RIT | Chester F. Carlson Center for Imaging Science
Digital Imaging and Remote Sensing Laboratory

Annual Report

2022-2023

Cover Photo: The Tait Preserve has served as a site for countless experimental campaigns conducted in support of DIRS laboratory research programs. This georeferenced mosaic was created using high-resolution RGB imagery collected using the laboratory's DJI Mavic platform. Present in the scene are the novel subpixel targets (green targets in the upper left quadrant) designed and created by DIRS doctoral candidate Chase Cañas under the supervision of Dr. John Kerekes. [Photo credit: DIRS sUAS Research Laboratory].

From https://www.rit.edu/arenas/tait-preserve:

Located in Penfield, N.Y., approximately 20 minutes from RIT's Henrietta campus, the Tait Preserve features a diverse landscape of hills, deciduous hardwood forests, and open meadows in addition to Redman Lake and Irondequoit Creek, which flows through the property. The Preserve is home to a menagerie of animals, including deer, turkey, beaver, fox, coyotes, and a wide variety of spectacular migratory and non-migratory birds. Students and faculty have utilized these natural resources to great effect as they conduct research across various disciplines. Visits by appointment or reservation only.

RIT acquired the Tait Preserve in 2019 via an enormously generous donation from Amy and Bob Tait, for whom it is named. For many decades prior to being owned by the Taits, the property operated as a sand/gravel quarry and a concrete mixing plant. Redman Lake, the property's 60-acre lake, was created in the early 20th century to pursue the sand and gravel that was contained underground. Over time, the property changed form as the material was excavated and deposited in different areas until it reached its current configuration. Since functioning as an industrial site, the property has been undergoing a process of ecological restoration and enhancement, which continues today.

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Foreword

Carl Salvaggio

Foreword

The 2022-2023 fiscal year has recently concluded, and all of us in the Digital Imaging and Remote Sensing (DIRS) laboratory have experienced another exciting, successful, and productive year. We have continued to improve the niche expertise in our group, our students have continued to impress us with their research and impressive gains in their skills, and we are very excited about the new faculty additions to the Chester F. Center for Imaging Science and the new capabilities that they will bring as future collaborators in the areas of artificial intelligence, machine learning, deep learning, and computer vision. Things are evolving so quickly in the field of Imaging Science, especially in the disciplines of computer vision and computational imaging, and we are so lucky to be part of such a vibrant school to train our students in the entire imaging chain and then have them contribute so prolifically to our remote sensing-related research.

Speaking about education in Imaging Science, we are fortunate to have 6 tenured faculty in the Center that are members of the DIRS laboratory. We reported last year that Emmett Ientilucci was the recipient of the 2020-2021 Richard and Virginia Eisenhart Provost's Award for Excellence in Teaching. We are excited to report this year that our own Jan van Aardt was the recipient of the 2021-2022 Eisenhart Award for Outstanding Teaching. This award is RIT's highest honor for tenured faculty. It recognizes a faculty member who excels at teaching and enhancing student learning. We could not be prouder of Jan for the work that he does, year after year, to educate the next generation of Imaging Science graduates. This speaks so highly to how our laboratory affiliated faculty are dedicated to teaching excellence.

If you were ever a part of the DIRS laboratory, you may have never realized the size of the organization. We are 25 members strong at this point, plus the many others across the university who are critical collaborators on many of our research programs. We are 13 research staff, 6 tenured/tenure-track faculty, 4 research faculty, 2 administrative staff, and 1 post-doctoral researcher. We are entering into our 40th year of existence this year, a truly unbelievable thing to imagine. If I had to tell you that I thought I would be blessed to be part of this organization 40 years after Dr. John Schott recruited me as a student in 1984, that would obviously be a misstatement. I am, however, extremely proud and excited that this is the case. I think that sentiment is shared by all our members, from the newly joined to the longest-tenured individuals.

This year Jacob Irizarry has joined our group. Jacob is a remarkable three-dimensional digital artist that has joined our team, but since joining us we have seen that he is so much more than this. His insights have already greatly improved our scene development workflows, and his developing domain expertise and project management skills are going to make him a valued researcher for many years to come. We are all thrilled to have you here!

We did have to say farewell to one of our laboratory research staff members this year; David Conran accepted a great opportunity at Lockheed Martin in the Philadelphia, PA area. This is David's hometown, and we wish him the best in his newest endeavor and are happy that he will be close to his family. While it is always sad to have anyone leave the laboratory, it always makes us very proud that these folks go on to provide such sought-after leadership, expertise, and skills to other organizations in the remote sensing community – they are always a great reflection on where they came from. We wish David the best and will always consider him to be a part of the DIRS family.

I am so grateful for the support we get each year from the many organizations that are needed to run a research laboratory on a university campus. Here at RIT, I want to thank many individuals that help us every day, and forgive me if I miss any individual as there are so many. Katherine Clark, Denis Charlesworth, and Susan Michel from Sponsored Research Services (SRS) provide so much guidance day-to-day to help us from project beginning to end, Keisha Burton and Amanda Zeluff from Sponsored Program Accounting keep us on the straight and narrow and provide all the guidance to keep our many projects compliant with contract requirements, and Benjamin Vetter and David Kloc from Human Resources for the countless hours they have spent with me to make the DIRS laboratory a place that supports the needs of all of it members. All of these folks are so important to us in making this laboratory a place where we can all function to the best of our abilities.

