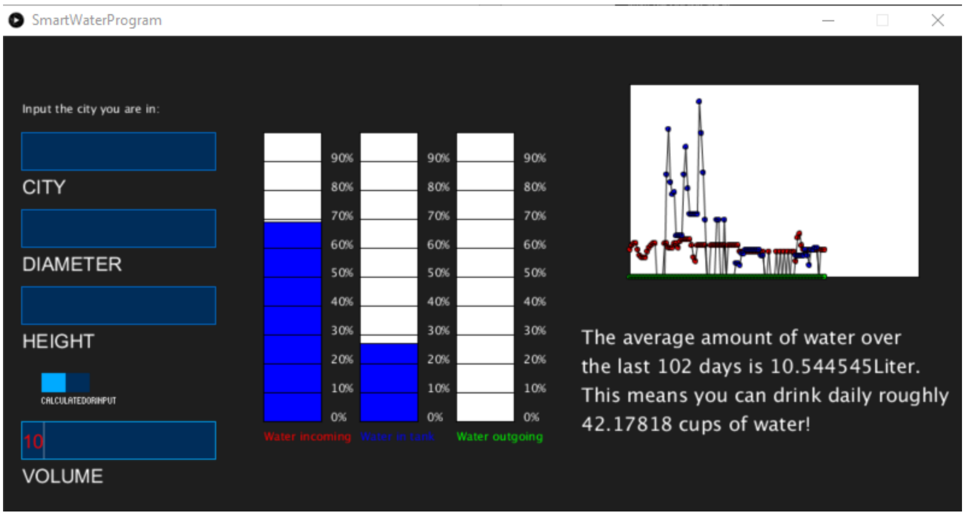
UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT



WELLBEING

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Table of Contents

Chapter 0: Introduction

The goal of this project is to create a smart environment to solve a problem on the theme of disasters. The topic we chose to work on is the unreliability of water supplies in underdeveloped countries. In many countries there is uncertainty on how much rainfall will fall in the coming days and what this will mean for the available water in a community. This project aims to solve this issue by creating a simple cheap water station which can register how much water is inside a water storage container and calculate how long that supply will last. The station is made using Arduino and Arduino compatible sensors and will be able to measure the water flow leading into the tank and the water level at any given moment. The software behind the project will record this data, together with other data we can collect open source, and make predictions on how much water there is available for usage.

This problem has been chosen after a long ideation phase. As the first half of this report shows, we have spent quite some time exploring and searching for a specific disaster problem we could attempt to fix. We started on identifying general disasters and then looked into how we could provide simple solutions that could have a big impact. We have chosen this problem because we believe it is a tangible problem that can influence many people’s lives. This is also why we aimed to keep our solution flexible to different environments and compatible with all sorts of water tanks. For example, the water flow sensor is a relatively cheap and easy to use sensor which fits the requirements. We also wanted to keep the output data easy and comprehensible. Therefore, we chose to use a simple display screen instead of making an app or touch screen device. Most of the calculations and data become invisible to the user, resulting in a small scalable device that can be controlled from a distance.

This report will lead you along the journey of creating our first smart environment. It was a challenging project with many new obstacles which allowed us to be inventive and creative. We enjoyed working on a real tangible problem in a team like this, even though covid-19 did not allow us to meet physically. Nevertheless, we hope our product can show effectiveness in relieving the disaster of water shortness and provide a creative impulse.

Chapter 1: Literature Review

This chapter shows a collection of 20 articles from the ideation phase of our project. The articles offer a very broad exploration of the theme of disasters and already indicate some problems we found interesting. Every item starts with the title, followed by the MLA cited source and the link to read it. We also provided short summaries for every article to highlight the most interesting parts regarding the project.

Article 1: Epidemics after natural disasters
Watson, J. T., Gayer, M., & Connolly, M. A. (2007). Epidemics after natural disasters. *Emerging infectious diseases*, *13*(1), 1.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2725828/
Summary: The risk factors for outbreaks after a disaster are being discussed, the communicable diseases that are likely to be important are being reviewed and priorities to address communicable diseases in disaster settings are being established.

Article 2: The macroeconomic consequences of disasters
Noy, I. (2009). The macroeconomic consequences of disasters. *Journal of Development economics*, *88*(2), 221-231.
Link:
https://www.sciencedirect.com/science/article/pii/S030438780800031X?casa_token=BR9cDGRNcfkAAAAA:jJHbr1rBUPhRdfQO3WSODX1iNzoGJhIiWu_c3YDrxSm7II-Jcom6bEZV6PTYShoIB8lFTr7HEQ
Summary: A close study of the determinants of adverse macroeconomic output costs, as a result of disasters, that reveals several interesting patterns.

Article 3: Mental health consequences of disasters
Goldmann,E., & Galea, S. (2014). Mental health consequences of disasters. *Annual review of public health*, *35*, 169-183.
Link: https://www.annualreviews.org/doi/abs/10.1146/annurev-publhealth-032013-182435
Summary: An overview of research on the presentation, burden, correlates, and treatment of mental disorders following disasters. Besides that the challenges to studying the mental health consequences of disasters are described and the limitations in current methodologies are discussed.

Article 4: Ad hoc peer-to-peer network architecture for vehicle safety communications
Wai Chen and Shengwei Cai, "Ad hoc peer-to-peer network architecture for vehicle safety communications," in IEEE Communications Magazine, vol. 43, no. 4, pp. 100-107, April 2005, doi: 10.1109/MCOM.2005.1421912.
Link:https://ieeexplore-ieee-org.ezproxy2.utwente.nl/abstract/document/1421912
Summary: The discussion and research of peer to peer networks to be used in first responder vehicles to get them online as fast as possible after a disaster that took out the normal communication network. This is done so that the first responder can communicate with all the other first responders in range.

