UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

JJJJAZD

(pronounced Jazz)

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Chapter 0: Introduction

Our team consists of Anica Krüger, Jan Kröger, Justen Ter Horst, Dimitar Yolovski, Jonathan Jeuring Zalfa Imtinan and Jacelynn Moesker.

The problem that we have chosen to tackle is the ongoing flooding problem caused by a combination of poor water management and an increase in rainfall due to climate change. The poor water management problem causes strain to the current sewage system.

The solution we chose is a very simple one. We want to connect two sensors to our Arduino. The first is a water level sensor and the second is a water flow sensor. These two sensors will be placed inside a pipe. The outputs we would get from the sensors can be used to determine/ sense if there is a blockage in the pipes. For example, a high water level and low flow speed would mean a blockage. A low water level and a high flow speed would mean that the water can easily pass through the pipe. If a blockage is detected somewhere, the Arduino will give a warning signal.

We chose this solution for various reasons. The main reason is that it is simple and can be easily implemented. This is important because we only have a limited amount of time and it needs to be possible to apply this solution in the real world. The sewer systems do not have to be fully redesigned, because only the sensors need to be added. Another advantage to this solution is that we can collect data based on where the weak points are in the sewage system so that preventative measures can be taken.

In addition to being practical, the problem we've encountered, which is flooding caused by climate change, has been thoroughly researched. According to [24] there has been more than $40 billion in damage worldwide annually. Furthermore, [25] and [26] not only shows that 2.2 billion people are exposed to flooding, but also the workers that deal with the sewage system are affected by it too.

Sensors such as [27] have been proven to prevent leaks in pipes for years now, and research on monitoring pipelines have proven to be effective [28]. Our solution combines these two concepts in order to solve multiple problems at the same time.

Chapter 1: Literature Review

21 meaningful publications on the general subject of climate change.

The impact of biodiversity loss and how it occurs. [1]
Biodiversity is essential to the survival of our planet. The loss of biodiversity is prone to reduce the flexibility of our environment and its ability to recover from- and take blows. One of the main causes is loss of habitat which then leads to lower resources for the species, higher chance of inbreeding which then again lowers the overall survivability of the species in question. Lastly, the endangerment of certain keystone species brings at risk the downfall of the entire ecosystem. Which could spell the extinction for all species within that biosphere.

A summary of the risk due to climate change in the sectors: water, crops, heat, weather, and health. [2]
Due to global warming, many things are now forming more potential dangers for humanity: the loss of ice and the rising sea levels are generating more significant risks to the freshwater supply, many areas where the vast majority of our crops come from risk losing a significant amount of arable land and growth rate of crops, increased temperatures can see more risks of fires and deaths due to overheating, changing weathers have seen the amount of natural weather-based disasters (tornados, heavy storm, etc.) triple between 1980 and 2014 leading to hundreds of billions of dollars worth of damages everywhere and increased health risks looking at more exposure to the sun, disease-carrying insects and mental health issues due to trauma caused by natural disasters.

Global energy consumption [3]
This research shows data about energy consumption andCo2 emissions, which are country-specific (shows the countries with the highest consumption). Data have shown about the use of key energy (data in coal, energy, oil, electricity) with the one that has the most consumption which would be electricity.

Global energy consumption [4]
This article shows data on the world's energy consumption and how it changes each year, which includes country-specific data on how much they use such as coal, oil, and natural gas. It also shows electricity consumption in separate data including which country produces the most and consumes the most.

Reconciling anthropogenic climate change with observed temperature 1998-2008 [5]
In this research, they compare the temperature rise between 1940 and 1970 and after 1970. It shows that there is a connection between greenhouse gases and sulfur emissions. In the period between the '40s and '70s, it can be seen that the temperature doesn't increase at all because the cooling of sulfur emissions rises more than the heating of greenhouse gases. It draws as a conclusion that in an effort to limit acid disposition which pollutes the air we have allowed the concentration of greenhouse gases to rise and thus temperature to do so as well.

Effects of temperature rise on crop growth and productivity [6]
The research is about global warming and how it would affect crops. It looks at the change of temperatures during the day-night cycle, how climate change would affect crop yields and what is the increase of the need for water. It focuses mainly on Pakistan but it takes into consideration other countries as well. It is shown how a change of temperature affected crops and to be more specific what the decline of crop yields is. For example, a one-degree rise results in a 10% decline in rice production. Another topic that it tackles is the increasing need for water when it comes to plants, a growth of 3 degrees results in 29% more water consumption.

Impact of temperature rise of 1.5 degrees to Asia's glaciers. [7]

The article talks about how the temperature rise will affect the glaciers in several regions in Asia. The research shows models for the different temperature rises and how they will affect the glaciers, the water supply, and water access. It is predicted by the Representative Concentration Pathway (RCP) that the losses can vary from 49 to 69% of the total glacier masses. This will change the downstream availability significantly especially for RCP of 8.5. The study concludes that the high mountains of Asia are warming more rapidly than the global average and differences between the RCPs are so large that the tree-planting can span from saving the glaciers for generations to losing them by the end of the century.

