UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

Team S.O.M.B.R.E.R.O

Stationary Observant Multi-sensor Battery-powered Rapid Evacuation Response Operator

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Chapter 0: Introduction

We are team “Sombrero”, a multicultural team of 7 undergraduate highly motivated University students. With our palette of skills and backgrounds from Creative Technology, Mechanical Engineering, BioMedical Engineering and the Visual Arts, our team is ready to create versatile solutions for a plethora of problems.

Over the past 10 years, the world has experienced an average of 64,100 wildfires annually and an average of **6.8 million** acres burned annually. Wildfires have ravaged forested areas since history began, but in recent years they have gotten a lot larger and more frequent. Whether this is due to human impact on the environment or other factors, the problems and risks they pose persist. Their destruction of flora, fauna and infrastructure is catastrophic.

In order to permit rapid response to emerging fires and to allow real time updates to communities that might be affected we propose Project: Sombrero, a network of sensors and a connected app that allows rapid detection of emerging blazes and tracks the movement of fires. Each sensor functions independently, and without a central power supply for the network to provide maximum reliability.

Our solution is future oriented as it has a low environmental impact and little to no disruption to native biospheres. We want to create a system where firefighters can detect a fire before it becomes a problem in order to save ecosystems and create a future we can be proud of.

Chapter 1: Literature Review

List of Publications:

1- Title: Pluvial flooding: new approaches in flood warning, mapping and risk management

Summary: In this paper several warning services for sources of flooding other than from fivers and the sea are investigated. The focus lies on pluvial flood (flood that results from rainfall generated overland flow) warning services.

Link: https://onlinelibrary.wiley.com/doi/10.1111/j.1753-318X.2009.01034.x

Citation: Falconer, R.H. (2009), 'Pluvial flooding: new approaches in flood warning, mapping and risk management', Journal of Flood Risk Management, 2(3), 10.1111/j.1753-318X.2009.01034.x

2- Title: Wildfires, Global Climate Change, and Human Health

Summary: A summary of the status of wildfires under climate change, current knowledge and gaps about the health risks of wildfires, and the challenges of developing and implementing strategies for reducing associated health risks.

Link: https://www.nejm.org/doi/pdf/10.1056/NEJMsr2028985?articleTools=true

Citation: Rongbin Xu, M.B. (2020), 'Wildfires, Global Climate Change, and Human Health', New England Journal of Medicine, 10.1056/NEJMsr2028985

3- Title: Prevention and management of health hazards related to heatwaves

Summary: This article describes a study which is designed to improve public health responses to heatwaves. Results showed that prevention requires multiple actions, like a health system which coördinates with meteorological warning systems to give public and medical advice, and which improves urban planning.

Link: https://www.tandfonline.com/doi/pdf/10.3402/ijch.v68i1.18293?needAccess=true

Citation: Matthies, F and Menne, B. (2009), Prevention and management of health hazards related to heatwaves, International Journal of Circumpolar Health, 68:1, 8-12, 10.3402/ijch.v68i1.18293

4- Title: Geomorphological Hazards and Disaster Prevention

Summary: This source relates to all geomorphological hazards, such as volcanic eruptions, earthquakes, mountain/ flood/ weather hazards... This source also contains basic concepts on the hazard assessment for risk analysis and management.

Link: https://books.google.nl/books?hl=en&lr=&id=-nDlilgu08YC&oi=fnd&pg=PA1&dq=disaster+prevention&ots=pD3T1rOBzK&sig=BH1k7ILPdQWDAl8_1t0z-YgrgJw&redir_esc=y#v=onepage&q=disaster%20prevention&f=false

Citation: Alcántara-Ayala, Irasema, and Andrew Shaw. Goudie. *Geomorphological Hazards and Disaster Prevention*. Cambridge University Press, 2011.

5- Title:Real-time tsunami inundation forecast system for tsunami disaster prevention and mitigation

Summary: About tsunami forecasting systems, which developed a real-time tsunami inundation forecast system that can complete a tsunami inundation and damage forecast for coastal cities at the level of 10-m grid size in less than 20 min.

Link: https://link.springer.com/article/10.1007/s11227-018-2363-0

Citation: Musa, Akihiro, et al. “Real-Time Tsunami Inundation Forecast System for Tsunami Disaster Prevention and Mitigation.” *The Journal of Supercomputing*, vol. 74, no. 7, 2018, pp. 3093–3113., doi:10.1007/s11227-018-2363-0.

6- Title: Recovery Marketing: What to Do after a Natural Disaster

Summary: This source refers to economic recovery after a natural disaster which in some places such as in islands it is more difficult to recover from. This journal gives tips on how to keep tourism in the first few critical months after the disaster, as well as teaching flexibility when action is needed.

Link: https://journals.sagepub.com/doi/abs/10.1177/001088049403500220

Citation: Durocher, Joe. “Recovery Marketing: What to Do after a Natural Disaster - Joe Durocher, 1994.” *SAGE Journals*, journals.sagepub.com/doi/abs/10.1177/001088049403500220.

7- Title: Epidemics after Natural Disasters

Summary: Authors of the article state possible risks for outbreaks after a disaster, consider which diseases are seemingly to be crucial and define the priorities for preventing communicative diseases in natural disasters.

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2725828/

Citation: Watson, J. T., Gayer, M. and Connolly, M. A. (2007). Epidemics after Natural Disasters. *Emerging Infectious Diseases*, 13(1), 1. https://dx.doi.org/10.3201/eid1301.060779.

8- Title: Natural Disasters

Summary: Author provides observations and suggestions for the possible reasons of the natural catastrophes.

Link:
https://books.google.nl/books?hl=ru&lr=&id=wnt0DwAAQBAJ&oi=fnd&pg=PT11&dq=disasters&ots=oxuioQpE7E&sig=eBOHO_9ZZUZ1VGPzd3gMOA3YogU&redir_esc=y#v=onepage&q=disasters&f=false

Citation:

9- Title: Catastrophic Natural Disasters and Economic Growth

Summary: This paper examines the impact of the natural disasters on the economic growth on the example of a few countries affected by severe disasters. Authors conclude that only large disasters have a negative effect on economic growth and can also lead to the political changes and revolutions.

