A micro-UAV-based prototype for high resolution phenotyping under hydrocarbon-induced plant stress

Introduction

Oil spills are a global problem that gradually affects ecosystems, severely deteriorating the availability of the soil resource (FAO, 2015). This type of contamination affects plants, humans and animals due to the presence of numerous toxic components. Hydrocarbons have been reported to form a hydrophobic layer in the soil, causing drought and anoxic stress to plants, due to decreased water availability and increased oxygen demand by soil microorganisms (El-Bakatoushi, 2011). Depending on the chemical and biological characteristics of the soil and the type of hydrocarbon, the soil can recover naturally. However, remediation technologies allow the natural decontamination process to be accelerated using microorganisms or plants (Noomen, 2015). Phytoremediation is one of the methods used to clean up contaminated sites, for example, by introducing hydrocarbon-tolerant plant species or native pioneer plants (Palma-Cruz, 2016). Therefore, understanding the phenological and ecological changes that occur to plants used for soil remediation is essential to determine their potential for phytoremediation. In recent years, the use of UAV (Unmanned Aerial Vehicle) technology as a Remote Sensing Platform (UAV-RSP) has emerged as a new approach to high-performance phenotyping (HTP) in a non-invasive way and with high temporal, spatial or spectral resolution, thanks to the availability of miniaturized light spectrum and imaging sensors, among other types (Yang et al., 2017). An important category in this area are micro-UAVs, due to its low cost and low weight (Max Take-Off Weight, 200 g < MTOW < 2 kg). This work describes the integration of a micro-UAV for the aforementioned application.

Remote sensing sensors

An ideal remote sensor for a UAV-RSP must collect the measurements of interest with comparable resolution in the spatial, temporal and spectral domains and georeference data. Furthermore, the data should be accurate, repeatable, and robust to environmental and operational variables. However, due to various physical, technological and regulatory restrictions, the design of UAV-RSP and its operating methods are still challenging, even for specific operating scenarios (Yang et al., 2017), (Aasen, Honkavaara, Lucier, & Zarco-Tejada, 2016). Considering the above factors and the application requirements with a limited budget, in this work the adaptation of a commercial UAV-RSP was chosen, which includes a multispectral camera and a variety of specialized sensors for precision agriculture. To this micro-UAV, a high spectral resolution micro spectrometer and a thermal micro camera were incorporated in order to collect data related to water stress, such as the Photochemical Reflectance Index (PRI) and the canopy temperature (Zarco-Tejada, González-Dugo, & Berni, 2012). The characteristics of the remote sensing sensors selected for the prototype are presented in Table 1.

Conclusions

In this study, the concept of a micro-UAV based prototype for the monitoring of vegetation that grows in an environment contaminated by hydrocarbons was presented. The strategic value of the micro-UAV prototype is on the assessment of soil recovery strategies such as phytoremediation by means of an efficient, cost-effective and low-weight equipment. At the current state, prototype integration has demonstrated to be feasible. However, several field validation tests are necessary in order to evaluate its capabilities for HTP in phytoremediation of real hydrocarbon contaminated sites.

References


Table 1. Sensor characteristics of the prototype sensors.

<table>
<thead>
<tr>
<th>Sensor type</th>
<th>Brand</th>
<th>Model</th>
<th>Spectral band</th>
<th>Spectral resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multispectral imaging sensor</td>
<td>Parrot Sequoia</td>
<td>Multi</td>
<td>Green: 550 nm</td>
<td>+/- 40 nm</td>
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<tr>
<td>Red: 660 nm</td>
<td>+/- 40 nm</td>
<td></td>
<td></td>
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<tr>
<td>Red Edge: 735 nm</td>
<td>+/- 10 nm</td>
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</tr>
<tr>
<td>NIR: 790 nm</td>
<td>+/- 40 nm</td>
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</tr>
<tr>
<td>STS-Vis Point (FOV) spectrometer</td>
<td>Ocean Optics</td>
<td>VIS (350-800 nm)</td>
<td>3 nm (FWHM)</td>
<td></td>
</tr>
<tr>
<td>FLIR Lepton thermal camera</td>
<td>FLIR</td>
<td>LWIR (8-14 μm)</td>
<td>5-10% (typ)</td>
<td></td>
</tr>
</tbody>
</table>

Micro UAV-RSP integration

The integration of additional sensors to the factory design of a Parrot Bluegrass Field micro-UAV was carried out using the STS Developers Kit. This kit has an API that allows remote monitoring of STS spectrometer data through a WiFi network, reading the spectrometer data through the USB port. To capture the images of the FLIR Lepton® thermal imager, the Flir Lepton development kit and the GPIO interface of the Raspberry Pi computer were used. To install the thermal imager, a plastic housing was designed and printed in 3D. The concept of micro-UAV-RSP integration is shown in Fig. 1. Examples of measurements captured by each type of sensor are shown in Fig. 2.

Fig 1. Prototype sensor integration concept.

Fig 2. Examples of measurements taken the remote sensors of the prototype.