NASA Space Apps Challenge 2017

Category: Warning! Danger Ahead!

Challenge: And YOU can help fight fires!

Team: GalaxCY

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#1 Place in Space Apps Limassol (Cyprus)

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1. Intoduction

Our team, GalaxCY, aims to provide real-time forest data to the forest fire department for early fire detection. More specifically, we have developed a system, which combines various NASA Satellite data and data from our own devices, called Protego, in order to help forest fire managers deal respond faster, more accurately and more cost effectively with fire threats in forest areas.

In every forest, there are three living organisms that need protection and GalaxCY protects all of them. Firstly, we protect the flora inside the forest via our interconnected devices Protego [Ch. 3], by immidiately detecting fire. Secondly, we protect the fauna in the forest by concentrating more Protego Orchestra [Ch. 3.a] in the areas with high percentages of animal population. Last but not least, we protect humans with our Protego mobile application [Ch. 5.a], which incorporates a hybrid function meaning that in an emergency scenario it works 100% even without individual internet access.

From 3D printing our own devices and fabricating our own PCBs, to creating our own evacuation algorithms, we have developed all hardware and software from scratch over the last few days. We have put extra effort to not only theorize our ideas, but truly put them into Rapid Application Development with constant user feedback. By putting our ideas into action, involving local forest fire departments and focusing on prototype development in the last few days, we hope to better prove the true significance of our tangible solution.

Let’s explore it!

2. NASA Satellites

GalaxCY's aim is to fully utilize NASA's generously provided datasets. We have implemented the incorporation of data from MODIS and FIIRS in our mobile application and in our algorithms, in order to display NRT fire hazards with Google API and predict and warn about existing and future hazard areas, such as regions prone to fire, landslides and floods.

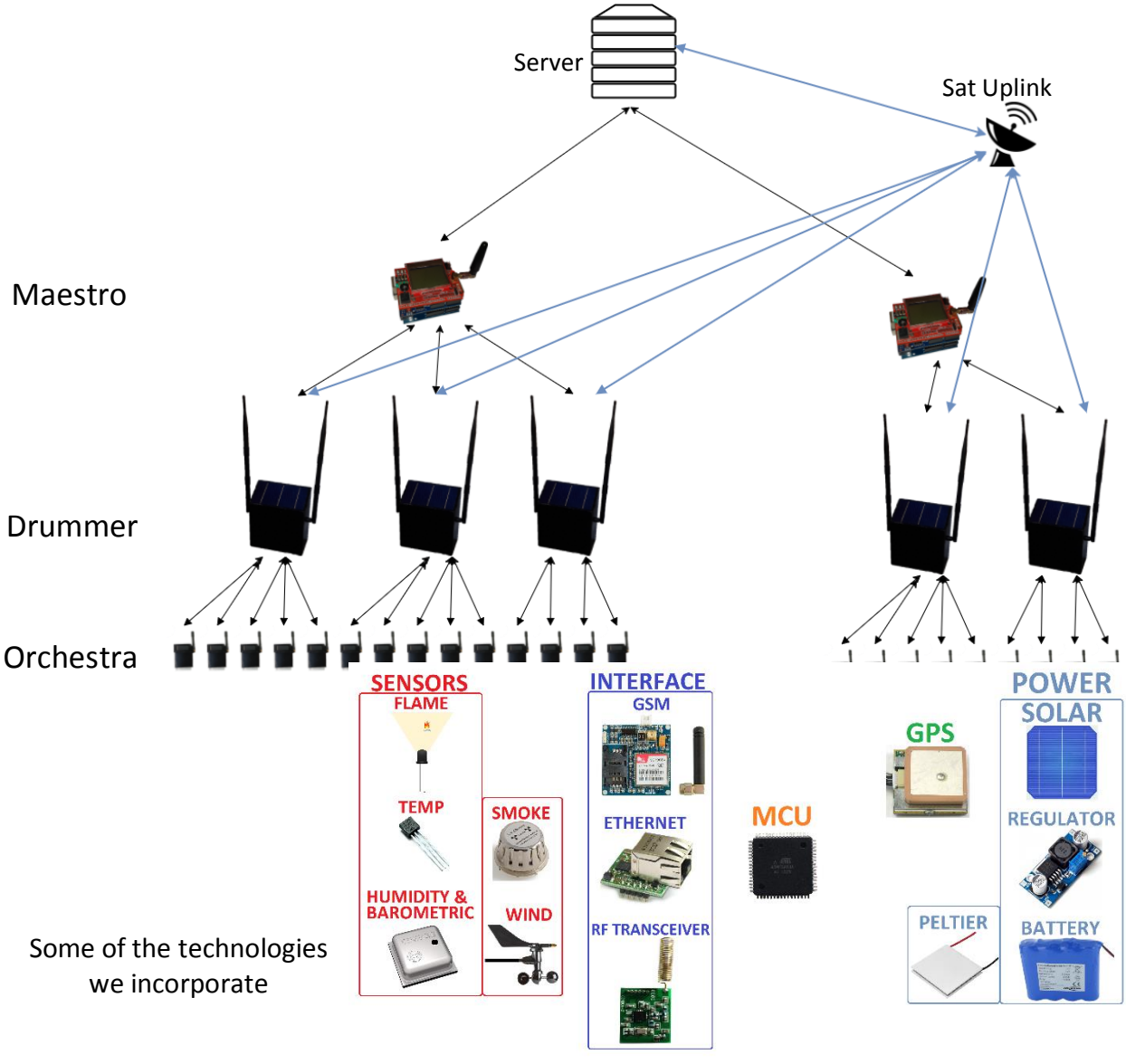
Examining MODIS, we developed the code on Android Studio, which takes MODIS14A2 datasets and computes the data according to "MODIS Collection 5 Active Fire Product User's Guide V2.5 by Louis Giglio", by applying all formulas and equations in order to extract the coordinates of the medium-high confidence fire hazards around the globe. Despite the 3-5 hour latency, MODIS data when displayed on the map, gives a holistic perspective of a fire hazard over the past hours/days and assists the forest fire department in tracking the fire, extracting useful pre-fire and post-fire data and accessing damage extent. The application is available both to the local fire department and firefighters and to the general public.

