UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

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Chapter 0: Introduction

This project for Smart Environments (module 2, B-CreaTe) is on the subject of disasters. We, Team EnviroGuard, are a creative group of seven students. This paper contains the results of our team`s brainstorm, progress and conclusion. The goal of this project is to use a variety of skills to design, program and create a smart product that targets a specific problem.

To find a problem regarding the general subject of disasters, the first step was to have a brainstorm, of which the results are documented in the following chapters. The selected problem for this project is water scarcity, which is the lack of (fresh) water resources. This problem has a lot of potential solutions that will work great with the smart environments module.

Water scarcity is a worldwide problem that causes draughts and lack of basic needs. Our team is very concerned with these prevailing circumstances, as water is the most essential nutrient for all human survival. It is not only necessary for strictly physical human needs, but also for the countless other ways we use water. Both humanity and nature use water for various purposes, and are ultimately dependent on it.

A smart solution to this problem is a smart sink. With this sink water usage from taps will be reduced because this product will show the user the total water consumption, and it is provided with multiple settings and options for you to use the ideal amount of water for every occasion.

The main motivation of our team is to make a great smart device that will help in the struggle against water scarcity and to create a more sustainable future. Furthermore, we believe this solution could really make a difference if implemented on a large scale and will be a nice example of how smart home technology can play a big role in reducing water waste.

Chapter 1: Literature Review

Natural Disasters[1]

The book is a compilation of studying every natural disaster in a scientific way. It is possible to find predictions and strategies to many of them, using different natural phenomenons and some physics formulas.

Epidemics after Natural Disasters[2]

This article talks about the chances of epidemics after disasters. In general this chance is quite low according to the article. With a displaced population that doesn't have good access to basic needs, communicable diseases are quite common. This is the reason why post disaster this should be looked into immediately. However, this article believes that people should not fear an epidemic after a disaster. There is post disaster surveillance that is quite fast at identifying risks, however, sometimes there is not enough background data or resources to identify diseases well enough.

Infectious diseases following natural disasters: prevention and control measures[3]

Natural disasters and infectious diseases outbreaks represent global challenges towards the achievement of the Millennium Development Goals. The article`s study described risk factors and potential infectious diseases following major natural disasters recorded from 2000 to 2011. Therefore it is important for the public, policy makers and health officials to understand the concepts that disasters do not transmit infectious diseases; the primary cause of death in the aftermath of a disaster is noninfectious.

Growing water scarcity in agriculture: future challenge to global water security[4]

It analyses water scarcity originating from both climatic phenomena and water partitioning disturbances on different scales: crop field, country level and the global circulation system. The implications by 2050 of water scarcity in terms of potential country-level water deficits for food self-reliance are analysed, and the compensating dependence on trade in virtual water for almost half the world population is noted.

CO2 Capture and Storage: Closing the Knowing-Doing Gap[5]
The capture of CO2 is getting more attention as it could help reduce the CO2 emissions from the fossil fuels industry. CO2 capture is very much possible but for it to be widespread implemented it still needs to be less costly to capture CO2 and store it, and the key players involved just don’t have economic incentives to start right now. This paper discusses CO2 capture and storage projects that have been initiated around the world.

Rationing of Resources: Ethical Issues in Disasters and Epidemic Situations | Prehospital and Disaster Medicine[6]

Disasters can need a lot of resources, but sometimes there are not enough. This paper provides a guide that clinicians can use when resources are scarce. It is important to make the best use of medical and human healthcare resources, during epidemics or disasters this can evolve ethical issues (beneficence and justice). The paper also covers some predictions of resources needed for certain disasters and comments on what would happen if there are not enough resources.

Pollution prevention at ports: clearing the air[7]

Seaports are one of the main reasons of environmental air pollution, especially near coastal areas. Many sources (such as marine vessels, trucks, locomotives) impact negatively on air quality with large emissions of diesel exhaust, particulate matter, and nitrogen oxides. This causes health effects over local people such as respiratory diseases (asthma), cardiovascular disease, lung cancer. A preventive approach would consist of reducing marine traffic, greener design of new terminals, emission control. Examples about restriction of port-related air pollution are use of low-sulfur diesel fuel; limitation of truck idling.

Powering Through the Storm: Microgrids Operation for More Efficient Disaster Recovery - IEEE Journals & Magazine [8]

Distributed energy resources, organized in a microgrid, were used to provide reliable electricity supply (via recovering and rebuilding efforts) in the appearance of disasters. Microgrid is a subset of an electric power system (EPS). It is available for higher power supply and is secure for critical loads, investment deferrals in transmission and centralized generation plants.

