause of the problem. The requirements are a bucket with a net, a way to keep it just below the surface level of the water, a way to measure the amount of trash inside the bucket and a human to empty it when it is full. This would help the plants inside the lake to receive sunlight and make oxigen so the fish would survive and not suffocate. To test it you can have a cup just below the surface level of water and watch it flow inside it, all of the plants on the surface will enter the hole. This could impact surtain fish which like to hide under the cover of these surface plants. The seabin project can give a lot of inspiration [29]

Solution 6

Another possible solution is helping the farmers harvest mixed crops on their farms by helping them separate their seed in the planting device so they can be planted in a fast way. At the moment farmers usually plant the same crop on a large piece of land and because of this more nitrogen remains in the soil. With the planting machine automatically dispensing the right seed it can save the farmer time and gives it a reason to implement this idea because it shouldn't cost him time to separate the seeds. With the implementation of more mixed crops the nitrogen production through farming would be set back a bit because of more efficient nitrogen intake by the crops[30]. There shouldn't be any risk involved by this idea because the idea shouldn't need help from a human, the only risk that this idea could have is that the crops can't completely grow because of weather conditions but this can be checked before doing the seeds you want to use in the machine. The requirements for this idea aren't that big, the only things that are really needed is a sensor that can spot the difference between the seeds and a program that can decide which seed it is and which seed should be planted next. Or another variant is that the seeds are already separated by the farmer and the machine measures where which seed should be planted. We can demonstrate this idea by showing how the machine separates the different seeds and checks the ground to see which seeds should be planted.

Solution 7

A small ball and tube that is connected to a floating platform that can move through water to do measurements on water samples to measure the amount of NO_3- (nitrate) in the water. When the ball has its preferred gps position, it slurps small volumes of water to the floating platform. While measuring on more and the same gps-points, all the results that are stored in a 3d data map can visualize the flow and the origin of the nitrate. From these results you can e.g.

- Analyze from which direction and piece of land the excessive nitrate comes from and warn farmers in the directions around the lake that they are using too much fertilizer
- Predict where more algae composition will happen on a lake and already employ resources on the high concentration NO_3- parts of the lake with heterotrophic bacteria to stimulate denitrification.
- See that a certain highway besides the lake is the source of more nitrous oxide.

The floating platform can consist of a mass spectrophotometer instrument or a nitrate sensor that compares the wavelengths of the sample with the wavelengths of nitrogen-N substances, to see what wavelengths are absorbed and the intensity of the light coming through to check if NO_3- is present and how much. Besides, it also needs to have a rollout system to let the ball be at a certain gps height and a pump that can take water samples to the platform. The ball needs to consist of a gps micro-computer.

Alternative: a submarine that has a built in spectrophotometer with leds or a nitrate sensor. When it moves it keeps its "room" for water open, at a certain gps point it closes its room and measures that sample on the presence of nitrogen. Risks: water pressure, water flow, nitrogen not measurable due to other substances, signal loss in water, stuck in ground or water plants, eaten by bigger fish, floats up.

Chapter 6: Solution Selection

Measuring Water Quality

We chose the idea of a mobile water water quality instrument that is adaptable and transportable through water. It measures the water quality of lakes and ponds in different locations with a pH sensor. Monitoring water quality can be used to identify environmental problems and take preventive steps. In our case could results of overload polluting be tracked and managed to the source to be able to adjust the system itself and its surrounding [31]. This solution solves a part in the healthcare of aquatic ecosystems by helping to prevent more pollution of the area's where the quality of water is crossing its limits. In terms of the impact on the climate, ongoing change of water quality parameters could induce chemical reactions and harm the aquatic environment to the extent that it is not able to recover itself. Byproducts could create gasses that could contribute to global warming. Furthermore, the extreme climate itself also plays a role, rain and storms can exaggerate the runoff of nutrients from agricultural farmland and higher temperatures provide the possibility for algae and phytoplankton to grow more [32].

We have chosen pH , because in a lot of chemistry equations with different substances that are going on in water, H^+ ion is used. Which makes it easier to decide from one value and all those equations, where the equilibrium will lay and what substances will be released more, which makes it acidic or basic.

The instrument will consist of water quality sensors like a pH-probe that could send its data and position wirelessly to a receiver, where the data will be stored. Humans need to transport the floating instrument to different water-locations, and collect the data with a standby computer. The risks would involve that we cannot specifically determine which aspects or chemicals are the factors of unhealthy water quality, we could give an estimation of the polluting source and share the monitoring data with others. Another risk would be the autonomous mechanism of the floating instrument. It will be a challenge to make it operational on its own, because it should move and measure on the right places in the right time interval with occurring errors that need to be tackled by the intelligence of the device itself [33]. Finally, electronics could be in short circuit due to water splashes, this can be prevented by making the open circuits waterproof with foil or tape.

We will validate our instrument by letting it move through water and take samples at various gps locations. We will take pictures of the water to forecast what the water quality will be. We send the samples to a laboratory that could analyze the exact values of the taken sample. At the end we compare our own received probe data, laboratory data and picture analysation to determine if our results from the instrument are corresponding to each other. When the demo day arrives the function of the instrument is preferably demonstrated in a pond nearby, else we use different buckets of different positions, to show the difference in pH-value of those waters.

This solution fits a smart environment, because it is a synthetic sensing instrument that is self governed and wirelessly distributed in aquatic environments that is not directly accessible for humans to measure in. The code in the instrument makes the device intelligent to figure out the pH by itself and handle context-aware situations, like knowing when to measure based on sensed water. We get information about where it is located directly with our measurements, which makes monitoring of a lot of data possible. This will help monitor the environment and can provide efficient helpful action for the sustainability of that environment.

The decision to go into the water quality direction is one of the most effective directions right now. In the beginning of the project, after our research, we came to the decision to find a solution for the monitoring of nitrogen contamination to prevent aquatic ecosystems from dying out. We wanted to build an instrument that could be attached to an autonomous drone that flies to certain coordinates and measures the nitrogen levels of surface water and soil samples. The data of the locations and the nitrogen levels are displayed in a heatmap with a database connected to it. We came across the problem that we could not find payable ultraviolet emitters to create a spectrophotometer to measure water samples of nitrogen. An additional risk would be that the instrument is too heavy for a drone to carry around.

Chapter 7: Methodology

Division into Modules

1. First we need to research and collect the sensors that are suitable for the instrument, some that should measure the water quality, give the position of the device and give all that data via a wireless connection.

2. Secondly we are going to figure out how the sensors work and calibrate them. Then we can connect them all, so that we can also combine all the code. The code will provide the water quality on each gps-location where it is measured.

3. We are going to validate the whole instrument by a lab test, where we have cups with determined pH values. After this test, we can adjust and improve the instrument and the code even more. Finally, we are going to validate the instrument in a lake or pond that has a known water quality.

4. After the validation, we can change the code if needed and prepare ourselves for the demonstration and the presentation.

Modules

Corresponding tasks are grouped together into modules.

Module	**Tasks**	**Who**
Intelligence	- Explain methods of measuring water quality levels in water - Healthy limits of pH and other power quality parameters. - Which molecules are measured and polluting? - What do polluting lakes look like? identifications	**2 Yrjö, Jakub**
Sensor Design and Programming	- List of needed equipment and components - Program each sensor to make it work - Battery powered possibility - Circuit scheme - Construct the full water quality sensor	**2 Jakub Denzel**
Product Design	- Design the casing for the instrument - Fit all the sensors - What is possible in the sense of 3d-printing - Make it waterproof	**2 Madelon, Tim**

Programming	- Pseudocode - Flowchart - Convert flowchart/ pseudocode into code - Combine sensor code with written code - Search additional code if needed	**4 Denzel, Madelon, Mitchell, Matthijs**
Presentation	- 3-min prototype presentation - Presentation demo day	**3 Mitchell, Tim, Matthijs**
Document structure	- Chapters are being updated - Document is well-structured - Collect and write down feedback - Everything is documented corresponding to the rubric and powerpoint slides - Sources are correctly cited - Put files into CreaTe Archive	**1 Yrjö**
Management	- Update planning: where are we, time left, what needs to be done - Deadlines for when which part needs to be done and someone to check those - Interaction with teacher/ other outside persons - Order required equipment	**1 Matthijs**
Testing	- How can we validate our sensor? - Describe operation lab test - Research what liquid to use to prove pH - Arrange lab test materials; demiwater - Prepare lab test samples - Describe operation field test - Research which places are acidic and where to do our field test - Arrange field test materials - Video how product works on field-day - Picture characteristics of healthy/ dirty lakes - Repetition Demo Day - Prepare Final Demo Day	**2 Tim, Yrjö**

Intelligence

Water quality

The quality of water itself can be determined by a wide range of parameters. The parameter that has our main focus is the pH. Other factors like turbidity, nitrate and dissolved oxygen are also of concern, which are mentioned in the theory down below.

pH

pH can be an indicator to tell if water is healthy enough, to conclude that possible toxic chemicals can cause changes. The pH is distributed over a logarithmic scale, herein the concentration of H^+ and OH^- are proportional to each other. If a H^+ or a proton gets released by an acidic substance and a base substance could take a H^+ or a proton. A usual healthy pH value for lakes is 6 - 8 pH, the optimum lies around 7.4 pH.

pH affects and causes

- Heavy metals: Metals like aluminum, copper, cadmium are released into the water at lower pH levels, due to an increase of H^+ ions.
- CO_2 concentration: The reaction with water and CO_2 results in carbonic acid, which will react further and release an H^+ ion. If there is an excess of CO_2 the equilibrium will switch more to the right, so more acidic substance will form and the pH will decrease. CO_2 emission causes this problem.
- Acidic rain: Rain water has a pH around 5.65, for that reason a lake can be more acidic after it rained. Three main factors are the reactions of water (rain) with CO_2 , nitrogen- and sulfur-oxides in the atmosphere.
- Pollution of fertilizers and chemicals in wastewater is also known as acidic runoff, which decreases the alkalinity. Instead the wastewater can be more base with soap-products in it.