White paint to reflect sunlight [8]

- Newly developed white paint can be used to reflect more sunlight from surfaces.
- Old white paint could not cool down surfaces below the ambient temperature, the new paint can do it meaning people don't need to use as much air conditioning.
- The cost of the new paint will be similar to the cost of the older white paint.
- There might be problems with getting the barium sulfate that is needed for the paint.

Small hydropower [9]

- Hydroelectricity comes in many different sizes. Together they are the largest source of renewable energy.
- Small hydro usually uses run-of-river which means that energy can be gathered from flowing water without a large dam or the need to store a lot of water for a long time.
- The flow of water gets turned into electricity using a turbine. Choosing the right turbine is very important as many different aspects work better in certain environments.
- The world is not using small hydro as much as it could and should be doing.
- There are many advantages of using small hydro like sustainability and predictability, but there are still some difficulties because every site is different.

Hydropower potential [10]

- Hydropower is energy efficient, lasts a long time, is flexible, and there is a lot of potential left.
- There is untapped potential on every continent. Although some countries already make a lot of use of hydroelectricity, more can be done in a lot of places all over the world.
- There is some opposition to hydropower because people don't like large dams. A dam can have a large impact on the environment.
- However most dams aren't even used to generate electricity, but for irrigation water.

Tree planting [11]

- The tree-planting initiative that Bangladesh has started included trees from the Acacia family, which absorb too much water and harm local crops.
- There is a group doing contemporary landscaping for buildings and uses plants that are ultra-align with the local ecosystem.

Sustainable architecture [12]

- Debates about sustainable architecture are shaped by different social interests that are based on different interpretations of the problem.
- These environmental concerns are both time and space-specific.
- Rather than searching for a singular optimal technological pathway, it is vital to recognize and listen to the voices of the debate and the visions they express on the environment and go on from there.

Flood prevention [13]
There are many ways to prevent flooding.

- One of them is to create a flood barrier, made of metal that is placed on the bottom of the body of water or create a frame that is located on the coast. Raised embankments can also be used to increase the level of protection but there must be a barrier to support it.
- Natural flood management consists of small measures to reduce the flow of water before it reaches the larger rivers. This could be small barriers in ditches and fields to divert the water into open land. These measures are meant to complement the flood barriers.
- Sustainable drainage allows water from rain to pour into the open ground rather than the water system, which could lead to flooding. The ground should be able to absorb the water. A basin could also be built to collect rainwater in the meantime, acting as a river.

Geoengineering [14]
A politically highly discussed topic is the topic of geoengineering. The idea came up after a massive volcanic eruption in the Philippines. The eruption threw a lot of particles into the stratosphere that partially blocked the sunlight that was shining on the earth. The result of this was that in 4 years the earth's temperature dropped by 0,3°C. An idea to lower the earth's temperature would be to manually put sulfur dioxide particles into the stratosphere. This method is highly debated because it is not sufficiently researched enough.

Better cities [15]
Especially big cities will experience the results of climate change because cities have a high population density and a high building and infrastructure density.
Cities are not prepared for longer heat periods, more frequent floods, and in general more extreme climates. To prevent this and prepare cities for this some improvements could/should be made: Brighter building material, more greenery, and more shadow could reduce heating of mineral materials. Furthermore, intended airways in the city's construction plans could improve air quality and help cool the city.

Mitigating global warming with surface reflectance [16]
A method that gets used a lot already to prevent water evaporation is putting reflective covers on top of water reservoirs. For example, in Australia, a 170km^2 water reservoir that supplies the entirety of South Queensland with water is covered with floating white covers that reflect the sunlight. If the covers were not there, the amount of water that evaporates is equivalent to the amount of water that would be used in one day. If water supplies would get slim in the future, this would be a solution to adapt to the shortage of water.

Forests as climate protection [17]
For the global carbon cycle, forests build an essential ecosystem. On the one hand, the System removes tons of anthropogenic carbon every year. On the other hand, the area of forests stores large reservoirs of carbon. Hand in hand with this idea goes the problem that the stored carbon could return to the atmosphere through f.e. wildfires. Another fact that will impact the concept of forests as climate protection is that forestry can have socioeconomic and environmental impacts. To succeed with this idea, politics has to help, and you need the involvement of the tropical regions.

Mobile phone-based project to send weather data to farmers to help them plan [18]
The project is used in Uganda to help the farmers who are affected by climate change. Agriculture depends on the weather, which changed and will change a lot through climate change. The higher temperatures are seen in the food security and the quality and the quantity of water. Therefore the project contacts the farmers through mobile phones and radios to send them the newest weather data to help them plan. Through that, the crop loss got minimized and the damages as well. Another good point is that this project can be introduced to other countries to help their agriculture.

Sending data to countries that are threatened by sea-level rise [19]
The project should protect countries that are threatened by sea-level rise. Therefore, the project invented applications to help the government plan its actions and prepare for a sea-level rise. Through that, they protected the environment, society, and nature. They collected information, reports, and analytics to identify countries with high risks and help them plan and make decisions. Besides the software, there are also training sessions to ensure that people can use the tool.