Furthermore, we use satellite data from roads and paths on Earth, which were entrusted to us by local authorities, to provide the optimal route either to escape from a fire, or to tackle and extinguish it. Taking into account the means of transport (on foot, by car, by firetruck) our mobile app suggests the best route to take.

Our system does not stop at only downloading data. Our team has walked the extra mile and aims to use upwards communication (satellite), as part of the hybrid function of Protego. This complements our solution as a tool that takes advantage of satellite technology not only in withdrawing data, but also in transmitting data.

3. Protego

Protego is a series of small, reliable, fault tolerant and cost-effective devices, which we developed and operated in order to detect forest fires in real-time. Some of the technologies used by the waterproof and environmentally friendly Protego system are GPS, GSM and RF. The purpose of the Protego devices is to alert the local forest fire department of fire detection faster and more accurately than ever before. It comprises three devices needed in different proportions. The three devices used in this massive network of sensors are: one “Maestro” in every forest fire department, several “Drummers” at key forest positions and numerous “Orchestra” sensor nodes placed in the forest close to Drummers. They are structured as below, in a Star Topology Network, which is one way that the network can operate. Another would be a Mesh Topology, where each node will be able to communicate with other neighboring nodes. We do not propose the Cluster or Tree Topology because data can be lost in the case of failure of an intermediary node.



Some of the technologies we incorporate

a. Orchestra (Protego)

i. Functions

The Orchestra device is placed on the tree as seen on the video. Inside the forest, every few hundred meters, depending on forest density, there is a tree with an Orchestra device on it. Charging from a solar panel, it uses green technology to operate and recharge its battery every day. With our setup, we have aimed for extra low operating power consumption, so it can work for a while even without its daily charge. However, even in the extreme case of a battery or charging malfunction, it still has a peltier underneath, which is used for the **Kamikaze function**: if for any possible reason there is no power to operate one Orchestra, it is definitely not useless. If there is a fire around or below it and the temperature rises suddenly, the peltier generates just enough current, so that before the Orchestra melts down from the fire, it kicks into life and sends a fire distress signal to its Drummer, which raises the alarm in the entire network. Apart from a digital alarm, there is a high-range buzzer in every Orchestra which is activated once the alarm is raised, thus warning everyone within its wide proximity.

