UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

RedBull Racing

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Chapter 0: Introduction

Global warming affects the planet in a myriad of ways. Causing problems around the world that will only increase over time. Solving all these problems in a single project is impossible. Therefore one topic was chosen to focus on. The chosen topic is that of the rise of mosquito-borne diseases due to climate change.

The transmission of mosquito-borne diseases is caused by intricate interactions between the environment and population. The spreading of diseases is influenced largely by climatic conditions such as temperature and humidity. The results of climate change on the transmission of diseases are for example higher biting rates, faster pathogen replication, shorter reproduction times, and longer optimal breeding seasons.

There are certain weather conditions that mosquitoes thrive in. Mosquitoes are attracted to still-standing water, a high temperature, and high humidity levels in the air.
This caused the following solution to be developed in order, not to control the population of mosquitoes, but to help prevent the spread of diseases caused by mosquitoes entering buildings, and structures inhabited by humans.

The solution that was decided to be focused on is based on checking whether conditions outside and inside the house are at the optimum range for mosquito reproduction. This will be done by utilizing various sensors, including humidity and temperature as well as wind speed. When the risk of mosquitoes being in, around, and inside the house is high, this will activate a “lockdown” protocol: curtains will roll down, causing windows and doors to be “filtered”, helping to prevent mosquitoes from entering and potentially biting, preventing the spread of diseases.

Chapter 1: Literature Review

1. **Enhanced greenhouse effect**

Estimating the global risk of anthropogenic climate change

The analysis analyses the global risk of anthropogenic climate change. It takes into consideration the difference between a global temperature increase of 1.5 °C or 2°C. The risk factors of the analysis are based on three IPCC special reports that focus on the effects of Climate change. The analysis finds that even with a low amount of greenhouse gas emission the global risk factor will most likely double. The analysis recommends an increase in social adaptation and global mitigation to lower the risk factor. It also discusses three scientific challenges: evaluating how systematic climate risk is, assessing the effectiveness of adaptation, and understanding how effective societal adaptation can be.[5]

2. **Increasing temperatures**

The effect of temperature rise on grain production of certain winter crops (wheat, mustard, barley, and chickpea) in northwest India was assessed using historical data and a dynamic crop growth model, WTGROWS. The best time to sow was also determined in light of the seasonal temperature increase. Temperature changes are most likely to have an impact on the output of these crops, particularly wheat, which is already exhibiting symptoms of stalling in most parts of northwest India. The study of solar radiation–temperature interactions in wheat reveals several intriguing tendencies that differ from location to location. Given the tendencies in global climate change, a shift in sowing time is proposed as an adaptation approach. The basic and empirical relationships between yield and seasonal temperature change may be utilized to make a rough approximation of these winter crops' yield dependency on temperature rise. [23]

3. **Melting ice caps**

Glaciers and ice caps are fueled by snowfall and frost, and they lose mass and surface by melting or breaking off. We can not calculate the future development of these glaciers and ice caps, because we can not predict precipitation and temperature far enough into the future to be able to get any usable results. We can, however, say that they will decrease in surface and mass, because the current conditions are in favor of the factors that make them decrease, and we aren’t able to change that in a short enough period. [21]

4. **Rising sea level**

Three things are causing the sea level to rise: glaciers and ice sheets melting due to global warming, a slight expansion of water due to a higher temperature, and more of the water from land ending up in the ocean due to things like groundwater pumping. The primary cause, though, is global warming. This is significant because a very large number of people live on coastlines. The article mentions that “8 of the world’s 10 largest cities are near a coast”. A rise in sea level leads to more flooding, shoreline erosion, and storms. Important infrastructure will be damaged more often, putting even more people at risk and leading to repair costs. This also damages existing ecosystems, making it harsh on wildlife and can cause freshwater to get contaminated with saltwater. [10]

5. **Wildfires**

Is global warming causing more, larger wildfires?

According to research, there are four main critical factors that, combined, make up the reason for the increase in wildfire activity. Those four factors are earlier snowmelt, higher summer temperatures, longer fire season, and expanded vulnerable areas of high-elevation forests. Over the 34 years studied, years in which the snow would melt early (hence a long dry summer period) had five times as many wildfires as years in which the snow would melt later.
So less moisture equals more wildfires. With the warming of the earth, this could give us a disastrous forecast. [22]

6. **Decreasing agriculture**

Global food security under climate change

The article looks at how food security is affected by climate change. It divides food security into four elements: availability, stability, utilization, and access. Food availability is expected to be affected by rising Co_2 levels, rising temperatures, and an increase in natural disasters. Stability is expected to be affected by weather becoming more variable. Utilization is expected to be affected by higher temperatures leading to more cases of food poisoning and increasing outbreaks of diseases. Access is expected to be affected by changing food prices. [7]

7. **Species going extinct**

WILDLIFE IN A WARMING WORLD

The report looks at the effects of manmade climate change on wildlife survival. The report does this by specifically looking at the WWF's 35 Priority Places which are regions that contain irreplaceable biodiversity. In these places, they then look at the Percentage of species projected to be at risk of local extinction by the 2080s.