Link:
https://www.mitpressjournals.org/doi/abs/10.1162/REST_a_00413?casa_token=Ax9cDOMNuUEAAAAA%3AYLOuEkru2KX60PE_nBJhq4a1gF-uYSb51iYNkM6d49q_yD0C8FFu6TMfTbTnxjuhddcMgg7YLqQ20Q&

Citation: Cavallo, E., Galiani, S., Noy, I. and Panatano, J. (2013). Catastrophic Natural Disasters and Economic Growth. *Review of Economics and Statistics.* 95(5), pp. 1549-1561. https://doi.org/10.1162/REST_a_00413

10- Title: Sea-level rise and its possible impacts given a 'beyond 4℃ world' in the twenty -first century

Summary: In this paper the impact of the rise of sea levels across the globe are examined. Specifically the impact of two major ice sheets if the global temperature is raised by 4 degrees celsius.

Link: https://doi.org/10.1098/rsta.2010.0291

Citation: Nicholls, R. J., Marinova, N., Lowe, J. A., Brown, S., Vellinga, P., De Gusmão, D., . . . Tol, R. S. J. (2011). Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369(1934), 161-181. doi:10.1098/rsta.2010.0291

11- Title: Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter

Summary: The paper is about the dangers of air pollution and the causes of this fine outdoor particulate matter.

Link: https://doi.org/10.1073/pnas.1803222115

Citation: Burnett, R., Chen, H., Szyszkowicz, M., Fann, N., Hubbell, B., Pope Iii, C. A., . . . Spadaro, J. V. (2018). Global estimates of mortality associated with longterm exposure to outdoor fine particulate matter. Proceedings of the National Academy of Sciences of the United States of America, 115(38), 9592-9597. doi:10.1073/pnas.1803222115

12- Title: Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA

Summary: The paper is about how climate change and wildfires affect the forests in the Pacific Northwest. The effect of a warmer and drier climate will result in longer wildfires, insect outbreaks and a larger chance of reburn, which could significantly harm or even stop the regeneration of vegetation.

Link: https://doi.org/10.1186/s42408-019-0062-8

Citation: Halofsky, J. E., Peterson, D. L., & Harvey, B. J. (2020). Changing wildfire, changing forests: The effects of climate change on fire regimes and vegetation in the pacific northwest, USA. Fire Ecology, 16(1) doi:10.1186/s42408-019-0062-8

13- Title: Natural Disasters and Risk Aversion

Summary: This journal article discusses the impact of natural disasters on the financial behaviours of markets and individual investors

Link: https://www.sciencedirect.com/science/article/pii/S0167268120302298

Citation: Bordeau-Brien, M., Kryzanowski, L. (2020) Natural disasters and risk aversion. Journal of Economic Behavior & Organization

14- Title: Human–Environment Natural Disasters Interconnection in China: A Review

Summary: This study assesses the connection between human behaviour and natural disasters.

Link: https://www.mdpi.com/2225-1154/8/4/48/htm

Citation: Ali, R.; Kuriqi, A.; Kisi, O. Human–Environment Natural Disasters Interconnection in China: A Review. Climate 2020, 8, 48.

15- **Title: International Migration Responses to Natural Disasters: Evidence from Modern Europe's Deadliest Earthquake**

Summary: This paper discusses the effects of natural disasters on human migratory behaviour

Link: https://www.nber.org/papers/w27506

Citation: Spitzer, Y., Tortorici, G., Zimran, A. (2020) International Migration Responses to Natural Disasters: Evidence from Modern Europe's Deadliest Earthquake. National Bureau of Economic Research

16- **Title: Climate change adaptation and disaster risk management : an Asian perspective**

Summary: the paper looks at how asian countries are handling their disasters and climate change

Link:https://www.emerald.com/insight/content/doi/10.1108/S2040-7262(2010)0000005007/full/html

Citation: Shaw, R., Pulhin, J. M., & Pereira, J. J. (2010). Climate change adaptation and disaster risk management : an asian perspective (1st ed., Ser. Community, environment and disaster risk management, v. 5). Emerald. INSERT-MISSING-URL.

17- **Title: The US COVID-19 pandemic in the flood season**

Summary: the paper talks about how the two disasters of the flood season and the covid-19 situation can cause for a lot of friction, since the floods cause for groups of people to move out of their house

Link:https://www.sciencedirect.com/science/article/pii/S0048969720361635?via%3Dihub

Citation: Xinyi Shen, Chenkai Cai, Qing Yang, Emmanouil N. Anagnostou, Hui Li,
The US COVID-19 pandemic in the flood season,
Science of The Total Environment,

18- **Title: Disaster Recovery Planning for Communications and Critical Infrastructur**

Summary: Addressing the vulnerabilities in today's critical infrastructure to natural disasters and terrorism

Link:
https://books.google.nl/books?id=wVPm1t4FbQAC&printsec=frontcover&hl=nl&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

Citation: Wrobel, Leo A. Wrobel, Sharon M.. (2009). Disaster Recovery Planning for Communications and Critical Infrastructure. Artech House. Retrieved from https://app.knovel.com/hotlink/toc/id:kpDRPCCI01/disaster-recovery-planning/disaster-recovery-planning

19- Title: Disasters and Development

Summary: A look at how disasters affect development around the world.

Link: https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/159887/cuny_intertect_000001_49.pdf?sequence=1

Citation: Cuny, Frederick C. (1983) Disasters and Development. Intertect Press.

20- Title: Social-Ecological Resilience to Coastal Disasters

Summary: How damage done by coastal disasters can be coped with by having social-ecological systems in place.

Link: https://science.sciencemag.org/content/sci/309/5737/1036.full.pdf

Citation: W. Neil Adger, Terry P. Hughes, Carl Folke, Stephen R. Carpenter and Johan Rockström (2005) Social-Ecological Resilience to Coastal Disasters.

Chapter 2: Identification of General Problems and Challenges

List of General Problems :

Problem 1: A natural disaster is difficult to predict and therefore it is harder to make precautions. Often the time and the place of where the disaster will take place is unknown. So, a challenge for inventing a solution for natural disasters is making the events more predictable.