Alkalinity

Alkalinity is the quantity of being able to stop pH from changing, the higher the alkalinity the better it can prevent pH from changing like a buffer. This is due to the increase of carbonates (CO_3^{2-}, HCO_3^-), minerals (sodium, calcium, magnesium-carbonates), limestone ($CaCO_3$) and ionic compounds (salts). Besides, dissolved earth metals will release an OH^- ion. A lake with a higher alkalinity or buffering capacity can contain more rocks or is evaporating more often (residu are carbonates).

pH	< 5.0	6.5 - 9	> 9.0
Fish affects	Fungal infections Physiophysical damage Less shell growth, by reduced $CaCO_3$ Death	Healthy	Affected skin and gills Death

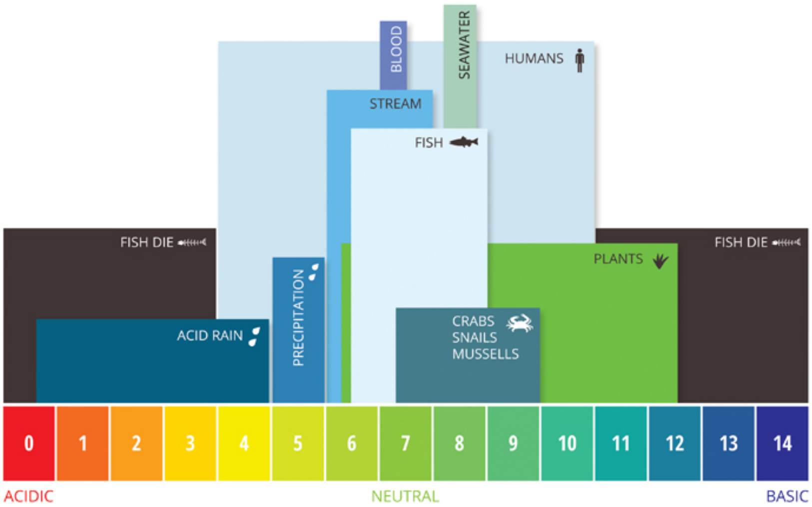

Figure 1 from [34]

Eutrophication

This process is caused by an increase in phosphorus and nutrients (nitrogens) into the water, due to adjacent fertilizer for lawn factories, grass- or farmlands. Algae and water-plants take up hydrogen for photosynthesis and can grow rapidly. This process increases the pH of the surface water. Plants sensitive to the added nutrients may grow, but the remaining plants could become extinct out of the lake. Besides, overgrown plants block sunlight for the plants at the bottom of the lakes. If these two causes are actually happening microorganisms have more organic matter to decompose. They use oxygen for aerobic respiration, which decreases the pH. The lake changes from oligotrophic to an eutrophic lake with less dissolved oxygen for organisms to live in, this will cause a decrease in pH mainly at the bottom of the lake. Even though pH could be stabilized in the end by the ecosystem itself, aquatic life will stress and die from the lack of oxygen [35].

Turbidity

This indicates the amount of light that is able to pass through a sample of water. Turbidity is caused by the amount of suspended solids in the water, which can consist of algae, clay, silt, plankton and other organic compounds. More particles increases the possibilities for attachment places of polluting substances and provides a safe place for microbes. Organic matter that decomposits can release pesticides, metals and phosphorus [36].

Brown lakes

Dissolved organic matter from surrounding woods and wetlands determines the brown color in water. [37]

GPS

To collect the GPS data we can couple this to when we do our measurements with the water quality instrument. When we measure the water sample we can use the GPS sensor to collect multiple factors for the exact location of the drone. With the GPS sensor we can collect the time of our measurement, we can check the longitude and the latitude using the sensor, we can check how many satellites the sensor has checked and the altitude of the drone. The advantage of using a GPS sensor to track these statistics is that the data will be more precise than when a human does it and because we make the drone for a lake so the data becomes really accurate. This is because the location is decided by using multiple satellites to receive the data and because it's really open on a lake the data won't be interfered as much. Because autonomous flying isn't allowed in the Netherlands we can't make the drone use the GPS sensor to fly between different spots. If we want we can make the Arduino separate the different types of data but at the moment it isn't necessary yet, but this can be changed.[38]

LoRa

For the LoRa connection, data is transferred over a certain bandwidth with a certain frequency. In the Netherlands you can have a frequency of 863-870Hz or 433Hz. The laws of the government of the Netherlands tells us that we can use radio-wavelengths to determine the characteristics and the parameters of a certain object. [39]

Sensor Design

NEO-6M GPS Module with Antenna

GPS is a certain type of a GNSS system [40]. The difference between gps and gnss is that gnss sensors can get access to all networks of satellites, so to be able to have a more accurate coordinate. The NEO-6M GPS Chip is sensitive, highly accurate, and can track up to 22 satellites.

- Calibration: To use the coordinates of devices which have a gps module, e.g. a smartphone.

HC-12 SI4463 Wireless Serial Port Module - 433Mhz

LoRa stands for long range, which can transmit data in two directions over a long distance with the construction of a receiver and a sender. They use a radio band of 433 Mhz with radio waves to transfer data to each other. You can use the LoRaLib library in Arduino for example to already work and experiment with two loRa transmitter and receiver components.

Power Module

The wireless instrument is provided with a separate battery element of 9V. The arduino converts 9V to a usable 5V.

Grove - pH Sensor Kit (E-201C-BLUE)

An electrolyte probe that is sensitive for hydrogen concentrations.

- Calibration: Measure the pH of demineralised water (pH 7). Use the difference of the measured value of the sensor with pH is 7 and use that difference as a variable. Check the difference between acidity and alkalinity by using

Product Design

Ideation

To know how to start on the casing, the dimensions and combination of all the sensors combined needs to be known, so ideas of the casing can be sketched. Also we look at the possibility of using 3d printing. Questions that can be asked are:

- What does the sensor consist of?
- What does the instrument look like?
- What are the exact dimensions?
- What materials are good to use?

Creating

If we know the size of the complete set of sensors, we can start to create and experiment with the materials that we have. Since we are making something that floats through water, it needs to protect the components from droplets of water to prevent short circuits. The question we can ask yourself while we are in the creating process would be:

- How can the outside sensors be attached to the case?
- How far should the sensor be in the water?
- Making sketches on paper
- Designing prototypes
- Test prototypes
- Print 3D parts
- Is the sensor waterproof by itself?

Programming

Pseudocode

- Send the location of the gps sensor when the button on the laptop is pressed to the laptop.
- If the water sensor activates, measure the ph Level using the ph sensor multiple times over a certain time period. Using this, calculate the average to prevent an error value to be chosen.
- If the ph sensor has gained data, send both the data of the ph sensor and the data of the current location of the gps sensor via the LoRa sensor.
- If the LoRa sensor has sent its data, wait for the sensor to go to the next location using the gps sensor.

Programming Challenges

- How to analyze the data?
- How to get useful information out of the ph-meter?
- How to process this data?
- Which programming processing data method can we use?
- How to put the gps coordinates into processing?

Testing

pH sensor

To be able to use the pH-sensor, we calibrated it. This means that the pH-values that the pH sensor displays need to be accurate to the substance that we are measuring. This indicates if we need to offset something in the code. The pH sensor needs to show in global lines if the water quality is acidic, neutral or alkaline. We also want to know what the stabilization time will be of the sensor, so we know when we can read the data from the pH probe in the field. The liquids that we use have a known pH value out of this article [41].

- Demineralized water: contains no minerals, no chloric substances, no salts. The pH of demi water is equal to 7, which can be used as a natural substance to calibrate.
- Lemon Juice: lemon out of concentrate, pure lemon juice has a pH of 2.2.
- Multi degreaser (oven-cleaner): pH of 13.8.

Figure 2: setup calibration experiment, lemon juice, demineralized water, multi degreaser.

Process

1. First calibrate the sensor with demineralised water of 7 pH.
2. Leading end is cleaned with a 7 pH buffer before measuring a new fluid.
3. Put the leading end in the measured liquid and turn on a timer at the same time.
4. Wait until the value reaches the desired pH-value and stabilizes around that value. At the same time, read the elapsed time.
5. After the measurement, clean it with demi water (7 pH) and put on the protective sleeve with a small amount of potassium chloride [42].
6. If the sensor gives inaccurate readings, soak it in potassium chloride [43].

GPS

To know if the values from the GPS-sensor are correct, we need to have validation values that are accurate. We use the GPS location from an Apple Iphone out of the Apple maps app and a pinned value on google maps on a laptop, both from our experiment location.

Field

For the validation of our sensor we are going to measure the pH- levels of 3 puddles on and adjacent to campus. We choose the three specific puddles based on real-life visual aspects and the correlation with the parameters of water quality. We looked at the watercolor, turbidity, surface water vegetation, quality of the vegetation on the shores and the state of surrounding nature. The three puddles are very close to each other, so big differences in pH can be in relation to one cause close to all of the three. Besides the visual characteristics, we establish a hypothesis for the value of the pH based on the “Intelligence” of water quality.

Figure 3: red: puddle 1, yellow: puddle 2, green: puddle 3.

1. The first puddle looks clean, light light-reflection, little contamination on the shores, assuming it is cleaned recently, plants at the shores are darker, some branches floating, around 1 meter transparency and surrounded by mowed maintained grass.
    - No aspect should conclude that there are pollutants making the water more acidic, like a dense turbidity or dead vegetation. So the lake would have a natural value between 6 and 8 pH.

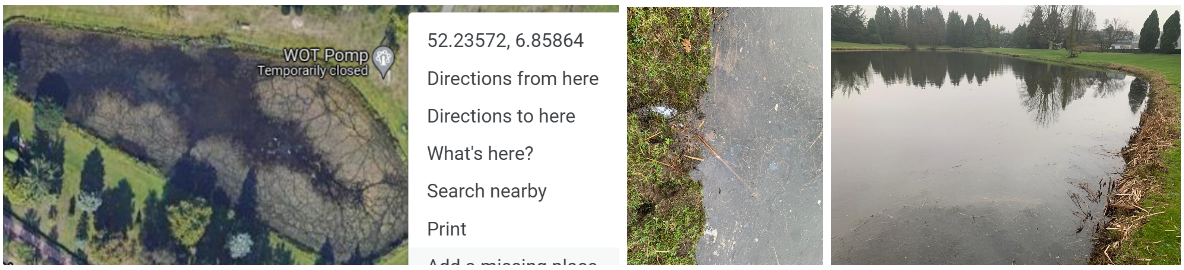

Figure 4: puddle 1

2. The second puddle lays 50 meters away from the first puddle. The plants just under the surface water are getting a brown layer on top of them, brown/orange color, no see through after an estimated 20 cm, also surrounded by mowed maintained grass, but closer to the woods and some duckweed on the edges of the lake.
    - This usually means that the water has a high concentration of dissolved organic matter and a high turbidity [44]. Less sunlight will be able to reach the bottom of the lake, so less oxygen is available for photosynthesis at the bottom of the puddle. [45]. Pollution is often present in acidic circumstances. [46]

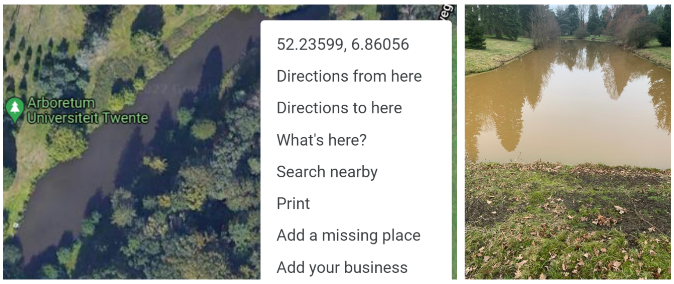

Figure 5: second puddle

3. The third puddle looks the same as and is closer to puddle 2, the pH results can be compared to see if there is a problem in the area of the 2 puddles. We see an orange/ brown color, vegetation floating, thicker orange paste on the plants of the shores, dead vegetation and forest around the puddle.
    - The most common scenario for this is contamination consisting of vegetation or soil in the nearby area. Pine or fir needles can cause acidic runoff due to composition. When it rains, more acidic runoff can flow into the puddle out of the composition of surrounding dead vegetation. The toxic influence of soluble metals increases when they have access to the H^+ ion [47]. The floating vegetation can cause eutrophication.