The report finds that at a 2°C global temperature rise, about 25% of species in the Priority Places are at risk of local extinction. At a rise by 4.5 °C, the risk percentage rises to almost 50%. The report recommends: collecting more data to be able to act in an informed way, supporting communities to conserve nature, protecting Priority Places, and working together. [6]

8. **Carbon capture**

Carbon capture and storage is the process of removing CO2 before or after combustion. There are 3 methods of capturing carbon. pre-combustion, post-combustion, and oxy-fuel combustion. pre-combustion capture removes part of the CO2 before the completion of combustion. Post-combustion capture captures the CO2 from the gasses resulting from the combustion. and oxyfuel combustion is combustion using pure oxygen which results in a very low CO2 output that can easily be captured. The captured CO2 can be stored underground since bedrock is porous and gas can permeate in the openings. [17]

9. **El Niño**

El Niño/Southern Oscillation describes a shift in wind and temperature that occurs every few years in the Pacific Ocean, near the equator. There is also La Niña, which is the opposite of the shift that occurs with El Niño. Both have tremendous impacts on climates which can be felt indirectly worldwide. El Niño leads to a slight increase in temperature as less warm water is cycled deep into the ocean. El Niño leads to increased rain and flooding in South America and can lead to droughts in Asia. This impacts food production which causes economic strain. El Niño/La Niña are natural processes. [11]

10. **Who produces the most carbon emissions**

In this report researchers quantified the output of emissions by grouping all produced fuels and calculating their tonnes of CO2 equivalent. The result of this research shows that the 100 largest producers of carbon emissions by this standard make up about 71% of all global emissions. [10]

11. **Deforestation**

Forests, mainly tropical forests, make up the second-largest CO2 reservoirs in the world, the first being oceans.When forests are growing, or in other words are still relatively young, photosynthesis surpasses respiration, meaning these forests consume a substantial amount of CO2 more than O2. Once these forests are cut down, much of the once stored CO2 is then once again released into the atmosphere.This is then attributed as the main reason why deforestation and forest degradation are major contributors to global warming. [3]

12. **Acidifying and warming of oceans**

Since the end of the preindustrial era, the global oceans have absorbed 29% of the entire world's CO2 emissions.Hydrogen ions are what turn a solution acidic, hence once the Hydrogen ion concentration in the ocean becomes too great and the levels of bicarbonate ions become too low, the ocean surfaces start becoming acidic.Many crustacean life forms in the oceans rely on the bicarbonate ion levels, to build their shells and grow within the ocean environment.As a result of this, ocean surfaces are 30% more acidic than they were at the beginning of the industrial revolution. Oceans' CO2 absorption rate is directly related to ocean surface temperatures.In the past years, it has been seen that the polar ice caps are melting at alarming rates, which can only mean that the ocean surface temperatures in the region are rising, and hence directly warming the area. [8]

13. **Coastal erosion**

The predicted increase in sea level for the 21st century is from 10-90cm. 10cm wouldn't have much of an impact, but it's also an extreme lower bound prediction, whereas 90cm would have vast consequences. Over 100 million people live within a meter of sea level. Entire islands could be wiped off the map. The increase in sea level compounds coastal erosion, "the rate of shore erosion is approximately two orders of magnitude greater than the rate of sea-level rise". The loss of coastline exposes buildings and infrastructure more directly to wear from the ocean. [12]

14. **More mosquito-borne diseases due to higher temperatures**

Mosquitoes and mosquito-borne diseases and their pathogens thrive in warmer environments. These can also be seen as weather stages change, mosquitoes are much more common during the summer period, rather than winter. While warmer temperatures can bring about droughts, it's the stagnant pools of water as well as indoor water storage, that create perfect breeding parameters for mosquitoes. This means that with an increase in overall global temperature, summer weather may last longer, and thus prolonging the infection period, and causing mosquito-related deaths to soar exponentially. [9]

15. **Energy consumption in commercial buildings**

Between 2001-2011 the energy consumption has increased by 43.77% globally. This huge growth happened even though 1/3rd of the world's population still does not have access to electricity. At the moment the growth in energy consumption is faster than the growth of the world's population. This is because of the increasing need for individual energy. In Europe commercial and residential buildings use about 38,7% of all energy. The majority of this energy goes to space and water heating. Besides this, energy usage for appliances is growing every year. [4]

16. **The ozone hole and its effects**

For some reason, humanity has had an impact on ozone levels over Antarctica. In the past decade, total ozone levels there have declined by around 50%. The ozone layer around our earth stops UV radiation, which can penetrate organisms' protective layers. UV radiation can cause cancer, sunburn and can damage DNA.
Nowadays, there is a global program that tries to limit the amount of ozone-reducing gasses that are emitted, so the ozone layer can be preserved.
[14],[16],[19]

17. **Solar radiation**

Changes in energy-related parameters in climate models from 1950 to 2100 give a new viewpoint on critical climate change concerns, highlighting the importance of shifting clouds in providing an aperture for solar radiation. Longwave (LW) radiation abnormalities, on the other hand, are thought to dominate the planetary imbalance, and that warming is caused by a "blanketing" effect.