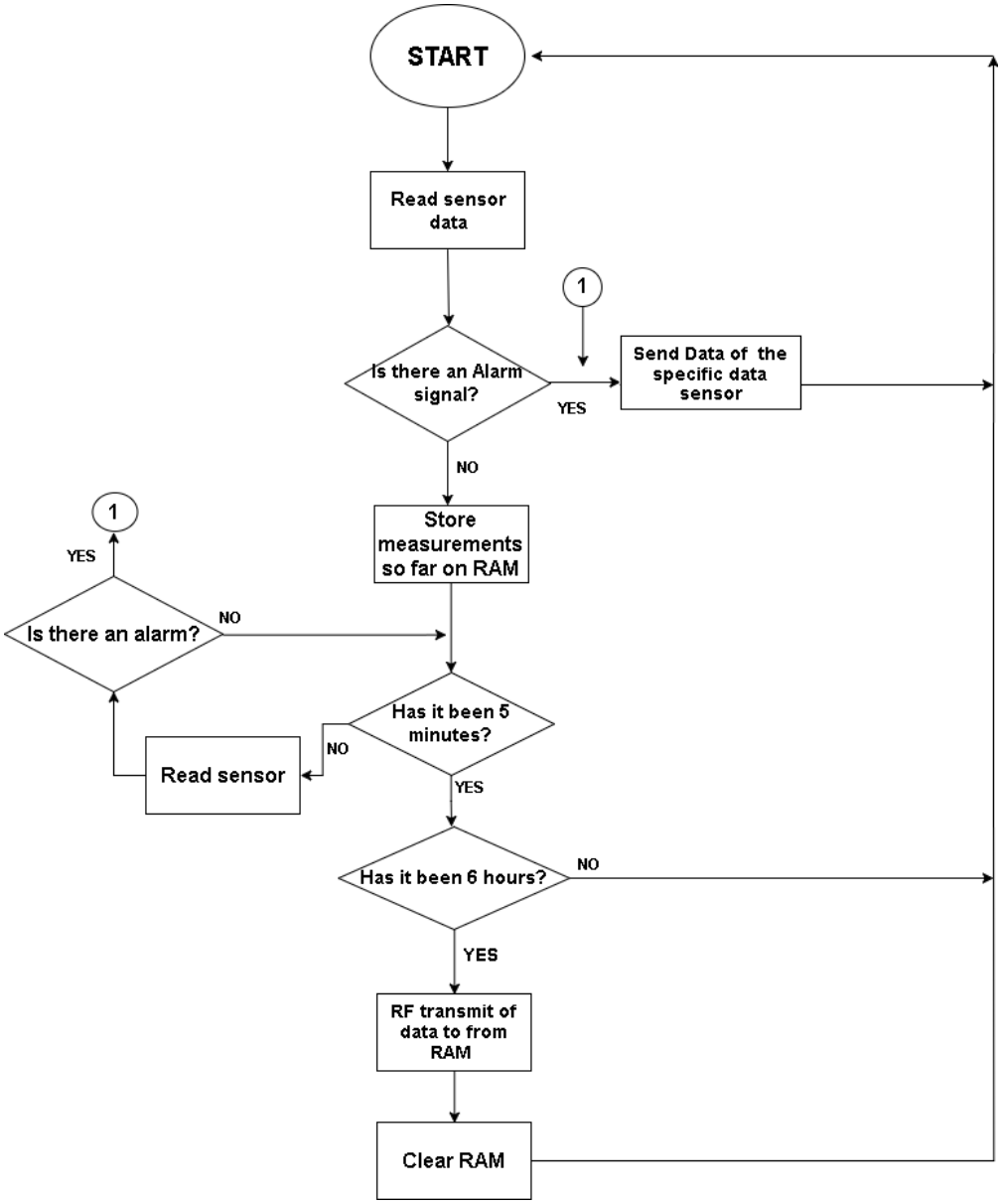
Orchestra transmits via RF its own collected data from its sensors to the Drummer directly. The network of Orchestra is a Star Topology Network designed so that data passes through the Drummer before reaching the Maestro. Another, but perhaps more costly option, would be a Mesh ZigBee Network.

