Smart Environments Project: Disasters

Myriad

Altea Vesta Junio
David Huybens
Max Haverkämper
Naomi Ruis
Nienke Timmermans
Yekaterina Michshenko

Chapter 0: Introduction

The Smart Environments Project is part of Module 2. The objective of this project is to build a prototype that follows the theme for this year: “Disasters”. Team Myriad consists of 7 members; Altea Vesta Junio, David Huybens, Jasper Witten, Max Haverkämper, Naomi Ruis, Nienke Timmermans & Yekaterina Michshenko. The theme “Disasters” encompasses all sorts of events that can occur; it can be both natural or man-made. We have collectively decided that the problem that we are addressing is water supply failure. It is an important issue as it addresses a basic necessity; water. The water supply system is key to making sure that everyone has access to clean water. Problems such as leakages would mean an inefficient system that is not beneficial for anyone.

Our prototype is heavily inspired by EchoShoreDX, which is a water leakage detection system that uses sound waves to detect where the leakage is coming from. It will feature microphones that will pick up the sound made by the water leakage. The data that is collected will be stored via arduino and can then be directly analysed. We like that it's possible to immediately notice when there is a leakage inside the pipe. The project includes sensing, sound recognition, data collection and analysis which makes it very dynamic. For this we use smart tech and certain elements of processing and Arduino we want to experience with. Everyone on our team likes the variety in this solution. In addition to that, we can use our existing knowledge we gained in programming and sounds and circuits to work this sensor based project together.

Chapter 1: Literature Review

Definitions

Landslides and Mudslides

Landslides or mudflows are bodies of earth saturated with water, that way it isn’t stable anymore and can start to move (CDC, 2018). This has an increased chance when there’s little to no vegetation on the piece of land for example after a wildfire. They usually occur in or after an intense storm and rainfall (CDC, 2018).

Floods

A flood consists of a lot of water covering for example streets, the severity of floods can differ a lot. Floods are the most common weather disaster (Earth Networks, 2020). First we have river floods, this occurs with heavy rainfall and/or snowmelt. These happen slowly or very quickly and are most common in rivers that are dry in the summer (Earth Networks, 2020).

Second we have coastal floods, these happen when it storms at sea or with unusual high tides. When a coastal flood occurs rapidly it is also called a storm surge, these can be really dangerous. Because it happens so quickly, there is little to no time to prepare. Many people die from storm surges (Earth Networks, 2020).

Third we have inland flooding or urban flooding, these happen in non-coastal areas. They are most commonly caused by heavy rainfall and snowmelt, but sometimes also because of debris dams. These floods are often bad, because the water has nowhere to go (Earth Networks, 2020).

Lastly we have flash floods, these are also really deadly. This is an inland flooding that happens really fast, within 3 - 6 hours of extreme heavy rainfall. They can also happen when a dam breaks. Flash floods are the number one cause of deaths by weather disasters. They destroy everything in their path, they rip trees from the ground, carry boulders and can even carry small houses. Also because it's so fast, there's no time to prepare (Earth Networks, 2020).

Wildfires

Forest fires occur randomly when it's warm and dry and can be started with a lightning strike or a spark from a human, it has been doing so for millions of years (National Geographic Society, 2019). A forest fire can occur on the ground, which is called a surface fire, or on the top of trees and bushes, which is called a crown fire (National Geographic Society, 2019). Wildfires can be dangerous for humans, one wildfire even destroyed almost a whole town, killing 86 people. But wildfires are also good for nature, it destroys diseases, destroys an abundance of insects and opens up sunlight for new plants to grow. Although with the global warming event we have, it unfortunately isn't (National Geographic Society, 2019).

Disaster Examples

Flint Water Crisis

The Flint Water Crisis first began in 2014 (CNN, 2016). The problem arose when the officials switched the water source for the residents and used the polluted water from the Clint River (CNN, 2016). This caused serious health problems for residents as it was found that the water contained unusually high levels of lead (CNN, 2016). The local authorities also were not helpful in disseminating useful information to residents (CNN, 2016).

Heavy Rainfall

On the 5th of July 2018 heavy rainfall created a disaster in south Japan. The rain created floods and landslides.On the 8th of July 92 people were missing and there were 48 death victims (Kageyama, 2018). In one area in Kochi the rainfall was 26.3 cm in 3 hours. Even cars were washed away by the floods the rain created. This is the highest value determined since records started back in 1976 (Kageyama, 2018). More than 910.000 people had to leave their homes back then because of this disaster (Kageyama, 2018).

Virus Ebola

For over two years the outbreak of ebola in the Democratic Republic of the Congo has existed already (World Health Organisation, n.d.). 2299 people died because of the virus and 1162 people survived Ebola. Because of the good work from affected communities, the virus did not spread in way more areas. 16000 local frontline helpers in addition with 1500 people from the WHO work there to fight the virus (World Health Organisation, n.d.). Preparation in neighbouring countries should limit the risk of a bigger outbreak of Ebola (World Health Organisation, n.d.).

Typhoon Vamco

A typhoon killed 42 people in Manila in the Philippines on the 13th of November 2020 (Gomez & Favila, 2020). More than tens of thousands people have been rescued and 20 people have been missed. With the speed of 255 kph the Typhoon Vamco wasted the region. In the capital region floods reach several cities where the water rises up to the second and third floor (Gomez & Favila, 2020).
Nearly a half million people could be evacuated before the typhoon arrived.
The Philippines has a high potential risk of disaster because of active seismic volcanoes and about 20 typhoons every year (Gomez & Favila, 2020).

Monsoon floods

Monsoon rains have triggered major floods in a number of countries across Asia, contributing to dam failures, rivers spilling their banks, landslides, and mudslides (Pradhan, 2020). Monsoon season happens every year in some areas of the world. It has been raining in Bangladesh, China, India, Japan, Nepal, Turkey, Vietnam, Pakistan, and South Korea. Flash flooding, lightning, dust, and strong winds may be observed during this season. For example, in Thailand, the flood-hit as many as four feet in some of the neighborhoods on August 14, 2020 (Pradhan, 2020). Overflowing rivers caused by monsoon rains have swamped buildings and flooded farm fields in eastern Thailand.

There was a storm of the third category in the northern part. Health and psychological counseling are crucial. If after any tragedy, these problems are still critical, the added stress of relocation during COVID-19 is troublesome (Pradhan, 2020). Additionally, after an evacuation, underlying medical issues must expect to be held. There is a strong necessity for water, sanitation, and hygiene. Efficient weather forecasting systems are to be established by the Government for prompt intimation and evacuation of flood-prone areas, which would significantly help to control many other damages caused by floods (Pradhan, 2020).