Article 5: AIDR: artificial intelligence for disaster responseAIDR: artificial intelligence for disaster response
Muhammad Imran, Carlos Castillo, Ji Lucas, Patrick Meier, and Sarah Vieweg. 2014. AIDR: artificial intelligence for disaster response. In Proceedings of the 23rd International Conference on World Wide Web (WWW '14 Companion). Association for Computing Machinery, New York, NY, USA, 159–162.
Link: https://dl-acm-org.ezproxy2.utwente.nl/doi/abs/10.1145/2567948.2577034
Summary: Trying to prevent an information overload for the responders during a crisis by training a neural network to categorize tweets(already filtered on relevancy by hastags) further into categories (among others needs and damage). The network is trained by a group of trusted annotators during the crisis who categorize the first training tweets. This resulted in the program AIDR (Artificial Intelligence for Disaster Response) system. This helps the responders obtain real time filtered data.

Article 6: Pre-positioning of emergency supplies for disaster response
Carmen G. Rawls, Mark A. Turnquist, Pre-positioning of emergency supplies for disaster response, Transportation Research Part B: Methodological, Volume 44, Issue 4, 2010, Pages 521-534, ISSN 0191-2615, https://doi.org/10.1016/j.trb.2009.08.003. (http://www.sciencedirect.com/science/article/pii/S0191261509001118)
Link:https://www-sciencedirect-com.ezproxy2.utwente.nl/science/article/pii/S0191261509001118
Summary: Strategically placed resources are a huge help in dealing with the aftermath of a disaster, but beforehand knowing where to place them usually is guesswork due to the nature of disasters. The researchers have made a mathematical model of distribution centres and its resources to see where they should be placed. The model is optimized to be able to support a large network of resources. With this information resources can be optimized and therefore the immediate help can be much more sufficient.

Article 7: Joint evaluation of the international response to the Indian Ocean tsunami: Synthesis Report
Rachel Houghton. “Joint evaluation of the international response to the Indian Ocean tsunami: Synthesis Report.” TEC. July 2006. 117-125.
Link: https://web.archive.org/web/20060825234109/http:/www.tsunami-evaluation.org/NR/rdonlyres/2E8A3262-0320-4656-BC81-EE0B46B54CAA/0/SynthRep.pdf
Summary: The studies in this report point to reform agendas that require attention and careful scrutiny. They provide insights into how best to respond to current and future challenges and provide disaster relief and recovery.

Article 8: Predicting the next big earthquake
Franklin Wolfe. “Predicting the next big earthquake.” Harvard University, The Graduate School of Arts and Sciences. April 22, 2019.
Link: http://sitn.hms.harvard.edu/flash/2019/predicting-next-big-earthquake/
Summary: This report discusses options for solving the problem using artificial intelligence that will predict an earthquake in advance to increase resilience or improve probabilistic models by better understanding this process.

Article 9: Seismic history of the Maltese islands and considerations on seismic risk

Pauline Galea. “Seismic history of the Maltese islands and considerations on seismic risk.” Physics Department, University of Malta, Malta. December, 2007. 735-738.
Link: https://www.annalsofgeophysics.eu/index.php/annals/article/viewFile/3053/3096
Summary: The study found that the structures of buildings in the Maltese Islands are highly vulnerable and construction methods need to be modernized to protect against seismic effects.

Article 10: The companion to development studies
Desai, V., & Potter, R. B. (2013). *The companion to development studies*. Routledge. Chapter 6.5, pages 351-353.
link:https://books.google.nl/books?hl=en&lr=&id=AO4jAwAAQBAJ&oi=fnd&pg=PA351&dq=disasters&ots=6glFCpIkH0&sig=uRapoZM_eTsunFuJLBMOCE_yknA#v=onepage&q=disasters&f=false
Summary: Natural phenomena like earthquakes or storms are only disasters when they affect humans. Disasters happen because people decide to live in dangerous areas. Disasters strike harder in poorer societal groups. Rich people can relatively easily recover, while the poorer people in the same country struggle to catch up even decades later. Natural disasters delay development in poorer countries and create more poverty

Article 11: Symptomatology and psychopathology of mental health problems after disaster
Foa, E. B., Stein, D. J., & McFarlane, A. C. (2006). Symptomatology and psychopathology of mental health problems after disaster. *J Clin Psychiatry*, *67*(Suppl 2), 15-25.
link:https://d1wqtxts1xzle7.cloudfront.net/5816097/1000011335-1.pdf?response-content-disposition=inline%3B+filename%3DSymptomatology_and_psychopathology_of_me.pdf&Expires=1605727571&Signature=Podq8MH6kvDiRLLoVn6XLapO9WoYEjieadWgSF70wku6~coGTbo91KFlDfNbjW4fZUI1YPwacq4oC7hj7a7H~jA~Swch2HAuR49BRUqtSIUjKpTGq9RJRGSHQfsOf~m4JLhHGs7alOtY2DUnAoZrV1HTzBxWZ2fqSk7YPnOZJtyzg8o3CkK~jooPvVLzOMyES0c6jfTBVKb9DTnZ0HQNAyj1I5gGQhQjOQIy7FgoO5pv1bN2RwBAz5F7QIDyGptNJRzoaeOOp0Niq~UUxRsNBb3vq9-sFZC3tv02FTdffwDr6f0~9KowBOvUEuc5IoNYj2moJEZzOIZ3X3K5T2TkgQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA
Summary: Acute stress reactions are common and expected after disaster and other trauma. While these can be distressing to the individual concerned, resilience is also common and most affected individuals recover with time. In some cases, however, recovery is incomplete, leading to a number of psychiatric conditions, of which PTSD is the most frequently encountered. PTSD often coexists with a variety of psychiatric and physical disorders, which further increase the burden of suffering experienced by the patient.

