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Drone Equipment and Configuration for Crude Oil Spill Detection in Water

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Abstract

Purpose: The objectives of this article was to outline the various equipment and configuration of drones which can be used to detect and support oil spill response in water. The study aimed at identify the type of sensors that can be mounted on drones for effective crude oil spill detection in water.

Methodology: A systematic review of past articles on drones in disaster management was done. In this article, various parts of drone and configuration was tested. Sensors capable of detecting crude oil in the visible, infra-red, near infrared, laser fluoro-sensor were elaborated.

Findings: A drone can properly be used for oil spill response operations. Appropriate sensors mounted on the drone can detect oil spill in water and can also access locations which are not readily accessible to large ships and other aerial patrol platform. The limitation of drones is the payload capability and its inability to operate well in windy weather.

Recommendation: Since data collection with drone are faster, cheaper and easier during an oil spill response operations, it is highly recommended to mount the suitable sensor capable of detecting oil sheen even during nighttime operations.

Keywords: *UAV-Drones, oil spill, sensors, DJI Phantom*

Introduction

A drone can be defined as “a land, sea, or air vehicle that is remotely or automatically controlled (Domaille & Campion, 2018). The drone family is not composed solely of flying objects. There may be as many different kinds’ terrestrial drones, marine drones, submarine drones, and even subterranean drones. Drone aircrafts, also known as an Unmanned Aerial Vehicles (UAV) or Unmanned Aircraft Systems (UAS) has gained more importance in environmental monitoring as well in oil spill response around the world. Today, UAV or drones have many and various applications at a global level. The operations that require the use of a drone are both for simple freight transport and for dealing with natural disasters such as an earth quake, fires, floods, tsunamis and similar emergencies (Michail, Avraam & Dimitrios, 2019).

Drone aircrafts have the potential to deliver information quickly and economically in areas with access difficulties and have the ability to fill an important gap in surveillance capability. UAS cover wide range of scales of applications for oil spill response and can in principle be matched to operational requirements, helping to form a hierarchy of observational scales. UAS are able to fly with low altitudes below clouds which minimizes the cloud effects in imaging and targeted object appreciation. This makes a drone suitable for spill response as well as detection and confirmation of potential crude oil spill in oceans. They are able to overcome some of the limitations encountered by other means of aerial and in situ observations. For example satellite observations can be constrained by the sensor’s spatial and spectral resolutions, atmospheric conditions, revisit time and cost (Domaille et al., 2018). For the drone to achieve this, there are some auxiliary equipment and configuration needed to ensure it has the capability of performing the effective function of surveillance and detection.

In this article, the parts and equipment used in drones to take off, fly, capture images, landing and provide situational reports to emergency response unit are elaborated. Unmanned aerial vehicle technology covers everything from the aerodynamics of the drone, materials in the manufacture of the physical UAV, to the circuit boards, chipset and software, which are the brains of the drone. This study essentially targets the drone equipment, parts and configuration for effective detection crude oil spilled in water. Not all drones have the capability to perform surveillance and aerial reconnaissance to collect data and images for analysis. Different drones are used for different applications and this article focus on the use of DJI Phantom drone coupled with mounted sensors to detect oil spill in water.

Literature Review

Drones have been around for more than two decades, (*Divya Josh*i) but their roots date back to World War 1 when both the U.S. and France worked on developing automatic, unmanned airplanes. But the last few years have been significant in terms of drone adoption, usage expansion across industries, and global awareness. Unmanned Aerial Vehicles (UAV) platforms are typically grouped into two main categories. Rotary wing UAVs and fixed-wing UAVs. The ability for vertical take-off and landing (VTOL) as opposed to horizontal take-off and landing (HTOL) constitute one of the criteria for categorization. Fixed-wing UAVs have a relatively simple structure making them stable platforms easy to control during autonomous flights. Efficient aerodynamics enables longer flight duration and higher speeds, which make them ideal for applications such as aerial survey requiring the capture of geo-referenced imagery over large areas and over long distances (Conte & Doherty, 2009). Rotary wing aircraft (multi-copter or multirotor) have more complex mechanics which translates into lower speeds and shorter flight ranges. Amongst their strengths, rotary wing UAVs can fly vertically, take-off and land in a very small space, and can hover over a fixed position and at a given height. This makes rotary wing UAVs well suited for applications that require maneuvering in tight spaces and the ability to focus on a single target for extended periods (Conte et al., 2009)