Moreover, we have implemented a triangulation algorithm, according to which a flame detected at a distance by two, three or even four Orchestras is identified at its exact location on the map, thus raising our accuracy.

Every time a sensor captures data-, it checks if it raises an alarm. Alarm sensitivity can be adjusted by issuing an alarm if a custom combination of flame, smoke and temperature exceeds a specific level. An alarm can also be raised if a nearby Orchestra raises an alarm. We have thoroughly planned out how often data will be transmitted in case or not of a fire.

Situation No	Meaning	Map color [Ch. 5]	Data/minute
0	Everything OK	Green	Every 6 hrs
1	I know it's coming. Stand-by.	Yellow	Every 5 mins
2	I smell smoke	Grey	Continuous
3	I see fire	Vivid Red	Continuous
4	Kamikaze Enabled	Dark Red	Continuous

ii. Flowchart



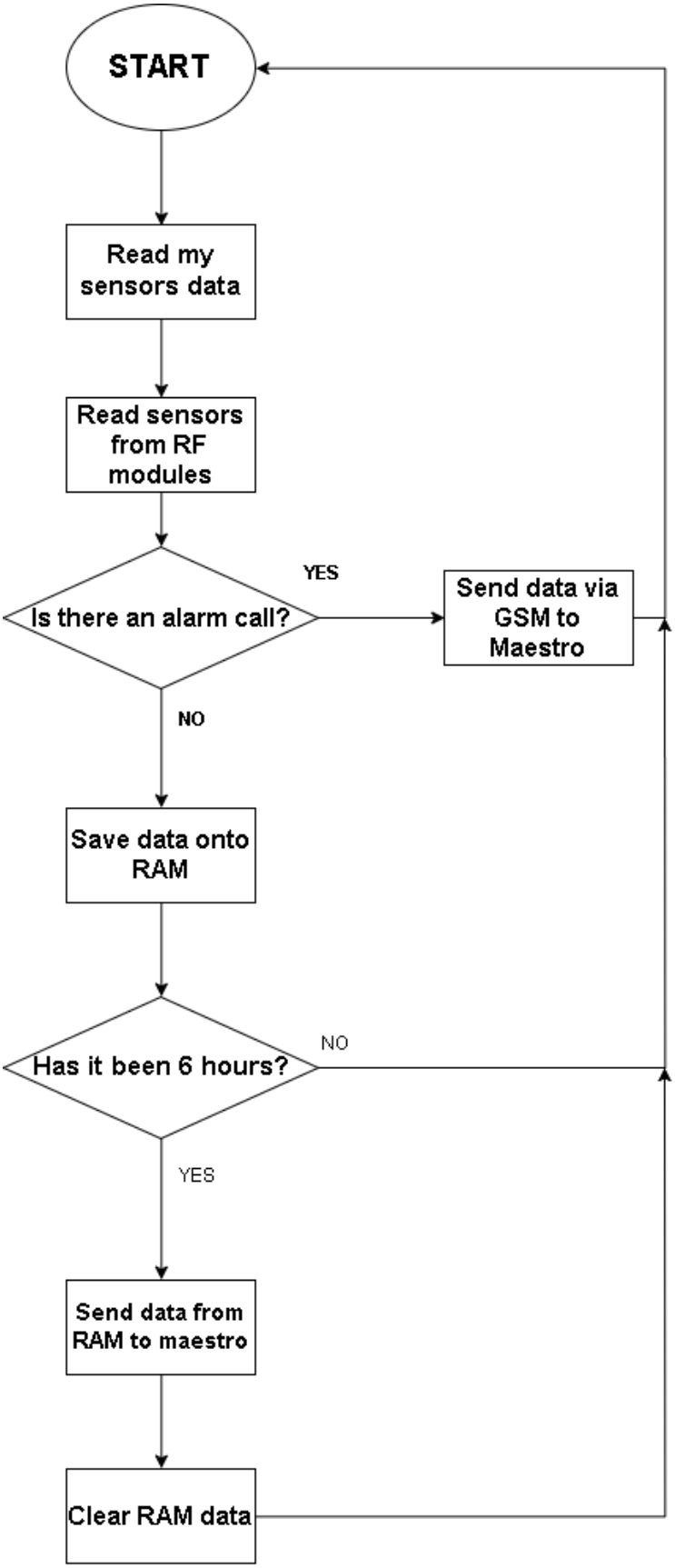
b. Drummer

i. Functions

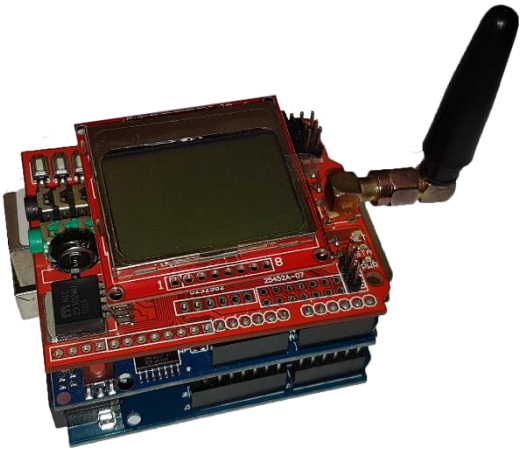