The planetary albedo, which may fluctuate at high latitudes as snow and ice change, or more broadly as clouds or aerosols change, is the principal restriction on incoming top-of-atmosphere (TOA) solar radiation, aside from the sun-Earth geometry. Clouds also aid in the regulation of outgoing longwave radiation (OLR). [25]

18. **Fossil fuel**

Publications collecting historical energy information allow for the estimation of fossil fuel CO2 emissions dating back to 1751. Etemad et al. (1991) provided a comprehensive compilation of coal, brown coal, peat, and crude oil output by country and year. The energy statistics time series is extended back to 1751 by footnotes in the Etemad et al. (1991) publication. Mitchell offered summary summaries of the fossil fuel trade (1983, 1992, 1993, 1995). Mitchell's research tracks solid and liquid fuel imports and exports by country and year. These pre-1950 production and trade data were digitized, and CO2 emissions were calculated using the methods described in Marland and Rotty (1984) and Boden et al (1995). Andres et al. give more information on the contents and processing of historical energy statistics (1999).

The estimates of CO2 emissions from 1950 to the present are based mostly on energy figures given by the United Nations (2009). [26]

19. **Solar panels in the Netherlands**

The last few years, the amount of solar panels in the Netherlands has increased rapidly. Not only are there more and more panels placed on rooftops, but the number of photovoltaic power stations (or also known as solar panel parks) has also increased as well. In 2020, 25% of all power came from renewable sources, while a year prior that was 18%. The amount of energy coming from solar panels has increased by 50% between 2019 and 2020. [18]

20. **BioUrban**

In the city of Puebla, a starting company named BioMitech has developed a helping solution to the increasing pollution on earth: the BioUrban. This is an artificial tree that can suck up as much CO2 as 368 trees could, and exchange it for Oxygen. The BioUrban measures 4.1 meters and makes use of microalgae. Their purpose is not to replace real trees, but to be placed where there is not enough space for a real forest to be planted, such as crowded and busy cities. [20]

Chapter 2: Identification of General Problems and Challenges

For picking certain topics from the list, we thought it would be useful to pick those which are rather general and broad, instead of the more specific topics. These would be easier to work with in the future of this project, although it does not show we will according to the upcoming assignments.

1. **Enhanced greenhouse effect**

The main source behind the entire climate change problem: the problem of the increasing amounts of CO2 in the air, the warmth being trapped on earth, and therefore the temperature constantly rising. What can we do against the enormous (increasing) amount of CO2? What effect will the increase in CO2 have on the world?

2. **Increase in sea level**

Increases in sea level are caused by glaciers and ice sheets melting due to global warming, a slight expansion of water due to a higher temperature, and more of the water from land ending up in the ocean due to things like groundwater pumping. If the sea level continues to rise this will lead to more coastal erosion, more floods, and storms. This will endanger important infrastructure and ecosystems
How can we prepare for floods? How can we decrease the damage caused by floods? How can we protect ecosystems from rising sea levels?

3. **Energy consumption in commercial buildings**

Most of the energy used in residential and commercial buildings is going towards the heating and cooling of spaces and water. However, there is a growing trend in using energy for devices and appliances.
While monitoring general energy usage is quite easy, it is difficult to monitor which specific devices and rooms are using the most energy in buildings. What is specifically using the most energy in the building? What is the least invasive way to limit the usage of energy in homes and buildings? Is the solution going to be cost-efficient enough to where the energy savings will pay off in a short period?

4. **More mosquito-borne diseases due to higher temperatures**

As mosquitoes thrive in warmer temperatures. Increasing temperatures will therefore cause an increase in the rate of infections and thereby death caused by mosquitoes.
How can we prevent mosquito infections? How can we improve recovery from infections?

5. **Contamination/salinization of freshwater**

Freshwater sources are getting contaminated by saltwater due to the rise in sea level. This damages ecosystems and makes the water unusable for humans. Is there a way for us to prevent the salt from getting into the freshwater or efficient ways to remove the salt?

6. **The collapse of ecosystems**

In nature, everything is in balance. There is a system that makes sure that everything remains the way it is. However, the littles changes can disrupt all balance, having catastrophic results. Climate change is creating many of these changes in ecosystems such as rising temperatures, floodings, extreme weather conditions, and forest fires.
These changes may lead to the extinction of species.
What can we do to maintain or regain balance? How can we save species from extinction?

7. **Solar panels**

The use of solar panels has become larger and larger over the years and has shown significant results when looking at the total amount of green energy over the years. Together with wind turbines, these green energy sources are believed to be the main source of renewable energy in the future. Will this be true? How can we make this prediction a reality?

8. **Fossil fuel**

Fossil fuels are the main source of energy in the world. On the other hand, they are also the world's number 1 CO_2 pollutant. In 2018, it was determined that 89% of the CO_2 emissions in the world were attributed to fossil fuels. Fossil fuels are greenhouse gasses that trap heat in our atmosphere. This causes the overall world temperature to rise. Coal is the dirtiest of the fossil fuels and on its own makes up 0.3 degrees C of the world's overall temperature rise, hence making it the single largest contributor to global warming. [13]

How can we overcome the problems that occur with switching from fossil fuels to energy sources that are less harmful to the environment? What are the biggest problems that we have to overcome? How can we try to limit the amount of pollution from machines that still use fossil fuels? Is there a way to convert the gasses they emit into less harmful gasses?

9. **Wildfires**

As a result of the increasing temperatures, the number of wildfires has risen dramatically. This is not only because wildfires happen faster because it is hotter, but also because the amount of moisture in the air is less due to this fact. What direct solution is there to prevent the growing wildfires? Is there a way we can stop wildfires from spreading?

Chapter 3: Identification of Relevant Problems

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

1. **Energy consumption in commercial buildings**

Commercial and residential buildings in Europe use about 38,7% of all energy [4]. Being able to use this information as effectively as possible can help save energy making the problem relevant. Making buildings use energy as effectively as possible right now will save a lot of energy in the future making it urgent. It's interesting because there are many ways we can start looking at it and energy consumption in buildings is something that is directly affected by us.

2. **More mosquito-borne diseases due to higher temperatures**

Mosquitoes are one of the world's most deadly animals because of the diseases they carry[27]. This makes preventing their increase very relevant and urgent. It's an interesting topic because we can look at the way diseases are spread and what kind of environments mosquitoes thrive in. It's also interesting because no one likes mosquitoes and decreasing their numbers would be nice in this case.

3. **Solar panels**

Ever since we discovered the extremely damaging impact of pollution caused by finite resources, we have been trying to replace those energy sources with renewable ones, such as solar panels and wind turbines. We must speed up this process because there is growing energy demand. This makes it very relevant and urgent. It is rather interesting to look at the progress we've made over the last few years due to the impact of renewable energy.

4. **Wildfires**

Because of rising temperatures the rate of wildfires is rising. This is harming ecosystems, infrastructure, and agriculture which makes preventing wildfires very relevant and urgent. It's an interesting topic because there are multiple factors influencing forest fires we can look into and there are many things it affects.

5. **Floods**

Floods are increasing because of rising sea levels. They damage ecosystems, infrastructure, and agriculture. Preventing them therefore is very relevant as it affects many things. The consequences of a fallen ecosystem or balance in nature are worse than most people think. It's urgent as sea levels keep rising [10]. It's interesting as it can directly influence the Netherlands which is the country we're all currently living and studying in. Most people would become homeless, and lose all of their belongings.

Chapter 4: Problem Selection and Motivation

We chose to tackle the problem of the increase in the prevalence of mosquito-borne diseases due to higher temperatures. [9] The first reason we chose this subject is that we thought it was possible to make something. The second reason is that it's quite specific and not too broad. The third reason is that it's a slightly more original and less talked about topic than the rest of our topics.

The most important reason for choosing this subject however is of course that it's an urgent and relevant topic. For example, in the past five decades the incidence of dengue, the most rapidly spreading mosquito-borne viral disease, has increased 30-fold [28]. Because of global warming mosquitoes will only thrive more due to higher temperatures and higher humidity [9]. As the amount of mosquitoes rises so does the chance of getting infected by the pathogens they carry. Another problem is that the areas most affected by mosquito-borne diseases aren't the countries with the best healthcare making the effects of the diseases even worse. [28] [29]

Mosquito-borne diseases are spreading throughout the globe and all of a sudden resurfacing in locations where they had been dormant for decades. They are expensive and hard to treat, and they spread so quickly that it's usually not feasible to treat. Those reasons are why it's even harder to battle this problem in the places in the world where they are most common. They are most common in areas of the world where it is warm and humid. People In these countries tend to live in poverty. This is why we want to find a way to prevent the spread of the diseases in the first place or stop the mosquitoes from infecting humans.

Although the other topics were certainly interesting and urgent as well, and are in dire need of a solution, we came to the decision that these subjects were not the most suitable for this project. We thought that the topics of the solar panels, wildfires, and floods were too big of a scale and we could not properly work on something this broad and big. As for the subject of commercial buildings, we simply thought that this topic is used and talked about a lot and wouldn't be original anymore: we most likely would not be able to contribute much anymore.