An overview and assessment of the various health and safety risks global warming brings to labourers [20]
Global warming is having more and more previously negligible effects on the health and safety of workers. But with the increase in temperatures, many risks come: from dehydration and other heat-related conditions to more frequent contact with disease-carrying insects and dangerous chemicals that are released in larger numbers by the increasing temperatures. Furthermore, more common weather extremes such as storms may pose serious threats to outside workers such as high-rise construction and commercial fishing. To mitigate these effects we require a 3 step approach: lowering greenhouse gas emissions, adapting to the effects of climate change with appropriate measures, and revising current health and safety measures and procedures.

Energy Efficiency 2021 [21]
There is a net-zero emissions scenario in 2050, which is the goal of energy efficiency. Energy efficiency has improved in the past year however to reach this net-zero energy efficiency has to double its recovery. After the covid economic activity is predicted to bounce back which will also increase the energy demand, because of the pandemic, energy efficiency was not the best. At this moment one of the best solutions would be the government constraints and role towards the use of energy and laws on energy efficiency to be implemented internationally. This article gives out the most cost-effective actions to reduce CO2 emissions.

Chapter 2: Identification of General Problems and Challenges

Identify 8-10 general problems & challenges from the list of publications in Chapter 1

1. Less crop yield and increase of water usage due to changes in temperature.
2. More rapid melt of Asia's glaciers due to the rise of temperature will result in changes to the water supply and access.
3. Get more information on people who are affected by climate change.
4. Some tree planting plans can be even harmful to the local ecosystem.
5. More dangerous working conditions for field workers.
6. Rising sea levels are becoming a bigger danger to many coastal areas.
7. Many attempts to affect global warming have been executed improperly or lack international coordination and cooperation.
8. It's a known fact that trees take carbon dioxide out of the atmosphere and are a key instrument in reducing greenhouse gasses yet forestation is at its peak.

Chapter 3: Identification of Relevant Problems

Identify 5 new problems you find relevant, urgent, and interesting, not yet been addressed effectively

1. *Agricultural problem*
    a. The current increases in temperature due to global warming are expected to impact agriculture massively. The main problems that are to be expected are; loss of large amounts of arable land and a general decrease in agricultural output. Combined with a significantly increased consumption of water and shrinking water reserves globally. The last major issue would be the introduction of foreign insects and diseases that could threaten the breeds of plants and animals that are relied on. [2] [6] [12]
2. *Increased greenhouse gasses due to local customs*
    a. In local customs such as during the festival of ghosts that is mentioned in [22], the burning of joss paper can increase the carbon emissions and particulates. Other customs like the lantern festival in Japan can lead the lanterns to the forest and increase the chances for forest fires.
3. *Flooding*
    a. There will be more and more floods in the future as the sea levels are rising and extreme weather becomes more common. Some countries will be influenced by the rising sea levels and not all of those will be fully prepared for it politically or in terms of money [19]. The other problem is caused by rivers overflowing because if places are not properly prepared the flooding will cause destruction [13].
4. *Lack of spread of knowledge to the concerned community*
    a. The problem is that strongly affected people do not have enough information for planning or reacting to climate change. The issue focuses on the social situation and how to adapt people's behaviour to climate change. [18] [19]
5. *Decrease in biodiversity due to human-made architecture*
    a. Plants that are not suitable for the local environment would result in wasted resources for other plants by absorbing too much of them. [11]

Chapter 4: Problem Selection and Motivation

For this assignment, this team has decided to take upon us the problem of flooding. Many countries in the world face issues caused by flooding; from damage to biodiversity and biospheres to damage to infrastructure and facilities like hospitals. However, quite a few of those countries also face very dry summers. And often have severe water shortages in the dry periods. Whilst having an incredible abundance of water in the flooding seasons.

Here you can already start seeing one of the main problems behind flooding; inadequate water management. With proper water management on inefficiency: flooding, especially flooding in internal waterways like rivers and channels, can be severely decreased and also used to solve other issues the country may face. Furthermore, by limiting the impact of flooding and protecting people and biospheres from flooding we can save a lot of money on repairs and other such measures.

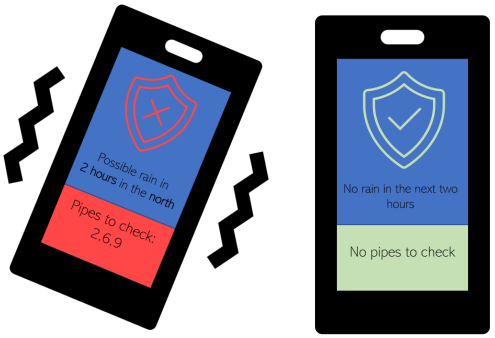
We want to focus on the area that includes flooding due to poor sewers. Here we are dealing with existing measures, which have to be adapted to the aggravated climate situation. Due to climate change, more significant amounts of water require a better sewage system.

The significant problem is that sewage systems are often clogged with leaves or trash, increasing the height of the water and also the chances of more flooding.

Addressing this problem and creating a safer sewage system would mitigate the severity of the flooding and adapt the current situation to climate change.

Seeing these reasons combined with some of the ideas that have already come up within our group, we have so far decided that we want to try and mitigate the issue of flooding caused by poor sewers systems.