Figure 6: third puddle

Demo Day

- We have some water in buckets from the lakes where we measured before, during the demo we can't fit the hole installation in the bucket so we only let the water sensor and pH-meter into the water.
- Because these measurements should have really high or low results we can also take measurements in cups with the fluids we used for the lab experiment(lemon juice, demi water and degreaser.
- We can show how all data gets sent from the arduino in the boat to the arduino connected to the receiver.

Future Scenarios

Basic

The basic plan that we are going to execute is to create a floating instrument that could measure pH levels out of water at different gps points. The instrument knows when it can perform the measurement. After the measurement the arduino needs to be able to send the data of the GPS and the pH-probe to the computer by a LoRa communication. On top of that we are mostly testing and justifying the sensor in a sense that it could measure the right pH-value by a calibration, lab tests and field experiments.

Advanced

Drone

We would implement a drone if the instrument gives the results we want and when the sensors are working nicely together. We can design a part of the case that could be attachable on a drone. To make sure that the drone will not stick with the instrument all the time, it can have an electromagnet switch that is attached to the bottom of the drone. If we want to make it more challenging we implement software for the drone to make it autonomous. We send selected gps-coordinates to the drone that needs to be measured. Besides, it's illegal to fly autonomously, we can try it in Germany or let somebody control the drone.

Programming

After we have gained the correct results we can think about implementing a database connected to a visualization application. The database could be a realtime Excel or Firebase database, so we can link this live data to a point density analysis program if we want to have live updates. Realization of Firebase: connect the Arduino IDE Firmware to Java project with importing Processing library.

Point Density Analysis (HeatMap)

The GPS-location and the pH-value can be combined on a point density map, where density clusters visualize the strength of the pH-value in a lake. This can be done using processing. The cons of using Processing can be that you cannot use a real time world map. Instead of using Processing we could make use of a heatmap layer that we can apply onto the already existing Google Maps layer. We can make our own html website, implement Google Maps and connect the website to a database or liveloaded array of gps points and pH-values. Explained in these sources[46][47]. Also a good alternative could be Tamblo heatmaps.

GIS

The information from the database can be implemented into a Geographic Information System, like Qgis and Esri. You can implement and visualize maps with data. You can also think about an online map provider. QGIS [50], ArcGis [51] [52]

Chapter 8: Validation

Testing: pH sensor

Demiwater

Experiment 1

```
Voltage:1.78    pH value: 6.84
Voltage:1.78    pH value: 6.82
Voltage:1.78    pH value: 6.88
Voltage:1.78    pH value: 6.84
Voltage:1.78    pH value: 6.87
Voltage:1.78    pH value: 6.86
Voltage:1.78    pH value: 6.88
Voltage:1.78    pH value: 6.87
Voltage:1.78    pH value: 6.88
Voltage:1.78    pH value: 6.87
Voltage:1.78    pH value: 6.88
Voltage:1.78    pH value: 6.87
Voltage:1.78    pH value: 6.89
Voltage:1.78    pH value: 6.89
Voltage:1.78    pH value: 6.89
Voltage:1.78    pH value: 6.89
```

Figure 7: after 1 minute

```
Voltage:1.78    pH value: 6.93
Voltage:1.78    pH value: 6.96
Voltage:1.78    pH value: 6.97
Voltage:1.78    pH value: 6.94
Voltage:1.78    pH value: 6.94
Voltage:1.77    pH value: 6.99
Voltage:1.78    pH value: 6.97
Voltage:1.77    pH value: 6.98
Voltage:1.77    pH value: 7.02
Voltage:1.78    pH value: 6.97
Voltage:1.77    pH value: 6.99
Voltage:1.77    pH value: 6.99
Voltage:1.77    pH value: 7.01
Voltage:1.77    pH value: 7.00
Voltage:1.77    pH value: 7.01
Voltage:1.77    pH value: 7.00
```

Figure 8: after 1.5 minutes

Conclusion: pH is readable after 1.5 minutes (90 seconds) to get an accurate reading of the measured substance.

Experiment 2

```
Voltage:1.76    pH value: 7.30
Voltage:1.76    pH value: 7.32
Voltage:1.76    pH value: 7.35
Voltage:1.76    pH value: 7.28
Voltage:1.76    pH value: 7.36
Voltage:1.76    pH value: 7.33
Voltage:1.76    pH value: 7.30
Voltage:1.76    pH value: 7.32
Voltage:1.76    pH value: 7.29
Voltage:1.76    pH value: 7.31
Voltage:1.76    pH value: 7.34
```

Figure 9: after 1.5 minutes

After 1.5 minutes, the pH gets higher than the result in experiment 1.

Lemon Juice

Experiment 1

```
Voltage:1.92    pH value: 4.23
Voltage:1.92    pH value: 4.20
Voltage:1.92    pH value: 4.22
Voltage:1.92    pH value: 4.22
Voltage:1.92    pH value: 4.22
Voltage:1.92    pH value: 4.22
Voltage:1.92    pH value: 4.20
Voltage:1.92    pH value: 4.24
Voltage:1.92    pH value: 4.24
Voltage:1.92    pH value: 4.19
Voltage:1.92    pH value: 4.21
Voltage:1.92    pH value: 4.20
Voltage:1.92    pH value: 4.21
```

Figure 10: after 1.5 minutes

Experiment 2

```
Voltage:1.92    pH value: 4.24
Voltage:1.92    pH value: 4.24
Voltage:1.92    pH value: 4.22
Voltage:1.92    pH value: 4.25
Voltage:1.92    pH value: 4.23
Voltage:1.92    pH value: 4.25
Voltage:1.92    pH value: 4.23
Voltage:1.92    pH value: 4.25
Voltage:1.92    pH value: 4.24
Voltage:1.92    pH value: 4.23
Voltage:1.92    pH value: 4.24
Voltage:1.92    pH value: 4.25
```

Figure 11: after 1.5 minutes

The results have an average pH value of 4.23. This is higher than the expected value of 2.2 pH. This is most likely due to the lemon juice that is being used for the measurement. The lemon juice is out of concentrate, so partially water which makes it less acidic than pure lemon juice. The pH determination value can get stretched, but the demi water 7 pH was correctly measured.

Degreaser

Experiment 1

```
Voltage:1.46    pH value: 13.04
Voltage:1.46    pH value: 13.05
Voltage:1.46    pH value: 13.04
Voltage:1.46    pH value: 13.04
Voltage:1.46    pH value: 13.07
Voltage:1.46    pH value: 12.99
Voltage:1.46    pH value: 13.11
Voltage:1.46    pH value: 13.05
Voltage:1.45    pH value: 13.12
Voltage:1.46    pH value: 13.08
Voltage:1.46    pH value: 13.10
Voltage:1.46    pH value: 13.04
Voltage:1.46    pH value: 13.10
Voltage:1.46    pH value: 13.07
Voltage:1.46    pH value: 13.09
```

Figure 12: after 1.5 minutes

The value of over degreaser should be 13.8. The equilibrium was already stated after 1 minute, which raises the question if we should use 1 minute instead of 1.5 minutes.

Error

```
Voltage:0.09    pH value: 39.21
Voltage:0.09    pH value: 39.26
Voltage:0.10    pH value: 39.13
Voltage:0.09    pH value: 39.27
Voltage:0.07    pH value: 39.61
Voltage:0.11    pH value: 38.94
Voltage:0.15    pH value: 38.08
Voltage:0.11    pH value: 38.91
Voltage:0.09    pH value: 39.27
Voltage:0.09    pH value: 39.22
Voltage:0.09    pH value: 39.35
Voltage:0.09    pH value: 39.30
```

Figure 13: interruption while doing experiment 1 with the oven cleaner.

We measured extremely high values. We put it out of the multi degreaser and it still happened, which means that it has something to do with the inner construction. This can be a risk while measuring in the field as well.

Testing: pH sensor before field-test

Demiwater

Experiment 3

```
Voltage:1.75    pH value: 7.37
Voltage:1.76    pH value: 7.33
Voltage:1.76    pH value: 7.31
Voltage:1.76    pH value: 7.26
Voltage:1.76    pH value: 7.31
Voltage:1.76    pH value: 7.29
Voltage:1.76    pH value: 7.34
Voltage:1.76    pH value: 7.25
Voltage:1.76    pH value: 7.30
Voltage:1.76    pH value: 7.20
Voltage:1.76    pH value: 7.28
Voltage:1.76    pH value: 7.28
Voltage:1.76    pH value: 7.29
Voltage:1.76    pH value: 7.21
Voltage:1.76    pH value: 7.23
Voltage:1.76    pH value: 7.25
Voltage:1.76    pH value: 7.29
```

Figure 14: measure pH value after 1.5 min with demi water, by using the Servo connected to the pH-probe.

Saturated sodium chloride

The packaging of the ph meter was included with a small tube with an unknown liquid. We overlooked it, because there was no description in the packaging or in the online datasheet. Finally, out of curiosity we found out that this solution has a pH of 7, which means it could have been used instead of demineralised water [53]. For this reason, we wanted to test out and offset the calibration code to this solution.