Puerto Rico Earthquakes

There have been 2,455 earthquakes in southern Puerto Rico since December 22. The original loss estimate is $3.1 billion (USGS, 2020). More than 600 buildings were destroyed after the earthquake of 7 January, including apartments, churches as well as other buildings. Several thousand people have taken shelter in emergency centers and in the city. A big amount of people were affected by the earthquakes (USGS, 2020). One person was killed on January 7 during the quake, some people were just injured. Two humans died of heart attacks. The January 7 quake has altered the hydrological characteristics of the region, showing changes in cubic feet per second flow (USGS, 2020). The hot springs of Coamo, situated more than 43.5 miles from the earthquake spot, have seen both the temperature of the water and the strength of the water rise after January's earthquake (USGS, 2020). The Director of Emergency Management in Puerto Rico and two other officials were dismissed by the governor after local residents discovered a warehouse full of emergency equipment, intended to evacuate Hurricane Maria, which had not been delivered as part of the storm relief. Supplies included infant bottles, clothes, water, and other supplies (USGS, 2020).

Russian Arctic oil spill pollutes big lake

On the 29th of May, 2020 a significant portion of diesel spilled into a vast lake near Norilsk in Northern Russia (BBC News, 2020). Approximately 21,000 tonnes of oil spread across 12 miles via the water stream causing one of the worst ecological catastrophes in the modern history of the planet. Scientists believe that the oil storage tank started to leak because of melting permafrost so it weakened the tank and spilled through the whole water area of Norilsk. The Whole Greenpeace group compared this disaster to the 1989 Exxon Valdez in Alaska (BBC News, 2020).
The Norilsk Nickel co. that is responsible for the events occurred in Norilsk, Russia was held accountable and paid fines totaling 146 000 000 dollars. The whole Norilsk ecosystem and contracted the coincidences of the pollution where they still could (BBC News, 2020).

Disaster Response

Disaster Response Using Robots

Robots are utilised to aid rescuers when responding to natural disasters (NBC News, 2018). They are used to scope out the surroundings and locate survivors which is useful for planning a rescue mission (NBC News, 2018). They are beneficial as they ease the workload and are effective in helping to rescue more individuals (NBC News, 2018). It is versatile and can be used for numerous situations such as earthquakes and floods as they can come in different sizes (NBC News, 2018).

Local responses to disasters: recent lessons from zero-order responders

This publication discusses the need of zero-order responders, the first ones at the scene of the disaster, and the way they can help in the disaster response and risk reduction (Briones, Vachon & Glantz, 2018). They make use of two examples of two extreme weather examples (El Niño Costero (Peru), and the Hurricanes Maria and Irma (Puerto Rico)) to emphasize the urgency to increase communication and resources to predict and respond to the event (Briones, Vachon & Glantz, 2018).

Operations research in disaster preparedness and response: The public health perspective

This publication is about the use of operations research in decision making processes (Stilianakis & Consoli, 2013). The operations research is an area where methods of computer sciences, mathematics and economics are used in these processes for disaster preparedness and response (Stilianakis & Consoli, 2013). They make use of examples of natural disasters (Meteorological, hydrological, climatological, geophysical and biological) (Stilianakis & Consoli, 2013). Several modelling methods, such as analyses, various models and techniques, used in disaster response can help public health decision makers on acting on these issues when having to deal with these natural disasters (Stilianakis & Consoli, 2013).

Area-Optimized UAV Swarm Network for Search and Rescue Operations

This Paper is about the use of large amounts of drones for search and rescue operations, controlled by a neural network (Ruetten, Regis, Feil-Seifer & Sengupta, 2020). All the UAVs are used in a mesh network, to maintain connectivity over large distances (Ruetten, Regis, Feil-Seifer & Sengupta, 2020). Also, no prior mapping of the area is needed; the drones connected to the neural network will make their own flight path and stay clear of their neighbors (Ruetten, Regis, Feil-Seifer & Sengupta, 2020).

The Drones can be used to search large areas after natural disasters or in the case of a missing person (Ruetten, Regis, Feil-Seifer & Sengupta, 2020).

Disaster Risk Assessment

Guidelines for assessment in emergencies

The “Guidelines for assessment in emergencies” are used by the members of The International Federation of Red Cross and Red Crescent Societies and are meant to provide a framework for assessing a situation (IFRC, 2008). The assessment is based on the evaluations made during a field visit to the area. Before a field visit is made, the region is categorized into 3 different priority levels (IFRC, 2008). Priority 1: area/population is directly affected, priority 2: area/population is indirectly affected and priority 3: area/population unaffected or minimally affected (IFRC, 2008). It is made to identify the problem and to gain an insight of its source and consequences (IFRC, 2008).

Guidelines for Assessing the Human Impact of Disasters

The assessments made by using the “Guidelines for Assessing the Human Impact of Disasters” are meant to gain an understanding of the consequences of a disaster on a community (UNDP, 2019). The findings are then used during the short- and long term recovery (UNDP, 2019). It uses five main indicators to measure the impact of a disaster: living conditions, health and education; livelihood; food security; gender equality and social inclusion (UNDP, 2019). The main goal is to prevent poverty (UNDP, 2019).

Assessing Damage after Disasters

This toolkit asks two questions to analyze the consequences of a disaster: ‘what has happened?’ and ‘what needs to be done?’ (Rawal & Prajapat, 2007). The first focuses on quickly understanding damage and the immediate needs and the second is to help carry out long term recovery (Rawal & Prajapat, 2007).

The Challenges of Tsunami Disaster Response Planning and Management

The Indian Ocean tsunami in 2004 was one of the worst natural disasters and made people realise that an improved disaster management and prevention was needed (Tolentino Jr., 2007). Priorities for this tsunami management include community capacity building, action plans (for example, where people should go for protection), warning systems that also cover other natural disasters and developed preparedness (Tolentino Jr., 2007). With current realities and past evidence a more effective management should be developed to prevent, or at least reduce, many deaths and mass destruction (Tolentino Jr., 2007).

Food Security Risk Assessment

Food Security is an issue that every country faces to a certain extent. It is a complex problem as it is dependent on numerous factors such as inadequate educational levels and the progression of economic progress (Smith & Meade, 2019). To measure the level of food insecurity, The United Nations Food and Agriculture Association (FAO) created a system; the Food Insecurity Experience Scale (FIES) (Smith & Meade, 2019). The FIES has 8 questions that test certain experiences and resources and is given to a group of 150 people coming from over 150 countries (Smith & Meade, 2019). The FAO uses the data collected and compares the gravity of each country's food security based on their FIES Global Standard Scale; FAO developed 2 scales; Moderate Food Insecurity and Severe Food Insecurity and modifies it based on the country so that it is comparable on a global scale (Smith & Meade, 2019). The utilisation of FIES has helped narrow down the factors that are most likely to contribute to Food Insecurity (Smith & Meade, 2019).