Chapter 5: Potential Solutions



1. **Alarm system on each sewage system**

This solution partially solves the problem of flooding caused by poor sewage systems because it focuses on the prediction and the proper provisions for rain. Risks related to the alarm system are that the weather data is wrong or imprecise, and decisions are made on incorrect data.
For this solution, you would need software and hardware installed, and humans will interact with the software, so it must be user-friendly.
The software needs newly updated weather data and the city's location or a specific pipe to give particular alarms. The hardware could be a phone that makes noises when the rain arrives, and this alarm will be early enough to react to it and prepare/check the pipes before the rain.
This solution has potential because then the worker can react before the rain arrives and check the pipes with, for example, our second idea, that there are sensors in the pipes. Yet also, without the sensors, the workers can check if the cover of the sewage systems is free from leaves or trash.
The solution's positive impact is that the people do not react if the rain has already started or if there are the first signs of flooding. They will respond hours before the possible catastrophe to alleviate the effects.
You need access to the weather data and create software to validate this idea. After that, you could test if the weather data is updated depending on the phone's location or the specified location of the users. The next step could be to search for accurate weather data for districts of the city and to name the pipes affected by the rain.
The final test phase is to check if the software is user-friendly and if the alarm works properly.
For the presentation, you could install the software on phones and let the viewers themself test the software. Due to the limited amount of time, it would be good to limit the location to one city (for example, Enschede) and work on that city in detail. Then you could print out an extensive plan of the town and the sewage system and show the viewers which pipes can be affected by the next rain.

2. **pipes with sensors that senses**

One of the main reasons for flooding would be a blockage of drains or a full sewage system. This solution would solve the problem, with the help of sensors that would be located inside the pipes of the sewage system as well as on top of the drains. The sensors on the water drains would be to see whether the drains are empty or not and make sure that there's enough space for water to flow through. Another sensor would be located in the pumps of the sewage systems; these sensors would be keeping track of the speed and height of the water. This would calculate the amount of water stored in the pump and whether the water is actually flowing. The sensor of the water height would be approximately placed after every couple of meters of the pipe and would be around ⅔ of the pipe, this would be to ensure that there is time for the water department to actually check up and check out the problem.
This solution would have such a great impact on the environment since it is to anticipate the possibility of flooding itself and analyze the problems before it actually has a severe impact. It would make it more convenient for the workers since they won't have to check them individually since it would take a long time and miss some.
This solution would work really well hand in hand with our first solution to make it possible for the workers to get alerts and also use the help of the whole community. However, it is not dependent on it since it would still be helpful for the workers to gain this information since they are the ones that are obligated to take care of and fix the problems themselves.

3. Maps for the sewage system

Make a “google maps” with where the pipe is, and where the most concentrated trash is
As an addition to the first solution, the mobile app could have a function where it maps the location of all pipe systems, the sensors which are located in the pipes will trigger the app, by letting it know that it is overflowed or that the pipe on that location is clogged. By assisting sewage workers to find the source of the blockage, the efficiency of flood prevention increases.
Furthermore, the app is linked to all sewage workers and calculates the fastest route to the source of the blockage. The source is found by looking at the pipe with the highest amount of water depth.

4. Filter system where the trash doesn't get accumulated

Design a sewage system that is able to detect the type of material that goes inside it and then release a filter that collects the garbage and separates it from the water.
The way it is going to work is by having cameras that are looking at the water stream. They will be operated by previously designed AI which is going to be able to distinguish garbage from the water. After the program has found that there is an existence of garbage in the water stream, it is going to release a filter net that is going to capture the flowing litter and then transfer it to a separate system which is connected to a container where the garbage is collected.

5. Changing the lids of the sewage system

By adding more filters with smaller “gaps” for trash to pass through, one can prevent the trash from clogging up in unexpected places. Instead, these filters have to be cleaned up every now and then.
This solution will stop some of the cloggings but unfortunately not all of it. This means that other solutions have to be implemented as well. So this isn’t really a full solution, although it will help.
A downside to this solution is that cleaning the filters can be some work. The amount of work strongly depends on the place where the filter is installed, so the viability of this solution depends heavily on the location.

6. Self-cleaning sewage covers

With the use of sensors, sewage covers could be made smarter and they would be more efficient. With an infrared sensor on the cover or pressure sensor underneath the cover of the sewage cover, it could detect if there is trash, leaves, etc. laying on top of it. The benefit of this would be that the sewage covers are rarely blocked and water can constantly flow into it without difficulties. When it's raining a lot, free and open sewers are necessary because otherwise the water would just stay in the city and destroy/hinder or just simply annoying.

Chapter 6: Solution Selection

There are a number of reasons we have chosen to go with solution 2:

Firstly, the system would be easy to adopt and implement. Not requiring the full redesigning of the existing sewer network and only the addition of the new sensors that can be done without massive overhauls.

Secondly, once the system is implemented we can passively collect data on where blockages are most likely to occur, allowing for more preventative measures to be made on time.

Lastly, we chose this solution because we think that with this we can achieve the most during the time we have been given for this project and actually devise a solution that can be applied in the real world and have tangible positive impacts in the areas it can be implemented.

The reason why we did not opt for the first solution is that the software already exists, it is essentially a weather app that acts passively. Thus, not preventing flooding. However, we wanted a solution that acts actively.

