A Drone-Based Approach to the Inspection of Radioactive Materials in Landfills

Luciano Cantelli Dario Calogero Guastella Giovanni Muscato **Giuseppe Sutera**

Dip. di Ing. Elettrica, Elettronica e Informatica - Università degli Studi di Catania

Santi Spartà

Radiation and Robotic s.r.l. – Acireale (CT) Italy

Abstract

The illegal disposal of radioactive materials represents a severe threat to both the environment and humans. Inspections of the landfills are usually performed by human operators in order to detect those radioactive sources. Robotic solutions can help in such a risky task, by avoiding the exposure of the operators to radiations. In this work a multi-rotor has been developed, in order to perform the waste inspection and to eventually build a georeferenced radioactivity map.

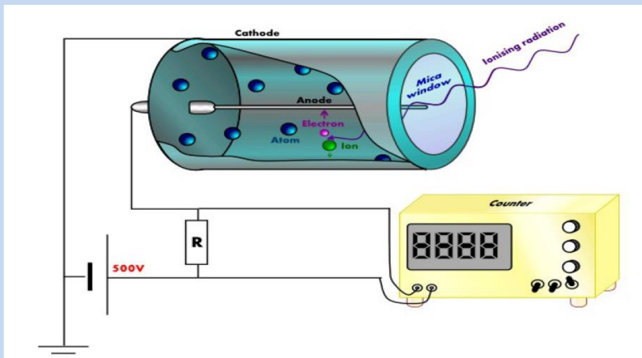
Geiger counter

In the field of aerial vehicles for radiation detection, multi-rotors are preferable compared to fixed-wing vehicles as they allow the adoption of **Geiger counters**, which are light-weight inexpensive sensors for ionizing radiations. In particular, multi-rotors can execute slow low-altitude survey missions, which are needed to keep the sensor close to the potential source.

A Geiger counter is based on a glass bulb filled with a low-pressure inert gas, under a high voltage (400 – 900 V).

Whenever a photon of ionizing radiation hits the gas, it becomes conductive and an electrical charge passes through it. Such a charge is amplified by the Townsend discharge effect within the tube, thus allowing its measurement with a suitable pulse detector.

A bulb from a Geiger counter



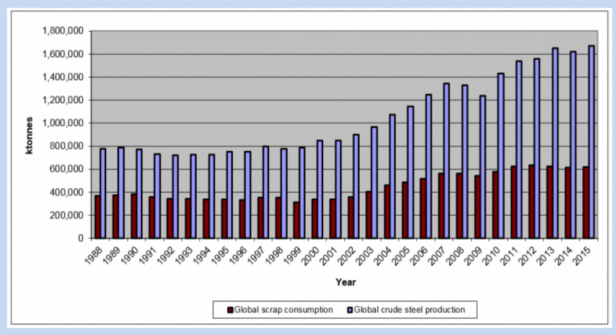
Geiger counter working principle

Motivation

The adoption of radioactive materials in a wide spectrum of applications poses a severe issue about their disposal, which may not always respect legal provisions. Those radioactive sources, which have, intentionally or not, ended up in garbage and debris, are referred to as ***orphan sources***. The risk related to orphan sources is particularly relevant in scrap metal yards where by melting radioactive materials with non-radioactive metals will produce a recycled radioactive metal.

Abandoned orphan source

(Source IAEA)