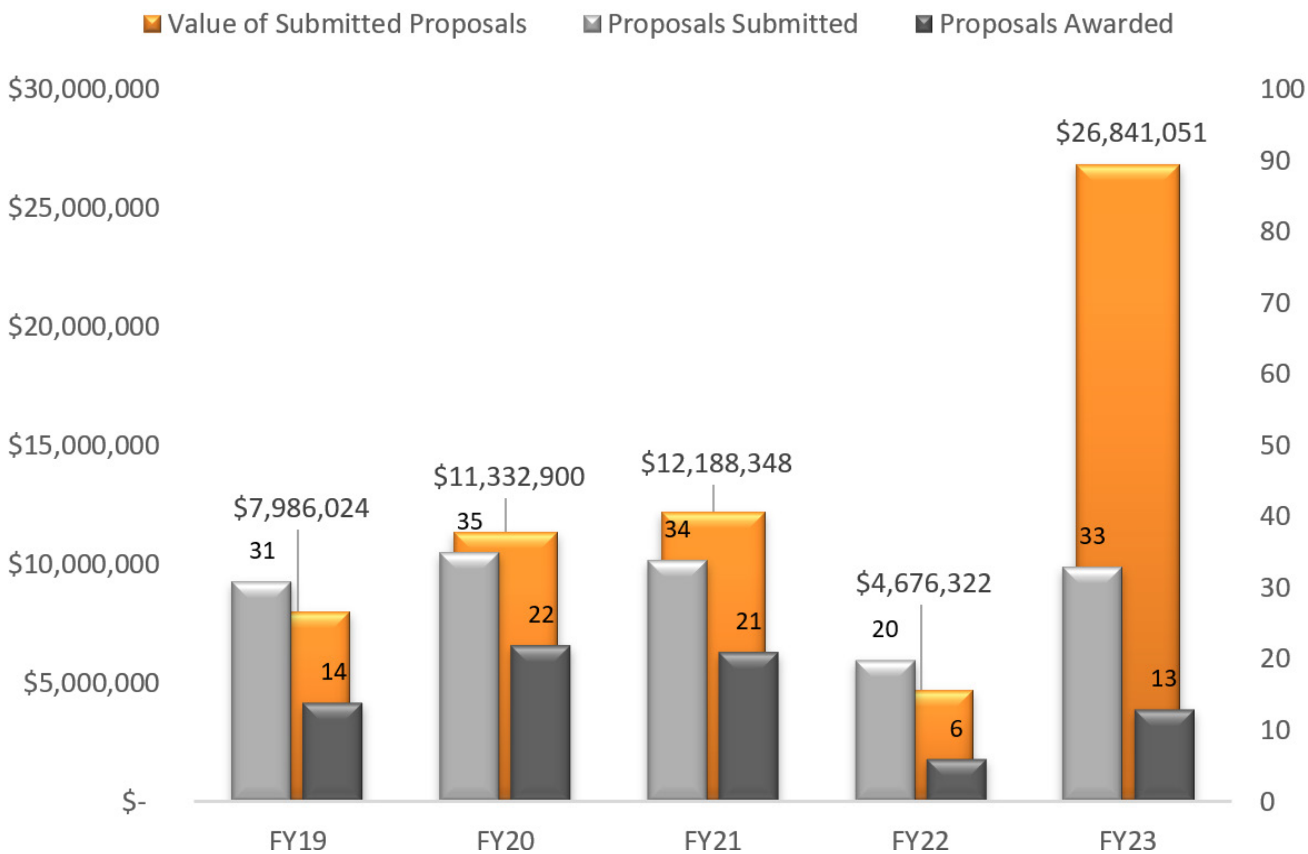
The support of our outgoing Center Director, David Messinger and our new Center Director, Susan-Houde Walter, along with our College of Science Dean, André Hudson is always so magnanimous, thank you so much for giving us the opportunity to do what we do. Ryne Raffaelle, our Vice President for Research continues to be aligned with our goals for the future, and helps us to achieve these every day. President David Munson and Provost Ellen Granberg could not be more supportive of our endeavors and continue to challenge us to be better each and every year. We wish our Provost the best as she takes on the next big opportunity in her career, and we will indeed miss the support she has provided us during her entire tenure here at RIT. Thanks to all for giving us such a great academic environment in which to thrive.

The DIRS group looks forward to carrying on the tradition of excellence that our laboratory has always exhibited. We have the fortune of building on a strong foundation that has been built throughout our first 39 years, and the responsibility of continuing this level of excellence well into the future.