Minimizing The Effect Of Natural Disasters[9]

It is impossible to prevent an act of god from inflicting damage on railway infrastructure, but there are some appropriate measures: railways must always remain aware of conditions on and near their tracks, and must take appropriate steps whenever there is a risk of a disaster; we must increase the reliability of technologies used to predict natural disasters.

An Investigation on Multi-Buoy Inversion Method for Tsunami Warning System in South China Sea[10]

This paper is about an investigation using a multi-buoy method to provide a tsunami warning system, in this case in the south china sea. It turns out that the method works well and that in order to have it working correctly the waring system should deploy one or two buoys along the west side of the Manila trench.

The Next Global Depression Is Coming and Optimism Won't Slow It Down[11]

This article is about depression in this pandemic or covid-19 era. Many people lose their job, their payroll gets deducted, and many healthcare systems buckle under the strain. Many people worldwide couldn't get the vaccine and covid-19 tests because they have no money to pay for the test nor the vaccine. This problem often happens in developing countries. However, there could be many solutions to solve this problem. Word leaders could resist the urge to tell their people that brighter days are just around the corner since people need leaders to make tough decisions.

Volcano Warning Systems - John Seach[12]

Website contains information on volcanic activity and grants warning systems for Colombia, Vanuatu, Alaska, New Zealand, Russia and Indonesia. There are two main volcano warning systems - colour codes, and alert levels. The colour code warning system contains 4 levels, from level 1 to 4, where 1 indicates moderate risk of eruption, and 4 indicating very high risk of eruption. Warning systems are specific for each volcano. The website mentions impossibility on the prediction of dates of eruptions, as the warning systems are based on merely a probability of an eruption or hazard.

Coronavirus pandemic "a disaster" for gambling addicts[13]

In the UK, the impact of the coronavirus, namely freed-up money, sport cancellations and boredom could have caused an increased risk for people suffering from gambling addiction. Many betting shops and gambling sites are removing adverts from TV and radio. Campaigners want to see this extended to social media and direct marketing (billboards, etc). Due to the sports betting market being unavailable, addicted gamblers are moving to online gambling instances. The poorer mental health of people due to the pandemic may also cause an increase in gambling problems.

Tsunami Evacuation Drill System Using Smart Glasses[14]

Evacuation drills are used to reduce damage from natural disaster, but participants are not always committed to such drills. For this reason a game-based evacuation drill was proposed. The game-based evacuation drill got organised at several schools and resulted in the discovery that it can improve student motivation for disaster prevention.
In case of an earthquake, people in coastal areas must move very quickly to evacuation sites, therefore existing game-based evacuation drill methods cannot be used for tsunami evacuation drills, as it is not safe for participants to run while looking at a tablet or wearing a head mounted display. The use of smart glasses for game-based evacuation drills could solve this problem, as they are see-through and enable a user to view information and a tsunami

simulation while moving quickly.
The problems the smart glasses have are that the information displayed on the screen may be too small for some participants, a low accuracy of the tsunami simulation, and some participants may lose focus on their surroundings which makes it unsafe for them to move quickly.

Protecting the power grid from solar storms [News] - IEEE Journals & Magazine [15A]
Could Solar Storms Destroy Civilization? Solar Flares & Coronal Mass Ejections[15B]

Every so often the sun emits a big explosive burst of charged particles that makes its way to earth. Under the right conditions these bursts could destroy our power grids. For example, a geomagnetic storm in March 1989 blacked out the entire province of Quebec, leaving millions of people in the dark. Now this raises the question: Are we prepared for a repeat, or a storm 10 times worse, like the 1859 solar superstorm?

Active Disaster Response System for a Smart Building[16]

Paper describes the design and implementation of a proof of concept disaster response system, which can automatically perform tasks when a disaster or disaster warning occurs. Tasks include opening doors, windows, cutting off power lines or gas valves. Through the systems network, trapped victims for example, gain the possibility of sending messages to the outside world to let them know of the victims state. This system was developed to solve the issue of the inability of existing warning systems and their incompatibility with household appliances or embedded controllers.

SARS-CoV-2 Exposure and Infection Among Health Care[17]

One of the current disasters is COVID-19, this report talks about the increased risk for health care personnel in the workplace. A lot of statistics are shown about current data regarding this matter. The report wants to highlight the importance of wearing appropriate masks etc, especially in congregate living or long-term care settings, and the importance of interventions to prevent exposures for health care personnel. Sometimes these exposures have been wrongly classified as low-risk or no risk.

Natural Barriers to Natural Disasters[18]

A bioshield is the use of vegetation to protect against natural disasters such as tsunami and storm surges. After several coastal disasters the concept to use bioshields as natural barriers became more favoured. A report about the protective function of coastal vegetation that was published after the devastation of the Indian Ocean Tsunami of 26 December 2004, was followed by articles that used data to support the idea to use bioshields. Later work that used the same datasets argued that the correlation between area of coastal vegetation and tsunami damage was false and that the vegetation could only justify a small reduction in damage.

To draw a conclusion about the effect of coastal vegetation, there are multiple physical, socio-economic and other factors that must be removed.
Tsunami and storm surges are utterly different from waves, therefore you cannot assume that the science on the ability of vegetation to weaken waves supports the concept that vegetation can reduce damage from tsunami and storm surges.
Bioshields can also have a negative impact. One example of this is the flattening of sand dunes in India to make place for plantation, reducing the protectiveness of dunes against storms and destroying sea turtle nesting habitat. To avoid negative impacts, decisions about site selection and placing native species in appropriate locations are important. For these decisions the use of a decision tree is suggested for policy-makers.

Environmental Hazards[19]

This book "Environmental Hazards: assessing risk and reducing disaster" written by Keith Smith provides a lot of information about disasters. The nature of hazards are discussed, defining, measuring, explaining and managing disasters to assessing them (and commenting on the role of information technology) and reducing the impacts. In the second part multiple disasters are extinguished and their nature is discussed as well as protection, mitigation and adaptation.

Crisis Mapping During Natural Disasters via Text Analysis of Social Me[20]

The article describes a crisis mapping system that analyzes a textual content of disaster reports. The system produces accurate crisis maps by combining the information of damage detection and message location. It detects damage areas and gives the opportunity to prioritize rescue effort when it is most needed.

Energy management in seaports: A new role for port authorities. [21]

Paper makes a case for seaports to engage in more environment-aware energy use, analysing Hamburg and Genoa's seaports and showing their efforts on coordinating and rationalising their energy needs. Paper not only argues that the active management of energy usage in seaports can offer substantial efficiency gains, but also contribute to the development of new alternative revenue sources, in the end improving the competitive position of the seaport.

Chapter 2: Identification of General Problems and Challenges

Pan-/epidemics
- COVID-19
- Risk for Health Care Personnel

Natural disasters
- Big Solar storms
- Tsunami
- Earthquake
- Volcanoes

Consequential damages of (natural) disasters
- Damages on railways

Power Outages
- Malfunctioning (essential) machinery

Lack of resources because of disasters
- Lack of basic needs post disaster
- Ethical problems for distributing medical and human healthcare resources

Pollution
- Air pollution
- CO_2 capture and storage

Postdisaster symptoms (such as depression, addiction, and loneliness)
- Freshwater scarcity / overuse of water

Chapter 3: Identification of Relevant Problems (all links in bibliography)

Wildfires - Because of the climate changing rapidly, the area that gets damaged by wildfires increases every year. They are not only impacted by, but also impact climate change, because wildfires release carbon dioxide and other pollutants into the atmosphere, increasing global warming. Next to that, they permanently damage forest ecosystems in severe cases. Lastly, people and property need protection from fires. Especially smoke from wildfires can be a serious risk to public health.

Water scarcity - It is caused by climate change and is one of the reasons that leads to increasing droughts. Water scarcity has already a major impact over the world - availability to supply water for domestic needs, food and industrial uses. The main problem is how to ensure sustainable water resources management; how to increase water productivity. The purpose is to create long-term strategies for water and land uses. For example, in North Africa, Central and West Asia water availability is less than 1000 m^3/capita per year. This will lead to many agricultural problems.

Solar Storm Catastrophe - Solar storms can damage power grids, cell towers and communication networks. It works similarly to a human built electromagnetic pulse or EMP weapon that could temporarily wipe out the networks that connect and sustain us. The main problem is how to detect these solar storms so you can prepare and temporarily shut down power grids for example.

Mental health problems because of disaster - A lot of people experience trauma after a disaster, maybe because of the loss of a loved one or shock. Nowadays people experience mental problems during COVID-19, some people experience loneliness, stress or even depression. In these times it is necessary to bring attention to this and to support those people. Surveillance is also needed, not everyone knows they are experiencing these issues.