Chapter 5: Potential Solutions

These are our possible solutions:

1. Sensors around the house with recommendations for going outside or taking preventative measures, with a display or text message which you can read.
There are a few ways in which mosquitoes could be detected. One option would be trying to detect the mosquitoes directly using a camera system [33]. Another option is using audio, identifying the sound a mosquito makes [35]. Both of these methods require quite a bit of processing. An easier method would be identifying conditions in which mosquitoes thrive and using that information to determine when to alert users. When the environment is within the range of humidity and temperature that mosquitoes survive in, an alert could be sent to a user's phone via text message or a notification informing them of potential mosquitoes and advising them of proper precautions.

2. A portable sensor box, with a battery, which you can take with you on vacation to get accurate advice for the region.
There are two kinds of measurements on which the advice for a region could be based. The first one would be to measure the number of mosquitoes. For this measurement, a camera and mosquito detection program would be needed. The latter would require a lot of computing power [33] and wouldn't work great on a small portable box one could take with them on vacation.
The second kind of measurement would be to measure the air humidity and temperature and then based on that calculate how well a mosquito would thrive in the environment. This would be easier to implement into a portable device.
A connection with an app and the device might be possible so no display is needed on the box itself. Meaning less power is used by the box.

3. Making a spot that attracts mosquitoes, and a camera detecting the number of mosquitoes and then comparing this to the usual average for this region.
To achieve this solution we have to be able to detect mosquitoes. The easiest way to do this seems to be with a camera. Sonar wouldn't work because it needs a narrow beam and a narrow radiation pattern. Temperature measurement also wouldn't work for mosquitoes that are cold-blooded. One way to detect a mosquito with a camera is to detect color differences. To do this there needs to be a big contrast between the mosquito and the background so we would need a white background. Another way is tracking the mosquito. This is done by looking at the difference between images. [33]
The other part of this solution is to attract mosquitoes. To do this the most effective way seems to be to use carbon dioxide traps. These traps will make it easier to measure the number of mosquitoes in the area. [34]

4. Making a home automation system with sensors that read the outside conditions, and then making changes, so putting screens in front of your windows, or turning the aircon on instead of opening a window. Maybe turning a fan on/off?
For this method, we would use the same methods for detecting mosquitoes or the conditions in which mosquitoes thrive, and then use that to control devices in a smart environment.

5. Stimulating the planting of mosquito-repelling plants.
Since plants are unable to flee from danger, they have been using chemical defenses to protect themselves from enemies. They release toxins, which make insects for instance feel like shit. Some plants have throughout evolution created toxins that are repellent for mosquitoes. Sometimes the plant as a whole can serve as a good mosquito repellent, and sometimes the repelling oils need to be extracted from the plant. In both cases, stimulating plants in the area will help. [30]

6. The other option is a system that sprays a non-toxic mosquito repellent depending on the time of year/ conditions. Non-toxic mosquito repellents do exist, for example, lavender, lemon eucalyptus oil, cinnamon oil[31],[32]. They are effective in repelling mosquitos and killing the mosquito eggs in a very localized area. However, these usually only last for about 3 hours so a system that automatically disperses it in rooms periodically based on outside conditions would work quite well.

Chapter 6: Solution Selection

Of the 5 possible solutions, we determined that solution 4, the smart home solution, was the best choice for this project. The solution that focuses on mosquito repellent plants is far outside the scope of this project, while the rest of the solutions are all closely related. We didn't select the third solution because it focuses on detecting mosquitoes themselves, which would require the use of advanced programming. The remaining solutions all measure the properties of the environment to determine when to take action. The other solutions all need to measure the humidity and temperature of the environment, which should be achievable for this project. Overall, solution 4 centers around a smart home. This fits well with the focus of the project and is achievable while remaining challenging enough. It's also more interesting because it interacts with devices around the house instead of just sending a text or notification.

The table below contains an outline of our project modules and who does what.

Module	**What**	**Who**
Temperature and humidity sensors inside	Creating a sensor that measures the humidity and temperature inside to decide on the measurements needed	Denissa, Door, Tjeerd
Temperature and humidity sensors outside	Creating a sensor that measures the humidity and temperature outside to decide on the measurements needed	Denissa, Door, Tjeerd
Mosquito research	Researching the preferable circumstances for mosquitoes to thrive. Based on this information the system will decide when actions need to be taken	Nina
Outside weather forecast checker	A program to check the weather forecast of the area to use for an environment assessment	John
Home automation system: contains two parts		Hielke, John, Rafael
part one: controlling the machines	Making the sensors be able to send information, receiving this information and sending a command to the moving parts of the system	Hielke, John, Rafael
part two: deciding course of action based on sensors	The program that decides when action is necessary. This decision is based on information provided by the sensors	Hielke, John, Rafael
Team leader	Organizing the team; Submitting files	Hielke
Documentation	Keeping the documentation file up to date	Door, Rafael

Purchases	purchasing materials	Door, Rafael, Hielke
Preparing the final demo		Hielke, Nina, Tjeerd, Denissa, Door
Presentations		Hielke, John & Tjeerd

Chapter 7: Methodology

Data collection

- Humidity and temperature sensors connected through arduino
- Data sent to mobile phone through bluetooth module HC-05

Data visualization

- Mobile phone app
- Data sorted into categories of inside and outside temperature & humidity

Research into the topic of optimal conditions, with respect to humidity and temperature, for mosquito reproduction was carried out in order to understand best in which interval the DC motors controlling the blinds should be activated. Research into a discrete 3D printed housing for the components was carried out as well to better the comfort and seamless integration of the apparatus into its environment.