Flash droughts present a new challenge for subseasonal-to-seasonal prediction

Flash droughts are droughts that arise in a matter of weeks or months, when the evaporation is much larger than the soil moisture can restock (Nature Climate Change, 2020). Resulting in the destruction of crops and possibly leading to food shortages if central farming areas get hit (Nature Climate Change, 2020). The detection of these droughts are rather difficult. This publication tries to give perspective to the hidden dangers of arising droughts (Nature Climate Change, 2020). Also, they try to reflect on the existing early warning systems and the improvement needed for detecting flash droughts even better (Nature Climate Change, 2020).

Solar Storm Threat Analysis

The following article analyses the dangers of solar storms and describes the effects on: power plants and the power network, the transportation sector, Oil and Gas Pipelines, Long Distance Communication Lines, humans and our planet (Marusek, 2007).
Most solar storms only have minor effects on Earth; power and communication outages, the loss of a few satellites and a beautiful "Aurora borealis" in the night sky, but as the intensity of these storms increases, the effects will be far worse than stated above (Marusek, 2007). Leading to the loss of our satellite network, power network and even increasing the change of cardiac arrests by 4 times (Marusek, 2007).

Chapter 2: Identification of General Problems and Challenges

Problems Arising from disasters and challenges of the aftermath

1. Food shortages caused by crop destruction.
   There are many possible ways in which crop destruction can occur, crops can be destroyed by wildfires, droughts, heavy rainfall, earthquakes, mudslides and floods. The ecosystem is a sensitive system easily disrupted with major consequences for the dependent people. If the food supply is depleted, starvation is imminent.
2. Loss of telecommunication caused by damage to the network.
   The telecommunication network is mostly made up of ground cables, easily destroyed by earthquakes, floods and solar flares. The loss of internet connection can have serious consequences for the stability of society. People won't have access to digitized money, and therefore no access to food.
3. Power outages caused by damage to the network.
   The power network is indispensable for modern society, people rely on it for heating, refrigeration, transportation, powering equipment and lighting. This can severely destabilize civilization, and have major consequences for functioning of daily life.
4. Public unrest/destabilized governments.
   Governments are the ruling bodies of a country and set up policies for everyone to adhere to. When governments are disrupted because of certain factors, public unrest follows as there is no one to enforce the rules. This can lead the country to worsening conditions such as economic instability, increased dangers for residents and much more.
5. Medical facilities overloaded or even destroyed.
   If too many people need medical care at once, a facility can overload; this means they can’t handle the amount of people coming in. If this happens some people can’t get treated, they also can’t get treated if the facility is destroyed by a disaster.
6. Fuel/gas shortages, causing lack of transportation and heat sources.
   If you don’t have fuel anymore you can’t transport medical supplies or food. Heating of houses or cooking is also not possible without gas.
7. Damage to the infrastructure, causing transportation problems.
   Proper working infrastructure is one of the most important factors of good transportation. If this is damaged or completely destroyed, the possible lack of food and medical supplies can have tremendous effects in the aftermath of a

disaster. Resulting in even more casualties due to starvation and lack of healthcare.

8. Water shortages or contamination, causing health issues.
   Contaminated water is related to the transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid and polio. Absence of water can cause trachoma, conjunctivitis and other serious diseases like skin infection.
9. People go missing or getting trapped.
   In means of earthquakes, tornados or other natural disasters that can cause houses or buildings to collapse, people can get trapped or go missing because of the rubble from the collapsed buildings.
10. Excessive rainfall is a serious crop problem.
    Excessive rainfall can cause direct damage to crops, as well as oxygen deficiency and restricted growth. This all results in either less crop growth or no crop growth at all, which will result in a food shortage.

Chapter 3: Identification of Relevant Problems

Floods

Floods create big problems in many regions in the world.
The first negative impact of floods is that they can hit agricultural cultivation very hard. A flood can damage big areas where food is grown up. So, for example, a whole season of harvest can be destroyed from one flood. Because of that, farmers won't get harvest and can have an economic disaster.
In addition to that it is a big problem in areas where there isn't enough food. So if a flood destroys many agricultural crops from an area, it is possible that many people will starve in these regions.

The second impact of floods can be that they can damage the infrastructure, buildings, cars and a lot of other things. When that is the case they often flood through the city. Because of this, it may happen that people get hurt or even die because of the floods.

The big problem with floods is that they cannot be prevented or controlled. They have much power and it is not possible to stop them. In addition to that, they have different triggers that cannot be controlled by humans. For example, Floods can be triggered by heavy rainfall and preventive measures are put in place however those measures are limited and cannot fully control the impact that a flood can have.

Water Supply Infrastructure (Pipes)

There are several methods in which pipes can be damaged. One of these reasons is the occurrence of natural disasters. Earthquakes, tornadoes and heavy rainfall can heavily damage pipes due to their immense strength. Weather is also a key factor to water pipe damage. Cold/freezing weather is more likely to result in pressure build-up in the pipes eventually causing it to burst. Corrosion is also a likely cause for damage done to the pipe (Schuelke Plumbing, n.d.).

Destruction of Communication Networks/Devices

Communication networks are very important in our everyday lives, but also when unusual events might occur. An example of events where communication is seriously vital are disasters. Various disasters, like tornadoes, earthquakes or floods, can do a lot of damage to these communication networks (Menon, Pathrose, and Priya, 2016).

The communication between rescue workers and the victims during disaster recovery needs to be efficient to have the least possible damage to life and properties and to be able to help injured people immediately. Rescue officers need to be able to get to different locations within the area of destruction to take care of injured people, find more survivors of the disaster and minimize the damage. Reliable communication during reconstruction after the disaster happened is also of great importance. Any delay in time because of communication failure can be lethal for unrecovered survivors or can cause too much damage to, for example, infrastructure or houses (Menon, Pathrose, and Priya, 2016).

Food Insecurity

Food insecurity is an issue that is multifaceted. It can be affected by various factors such as crop failure, natural disasters or human factors, such as their socio-economic status. There is a perception that it is a problem that only relates to developing countries, however, as mentioned before, food insecurity stems from different factors. As such, it is not solely dependent on a country's economic situation. Food insecurity does not automatically mean a shortage of food supply. The uneven distribution of food can also be considered as food insecurity and this particular problem can be traced back to economic and social factors that restrict groups of people from having access to food.

Water Quality

The quality of the water is very important to the survival of humanity. It is a fragile system that needs to be handled with care. There are several issues that can affect water quality, such as: water borne bacterial diseases, heavy metals and oil spillages. All of the cases mentioned above will have severe consequences for the well-being and health of the population.