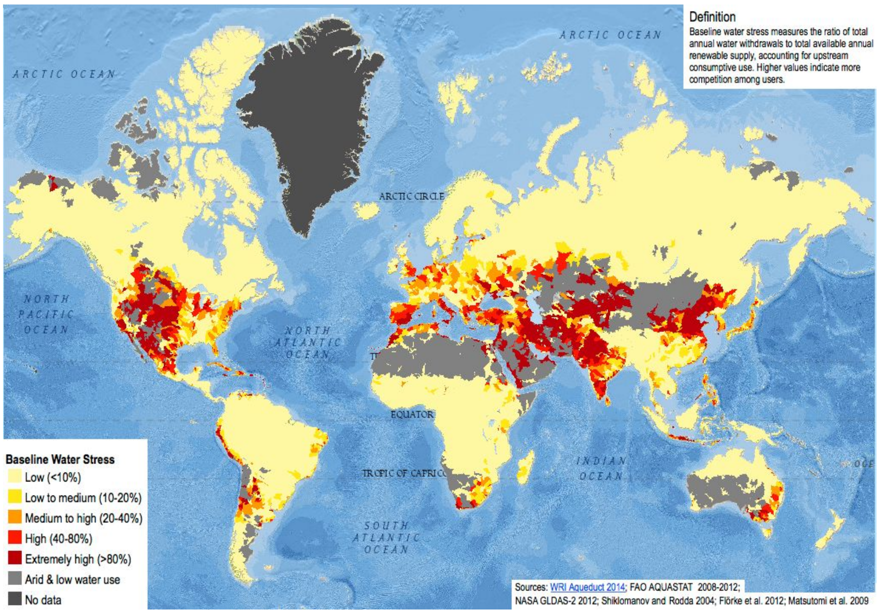
Hurricane - Over the years, hurricanes have been the main disaster that happens in the USA and many other countries. Many people suffer from the loss of a loved one and valuable belongings. People and scientists have and still develop ways to prevent people suffering from hurricanes. With the help of data storing and analyzing the climate would help a lot with the disaster. Such as, measuring the water pressure and wind speed.

Chapter 4: Problem Selection and Motivation

For this project we decided to tackle the water scarcity problem and our aim is to come up with a smart and innovative solution;

Water Scarcity

The growing population of the planet leads to a shortage of water resources in the world. Water scarcity means the lack of fresh water resources to meet the standard water demand. This problem was listed as one of the largest global risks in 2019.



A representation of water scarcity across the world. (source)

Half a billion people around the world face severe water scarcity problems all year round, with the locations of these scarcities being scattered around the world, mainly concentrating on the region slightly above the equator. The essence of the problem of water scarcity lies in the geographic mismatch between freshwater sources and demand, with climate change, the increasing world population, improving overall living standards and changing consumption patterns being large contributing factors as well. Water scarcity has negative ties to decreases in the size of freshwater sources, like lakes or rivers. As a quick example, the massive lake Chad in Africa has had its size reduced by 90% since the '60s.

Our team is very concerned with these prevailing circumstances. Water is the most essential nutrient for all human survival, not only for strictly physical human needs, but also in the countless other ways we use water. Humanity has used water for various purposes, and nature needs water too. For the further prosperity of our civilization, along with nature, it is necessary to solve all possible problems that threaten the extinction of life on Earth. This is why we have chosen to construct a project around the alleviation of this problem. We want, due to the severity of this problem and due to its urgency, to help and do our part in guarding the environment.

Chapter 5: Potential Solutions

There are a lot of aspects you can look at when talking about water scarcity. For example surveillance, awareness and smart products. In the following potential solutions we took one of these or a combination into account that will help contribute in reducing water scarcity. With our solutions the problem itself will not be fixed. However, we do believe that every bit counts.

Smart water app

The first idea is a smart water app. This app allows you to manage and view your water consumption. It is a smart home device/app that measures your water usage and provides this information back to you. It analyses the usage of your house, hotel, cafe or restaurant. Together with some general information you provide beforehand, for instance the amount of people living there or in case of a cafe the estimated guests per day, it will calculate an estimate. For the first time it will analyse the water usage and compare it to the estimate. This will show you where you lose the most water. The app also has a fun option to have daily, weekly, or monthly goals. If you achieve your goal you fill up a meter tracking your total water saved. In addition to this you can also set a limit to certain water supplies, for example when using this together with a smart bathroom.
The device could also be provided with a function to detect any leaks. With this leak function you can also notice if the tap is still on. After long amounts of time the app could give you a notification, or you can check before you leave the house.

In practice we would make an app using arduino and measure the water flow and volume. Using a water flow sensor we can build it with a few extra components and an arduino. This sensor works with the “hall-effect”. For this sensor we would also need parts of a pipe and the necessary tools. Next to this we would make an application to view the water statistics, we would also make a program that analyses the water flow and volume and provides the analysis to the app. It would be nice to have a program that will estimate water consumption according to the information filled in on the app, for this we would have to do a lot of research in water consumption. We should then also provide the app with goals, which could also be changed by the user theirselves.

Smart water trash

The second idea for preventing water scarcity is Smart Water Trash. The idea is to create a place where people can throw their water and therefore, it can be distilled and reused. For example, if you have a bottle of water and you do not want to drink the whole amount of water, on the next day you would refill this bottle with fresh water instead of drinking the old one. Having a Smart Water trash in this case would be a great idea because you can throw the water into this trash and instead of wasting it, you will save it and you will be able to reuse it. Moreover, there is another functionality that this water tank can provide - it keeps track of how much water is wasted and gives tips to the user how to use the water wisely in order to save it. In cases when the user has wasted a small amount of water, the water tank will give good examples for what the water is being used.