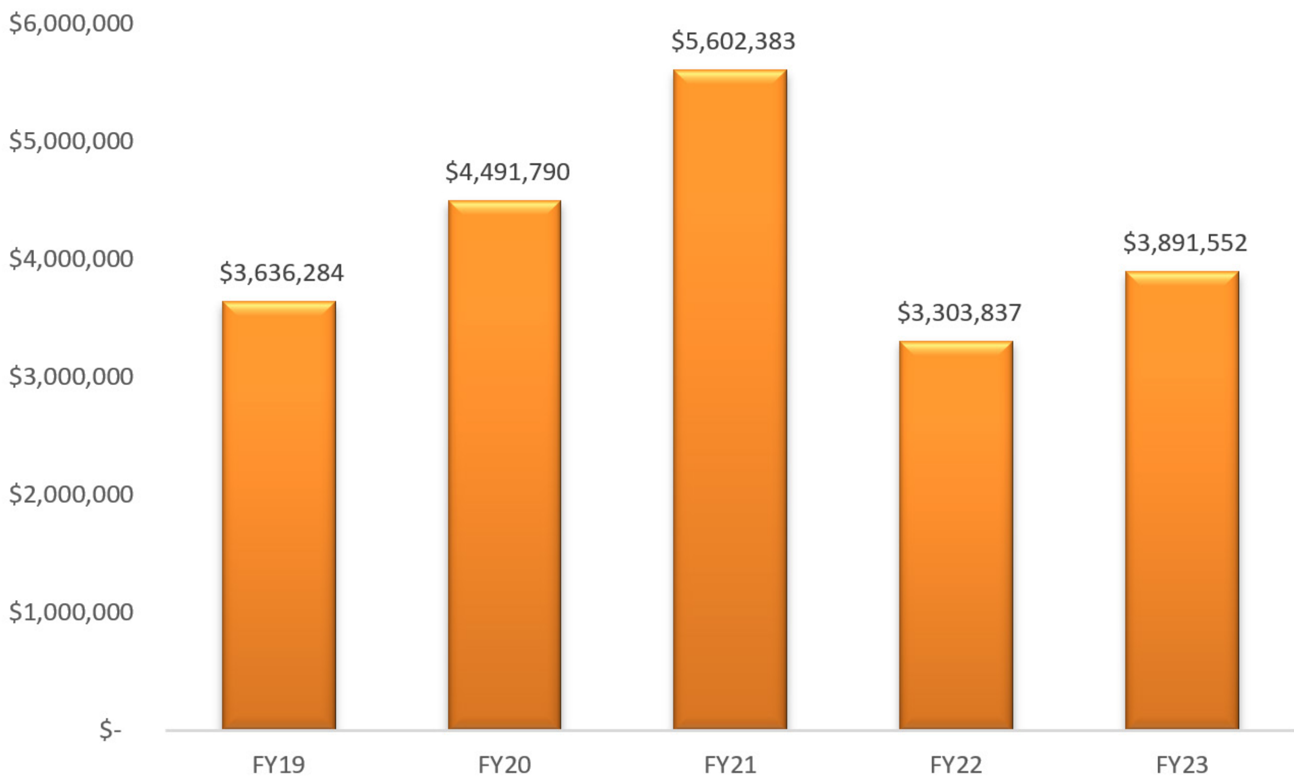
My warmest regards,

Carl Salvaggio

Performance



Proposal activity by fiscal year for the principal investigators associated with the Digital Imaging and Remote Sensing Laboratory.



Fiscal year obligated funds for sponsored research projects for the Digital Imaging and Remote Sensing Laboratory.

Research

The following represents selected projects conducted by the students, research staff, and faculty of the Digital Imaging and Remote Sensing Laboratory during the 2022-2023 academic year. These projects are in various stages of their lifecycle and are representative of the widely varying interests and capabilities of our scientific researchers.

DIRSIG5 Development

Principal Investigator: Scott Brown

Team: Adam Goodenough, Grady Saunders, Jeff Dank, Byron Eng, Serena Flint, Jacob Irizarry

Project Description

This year's development of DIRSIG5 was focused on expanding support for more state of the art tools and file formats, improving user experience, and adding support for features that were previously handled by DIRSIG4. Many exciting improvements and features were added through various collaborations and projects both internally and externally.

Project Status

The DIRSIG5 codebase continues to be improved through various internal and external projects. This year, many quality of life improvements were made to improve the user experience. The new GUI editor for the DIRSIG5-era simulation file (.jsim) was vastly improved with many feature additions which support nearly all DIRSIG5 plugins. This improvement lowers the barrier to entry for new users and allows them to use DIRSIG5's expanding feature set with much greater ease. This is also a productivity improvement for experienced users, as they can now add and remove plugins much more quickly than was previously possible.

Another recent area of focus and research is with respect to scene building and simulation preview workflows. These efforts have included exploring how to make scene building and management directly leverage geospatial data and GIS software. Exploration of evolving geo-spatial scene standards including the Open Geospatial Consortium community standards for "3D Tiles" and "Indexed 3D Scene Layers (I3S)" has begun. An add-in for Blender that allows the user to import and export DIRSIG's current scene descriptions and interactively configure and preview simple image acquisitions is being used in-house and will soon be made available to the user community. With these Blender tools users can edit scenes and platform input files directly in the Blender interface. Previously a full (or "preview mode") DIRSIG render was required to view platform and scene input results. This caused a labor-intensive iteration process to fine tune these inputs. With the new Blender tool, the fine tuning process can be done much easier, faster, and with improved results.

