Unmanned Aerial Systems Imaging System Creation for Water Quality Analysis

A 2015 CIS MicroGrant proposal by

Victoria Scholl
Principal Investigator
Motion Picture Science & Imaging Science
Undergraduate at Rochester Institute of Technology

Advisor:
Aaron Gerace, Ph.D.
Senior Scientist
Digital Imaging & Remote Sensing Laboratory
Chester F. Carlson Center For Imaging Science

Abstract – Water-based research is critical to human life and the health of the environment on our planet. The process of water quality analysis is often performed using remote sensing systems, which surpass ground-based tactics in their efficiency and range capabilities for the determination of constituent and pollution levels. However, traditional airborne and spaceborne systems that image bodies of water suffer serious limitations related to the integrity of their data and frequency of collection. As the use of unmanned aerial systems (UASs) becomes more prevalent and imaging technologies advances, an opportunity to perform the traditional scientific study of water quality with a nontraditional remote sensing platform presents itself. UASs are cost-effective and able to image specific regions with high resolution at low altitudes. The proposed project involves purchasing a multispectral six-camera system with spectral bands ideal for water quality analysis, mounting it onto a UAS, producing a calibration protocol, and using the system to generate in-water constituent maps in near-real time. This imaging system can also be adapted for other remote sensing applications and will be a valuable addition to the Digital Imaging and Remote Sensing laboratory at the Chester F. Carlson Center For Imaging Science.

Dollar Request: $5,000

Desired Funding Dates: 6/1/2015-5/1/2016

Scientific justification

Introduction

The U.S. Environmental Protection Agency (EPA) protects human health and the environment through the development and enforcement of regulations and environmental laws. It studies and measures the state of environmental features and provides this information to the public for education, awareness, and support of fish and wildlife. Under the Clean Water Act, lists of impaired waters must be developed to identify waters that are too polluted to meet the water quality standards set by their states[1]. The Rochester Embayment, primarily consisting of the region near where the Genesee River flows into the Lake Ontario Central Basin, is on the EPA's impaired water list. Traditional remote sensing platforms have been used to monitor its water quality, but each has its serious limitations.

Temporal, spectral, and spatial aspects of image collection are difficult tradeoffs. The NASA Jet Propulsion Lab Airborne Visible InfraRed Imaging Spectrometer (AVIRIS) instrument gathers hyperspectral image data on a Twin Otter aircraft using 224 contiguous spectral bands spanning the 400 to 2500nm wavelength range [2]. In 1999, AVIRIS was used to image the Rochester Embayment area with impressive spectral resolution. Unfortunately, as an airborne platform used to only collect this data once, it is not practical for long term monitoring. Conversely, the NASA Landsat 8 satellite is a spaceborne platform launched in 2013 that images the entire Earth every 16 days. This makes Landsat 8 attractive for monitoring ecological change regularly over time. However, its multispectral band combination is not ideal for water quality analysis. The presence of atmosphere and clouds during collection is an issue because it influences the measured signal and calculated water parameters, leading to possible misinterpretations or misleading conclusions. Only two cloud-free scenes have been obtained of the Rochester Embayment since Landsat 8 achieved orbit. In addition, the spatial resolution of a system orbiting at such a high altitude is limited to 30m pixels. This low resolution limits the ability to assess finer constituent fluctuation within a body of water, which may be important for some applications.

A newer, alternative type of system which can overcome these limitations is on the horizon. Unmanned Aerial Systems (UASs) are aircraft systems that are flown remotely through pilot control or autonomously through the use of computers. The Northeast UAS Airspace Integration Research (NUAIR) Alliance operates and oversees UAS test ranges with the ultimate goal of safely integrating UASs into commercial airspace. RIT is one of their partners and has been designated as one of the primary UAS research and development academic institutions in New York to further advancements with this technology [3].

Considering models that are reasonably priced, capable of carrying 3+ pounds, and feature onboard GPS for geo-referencing purposes, this technology has advanced to a point where it is attractive for endeavors within the scientific community. This work proposes to create a UAS-based imaging system for remote sensing applications. More specifically, a 6-band multispectral camera will be used to image bodies of water such as those within the Rochester Embayment

area to monitor their constituent levels. The UAS's low flight altitude reduces the issues introduced by imaging through large amounts of atmosphere from space, and the ability to select a custom combination and range of filters for each of the 6 cameras will allow the system to have an ideal spectral sensitivity for water quality analysis. Data collection will no longer be limited by an orbit, pilot availability, of the presence of clouds.