Article 12: Smart disaster notification system
Sikder, M. F., Halder, S., Hasan, T., Uddin, M. J., & Baowaly, M. K. (2017, September). Smart disaster notification system. In *2017 4th International Conference on Advances in Electrical Engineering (ICAEE)* (pp. 658-663). IEEE.
link:https://ieeexplore.ieee.org/abstract/document/8255438
Summary: The article describes a smart notification system they built to warn people about possible disasters and tell them what to do. The application can alert for potential disasters like heavy rain, flood, wildfire and more. They can also recommend an optimal route to

safety by mapping shelter places. They analyse all sorts of weather data collected from the internet to predict natural disasters which is pretty cool.

Article 13: Earthquakes Are Jolting the Netherlands. Gas Drilling Is to Blame
Reed, S. (2019, 24 oktober). Earthquakes Are Jolting the Netherlands. Gas Drilling Is to Blame. The New York Times.
link:https://www.nytimes.com/2019/10/24/business/energy-environment/netherlands-gas-earthquakes.html
Summary: The article shows the other importance of finding alternative energy sources next to global warming. In Groningen the ground is shaking due to gas drillings below the ground. Homes have become ruins in a period of 10 years and in a town at the center of the quake zone, 80% of the houses require demolishment.

Article 14: NASA's First Planetary Defense Technology Demonstration to Collide with Asteroid in 2022
Surowiec, J. (2019, 6 mei). NASA's First Planetary Defense Technology Demonstration to Collide with Asteroid in 2022 –. NASA Solar System Exploration.
link:https://www.nasa.gov/planetarydefense/dart
Summary: NASA is preparing for DART (Double Asteroid Redirection Test). As space asteroids form a threat for human kind it is important to be able to redirect asteroids, which could potentially hit earth, to a different path. NASA is going to test this system by crashing it into a moonlet in 2022. Launch will be in summer 2021 on a SpaceX falcon.

Article 15: How AI can improve disaster resilience and relief
van Heteren, A., Hirt, M., & Van der Veken, L. (2020, 14 januari). How AI can improve disaster resilience and relief. World Economic Forum.
link:https://www.weforum.org/agenda/2020/01/natural-disasters-resilience-relief-artificial-intelligence-ai-mckinsey/#:~:text=Artificial%20intelligence%20can%20improve%20disaster,key%20to%20maximize%20its%20benefits.
Summary: As natural disasters become way more common, modern technologies like AI can help support emergency responses to work more efficiently. Artificial intelligence could be used to monitor social media and identify people in need or assess floodings using satellite images without the need for humans to process the data, which could waste valuable time.

Article 16: Social Media in Disaster Risk Reduction and Crisis Management
Alexander, D. E. (2013, 4 december). *Social Media in Disaster Risk Reduction and Crisis Management*. Science and Engineering Ethics.
https://link.springer.com/article/10.1007/s11948-013-9502-z?error=cookies_not_supported&code=e811ce1f-3571-4c49-b9d7-69ff49016b47
Summary: Social media can be used in several ways for disasters like listening to public debate, monitoring situations, extending emergency response and managem lent, crowd-sourcing and collaborative development, creating social cohesion, furthering causes (including charitable donation) and enhancing research.

Article 17: Method and system for disaster recovery of data from a storage device

Ma, K. (2003, 14 mei). *Method and system for disaster recovery of data from a storage device*. Google Patents. https://patents.google.com/patent/US7415115B2/en
Summary: This is an invention for securing data after something happened to it, so it is not lost and nobody else can get access to it.

Article 18: Disaster: Prevention, Preparedness and Action
SALLY BUCHANAN, S. B. (1981). *Disaster: Prevention, Preparedness and Action*. illinois. https://www.ideals.illinois.edu/bitstream/handle/2142/7196/librarytrendsv30i2g_opt.pdf?sequ
Summary: Books can be preserved using different methods, like heating them to dry them up after floods, if books get destroyed it would be a disaster, because they contain a lot of knowledge.

Article 19: Disaster Prevention and Preparedness
Sena, Woldemichael, L. S. K. W. (2006). *Disaster Prevention and Preparedness*. cartercenter. https://www.cartercenter.org/resources/pdfs/health/ephti/library/lecture_notes/health_science_students/lln_disaster_prev_final.pdf
Summary: "Disaster prevention and preparedness is a newly designed course for health science students. The aim of the course is to equip students with knowledge and skills of developing feasible disaster prevention plans and preparedness before a disaster happens to minimize the risks and the resulting damages". It is a course that teaches people to see disasters coming and to teach them plans to minimize the risks and the damage done. It teaches how to prevent it and deal with the consequences of the disaster.

Article 20: Culture of preparedness: household disaster preparedness
Culture of preparedness: household disaster preparedness | Emerald Insight. (2008, 29 augustus). Emerald. https://www.emerald.com/insight/content/doi/10.1108/09653560810901773/full/html
Summary: This study emphasizes the importance of individual preparedness, if individuals aren't ready for a disaster it is much harder to prevent it or have minimal risk.

Chapter 2: Identification of General Problems and Challenges

In this chapter we will explore some general problems and challenges regarding the theme of disasters based on the literature research from chapter 1. We discussed 8 issues that are still very broad and can be found in many forms and applications in disasters. After discussing how the problems are often caused and what kind of damage they might form, we also started contemplating ways or directions in which we can look for solutions to these problems. Below is the full list of the problems and our thoughts on them.

Loss of communication network

In a lot of natural disasters, the communications network is damaged resulting in difficulty for both first aiders and resident's communication often slowing down workers crucial time in finding missing persons and/or getting an overview. Often the rescue workers have walkie talkies or other devices to communicate with each other. The main problem is the communication with the people who live in the area of the disaster. Article ten from chapter one explains that disasters mostly happen because people decide to live in dangerous areas. When you know an area is prone to, for example, earthquakes you can install communication devices in the houses that can call to the rescue time when the house has sustained damage. Or you might think of creating a device that can tell whether there were still people inside the house so that the rescue teams have a clear overview of the situation.