Problem 2: Geomorphological Hazards directly correlate with the mapping and modeling of the Earth's surface processes, earthquakes, volcano eruptions and more, which many of directly affect human societies. "Earthquakes account for the majority of deaths from a range of natural disasters which amounts to about **60,000 people** a year worldwide" (https://openknowledge.worldbank.org/bitstream/handle/10986/4042/WPS4823.pdf)

Problem 3: Natural hazards effect on the different aspects of social life. Besides obvious consequences like death and damages, there are another social problems like risk of communicative disease and economic growth

Problem 4: Climate change can cause wildfires to last longer and significantly harm the regeneration of the forests to the point where there will barely be any regeneration.

Problem 5: Since predicting natural disasters is difficult, we have to rely on humanitarian aid, financial investment etc. leading to long recovery times from the aforementioned disasters.

Problem 6: a country or region can suffer from multiple disasters at the same time, which can make the disaster harder to solve

Problem 7: Natural disasters can cause primary resources to become unavailable causing large groups of people going to the same resource spreading diseases.

Problem 8: More than 700 million people live in low-lying coastal areas exposed to extreme sea-level events including Tsunamis. Recent events (tsunami in the mediteranean seas) showed once again that being prepared for such occasions can be vital for the rescue of human lives.
(https://www.who.int/health-topics/tsunamis#tab=tab_1)

Chapter 3: Identification of Relevant Problems

Problem 1: Wildfires
Decreasing the impact of wildfires on the surrounding environment by halting their spread and/or allowing rapid response.

Problem 2: Sea Levels Rise & Tsunamis
Defending against the sea level rise and the higher frequency of tsunamis in the world.

Problem 3: Floods & Epidemic
Floods are still very common and with the current epidemic there are increasing chances of spreading the virus.

Problem 4: Epidemic & Social Life
Pandemics drastically impact social life, increasing the likelihood of developing depressions or other mental problems.

Problem 5: Economy Recovery
Normally a country needs a long economic recovery after a disaster and a lot of countries rely on tourism as a major income source, so as there is an increase in demand for recovery there is a decrease in income, causing the country to never recover fully.

Chapter 4: Problem Selection and Motivation

Problem: Wildfires
More particularly, we will be focusing on decreasing the impact of wildfires on the surrounding environment by halting the spread of the wildfire and assisting to a rapid response. We will be targeting the early stages of the fire and possible defence mechanisms that could slow down the spread and save precious time.

Motivations:

- By preventing wildfires or by stopping the spread quickly, the contribution to climate change is minimized.
- Wildfires are still a very common problem worldwide.
- Wildfires are still a largely unsolved problem.
- Because of wildfires, people living nearby are forced to move to a safer location, leaving their house behind.
- Wildfires are so devastating that it has endangered many species of plants, animals and other organisms.

Specific issues we want to address

- Rapid response against beginning wildfires
- Stopping the spread of existing wildfires
- Static defenses against wildfires
- Monitoring the spread of wildfires for rapid response

Chapter 5: Potential Solutions

AI/Robotic wildfire fighting with a fleet of drones equipped with fire extinguishing items

- **problem solved:** Stop the wildfire
- **risks:** Drones could catch fire or break down creating a hole in the "drone wall" allowing the fire to spread
- **requirements:** A substantial drone fleet armed with some way to effectively extinguish fires from a safe distance. This could be by deploying a to the ground sinking smoke that starves the fires from oxygen or by making the drones really big and having them carry water.
- **potential/impact:** Could stop wildfires from getting out of control and allows for an immediate replacement of the firefighting force where only the batteries have to be replaced instead of exhausting a person and having to wait for them to get back on their feet.
- **test/validation:** Prototype one or two drones that respond to a "live" fire while also communicating with each other/a fake "drone fleet"
- **demonstration:** Light a target on fire and let it be successfully extinguished by the drone(s)

Easily deployable "firewalls" to contain a wildfire.

- **problem solved:** Stopping the spread of wildfires
- **risks:** If walls aren't deployed effectively, or are broken through, a secondary system is needed
- **requirements:** Flexible or modular pieces that are fire resistant, and are lightweight and easy enough to set up to be rapidly deployed. Additionally it needs to be large enough to stop sparks
- **potential/impact:** Eco friendly and low impact.
- **test/validation:** Prototype a small module of a wall to set up
- demonstration: Attempt to set wall on fire or see if sparks will pass over it

Warning system to detect the spreading of wildfires.

- **problem solved:** In most cases wildfire is detected by firefighters when it is burning in a large area which makes it more complicated to distinguish the fire. Warning systems will trigger when a fire on the early stage will be detected.
- **risks:** Fire starting on the uncovered area right between the sensors will not be detected on its early stage.
- **requirements:** Installation of the system for significant areas requires high financing and loads of volunteers.
- **potential/impact:** Distinguishing the small fire will prevent extinction of large forest areas.
- **test/validation:** Test the sensor itself whether it triggers on fire and smoke. Complete a series of tests to choose fireproof material.
- **demonstration:** Execute the system on the small area with a controlled fire.

Drones that immediately warn firefighters as soon as a fire is detected

(Thermal Cam drone)

- **problem solved:** the time between people noticing the fire and the firefighters being contacted might be significantly lower if a drone could immediately warm firefighters the second a fire is started
- **risks:** might also trigger upon seeing a campfire, not guaranteed to be useful since the firefighters still have to show up and that might also take some time, fire might be hard to detect with a lot of daylight since one of the easiest ways to detects a fire would be for the drones to search for a lightsource but that might not work in the bright daylight.
- **requirements:** drone, sensor to sense fire, a way for the drone to contact local firefighters.
- **potential/impact:** fires being noticed before they get the chance to spread, so that they are relatively easier to put out and the damage the fire does could be lower
- **test/validation:** we could test it by looking if the sensors on the drone can even sense a fire. for instance is it possible to use sensors that track light to find fires or should we use sensors that detect smoke. as soon as we have found a way to sense the fires we could test if we are able to link it to one of our own phones to see if the alarming function works.
- **demonstration:** let the drone find a fire (or a simulated fire) and alarm one of the team members