Experiment 3

```
Voltage:1.71    pH value: 8.45
Voltage:1.71    pH value: 8.42
Voltage:1.71    pH value: 8.45
Voltage:1.71    pH value: 8.43
Voltage:1.71    pH value: 8.45
Voltage:1.71    pH value: 8.42
Voltage:1.71    pH value: 8.48
Voltage:1.71    pH value: 8.44
Voltage:1.71    pH value: 8.45
Voltage:1.71    pH value: 8.42
Voltage:1.71    pH value: 8.46
Voltage:1.72    pH value: 8.38
Voltage:1.71    pH value: 8.46
Voltage:1.72    pH value: 8.39
Voltage:1.71    pH value: 8.47
Voltage:1.72    pH value: 8.39
Voltage:1.71    pH value: 8.47
```

Figure 15: value of the pH of saturated sodium chloride with the untouched offset in the code.

If we look at the difference between the pH value of distilled water and saturated sodium chloride, we can conclude a difference of around 1.4 pH, which is quite a lot if they both should have a pH of 7. We adjusted the value of the offset in the code until the pH value in the Serial monitor settled to a pH of 7.

Degreaser

Experiment 2

```
Voltage:1.60    pH value: 9.20
Voltage:1.60    pH value: 9.16
Voltage:1.59    pH value: 9.24
Voltage:1.60    pH value: 9.20
Voltage:1.59    pH value: 9.24
Voltage:1.60    pH value: 9.20
Voltage:1.59    pH value: 9.23
Voltage:1.60    pH value: 9.19
Voltage:1.60    pH value: 9.20
Voltage:1.60    pH value: 9.18
Voltage:1.59    pH value: 9.37
Voltage:1.60    pH value: 9.17
Voltage:1.59    pH value: 9.24
Voltage:1.59    pH value: 9.31
Voltage:1.60    pH value: 9.21
Voltage:1.60    pH value: 9.21
Voltage:1.59    pH value: 9.23
Voltage:1.60    pH value: 9.22
Voltage:1.60    pH value: 9.20
Voltage:1.60    pH value: 9.21
Voltage:1.59    pH value: 9.23
```

Figure 16: pH values of degreaser with the offset resulting from the previous experiment.

The pH-results of the degreaser are lower than the expected pH-value of 13.8, so we tried a different value of the offset.

Experiment 3

```
Voltage:1.42    pH value: 13.23
Voltage:1.41    pH value: 13.42
Voltage:1.41    pH value: 13.42
Voltage:1.41    pH value: 13.38
Voltage:1.41    pH value: 13.46
Voltage:1.42    pH value: 13.38
Voltage:1.42    pH value: 13.37
Voltage:1.42    pH value: 13.35
Voltage:1.42    pH value: 13.37
Voltage:1.42    pH value: 13.34
Voltage:1.42    pH value: 13.37
Voltage:1.42    pH value: 13.34
Voltage:1.42    pH value: 13.37
Voltage:1.42    pH value: 13.29
Voltage:1.41    pH value: 13.56
Voltage:1.39    pH value: 13.91
Voltage:1.39    pH value: 13.92
Voltage:1.39    pH value: 13.89
Voltage:1.39    pH value: 13.86
Voltage:1.39    pH value: 13.77
Voltage:1.41    pH value: 13.49
Voltage:1.42    pH value: 13.28
```

Figure 17: pH-values of the degreaser when the offset (deviation compensate) is set to 40.52740741 .

Demiwater

Experiment 4

```
Y52.239532
X6.856950
P7.23
Y52.239524
X6.856954
P7.18
Y52.239517
X6.856958
P7.16
Y52.239509
X6.856963
P7.17
Y52.239498
X6.856968
P7.23
Y52.239490
X6.856971
P7.26
Y52.239486
X6.856975
```

Figure 18: ph values of demi water with an adjusted offset value, and the supplemental gps coordinates.

The first experiments of “Testing: pH sensor” are the most accurate in our case. For that reason, for experiment 4, we measured demi water again and adjusted the pH of 7 on that liquid and not on the Saturated sodium chloride, because the values of the degreaser were more accurate when you would use the offset of distilled water.

Testing: GPS

Obtained values from known devices at the location of the experiment:

- Laptop, Google maps (pointed location): 52.23936*N, 6.85713*E
- Iphone, Apple maps (phone location): 52.23936*N, 6.85708*E

Experiment 1

```
P0.66           P2.05
Y52.239349      Y52.239315
X6.857107       X6.857132

P0.61           P2.06
Y52.239349      Y52.239318
X6.857106       X6.857134

P0.51           P1.97
Y52.239353      Y52.239318
X6.857104       X6.857135

P0.55           P1.94
Y52.239353      Y52.239322
X6.857102       X6.857136
```

Figure 19: Gps coordinates

If we compare the obtained values with the measured values with the GPS sensor, we see that they meet each other for the values 52.2393*N and 6.85713*E. The sensor is accurate to the 10th meters (4th digit after the comma). The values of the sensor fluctuates over a couple of meters.

Product Design

Prototyping 1

We made two prototypes from a lunchbox and a pool noodle. Prototype 1 has the pool noodle underneath it and prototype 2 has the pool noodle on the side/bottom. During the water test it became clear that:

- Prototype 1
  - Stayed floating most of the time when we did not touch it
  - It capsized when we pushed too hard on one of the sides
  - When it capsized it did not got back up straight again
  - It felt wobbly when we pushed it down into the water
- Prototype 2
  - Stayed floating all of the time when we did not touch it
  - When we pushed it to one side or another it did not capsize
  - It felt quite stable when we pushed it down into the water
- Using one lunch box is too small for fitting all of the components
- Stacking two lunchboxes is possible but not useful if all components need to be connected and some of the sensors are too high which mean that you have to cut holes in every box to fit the sensor
- One bigger box is easier to use and can fit everything

Sensors inside the box or on the outside
We use different sensors, some need to be in the water and some do not. For the sensors that need to be out of the water it is the most convenient to be in the box. The sensors that need to be in the water can go in the box and then we need to cut a hole through the box which makes it not watertight anymore. This can be a problem because water now can get in the box and close to the other sensors. Making the sensor out of the box makes it more vulnerable to the environment.

The pH sensor needs to go up and down out of the water during testing. This can be done by using a servo which is connected to threads to lift it up and down. The sensor can go diagonal through the box leaving space from the bottom so water can’t get in but the sensor can go up and down.

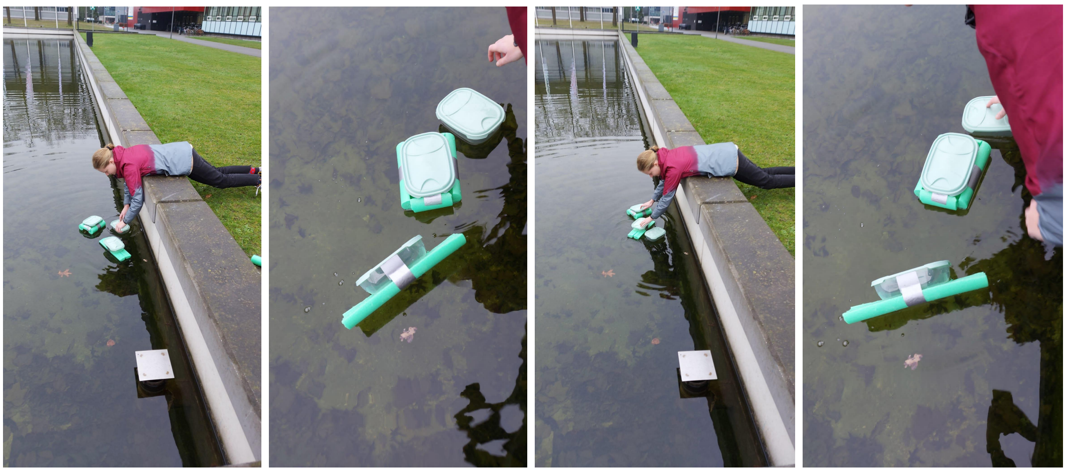

Figure 20 primitive tests of the arduino

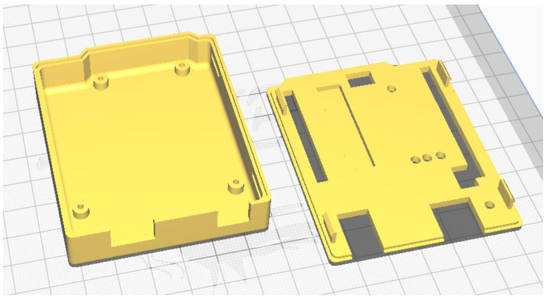

Figure 21: arduino casing [54][55]

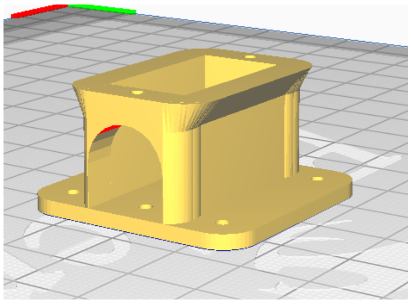

Figure 22: 3d model of servo holder [56]

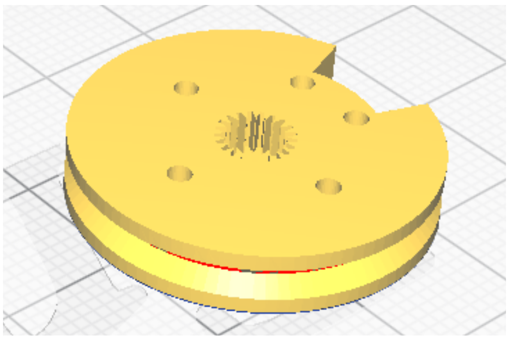

Figure 23: servo pulley [57]

Prototyping 2

The lunchbox is big enough to fit all of the components so we are using that one. The pH sensor and the water sensor are going to be on the side of the lunch box. For holding it in place on the side there are a couple of options:

- Attach servo on the outside of the box
- Attach the servo on the inside of the box and make a hole in the box to let the servo go half through.
- Make the sensors next to the pool noodle
- Cut a piece out of the pool noodle to fit it there

After making the options we came to the conclusion that it was the easiest to fit the water and pH sensor outside of the box and cut the pool noodle to fit the sensors half next to it. For the wires we created a hole in the lid, let the wires through this hole and sealed it off using a combination of duct tape and a plastic bag. This should prevent water from coming in from the top. The hole for the servo motor was also sealed shut using a glue gun.

Another thing we did was fitting all the components together in one box and connecting every component with the arduino.

All the other components are now in the box which makes the box much more heavy. So to prevent it from tipping over we made a bigger construction from the pool noodles which fits around the lunch box.

We attached the sensor on the servo with springs, duct tape and threads and through testing we could attach it on the correct height. Now the sensors can touch the water and when the servo turns the sensors get lifted out of the water.

