This is a document detailing more of our project as mentioned in the video pitch. We hope our idea can contribute in some way to Singapore's preparation against unpredictable events that may occur due to the effects of Climate change.

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Problem Statement

Our problem statement was “Preventing the spread”.

We realized that the effects of climate change, such as increasing average temperatures and increasing record high temperatures, are only going to get worse in the next few years. Singapore has few, as compared to other countries, but treasured forested areas and most of these areas will be more prone to wild/forest/vegetation fires starting due to the potential of dryer weather and reduced humidity that climate change will bring about.

Since Singapore is at the center of the equator, we will feel the effects of the rising temperatures more, and especially with our four-season summer, wildfire risk is expected to rise.

For example, the unusually dry spell in Singapore has led to a sharp increase in the number of vegetation fires in the first six months of this year (2019), reaching a three-year high. A blaze broke out near East Coast Park (ECP) recently in August 2019, affecting an area about the size of two football fields. A raging vegetation fire can expand by an average of more than one football field in three seconds. (Awang, 2019) With the high speeds at which vegetation fires can spread, if a fire is started, the spread will be fast and expansive and if not taken care of in time, a lot of greenery will be destroyed. For example, the Singapore Civil Defence Force (SCDF) said 555 vegetation fires were reported in the first half of 2019, a 56 percent jump from 356 in the first half of 2018, and an even bigger increase from 100 in the same period in 2017. The increasing number of vegetation fires should already be a worrying sign of what’s to come for our forests and areas with greenery and hence more should be done to respond to these fires quicker to contain the damage and spread.

Even reducing the response time by even a few seconds, which can prevent a comparable amount of ecological damage, can go a long way in preserving the precious amount of greenery we have left in our garden city

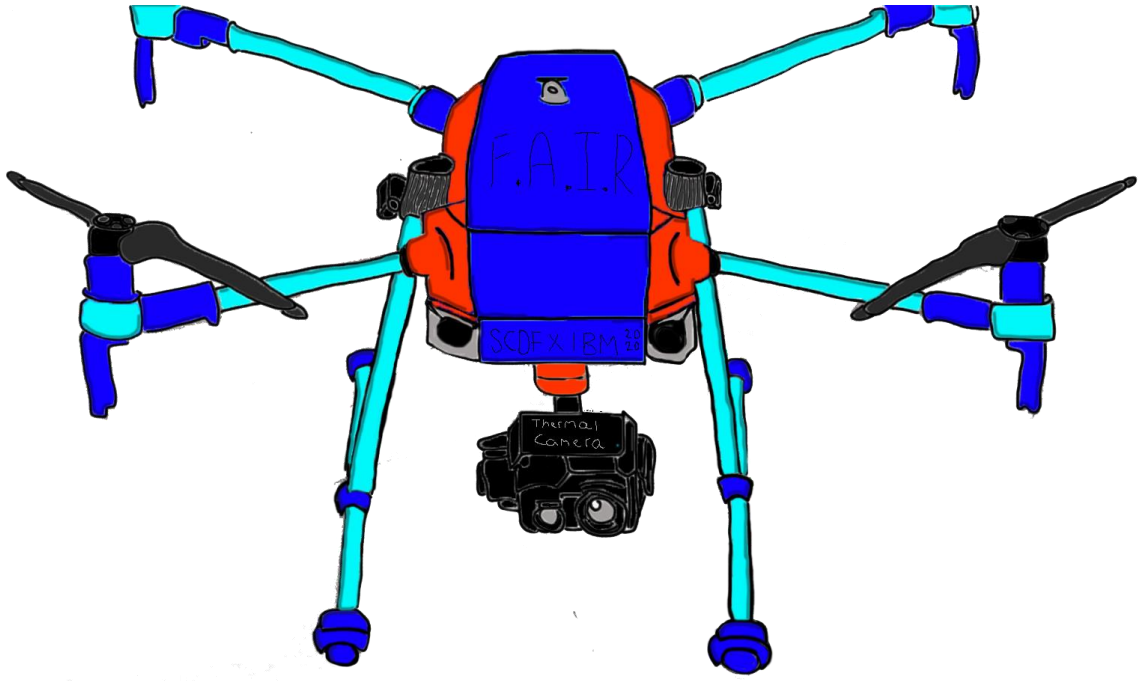
and that is why our project seeks to aid in quicker intervention measures for the SCDF.