This also applies to the third solution where it is not a full solution, but it can be powerful if combined with solution two. So the sewage workers know where they happen when they happen and it allows the workers to identify where the clogs often occur. In addition, the data needed to create the software costs time that we simply do not have.

The fourth, fifth and sixth solutions are not practical due to the fact that they would require an AI capable of distinguishing trash from the water, which would require a large amount of programming. On top of that, we would need to have a major overhaul of the existing sewage infrastructure respectively. These solutions are less economically attractive than a sensor system that can be integrated into existing infrastructure.

LIST OF MODULES TO BE COMPLETED:

Module Number	***Description***	***People***
1	**Programming with Arduino with sensors**	Jan, Dimitar, Jacelynn
1a	Designing the diagram (class diagram)	Jan, Dimitar
1b	Figuring out the logic of the program	Jan, Dimitar
1c	Building Arduino	Jan, Dimitar
1d	Draw the schematic	Jan, Dimitar
1e	Presentation of Program	Jan, Dimitar
2	**Testing**	All
2a	Mathematical prediction of what values should be expected	Jacelynn
3	**Presentation preparation -> model building**	Jonathan, Justen, Anica
3a	Acquiring the pipes from DesignLab	…….
3b	Draw the diagram of the model building	Anica, Justen
3c	Buy materials for model	Jonathan, Justen, Anica
3d	Build model	Jonathan, Justen, Anica
3e	detail model (finalize)	Jonathan, Justen, Anica
4	**Find out which sensors are needed, calibrated or not**	Jan, Dimitar
4a	Acquiring the sensors (could be through Alfred or Edwin(PPC)	Jacelynn

	or SE Project lecturer	
5	**Data analysis**	Zalfa
6	**Documentation**	Anica
7	**End Presentation**	Justen

Chapter 7: Methodology

Materials Needed:

- **Prototype:**
  - Water flow sensor
  - Water level sensor
  - Pump
  - Circular connector
  - Internal cable clamping
  - Clamping ring
  - Jumper cables
  - Arduino UNO
  - Horizontal pipes
  - Water
  - Valve
  - A power source (for the Arduino)
  - LED
  - Speaker

- **Model:**
  - Wooden frame

Sensors:

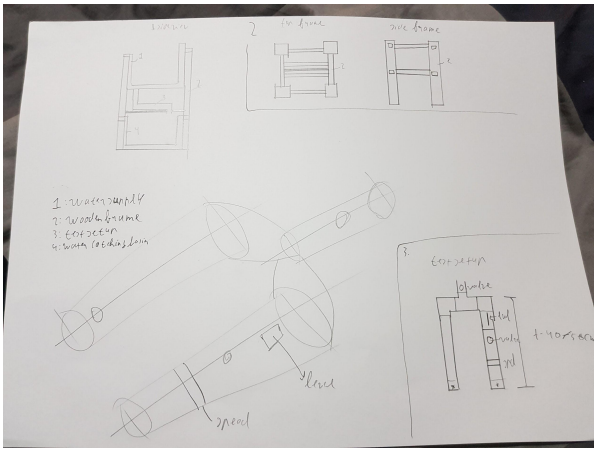
The sensors would need to be calibrated in order for us to obtain data that would be as accurate as possible. We would need to have 2 types of sensors which are water flow and water level sensors; water flow sensors would be to know whether there is water flowing through the pipes, and water level sensors would check the height of the water inside the pipes. These two sensors would be connected to different indicators; a speaker/ alarm to know the water level, and an LED to indicate the sound.

Data collection and Analysis:

The use of Arduino would allow us to program and store data that would be obtained. Beforehand we would collect data when the pipe would be full and when there is no blockage at all, this would help as a reference.

The data that would be used will be the ones that we gathered up with the use of our water flow sensor and water level sensor connected to the Arduino board. To analyze the data we would look into the water height as well as the flow. How it will work would be by installing the water level sensors before the water flow sensors; the water level sensors to check the height of water then it will look at the values from the water flow sensors which would be compared to the previous values that were tested beforehand and see if there is a decline in the flow. To do this we would set a certain range of the measurement which would send a signal whenever it exceeds the threshold, in addition since both sensors are capacitive we can use a library to obtain the measurements needed to make it as accurate as possible.

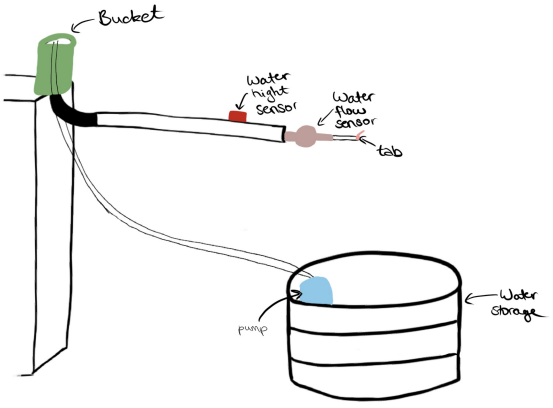
Schematics for the test setup



The main construction (see points 1 and 2) for the testing consists of a frame with at its top a basin for water. Connected at its bottom will be a series of pipes in an upside-down U shape (see point 3). Its left side shall consist of a length of pipe equal to the other half but with only a valve at its end. The second part of the piping shall consist of a section of pipe with the water height meter. Followed by a valve section with the last piece having the water speed sensor. This will allow us to generate two outputs wherein one we can show the baseline expected and the other show what happens when the pipe is clogged (simulated by partially/fully closing the valve). At the bottom of the installation is a reservoir that captures the water used and allows a pump to transport the water back up to the top of the installation for a guaranteed constant flow (see point 4).