Research Innovation justification - UAS research and development is one of the most important avenues in the current technology landscape. Their use is becoming increasingly common in many of the industries serviced by remote sensing - military, agriculture surveying, forest fire detection, search and rescue, overall detection and monitoring, and more. It is critical that CIS invests its time and resources into developing this promising and prevalent technology. For meaningful and accurate spectral measurements that are critical to remote sensing, a high-quality camera system is required. The people and resources available within the Chester F. Carlson Center for Imaging Science will provide the perfect level of support and expertise to carry out this innovative research project.

Budget Request – I am requesting $5,000 to be matched by Aaron Gerace and Carl Salvaggio, producing the $15,000 needed to buy the multispectral camera system to be mounted on the UAV.

Budget Justification – The camera system is a Tetracam 6-camera Micro-MCA (Multiple Camera Array) snap, and was chosen for this UAS imaging system for multiple reasons: Rolling shutter artifacts are minimized and the down-facing cameras are already synchronized and registered with one another for accurate temporal and spatial registration between images [4] . The narrow-band spectral filter in between the lens and sensor of each camera is customer-specified and will be intelligently chosen for water quality parameter identification. The specific VNIR bands will be determined through modeling optimal identification of water quality parameters of interest.

<div align="center">

Project plan

</div>

Overview

This project will focus on the generation of a UAS-based imaging system to ultimately measure in-water constituent levels in near-real time. By combining off-the-shelf UAV and camera technologies, the main bulk of the project involves developing algorithms to stitch together captured imagery, implement algorithms to perform water quality parameter identification, and present constituent maps as the end product. The accuracy of these maps will be compared to those generated using Landsat data as well as ground truth collected from the body of water being imaged.

To understand the radiometric response of the multispectral camera system, an in-situ ELM-based calibration procedure will be performed. Panels with a series of known reflectances will be placed in the scene. During the time of collection, ground-based reflectance measurements

will be made of the panels. The sensor gain and bias can then be determined through a linear regression between the measured panel reflectance and corresponding image digital count values. This calibration procedure helps to account for signal contributions from the atmosphere and instrument drift.

Efforts at RIT to support the monitoring of the Rochester Embayment are ongoing. Under a grant by the USGS to support the Landsat Science team, students and staff are already taking in-situ measurements of key bodies of water in the Embayment, so no complicated lab procedures will need to be learned on behalf of the research team regarding the collection of ground truth.

This project will incorporate all steps of the imaging chain and involve a variety of staff and students within and outside of the Chester F. Carlson Center For Imaging Science. At the completion of this project, equipment will join the Digital Imaging and Remote Sensing laboratory collection of instruments to be used for future remote sensing applications.

Major milestones and anticipated timeline:

Summer 2015
  June-July
  - Modeling to choose spectral bands of camera filters
  - Hardware acquisition
  - Mount camera system onto UAV
  - Introduction to UAV control software
  August
  - Preliminary calibration
  - Preliminary image collection through remote piloting control & ground truth measurement

Fall 2015
  - Advanced characterization and calibration (geometric, radiometric) of system
  - Develop code to stitch images together
  - Apply existing in-water parameter retrieval algorithms to estimate water quality parameters
  - Program UAV collection paths for automated collection

Spring 2015
  - Refine algorithms
  - Improve performance for near-real time
  - Compare results to Landsat
  - Write report summarizing results and outlining future work

Outcome:
Concentration maps of 3 parameters in real-time or near real-time. Initially, concentration maps will be generated immediately after flight collection. These results will then be compared to those obtained from Landsat efforts as provided by Javier Concha.

Dissemination of results: Presentation of concentration map results and comparison to Landsat. A report will be written describing the project, issues related to using drone technology to conduct remote sensing studies, and future work that can be done to improve and expand the system's capabilities.

The team is aware of and respects current restrictions in place regarding the use of UAVs outside of designated flight zones.

Resources

[1] "Impaired Waters and Total Maximum Daily Loads." *Water Laws and Regulations: Clean Water Act*. United States Environmental Protection Agency, 12 Mar. 2015. Web. 05 May 2015. <http://water.epa.gov/>.

[2] "AVIRIS Overview." *AVIRIS - Airborne Visible / Infrared Imaging Spectrometer - General Overview*. NASA Jet Propulsion Laboratory, 22 Apr. 2015. Web. 05 May 2015. <http://aviris.jpl.nasa.gov/>.

[3] "Northeast UAS Airspace Integration Research Alliance (NUAIR)." *NUAIR Alliance*. NUAIR Alliance, 2015. Web. 05 May 2015. <http://nuairalliance.org/>.

[4] "Tetracam Micro-MCA." *Tetracam's Micro-Miniature Multiple Camera Array System*. Tetracam, Inc, 2011. Web. 05 May 2015. <http://www.tetracam.com/>.