The engineering materials used to build the drone are highly complex composites designed to absorb vibration which decrease the sound produced. These materials are very light weight. Most drones use a variety of sensors to accomplish what is called "state estimation." They use microelectromechanical (MEMS) chips to measure acceleration and rotation (Konstantin, 2015). Most of the latest drones have 3 types of Return to Home technology namely Pilot initiated return to home (by pressing button on remote controller or in an app), a low battery level (where the UAV will fly automatically back to the home point) and loss of contact between the UAV and remote controller (with the UAV flying back automatically to its home point). More rotors also means more lift. Lift is the push that spinning propellers create beneath a flying machine (*Nathan Chandler*). The more lift a device has, the higher and faster it can go and the more weight or payload it can carry. Drones are divided into three classes as shown on the table 1 (*Dan Gettinger*).

Table 1: Classes of drones

Class	**Characteristics (payload)**
Class I	Less than 150kg
Class II	Between 150 and 600kg
Class III	Greater than 600 kg

UAV drones are equipped with different state of the art technology such as infrared cameras, GPS and laser (consumer, commercial and military UAV). Drones are controlled by remote ground control systems (GSC) and also referred to as a ground cockpit. (Fintan, 2020).

The rise of drones

Drones in 2012 saw a rise in the market and technology as costs went down and capabilities up. Much of this was driven by lower prices for the important electronic components which was driven by the rise of hundreds of millions of smartphones and game machines. Accelerometers, gyroscopes, electronic barometers, compasses and GPS – the same instruments in smartphone help keep a drone flying. Cameras are also getting smaller – again driven by the market for millions of them inside smartphones and consumer digital cameras. Many drone manufacturers exist and for the purpose of this article, the DJI Phantom drone was configured and see its efficiency in detecting oil in water.

Drone come in all shapes and sizes—from long-range, high-endurance models to small, human-portable UAVs with ranges of a few miles. A large UAV offers outstanding performance and capability (carrying VIS, IR, and SAR sensors, but at a high cost). A family of smaller, lighter UAVs offers a more balanced approach between capabilities and costs for oil spill response. These UAVs are propelled by gasoline-powered engines, are capable of programmed or manually controlled flight and require minimal space for launch and recovery. UAV systems generally include a ground station used to program missions, make in-flight adjustments, and receive, process, display, and potentially disseminate real-time imagery and imagery products. The smaller UAVs can be packaged with their ground station to fit into a mid-sized sport utility vehicle and they typically involve relatively simple assembly and user friendly operation. Operational sensor packages that are small enough to meet payload restrictions for small UAVs include panchromatic (VIS) and IR imagers. (GRACE 2017)

Methodology

A drone composed of a flying platform, an aircraft designed to operate without human pilot on board; the elements necessary to enable and control navigation, like take-off and launch, flight and return to home/landing; and the elements to accomplish the mission objectives as sensors and equipment for data acquisition and transfer of information. It also includes devices for precise location for tracking purposes. For the purpose of oil spill detection, a drone requires the payload combination of sensors capable of detecting crude oil in water. This can be achieved by using either the active or the passive means.

The passive means is the technique of using optical camera in the visible and infra-red spectra. Active means involves the use of laser fluorescence sensors and radar for real time data collection and viewing. The surveillance method can use any of the sensor, Visible spectrum imaging; Infrared spectrum imaging, (*Valente et al*) and Fluorescence excitation.

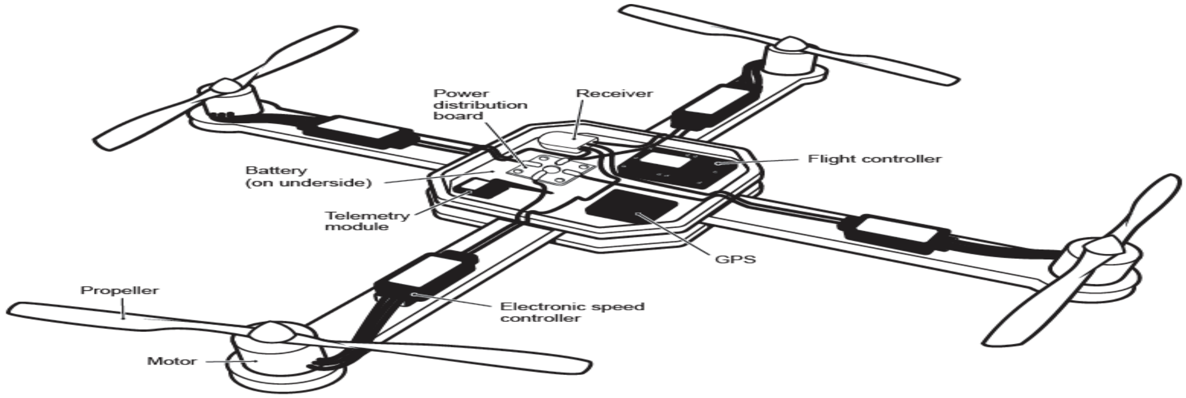

Figure 1: Drone schematics

The DJI Phantom drone

Introduced in the market in 2012 by Frank Wang Tao the founder of HeriansyahR. The DJI Phantom model has quickly evolved in technology with more advanced prototypes now available in the market. With the incorporation of accelerometers, gyroscopes, electronic barometers, compasses and GPS which are the same instruments found in our smart phone, they help to keep the drone flying. Built-in intelligence makes it easier to fly and less likely that the operator will lose it. DJI drones includes a high quality camera which makes the drone to be in constant view in the sky. DJI Phantom with its great technological features are less likely to misbehave or crash due to pilot error or hardware/software (Fantomas, 2016)

Parts of the System

The major parts of the system are as follows:

- Phantom Quadcopter with Flight Controller – this is the main body and the “flying machine” which lifts the camera. It consists of mechanical parts such as the battery, motors and propellers, however most of the magic resides in the flight controller (a computer) and the many sensors – all of which are tied together with programming (software).

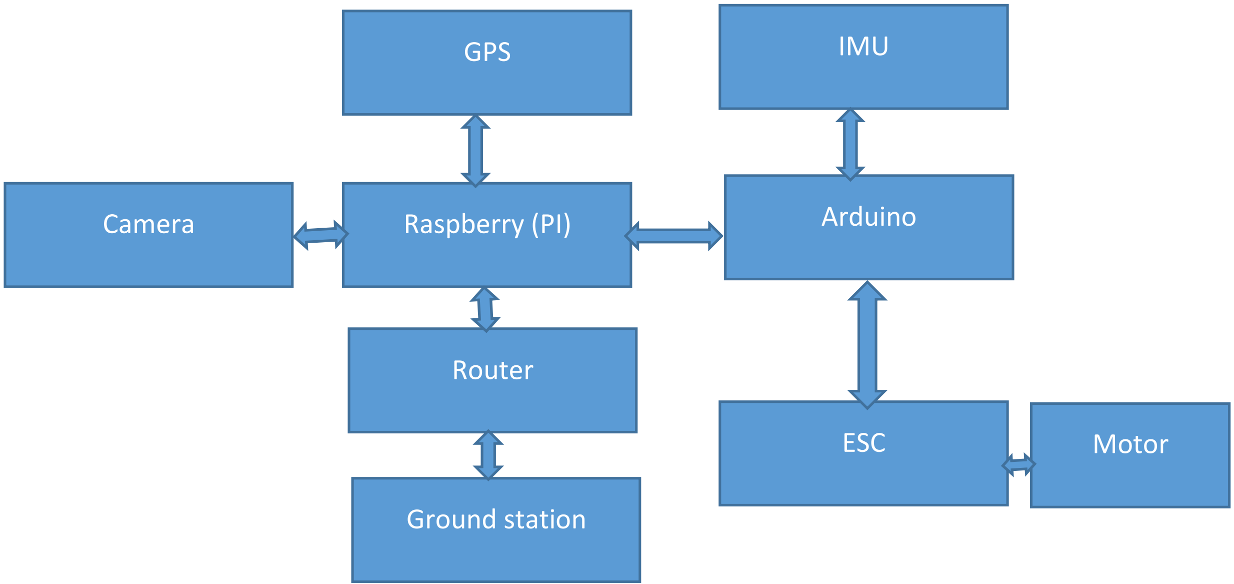

Figure 2: Drone system circuit

Source: Mohamed Ifan

A- Camera and Guimbal

The Camera and Gimbal are hung below the quadcopter and contain their own controller as well as motors which keep the camera steady. The MicroSD card which records the photos and video is also located in this subsystem. It rotates about the x,y and z axis to provide stabilization and pointing of cameras and other sensors.

Figure 3: Guimba and Camera

B- Raspberry

Raspberry Pi is the name of a series of single-board computers made by the Raspberry Pi Foundation, a UK charity that aims to educate people in computing and create easier access to computing education. The Raspberry Pi is a very cheap computer that runs Linux, but it also provides a set of GPIO (general purpose input/output) pins that allow you to control electronic components for physical computing and explore the Internet of Things (IoT).

C- Inertial measurement unit (IMU)

An inertial measurement unit works by detecting the current rate of acceleration using one or more accelerometers. The IMU detects changes in rotational attributes like pitch, roll and yaw using one or more gyroscopes. Some IMU on drones include a magnetometer, mostly to assist calibration against orientation drift.

D- Electronic speed control

An electronic speed controller or ESC is a device installed to a remote controlled electrical model to vary its motor's speed and direction. It needs to plug into the receiver's throttle control channel. ESC is connected to the battery as a power source via a socket or via power distribution board first (HeriansyahR). The level of accuracy of motor rotation is very important to maintain the stability quadcopter.

Figure 4: Electronic speed controller module

E- Global Positioning System

Global positioning system gathers satellite data in order to determine the area or position of the drone itself. The data collected is also fed into the main flight controller and can assist to map the area of interest.

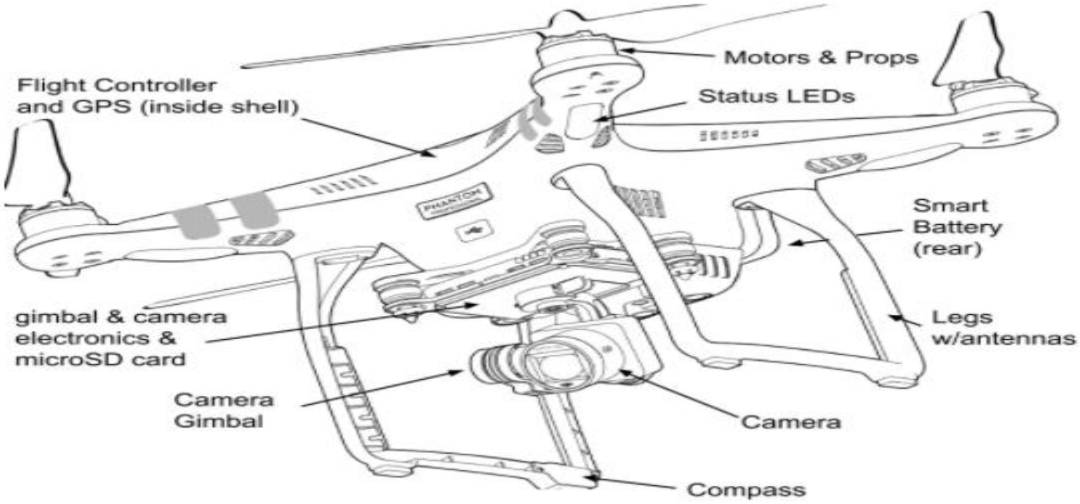

Figure 5: parts of phantom 4 drone parts

Source phantom 4 user manual

An unmanned aerial vehicle system has two parts, the drone itself and the control system. The nose of the unmanned aerial vehicle is where all the sensors and navigational systems are present.

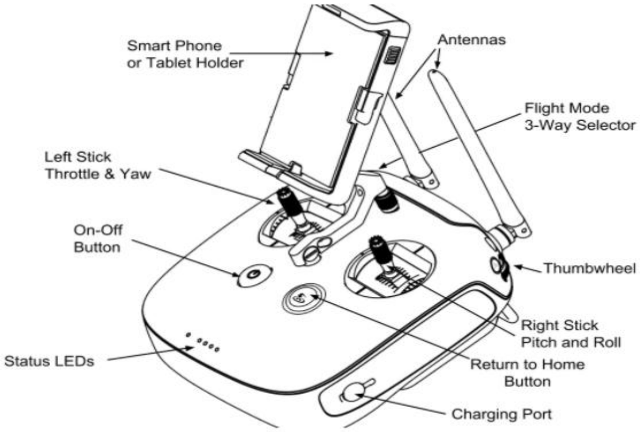

Figure 6: Drone controller Tx basics

Source: Phantom 4 user manual

Used of DJI Phantom for Oil spill detection in water.

When an oil spill occurs, the oil may spread across kilometers generating several oil slicks Oil (Aznar et al, 2014). Slick detection and thickness sensor are mounted on the drone to measure oil presence (*Mervin, 2017*). Demonstrations on how drone can detect oil slick was done by (*Christian Haselwimmer 2017*) but with focus on shore and coastline slick detection. No offshore simulation was done. Demand for surveillance increases as the incident progresses, and the program often divides into a tactical and a strategic role. The tactical role includes support to response operations such as mechanical recovery, application of dispersants, controlled in situ burning, and shoreline assessments. The strategic role is focused on providing a synoptic overview of the overall extent of the release, identifying resources at risk, and gathering information to assist trajectory analysis.

The use of drones in oil spill response can be based on four segments: Crude oil spill scanning with compact multispectral imaging sensors, GPS map creation through onboard cameras (*Margaritoff 2018*) heavy payload transportation, and slick movement monitoring with thermal-imaging camera and providing situational awareness to the response team. Often, a variety of different sensors is required to cover all wave lengths of interest: (*Hanno and Ernö,* 2019),Visible spectrum imaging; Infrared spectrum imaging and Fluorescence excitation.

There are special sensors for spill detection. The integration of multi-sensors platforms are combined sensor package which are commercially available. Multispectral (MS) refers to passive sensors that measure reflected and/or emitted radiation in the UV, VIS, and IR wavelengths in a relatively small number of discrete spectral bands (4–50 spectral bands). A multispectral image sensor captures image data at specific frequencies across the electromagnetic spectrum. The wavelengths may be separated by filters or by the use of instruments which are sensitive to particular wavelengths, including light from frequencies beyond our visible sight, such as infrared. Spectral imaging also allows for extraction of additional information which the human eye fails to capture (Fintan, 2020).

Figure 7: DJI phantom drone with multi spectral cameras mounted.

Source: Fintan Corrigan

The DJI drone uses small wireless cameras, capable of real-time video feed transmission over distances of up to 2 km, and multispectral cameras for more thorough analysis.

Sensors for oil detections.

Optical techniques, laser fluorescence and microwaves are the three broad sensor types used for oil detection in water.

A- Optical Techniques: this are the widely used means for image capturing.

Oil has an increased surface reflectance above that of water in the visible (~400 to 700 nm), but shows limited non-specific absorption tendencies. In the visible band, oil has no sharp spectral features, and hence appears black, brown or gray to the observer.

Infrared Sensors

Oil absorbs solar radiation and re-emits this radiation as thermal energy mainly in the 8-12 µm spectral region (Carl & Mervin, 1996). Thick oil appears hot in infrared images, intermediate thicknesses appear cool, and thin oil or sheen is not detectable. At night the reverse is observed. Infrared remote sensing is mostly has taken place in what is known as the thermal infrared region with wavelengths between 8 and 12 µm. Tests of mid-band IR systems (3 to 5 µm) have indicated that these sensors may have some utility (Hover & Plourde, 1994).

Ultraviolet Sensors

Crude Oil is highly reflective of ultraviolet (UV) radiation even at thin layers (<0.01 µm).

(O'Neil, Neville & Thompson, 2003). Sheens of oil can mapped using the Ultraviolet sensors.

Ultraviolet and infrared images are often overlapped to produce a relative thickness map of oil slicks. Ultraviolet data are subject to many interferences or false positives including, wind slicks, sun glint and biogenic materials. UV sensors are not commonly used in an operational response mode and will not have a strong role in the future except in conjunction with IR techniques.

B- Laser Fluorosensors

Laser fluorosensors employ the property that certain compounds (primarily aromatic hydrocarbons) in the oil absorb ultraviolet light and re-emit a portion of this energy in the visible region of the spectrum. Different classes of oil yield slightly different fluorescent spectral signatures and intensities. One can therefore differentiate between different classes of oil under ideal conditions (Brown et al., 2003). The majority of laser fluorosensors used for oil detection employ a laser operating in the ultraviolet between 300 and 340 nm. Oil fluorescence is typically in the region between 400 and 650 nm with peak intensities in the 480 nm region. There exists a phenomenon known as Raman scattering. The water molecules can absorb the incident laser pulse and return the incident energy minus some rotational vibrational energy.