Improved test setup

The main idea for our testing was changed during the process of the testing since we didn't think that it was necessary to have two piping systems and this would work as well. First, there would be a water container that's connected to a bucket that has to be on a higher surface, and with the help of a water pump, it will take the water upwards. The bucket on top would have a hole at the bottom where the pipe can be placed, however, we will take into account that the pipe needs to have an angle downwards with the water flow sensor at the end of the pipe and a tap that can be turned on and off to show the blockage. In addition, the pipe would also have a water height sensor connected from the top part of the pipe inside.



Budget and what is needed:

Water flow Sensor	14.94 euros	https://www.otronic.nl/a-62712241/sensors/water-flow-sensor/?gclid=CjwKCAiAh_GNBhAHEiwAjOh3ZAxZd5N03R2hSNg0qd35bbtZUePwRBRiKdH4pVYzFo0AkIr7rNKlMhoCgrIQAvD_BwE
Kiddy pool	7.99	https://www.bol.com/nl/nl/p/intex-zwembad-sunset-glow-3-ring-61x22cm-kinderzwembad/9200000064125953/?bltgh=vf--kD3148oFZBM0oYpOIQ.kC7bs57b1T-0MoTbm-hNXQ_0_8.10.ProductTitle

Water Flow sensor

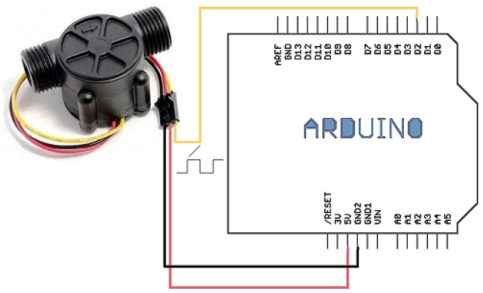
How it works:

The water flow sensor consists of three main parts. A turbine that is connected to a pipe input and a pipe output, a magnet that is in the centre of the turbine and a hall effect sensor(more on that later).

It works the following: If water is running through the pipes, it moves the turbine with the magnet in the centre. Due to the magnet spinning, the hall sensor senses a magnetic field rotation and outputs a high and low-level square wave(pulse). The frequency of the square wave output is dependent on the speed that the turbine is spinning, which is of course dependent on the flow speed of the water.

How to connect it:

The water flow sensor has three cables to connect. Two cables are used as an interrupt. An interrupt senses a certain state in the output (in our case a peak in the output) and stops the main action of analyzing the output to send the data. The last cable is just a simple connector cable to a PIN on the Arduino or breadboard.



https://www.electroschematics.com/working-with-water-flow-sensors-arduino/

How to calculate:

To calculate the flow speed from the square wave output, we can use this formula:

*Waterflow(Liters/hour)= flow frequency * 60 / 7.5*

Or determine the water's flow rate by measuring the cross-sectional area of the pipe and the average velocity, which will be the length of the pipe multiplied by the flow frequency. **[30]**

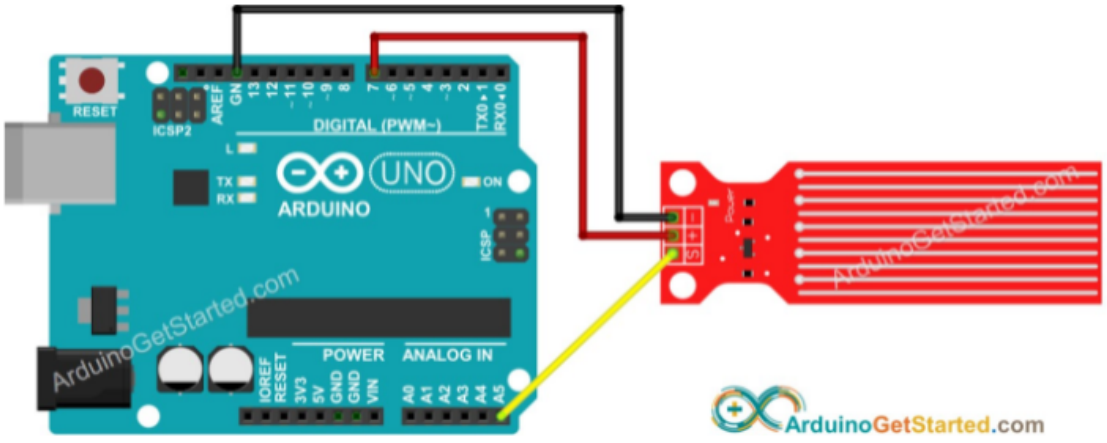
Water Height Sensor [31]

How it works:

The more water the sensor is immersed in, the higher the output voltage will be in the signal pin. The sensor has 10 copper traces that come in contact with water, 5 power traces and 5 sense traces. There is one sense trace between every two power traces. These traces are connected by water when submerged. The traces act as a variable resistor that depends on the water level. It has an inversely proportional relationship with the height of the water. So a higher water level means lower resistance. By measuring the voltage we can determine the water level.

How to connect it:
In order to prevent the sensor from corrosion too fast, the Vcc of the sensor should be connected to the Arduino's digital pin and only set to HIGH during measurement and not constantly.

Of course, an ideal sensor would need to withstand wear and tear for longer periods of time. In order to do this, the copper traces could be replaced with non-corrosive metals such as stainless steel.



[31]

How to read data:

Due to the water's potential impurity, because impure water could be conductive which would disrupt the readings of the sensors, the sensor needs to be calibrated first. [31] provides us with the code to read the values of the sensor. The sensor will only begin to measure once the minimum water height is reached. This is how we will calibrate the sensor.

Timeplan:

What?	Until when?	Who?
Research	22.12.2021	Jan+Dimitar+Jacelynn
Explanation Sketch	22.12.2021	Justen
Timeplan	22.12.2021	Anica
Sketch another idea	14.01.2022	Zalfa
Programming with Arduino (see different Modules in Chapter 6)	17.01 - 21.01.2022 (one week earlier than Presentation to have enough time to adjust)	Jan + Dimitar
Testing	Starting from 17.01	All
Mathematical prediction	21.01 to see if testing really works + proofs for presentation	Jacelynn
Model building (see different Modules in Chapter 6)	17.01 - 21.01.2022 (one week earlier than Presentation to have enough time to adjust)	Justen + Jonathan + Anica
Data analysis	24.01.2022	Zalfa
End Presentation	24.01.2022	Justen
First Prototype Presentation	21.01.2022	All / Justen speaking
Documentation	23.01.2022 (finish chapter 8 and 9)	All (separate work based on each topic)
Acquiring the sensors and model materials	14.01.2022	Jacelynn

Chapter 8: Validation

Validate your results through some tests and/or some scientific evaluation process

<To be prepared for the 8th to 9th week>

-Building a hypothesis with the math model and the research
-

Chapter 9: Results and Conclusion


[32]

Throughout the process of implementing our experiment, we've made changes along the way including the layout and the way the prototype works in a more efficient way. We decided that we could use 1 piping system instead of 2, this is because we didn't end up finding the purpose of creating two valves since we achieve the same result with only 1.

During our testing, we are really glad to say that our prototype works the way that it's supposed to. We managed to pump up water from the kiddy pool to the bucket where the water will flow into the pipe and it's where data is starting to get gathered. The water sensor will show the water height and as the water reaches the end of the pipe it passes through the water flow sensor. The water height sensor data starts from the value 194 in our test with the highest value of 562, the number will increase according to the amount of water inside the pipe (562 is equivalent to a full pipe). With the help of the water height sensor, it would show whether or not the pipe is filled up or has more water than its normal amount. Whereas the water flow values are in the range of 0.00 to 3.51, where 0.00 shows that there is no water flow. With this, it would be easier to determine if the water is flowing through the pipe or a blockage has happened.

We created a system where there are 4 LEDs that will turn on in different conditions such as; high water level and low water flow, high water level and high water flow, low water level and high water flow and lastly low water level with low water flow. Aside from that we also added a buzzer indication with two different sounds where the first one for a high water height and low water flow which is an indication of a possible clog in the pipes, where the second one with low water level but high water flow which tells us that one or both of the sensors might have an issue. To have a better understanding of the data we also created a visualization or user interface with the help of processing that projects the values of both the water height and flow out in real-time.

We can see that our idea could be further developed and work even more efficiently in the future. One could add infrared sensors to better view the blockage or record additional sounds with a microphone. If you work with several of our developed prototypes, you could find out the exact location of the blockade and how long it is so that workers can go down in that area purposefully. Besides other sensors, you can design an even better user interface, with a map to see the location directly and with warning sounds and different lights for different scenarios, from garbage to leaves to rats. In addition, what we created and tested so far is a prototype and therefore we think that we can expand and test it on a bigger and more accurate scale although it means that it requires a larger sensor network.

We must further develop our idea, and we should continue to think about the problem of the sewers, as this could mitigate flooding. Still, water is a valuable resource and will become more and more critical in the future in terms of climate change and increasing population.

Water Height	Water Flow
198	0.00
197	0.00
195	0.00
194	0.13
194	0.13
285	0.40
426	0.81
453	1.22
460	1.35
513	1.62
542	1.89
547	2.16
562	2.43
549	0.40
528	0.00
508	0.00
492	0.00
487	0.00
482	0.00

483	0.00
478	0.00
480	0.00
517	2.30
520	3.51
514	2.97
506	2.84
502	2.84
497	2.70
500	2.70
496	2.70
494	2.57
495	2.57
495	2.43
496	2.43
498	2.30
504	2.57
488	2.30
503	2.16
480	2.30
479	2.16
468	2.03

463	2.03
462	1.89
454	1.89
454	1.75
447	1.75
442	1.75
431	1.62
428	1.49
412	1.49
396	1.35
382	1.35
360	1.22
320	1.08
277	1.08
275	0.81
275	0.81
275	0.27
276	0.13
278	0.00
277	0.00
277	0.00