Need for immediate resources

When a crisis occurs, beforehand well-positioned resources can be of immense value to workers and residents providing food, health packages, power etc.
When a crisis occurs, quick and efficient response could save many extra lives. Many times, we have first world countries sending in care packages after we have received and processed the news of a disaster. If we could identify what kind of resources are most needed quickly, lives can be saved. Article fifteen from chapter one also describes a way to map this need for immediate resources using Artificial Intelligence.

Traumatization of survivors

After a disaster has happened many survivors cope with psychological symptoms and disorders due to the traumatic event. This can, for example, be a natural disaster in which people have lost their homes or a trauma caused by shocking imagery. Retaining the capacity to continue functioning after a traumatic event is difficult and continuing without professional help in many cases makes the situation worse. Providing a personal therapist for everyone in a community after a disaster is impractical and often unrealistic. Coming up with a large-scale trauma treatment device you might be able to help people in a less personal but hopefully still useful way. There are already robots that can detect emotions and help people calm down, it might be possible to create a device that allows people to speak about their trauma and allows them to deal with what they have gone through.

Infrastructure damage

Road closures or obstructions make it hard to transport people into safety and distribute resources towards them. The roads are the main ways of transportation of immediate resources and can transport people into safety and to hospitals. When roads are obstructed it can take much longer to transport these resources and people, wasting valuable time. Transportation over air or water needs time for adaptation to gather the vehicles. It is therefore important to clear roads as quickly as possible when this is possible. To safe lives one can implement devices that can track where the roads are damaged and how they can be cleared up quickly. This should then be done with drones or other devices that can provide an overview of the area.

Spreading of diseases.

Water safety can be compromised by natural disasters. This can lead to several disease outbreaks, which can lead to even more casualties. In this context there is a clear lack of hygiene and clean water that can rapidly have gigantic consequences. When we want to avoid this one could think of quick action that can increase hygiene measures and provide clean safe water. The main problem is that first aid emergency housing or camps are made to be built quickly and provide shelter to a lot of people. However, hygiene measures are normally not the top priority in this case. It could be useful to

Education of risks

People are often unprepared for disasters, leading to much more damage and making the recovery process even harder. People can be taught how to react to a certain disaster and this way minimizes the risk and prevent the negative consequences. When people are aware of the possible natural disaster that can occur in their environment they can prepare for these situations and make the right decisions to save lives. The challenge here is to gather people and find an expert that can educate them.

Issues in operating online

Disasters often require flexibility from people to move from physical face to face communication to a digital online world. As we can see from the problems above, many can be solved by using technology to communicate or measure data. When the world is forced into a lockdown due to a pandemic, this requires adjustability from many people to start working with technology they might not be too familiar with full-time. It is important that people get the chance to adapt to this new environment and learn how to maximize the potentials of communicating online. Communication is one of the most important issues in disaster management and the communal ability to exchange information online can potentially save lives.

Inequality in recovery chances

Natural disasters and subsequent recovery efforts consistently exacerbate economic inequality. Poorer people are often forced to live in more dangerous areas prone to natural disasters as they cannot afford to live elsewhere. Besides that, compensation for losses of possessions also bias people with higher income with insurance companies providing financial coverage. It can take decades to rebuild a poor city after an earthquake, while richer people often have enough money spare to take care of themselves quickly. In order to decrease this gap of inequality, low-income families should be given more help and tools to rebuild what they lost after a disaster.

Chapter 3: Identification of Relevant Problems

This Chapter will explore 5 new relevant problems that have not been addressed to a great extend yet. These are problems we did not directly read about in our literary research, but we still wanted to explore them for a broader vision as we are still in the ideation phase.

Unawareness of water usage at home

In the recent past, the demand for freshwater worldwide has increased largely due to the world's growing population, as well as changing lifestyles and eating habits that have been associated with higher water consumption. The increase is more pronounced in urban settings which normally have higher population densities in addition to production industries that typically consume large amounts of water. People waste a lot of water in their daily lives at home. They are unaware of their water usage and don't see the preciousness of it.
A smart water meter is a standard or conventional water meter. However, to make it 'smart', the meter is attached to a device that allows continuous electronic reading, storage, display and transfer of water consumption data. In particular, the ability to collect, analyse and relay water use data to the water user almost in real-time has the potential to cause significant changes in water use behaviour patterns.
https://watersource.awa.asn.au/wp-content/uploads/2019/02/001-Koech-Richard_v1.pdf
This could make people aware of their water usage and let them view their data in an app, the same way people can check their electricity usage.

Bringing in bottled water after disasters uses a lot of plastic waste.

Often in case of natural disasters, the water safety in the area is compromised. Clean drinking water is one of the most important and necessary resources provided by several emergency aid organisations. Usually aid organisations supply bottled water. While distributing bottled water is a quick way to provide clean drinking water, it results in much plastic waste. A smart water filtering system that cleans the dirty water in the area of the disaster, could provide clean drinking water, without leaving a lot of plastic waste. To make sure the water is evenly distributed over the population, the system could limit the amount per person.

Communication between emergency services

As a result of a natural disaster, the communication network is often damaged. This is very challenging for the first aiders and the local population, since this slows down collecting crucial information to help where necessary. Many areas become inaccessible, which makes providing help even harder without communication. To coordinate this the emergency services could have a sort of peer-to-peer network structure attached to their vehicles using which they can still share data and coordinate. This would mean they still can communicate with each other and get a sense of the scope of the disaster and the urgency of what kind of help is necessary at that time.