Optimal location for implementation

In order to understand where this prototype should be implemented, one must first understand where and what mosquito hotspots would look like. These hotspots are normally dark humid areas. However, in order to best use this prototype, there should be various units spread out throughout the area in which it is desired to control mosquitos. Optimal places would be areas in which the humidity and temperature could have the perfect reading, hence placing them in the opposite side of heaters would allow for an accurate temperature reading of the room, as well as not too far away from windows. This allows the sensors to collect eligible data and act accordingly.

To Do

- ☐ Getting humidity sensors
- ☐ Getting temperature sensors
- ☐ Getting wifi modules
- ☐ Researching mosquito environments
- ☐ Connecting sensors to a machine/Arduino
- ☐ Controlling appliances through Arduino
- ☐ Programming when action should take place
- ☐ Making a (miniature) roll down window screen
- ☐ Building our model home
- ☐ Casing our sensors and control unit

- ☐ (If time left app/text connection via phone)

Validation of Data

In order to validate our results the humidity that the sensor measures will be affected by the use of a plant sprayer. The sensor should report this change which will result in measures being taken. These measures will consist of a window screen rolling down in a miniature home to prevent mosquitoes from entering. The miniature home is a way to show the solution is valid without having to construct a life-size window and window screen

Part of the individual sensors has to be finished before we can integrate them into our project. Therefore, this will be the part which we are going to focus on first. After this, the part of the research will be hugely important, because we're going to have to calibrate the actions taken by the Arduino to the conditions of the environment.

Risk assessment of Data Validation

To keep this validation method as safe as possible, one must consider the implications of using water near electronic devices such as the arduino. Even though the plant sprayer is a good technique to check whether the sensors are working properly and collecting data, one must keep in mind not to spray directly onto the sensors but rather spray around them and wait to check for a change. This way water never hits the sensors and arduino directly, minimizing the potential safety hazards of water near electricity.

Target Audience

Since our solution involves sensors and a microcontroller, it will, of course, cost money. The audience we're targeting therefore is more the people who already have a smart-home solution in place. This would mean that we could use an already existing infrastructure.

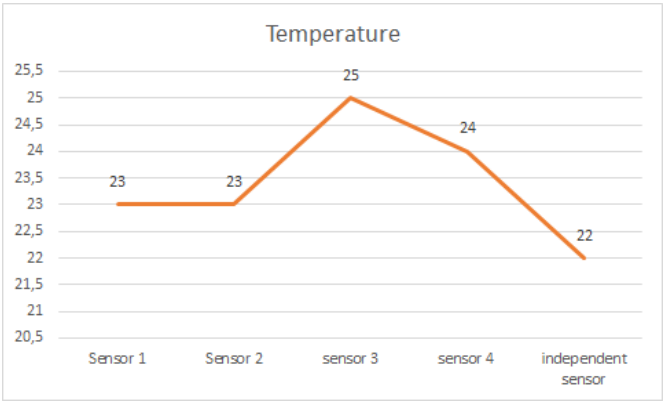
List of sensors used:

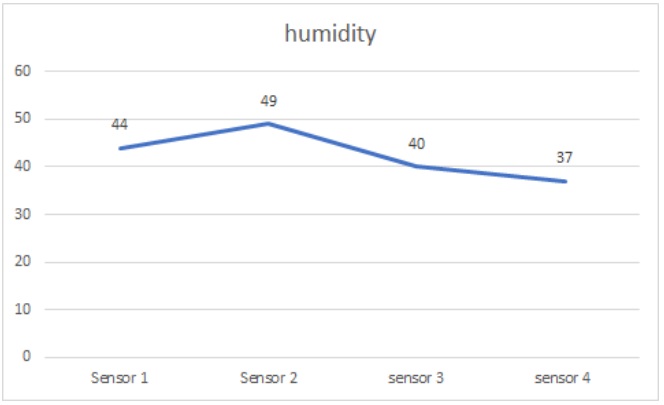
Sensors used in the construction of the Mosquito Observation System (MOS):

- ☐ Humidity and Temperature sensor DHT11 (2.50Eur). x2
- ☐ DC motor 9V (comes in Proto Arduino kit).
- ☐ Bluetooth module HC-05 (If connection to phone via app is made, already owned).