Leakage detection device

This idea contains a waterproof device that you can install in your home water system and that will monitor things like water pressure in different points in your home water system. This smart device is then connected to your device of choice to give you a notice/alarm when there is a leak somewhere. It will tell you where the leak is located and give suggestions on how to proceed further to fix this problem. (For instance giving the best prices for plumbers or diy guides.) This device will be simple and controlled with an arduino and also be in a waterproof housing, and comes with all the necessary instructions to install in your own home/hotel/business/school water system! Saving you costs on water and helping the water crisis! Slow or fast leak, the leakage detector 3000 will help you!

Smart Tap

This solution is a tap that saves a lot of water in many different ways. The first way to save water, being that the water that normally gets wasted when you wait for it to get warm (or cold), automatically gets circulated back to the boiler or a tank so that it can still be used. Another way to save water with this tap is that you can "tell" the tap exactly how much water you need. This way you avoid spilling or needing to pour out and waste the extra water. Next to telling the tap how much water you need, you can also tell the tap what you need the water for and it will adjust its nozzle to fit the use. For washing your hands or cleaning vegetables, for instance, you can save water by "spraying" water, instead of letting it flow. The tap also notices when it is left on or when it is dripping and will notify you of this. Finally, the tap keeps track of your water usage and gives advice on how to use less.

Cleaning

This idea is a smart purifier. It is a device that the consumer could buy physically and there will be an application for it. The device can be installed in people's houses or restaurants which will contain or collect dirty water from rain and from sea water. And when the application is run by the owner, the owner could choose which temperature they want the water to be. The application will show that after the first filtration is in action, whether the water is safe to drink or not. If it is drinkable, the application will notify that the water is clean and ready to use.

In practice we could make the device and the application using Arduino which we have to include a few extra sensors such as IR sensor and micro servo.

Distribution

The smart water distributor is a home appliance system which distributes water effectively, reusing wasted water and distributing hot and cold water where needed. Water left over from a tap or shower is stored in a small tank, where it goes through some simple pH testing and/or some simple filtering, and is then re-used in your home is spots where 100% clean water is not extremely necessary, such as inside central heating systems or toilet bowls. The hot water distribution is done by setting up an automatically filling tank close to your home's boiler, which can then instantly distribute hot water when needed in small doses (so the first few seconds of a shower that still has to warm up, or a faucet).

Evaporation prevention

The 7th solution is to produce more such things as shade balls, also known as bird balls. The shade balls are floating on the top plastic spheres that slow evaporation of liquid and prevent sunlight from chemical reactions among some components in water. The idea is to produce more shade balls and place them in many water reservoirs. It is possible also to make shade balls different forms, but the sphere is the best variant due to its comfort.

Chapter 6: Solution Selection

The solution we decided on together is actually a combination of two or three original solutions. We decided to make a **smart sink**. This product will be a combination of a smart tap, smart water app and leakage detector. You can save water with this smart tap by “telling” the tap exactly how much water you need. There will also be a monitor that will look at your water usage. This way you can manage and view your water consumption. In addition to this the smart sink will also be able to detect a leak of somesorts. It will analyse the water flow and tell you if the tap is still dripping or if there is a leak.

In an advanced version of our smart sink we would like to make an app that will show you your consumption and you will also be able to set goals. In addition the app could also give you tips after comparing your water usage and your home situation to an average. The app will send you notifications when there is a leak as well as provide suggestions on how to proceed with fixing any leaks. Our advanced version would have a touchscreen display or an app where you can view your water usage, leakage details and where you can select the amount of water you want from the tap or choose a function.

Our motivation behind choosing this solution is that we think it would really help with decreasing water scarcity. In our opinion this device will be doable for us to make, while still being a challenge. We combined the parts of the solutions from chapter 5 that we saw most potential in and made a new solution that we are very happy with.

Modular approach
1: Team leading
2: Coordination (within module group)
3: Programming
4: Design
5: Construction
6: Documentation
7: Demo Responsible
8: User interaction research

Bektur Musaev: team leading, documentation, design
Ties Poutsma: design coordination, design, construction (+preparation)
Yoalina Kalcheva: programming coordination, programming(sensor work), design
Michelle Gommers: documentation coordination, documentation, programming (main programme + app coordination)
Noah Busger op Vollenbroek: construction, design (+app design), demo responsible
Bima Ade Dharmaputra: programming (sensor work), construction, user interaction research
Ole Salet: construction coordination, construction, documentation

Chapter 7: Methodology

We will be making a smart sink with four buttons, a water consumption meter (and possibly graph) and a leakage detector. For our basic version we will use our laptop display and processing. In the advanced version we would make some type of app. We will be using a jerrycan to store the water, and a hose to transport it. The hose will be connected to three parts which we control with arduino: a water pump, water flow sensor and a solenoid valve. Using the pump we get the water from the jerrycan to the tap and using the solenoid valve we turn the tap on and off. The water flow sensor is used to calculate the water volume as well as to detect leakages. We will detect a leakage by monitoring the water flow and combining this information with the user's command. Using this technology the smart sink will also send a warning when the tap has been on for a long while.