Global steel demand vs Global scrap supply

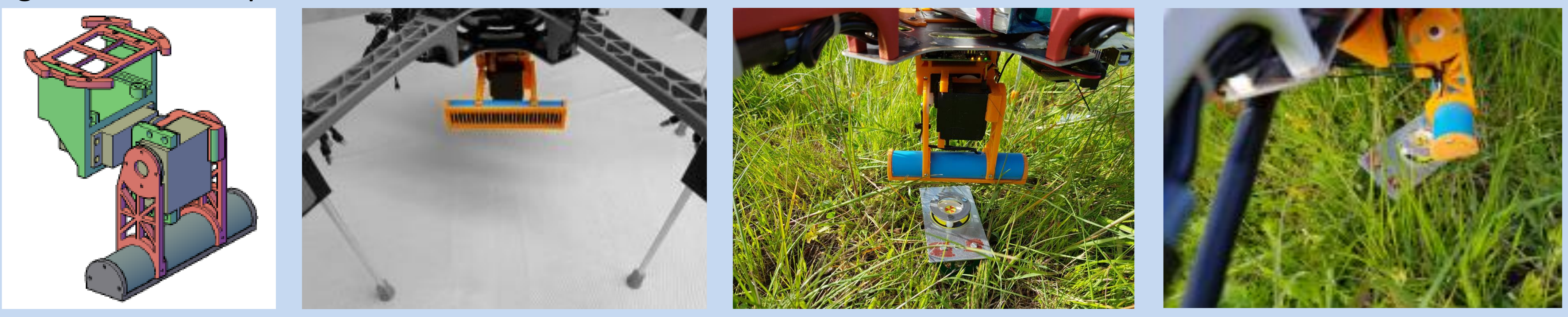
(https://www.steelconstruction.info/Recycling_and_reuse)

Once a radiometric alarm is triggered, the identification and localization of the dangerous element is typically performed by human operators. This procedure consists in a slow check of the waste material by distributing the material on a controlled area. After that, a manual search of the origin of the radiometric anomaly is patiently performed.

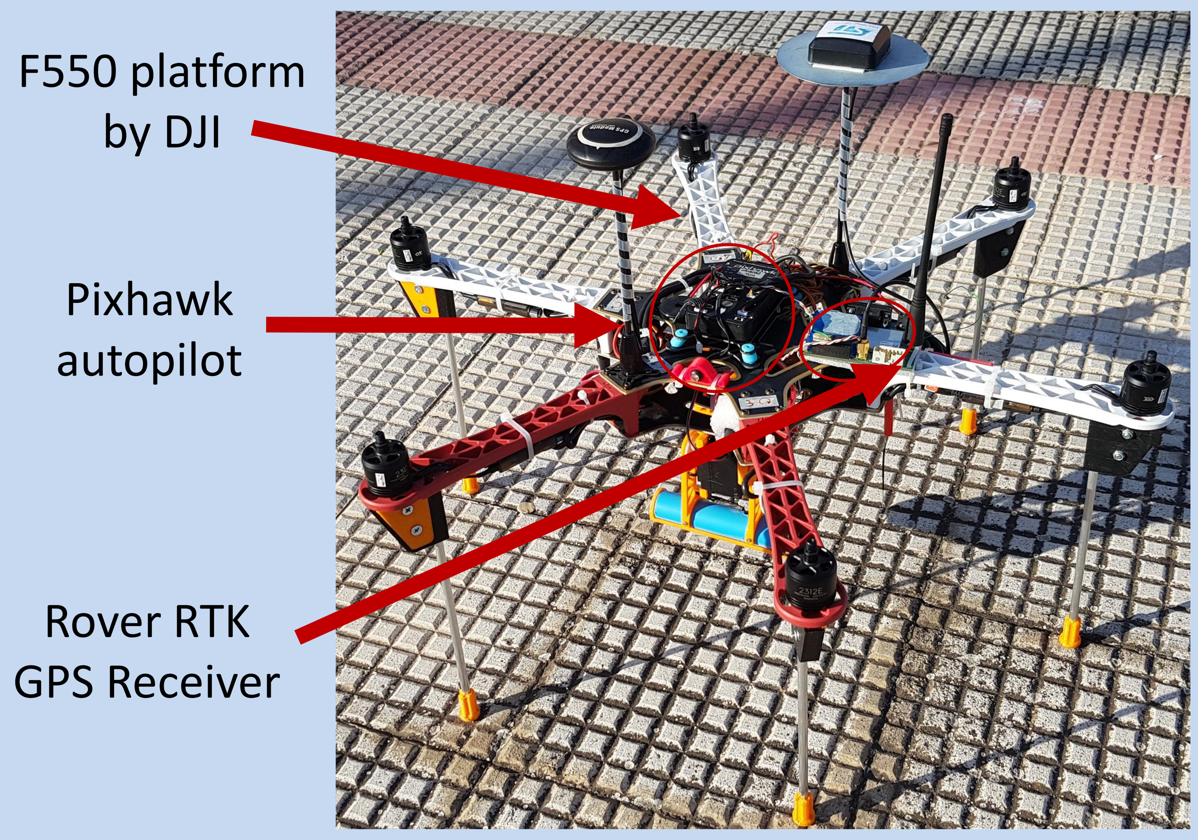
Typical inspection by a human operator

The proposed system

Our solution has been implemented on a commercial hexacopter, an **F550 frame by DJI**, which has been equipped with a **Real-Time Kinematic GPS**, a **Geiger sensor** and an **Arduino Nano** board for the sensor data processing and logging. This board has been also used for the communication with a ground station through a Wi-Fi module, by implementing a custom telemetry system based the MQTT protocol (Message Queue Transport Telemetry). Thanks to the ground station the operator is kept at a safe distance, where he can continuously observe the radiation values of the explored spot. As autopilot, a **Pixhawk** control board has been chosen, running the open-source PX4 stack. A taller landing gear was specifically designed, to host **a custom 3D printed gimbal**, introduced to keep the Geiger sensor always pointing downward during the flight and also to protect the sensor bulb.



3D model of the custom gimbal and the detail of the gimbal in the final setup

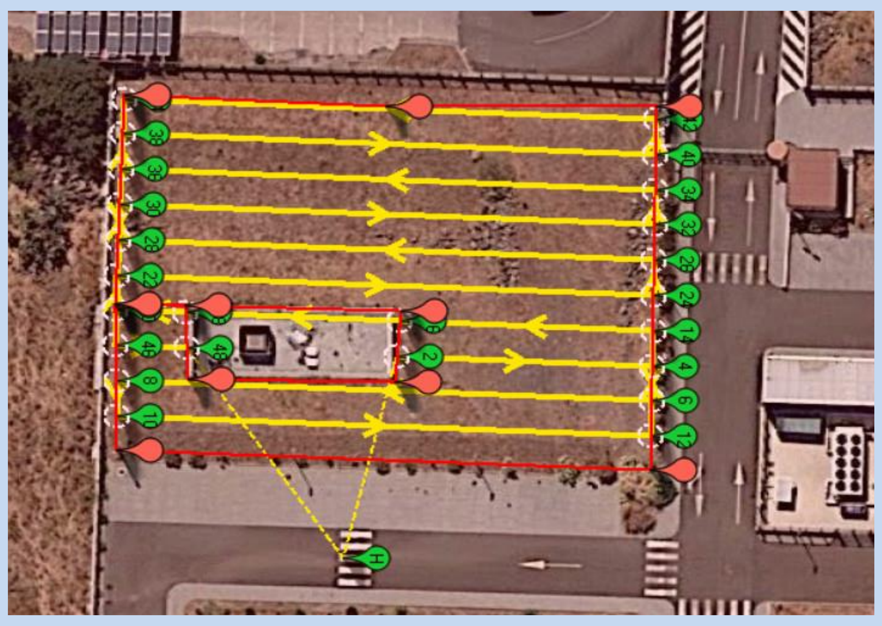


The final setup of the developed drone

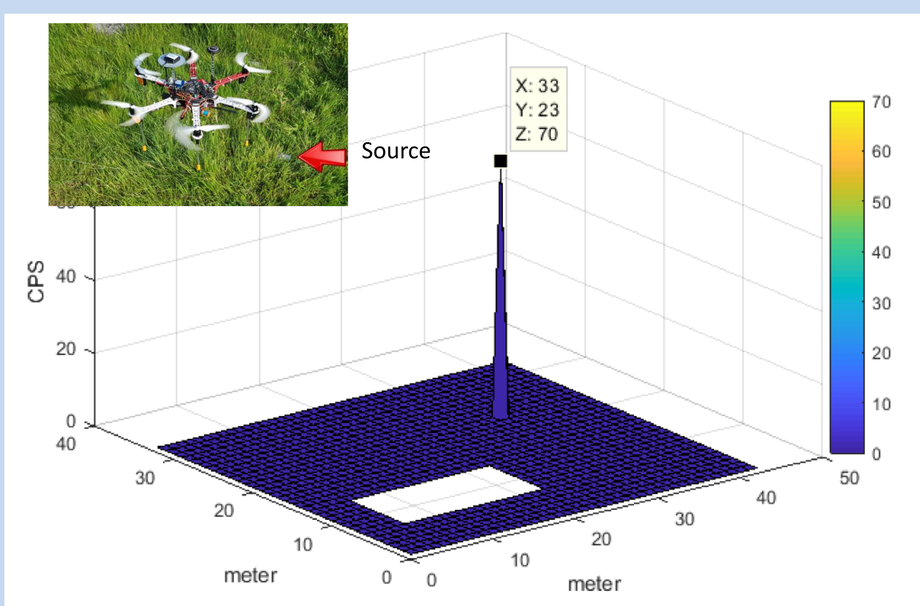
Experimental tests and results

In order to test the proposed system, several assessment flights have been performed in closed areas and monitored by specialized personnel. The RTK-based navigation allowed the drone to reach the target position with centimetric accuracy. The sensor performance was evaluated *at different altitudes* from the radioactive source, ranging from 50 to 200 cm. The results of such acquisition trials are graphically shown. By observing such a graph, the scanning altitude during the survey was fixed at one meter, as it guarantees an appreciable radioactivity detection.

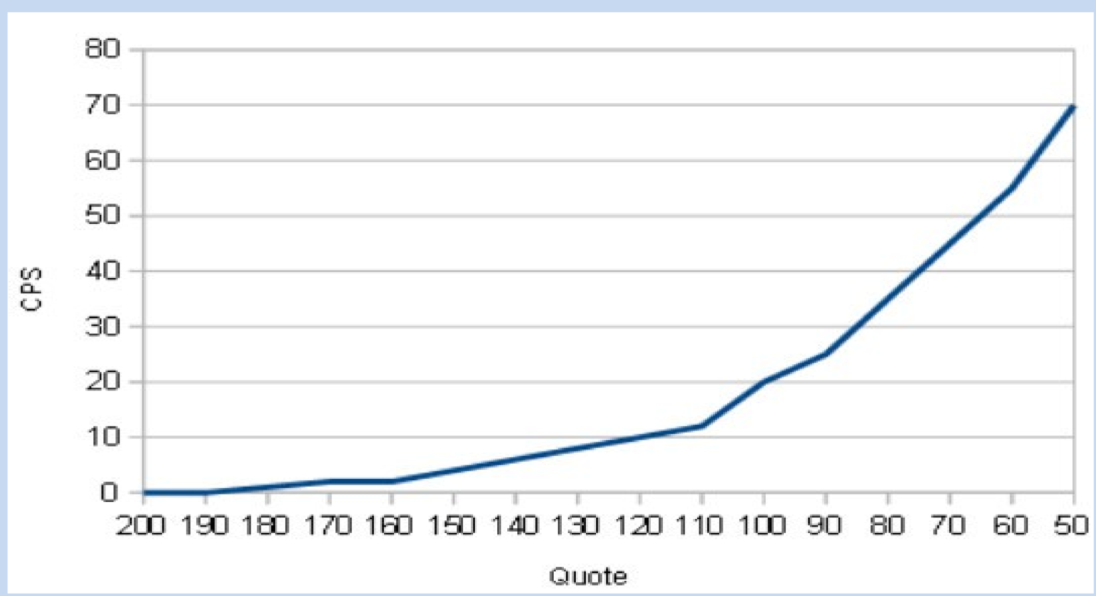
The result of a scanning mission over an outdoor environment is presented below. It is a local radioactivity map of the considered environment including a radioactive source, visible as a peak.



Planned path for the survey mission



Radioactivity map for the considered mission



Graph showing the trend of the counts per second (CPS) of the detected radiations vs. the scanning altitude

Conclusions

The developed solution proved to be an inexpensive and effective platform for the detection and mapping of radioactivity in outdoor environments in a safe mode for the operators. This was achieved thanks to the navigation system accuracy and the adoption of the Geiger counter. The main limitation of such a sensor is the deadtime after a single acquisition, compared to other radioactivity sensors. However, the employment on multi-rotors capable of performing slow and low-altitude scanning missions mitigates such a limitation of the low-cost sensor adopted.