We made a hole in the top of the lunchbox to let the wires go through. We made this hole waterproof by connecting a plastic bag on the inside and by using duct tape on the outside. For the sensors that needed to be waterproof we used duct tape and electrical tape.

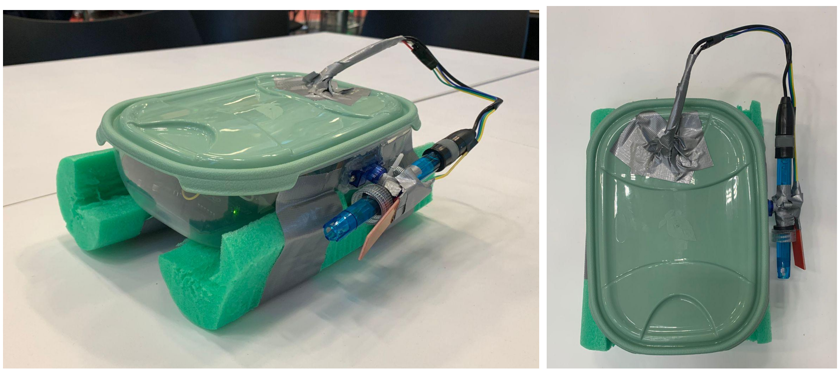

figure 24, The casing around the arduino

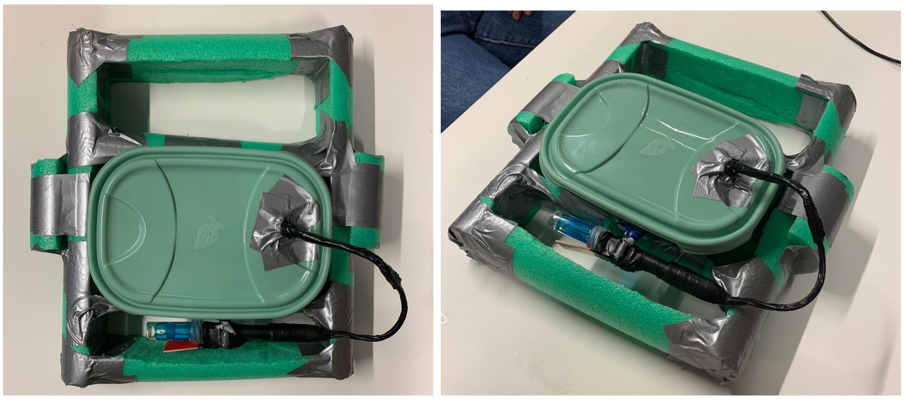

Figure 25, Final end casing

Samples: pH strips

To be able to know the pH results from the samples from the lake, we use pH-test-strips. We use two types of strips that vary in two ranges, 3.6-6.1 and 7.0-14.0 pH. We used these ranges, because of our hypothesis that the value from healthy water would be between 6 and 9 pH [35]. There was no option to use test-strips between 6 and 7 pH, but those were not available on Campus. We test each sample 1 time and prefer to do a second test, to see if our first test was accurate.

Visual waterquality characteristics

Sample 1: Clean water, a little bit thea greenish, some floating organic material.
Sample 2: Light orange water, less transparent.
Sample 3: A lot of turbidity, orange color, small floating particles.

Experiment

1. Put a teststrip of 7.0-14.0 and a teststrip of 3.6-6.1 at the same time into the sample of all three samples. Keep the strips in the water for 5 minutes, then shake some additional water off of the strip and let it dry.
2. The result from the 1st experiment concluded that all samples would have a value higher than 6.1, because they kept the same color. This means that we don’t need to use the strips of 3.6-6.1 pH anymore.
3. For the 2th experiment, we tested the samples with the 7.0-14.0 pH teststrip.

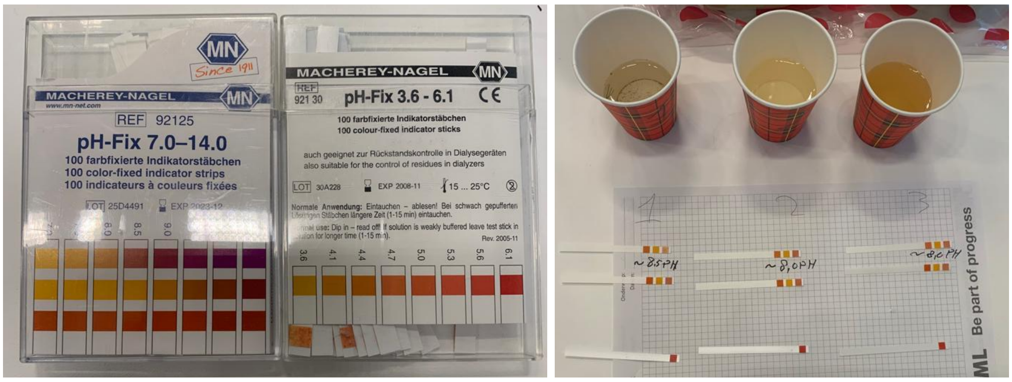

Figure 26, the experiment set-up for testing the pH of the collected samples

Out of the measurement we got the results that showed us the following:

Sample	1	2	3
pH range	~8.5	~8.0	~8.0

The right result from the first pH-strip of sample 1 changed after a long time, but was darker in the direction of violet, which means it was increasing to the 8.5 pH. We can conclude from this experiment that an increase in turbidity and color changes could make water more acidic. Besides, puddles that are clear and brown which contain some floating natural items, can be more basic.

Chapter 9: Results and Conclusion

Results

The final results of the pH-levels with the accompanying GPS-coordinates are found from the field experiments from the three chosen puddles, which are explained in the Methodology. The results consist of text-files which are shown in the Appendix. We start with a description of the process of the measurement, followed by a summary of the results. Finally we give conclusions based on the data itself, its changes in flow over time and in connection with our validation and theory.

Process

The instrument has been prepared for use, by cleaning the tip of the sensor and checking if real-time results were already received by the laptop. Thereupon, the floating instrument was getting placed into the water next to the shore. We sended a controlled signal to let the pH rotate into the water and start recording the results. The servo is supposed to come up after two minutes, when the recording of the results will automatically stop as well.

Puddle 1

Figure 27, The final product measuring in puddle 1

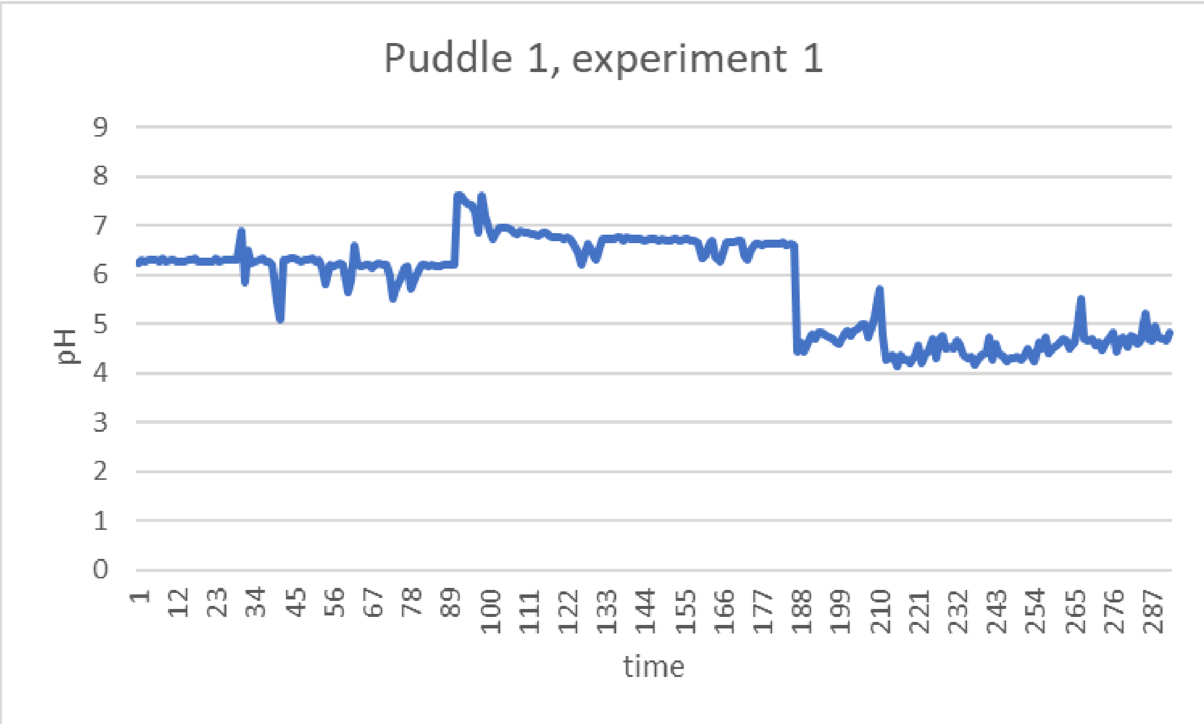

Figure 28, The results of the first experiment in puddle 1

time	0 s	90 s	186 s
Average pH at distinguishing intervals	6.19	6.74	4.59

Coordinates Apple Maps	52.23572°N, 6.85881°E
Coordinates Google Maps	52.23574°N, 6.85867°E
Average gps-coordinates instrument	52.23576°N, 6.85867°E

At the beginning, the control of the start of the measurement took a while, so it took 90s until the sevro rotated. From that moment, it measured a pH of 6.74 pH. After the 90s the servo turned back and the storing of the value's stopped when the executor pressed “esc”.

The pH-value from the first puddle from the sample-experiment with the pH strips was 8.5. If we compare that value to 6.74 pH, they have a difference of 1.76 pH. This is a big difference. From our experience, the pH strips are more accurate than the pH-probe, because there were a lot of fluctuations with the calibration measurements of the pH-probe, so we already kept in mind that the pH-probe could fluctuate in the field as well. From this measurement we would conclude that the puddle is still healthy, because its pH-value lies in the range of 6.5 to 9.0 pH. The GPS-coordinates of the northern hemisphere are equivalent to the meters and the coordinate-value of the eastern hemisphere is equivalent to the value of Google maps, but not to the value of Apple Maps. Overall the gps-coordinates are meticulous.

Options for future adjustments would be calibrating the pH-probe with distilled water before every measurement in another lake. An automatic calibration program could change the offset, so that the value of the calibration liquid would be 7, then the servo will go back into the water.