Hence, we have decided to come up with a drone and some code that will help us to respond to vegetation/forest fires quicker. Targeting 4 main areas: Tengah Forest, Bukit Timah Nature Reserve, East Coast Park, and The Central Water Catchment.

Our Drone

Taking inspiration from DSLRPro's Matrice 210 Drone, a commercial drone designed for First Responders that is available on the American Market (Online store, DSLRPros). The features we are looking for our drone are:

- Rugged Body with at least IP43 Rating to withstand light rain
- Flight speed of at least 40 mp/h or 64 km/h
- Flight time of at least 30 minutes.
- Minimum payload capacity of 1 kg
- Gimbal capacity for cameras
- Operational range of at least 7 km



Another key specification of the drone is the operational temperature range which is typically between 0° to 40° C for higher-end drones. However, as we're dealing with surface fires on the forest floor which might have flames reaching temperatures of 800°C or more (Gabbert, 2011), this is a very big issue.

After much research, we discovered a drone model built by the Korea Advanced Institute of Science and Technology (KAIST) named FAROS or Fireproof Aerial Robot System. This drone can withstand temperatures of up to 1000 degrees Celsius, or 1832 degrees Fahrenheit. The FAROS is covered with aramid fibers to protect its electric and mechanical components from the direct effects of the flame, making it fireproof and flame-retardant. (Atherton, 2016)

For the drone's navigation system in-flight, we will be adopting a system similar to the Waze navigation system. By simply driving around with Waze open on your device, you share real-time information that translates into traffic conditions and road structure. At the same time, Waze will actively report to the community on traffic, accidents, police traps, blocked roads, weather conditions, and much more. This information is then collected and immediately analyzed in order to provide other Wazers with the most optimal route to their destination. Next time a specific road is driven with the app open, Waze will know to compare data between each possible route and will know how to better suggest the optimal route. (Google, Waze help section)

Functionality

We will have roles for drones split into two, Patrol drones and search drones. Drones on patrol are continuously checking for signs of fire or spikes in thermal readings through the modern thermal imaging sensors.

At the start of operations, the drones will be deployed from "control air bases" which we plan to situate at fire stations near the 4 areas stated above. Taking inspiration from Airobotics, a manufacturer of Automated Industrial Drones whose technology is already being used by the Singapore Police Force (SPF), these control air bases simplifies the operation of the drones by pre-defining the routes of the drones and takes charge of the automatic deploying and landing of the drone while analyzing aerial data and providing a real-time aerial video feed to personnel on the ground. (Airobotics website) With the further use of data and python scripts to determine the months with the highest risk of fires and how many drones should be at each station, we can increase the efficiency of the use of our resources.

The drones will mainly be automated and pre-programmed. However, in special situations, the response team can manually override the drone and control it themselves. This will be further elaborated on later.

Adapting from Waze's navigation system, we will need to upload data of the terrain and pathways of these forests into the drones and train them to find the most efficient routes and travel times from place to place. Using visual recognition that we've created from IBM's Watson Visual Recognition (elaborated more below) we can accomplish this and enable them to be able to navigate to the source of the fire when fires are detected and even locate civilians within the vicinity of the source to escort them out quickly.

We are utilizing IBM's Watson Visual Recognition to detect images of smoke, fires, and humans. We have trained an IBM Visual Recognition service by feeding it images labeled 'smoke', 'humans', and 'fires' for it to learn how to differentiate and detect them. We have also trained it to identify trees under the label "negative" for easier detection of the other labels. (As seen on Github).

When a drone on patrol detects a fire, they become the "master" drone and quickly fly over to the source to report its location and thermal feed on the fire spread while calculating, using its navigation system, the quickest route from whichever entrance the SCDF fire team and first responders enter from and pinging it to them (input comes from scdf team), the rest of the drones on patrol and the search drones (being deployed automatically from the fire station that the area is assigned to) begin to search for signs of life around the area. When a drone detects humans using the visual recognition software, it will ping the control center and their location, the number of people detected, along with the images of the humans. The authorities can then assess the situation and carry out 2 options:

Option 1: If the location reported is not in close proximity to the fire, the authorities can use the drone's in-built GPS system and audio system and have it help guide the people out of the forest to safety.

Option 2: If the location reported is deep within the forest or most of the exits have been blocked off by the fire and are too dangerous to use, the authorities can choose to override the drone's AI and manually control the drone to help guide the people through the safest exit route or towards the firefighters.