Spray system around a house which sprays a fire retardant when smoke is detected

- **problem solved:** The fire won't be able to spread to the houses/ the spreading will significantly slow down. This gives the local residents more time to get away, or to find shelter in their own home.
- **risks:** false alarm: the alarm can also go off when smoke not from a wildfire is detected, for example when there is a campfire nearby.
- **requirements:** The spray system has to be placed in a circle around the house. The distance between the spray system and the house should not be too small, to make sure that the fire can't jump over to the house. Multiple smoke detectors have to be installed to cover all the sides the fire can come from.
- **potential/impact:** Houses will be less damaged, which saves rebuilding costs. Also, the residents get more time to evacuate to a safer place, or in an ideal situation, the residents can stay in their own home.
- **test/validation:** This concept can be tested by building a house on a smaller scale and by stimulating a fire. The simulation can take place with different wind speeds and at different environments. This design will perform most optimal in an environment where the house is not directly surrounded by trees.

to be continued at page 14

- **demonstration:**

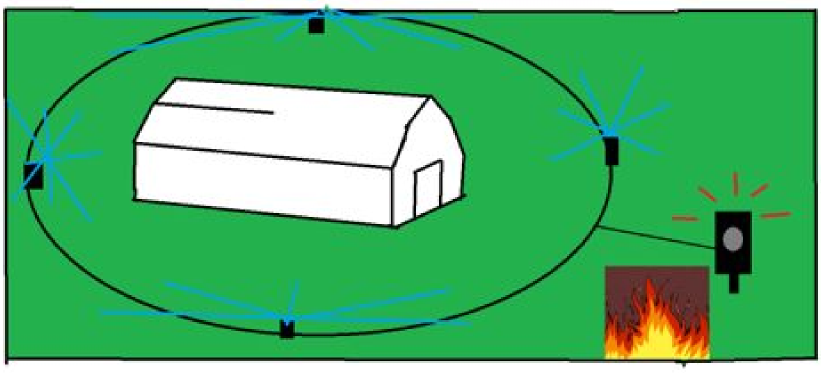

Fig 1: sketch of the sprinkler system

- **Extension:** the concept can even be extended by placing a water spraying system on the roof of the house, which will also go off when smoke is detected. In this way, the house is extra protected against fire.

HFCs mines, that absorb heat and limit the spread of a fire

- **problem solved:** The fire will be slowed down and blocked from spreading further.
- **risks:** With really high trees the fire could be outside the mine's radius and might simply jump over the fire, leading for the fire to spread regardless, but it will still slow down. Vandalism and accidents are also a big factor as anyone could mess up or play with a "HFC mine" founds in the middle of a forest.
- **requirements:** The mines can be placed on trees at a height of 2 to 3 meters and the trees will be chosen systematically for the particular geographical region. Predetermined scenarios of the potential fire spread that could also help in positioning the mines at their most optimal location.
- **potential/impact:** Controlling a wildfire or even slowing down a fire for only seconds could save countless lives, because the early states of a fire are the most crucial and controlling the spread, even for a few minutes, will allow the firefighters to stand a better chance against the fire.
- **test/validation:** The concept can be tested by being able to release a gas once smoke is detected from 2. meters outdoors. (HFC can be used or other for colored gas for testing purposes)
- **Demonstration:** *see figure 2.*
- **Extension:** The mine could also contain 2 separated chemicals, that makes a solid chemical reaction upon release, and

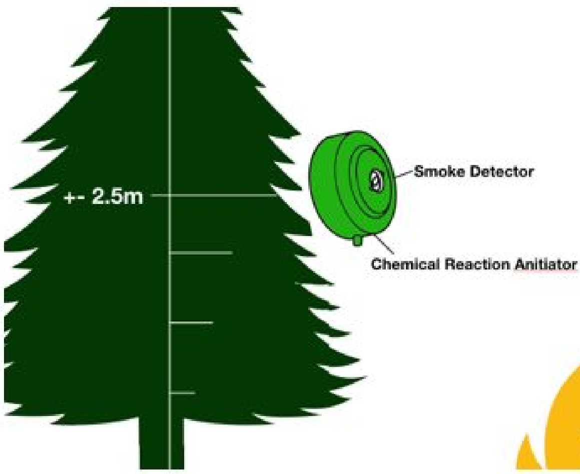

Fig 2: Sketch of the HFC mine

Drones used to create a backfire in combination with drones fighting the backfire.

- **problem solved:** Creating a backfire is very dangerous and is mostly done by experienced firefighters using a propane torch, but it's effective to create or to enlarge firebreaks against big wildfires.
- **risks:** When not done properly, more wildfires can be created. However, these backfires will be less intense than the actual wildfire. Also there is a risk where the drones fighting the backfire can't extinguish all the fire and a small portion will start another fire unnoticed, so there still have to be firefighters on the ground, but only less than before.
- **requirements:** 2 drones. one for creating the backfire, which needs to cause a fire line where the intensity is controlled and it needs to create a continuous line of fire and not miss certain parts. The other drone is bigger and can carry a larger load, a pressurized vessel and a water container or dry fire retardant or CO2 for different types of fire. This also has to be easily refuelable.
- **potential/impact:** Reduce the amount of firefighters needed for this task, so they can focus on the wildfire itself. Other people can also be trained for this purpose, since it requires less skill than firefighting and the person controlling the drone isn't at risk. Creating a backfire this way can get rid of the fuel source in the path of the wildfire, so you can create a barrier for the fire to change its direction from important places or to stop the spread of the wildfire.
- **test/validation:** it can be tested in a remote location with firefighters present by only creating a really small line of fire and letting the drones try to extinguish it first with the help of just a few firefighters if they don't succeed.
- **demonstration:** on a smaller scale you can create a small "forest" with some wood grass, moss, leaves and stones and set it on fire in the one end to create your "wildfire" and then try to create a backfire where you want your barrier to be, using the same things the drones deploys, and after that try to extinguish the fire using the equivalent amount of water of what a drone can carry on that scale. If it's effective a firebreak will be formed and the wildfire will not reach the other end.
- https://www.hummingbirddrones.ca/ignisii

Chapter 6: Solution Selection

Basic solution

System to detect the spreading of wildfires and send a warning to local residents via SMS (solution 3).

Motivation: Solution 3 appears to be the easiest solution to implement, most realistic and with equal importance compared to some of the other solutions. Warning residents in time can be crucial in providing a safe evacuation.
The goal of this project is to design a product that can detect if fire is nearby and send alarm to the local residents in their own home. To determine where the fire detectors are placed, databases about weather and ground conditions are used.