Every Drummer is placed at strategic locations and records barometric pressure, wind speed and direction, where it is situated. A drummer collects all the Orchestra data and its own data, and transmits everything through GSM to the Maestro. The Drummer sends the data every 6 hours, if there is no alarm. In case of a raised alarm, the sending flow of data is continuous, in order to ensure a live feed on the Maestro. The power consumption and recharging philosophy is similar and proportional (not equal) to that of the Orchestra.

In case the local or national GSM and 3G network breaks down completely, the hybrid function of the Protego is enabled so that the network continues to function and fulfil its purpose, according to our contingency plan [Ch. 3.d].

ii. Flowchart



c. Maestro

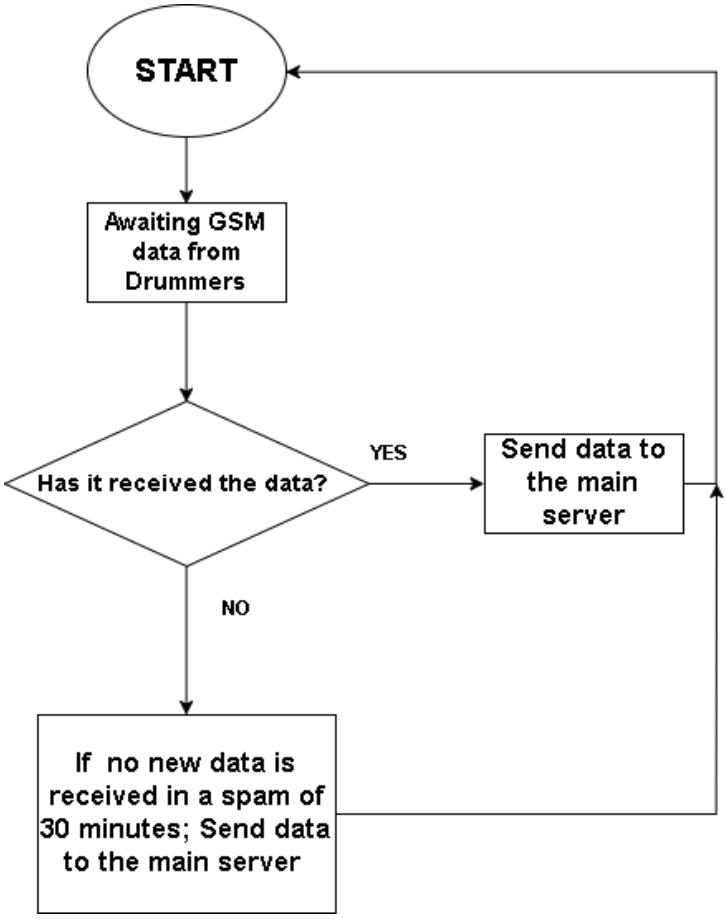


i. Functions

There is a Maestro in every forest fire department, which is in charge of a forest covered with Orchestras. A Maestro receives everything that a Drummer sends him through GSM. It is connected to a monitor at the forest fire department and provides a 24/7 live feed of the area according to the color map [Ch. 3.a.ii].