Heavy metals such as arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc and selenium can cause a multitude of health complications such as gastrointestinal (GI) disorders, diarrhoea, stomatitis, tremor, hemoglobinuria causing a rust–red colour to stool, ataxia, paralysis, vomiting and convulsion, depression and pneumonia (Duruibe, Ogwuegbu, Egwerugwu, 2007).

Water borne bacteria can also result in Vibrio cholerae that results in Cholera. Vibrio parahaemolyticus is the cause of Gastroenteritis (Cabral, 2010). Salmonella enterica will cause Typhoid fever and other serious salmonellosis (Cabral, 2010). Shigella is the cause of Bacillary dysentery or shigellosis and Escherichia coli is the most common cause of Acute diarrheas and gastroenteritis (Cabral, 2010).

Oil spillage also has a major effect on human health, it has short and long term effects. The short term effects are: memory loss, dizziness and irritability, headache, nausea and vomiting, chest pain, coughing and lung problems, fatigue, skin injuries, rash, and blisters and eye sores (Oil Spill Pollution Diseases, n.d.). It also has some psychological effects. The major long term effects of being exposed to crude oil are: Melanoma (a form of skin cancer), lung cancer, Hepatitis B/C and Leukemia (Ordinioha & Brisibe, 2013).

Therefore, access to a clean water source is vital for human survival as having a contaminated water source brings many problems. Having no water source can also be a great problem as dehydration is also a common cause of death during disasters.

Chapter 4: Problem Selection and Motivation

Failure of Water Supply Infrastructure (Pipes)

Motivation

Water Supply Infrastructure is an important feature for today's society. It is an efficient and safe process that delivers our most basic necessity: water. When it is destroyed or disrupted, it causes a lot of problems for a lot of different stakeholders. Its failure to function means that water cannot be delivered to residents and the condition in which the water is delivered is also important for everyone's collective well-being. This issue needs to be addressed as we feel that we need to be able to have uninterrupted access to water in a structured and well-planned manner. There are many factors that can cause water pipes to be damaged, so we thought that finding a solution that can be reactive would be fitting for our problem.

Chapter 5: Potential Solutions

Multilayered Pipe

The Multilayered pipe: a pipe consisting of 3 layers. The outer layer will be a silicon tube, that is flexible enough to withstand blunt force damage and won't rupture in any disastrous scenario. It will also keep the water inside the pipe when the main inner pipe breaks.

The second layer will be a CC (concrete cloth) layer. CC is a moldable material that hardens when it comes into contact with water. When the inner pipe breaks and the water starts leaking out, it will solidify the CC layer and mend the pipe in the broken area (Jun et al., 2020).

The third layer will be a regular pipe used as the main water transport pipe. This can be a stainless steel, copper or plastic pipe.

Smart Water Detector

The Smart Water Detector detects the presence of water in places where it should not be, records atmospheric temperatures and can alert you of freezing conditions that could lead to a burst of water pipe. It can also measure ambient humidity and warns when the air is so moist that it could contribute to mold development (Brown, 2019).

Other measuring techniques could require using other types of sensors. The estimated burst location and increasing pressure rate in the network can be measured by using sensors to measure pressures at different locations on a pipe (Bakker et al, 2004).

A water flow sensor can detect the rates changing and can send alerts about leakages. This data can be regularly collected, which gives people the necessities for control, monitoring and analysis of water systems, to prevent pipes from bursting as much as possible (Senseware, n.d.).

All this data from the sensors and the Smart Water Detector can be connected to a control system which will instantly turn off your water supply in an incident (Michael Brown, 2019).

Cured-in-Place Pipe

CIPP or Cured-In-Place Pipes is a process that involves plastic liner tubes that are embedded with resin and other materials. It is inserted into the pipe through a machine and air pressure is then used to make it expand and take on the form of the original pipe (Lloyd, 2019). It then goes through a process called “curing” which uses steam/hot water to harden the material. It is a possible solution as CIPP does not require any type of digging in order to fix the pipes (Lloyd, 2019).

MIT Water Robot

The MIT development uses a small, rubbery robotic device that looks something like an oversized badminton birdie. During operation, it is inserted into the water supply system through a fire hydrant. In the pipe itself, the robot moves with the flow of water, registering its movement. It detects even the smallest pressure changes with its rubber "skirt", which expands over the entire pipe diameter (Chandler, 2017). The device is then retrieved through another hydrant and the data collected by it is downloaded to a computer for analysis. Thus, there is no need to interrupt the water supply and dig up the pipe to find the accident site. So, it is an inexpensive robotic device that can find even tiny leak pipes with pinpoint precision, no matter what the pipes are made of (Chandler, 2017).

EchoShore-DX

The EchoShore-DX is a sensor that can detect the sound of water leaking because when water is leaking from a pressurized pipe, it makes a sound. This sensor can be placed in a fire hydrant and detect even the slightest noise inside a pipe. When an abnormal sound is detected, a signal is sent to a central hub of sensors. When a leak is discovered by one sensor, the hub asks the surrounding sensors for data as well to pinpoint the exact location of the leak (Echologics, 2020). That data is sent to the officials letting them know where to repair the pipe. The soundwaves the hub picks up are always being broadcasted to a big monitoring hub where abnormalities can be spotted. By putting it into the cap of a fire hydrant, the sensor is protected from salt, silt and dirt accumulation. This device could be modified to also be used on smaller pipes by putting them somewhere else in the pipe, although the sensor could be more vulnerable. It uses batteries so an occasional check up to see if the sensor is functional is required (Echologics, 2020).

BCG Sealant

Liquid German BCG sealant is added to the water pipe, pressure is applied, the sealant protrudes from the crack to the outside, interacting with carbon dioxide from the outside air, forming crystals that close the holes and eliminate the water pipe leak. It's like a cast on a fracture. And visually it looks like a stone build-up that will withstand temperature and pressure (BCG, n.d.).

Usage: First the water is pumped out of the pipe. Then the BCG is pumped into the pipe under pressure. Then the pipe is rinsed with water and the pipe can be used again. When the agent reaches a hole and comes into contact with oxygen it seals the pipe. According to the manufacturer it is permanent and resistant to ageing (Soldanshop24, 2013).

The problem is that the BCG agent has to be rinsed through the whole pipe and therefore a lot of liquid has to be used because it has to be under pressure.

At the correct place the inserted pipe is then inflated by air at the beginning and end parts. Since only the begin- and end-part are inflated, the space between the two "discs" is free and can be flushed with the BCG. In this area, BCG is applied and later the pipe is flushed. The two disks are connected in the middle with struts made of a hard material that keeps the pipe stable.

The construction of the pipe has a connection for a hose at the end and the beginning. With the help of this hose, the BCG and then the water can be pumped under pressure through the affected area.