Puddle 2

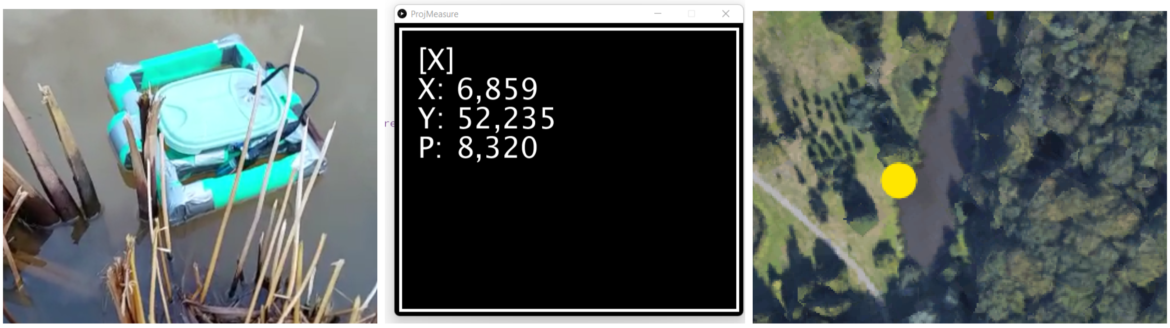

Figure 29, the boat in puddle 2

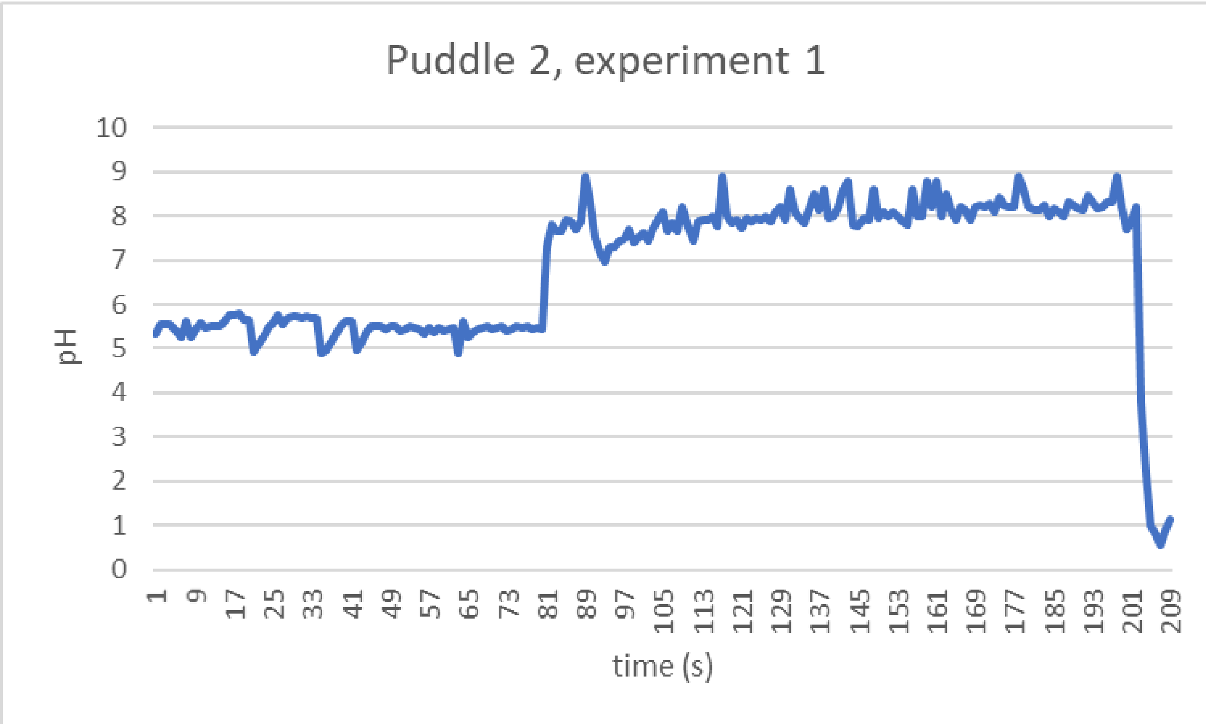

Figure 30, the results of experiment 1 in puddle 2

time	0 s	81 s	203 s
Average pH at distinguishing intervals	5.46	8.03	1.49

Coordinates Google Maps	52.23535°N, 6.85929°E
Average gps-coordinates instrument	52.23538°N, 6.85929°E

For the second puddle, it also took some time until the servo would receive the signal to rotate, 81s in this case. Once in the water it would measure for 122 seconds an average pH of 8.03. When the servo rotated back, it dropped to a pH of 1.49.

The measured pH-value of 8.03 corresponds to the test ph-value of the samples with pH-strips, namely a pH of around 8.0. When the servo rotated back, the pH-value did not stabilize to its original value of 5.46 when it was also in the air. That was also the case for the first puddle, but this time the difference is very big. One cause may be that the pH probe broke when the servo turned up too rapidly. Aside, we can conclude that the instrument measured the right pH on the right specified location. The GPS coordinates are equivalent to the point of a difference in meters, except for the value in the eastern hemisphere, which match exactly.

For the following adjustment moment a warning system could warn to repair or calibrate the pH-probe if the drop is very steep when the servo rotates back.

Puddle 3

Figure 31, the boat in puddle 3

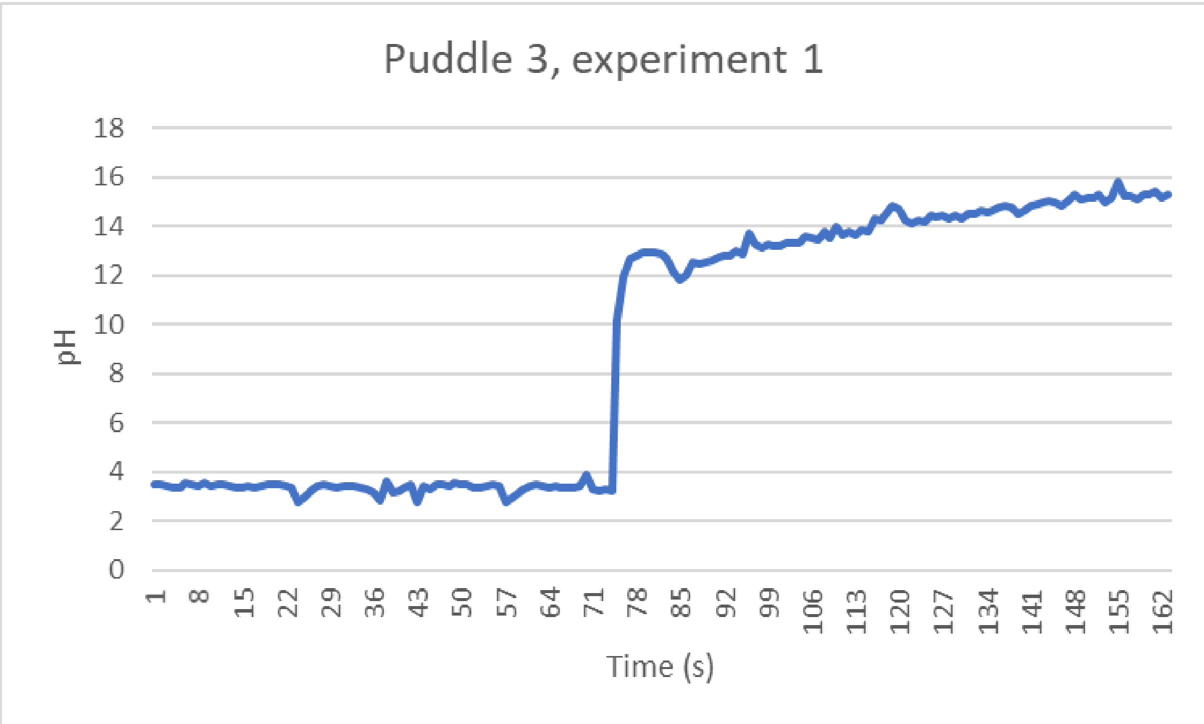

Figure 32, the results of experiment 1 in puddle 3

time	0 s	76 s
Average pH at distinguishing intervals	3.35	13.95

Coordinates Apple Maps:	52.23234°N, 6.86540°E
Coordinates Google Maps:	52.23239°N, 6.86545°E
Average gps-coordinates instrument	52.23538°N, 6.85929°E

It took 76 seconds until the servo turned and the pH-probe could measure a pH-value of 13.95. Finally, the servo wouldn't return back, so the executor stopped the real-time measurement by physical action.

The drop between the pH of air of 3.35 and 13.95 is unusually big. Besides, the measured pH-value with the pH-strip layd around 8.0 pH and is not close to 13.95. The pH-probe hicks up to the 14 pH, which means it doesn't count H^+ particles anymore. The GPS-coordinates of the northern hemisphere are correct up to the meter, but the numbers of the eastern hemisphere differ by a kilometer from the coordinates obtained from digital maps. We can conclude that the instrument did not work properly for the pH-probe, as well for the coordinate sensor.

For the next repair session, the electrode must be soaked in a solution of hydrofluoric acid for 3-5 seconds, clean it and soak it in a solution of potassium chloride to make it clean [43].