There will be four buttons:

1. Washing your hands (the tap will turn on and off for you to easily wash your hands and you will also get time in between to get soap)
2. Filling a water bottle (by pressing this button you will get 0.5 L water in an instant, enough to fill your water bottle)
3. A toggle function to turn the water on and off, in case you want a different amount of water.
4. Giving the user the option to change the amount of water they want. The amount of water will be calculated using the time and the water flow sensor (by looking at the water flow and volume over time). The button itself is made out of a slider to get a value between 0 and 500 mL and a small button to activate this function.

Aside from the three buttons and the warings on the processing sketch, the display(laptop) will also show the total water consumption. The total usage as well as the daily usage will be shown. In our ambitious plan we would make an app that will show statistics about your water usage as well. This would mostly be comparing your household to the average households.

Now for the construction we are going to use a jerrycan(for testing purposes) with a simple PVC electric water pump that draws its water from the reservoir. The water will be guided through our tap, constructed out of PVC tubes, where we will have the water flow sensor installed. Also the tab will get a controllable solenoid valve to turn the water on and off using arduino and processing. The tap exerts its water in the sink where the extra water will be disposed of(for testing purposes we circulated the water back to the jerrycan). All electronics will get hidden in a double sink with cabinets casing and will be kept separate from all water.

A specific list of the components we use for our project:

- A sink (with cabinet space underneath)
- Jerrycan (water reservoir)
- Water bucket (for storing used water)
- Hose (⌀25mm)
- Hose clamps (6x) (⌀25mm -40mm)
- Laptop with processing, arduino, and android processing software
- An android phone (on which to open the app)
- Arduino uno rev3 + usb connector cable
- Water flow sensor (hall effect) (⌀23-25mm)
- Water pump (12V, 19W) (⌀23-25mm)
- Solenoid valve (6-12V, 4.8W) (⌀23-25mm)
- 12V power adaptor (24W)
- Breadboard
- Breadboard cables (+ cables with alligator clips)
- Transistors (to manage the 12V with arduino)
- Hot glue/duct tape (to organize and secure the inside)
- Resistors (for controlling the solenoid valve & working with 12 V)

Chapter 8: Results and Conclusion

Findings and conclusions

In a lot of households a big part of water waste is through a tap, by using this simple concept the water waste can be reduced significantly. For instance when washing your hands the first few seconds you wet your hands, then you use soap for ideally 20 seconds and then rinse it off. During the time you use soap, you don't use the water but most people do keep the tap on. This is one of the problems we solve with our smart sink.

It is quite surprising to see that there are very few sinks that have a similar concept. There are smart taps that use voice recognition for example to get a specific amount of water. But it does not have a simple function to wash your hands for instance. This example also has an app where you can customize water amounts, eg. coffeepot. Other similar ideas include smart mirrors and the usage of user emotions.

Our product uses an app to control the sink as well as to get notifications and view your total water consumption. We found that we had to in particular look at the following aspects in regard to making the user interface:

Color - We made sure our visual design matches our project. Our goal is to reduce water scarcity and we are working with a sink, therefore we chose to use blue as our primary color.
Anticipation - The principle here is that our interface is user friendly. Users will know all information and tools needed for them to use the device.
Autonomy - In a user interface it is important to let the userers to make their own decisions, which is something we tried to implement when making the buttons. It is also important to keep status information up to date, this is why we decided to have a pop-up which is influenced by the smart sink's status. For instance there will be a warning when a leakage is detected.
Efficiency - The principal here is user's productivity. Users mainly use a smartphone rather than a computer. We made an smartphone application to make things more efficient for the user.
Interface - One thing that is deemed to be very important is for a user to always stop/undo a certain action. Because we are using an android app, we decided to use the back button android has. This will stop the current action and the tap will turn off. This way the user can easily undo a button they mistakenly pressed.

Observations

During the testing we experienced quite some problems. And have only recently been able to add water to our circuit, but only to a certain extent. In the first part of the testing phase, while we were connecting the items to arduino, we tested it with air. For the testing of the display we used an LED which would represent the water flowing. This worked pretty well, but in the second phase it turned out our pump was not strong enough to create a water flow. After a lot of testing and research we managed to use it, but it only worked half of the time.