In order to alert everyone who might be in the hazardous part of the forest, we make use of the emergency GSM network in collaboration with local telecoms partners and send an emergency SMS to everyone in the area by triangulating coordinates form telecommunication towers.

ii. Flowchart

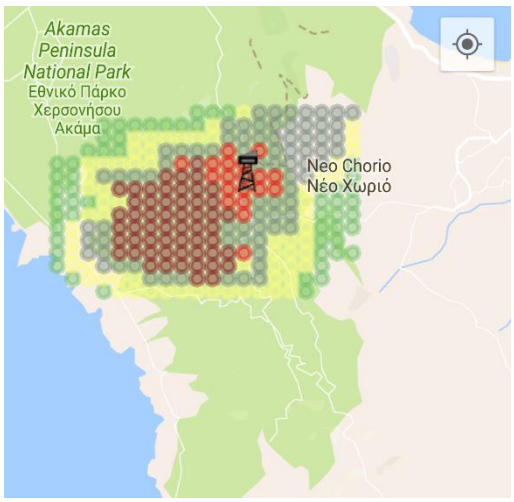


d. Backup Contingency plans

One of the best ways to accurately and conveniently move data from the Drummer to the Maestro is via the GSM network. Despite this, we have also considered multiple contingency communication options in order to achieve maximum fault tolerance and aim for no single point of failure. That is why, in the case a GSM network break down, we switch to multiple layers of hybrid mode and ensure that Protego is as fault tolerant as possible. If we are not even able to connect to an emergency GSM network with the assistance of telecoms operators, we utilize a plethora of other equally effective ways to ensure a constant flow of data to the Maestro in the following order from first to last layer: GSM, WiMAX, Satellite internet connection via a main Sat Uplink transceiver.

e. Interpreting Protego Display

Just from looking at an area covered with Protego, we can easily understand, where the fire started, where it spreads now and where it will spread in the future. Just from this picture, if dark red is kamikaze-enabled, red is flames, and grey is smoke, we know that the fire started somewhere south-west, it has moved northeast and due to the smoke, we know that the wind blows northeast, where the fire will probably spread. So, if we know this much from just a single picture, imagine how accurate we can be when we consider the wind speed and direction (which is measured by Drummers) and the Protego sensors against time.



4. Unmanned Aerial Vehicle

a. Functions

An Unmanned Aerial Vehicle (UAV) is catapulted into the air the second that two or more nearby overlapping Orchestras set an alarm. Strategically placed near the local forest fire department, the UAV, is ready 24/7 to be dispatched automatically and fly autonomously over the coordinates of the alarm. Equipped with a normal camera or a thermal camera, it serves to validate the Orchestra alarm. We propose that the UAV is catapulted once not one but two Orchestras have traced flames or smoke, in order to maximize fault tolerance and avoid false UAV deployment.

Why have we selected a UAV, instead of a fancy drone unlike everyone else? Three words: battery, speed and payload. While an expensive drone has only a maximum of 30 minutes of flying time, a UAV, such as the RQ11, has more than 2 hours of flying time and is much less affected by heat, wind or rain. With the UAV, due to its speed, we can investigate and validate a fire alarm in a matter of minutes. Furthermore, the UAV offers the option of more payload, which means that any sort of attachment such as a first aid kit capsule, can now be dropped as a care package for anyone on the ground. In the likely event of an intentional arson, the perpetrator may even show up on the UAV's camera feed.

The UAV, apart from fire alarm validation, can be put into fire-searching flight as a precaution on high fire risk days and areas. Also, a UAV can be used after a fire has been extinguished in order to assess the damage extent and take bird's eye view images. A combination of NASA satellite and UAV images will be analyzed in order to provide the local authorities with post-fire hazards such as future landslides and floods around the affected area.