Support was added for additional file formats, allowing the use of more state-of-the-art software when generating input files. This includes the Filmbox (FBX) format for 3D geometry, OpenVDB files, and Envi's Spectral Library (SLI) file format. The ability to import these files directly into DIRSIG improves the possible workflows when preparing inputs for DIRSIG scenes. The DIRSIG "scene_tool" was expanded to include an export to FBX option, which allows to the user to visualize DIRSIG scene geometry (gray world materials for now) including motion. The "scene_tool" was also enhanced to make it easier to directly lookup material, optical property, instance and geometry truth indexes produced at run time in the compiled scene HDF files.

Support was also added for MODTRAN6's new JSON input file. This input file is far more user-friendly than the old TAPE5 file. Supporting the new JSON file allows users to utilize the MODTRAN6 tools as they continue to develop and import the configurations directly.

A known DIRSIG5 limitation when sensor paths were very long (e.g. space applications) was addressed. This allows DIRSIG5 to be applied to Space Situational Awareness (SSA) / Space Domain Awareness (SDA) scenarios. Previously these scenarios could only be performed in DIRSIG4. With this improvement, all planned operational features in DIRSIG4 have been migrated (and in many cases improved upon) in DIRSIG5. The ability to run all simulations in DIRSIG5 not only improves radiometric fidelity and runtime when compared to DIRSIG4, but DIRSIG5's plugin infrastructure allows the flexibility to customize inputs and outputs by both the development team and savvy DIRSIG users alike.

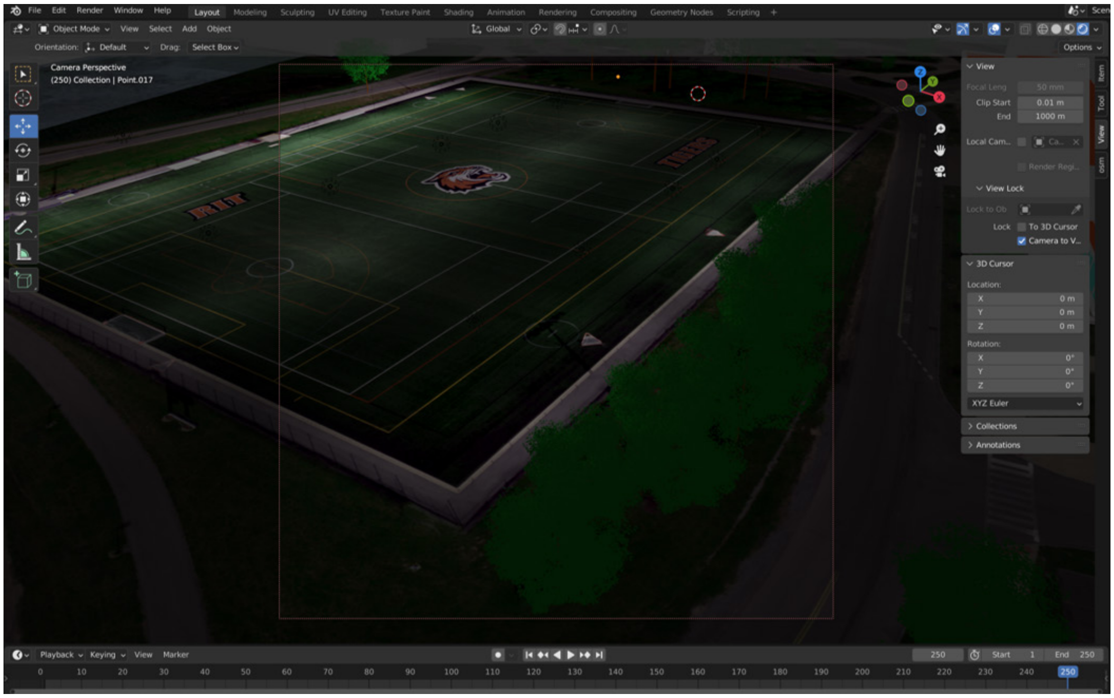


Figure 1.1: A Blender screenshot of a scene with trees, light sources, and an athletic field. The highlighted box represents the camera view, as configured in Blender.

Figure 1.2: A DIRSIG render of the resulting simulation exported by the new Blender tool.