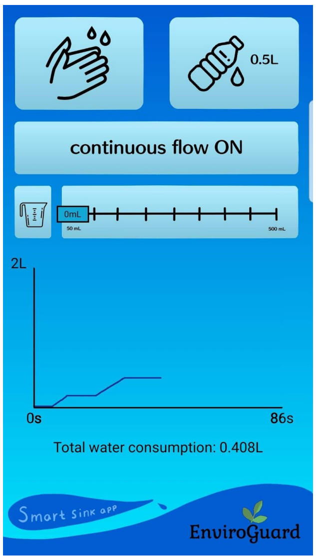
Our basic plan was fully completed and we even realised some of our ambitious plans. From our ambitious plan we managed to make an android application from which the tap is controlled. The option to set goals for saving water and to get tips about water saving is something we were not able to achieve however. In the app you can control the water flow, choose a set amount of water in mL and view your water usage. You can find your total water usage in a counter as well as a graph on the app. We chose an app instead of a display on the tap itself as we thought it would fit our solution better.

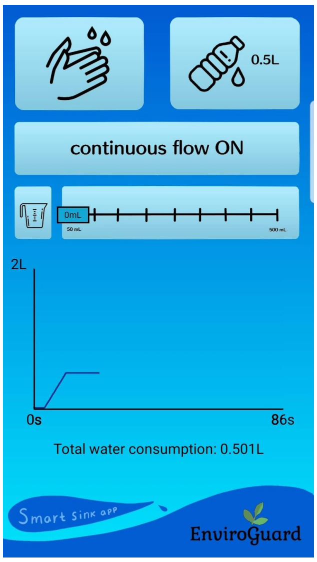
The android app was created using processing and works entirely through wifi. It is connected to a client application on the laptop which then communicates to arduino. In our first testing phases we used firmata to do this, later we tried to use our own arduino protocol to monitor the water flow sensor and control both the pump and solenoid valve but the pump would not turn on. In the end we used firmata and were quite successful in controlling both the pump and solenoid valve with the app. During the testing with water we calibrated the flow rate and added a delay for which the pump actually started pumping some water out of the tap.

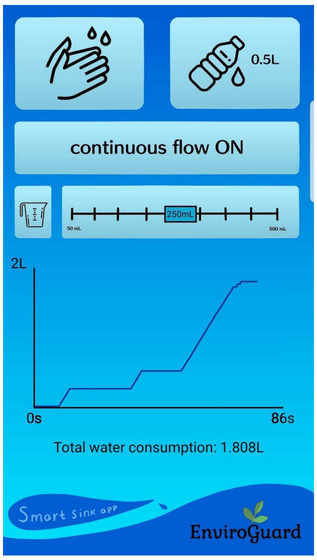
After testing the buttons and user interface in the android app we arranged/designed the buttons so that they are optimal and easy to use for the user. During testing we found that big buttons were necessary for ease of use and if your hand and fingers happen to be wet or dirty it needs a big contact space to register a button press. We took the principles about user interface as mentioned above into account for this. With these on our mind we tested multiple options and in the end came to an interface that works well on the inside (programming) as well as on the outside (user interaction).

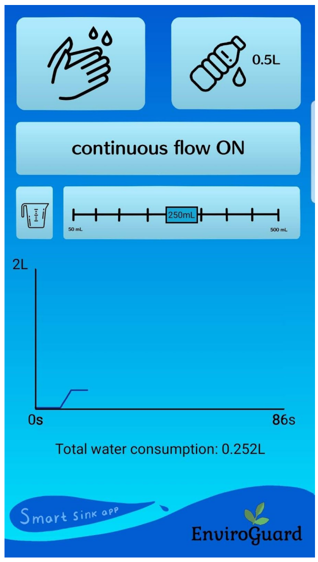
Sensory measurements

The sensors used for this project are a water flow sensor (based on hall effect), water pump, and a solenoid valve. These are connected to arduino and controlled through an android app. On this app there are four buttons of which the functions are:







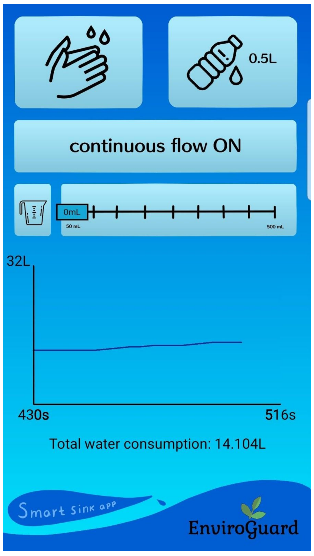


Button 1 - washing your hands(see P.1), the solenoid valve and pump are turned on for 5 seconds to allow the user to wet their hands, after which they have 10 seconds when they are turned off to get soap and scrub their hands, and lastly the tap will turn on again for 10 seconds to give the user enough time to rinse their hands. To compare the total water consumption of our sink and a normal sink we use the flow rate of 100 mL per second, this differs from the value in the picture above because due to an ill-working pump our flow rate was less than expected. Using our sink this would use 1500 mL, and for a normal sink the usage will be 2500 mL, which is almost double.