Clean water

A long-term humanitarian disaster is the lack of clean water for instance in Africa. This has a lot of factors contributing to it. The two factors that we can solve are a lack of hydrological data and climatic variability. Our solution would be to build a cheap system of sensors to get an insight to where the water really is, if it's clean and to build a model to predict based upon environmental factors if and when water is going to be available and sustainable or if there is going to be a drought.
Interesting link about a water quality and distribution monitoring system in Mali
https://www.dutchwatersector.com/news/digitising-water-quality-monitoring-in-mali

Unpreparedness regarding earthquakes

Seismologists annually register about 20 thousand earthquakes on Earth. Millions of people in large metropolises in earthquake-prone regions of the Earth are threatened by seismic disasters, for which people are not prepared at all or not sufficiently prepared. The earthquake warning system is capable of detecting primary and secondary earthquake waves and alerting residents through devices. This would be part of a solution that would give short term warnings whenever an earthquake might occur in the following hours. This could only allow the residents to search for quick shelter and would unavoidable still cause a lot of damage. Another solution of course lies in the construction

Wildfire response time

Wildfires are a big problem in some parts of the world, they are harder and harder to put out as they grow bigger. In order to prevent a wildfire to create millions of acres of damage and destruction it is important to detect the start of a wildfire as quickly as possible. This could be done by monitoring large areas and observing places that are showing very high temperatures. At a certain selected peak temperature, the system should send a trigger warning so that a team of fire inspectors could be sent. Or if we think even further you could send a drone or robot to check up on the situation. Of course, not all wildfires would be possible to be predicted this way, as we have people celebrating gender reveals with fireworks in the drought. However, mapping the temperature will provide quick updates on temperature increases and can sufficiently help in solving the response time.

Chapter 4: Problem Selection and Motivation

Our Problem: The uncertainty of availability of clean water at a storage facility.

A long-term humanitarian disaster is the lack of clean drinking water in dry regions with less financial assets. This has a lot of factors contributing to it. Mainly the hot dry climate in these areas brings a big challenge into existence. As we realistically cannot solve this or the poverty by creating a smart environment, we decided to focus on a solution that would allow more control and overview on the availability of water. This way we allow the users to keep track of their water usage and the sustain of their supply, without having the optimistic idea that we can magically increase the drinking water. Of course, telling people to just be more economical sounds very ignorant from our part, as we have never been in situations where there is water scarcity. We are fortunately in the position in which we can afford to waste water every day without having to face any consequences. By choosing this problem we simply hope to enable people to regain control on their water supply.
We therefor decided to focus on the uncertainty and lack of information on a lot of water supplies. We want to decrease the uncertainty on how much water there is available, how much is expected to fall in the near future and how much water could sustainably be used from that.

Motivation behind the choice

We thought this was an interesting problem with which we could make a realistic, tangible final product, and have an impact on many lives. During our meetings in which we discussed the problems we had come up with and their possible solutions we all tended to lean towards this problem. We already started discussing the issue to a greater extend and were all interested in the many ways to tackle this problem. We had members thinking of different ways to fight water scarcity by improving rainfall usage or water filtering. This problem seemed to allow us to think outside the box and allowed for more consideration than the other problems we discussed.

Realistic solution ideas

Our solution would be to build a cheap system of sensors to get an insight into individual storage facilities on all sorts of scales to determine the trends of how much water there is coming in, going out and currently available. We would be able to calculate how much water you can currently use and keep a track of when water is available.

Chapter 5: Potential Solutions

Solution 1:

Which subproblem are we solving?
The shortage of data. We will build a weather-station like device with sensors for detecting how much water falls, where it is, and how clean it is.

Sensors/ needed products:
Flowmeter
Turbidity sensor
Arduino
GPS module

(alternatively, this could be a rubber ducky-type box which would measure the flow in rivers)

Solution 2:

Which subproblem are we solving?
Lack of knowledge on what water is drinkable and what not

Sensors/ needed products:
1. Arduino Mega Board.
2. (16 * 2) LCD display.
3. Temperature sensor
4. The Turbidity Sensor.
6. An ultrasonic Sensor.
7. 4 RGB led.
8. A buzzer.
9. pH sensor

The only problem could be the turbidity sensor which would do most of the checking of cleanness and which is quite expensive.
Two examples that we could use to improve for our context and goal.
This project was created in order to find the source of pollution which had stopped a water treatment plant from working. It also used GPS to pinpoint the exact location. We might not need this part, but can adjust it to add sensor that check rainfall or other useful things in our context
https://create.arduino.cc/projecthub/chanhj/water-quality-monitoring-system-ddcb43?ref=tag&ref_id=water&offset=0
This project is more focused on warning people in case something is wrong with the water. It monitors a lot of data like water levels, pH, dirt etc. and notifies the user when something is wrong with the data
https://create.arduino.cc/projecthub/eani/water-quality-monitoring-and-notification-system-f85d23?ref=tag&ref_id=water&offset=1

Solution 3:

Which subproblem are we solving?
The unfindability and lack of insight in the water-distribution in Africa.

Sensors/ needed products:
A software (website) based approach using various sources to visualise where and how much water there is.
https://opendataza.gitbook.io/toolkit/open-data-resources/water-and-climate-data-resources
http://www.sasdi.net/search.aspx
http://www.fao.org/3/a0907e/a0907e00.htm

Solution 4:

Which subproblem are we solving?
The unknown predictions about the amount of water available based on weather data and current water supply

An all-in-one cheap solution which can be placed at a water source and displays the amount of water available in the source and predicts the amount that can be used per day until weather conditions refill the reservoir.

Sensors/ needed products:
Pressure sensor (amount of water available)
Connectivity (available Wi-Fi or satellite solution)
Arduino for processing sensor data.
Raspberry Pi for displaying prediction

Solution 5:

Which subproblem are we solving?
Absence of appropriate infrastructure.

Shortage of freshwater is not only the problem of Africa. A few other states have faced this issue, countries such as UAE, and Israel. The governments of these countries managed to overcome this obstacle by distilling salt water. Same technique may be applied to help the nations of Africa.

Sensors/ needed products:
Primary filter
Two rollable ultrafiltration membranes
Pump that supplies water under pressure to the filter elements
Automatic workflow control unit and nominative equipment
Storage tank for collecting purified distillate
Reagent tank involved in the restoration of the cleaning ability of reverse osmosis membranes

Solution 6

Which problem are we solving?
Lack of water reusability

A lot of water gets wasted, for example by taking a shower, if this water can be captured and filtered in a central reserve to lead it to places where there is need for water. This could best be used for the agricultural sector, because of the amount of water needed.

sensors/need products
Water filter elements
Pressure sensors (to know when there is need for water)
Control system to send water back and forth

Chapter 6: Solution Selection

The final solution we want to build is an extension of chapter 5's solution 4. We would like to make a device that sits on top of/in a water storage container (barrel, well, etc.) and that measures how much water is coming in, how much water is going out, how much water is in the container and predicts based upon that how much water you can use and when you'll be out of water.