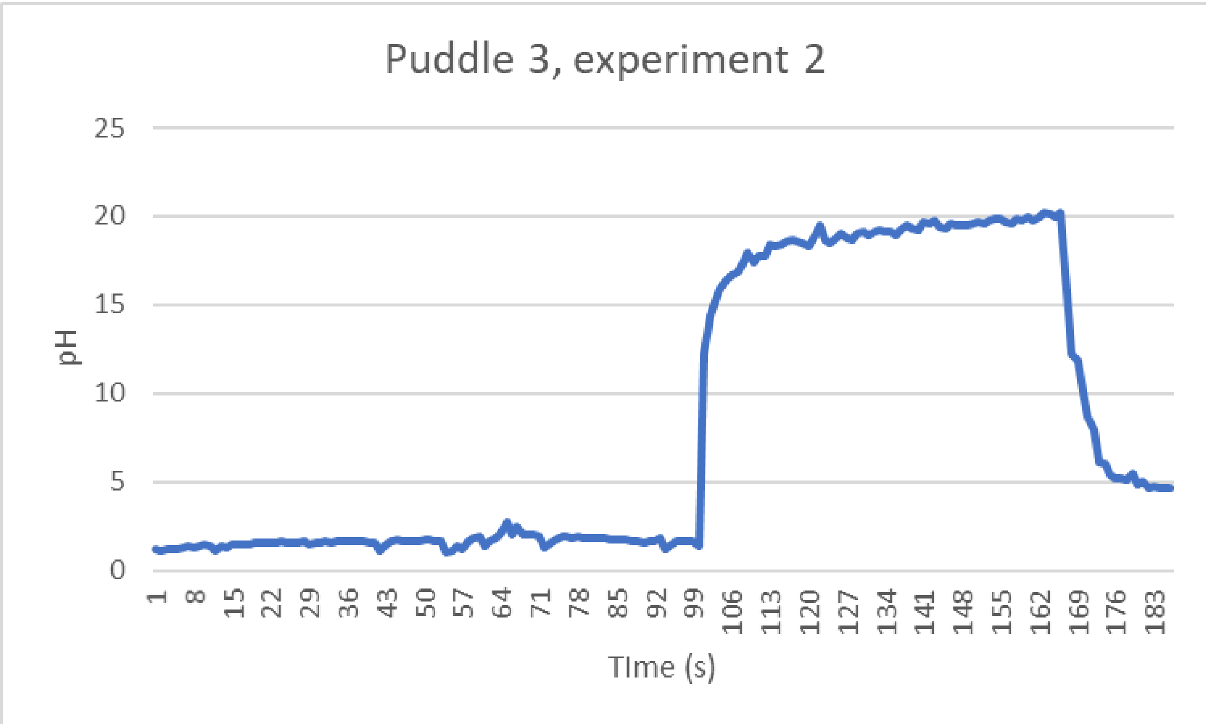

Figure 33, the results of experiment 2 in puddle 3

time	0 s	101 s	167 s
Average pH at distinguishing intervals	1.61	16.00	6,92

Coordinates Apple Maps:	52.23234°N, 6.86540°E
Coordinates Google Maps:	52.23239°N, 6.86545°E
Average gps-coordinates instrument	52.23240°N, 6.86543°N

The first experiment on puddle 3 gave inaccurate results, so we measured puddle 3 again to see if the results give stationary or permanent errors. If we look at the results, the servo measured an acidic air. After 101s, the servo rotated and the pH-probe measured a pH of 16.00. The servo turned back after 67 seconds, the pH-probe dropped exponentially and measured a pH of around 5 at the end.

The value of 16.00 pH is not even close to 8.0 pH out of the pH-strip experiment. If we would compare both experiments on puddle 3, we see the same relationship in results; it measured a lot of hydrogen activity in air and no hydrogen activity in water. Apparently the pH-probe can detect the water, but it cannot measure the right amount of hydrogen anymore; the scale of the pH is too big. Furthermore, the GPS-coordinates are accurate to within a few meters, for this reason we can question the erroneous GPS coordinates of experiment 1.

Evaluation

After the field-experiment we evaluated and raised the question what the cause could be for the difference in perceived results between puddle 2 and puddle 3.

- Puddle 2 had lots of short reeds on the shore and the water. The pH-probe could have hit something turned into the water. This would contradict our results from puddle 2, but maybe the calibration of the pH-probe was not accurate at that moment.
- We could have done too many measurements in a row and put the probe in the detecting liquid for too long [43].
- The pH-meter could not point in the water deep enough, due to friction of the servo on the side of the boat.
- The instrument undergoes much movement. To clean the tip of the probe we needed to tilt the whole instrument and we walked all the way to the 3th puddle, the vibrations could have caused damage to the probe.
- The servo could have turned around too quickly. the mechanical force from the servo could have broken something internally of the pH-probe
- The probe could have been used too long since it has been bought and not been maintained properly. The probe needed to measure in an unprotected environment for too long without its wet capsule.

The wireless LoRa connection and the servo did not react directly to the signal of the executor to turn the servo. Some factors could have influenced that problem.

- There was interference with other signals (noise), so the LoRa couldn’t send its data properly. On the contrary, due to the forest environment, the LoRa may not have reached the bandwidth at which the signal should be transmitted.
- The servo could have been broken inside or the wires are loose, so the signal could not direct the servo optimally.

Conclusion

In the end the question is if the creation can be satisfied as being a smart environment solution and it is hard to say. The final product uses sensors and electronics to measure the pH in the water and it can be used to regulate the environment by detecting the contamination of water by detecting the pH. In the end the final product could still be improved, because the ideas that were invented in this project could not all be used, e.g. the nitrogen sensor or making the pH-boat remotely driveable to have an easy way to determine the water quality in the lake.

Concluding the idea behind the boat’s casing works and the code that is written as well and it can also be used to measure the pH-value of the water, but in can still be improved a lot by using better sensors or by making the boat be moveable on it’s own in the water. It is a good way to detect the different levels of pH so it qualifies as a good monitoring system and smart environment solutions. Besides, the instrument will be helpful for better understanding of the environment around the area of the measured water and making effective decisions for the health of the environment itself. This will keep the ecosystem in balance and healthy and in the long term maintain the climate around it.

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Appendix

Code

Arduino Sender

// note: You need to install the AltSoftSerial and NMEAGPS libraries.

```
/*
  # This code is based on the PH test code from Grove for the PH Sensor
Kit (E-201C-Blue).
(https://files.seeedstudio.com/wiki/Grove-PH_Sensor_kit/Grove-PH_Sensor_k
it.zip)
  # It is also based on the sample servo program.
  #
*/

// inclusions
// these libraries can be downloaded through the Arduino interface
#include <NeoSWSerial.h>
#include <NMEAGPS.h>
#include <Servo.h>


// ph definitions
#define SensorPin A0          //pH meter Analog output to Arduino Analog
Input 0
#define Offset 41.25746741
#define samplingInterval 20
#define printInterval 1000
#define ArrayLenth  40  //times of collection

// global variables
int bdrate = 9600;    // global baud rate value

// pH variables
int pHArray[ArrayLenth];   //Store the average value of the sensor
feedback
int pHArrayIndex = 0;
int pHControlPin = 7;

// water values
int WATER_THRESHOLD = 200;
```

```
int inWater = true;
int waterPin = A1;
long waterTimer = 0;
static const int waterInterval = 100; // interval in ms between checks
whether it is in water.

// GPS values
static NMEAGPS gps;
static gps_fix fix;
static const int gpsInterval = 500; // interval in ms when the gps checks
for position
NeoSWSerial gpsPort(8, 9);

// Servo Values
static const int servoPin = 3;        // pin the servo attaches to.
static const long measuringTime = 120000; // time the sensor will be kept
in the water in milliseconds (currently 2 minutes).
static const long noWaterTime = 10000;  // timeout of servo when it isn't
in water (currently 10 seconds
static const int measuringAngle = 110;  // angle of the servo for
measuring
static const int standbyAngle = 0;      // angle of the servo on standby
long servoTimer = 999999; // timer that keeps track of time past since
trying to measure.
//long moveTimer = LONG_MAX;  // timer that makes sure the servo has time
to catch up.
boolean measuring;  // boolean that stores whether the product is trying
to measure.
Servo ourservo;   // servo object
//int servoPos;

// Wireless Communication variables
//NeoSWSerial wlCom(11, 12);
long commTimer = 500;
static const long commInterval = 1000;

// start of functional code
void setup() {
  Serial.begin(bdrate);
//  wlCom.begin(bdrate);
  pHSetup();
  waterSetup();
  gPSSetup();
  ourservo.attach(servoPin); // attaches servo to the servoPin;
}
```

```
void loop() {
  pHLoop();
  waterLoop();
  gPSLoop();
  commLoop();
  servoLoop();
}

inline void commLoop() {
  if (millis() >= commTimer + commInterval) {
  commTimer = millis();
  if (Serial.available() > 0) {
    String cmd = Serial.readString();
    cmd.trim();
    if (cmd.length() > 0) {
      measureCommand();
    }
  }
  }
}

inline void servoLoop() {
  if (measuring) {
  ourservo.write(measuringAngle);
  if (( inWater && millis() >= servoTimer + measuringTime) || ( !inWater
&& millis() >= servoTimer + noWaterTime)) {
    measuring = false;
  }
  } else {
  ourservo.write(standbyAngle);
  }
}

void measureCommand() {
  measuring = true;
  servoTimer = millis();
}

inline void gPSSetup() {
  gpsPort.begin(bdrate);
}

inline void gPSLoop() {
  if (gps.available( gpsPort ))// && millis() - timer > gpsInterval)
```

```
  GPSPrintFix();
  //gpsTimer = millis();
}

inline void waterSetup() {
  pinMode(waterPin, INPUT);
}

inline void waterLoop() {
  if (millis() - waterTimer > waterInterval) {
  int waterVal = analogRead(waterPin);
  // controls the control pin
  if (waterVal > WATER_THRESHOLD && !inWater) {
    inWater = true;
    digitalWrite(pHControlPin, HIGH);
  } else if (waterVal <= WATER_THRESHOLD && inWater) {
    inWater = false;
    digitalWrite(pHControlPin, LOW);
  }
  }
}

inline void pHSetup(void)
{
  pinMode(pHControlPin, OUTPUT);
  digitalWrite(pHControlPin, LOW);
}

inline void pHLoop(void)
{
  // controls the measuring
  static unsigned long samplingTime = millis();
  static unsigned long printTime = millis();
  static float pHValue, voltage;
  if (millis() - samplingTime > samplingInterval)
  {
  pHArray[pHArrayIndex++] = analogRead(SensorPin);
  if (pHArrayIndex == ArrayLenth)pHArrayIndex = 0;
  voltage = averagearray(pHArray, ArrayLenth) * 5.0 / 1024;
  pHValue = -19.185 * voltage + Offset;
  samplingTime = millis();
  }
  // printing the measured values to Serial
  if (millis() - printTime > printInterval && inWater)  //Every time
printInterval passes, print a numerical, convert the state of the LED
```

```
indicator
  {
//  Serial.print("Volt: ");
//  Serial.println(voltage);
  Serial.print("P");
  Serial.println(pHValue, 2);
  //  }
  printTime = millis();
  }
}

// GPS functions
inline void GPSPrintFix() {
  fix  = gps.read();
  // print values
  if (fix.valid.location && inWater) {
  Serial.print("Y");
  Serial.println(fix.latitude(), 6 );
  Serial.print("X");
  Serial.println(fix.longitude(), 6 );
  }
}


// pH functions
double averagearray(int* arr, int number) {
  int i;
  int max, min;
  double avg;
  long amount = 0;
  if (number <= 0) {
  //   Serial.println("Error number for the array to averaging!/n");
  return 0;
  }
  if (number < 5) { //less than 5, calculated directly statistics
  for (i = 0; i < number; i++) {
    amount += arr[i];
  }
  avg = amount / number;
  return avg;
  } else {
  if (arr[0] < arr[1]) {
    min = arr[0]; max = arr[1];
  }
  else {
```

```
    min = arr[1]; max = arr[0];
  }
  for (i = 2; i < number; i++) {
    if (arr[i] < min) {
      amount += min;    //arr<min
      min = arr[i];
    } else {
      if (arr[i] > max) {
        amount += max;  //arr>max
        max = arr[i];
      } else {
        amount += arr[i]; //min<=arr<=max
      }
    }//if
  }//for
  avg = (double)amount / (number - 2);
  }//if
  return avg;
}
```