The drones will have an audio system that can say various lines such as “Follow Me” or “Danger” to guide the people more smoothly.

On landing, the drones will be automatically landed by the control centre airbase for charging and redeployment.

(Airobotics, 2020)

Our purpose

Most of the areas we are using have large areas of forestation and usually “The age-old method works well up till now, by having the community to dial 995 when an emergency situation calls for us.” --from JQ(SCDF) on slack responding to one of our teammates. However, citizens may only

notice a fire when 1. The fire has become large enough to emit sizable smoke columns (InsightRobotics,2015) or 2. When they are close to the source of the fire and can feel the heat. Usually, by the time of realization, the spread of the fire would already be quite big making the Therefore, even if civilians (or volunteers and patrolling staff) were able to identify these fires and call the 995 hotlines using the traditional method, valuable and precious time may be wasted in the process. Hence, we feel that these high risk of fire areas, identified by our algorithm depending on the month, need to be more closely monitored by drones to prevent widespread fires from occurring.

If needed, the SCDF can ask for volunteers (with training) or get staff to pilot these drones to monitor these forested areas with a high risk of forest fires using our algorithm, monitoring the thermal levels, and looking for signs of a fire starting. However, only a fraction of these drones should be used for patrolling and most of the drones should be on standby for automated deployment to aid in early intervention.

It is worth noting that Singapore does not have a distinct history of forest fires. However, there is still a greater possibility of such events happening, due to global warming and other factors, which may be devastating as Singapore's scarce forested areas may become unrecoverable if extensive damage is done.

Locations

As mentioned above, there are 4 main areas in Singapore we have targeted for these drones to operate regularly in. For each area, we'll have a control centre set up at a nearby fire/police station where drones can be deployed and retrieved. They are:

1. Tengah Forest
2. Bukit Timah Nature Reserve
3. Central Water Catchment Area
4. East Coast Park

- Tengah Forest

  For Tengah Forest, we propose control centres be set up at Bukit Batok Fire Station and/or Jurong East Fire Post. Bukit Batok Fire Station is in very close proximity - approximately 600m from the edge of Tengah Forest (according to Google Maps). Jurong East Fire Post, on the other hand, is a mere 300m away. However, Bukit Batok Fire Station is able to serve the Bukit Timah Nature Reserve as well, being the second closest fire station to the reserve at approximately 2 kilometers.

- Bukit Timah Nature Reserve

  As mentioned previously, Bukit Batok Fire Station is a strong option to consider due to its ability to serve two areas at once. At the same time, Bukit Panjang Fire Post is in even closer proximity at 1.5 kilometres however it may not be worth the resources to add in a new control centre.

- Central Water Catchment Area

  For the Central Water Catchment, Bishan Fire Station is an optimal location for a control station due to it being right next to the MacRitchie Reservoir and the entire Central Water Catchment (within 100m). The diameter of the Central Catchment Area is 5 kilometres, therefore we'll need an operational range of at least 7 km on the drone for it to be safe and able to conduct patrols thoroughly.

- East Coast Park

  For East Coast Park, as it covers a long horizontal range, we think it is optimal to have 2 control stations for the drones: one at Kallang Fire Station (approximately 2 km away) and one at Marine Parade Fire Post (500m away) to ensure the entire stretch is covered and an incident such as the one that occurred in August last year doesn't repeat itself again (CNA)

With the drones' large operating range, we estimate that a maximum of 4 control centres is needed. They are at Bishan Fire Station, Bukit Batok Fire Station, Kallang Fire Station, and Marine Parade Fire Post. Bishan Fire Station is able to cover the entire Central Catchment Area while Bukit Batok Fire Station is able to cover both Tengah Forest and Bukit Timah Nature Reserve. Kallang Fire Station and Marine Parade Fire Post will cover the stretch of East Coast Park. As such, we can keep our resource expenditure at a minimum.

IBM Visual Recognition:

We are utilizing IBM Visual Recognition to detect images of smoke, fires, and humans. We have trained an IBM Visual Recognition by feeding it images labeled 'smoke', 'humans', and 'fires' for it to learn how to detect them. We have also trained it to identify trees under the label "negative" for easier detection of the other labels.

Data manipulation and usage to supplement drone deployment:

We have decided to write two python scripts to supplement drone deployment.