Chapter 8: Validation

The first step to validating future results was to compare the measured values of the used humidity and temperature sensor to each other and an independent sensor. The results of these measurements can be seen in the tables below:





There are a few things to notice about these measurements. The first being that no independent sensor was used for the humidity check. This affects the validity of the results since both temperature and humidity are being measured by the same sensor. However, the sensors can still be compared to each other, therefore these measurements are still credible. Now for the results themselves; The temperature sensors seem to sense a slightly too high temperature but this is a fairly low amount that can easily be accounted for. The humidity sensors have a greater distribution. This can be explained by reason that the air humidity was likely being affected by the breath of the researchers during testing.
From these results it can be concluded that the sensors are alike enough that all of them can be used for our research.

The next way to validate the results is to research the values mosquitoes thrive in. The results of our research regarding these values are as follows:

Temperature:
For *Ae. aegypti* and *Ae. albopictus* (carriers of dengue virus, chikungunya virus, Zika virus, West Nile virus, yellow fever):
Mosquitoes will bite at any temperature they are active. Mosquitos biting temperatures are between 15 °C and 36 °C, with the most activity at 28 °C, however, this temperature varies between different mosquito species. Females are able to sustainably fly between 15 °C and 32 °C, and feed more quickly between 26 °C and 35 °C. *Ae. aegypti* will die around 40 °C. [44]
The existence of dengue within *Ae. aegypti* is more common above 60% humidity and between 24 °C and 31 °C. [45]

Humidity:
Increase in humidity led to higher hatch rate, but temperatures above 32 °C yielded lower hatch rates. Higher humidity helps mosquitoes thrive, it's recommended to not water yards "that experience high temperatures such at 32˚and 35℃," to help control the population. Relative humidity has little effect on mosquitoes' ability to fly. Relative humidity between 30% and 90% had little effect. [41]
Mosquitos can lose up to 40% of their water content. Evaporation rate depends heavily on the humidity. Lower humidity leads to drier conditions, with smaller females. Smaller body size leads to lower vectoral capability. *Ae. aegypti* had the lowest mortality rate around 27 °C. [1]

Windspeed:
Wind is effective against mosquitoes, and a fan is recommended as a means of protecting oneself from mosquitoes in the backyard. [42]
Mosquitoes' average flight speed is about 1 meter per second. Traps catch far fewer mosquitoes with as little as 0.5m/s of wind, with a 75% reduction in caught mosquitoes with 1m/s of wind. "Trap catches are inversely related to wind speed at all velocities and even the lightest winds reduce mosquito flight." [43]

Overall:
Seems like humidity is difficult to use as a good estimator, but lower humidity is associated with lower lifespan, lower vectoral capability, smaller egg sizes and lower hatching rates. Possible targeting of humidity via survivability of viruses at relative humidity levels. Good bounds might be between 40% and 90% humidity. Temperature is a better estimator. Good bounds seem to be between 15 and 35 degrees as limits, we could probably use 22-32. Wind speed plays a large factor, it seems like if the wind is over 1 meter per second (3.6 km/h) there's relatively little risk.

Validation:
Due to the lack of available methods to reliably measure the local mosquito population as well as the lack of mosquitos at the time of developing the prototype, it was not possible to validate the effectiveness of our data personally. However, all available scientific literature on the subject points to our findings being true. This is why even though it was not possible to validate anything ourselves we still felt confident that our measured values were correct.

Chapter 9: Results and Conclusion

One of the first things the researchers came across during the assembling part of the research was the redundancy of a second arduino. The reason a second Arduino was believed to be necessary was that the researchers thought the inside and outside sensors would need a separate Arduino. The researchers later realized that a second Arduino was unnecessary as both sensors could be connected to a single one. This realization also made the wifi modules obsolete as there was no more need for communication between Arduinos. There was still a need for communication between the single Arduino board and the app but this connection could be established with a bluetooth module which one of the people in the research team already had experience with so it was decided to use this communication method.

During the later stages of the assembling the researchers concluded that establishing a connection between the Arduino and some weather measure database wasn't viable in the time given. This was in part due to the difficulty in programming the wifi module. For this reason and because of the researchers inability to acquire a wind sensor, the prototype is unable to acquire data about the wind speed. This is unfortunate because wind speed is an important factor in calculating the risk of mosquitoes. Therefore this does take away some of the prototypes' effectiveness, however because of the other measured values the prototype can still be effective.

Conclusion

For this project, we needed to select a topic related to climate change. Various topics were discussed, and eventually the topic chosen for further investigation in this project was the increase of mosquito borne diseases. We chose this topic because it is a topic that is not talked about very much, hence the importance of raising awareness for it. In addition, it is a very specific problem, making the generation of pinpointed solutions much simpler.

This topic is currently important to address due to an increase in global temperatures over the last few decades, caused by pollutants and increased greenhouse effect, mosquitoes have more widespread breeding grounds, leading to an increase in the percentage of infections caused by mosquito bites.