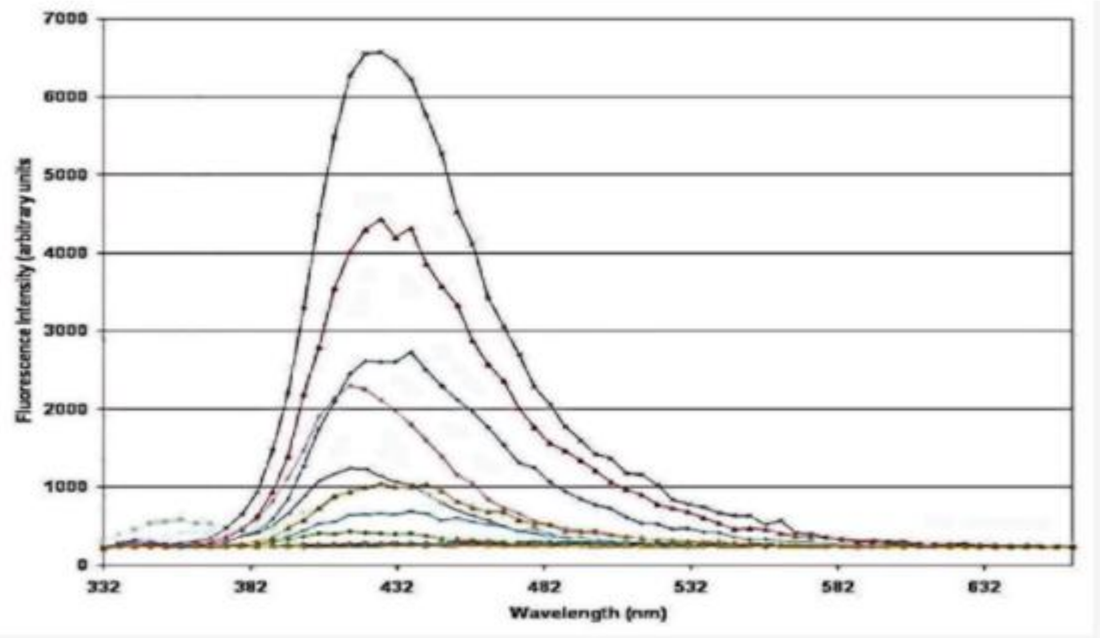

Figure 8: Fluorescence spectra for different crude oils after activation with a 308nm laser – source Environment Canada.

C- Microwaves

This involves the use of radar and passive sensor for spill detection. Radar has the advantage in the oil spill detection process due to its ability to see at night and through cloud or fog. With Water having an emissivity factor of 0.4, compared to 0.8 for oil. A passive device can detect this difference in emissivity and could provide a detection means for oil. GoPro or other compact high definition video unit with onboard storage. Real-time streaming of area of interest surveillance and data collection. With the wrong camera on your drone, you will never be able to take professional videos or photos. Some of the problems are rolling shutter, jello and barrel effect.

The incorporation of multi sensors is perfect in oil spill detection as it will provide multi-spectra bands according to oil absorption. Multispectral cameras work by imaging different wavelengths of light using one or several imagers, each with a special optical filter that allows only a precise set of light wavelengths to be captured by that imager. Once processed, the output of the camera data is a set of images where the value of each pixel is equal to percent reflectance of light for that particular wavelength. These sets of images are then stitched together to create geographically accurate mosaics, with multiple layers for each wavelength.

Obstacle Detection and Collision Avoidance Technology

The drone is an intelligent apparatus with proximity sensors which helps to avoid collision. The latest high tech drones are now equipped with collision avoidance systems. These use obstacle detection sensors to scan the surroundings, while software algorithms and SLAM technology produce the images into 3D maps allowing the drone to sense and avoid collision. These systems fuse one or more of the following sensors for collision avoidance: Vision Sensor; Ultrasonic; Infrared; Lidar; Time of Flight (ToF); Monocular Vision.