1. [Singapore Monthly Forest and Wildfire Risk Calculator]
   This script pulls two datasets from the Singapore Government's publicly available datasets from 70 public agencies (Data.gov.sg). These datasets are the 'Relative Humidity - Monthly Mean' and 'Surface Air Temperature - Monthly Mean' and we use them to calculate the risk of wildfire/forest fires during the different months of the year.

2. [Location-based Event Tracker]
   This script counts the number of events that occur in each location that entails a drone activation. As it collects information over time, it will be able to complement the function of the first python code, being able to identify high-risk months for specific locations.

These scripts are made to identify the risk of fires at certain locations during the different months of the year and will be used to determine the number of drones needed to protect Singapore against these events within a reasonable risk margin to maximize the efficiency of our available drones while reducing operating costs.

Limitations

There are some limitations to our project and here are some:

Regarding the datasets that we are using for our python code for [Singapore Monthly Forest and Wildfire Risk Calculator], the data is only on a monthly basis and not a daily update which will reduce the accuracy of our code significantly but with government resources, that can provide daily updates on relative humidity surface air temperature, we will be able to overcome this limiting issue for our code.

For the second python code [Location-based Event Tracker], the first 2 years of operation will not be useful as the program requires time to collect data to be able to provide accurate information. In the first year, the data cannot be accessed as an area risk factor because the database only gets updated annually to avoid errors involving blank months. During the second year of operation, the database will only contain the first year's data, thus being unable to provide an accurate prediction of the high-risk months. Only from the third year of operation onwards will the program be able to provide accurate high-risk months analytics. The program also does not take into account leap years in the calculation of the risk factor for the month of February, hence the risk factor for the months of February will be slightly inaccurate once and leap year is taken into account.

For our navigation system, it will take time for the drones to learn and internalize the best routes so it is recommended for more preparation time before deployment into service. Also, in order for the Waze-esque system to accurately give you the optimal route, it needs to have accurate data for all pathways in the forest and at the moment we do not have access to sufficient data regarding all forest routes in Singapore. However, with government resources and support, it should be feasible to map out all the routes of marked and unmarked pathways of these areas and internalize it into our drones.

The manual flying of drones requires training for volunteers and trained pilot services which usually do not come cheap. Hence cost will be an issue if SCDF does not deem the effort to be worth it. However according to the Intergovernmental Panel on Climate Change (IPCC), as shown in the pdf from the publication of "Global climate risk index 2020", estimates in its

recent Special Report on “Global Warming of 1.5°C” that the "mean net present value of the costs of damages from warming in 2100 for 1.5°C and 2°C (including costs associated with climate change-induced market and non-market impacts, impacts due to sea-level rise, and impacts associated with large scale discontinuities) are US$ 54 trillion and US$ 69 trillion, respectively, relative to 1961–1990(IPCC 2018a, p 15)” This shows the extensive economic damage that can result from the damage to infrastructure because of climate change. (Eckstein, David; Künzel, Vera; Schäfer, Laura et al.,2019) The investment into measures and technology for our project would be worth the costs as it can help to prevent greater economic damage that will end up in more costs.

Another limitation is the operational range and airborne duration of the drone. The operational range must be large enough to at least cover the diameter of the area while also having the time to be able to thoroughly check through for signs of fire. At the same time, in the event of a fire, the drones may not have sufficient battery life to last through the operation.

In the event where the firefighters take control of the drone to lead civilians away from the fire, there is no surefire way to communicate between the two parties. The civilians may be panicking and may not be sure what to do even if the drone has audio messages.

There is a privacy concern concerning the issue of the use of drones over community areas. Residents and civilians may be uncomfortable with the presence of the drones overhead with image-capturing capabilities. However, with a pledge to the transparency of the uses of drones and communication with the public, the citizens will come to trust the use of drones.

For Visual Recognition, there is a limitation of the drones incorrectly detecting and reporting inaccurate results. This can be minimized to a certain extent through having the drone reporting identified labels with a confidence score (confidence score which ranges from 0 to 1.0 refers to how confident the ai is that the label is accurately matched) greater than

0.49 to yield more accurate results. However, there is still a small room for wrongly identified labels to occur. To completely thwart this, the authorities can verify the reported image to confirm if it is correctly reported.

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Image of the comment left by SCDF personnel taken from slack channel #questions: