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CISA

Environmental Forensic

REMOTE SENSING TECHNOLOGY FOR ENVIRONMENTAL FORENSIC

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Introduction: definition and applications

Remote sensing, in its broad sense, involves acquiring information from a distance. But, in practice, it often refers to the 'process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance, typically from satellite or aircraft using specially designed sensors' (USGS). The sensors are either passive or active. Passive sensors record the natural energy reflected or emitted from a surface. Reflected sunlight is perhaps the most common source of radiation detected by passive sensors. Active sensors, on the other hand, detect the reflected portion of the radiation emitted by the remote sensing system itself. For example, in a microwave remote sensing system, a microwave is transmitted towards the target and the backscattered portion of the signal is detected by the sensor. Remote sensing has a wide range of applications including mapping, weather forecasting, agriculture, forestry, environmental monitoring, etc.

Remote sensing for environmental monitoring

Challenges to the quality and integrity of natural environments due to human interactions are diverse, but include oil spills, violation of land and wildlife habitat, water pollution, illegal waste dumping and wildlife crimes, such as illegal poaching and disruption of habitat and breeding areas. Environmental monitoring of the air, soil and water for pollutant presence is globally utilized to continuously assess the quality of the physical environment.

Traditional monitoring for the presence of pollutants involves field surveys, sampling and instrumental analysis. These monitoring techniques are important to identify and quantify the pollutant, but they are time consuming, expensive and, often, not in real-time. A method that provides an earlier indicator of a pollutant or other unwanted human interaction with a habitat or species, that can be easily accessed and interpreted by individuals whose job it is to monitor/prevent such activity, yet do not have access to analytical techniques, is desired. Remote sensing for environmental monitoring assumes significance in this context.

The use of remote sensing (RS) technology for environmental monitoring has a number of benefits including automated processing, wide coverage, good revisit capability and a vast range of identifiable features (Sizov et al, 2014; Gomez, 2019). High resolution satellite data has been used previously for environmental monitoring of oil fields (Sizov et al, 2014), wetlands (Jie et al, 2021), forests (Gomez, 2019), landfills (Lacoboaea and Petrescu, 2013), etc.

There are a range of sources of images (both optical and radar) that have been used for remote sensing of the environment including; ALOS PRISM, RapidEye, World-View-2 and Quickbird imagery (Sizov et al, 2014), those taken using Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI) (Jie et al, 2021) and European Copernicus sentinel satellites and MODIS (Gomez, 2019). Many of these are available online and include their processing standards. Landsat (ETM+, OLI), Sentinel 1(SAR), Sentinel-2 (MSI), Terra and Aqua (MODIS) are all free to use whilst ALOS-2 (PALSAR), Radarsat-2 and TanDEM-X are available under a research license. It has been noted that there are unparalleled opportunities being offered by the availability of diverse RS data like those provided by the European Copernicus programme and recent satellite LiDAR launches for environmental monitoring work (Gomez, 2019). Specific reporting requirements, for example when monitoring forests, requires frequent data acquisition (Diaz-Balteiro & Romero, 2008). Although the use of satellite data has proved useful, the best results are obtained using data from multiple types of aerial platforms and sensors, placed at different altitudes, integrated in a GIS and analyzed with specialized software (Errico, 2014) - see Figure 1.

Remote sensing for environmental forensic applications

Brilis et al. (2000) have discussed the application of remote sensing and photogrammetry in environmental forensics, as back as in 2000. A major advantage of using aerial photogrammetry (perhaps the oldest form of remote sensing), according to the authors, is its ability to provide

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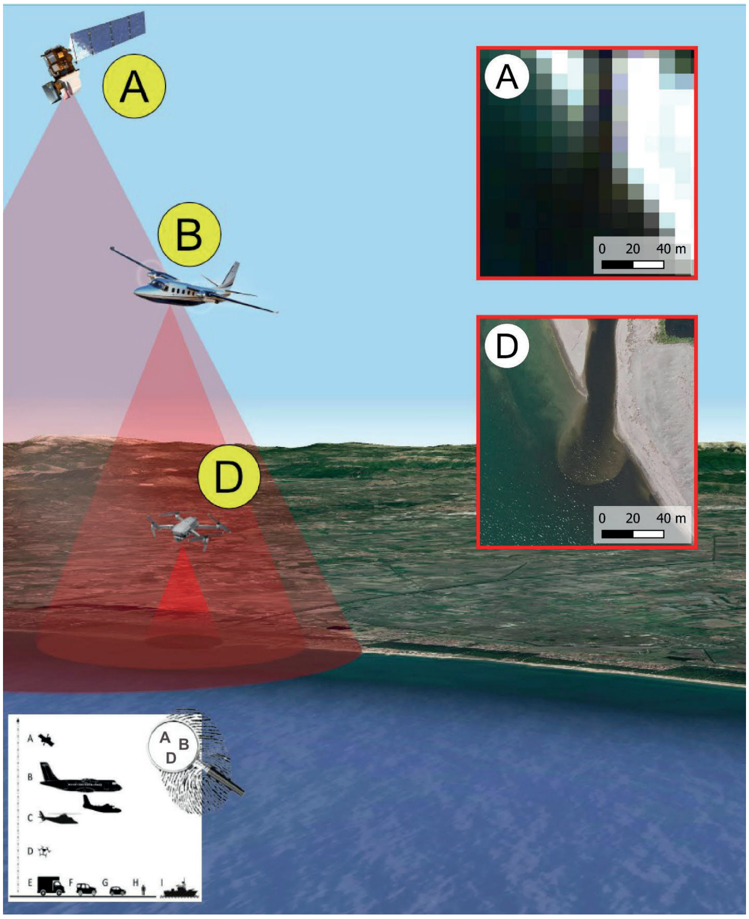

FIGURE 1: Hierarchical monitoring: multiple types of aerial platforms and sensors, placed at different altitudes and an example of different data acquired by satellite (A) and drone (D) targeted to the same area.

objective, detailed documentation of surface conditions at a specific time even in cases where access on the ground is denied to investigators. Where ever records are available, aerial photography can give valuable information concerning a site's waste handling practices which in turn can help in age dating of contaminant releases. Aerial photographs can be analyzed and interpreted to locate past barrel storage areas, open drainage ditches, stains on the ground, standing liquids, landfills, etc. that are often 'hotspots' as far as historical contamination episodes are concerned. In rare cases, aerial photographs, as forensic evidence, may capture fugitive emissions from industrial units or surface release of contaminants, which would help in fixing the responsibility in an otherwise difficult situation (Morrison, 2000).

Satellite remote sensing, though has the disadvantage of lower image resolution, can be extremely useful in environmental forensics, at times. One big advantage with the satellite remote sensing data is its use in tracking changes over a period of time. A series of images spanning over a period of time, of the site under investigation will reveal the changes in the handling pattern of the site and may offer valuable information in resolving the mystery regarding the timing of a contaminant release. Remotely sensed data regarding a site and its surroundings, like topography, land use, etc. may find use in the mathematical models used in forensic investigations. Investigations may lead to unjustifiable results if the changes that the topography of a site has undergone after the contamination episode, are not considered in arriving at a conclusion. Information obtained from satellite images assumes great importance in this context. An experienced image interpreter will be able to gather valuable information regarding the extent of contamination at a site from the variations in colours/ hues observed in the images of the place over a period of time.

The value of remote data is augmented by the correlation to the proximal and the in situ measurements.

A challenge that an environmental forensic expert would face during the in-situ monitoring of contaminated landscapes is the risk to his health due to the volatilization of pollutants. Maio et al. (2017) had demonstrated, on a laboratory scale, that thermal infrared (IR) remote sensing can discriminate between areas with volatilizing chemicals and differentiate between pollutant types and concentrations based on volatilization. Recent technologies of sensors, such as multi and hyperspectral cameras or gas-sensitive IR thermal imaging cameras, have introduced new potential in this field overcoming the limitations of the previous approaches. Lega et al. (2014) reported the use of a range of aerial platforms and an innovative application of thermal infrared remote sensing to detect several illegal activities like, illegal sanitary sewer and storm-drain connections, illicit wastewater discharges, etc.

The remotely sensed data detected at different altitude and that collected in situ, can benefit from their integration; indeed, a Multi-level and Multi-parametric monitoring framework, named MUM3 (Lega, 2018), outperforms the current routine monitoring programs because it combines and integrates multilevel and multiparametric data and information, creating a multi-layer dataset and allowing a complete overview of the phenomenon in a specific scenario. There are examples of the effectiveness of an integrated system both in the study of illegal landfills (Di Fiore, 2017) and coastal discharges (Ferrara, 2017).

By combining remote / proximal sensing (using drones) techniques with analytical / bioinformatic tools, it is possible to use environmental indicators that overcome the limitations of the individual parameters detectable in each acquisition layer. For example, it is possible to use bioindicators such as the cyanobacteria, detectable by remote, proximal and in situ monitoring, both to define the quality of the water and as tracers to define the relationships between the source of contamination and the target area (Teta, 2017; Esposito, 2019).

The range of applications of remote sensing in environmental forensics is wide. It is a useful tool in oil spill forensics to identify the spills and document the time and location of spill observations (Stout and Wang, 2016). It also finds application in the detection of unregistered cattle-breeding facilities, potentially responsible for hazardous littering (Gargiulo et al. 2016).

Concluding remarks

For the enforcement authorities, remote sensing provides a method capable of analyzing multiple variables on both spatial and temporal scales to indicate patterns of activity which warrant investigation and intervention. With the growing use of Unmanned Aerial Vehicles (UAVs), today often called drones, it is possible to have observations from low altitudes that improves the quality of data available to the enforcement agencies. This, coupled with the significantly enhanced data analysis capabilities of Artificial Intelligence (AI) and 'deep learning' techniques, is expected to drive the future of remote sensing in environmental forensics.

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