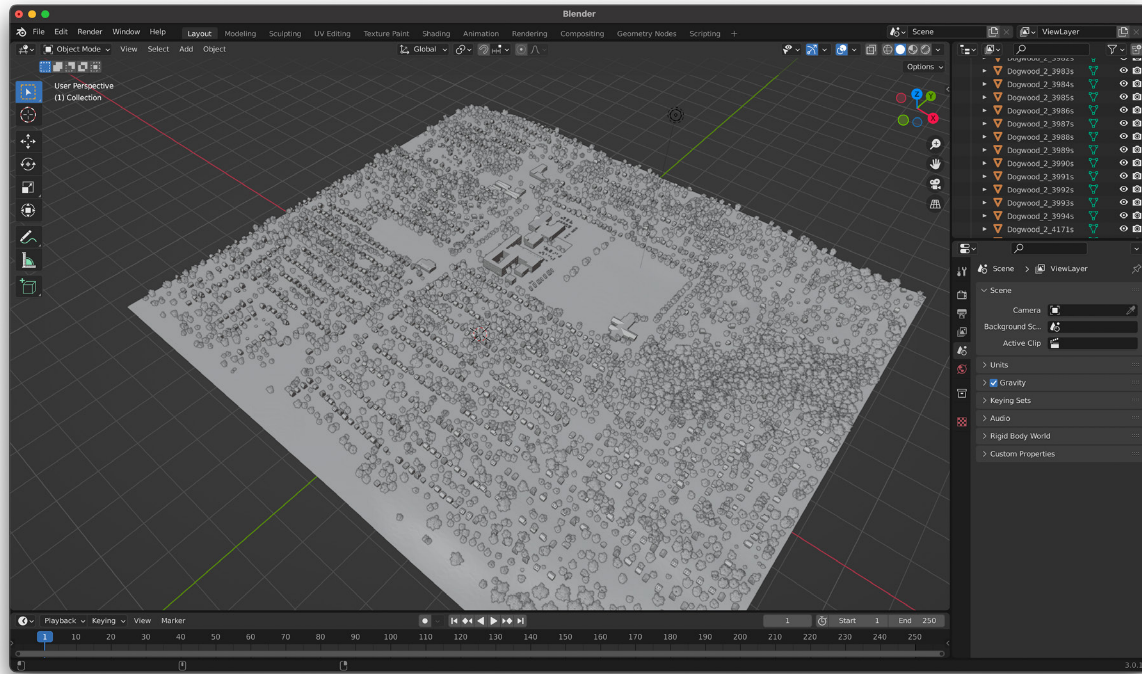


Figure 2: A screenshot of MegaScene1 in Blender via the new scene_tool FBX export tool.


Figure 3: DIRSIG5 simulation of the April 8, 2024 solar eclipse (note the moon shadow over the Great Lakes). This simulation showcases the Space Domain Awareness (SDA) improvements as well as the new EarthGrid plugin.

Improved Calibration & Validation Techniques to Ensure High-Quality Landsat Products

Principal Investigator: Aaron Gerace

Team: Eon Rehman, Nina Raqueno, Amir Hassanzadeh, Tim Bauch, Lucy Falcon, Gabriel Peters, Ethan Poole

External Collaborators: Tania Kleynhans

Project Description

The United States Geological Survey at EROS is committed to providing calibrated Landsat flight data to support consistent and traceable higher-level science outcomes. As a research institution, RIT is committed to investigating techniques and methodologies to support the sponsor's goals of providing users with high-quality, calibrated image data and validated higher-level science products.

Project Status

To ensure the quality of the developed and utilized algorithms, RIT has committed to improving the uncertainty calculation of the surface temperature estimation algorithm, specifically the split-window algorithm, by incorporating total perceptible water estimation. This approach utilizes MODIS for ground truth data and employs XGboost, a machine learning model, for the prediction task. The outcomes of this study have a positive impact on the uncertainty calculation of the split-window algorithm for surface temperature estimation. A journal article discussing the findings of this study is currently under review.

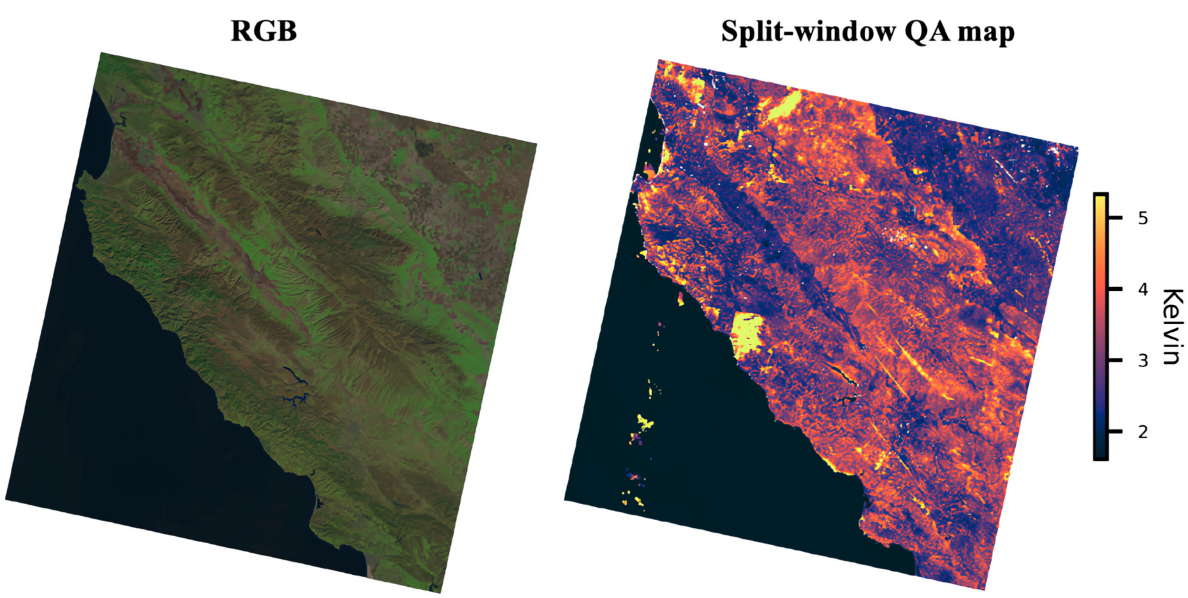


Figure 1: Landsat's RGB and corresponding thermal product QA map used in uncertainty estimation pipeline for split-window algorithm.

Water Modeling

Principal Investigator: Adam Goodenough

External Collaborators: David Chiba, Areté Associates

Project Description

Continued work in collaboration with Areté has focused on the further development of DIRSIG 5's in-water radiative transfer capabilities in the context of submerged object identification. The work over the last year has been under a Phase II option to add laser modeling capability to the surf zone in the context of Areté's PILLS (Pushbroom Imaging LiDAR for Littoral Surveillance) program. The light detecting and ranging (lidar) regime poses unique challenges to simulation that require the development of novel modeling approaches. Additionally, the type of lidar system itself (Streak Tube Imaging Lidar, or STIL, hardware developed by Areté) is a unique system to be verified against. One of the trickiest aspects of simulating lidar systems for water is that the air-water interface acts as a mirror directly reflecting energy to the receiver for very specific source-surface-receiver geometries and completely losing that energy otherwise. Generally speaking, the "acceptance" angle over which these types of directly reflected returns occur is very, very small and corresponds to regions on the surface that are several orders of magnitude smaller than any practical geometry (i.e. facetized) model of the surface can represent directly. If the effective receiver solid angle is much larger than the structure of the surface (capturing 10s of centimeters, or meters, of variation) then we can describe the probability of encountering these perfect geometries using a bi-directional reflectance distribution function (BRDF) such as one that follows the classic Cox and Munk slope distributions from 1954. However, the purpose of the STIL system is to capture surface (and volumetric) variations at a much higher resolution and we are forced to deal with resolved surfaces.

The work done in this area has focused on two aspects of surface returns. First, we must find out if and where an ideal reflection occurs within one of the facets (triangles) describing the surface. This assumes that the slopes at each vertex can be continuously interpolated to any internal position and applied to the (also continuously varying) relative positions of the source and receiver. The process was reduced to finding the intersection of three conics in a limited two-dimensional space. Once that "ideal" position is found, we can expand out and find the region that will reflect into the solid angle of the receiver a region which generally forms a triellipsoid shape.

The second component of the surface returns has been to incorporate the returns into the (gated) signal being modeled by the simulation. Because these reflective regions are extremely small relative to the instantaneous field of view of the receiver, we can't rely on stochastic processes to reasonably find them. Instead, we stochastically generate path and check for "enclosure" directly adding the reflected contributions to the remainder of the signal.

Implementation of the remainder of the lidar model has been focused on the in-volume and bottom surface returns. The approach here has borrowed heavily from the "beam" based approach that is used for passive (e.g. sun) returns using a "dual-mesh" that captures the focusing/defocusing and potential overlap of light coming from above the surface. It is an approach that is already used for lidar in general and the latest work combines and updates the beam representation in the context of in water lidar beam returns, as seen in the accompanying figure.

Project Status

The current phase of the project wraps up shortly after this report and will hopefully transition into an option that seeks to add in-water lidar modeling and polarization capabilities to DIRSIG 5. In the meantime, we continue to support tooling based on DIRSIG simulations and to develop faster simulation methods where appropriate.

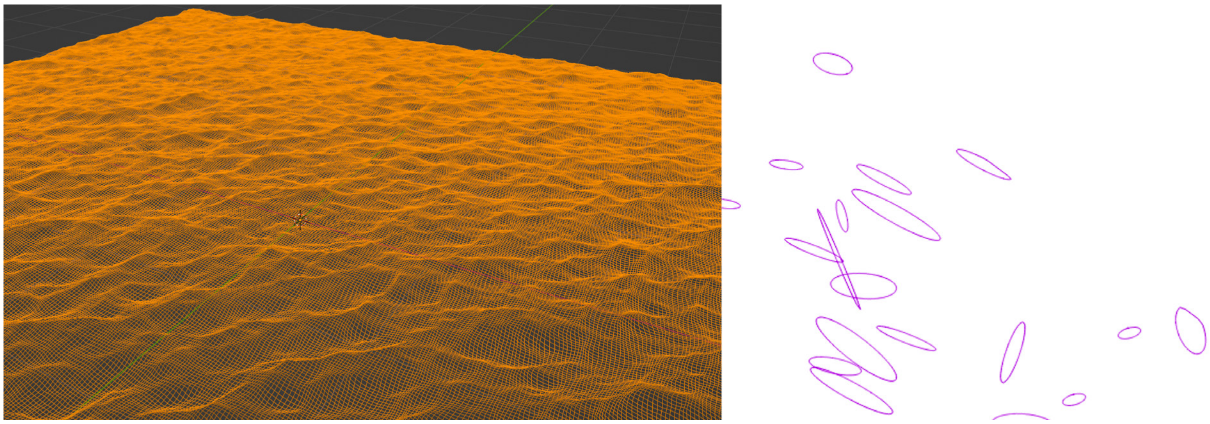


Figure 1: The type of facetized surface used for modeling the air-water interface (left) and a selection of over-plotted, directly reflected in a portion of a shared (half-unit) triangle coordinate system (note that the sizes are exaggerated for visualization reasonably sized regions (corresponding to real world apertures and flight altitudes) primarily appear as points relative to the triangle.