Button 2 - filling up a bottle(see P.2), this function makes use of the water flow sensor to measure the volume of water that has passed through the tap. Using this information we took into account the calibration and delay of the water flow stopping and beginning. The tap will turn off after dispensing the wanted amount, which is 0.5L (the volume of most water bottles). Total water consumption of our sink is 0.5 L, while using a regular sink this would be a little more due to inaccuracy or spillage.

Button 3 - toggling the tap on or off(see P.3), this will indefinitely turn the pump and valve on so you can use it as you please. If the tap has been on for a long time you will get a warning on the app reminding you of this. The total water consumption is similar to a normal sink and depends on the amount of time the tap is on.

Button 4 - getting a specific amount of water(see P.4), this button works similarly to button two, but this time you can select a specific amount through a slider on the app. You can select an amount between 0 and 500 mL in steps of 50 mL. The total water consumption of button 4 with our sink is the specific amount you ask for. When doing this with a normal sink the water usage would be more as humans are less accurate. However, for this button the user's ease is the biggest difference.



An extra element to the app is a total water consumption counter and a graph which shows the water usage of the user through time. For each of the four buttons the graph and counter can be seen. On the right is a picture where the app has been used for a longer while, the bigger the total water consumption is, the Y-axis will expand to make it fit better. In this example there was a total of 14 L of water used.

Problems

The main problem we encountered was the pump, as mentioned earlier. The pump worked some of the time and when it did the water flow was quite weak. We also experienced problems with using both the water flow sensor and the pump. The pump did not work when using serial communication between arduino and processing, whereas the water flow sensor did not work with firmata. It was quite strange, because while we were doing the exact same thing, the one time it did work and the other time the pump did not work. We believe this is because the pump was either broken, faulty or not good enough for this job. By testing the code with an LED we are sure the code should have worked for the pump, the wiring was also done precisely. For our prototype we used previously measured water flow data as well as delay times with our app to control the pump and valve accurately. We have managed to get the specific amounts of water you can select in the app. In addition to this we experienced quite some problems with delivery delays, which caused us to move up our construction days. There was also a small problem about the components not entirely fitting together, which we fixed by making our own waterproof connector pieces and using hose clamps to make it even more secure.

We also found out how hard it actually is to work in a group like this. It was very new for most of us and therefore did not go quite as smoothly as we had hoped. In the end most of our teamwork went well, but we could have been more efficient. In these times it is also quite hard to work together, because it is not really possible to physically meet up. To some extent where this was possible we made use of it, which was really nice.

Assumptions

Going into this big new project we had quite a few assumptions that were very wrong. After researching we made more achievable assumptions. Because of this we even managed to work on some of our ambitious plans. One of our assumptions was that our water system would be too powerful and that there would be way too much water pressure on our system parts. This was not the case at all, and we struggled with even getting good water pressure. We also had the assumption that the construction of our prototype would be pretty simple and straightforward, it turned out that, just like with programming, there is a lot of debugging and trial and error involved to make something work. Something which is not that bad, although frustrating, but it does take a lot of time which can be stressful.

We fortunately managed to do more of our ambitious plan than expected, we not only completed our basic plan but went beyond and created: an Android app, we actually obtained a real sink with cabinets underneath, an extra button where you yourself can choose the amount of water you want, and finally a water consumption graph for user feedback on water consumption.

Discussion

We believe that there is a big potential in smart sinks. It reduces water scarcity, as well as improving human interaction and ease. It is actually quite a simple but crucial concept with a lot of possibilities to grow. A nice add-on would be voice recognition and AI. This product with an app and simple interface can easily be deployed and implemented in a lot of houses and smart environments. This is something you would also like to see in smart or modern hotels and restaurants. It does not only reduce water scarcity but also adds a high tech touch to sinks as well as improved human interface and interaction with the sink.

When being used on a larger scale the product would be changed quite a bit. It will be altered to work with the water system of the house for both the water supply/drainage and leakage detection. Something else we would like to add on a larger scale are different temperatures. This was not possible with our prototype and would probably have been too advanced as well.

The app allows for endless possibilities to build upon for example analysing user data, comparing it to average households, adding more functions, brushing teeth, and providing tips. This increases the user's ease as well as making the smart sink more feasible for larger scales.

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