Arduino Receiver

```
#include <AltSoftSerial.h>

const size_t BAUDR = 9600;
AltSoftSerial link (8,9);

void setup() {
  // -- Serial init
  link.begin(BAUDR);
  Serial.begin(BAUDR);
}

void loop() {
  if(Serial.available() > 0)
  link.write(Serial.read());
  if(link.available()   > 0)
  Serial.write(link.read());
}
```

Processing ProjMeasure

```
import processing.serial.*;
import java.time.LocalDateTime;
import java.time.format.DateTimeFormatter;

/*
 * ProjMeasure - SE Project Measurements saver
 *
 * Displays the recieved data from an arduino reciever into a small GUI
and writes them into a .csv file
 * Also controls the probe servo
 */


// Constants
static final long MEAS_TOT = 10000;

// Objects
Serial serial;
DataWriteThread writer;
DateTimeFormatter dtf;

// State
boolean measuring;
long measureTimeout = Long.MAX_VALUE;

// -- Setup
void setup() {
  size(600, 500);
  dtf = DateTimeFormatter.ofPattern("HH-MM-SS");
  serial = new Serial(this, Serial.list()[1], 9600);
  writer = new DataWriteThread(String.format("PHMeasureData-%s.csv",
getTimeString()), serial);
  Runtime.getRuntime().addShutdownHook(writer);
}

// -- Drawing the gui
void drawGUI() {
  background(0);
  strokeWeight(5);
  stroke(255);
  noFill();
  rect(10, 10, width-20, height-20);
  textSize(50);
```

```
  fill(255);
  float data[] = writer.getLastData();
  pushMatrix();
  translate(40,80);
  text(measuring ? "[X]" : "[  ]", 0,0);

  translate(0,50);
  text("X:",0,0);
  text(data[0],50,0);

  translate(0,50);
  text("Y:",0,0);
  text(data[1],50,0);

  translate(0,50);
  text("P:",0,0);
  text(data[2],50,0);
  popMatrix();
}

void draw() {
  if (measuring) {                              // Measurment timeout
    if (measureTimeout < millis())
      measuring = false;
  } else {
    if (writer.hasData() && !writer.isAlive()) { // Write data when not
measuring
      writer.run();
      println("Writing to file");
    }
  }if (serial.available() > 0) {                // Getting data from
serial
    if (!writer.isAlive())
      writer.readChr(serial.readChar());
    measuring = true;
    measureTimeout = millis() + MEAS_TOT;
  }

  drawGUI();
}

// -- Controlls for the probe servo
void keyPressed() {
  print("Start Measurement");
  serial.write("aaaa");
```

```
}

// -- returns an accurate timestamp
String getTimeString() {
  return dtf.format(LocalDateTime.now());
}
```

Processing DataWriteThread

```
/*
  DataWriteThread

  The workhorse of the program, mantains probeData entries and saves them
into a file in a separate thread;

*/

class DataWriteThread extends Thread {
  ArrayList<probeData> dataEntries;
  PrintWriter file;
  Serial ser;
  String startTimeStamp;
  probeData lastData;

  // -- Constructor
  DataWriteThread(String filename, Serial ser) {
    file = createWriter(filename);
    this.ser  = ser;
    dataEntries = new ArrayList<probeData>();
    startTimeStamp = getTimeString();

    // dataEntries.ensureCapacity(200);
  }

  // -- Runs file writing routine
  void run() {
    file.println(String.format("---- MEASUREMENT [ %s : %s ]----",
startTimeStamp, getTimeString()));
    while (dataEntries.size() > 0) {
      writeEntry(dataEntries.get(0));
      dataEntries.remove(0);
    }
    file.flush();
  }
```

```
// -- writes one of entries
void writeEntry(probeData entry) {
  file.println(entry.getCSVDataLine());
}

// -- getters/ setters
// -- get last valid and full entry
float[] getLastData() {
  if (lastData != null)
    return lastData.getData();
  else
    return new float[]{0.0, 0.0, 0.0};
}
boolean hasData() {
  return !dataEntries.isEmpty() ;
}

void enterEntry() {
  if (!hasData())
    startTimeStamp = getTimeString();
  dataEntries.add(new probeData(ser));
  println("[MAIN]"+"Creating entry");
}

// -- Serial processing
String buff = "";
char prefix  = '\0';
boolean hasDecimalPoint = false;
boolean hasDecimals = false;

void readChr(char ch) {
  //-- Prefix
  if (Character.isLetter(ch)) {
    //Removes prematurely terminated message
    if (buff.length() > 1) {
      buff="";
      println("[DATA]: Removing garbage message");
    }
    prefix = ch;
  }
  // -- Digits
   else if (Character.isDigit(ch)) {
    if (hasDecimalPoint) {
      hasDecimals = true;
    }
```

```
      buff += ch;
    }
    //-- Decimal Point
    else if (ch == '.') {
      if (prefix != '\0') {
        if (buff.length() > 0)
          buff += ch;
        else
          buff += '0'+ch;
        hasDecimalPoint = true;
      }
    }
    //-- Endline
    else if (ch == '\n') {
      if (dataEntries.isEmpty())
        enterEntry();

      probeData entry = dataEntries.get(dataEntries.size() -1);
      entry.readParseSerialLine(prefix, buff);
      buff = "";
      prefix = '\0';
      hasDecimalPoint = false;
      hasDecimals = false;

      if (entry.isFull()) {
        lastData = entry;
        enterEntry();
      }
    }
  }
}
```

Processing ProbeData

```
/*
 * ProbeData
 *
 * A class that represents a data entry
 */



static final char lonPre = 'X', latPre = 'Y', phPre = 'P';
class probeData {
  float lon; // X
```

```
  float lat; // Y
  float ph ; // PH
  boolean phRecv = false;
  boolean lonRecv = false;
  boolean latRecv = false;
  String timeString;

  probeData(Serial s) {
    //Read the lines
    lon = 0;
    ph  = 0;
    lat = 0;
  }

  boolean isFull() {
    boolean a = phRecv && latRecv && lonRecv;
    if (a) timeString = getTimeString();
    return a;
  }

  void readParseSerialLine(char inchar, String numStr) {
    numStr = numStr.trim();
    // Checking for invalid strings
    println("[DATA]: "  + inchar + " : "  + numStr);
    if ( numStr.length() < 2 || numStr.contains("\n") ||
numStr.contains("\r")) {
      println("[ENTRY] invalid input");
      return;
    }

    float num = Float.valueOf(numStr);

    // Choosing the variable to put the number into
    switch(inchar) {
    case phPre: //PH
      ph = num;
      phRecv = true;
      break;
    case lonPre: //Longtitude
      lon = num;
      lonRecv = true;
      break;
    case latPre: //Latitude
      lat = num;
      latRecv = true;
```

```
      break;
    default:
      println("[ENTRY] Unexpected input: " + inchar);
    }
  }

  //Returns a string representation of the string
  String getCSVDataLine() {
    return String.format("%s;%f,%f,%f", timeString, lon, lat, ph);
  }
  //Returns the values in an array
  float[] getData(){
    return new float[]{lon,lat,ph};
  }
}
```

Puddle 1	Puddle 2
---- MEASUREMENT [15-01-09 : 15-01-80]----	---- MEASUREMENT [15-01-56 : 15-01-77]----
15-01-40;6,858689,52,235783,6,240000	15-01-11;6,859280,52,235340,5,340000
15-01-02;6,858695,52,235783,6,300000	15-01-09;6,859278,52,235340,5,530000
15-01-75;6,858712,52,235783,6,270000	15-01-09;6,859274,52,235336,5,530000
15-01-74;6,858712,52,235783,6,310000	15-01-09;6,859271,52,235340,5,540000
15-01-74;6,858712,52,235783,6,310000	15-01-11;6,859273,52,235336,5,430000
15-01-74;6,858713,52,235783,6,300000	15-01-09;6,859274,52,235332,5,260000
15-01-74;6,858714,52,235783,6,280000	15-01-09;6,859272,52,235332,5,060000
15-01-74;6,858715,52,235783,6,320000	15-01-09;6,859271,52,235332,5,250000
15-01-75;6,858715,52,235783,6,280000	15-01-09;6,859269,52,235336,5,450000
15-01-74;6,858717,52,235783,6,300000	15-01-09;6,859271,52,235332,5,580000
15-01-74;6,858717,52,235783,6,300000	15-01-09;6,859268,52,235332,5,480000
15-01-74;6,858719,52,235786,6,270000	15-01-09;6,859266,52,235332,5,510000
15-01-74;6,858725,52,235786,6,280000	15-01-09;6,859266,52,235336,5,490000
15-01-74;6,858726,52,235783,6,270000	15-01-09;6,859269,52,235332,5,520000
15-01-74;6,858726,52,235783,6,300000	15-01-09;6,859271,52,235332,5,620000
15-01-74;6,858726,52,235783,6,290000	15-01-09;6,859270,52,235332,5,770000
15-01-76;6,858724,52,235779,6,340000	15-01-09;6,859268,52,235332,5,750000
15-01-74;6,858723,52,235779,6,270000	15-01-09;6,859267,52,235332,5,810000
15-01-74;6,858723,52,235779,6,260000	15-01-09;6,859271,52,235332,5,670000
15-01-74;6,858726,52,235775,6,270000	15-01-09;6,859270,52,235332,5,640000
15-01-74;6,858725,52,235775,6,280000	15-01-09;6,859266,52,235332,4,940000
15-01-74;6,858723,52,235775,6,280000	15-01-09;6,859265,52,235332,5,010000
15-01-74;6,858724,52,235775,6,330000	15-01-09;6,859262,52,235329,5,250000
15-01-74;6,858724,52,235775,6,270000	15-01-09;6,859264,52,235329,5,470000
15-01-76;6,858723,52,235775,6,290000	15-01-09;6,859265,52,235329,5,590000
15-01-74;6,858725,52,235775,6,300000	15-01-09;6,859266,52,235329,5,750000
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Puddle 3

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