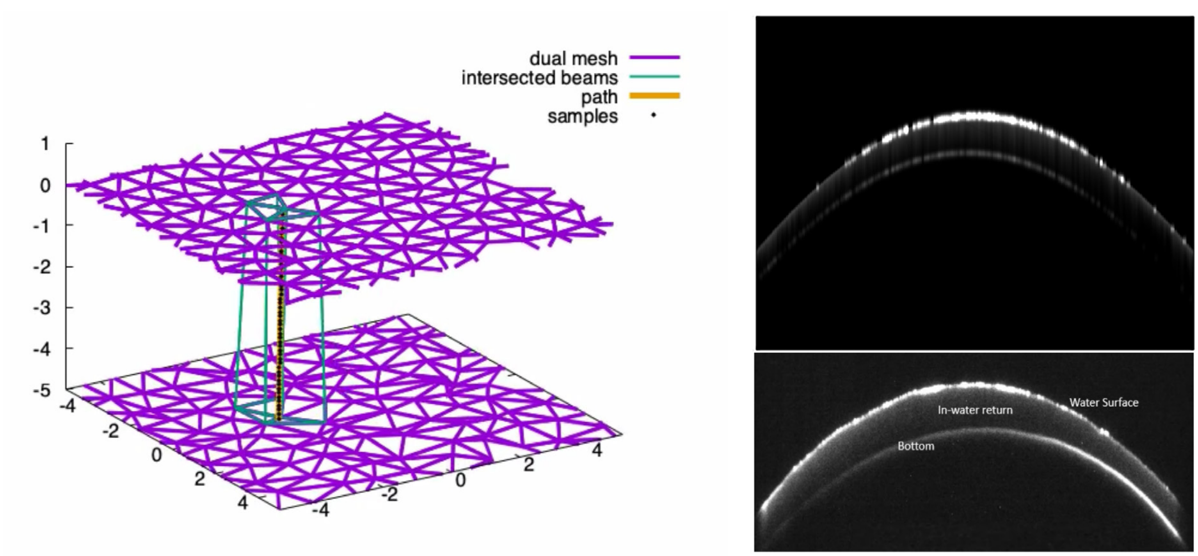


Figure 2: Simulations demonstrating the impact of entrained bubbles on the overall radiance signal (using a Hall-Novarini (HN) size distribution parametrized by a 10 m/s wind speed). The top row shows the qualitative influence of the bubbles on both magnitude and color on the simulated shallow water images.

Simulation and Modeling for VanZyl-1 SmallSat to Measure Land Surface Temperature

Principal Investigator: Rehman Eon

Team: Aaron Gerace, Matthew Montanaro, Michael Gartley

Project Description

Projection Description: Hydrosat's VanZyl-1, to be launched in 2023, payload is representative of an emerging class of small satellite payloads with a goal to enable accurate and timely thermal infrared (TIR) measurements for relevant Earth science applications. VanZyl-1 includes a primary TIR sensor (with two bands) with a projected ground sampling distance (GSD) of 70-m, and a secondary visible infra-red (VNIR) sensor (8 bands) with a GSD of 30-m. The TIR payload is an uncooled multispectral thermal imager fabricated using microbolometer arrays. Uncooled microbolometers are advantageous in that they eliminate the need for large and expensive cryocoolers, reducing both the cost and size of the payload. However, the use of microbolometer arrays introduces significant challenges that must be overcome to achieve the image fidelity observed with current spaceborne thermal instruments. The research group at RIT has been working on performing simulation & modeling to support the design and build of the VanZyl-1 thermal payload, design and conduct in-lab experiments to characterize the as-built system, and develop a calibration workflow to assess the performance of its in-flight system.

Project Status

Lab experiment was performed to assess the radiometric quality of the data acquired from the VanZyl-1 thermal sensor. The Noise Equivalent Temperature Difference (NEDT) and the absolute radiometric uncertainty of the instrument was estimated using blackbody-stare acquired at 300-K, see Figure 1. The radiometric characterization was performed at the two different time delay integration (TDI) modes of the sensor (high resolution and high sensitivity mode). In signal processing theory, the noise of averaged samples decreases with the square root of averaged samples, which was confirmed during the lab characterization (Figure 2). The spatial response of the instrument was also assessed during the lab measurements. The response to a knife-edge target was determined for samples of detector elements spanning the across-track field-of-view (FOV). The impact on the measured modulation transfer function (MTF) due to along-track motion of the sensor is reported in Figure 3.