We considered many solutions for this topic, however one showed more promising results. This solution consisted of having an apparatus that measures air humidity and room temperature, and sending this data to an app on the user's phone letting them know the real time conditions of the area in which the apparatus is placed. The apparatus is configured with a specific set of parameters regarding temperature and humidity, targeting the conditions under which mosquitoes are active. When these parameters are reached, the apparatus automatically covers the windows of the location it is placed in with screens. This helps to prevent mosquitoes from entering the area in which the device is installed, and therefore stop the expansion of the mosquito population inside the building which the device is trying to protect. This drastically reduces the chances of people being bitten by mosquitos, thereby lowering the infection rate of mosquito borne diseases.

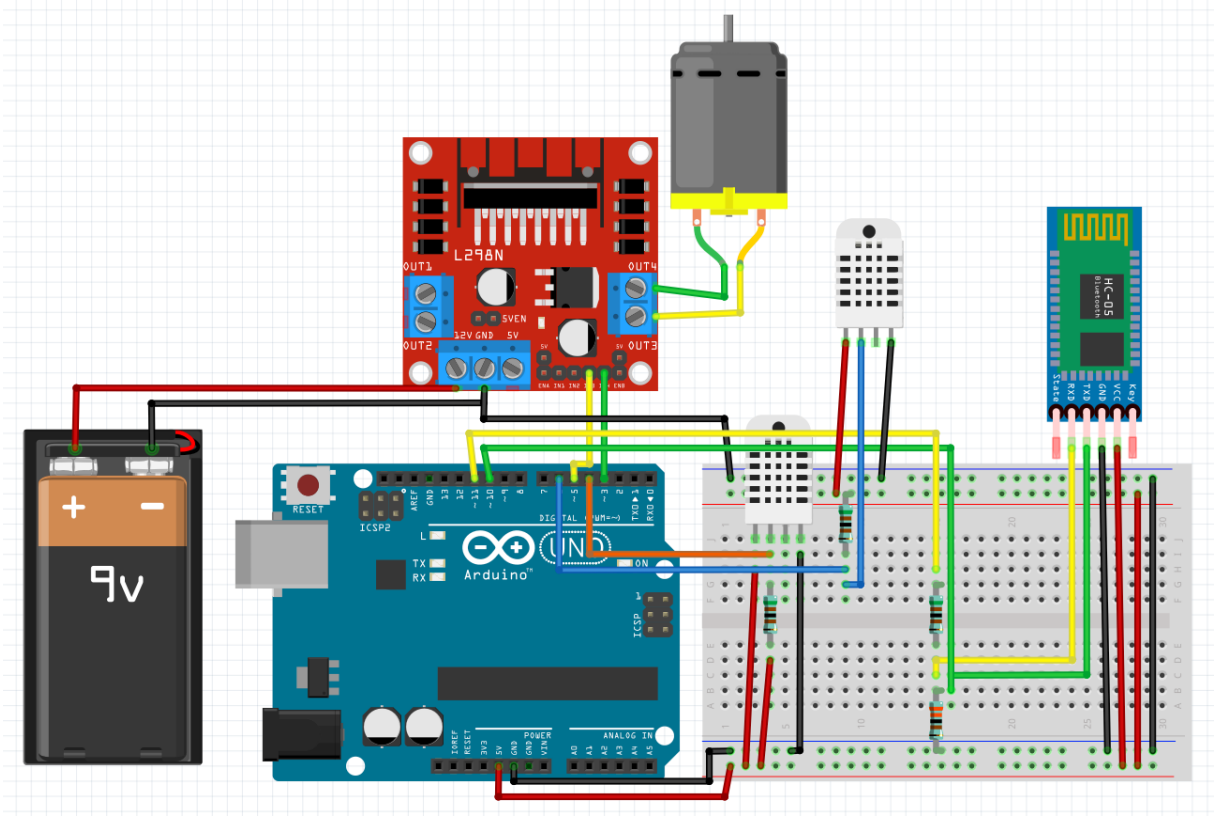
The solution built for the problem chosen, works quite effectively, measuring real time data with a small update delay. It was originally decided to connect 2 arduinos with wifi modules. However, this idea was later abandoned for a few reasons:

1. It was not realized at the beginning that once both Arduinos are connected to each other so they can send and receive data between themselves, the arduinos cannot connect to anything else.
2. Connecting the wifi modules was a big challenge and required additional adapters that were not known to be needed until a later time.

Therefore a much simpler method of connecting 1 arduino to a mobile phone app via bluetooth was adopted.

Overall, the prototype does not match the earliest expectation for it, it does however fulfill most of the demands set out for it. The most important missing part is the absence of a way to measure and visualize wind speed. This does considerably affect the effectiveness of the prototype. A great way therefore to improve the prototype is to add a method to receive data on wind speed.

Documentation:



Model home:

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