5. Mobile App

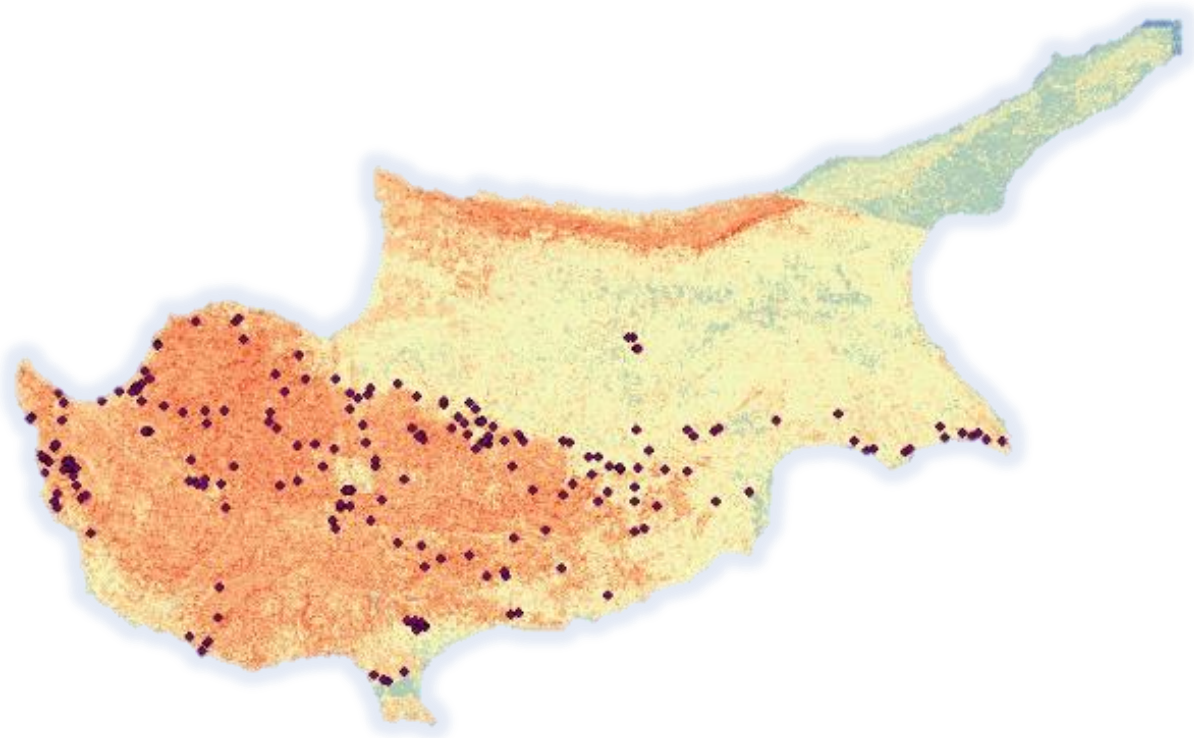
Please consult the extensive analysis of our demo GalaxCYProtego.apk in the file: Protego_App_User_Guide.pdf

6. Pre-fire and Post-fire

We used satellite data to create pre-fire and post-fire calculations. We display medium-to-high accuracy predictions of fire-prone areas in our Mediterranean island, Cyprus, by collecting data such as NDVI, altitude and terrain incline from local forest authorities and NASA Satellites.

For post-fire data, please refer our extensive analysis in Protego_App_User_Guide.pdf

For pre-fire data, we have created a fire-prone map of our island, Cyprus, as shown below:



7. Conclusion

All in all, we have developed a demo mobile application for firefighters and the general public, a system of forest sensors called Protego and quite a few extra features, such as pre-fire and post-fire features. With such a complete and efficient solution, we promise a future with fewer fires, early fire detection, more convenience and much fewer fatalities due to forest fires. We are GalaxCY.

8. Video Link

https://www.youtube.com/watch?v=ROuwbFfO_Tg&feature=youtu.be

9. References

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