Ambitious solution

Expand basic solution with an online website that includes a map with the location of the sensors in use and the estimated position of the fire if fire is detected. Even more ambitiously the site would also provide details on parametrics such as the wind speed and direction, and a location's environment. Parametrics like these could also be found in already existing websites and datasets like CORINE (a land cover dataset) and Forefire. Other examples for datasets are Windy API and AccuWeather API.

Motivation: Visualising the position and potential spread of the fire could provide valuable early signs of the fire's movement that firefighters could use to approach the fire in a more strategic way. Additionally, providing such an accessible system to the public would benefit locals by providing them with live updates on the fire, which could help them decide on which escape route would be more suitable if needed.

Extra Ambitious Solution

Develop a separate sprinkler system (solution 5), which would be remotely activated when detected fire is on the way.

Motivation: Activating the sprinkler system once the fire is detected will be an extra step that will give the residents some extra time to evacuate and let them be one step ahead of the fire. Having a better chance of seeing their house again in one piece after the disaster. Additionally the system could be used to prevent fire from entering specific high danger areas that could create a major and danger inconvenience if they were to catch fire (e.g. outdoor electrical power units).

Modular approach

- Welmoed: Data analysis (collection and use for automation/control/actuation) and documentation, research on parameter's fine tuning
- Matthijs: Hardware purchase, casing and wiring, sensors & calibration, programming, prepare final demo
- Theo: Team leading, management, coordination, feedback, prototyping
- Jelle: Validation, prepare final demo
- Luuk: Designing product, Material selection, final demo
- Dom: Presentations, Prepare Final Demo, Programming, Designing Product (Blender or Solidworks)
- Victoria: Searching for ideas and improvements, uncovering of possible risks

Table 1: Planning

Tasks	**W4** 30/11	**W5** 7/12	**W6** 14/12	**W7** 04/01	**W8** 11/01	**W9** 18/01	**W10** 25/01
Choose solution	X						
Methodology	X	X					
Prototyping		X	X	X	X		
Results & conclusion				X	X	X	
Final improvements						X	X
DEMO (29/01)							X

In our ambitious scenario we will always be one step ahead of ourselves, the equipment will work as expected and we will be able to bring our idea to life in time for final improvements. The warning system will successfully be able send a warning message and activate the and provide locals with valuable live updates on the fire, when/if fire is detected. All this will be beautifully showcased through our prototype during Demo Day.

We expect our basic scenario to only take place if something goes wrong, including step-backs using or manipulating equipment, malfunctioning code or unexpected natural disasters. For this scenario we expect to still make a basic warning system work, and send a message when fire or smoke is detected.

Chapter 7: Methodology

The final product consists of two parts: a device which can detect if fire is nearby and an alarm system that sends an SMS (to local residents by ideally using a geofilter) once the device is activated and smoke is detected to local residents.

In our ambitious solution, the alarm system will also upload the information on the internet through a website (that has the potential of an application), which can keep track of which alarms have gone off with a visual map, thereby confirming the location and early movements of the fire. To determine where to place the detectors, databases on a number of parameters such as speed of wind and ground vegetation are being consulted.
For our extra ambitious solution, a fire sprinkler system could be added.

Data collection

We collect our data for our basic solution from publications on the internet (literature research) and from the interview with Jelmer dam (national wildfire control coordinator).

For the website of our ambitious solution, we can make use of a few already existing databases and websites, which give information about for example the speed of wind and the kind of vegetation. Examples of those websites/ databases are: CORINE (land cover dataset), Forefire (wildfire simulator), Windy API and Accuweather API.

Data use and analysis

Wildfires are mainly caused by human negligence, for example cigarettes, burning cars, a BBQ left burning or other natural causes such as dry lighting. According to interviewed firefighter Jelmer Dam there are three main ‘ingredients’ for fire propagation: fuel, oxygen and temperature.

A few examples for conditions which are favorable for a wildfire are:

- Drought
- The kind of vegetation
- Relative low humidity
- Speed of wind
- Topography (fire spreads faster uphill)
- high temperature

For the implemented design of the Sensor/Transmitter Node there is only one main sensor in use, the MQ-2 Gas Sensor. This sensor transmits an analog value set by a threshold on the device itself. The MQ-2 sensor senses the amount of smoke, butane, propane, methane, hydrogen, alcohol and carbon monoxide particles in the air. If the amount of particles is higher than the threshold set by adjusting the screw on the sensor module it will output an analog signal to the Arduino according to how much higher the concentration of particles is than the selected threshold.

By placing a large number of sensors in a high risk wildfire area, the sensitivity of the wireless sensor network is increased. The MQ2 gas sensor has a range between 200 to 10000 ppm. The smoke of a wildfire can rise up to 23 km in the air, depending on the weather conditions. Smoke itself travels with a speed of 35-128 meter per minute (average of 80 meters per minute). We want to know where the smoke will go next within 5 minutes, so it would be favourable to place a Sensor/Transmitter Node (also known as SOMBRERO) every 300-400 meters.

As a smart product, the SOMBRERO Nodes and Hub must integrate with the environment. The product is designed in such a way that interaction with its environments is possible, for example with animals or heavy weather conditions.

Materials

The following materials are available to use for the final product design:

Sensor/Transmitter Node

- A hardware case
- MQ-2 Gas Sensor
- Arduino board
- Radio transmitter

Network/Receiver Hub

- Hardware case
- Arduino board
- Radio receiver
- LCD display
- WiFi connector

Extra ambitious plan: Fire sprinkler system

- Hardware case
- Sprinkler
- Radio receiver

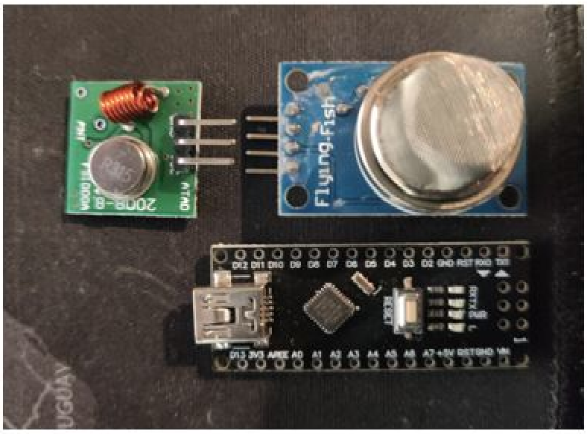

Fig 3: Sensor/Transmitter node materials

Fig 4: Network/ Receiver hub materials

Final Product design

The final product design can be seen in the simulations below made with Solidworks. Consisting of all the materials mentioned in methodology (page 18). For a closer look on the sensors, a schematic can be found in *Appendix B*.