There are a total of three hoses leading to the support pipe. One that pumps liquid in, one that pumps liquid out again and one with air that pumps up the air bumps.

With this solution a lot of water and BCG can be saved, because there is no need to build up pressure in the whole tube, but only in a certain area that can be determined in advance.

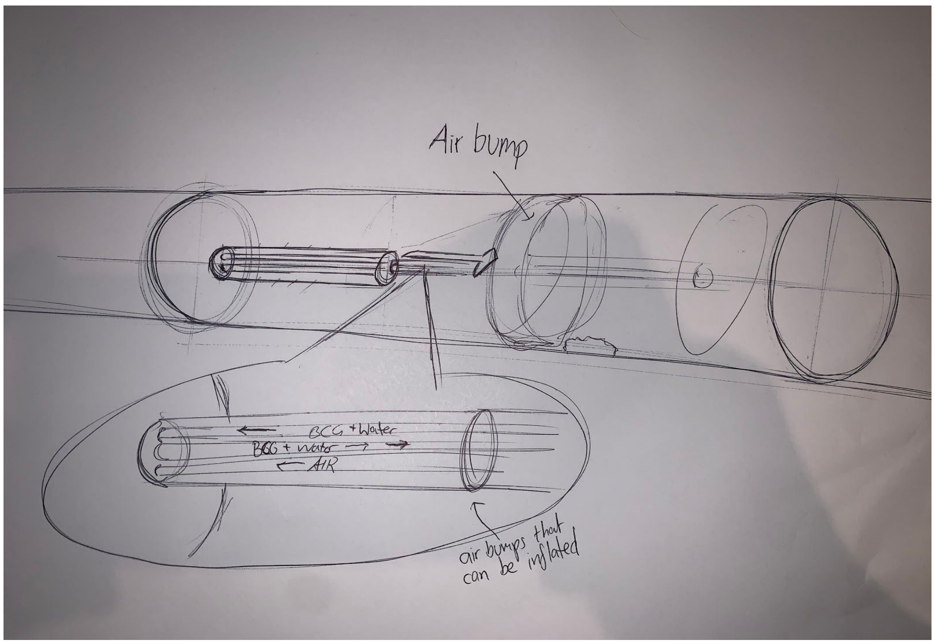

Fig 1: Sketch of BCG Sealant Deployment

Chapter 6: Solution Selection

Motivation for the Selected Solution

After much consideration, the EchoShore-DX solution was selected. This solution seems to be the most feasible for us as a team. It is very dynamic as it incorporates a lot of different elements. These elements include sensing, sound recognition, data collection and analysis and more. This solution can be used for all sorts of pipes, small and big, which is useful for the implementation of our instruments.

Our plan is to make a small test setup consisting of a short piece of pipe with three plugged holes in three different sizes. We will pump water through this pipe to simulate an actual water pipe and then attach our leak detector with microphone to the setup. We will then run several tests to collect data. By unplugging the holes one by one, we can see the difference between the sound of a normal pipe and a pipe with leaks. After analysing the data we can determine the thresholds of the different holes. If all goes as expected we will then be able to unplug a random hole and the device will notice and also be able to tell how large the hole is.

If we have some time left we want to make a system of multiple detectors. These devices can then work together to plot any leaks on a map of the area. This extension might help make the process of responding to a leak more efficient.

Chapter 7: Methodology

Materials Needed

- Plastic Pipes (See-through/Plexi-Glass)
- Pump
- Plugs on pipes
- Acoustic Sensors (Lab)
- Water
- Highly Sensitive Microphone (Lab)
- Arduino
- Sound Detector
- Drill
- Container
- Water

Sensor Calibration/Controlled Environment

The sensors would need calibration to make sure that the data collected would be as accurate as possible. There is also a need for controlled environments as the data collection involves sound. It is necessary to maintain a certain level of quietness in order to test the effectiveness of the microphone.

Data Collection and Analysis

Data will be collected through the use of programming and storage from Arduino. The data will be analysed by seeing if it can be comparable to other academic papers that also detect water leakage using sound.

The data we can use for our project is the data we are able to get from the microphone that is connected to the Arduino board. For the analysis of the data we can look for the volume (decibel) of the input-sound, the general spectrum of the wave and for details of the spectrum like the peak of the amplitude and the frequency of the sound input that we get from the microphone.

How can we process the data?

With the help of processing we can create a 128-Channel Spectrum-Analyzer that gets the data from the Arduino board. Another way is that the Adruino sends the data from a spreadsheet or a diagram that will then be possible to analyse.
The transformation that we can use for the microphone input sound is the Discrete Hartley Transform (DHT). To implement it you can use Fast Hartley Transform (FHT) and specifically the ArduinoFHT library. The maximal resolution with this Arduino library is 256 samples and the lowest 16 samples (vector-based) (Yavilevich, 2016).

Validation

For the validation we will observe the leaking pipe in the lab and check if our construction and all our instruments are implemented in the right way. We will also check the data that is sent to the sensors to see if they're accurate or not.

Roles And Responsibilities

Altea: Team Leading, Management and Coordination with Group Plan
David: Research and Design
Jasper: Prototype and Design
Max: Research and getting knowledge in unknown topics
Naomi: Research and Organiser
Nienke: Logistics and Data Analysis
Yekaterina: Data Collection

Things to research on:

Echoshore data for water leak sound detection and microphone compatibility with Arduino (Altea, David)

Range of sound detection (Jasper, Naomi)

- How much sound can the microphone capture
- External environment
- Extent of the water leakage

How do acoustic sensors detect the sound (Katya, Nienke)

- How do they work
- How does it present the data
- How does determine the leak sound from the others

Data collection/storage (Max)

- What data can be considered as water leakage vs. sounds

Logistics (Hardware Buying and Building):
Microphone
Pipes
Pump
Basin
Clamps & Connection Pieces
(Extra: High Pass Filter for Resistors)

Chapter 8: Results and Conclusions

The Set-Up

Fig. 1: Set-Up 1.0

Fig. 2: Set-Up 2.0

The set-up in Fig 1 is our original set-up for our prototype. The set-up that we built is based on our basic scenario where we only had our pipe set-up. We believe that this set-up is sufficient enough for data collection. It features a U-shaped pipe with a pump attached to it. The pump drives water through the pipe and it flows back down to the water basin. The water collected is collected in the water basin and is then pumped up again to go through to the pump. Then we drilled a hole in it which is 8 mm in diameter, but it made no difference to the audio spectrum. The pipe is connected to a piezo element which is also connected to the sound card. The sound card was used to amplify the signal and convert the signal from analog to digital. The data is then sent to the computer where it is recorded.

The set-up in Fig 2 was used to verify whether there would be a difference in the frequency of the pipe as there is a suspected relationship between the frequency of the sound that will be produced and the length of the pipe.

Results

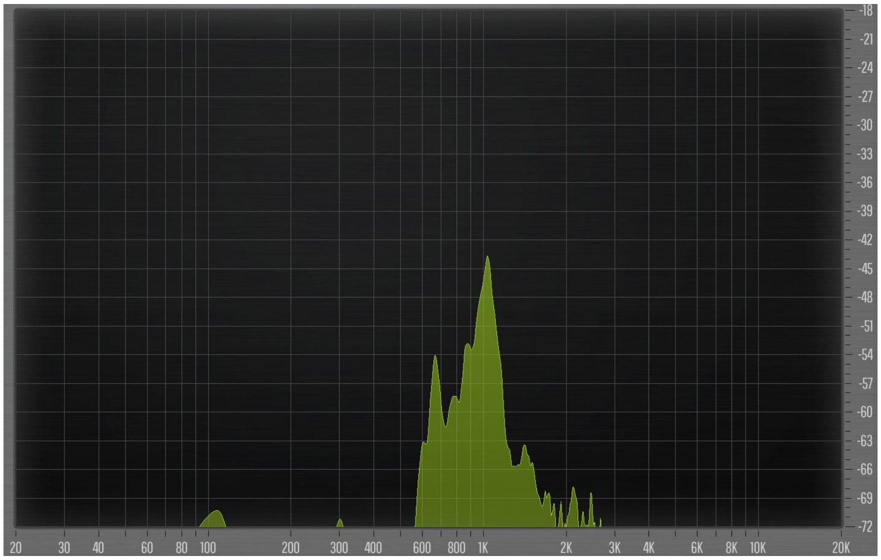

Fig. 3: Open pipe

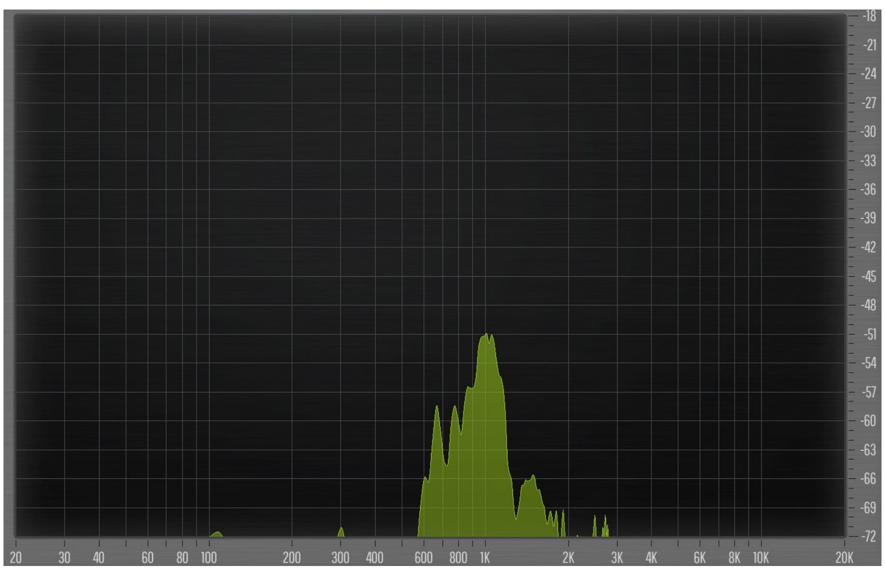

Fig. 4: Closed pipe

Fig 3 shows the spectrum analyzer of a pipe with an open hole. Fig 4 shows the spectrum analyzer of a closed pipe system. These graphs feature the hole of the pipe being open and close in succession with an undetermined time interval.

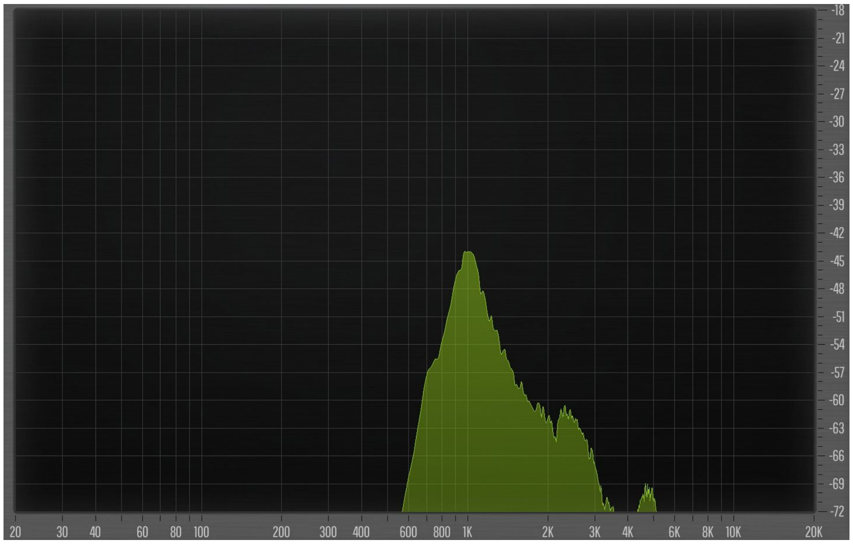

Fig. 5: Half-pipe

Fig 5 shows the collected data when having the half-pipe in our set-up. It shows the frequencies of the sound that was recorded. In this graph, it shows that a frequency of about 800 Hz was recorded.

Fig. 6: U-shaped pipe

The frequencies of the recorded sound when having the U-shaped pipe in our set-up can be seen in Fig 6. In this graph, it shows that the frequency is about 600 Hz.

There is no big difference between the frequencies of the Half-Pipe and U-Shape Pipe. However, the fluctuation of the frequency is too volatile to be analysed and draw conclusive results from. The highest peaks (1kHz) on the both graphs show the frequency that the pump makes.

Ideal Situation

There was a lot of water splashing around so we wanted as little electronics in the vicinity as possible. We recorded the sound separate from the arduino setup, with a very long xlr cable to an audio interface. There are two versions of the code. One can take in the piezo element as input. The other takes a WAV file as input and we used the latter for conducting our data processing. As there is no conclusive result to be drawn from the experimental data, the signal from the synthesiser was used to mimic the expected signal of the sound in the pipe.

The program uses FFT analysis to determine the change in the frequency spectrum, and notifies the user when a significant change is present.

Arduino_Leakage

```
/* Program for the Smart Environment end project.
  The program waits on 'a' through the serial port and turns a red LED and a buzzer on then*/

int LedPin = 13; //set LedPin to port 13
const int buzzer = 9; //buzzer to arduino pin 9


void setup() {
  Serial.begin(9600);
  pinMode(LedPin , OUTPUT); //sets LedPin to an output
}

void loop() {


  delay(1000);
  if (Serial.available() > 0) { //checking if serial data is there

    if (Serial.read() == 'a') { //when 'a' being read in the serial port
      tone(buzzer, 1000); // Send 1KHz sound signal...
      digitalWrite(LedPin, HIGH); //turns LED on
      delay(1000); //wait 1000 ms
      digitalWrite(LedPin, LOW); //turns LED off
      noTone(buzzer);     // Stop sound...
      delay(1000); //wait 1000 ms
    }
  } // end checking if serial data is there

}
```

Fig. 7: the Arduino code

SmartEnv_Mic_Anlyze | Analyze

```
/* Program for the end project in Smart Environment Module 2 of group Myriad.

This program is about detecting a leakage in a water pipe.
The programme can determine the amplitude of different frequencies using the processing.sound libary.
A frequency or a frame of frequencies can be defined from which the amplitude is checked.
If this amplitude changes beyond a defined frame, then the amplitude change in the defined frequency is interpreted as a leak in the pipe.
Therefore, a signal is sent to the Arduino via SerialPort.
The range in which the amplitude is not defined as leakage can be freely set.
(there are outcomment commands / they are for the caliartion of the microphone)
*/

import processing.serial.*;
import processing.sound.*;

Serial myPort;  //defines myPort as serial port
Analyze analyse;

FFT fft;
AudioIn in;
int bands = 512; //sets 512 frequency bands for the recording
float[] spectrum = new float[bands]; //creates an array with all Amplitues of frequencies
float Amp;
float AmpX; //gets the frequency of scanned frequency
float AmpXstore; //stores the Amp value of last processing
float MaxAmplitude; //shows the max. Amplitude of all frequencies
int calibrationTime;
boolean Leakage; //boolean for water leakage



void setup() {
  size(512, 360);
  background(255);
```

```
  myPort = new Serial(this, Serial.list()[9], 9600); //sets up myPort to 9600 bauds with Arduino connection
  analyse = new Analyze();

  fft = new FFT(this, bands);
  in = new AudioIn(this, 0); //sets audio input to mic 0
  in.start(); //starts audio input
  fft.input(in);  //patch the AudioIn

  AmpX = 0;
  Leakage = false; //boolean leakage is set up to false at beginning
  calibrationTime = 1000; //sets the calibration time to 1000ms
}

void draw() {

  background(255); //white background
  analyse.calculate(); //function calculate out of class Analyze
  analyse.leak();//function leak out of class Analyze
}
```

Fig. 8: Processing code version 1

SmartEnv_Mic_Anlyze | Analyze | Java

```
public class Analyze {
  void calculate() {

    fft.analyze(spectrum);  //analyses Amplitude- -> (spectrum = Amplitude in this code)
    MaxAmplitude = max(spectrum)* 1000; //stores the value of the highest amplitude (*1000 for better signal)

    for (int i = 0; i < bands; i++) {
      line(i, height, i, height - spectrum[i]*height*5 ); //(creates an animation of all amplitudes)
      int freq = i*43;  // bands = 512 * 43 is the frequency
      Amp = spectrum[i] * 10000; //amplitude of frequency [i]
      AmpX = spectrum[43] *10000;  //AmpX for certain frequency (sets to about 1860) --> Freuquency range of leakage sound, calulation: frequency / 43 = XXX   [CALIBRATION}

      //println("Amplitude is: "+  Amp + "  at Frequency of " + freq);  //shows the Amplitudes of frequencies till 20KHz(22KHz) [FOR CALIBRATION]
      //println("MaxAmplitude is: "+  MaxAmplitude); //can show the biggest amplitude of all frequencies [FOR CALIBRATION]
    }
     if (millis() >  calibrationTime) { //sets the calibration time
      if (AmpX < AmpXstore * 0.01 ||  AmpX > AmpXstore *100) { //if freuquency changes  [CALIBRATION]
        Leakage = true;  //sets boolean to true
        println("Leakage detected");
      }
    }
    AmpXstore = AmpX; //Update the value to its most recent
  }
   void leak() {
    if (Leakage == true) {
      myPort.write('a'); //sends 'a' to the arduino via Serial Port
      fill(255, 0, 0);
      textSize(32);
      textAlign(CENTER);
      text("Leakage detected!", width/2, height/2); //text for leakage detection
    }
  }
}
```

Fig. 9: Processing code version 1 (Analyze Class)

Fig 8 and 9 show the first version of the processing code. In the second version of the code, the input is different. We used a sound file as input instead of the microphone/piezo element.

Discussion and Conclusion

Looking at the data we collected, we can conclude that there is no noticeable difference in either frequency or amplitude between the sound from the pipe with the hole and the sound from the pipe without the hole. There could be a myriad of reasons why this was the case.

Firstly, it could be that the sound difference is too little to notice. The hole was very small after all and the piezo element might not have been sensitive enough. There is also a possibility that the piezo element was not the right tool to detect the desired sound.

Furthermore, the sound recorded could have been the water flowing out the open end of the pipe instead of the water in the pipe itself. This theory is supported by the fact the sound produced by the half pipe was significantly louder than the sound of the U-shaped pipe. It makes sense that when the sound has to travel half the distance along the length of the pipe towards where it was recorded, it is a lot louder.

Bibliography

Amado S. Tolentino Jr. (2007) “The Challenges of Tsunami Disaster Response Planning and Management”, https://www.iges.or.jp/en/publication_documents/pub/peer/en/528/IRES_Vol.7-1_147.pdf

Angeline G. Pendergrass, Gerald A. Meehl & Roger Pulwarty (2020, March). Flash droughts present a new challenge for subseasonal-to-seasonal prediction. Retrieved November 18, 2020, from https://repository.arizona.edu/bitstream/handle/10150/640941/s41558-020-0709-0.pdf?sequence=1

BBC News. (2020, June 09) “Russian Arctic oil spill pollutes a big lake near Norilsk.” Russia, Moscow. Retrieved November 17, 2020, from https://www.bbc.com/news/world-europe-52977740

BCG (2020). *Герметик для водопровода BCG устраняет течи труб.* Retrieved December 03, 2020, from *http://bacoga.ru/germetik-dlya-vodoprovoda-bcg-ustranyaet-techi-trub.html*

Cabral, J. (2010). Water Microbiology. Bacterial Pathogens and Water. https://www.mdpi.com/1660-4601/7/10/3657/htm

CDC. (2018, January 12) “Landslides and Mudslides”. Retrieved November 17, 2020, from https://www.cdc.gov/disasters/landslides.html

Chandler, D. L. (2017, July 17). Finding leaks while they're easy to fix. Retrieved December 03, 2020, from https://news.mit.edu/2017/robot-finds-leaks-water-pipes-0718

Duruibe, J. O., Ogwuegbu, M. O. C. & Egwurugwu, J. N. (2007). Heavy metal pollution and human biotoxic effects. *International Journal Of Physical Sciences.* https://academicjournals.org/journal/IJPS/article-full-text-pdf/59CA35213127.pdf

Ebola health update - North Kivu/Ituri, DRC, 2018-2020. (n.d.). Retrieved November 18, 2020, from https://www.who.int/emergencies/diseases/ebola/drc-2019

Echologics (2020) *Continuous Leak Detection Monitoring for Distribution Mains*, from https://www.echologics.com/services/small-diameter-leak-monitoring/echoshore-dx/

Fernando Briones, Ryan Vachon, Michael Glantz, (2018) "Local responses to disasters: recent lessons from zero-order responders", Disaster Prevention and Management: An International Journal, https://www.emerald.com/insight/content/doi/10.1108/DPM-05-2018-0151/full/html

Gomez, J., & Favila, A. (2020, November 13). “Strong typhoon leaves 42 dead, 20 missing in the Philippines.” Retrieved November 18, 2020, from https://apnews.com/article/floods-typhoons-typhoon-vamco-philippines-manila-4fd174fa6aa35c7d98fe4b1700e11ddc

James A. Marusek (2007) “Solar Storm Threat Analysis”, from https://www.jumpjet.info/Emergency-Preparedness/Disaster-Mitigation/NBC/EM/Solar_Storm_Threat_Analysis.pdf

Jun, Z., Wei, X., Xingzhong, W., Peiwei, G., Zhihua, Y., Lihai, S., & Jiang, W. (2020). Application and research status of concrete canvas and its application prospect in emergency engineering. *Journal of Engineered Fibers and Fabrics*. https://doi.org/10.1177/1558925020975759

Kageyama, Y. (2018, July 08) “Japan's flooding death toll rises as heavy rain continues”. Retrieved November 18, 2020, from https://www.independent.co.uk/news/world/asia/floods-southern-japan-death-toll-shinzo-abe-hiroshima-a8437136.html

Lloyd , R. (2019, April 22). An Underground Pipe Repair Method Raises Questions. Retrieved December 03, 2020, from https://undark.org/2019/04/22/cured-in-place-plastic-pipes-cipp/

M. Bakker, D. Jung, J. Vreeburg, M. van de Roer, K. Lansey, L. Rietveld (2014) "Detecting Pipe Bursts Using Heuristic and CUSUM Methods", from http://www.sciencedirect.com/science/article/pii/S1877705814000137

Michael Brown (2019) *Best water leak detectors for smart homes,* from https://www.techhive.com/article/3138905/best-water-leak-detectors-for-smart-homes.html

National Geographic Society. (2019, July 15). “Wildfires”. Retrieved November 17, 2020, from https://www.nationalgeographic.org/encyclopedia/wildfires/

NBC News. (2018, August 26). *Robot Rescue: Behind The Technology Deployed For Disaster Relief | NBC Nightly News* [Video] Youtube. https://www.youtube.com/watch?v=0yHjQKXWqYI

Nikolaos Stilianakis, Sergio Consoli (2013) “Operations research in disaster preparedness and response: The public health perspective”, https://op.europa.eu/nl/publication-detail/-/publication/8579c689-ff66-4c6e-b394-b9e57a4ae8dc

Oil Spill Pollution Diseases. (n.d.) Retrieved from https://www.environmentalpollutioncenters.org/oil-spill/diseases/

Ordinioha, B. & Brisibe, S. (2013). The human health implications of crude oil spills in the Niger delta, Nigeria: An interpretation of published studies. *Niger Medical Journal, Volume (54)*,10-16 doi: https://dx.doi.org/10.4103%2F0300-1652.108887

Pradhan, S. (2020, September 17). “Monsoon Floods”. New-Deli, India. Retrieved November 17, 2020, from https://disasterphilanthropy.org/disaster/2020-monsoon-floods/

Ruetten L., Regis P.A., Feil-Seifer D., Sengupta S. (2020). Area-Optimized UAV Swarm Network for Search and Rescue Operations. Retrieved From https://rrl.cse.unr.edu/media/documents/2019/1570608656.pdf

Schuelke Plumbing (n.d.) “Most common causes of burst pipes”, from https://spieplumbing.com/uncategorized/most-common-causes-of-burst-pipes/

Senseware (n.d.) *5 Ways to Prevent Pipe Bursts Using an IoT Smart Building Solution,* from https://blog.senseware.co/2018/02/12/5-ways-prevent-pipe-bursts-using-iot

Smith, M. D., & Meade, B. (2019, June 3). Who Are the World's Food Insecure? Identifying the Risk Factors of Food Insecurity Around the World. Retrieved November 17, 2020, from https://www.ers.usda.gov/amber-waves/2019/june/who-are-the-world-s-food-insecure-identifying-the-risk-factors-of-food-insecurity-around-the-world/

Soldanshop24. (2013, February 11). *BCG Flüssigdichtmittel, Rohr abdichten leicht gemacht, ohne große Kosten* [Video]Youtube. *https://www.youtube.com/watch?v=Q_OZptylw7s*

The International Federation of Red Cross and Red Crescent Societies. (March 2008). Guidelines for assessment in emergencies. Geneva. https://www.ifrc.org/en/what-we-do/disaster-management/responding/

United Nations Development Programme. (May 10, 2019). Guidelines for Assessing the Human Impact of Disasters. https://www.undp.org/content/undp/en/home/librarypage/crisis-prevention-and-recovery/guidelines-for-assessing-the-human-impact-of-disasters.html

USGS. (2020, March 9). Puerto Rico Earthquakes. Puerto Rico, San Juan. Retrieved November 17, 2020, from https://disasterphilanthropy.org/disaster/puerto-rico-earthquakes/

Varun G. Menon, Joe Prathap Pathrose, Jogi Priya, "Ensuring Reliable Communication in Disaster Recovery Operations with Reliable Routing Technique", Mobile Information Systems, vol. 2016, Article ID 9141329, 10 pages, 2016.

Vivek Rawal & Dinesh Prajapat. (2007). Assessing Damage after Disasters; A Participatory Framework and Toolkit. Gujarat India.

https://www.participatorymethods.org/resource/assessing-damage-after-disasters-participatory-framework-and-toolkit

What is a Flood?: What Causes a Flood?: Flooding. (2020, October 29). Retrieved November 17, 2020, from https://www.earthnetworks.com/flooding/

Yavilevich, A. (2016, August 27). Arduino sound level meter and spectrum analyzer. Retrieved December 10, 2020, from https://blog.yavilevich.com/2016/08/arduino-sound-level-meter-and-spectrum-analyzer/