We chose this solution because it was the most powerful one. With relatively little you can solve a big problem and help a lot of people. We also feel like this is a solvable problem for us, and a scalable one for if we have more or less time.

The basic solution

The basic solution is the software program that would run our water sensor. This program is going to be written in Processing and has simulated inputs and outputs. It will display and keep track of how much water is in our system, predict how long that is going to last and how much us

The ambitious solution

The ambitious solution has an output flow sensor and a water level measuring sensor that can be placed on any existing tank, no matter the diameter or size. Because of these sensors the device would at any given time be able to tell how much water is inside. This coupled with the aforementioned program will allow us to put our solution into the real-world. If we have more time afterwards, we can add extended features, for instance a GPS module to keep track of where the storage device is.

Expected issues

We will have to think of a way to properly waterproof our whole solution. Also given the corona-regulations making the physical part as a group is hard.

Proposed modular approach

❖ Visualize input and output (water levels)	**Ysbrand**
❖ Build the graphs	**Ysbrand**
❖ Build the JSON data storage	**Ysbrand**
❖ Calculate the amount of drinkable water per day	**Ysbrand**
❖ Deal with the inputs of our program coming from the user	**Ysbrand**
❖ Connect the physical input to the software	**Bram & Ysbrand**
❖ Create the API calls and integrate weather predictions from online source	**Hylke**
❖ Build and test the water level sensor	**Bram**
❖ Think of a way to validate data	**Dildora**
❖ Order the equipment	**Rachel**
❖ Do background research on possibilities of implementations	**Rachel**
❖ Keep track of project documentation	**Rachel**
❖ Branding and presentation	**Rachel**
▪ Name & Logo	
▪ Demo video	**Dildora**

Because only one person can work on the physical system, we have Bram working on the physical part and the testing. Communication is very important so that Bram can feedback to Ysbrand whether the code works and if not, how it could be changed.

Chapter 7: Methodology

In its most basic form, our smart system is aware of the amount of water that is in the tank at any given moment. It would get this data from looking at the water level in the tank. By using data for rainfall predictions, it can calculate the predicted addition of rainwater. Based on this information, the system can make predictions on how much water there will be available to drink and output that to the people using the tank as a water source.
Besides these basic functions, we can expand if we have the time and resources, by adding for example flow sensors at the input and output for more accurate data. However, we think it is also important to keep the system cheap and simple considering it should be available for poorer regions. This is also why we aim to keep the output as a simple display only showing 1 sentence like “next rainfall expected on… until then there will be … cups per day”. We do not believe the users would benefit from seeing a whole applet that could also display how much rainfall will be expected where and how much water is still in the tank. Of course, this could still be considered if it turns out it is achievable with the same resources, but we do not expect so.

Equipment

A simple water level sensor can be made by ourselves and connected to Arduino. Here is an example https://create.arduino.cc/projecthub/Pedro52/arduino-esp32-diy-water-level-sensor-and-diy-level-indicator-3d513d
For this example we would need the following materials:

- 6 pieces of electricity wire (1, 5 mm copper with black PVC cladding) stripped approx 1 cm at both ends
- a piece of electricity pipe 3/4 inch with a length that matches the depth of your reservoir
- 1 PVC 3/4 inch pipe extension
- 6 * 680KOhm resistors
- a 1 nF capacitor (for noise suppression)
- a cheap audio cable
- a piece of double sided prototype PCB board

If we want to use this example, we must research the effects of emerged copper wires after a long exposure to water and air. We also have to find improvements and adjustments to fit our water storage bin or tank, but it could be a very helpful base.

Time plan

Before Christmas break:
Buy all the equipment
Week of 4 January:
We plan to start our research and development the first week after the Christmas break. In the first week we aim to figure out how we can make a simple water level meter and to find an appropriate water tank/bin to work with.
Week of 11 Jan: first prototype presentation
During this week we have to make our first prototype. We aim to have a working water level sensor by the end of this week. We will work on the data processing during the week to be able to show in our presentation on Friday how our product will work.
Week of 18 Jan: exam week
Working on feedback from our presentation and further developing software. Decide on whether ambitious solution will be achievable.
Week of 25 Jan: final demonstration

Task division

Order all the equipment: Rachel
Create the physical hardware with the items: Bram
Build the user interface, graph, water Levels and data storage in processing, and build the connection with Arduino: Ysbrand
Build the link with the API: Hylke
Think of a way to validate the data: Dildora
Fix our documentation and keep track of progress: Rachel

For the software we need multiple elements. The first part of the software will need to be able to calculate how much water there is left in the container. Measuring this amount of water can be done with waterflow sensors or the water level sensor in the ambitious solution. Based on this data the software should be able to make a calculation on how much water is in the container.
Besides this first part of software, our smart environment will need software that calculates how much water can be used per day. The Arduino will need to be connected to a weather station from the internet to acquire the predictions on water fall in the coming days. After the program has received this information it will be able to calculate the average amount of available water per day. This output will be displayed on a small display screen in order for the users to get some insights on the water availability.

For the hardware part of the program, we will need one person to put all the equipment together and make the physical sensor. This person will have to coordinate the safety and check whether the code works in interacting with the product. Because we are working with electricity and water, we also must keep in mind safety and contact Alfred to check up on us.