The final design consists of a number of components. From top to bottom the components are as follows. First we have the solar cell protected by a glass plate, which provides the electricity during its use in the forest. Below the solar cell you see a probe sticking out of the inside to the outside of the casing. This is the temperature sensor, which makes it possible to measure temperature even when the casing is closed. Below the temperature sensor are 3 MQ sensors, which can measure various gasses such as smoke, carbon dioxide and flammable gases. Below those is a circuit board with 3 main components attached: A humidity sensor (the smaller one at the top), a transceiver module (the big Xbee module) and the arduino nano. The transceiver module is used for communication of the data through radio transmission (this may need an extra antenna a bit like the temperature sensor). The arduino nano is used for the processing of all the data and will send the signals through to the transceiver. Below the circuit board are the batteries which can store the electricity from the solar cell so the sensor can still operate in the dark. The batteries chosen are 3 18650-batteries, which can have a capacity of around half the size of a standard laptop and for the low energy usage of the sensor that is more than enough.

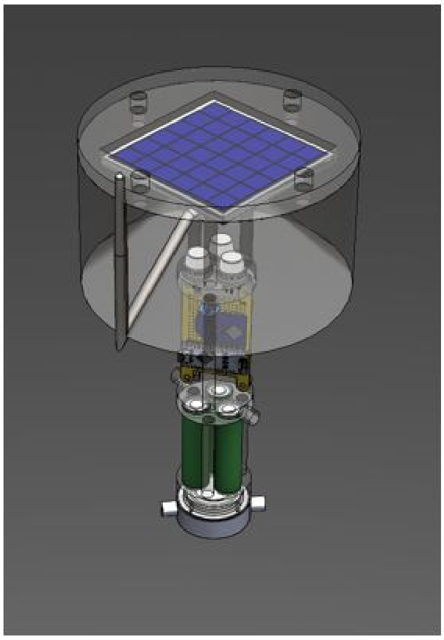

Fig 5: top view of inside of final product

At the very bottom there is a pancake motor driving a cylinder with pins on either side. This is for the reusability of the sensor, since the electronics can only withstand relatively low temperatures, so when the temperature becomes too hot the motor closes the sensor to protect the electronics (in this state only the temperature can be measured). If the temperature lowers to a point where the electronics can survive, the motor opens the sensor up again exposing the MQ sensor to the outside air. For the casing the design is made in such that it can easily be punt into the ground and that in the case of water condensing on the sides the water can flow out of the system. The bottom is completely separated from the top, so that it's completely modular and the bottom can be designed for a position in the trees or on street lights, so that it can be adapted to any environment.

Fig: 6: casing design

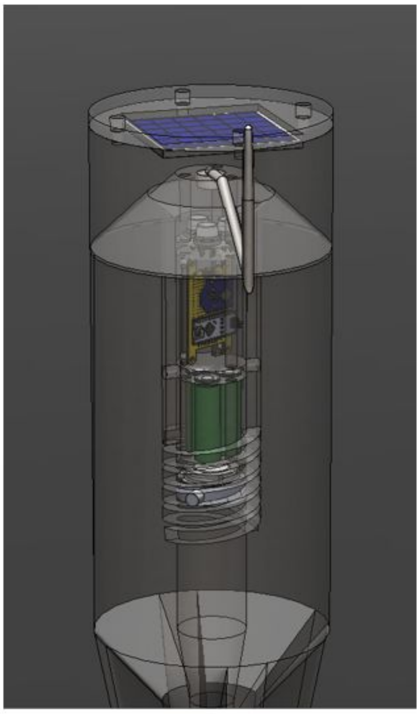

Fig 7: : Inside view of final design

Chapter 8: Results and Conclusion

The basic solution was to make a system which can detect the spreading of wildfires and send a warning to the local residents via SMS. The ambitious solution was to expand our basic solution with an online website that includes a map with the location of the sensors in use and the estimated position of the fire if fire is detected. The first steps for the ambitious solution were made, but unfortunately the ambitious solution was not finished on time. (progress on the website can be found in Appendix C).

Validation

The MQ-2 sensor was validated through testing, by feeding a gas to it and reading the output while adjusting the screw for the threshold. This process was experimented 3 times in 2 different settings to check distance sensibility / sensor' accuracy and difference between smoke & gas. When using gas, we simply turned on a lighter near the sensor and collected data/particles. For safety reasons, our validation with smoke is limited, as (controlled) outdoor fires are not very feasible in our geographical region (Netherlands). We thereby created a smaller fire and validated the detection of smoke through the data collected. We repeated this process 3 times with the distances of 10 cm and 1 meter to test the accuracy. The tested range may not be ideal but the data collected show promising results.

Table 1. Data Collected & Sensor Sensitivity

Gas (from lighter) at 10 cm	Fire Smoke at 10cm	Fire Smoke at 1 meter
897	925	629
1002	947	498
956	787	545

The sensor's range falls between 100 to 10000 ppm (parts per million, also expressed as mg/L and in this case 'particles'). The above table presents the values collected through the arduino with range 0 to 1023. Even 1 meter away the sensor seems to have a very decent sensitivity to the fire, however, the current testing does not currently guarantee the longer proposed distance nor can it estimate an average time of response.

To validate the SMS communication when the sensor detects fire, we used the WiFi microchip ESP8266. By connecting the chip to the Arduino we can send a web request to "IF THIS THEN THAT", a web service where you can connect applications mostly used for IOT(Internet of Things) projects. Using the IFTTT Webhooks application to receive the web request and applying the usefulness of IFTTT to transform that web request into an SMS by using the SMS functionality of IFTTT. Applying all of this into one creates a successful flowing alarm system from detected smoke to an SMS.

Discussion

Sensor works as intended, nevertheless a number of opportunities can still be explored, in regards to the use of materials, and the live status of the sensors. Within our ambitious scenario we would also be able to validate the sensor's communication with the processing application with an expected mapped position of the fire. However, time constraints did not allow us to experiment with the possibility and present this additional detail in our prototype (promising results await with various opportunities, progress found in Appendix C).

The material selection was conducted through EduPack, a material selection software, that allowed us to find the most suitable material in regards to fire resistance, density and price. The ideal researched material for the product is Graphite Foam, (more details found in Appendix A). However, the validation of the material is still to be determined as the material hasn't been accessed by our team yet (due to the pandemic's limitations).

Another validation that could be made is on regards to the location of the sensors, and how close they should be to each other to maximize functionality. Unfortunately, to validate our research and the estimate of 300-400 meters, the product would have to be multiplied and tested in a real forest fire or a similarly controlled environment.

Conclusion

To conclude, our basic plan is a success. SOMBRERO (Sensor/Transmitter Node) can detect fire and alert through SMS. However, many opportunities for improvements and further development are still waiting to be explored when it comes to our ambitious scenario and providing live online updates on the sensors and fire.

Our product could be improved by adding sensors that detect chemical fires and thereby increase the settings of the product. Additionally SOMBRERO's machine learning could be improved by making the sensors less sensitive to noise through calibration over time.

The scalability of the product is suitable for small areas usage as well, since it consists of a series of sensors so you can adjust the amount of sensors for the area. The effectiveness of the product should not be affected by the small area usage.

The installation shouldn't be challenging. The product can be shipped as a whole device, thus the only requirement is to find a place to install it. Installing it once is enough to put it into operation since no construction is needed. Besides, the product can be re-installed multiple times in different locations.

The product primarily can be used by forest protection agencies. However, afterwards it can be introduced to the markets for private use as well. The price is formed by correlation to the cost of the materials, labour and transportation costs. Should the product be picked up by a corporation or government agency, it has the potential to provide great assistance and eliminate risk of large scale forest fires, aiding in the fight against local fires, global warming and helping to preserve ecosystems.

APPENDIX A

Material Selection using Granta edupack

With the selection criteria of:

- non flammable material
- a minimal maximum service temperature of 750 degrees celsius (this is around the peak value of a forest fire)
- Thermal conductivity (probably the most important, to test if the material is insulating)
- An acceptable price per volume
- A low density (for the motor in the prototype to work)
- Yield Strength
- Durability against organic solvents (to test if it doesn't degrade over time in nature)

Name	Thermal conductivity (W/...
Basalt (f)	0,03 - 0,038
Vermiculite	0,0581 - 0,0704
Graphite foam (0.12)	0,07 - 0,2
Brick (low density refractory)(0.55)	0,15 - 0,19
Mullite foam (NCL)(0.46)	0,15 - 0,317
Mullite foam (0.70)	0,167 - 0,333
Mullite foam (0.65)	0,167 - 0,333
Brick (low density refractory)(0.75)	0,25 - 0,35
Cordierite foam (0.5)	0,25 - 0,417
Brick (low density refractory)(0.8)	0,28 - 0,38
Brick (low density refractory)(1.3)	0,3 - 0,5
Zirconia mullite alumina foam (0.63)	0,333 - 0,5
Brick (common, hard)(2.03)	0,4 - 0,8
Mica (p)	0,415 - 0,67
Alumina foam (92%)(0.61)	0,5 - 0,667
Alumina foam (99.5%)(0.745)	0,5 - 0,667
Terracotta	0,5 - 1,52
Alumina foam (99.8%)(0.4)	0,51 - 0,72
Silicon carbide foam (0.5)	0,55 - 0,708

Name	Maximum service tempera...
Graphite foam (0.12)	2,58e3 - 2,69e3
Alumina foam (99.8%)(0.4)	1,8e3 - 1,9e3
Brick (low density refractory)(1.3)	1,65e3 - 1,7e3
Mullite foam (0.70)	1,54e3 - 1,56e3
Alumina foam (99.5%)(0.745)	1,53e3 - 1,55e3
Mullite foam (NCL)(0.46)	1,52e3 - 1,54e3
Zirconia mullite alumina foam (0.63)	1,48e3 - 1,53e3
Alumina foam (92%)(0.61)	1,48e3 - 1,53e3
Vermiculite	1,42e3 - 1,52e3
Mullite foam (0.65)	1,39e3 - 1,41e3
Brick (low density refractory)(0.75)	1,28e3 - 1,38e3
Brick (low density refractory)(0.8)	1,3e3 - 1,33e3
Silicon carbide foam (0.5)	1,19e3 - 1,21e3
Cordierite foam (0.5)	1,19e3 - 1,21e3
Brick (common, hard)(2.03)	730 - 930
Brick (low density refractory)(0.55)	877 - 907
Mica (p)	500 - 900
Basalt (f)	500 - 850
Terracotta	673 - 773

Name	Price per unit volume (EU...
Vermiculite	115 - 344
Terracotta	966 - 2,09e3
Brick (common, hard)(2.03)	1,1e3 - 3,08e3
Graphite foam (0.12)	1,15e3 - 4,41e3
Brick (low density refractory)(0.55)	2,57e3 - 4,9e3
Brick (low density refractory)(0.75)	3,9e3 - 7,52e3
Brick (low density refractory)(0.8)	3,9e3 - 8,35e3
Cordierite foam (0.5)	4,07e3 - 6,85e3
Mullite foam (NCL)(0.46)	4,18e3 - 5,24e3
Mullite foam (0.65)	5,75e3 - 7,45e3
Mullite foam (0.70)	6,22e3 - 8,02e3
Brick (low density refractory)(1.3)	7,79e3 - 1,17e4
Zirconia mullite alumina foam (0.63)	1,06e4 - 1,51e4
Alumina foam (99.8%)(0.4)	1,23e4 - 1,93e4
Alumina foam (92%)(0.61)	1,53e4 - 1,99e4
Alumina foam (99.5%)(0.745)	1,93e4 - 3,74e4
Silicon carbide foam (0.5)	2,23e4 - 2,7e4

Name	Yield strength (elastic limit...
Terracotta	15 - 20
Brick (common, hard)(2.03)	6,9 - 14
Brick (low density refractory)(0.8)	1,8 - 2,7
Brick (low density refractory)(1.3)	1,8 - 2,7
Alumina foam (99.5%)(0.745)	0,9 - 2,2
Alumina foam (92%)(0.61)	0,6 - 2,1
Alumina foam (99.8%)(0.4)	1,9 - 2
Zirconia mullite alumina foam (0.63)	0,8 - 1,8
Mullite foam (0.65)	0,6 - 1,8
Mullite foam (0.70)	0,6 - 1,6
Mullite foam (NCL)(0.46)	0,6 - 1,3
Cordierite foam (0.5)	1 - 1,2
Silicon carbide foam (0.5)	0,6 - 1,1
Brick (low density refractory)(0.75)	0,75 - 0,95
Brick (low density refractory)(0.55)	0,35 - 0,75
Graphite foam (0.12)	0,48 - 0,53
Vermiculite	0,2 - 0,4

fig 7: material properties

APPENDIX B

Sensor/Transmitter Node Schematic:

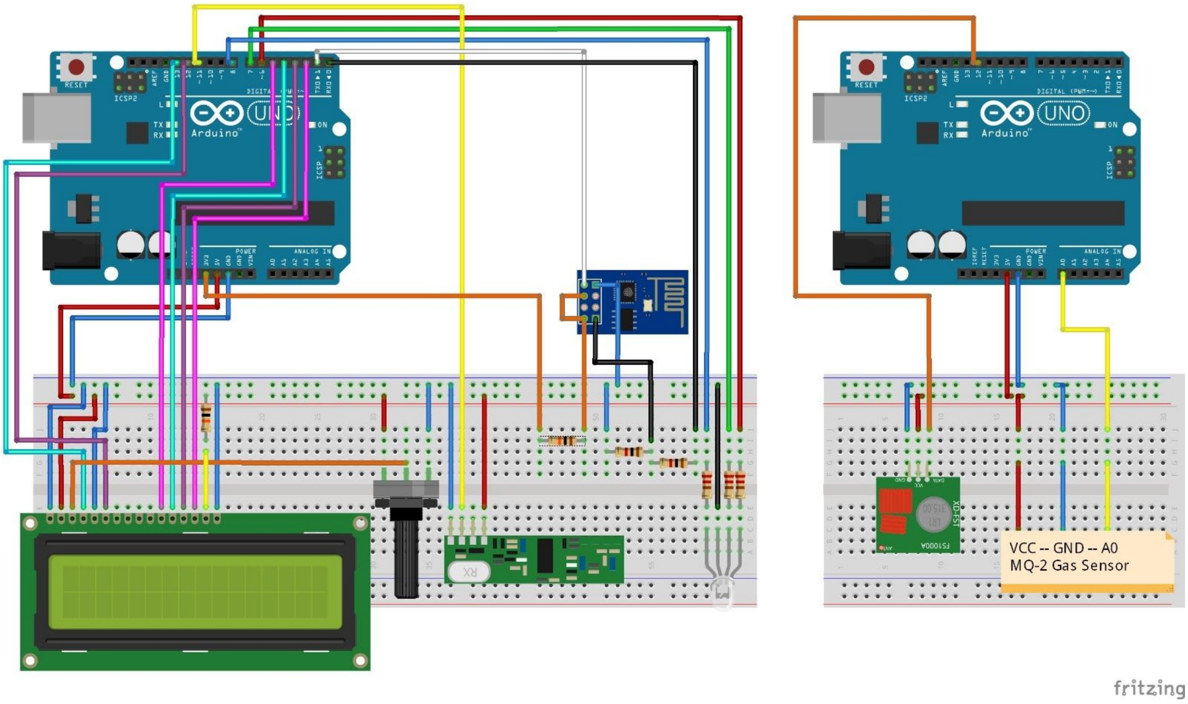

fig 8: Sensor/Transmitter Node Schematic

APPENDIX C

Potential web interface for SOMBRERO live status and fire update.

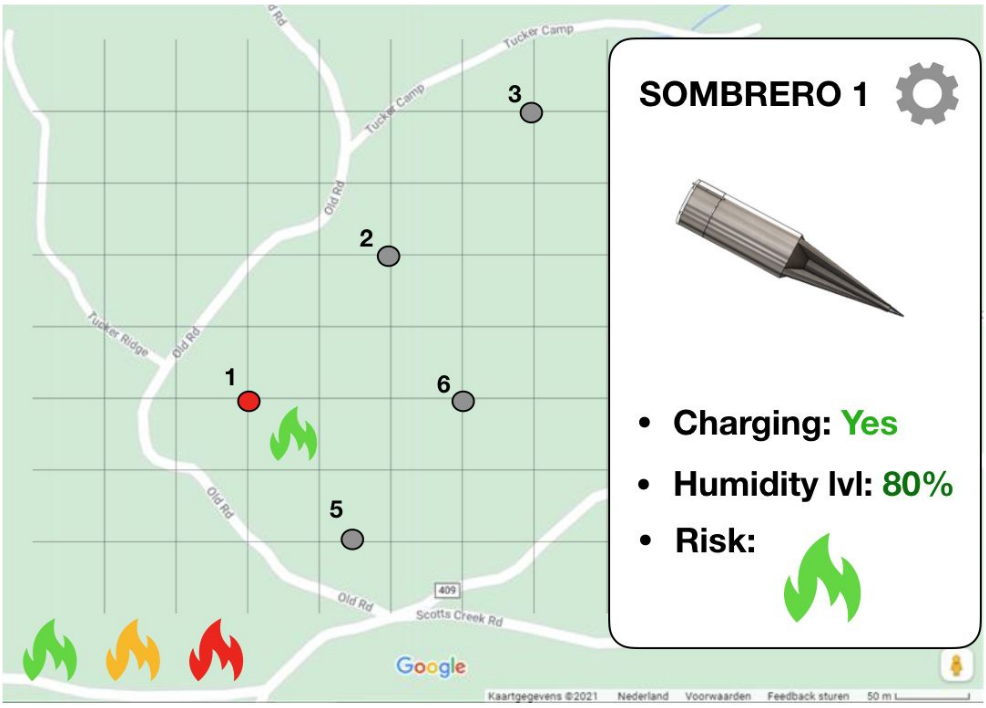

fig 9: design web interface (made in Processing)