Codes Used:

```
SE-project
int wtrLvlH = 12;// pins for LEDs  that show whether the water level is high or low
int wtrLvlL = 13;
bool lvl = false;// booleans used for activating the buzzer
bool flw = true;
int buzzer = 3 ; // buzzer pin
int waterHeight; // water height
int wtrFlwH = 8;// pins for LEDs  that show whether the water flow is high or low
int wtrFlwL = 7 ;
int flowPin = 2;// waterflow sensor pin
double flowRate; // holds the flow rate
volatile int count; // integer that stores the number of impulses
void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  pinMode (wtrLvlH, OUTPUT);// The next four are for setting up the pins for the LEDs
  pinMode (wtrLvlL, OUTPUT);
  pinMode(wtrFlwH, OUTPUT);
  pinMode(wtrFlwL, OUTPUT);
  pinMode (flowPin, INPUT); // receives data from the water flow sensor
  pinMode (buzzer, OUTPUT); // sets up the pin for the buzzer
  attachInterrupt(0, flow, RISING); // setting up an interupt which executes the flow method
}

void loop() {
  // put your main code here, to run repeatedly:
  count = 0;
  interrupts(); // in the next three lines the loop is interrupted, then we count the number of pulses for one second and finally we resume with the program
  delay(1000);
  noInterrupts();
  flowRate = (count * 2.25); // The next three lines convert the pulses to L/s
  flowRate = flowRate * 60;
  flowRate = flowRate / 1000;

  waterHeight = analogRead(A0); // gives a reading of the water height sensor
  if (waterHeight >= 393) {
    digitalWrite(wtrLvlH , HIGH);
    digitalWrite(wtrLvlL, LOW);
    lvl = true; // if the water height is high then we turn on the LED that shows it and we set the boolean for the height to true since thats the first sign of a clog
    if (flowRate >= 1.6) {
      digitalWrite(wtrFlwH, HIGH);
      digitalWrite(wtrFlwL, LOW) ;
      flw = false;  // if the water flow is high we turn on the LED for it and we set the boolean for the flow to false because it is not a sign of a clog

    }
    else {
      digitalWrite(wtrFlwH, HIGH);
      digitalWrite(wtrFlwL, LOW) ;
      flw = true; // if the water flow is low we turn on the LED for it and we set the boolean for the flow to true because it is  a sign of a clog


    }

  }
  else {
    digitalWrite(wtrLvlL, HIGH);
    digitalWrite(wtrLvlH, LOW);
    lvl = false; //if the water height is low then we turn on the LED that shows it and we set the boolean for the height to false since thats not a  sign of a clog
    if (flowRate >= 1.6) {
      digitalWrite(wtrFlwH, HIGH);
      digitalWrite(wtrFlwL, LOW) ;
      flw = false; // if the flowrate is high then the LED for it is on and we set the boolean for the flow to false because it is not a sign of a clog
    }
    else {
      digitalWrite(wtrFlwH, HIGH);
      digitalWrite(wtrFlwL, LOW) ;
      // if the flow rate is low we turn on the LED for it
  if (lvl && flw) {
    tone(buzzer, 1000);
  // if both of the conditions are true we receive a signal from the buzzer that there is a clog
  }
  else if(lvl == false && flw == false) {
    tone(buzzer,2000); // if we have a low water level and a high water flow then that might mean that there is an issue with one of the sensors so we receive a different signal from the buzze
  }
  else {
    noTone(buzzer); // the buzzer is off if there is nothing wrong
  }



  Serial.print(waterHeight);
  Serial.print(",");
  Serial.println(flowRate);
  delay(100);
}
void flow() {
  count++ ;
}
// method for counting the impulses
```

```
UI
import processing.serial.*;

Serial myPort;

int x,y;
boolean draw= true;
String val;                     //initial "big string" we get from arduino
String co[] = new String[2]; //sets up Array for the values of the sensors
String display1, display2;        //variables for saving the values of the sensors outside the array

void setup()
{

  display1="0";
  display2="0";

  size(1920, 1080);
  background(0);
  String portName = Serial.list()[0];
  myPort = new Serial(this, portName, 9600);          //sets port and baud rate
}
void draw()
{
  fill(220);                                        //big grey box with red outline
  rectMode(CENTER);
  stroke(255,0,0);
  strokeWeight(15);
  rect(width/2,height/2,1820,980,90);

  textSize(120);
  fill(0);
  text("Waterlevel: "+display1,150,400);              //displaying the values of the sensors on the canvas
  text("Waterflow: "+display2,150,800);

  stroke(255,0,0);                              //resetting values
  rectMode(CENTER);


  if ( myPort.available() > 0) {                  // If data is available,
    val= myPort.readStringUntil(10);              //reads until new line
    val= trim(val);                               //deletes all unnecessary spaces,enters etc.
    if (val!= null  && val.equals("release") == false) {      //if values is not "null" and values does not equal false)

      co = splitTokens(val, ",");                 //splits value at ","
      printArray(co);

      if (co[0] != null && co[1] != null) {
        x = int(co[0]);                           //sets coordinates from arduino to variables in processing
        y = int(co[1]);
        display1= co[0];
        display2=co[1];



      }
    }
  }
}
```

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