Chapter 8: Results and Conclusion

Data validation

The water flow sensor we used for measuring flow and volume with Arduino works according to the Hall effect principle. According to this effect, a voltage difference is induced in a conductor perpendicular to an electric current, and a magnetic field is perpendicular to it. Here, the Hall effect is used in a flowmeter using a small rotor in the form of a fan / propeller that is placed in the path of the fluid flow.
The fluid presses on the ribs of the rotor, causing it to rotate. The rotor shaft is connected to the Hall sensor. It is a device of a coil flowing with a current and a magnet connected to the rotor shaft, so when this rotor rotates, a voltage / pulse is induced. In this flowmeter, for every litre of liquid passing through it per minute, it produces about 4.5 pulses. This is due to a change in the magnetic field caused by a magnet attached to the rotor shaft. We measure the number of pulses with an Arduino and then calculate the flow rate in litres per hour (L / hr) and total volume in litres using a simple conversion formula.
The data line of the sensor gets pulled high when water flows through. Therefore, we can calculate the amount of water that has flowed through by dividing the flowrate of the sensor (L/minute) by 60 to get the flowrate per second, then by the number of times per second that we check it to get how much water there could flow per time interval. If we then multiply the number of times the sensor checked sensed water and returned a 1 to the Arduino times the L/time-interval we can calculate the water/second that is flowing. We multiply this by however many seconds we want for the flowrate per that number of seconds. We also want to know the amount of water the basin can hold. For a cylinder shape, the following formula is suitable for calculating the volume of the tank: $\pi*r(radius)^2*h(height)$. The user can also input this if it is known. We checked if it is reading the correct values by putting in a known amount of water and seeing how much our software says is in the system. This is further discussed further in the document.

Results

For our final product we have developed a processing software program. This program can take inputs and outputs in order to calculate how much water is in the system, how much water is coming in with the difference between those two how much water is going out. Or any combination of input, output and height sensors. We made the software modular so that it can be used in almost any situation. It stores the data of the input, output and water in the container of the last 100 days in a JSON file, so it doesn't get lost if it crashes. It shows you a nice graph of that data and a prediction of how many cups of water you can drink. We also tested this with a physical flow sensor. Therefore we have fully completed our basic solution and have started on building out our advanced solution.

The user inputs:

- City
  - This input gets used for the weather data that we pull from the API.
- Diameter & Height
  - This is the diameter and height of the container attached in Litre. Based upon this the software can calculate the volume of the container.

- Toggle
  - Using this toggle, the user can choose between the calculated size or the user inputted size of the container.
- Volume
  - This is the input for when the user knows exactly how much volume the storage container has.

The water levels:

The three water levels show the percentage of water running through that part of the system. The percentages of the water in the container get calculated based upon the size of the container that gets inputted by the user. The percentages for the other two get based upon the input size of the container. If water comes in it gets added to the total volume, this is done by scaling the value coming from the Arduino according to the flow rate of the sensor in litres per second divided by our framerate (60 frames per second) so that we know exactly how much water is added per frame.

The graph:

The graph displays the trends in the three known volumes of water. They can be distinguished between by their distinct colour. Our program keeps track of the last one hundred days of usage and puts that data locally in a JSON file. This means that if our program crashes this data is still available from the file and the program will also read this file on start-up so that it seems like nothing ever happened. The data is stored in this way so that we can look at the data and look for trends in it. If there are more than one hundred and two days stored the oldest day will be deleted. The program stores this data ones a day.

The calculated amount of water:

The calculated amount of water is the average amount of water there was in the storage container over the last one hundred days. This divided by an average cup of 250 millilitres gives you the predicted number of cups you can take out of the system.

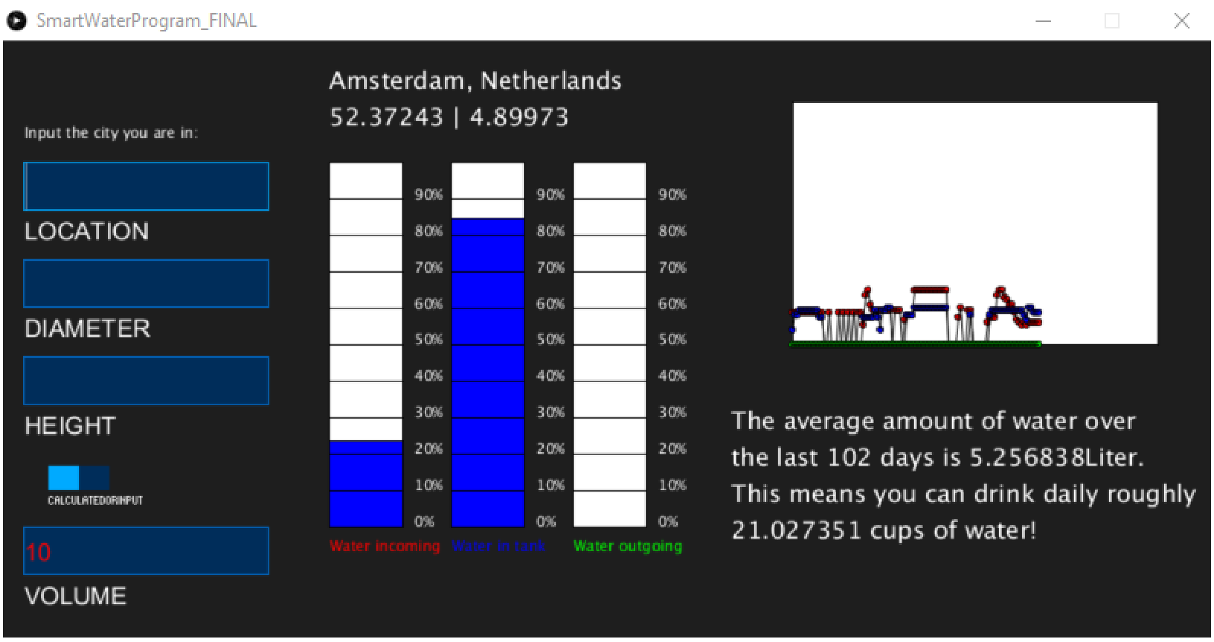


Figure 1: a screenshot of our program.

