Cullen Scholarship: Marine and Coastal Environmental monitoring using drone and aerial Hyperspectral Imaging sensor (PhD Award)

Background

The evolution of field deployable hyperspectral imaging systems for coastal and marine environmental monitoring represents an exciting and innovative development that could revolutionize marine monitoring approaches in the coming decades [1,2,3,5].

Whilst spectral imaging with multispectral sensors has been achieved since the late 1960s, recent advances in the spectral and spatial resolution of imaging sensors has opened-the-door to more detailed scene analysis through hyperspectral imaging systems [5,6].

Hyperspectral imaging, or imaging spectroscopy, is a technology that measures the continuous spectrum of the light hitting each pixel of the image sensor. Initially developed for satellite applications, hyperspectral imaging sensors typically acquire images across hundreds of narrow spectral bands within the visible, Near Infrared (NIR), and Mid Infrared (MIR) segments of the electromagnetic spectrum. This enables the construction of an almost continuous reflectance spectrum for each pixel in a scene which, in turn, allows for the in-depth spectral examination of scene features that would be less perceptible with the coarser bandwidths of multispectral scanners.

In recent years, there has been a considerable uptake of field deployable hyperspectral imaging within the discipline of environmental monitoring [7]. This is a potentially revolutionary transition that may lead to a step-change in existing monitoring methods and sensing modalities. Capture of higher bandwidth, resolution and quality image data may facilitate differentiation of materials with slightly different chemical compositions, or detection of biological processes or variable conditions in the environment. There is potential for detection and monitoring of many parameters including air and water quality, environmental parameters, habitats and species distribution e.g. assessment of invasive species.

Currently, hyperspectral imaging is generally performed by satellite or aircraft platforms, with recent advances in airborne and space borne technologies providing end users with rich spectral, spatial, and temporal information. As such, hyperspectral imaging has been well established in the remote sensing community to address many environmental questions. A lot of this research is focused on land studies however relating to agriculture, forestry, and pollution, with significantly less research undertaken in the marine and coastal environment.

Aircraft are the most common way to deploy these sensors, with the advantage of coverage of larger survey areas, but they involve expensive and complex logistical challenges. Very recently thanks to sensor miniaturisation, a number of pioneering optical sensors have emerged. These new devices are providing significant improvements to current monitoring techniques with the introduction of UAV (Unmanned Aerial Vehicles) based deployment, and lower cost portable approaches. Deployment of

hyperspectral sensors using drones is still in its infancy and more research and development is required to understand the real capabilities of this technology [8].

In 2020, the Marine Institute procured (via EMFF funding) a state of the art portable hyperspectral camera (Resocon Pika L) and a commercial drone (DJI Matrice300) with the intent to explore how drone based deployment of hyperspectral sensors can be used to address marine monitoring requirements, and improve or replace traditional monitoring methodologies.

Proposal

We propose **a structured four-year PhD project** on a full-time basis to advance research on the use of the Marine Institute's drone deployed hyperspectral sensor to monitor multiple aspects of the marine and coastal environment.

The research questions that can be addressed with the proposed technology within the Marine Institute are multiple and challenging, making this PhD research project highly relevant and timely.

Specific environmental monitoring challenges and questions will be defined following initial consultation with the relevant Marine Institute teams, to understand the key priorities that need to be addressed. Cross links are envisaged with Harmful Algal Bloom Monitoring, seaweed and seagrass resource assessment, Aquaculture catchment/water quality assessment, and Natura2000 site monitoring.

There will be suitable flexibility within the scope of the proposed research questions, project work plan and study area to allow the scholar to shape the project with their background and strengths as well as to enable the research to develop organically where opportunities for advancement present themselves through discovery. The project will aim to:

- Develop knowledge and skills in operating hyperspectral sensors coupled with drones to address marine related scientific questions.
- Understand the capabilities and limitations of hyperspectral sensors as monitoring tools for coastal environment. Can the sensor be used to monitor species, habitats and pollution in the coastal and marine environment? If so which ones and how?
- Development of spectral libraries for key species
- Development of optimal image classification algorithms for hyperspectral imagery along with identification of processing and storage capacities required for regional scale survey.
- Review the potential use of drone based hyperspectral output as a validation resource for classification of airborne and satellite based hyperspectral output.

Location of Scholar

The PhD student will be based in their host Higher Education Institute (HEI) and in the Marine Institute in Galway (split circa 50/50 in modules of time as agreed between the HEI and MI supervisors).

Outcome

The student will undergo a four-year training period learning new research methodologies resulting in a PhD thesis. The outcome of this PhD project will be:

- A research methodology paper focused on the use of hyperspectral sensor in combination with drones. This will be a technology paper that will look at the various aspects of this new technology, ideally comparing various drones and hyperspectral sensor capabilities and/or comparison with more traditional multi spectral methods.
- A research paper focused on analysis of environment monitoring capabilities of the hyperspectral sensors. Which environmental factors, species, habitats etc. can effectively be monitored with such technology and with what level of temporal and special resolution
- A research paper focused on the use of hyperspectral sensor to map and monitor intertidal and sub tidal seaweed species.
- A research paper focused on the use of hyperspectral sensors as a tool for carbon analysis within high carbon potential ecosystems such as seagrass and salt marshes.
- A research paper focused on the effect of environmental conditions and seasonal variations on spectral signatures within coastal regions.

Links with Marine Institute Strategic Plan 2018-2022

This proposal falls principally under Strategic Focus Area 3 - Research & Innovation, developing research capacity to support ongoing national and international operational and research programmes. This links to Strategic Focus Area 2 – Forecasting Ocean and Climate Change, specifically through improving our ability to determine seabed character, and in turn improving our benthic habitat, oceanographic & ecosystem modelling capacity. Improving knowledge of the connectivity and interdependence of seabed type, benthic habitat, and oceanographic and environmental bottom conditions will better support future modelling and scenario prediction ability, as well as resource management.

Specific Requirements

The scholar should have a primary degree in geomatics, engineering of environmental science, natural resource management, remote sensing or marine science, previous experience with using hyperspectral data is preferable but not essential.

Financial Details

Scholarships will be up to €27,500 per annum (maximum funding of €110,000 over four years). This amount comprises a maintenance award of €18,500 (Irish Research Council rate effective 1-Jan-21) to the student as well as payment of fees to the host higher education institution (HEI). The maximum fees payable to the HEI will be €6,000 per annum. The scholarship award also includes a budget of up to €3,000 per annum for eligible research costs (travel & subsistence, publication costs, consumables and other costs e.g. laptop) for the sole use of the student, and are payable on a reimbursement basis direct to the host institution where the postgraduate student (scholar) is registered. There are no

overheads payable on the scholarship. Publication costs are intended to cover publications on which the scholar is listed as first author and are published under Open Access. Scholars can also apply for additional funding under the Marine Institute's Networking Initiative, which is an annual call.

Marine Institute Co-Supervisor

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