UAV Drone Propulsion Technology

Craigi (2016) in his book entitled buying and flying drones outline that the propulsion system (motors, electronic speed controllers and propellers) are the drone technology, which move the UAV into the air and to fly in any direction or hover. On a quadcopter, the motors and propellers work in pairs with two motors / propellers rotating clockwise (CW Propellers) and 2 motors rotating Counter Clockwise (CCW Propellers). The rest of the body is full of drone technology systems since there is no space required to accommodate humans (*Fintan, 2020)*

They receive data from the flight controller and the electronic speed controllers (ESC) on the drone motor direction to either fly or hover. Top UAV drone motors and propulsion systems are highly advanced and include the following components; Motor Stator; Motor Bell (rotor),Windings; Bearings; Cooling System; Electronic Speed Controllers; ESC Updater; Propellers, Wiring and an Arm. The Electronic Speed Controllers signal to the drone motors information on speed, braking and also provide monitoring and fault tolerance on the drone motors.

First Person View (FPV)

Often used to describe cameras mounted on aerial (or any unmanned) vehicles which let the operator see what the aircraft camera sees in real time.

Figure 9: Fully complete mounted DJI phantom drone (Phantom 4 handbook)

Capturing high resolution images on a stabilized drone is very important. Using top photogrammetry software to process the images into real maps and models is just as important.

Table 2: Attribute for airborne sensor selection for oil spill remote sensing

Sensors	**State of development**	**Experience in use**	**Specific to oil**	**False target immunity**	**Coverage**	**Aircraft physical requiremnt**
Still camera	High	High	Poor	Poor	0.25-2	No
Video	High	High	Poor	Poor	0.25-5	No
Night vision camera	Medium	Medium	Meduim	poor	0.25-2	No
IR camera (8-14µm)	High	Medium	Medium	Medium	0.25-2	No
UV camera	Medium	Medium	Medium	Poor	0.25-2	No
Multi spectra scanner	Medium	Medium	Poor	Poor	0.25-2	Some
Laser flourosensor	Medium	Low	Good	Very good	0.01-2	Yes

Challenges and risk when using a Drone for Oil spill Response

The payload limitation is amongst the common issues an unmanned aerial system has. Night time image capabilities are sometimes limited and specialized sensors are needed during Nocturnal intervention. Used of drones during windy weather condition can be very challenging. There is the risk of losing sight of the equipment if not properly program for return to home application.

I- Results and interpretation

Drones or unmanned aerial vehicles are the best remote sensing platform to use during disaster management like oil spill response. Proper configuration of sensors and cameras can be very useful in information and data collection. Certain sensors are better than others in oil detection in water but combination of sensors will produce a multi spectral image capable of indicating the presence of different oil types. Drone if properly used can reduced the exposure of spill responders. It provides unique viewing angles at low altitude. Drone technology is also cost effective and highly deplorable (Guy, Willis, Zürich, 2015).

Not all drones are capable of capturing useful images and the DJI Phantom type has being identified as the most commonly used for mission reconnaissance. Water has a greater absorption rate at near infrared wavelengths range. This property enables water to be easily detected at night time and distinguished with petroleum products. From the spectra graph above, we can see in the table below the various sensors that are suitable for oil in water detection as well as their limitations.

Table 3: Sensor performance for oil in water detection

Sensors	State of development	Experience in use	Specific to oil	False target immunity	Coverage	Aircraft physical requiremnt
Still camera	High	High	Poor	Poor	0.25-2	No
Video	High	High	Poor	Poor	0.25-5	No
Night vision camera	Medium	Medium	Meduim	Poor	0.25-2	No
IR camera (8-14µm)	High	Medium	Medium	Medium	0.25-2	No
UV camera	Medium	Medium	Medium	Poor	0.25-2	No
Multi spectra scanner	Medium	Medium	Poor	Poor	0.25-2	Some
Laser flourosensor	Medium	Low	Good	Very good	0.01-2	Yes

II- Conclusion

The paper focused on the drones' parts or equipment and the configuration to enable it detect oil in water. The commonly used drone DJI Phantom was elaborated with its ability to support oil spill operations. Sensors capable of detecting oil in water has being reviewed. Drone operation is challenging with windy weather and oil detection at night is difficult except with the used of infra-red sensors. Payload limitation is also an issues. With the combination of multispectral sensors mounted on drone, oil in water detection can be possible and this will limit the exposure of spill responder personnel. The payload and the battery capability of drones remains a call for concern during surveillance missions.

Recommendations

As a drone can access difficult area without putting personnel at risk, I strongly recommend the use of these equipment to gather or collect information that can be analyzed and used. It's very useful in disaster management and even to monitor fire outbreak and evolution as well as used in agriculture to measure vegetation index.

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