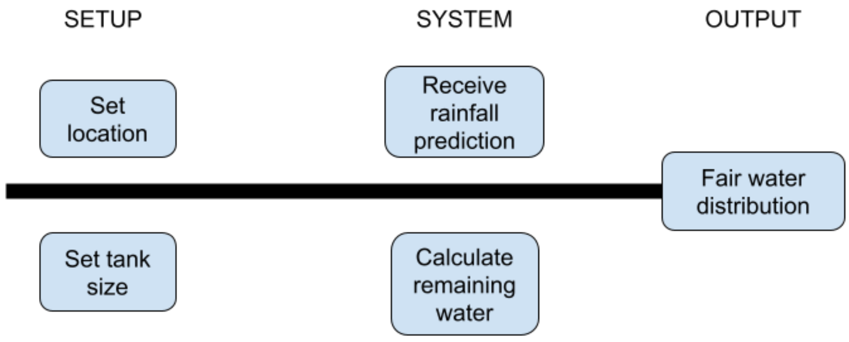


Figure 2: simple data flowchart

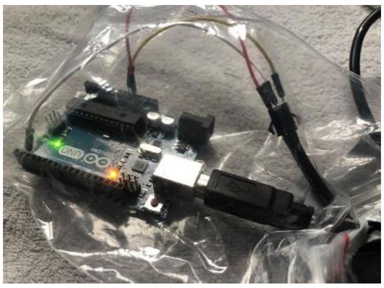
The location API:

Uses the given location data to find the exact location meant. When entering a city name the software will find the exact correct name, country and exact coordinates. Which can be used to request accurate weather data.

The software waits for a user to enter a city and hit enter. It then sends a HTML-get to positionstack.com API which returns a JSON with all relevant data. These are processed and displayed in proper manner. The program element also allows for expansions using different API's. For example, collecting weather data from outside sources almost always requires exact coordinates. Requiring these from the user can cause trouble because it can be hard to find these numbers without some special app or program.

The physical side

Here you see how the waterflow sensor is connected and how the water is supposed to flow through it. The water travels through the tubes and gets detected by the sensor. The sensor is easy to connect to the Arduino, with a cable to ground, 5V, and a digital pin. For safety there is a plastic bag around the Arduino, this protects it against spilling water.



When testing our device, we poured 200 mL into the tube, each time the waterflow sensor detected about 180 mL coming through. We tested the device five times and it detected 172, 181, 184,177, and 193 mL. It gives very consistent values, so that could be considered when calculating the values.

We couldn't figure out how to send the values from Arduino to processing, so right now it is unfortunately not possible to see the actual values in the processing program. With more time and manpower this can be solved though.

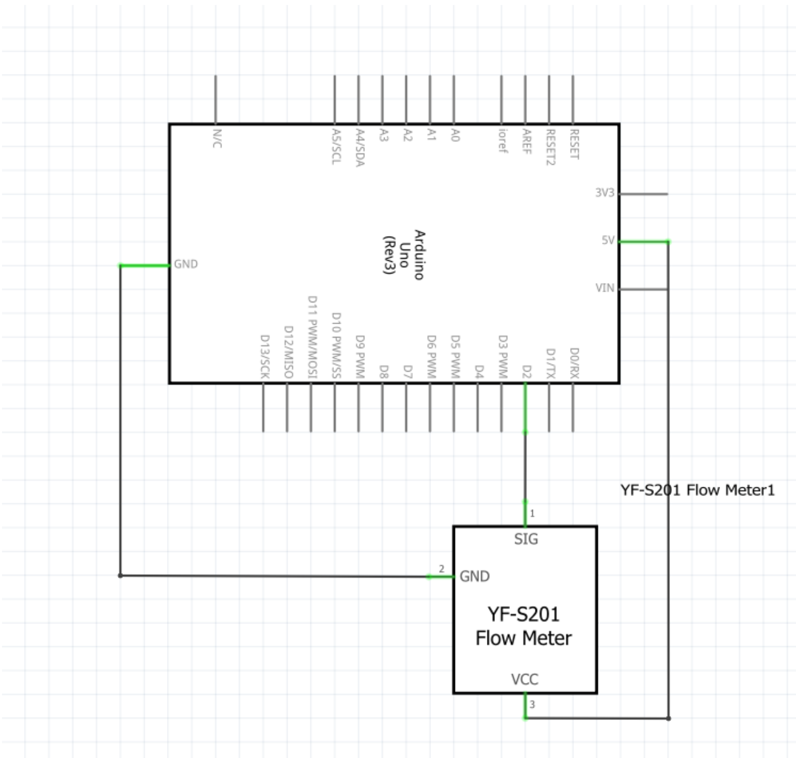


Figure 3: The diagram of how the sensor hooks up to the Arduino.

Conclusion

Our program helps solve the issue of unpredictability in water supply and gives an insight into the water flowing in and out of a storage tank. The original idea of the small device with minimal screen is not how it turned out due to corona and our small team, but all the other goals we set are met with this program.

Reflection

In the end, we are content with the smart environment we created, given these less-than-optimal circumstances. Due to the lockdown and some quarantine cases, we were not able to work on the physical environment together. This only made the communication between our team members more important as we were not able to physically feel and see our environment shape into the final product. We had some issues in the communication and did not always manage to provide each other with enough updates. After having addressed and discussed this, we decided to speak up to each other more and be more confident in giving people a push when they need it.

If we would have had more time, we would probably invest more thought and time in making the smart environment compact, making our parts work together better and allow for some extra features like GPS, and try different configurations of sensors. If we could allow the entire device to consist of only two water flow sensors and a hand size processor and display screen it would become much easier to handle and implement. Our software already supports this, so it is just writing the input class and hooking up the sensor.

Overall, we learned a lot about working together in a remote team like this and enjoyed seeing our work coming to life. We are proud of how we overcame the hindrances and put together a working smart environment.