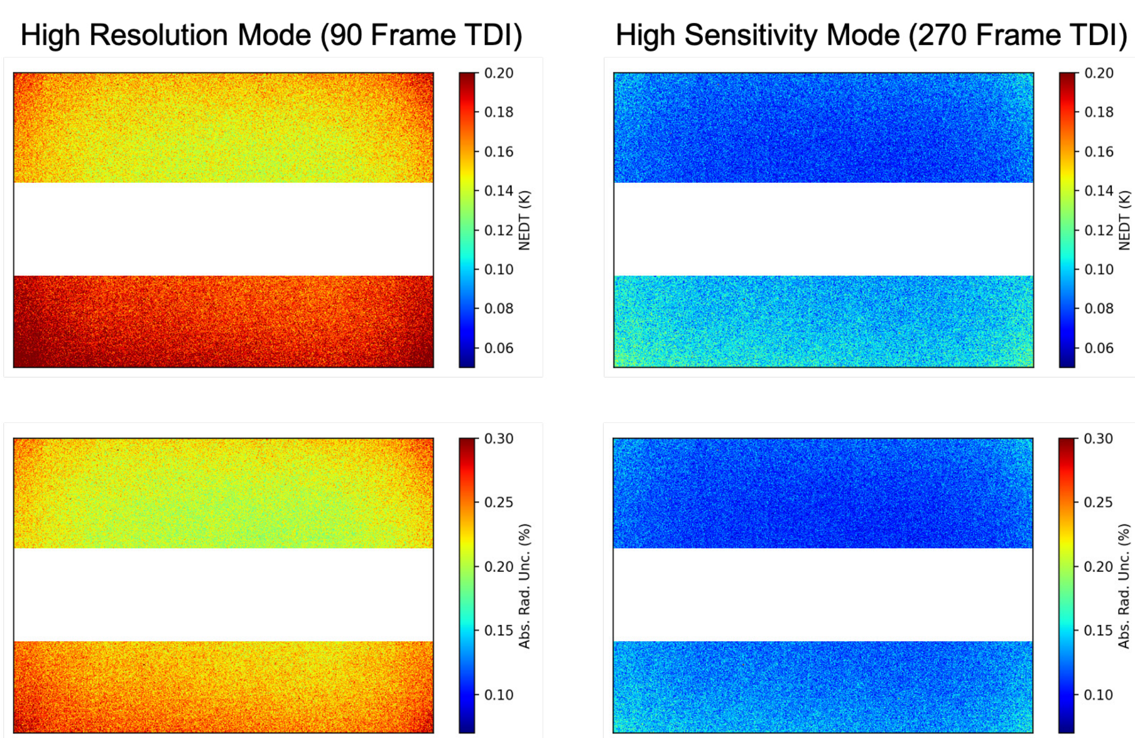


Figure 1: NEDT and absolute radiometric uncertainty of the VanZyl-1 sensor at the two TDI modes.

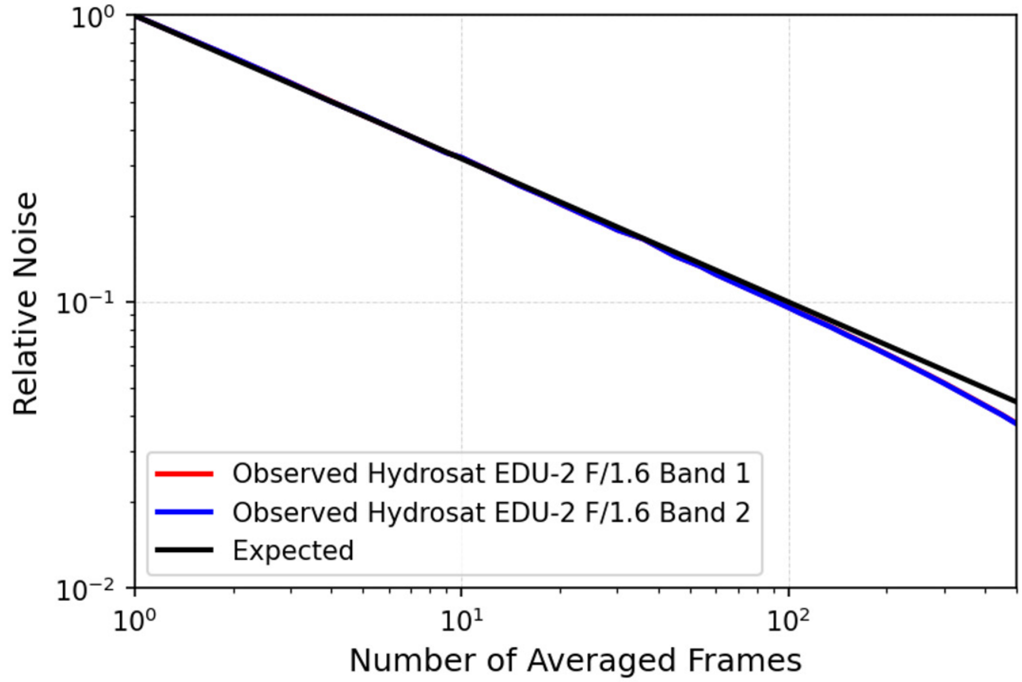


Figure 2: Noise reduction vs number of averaged samples.

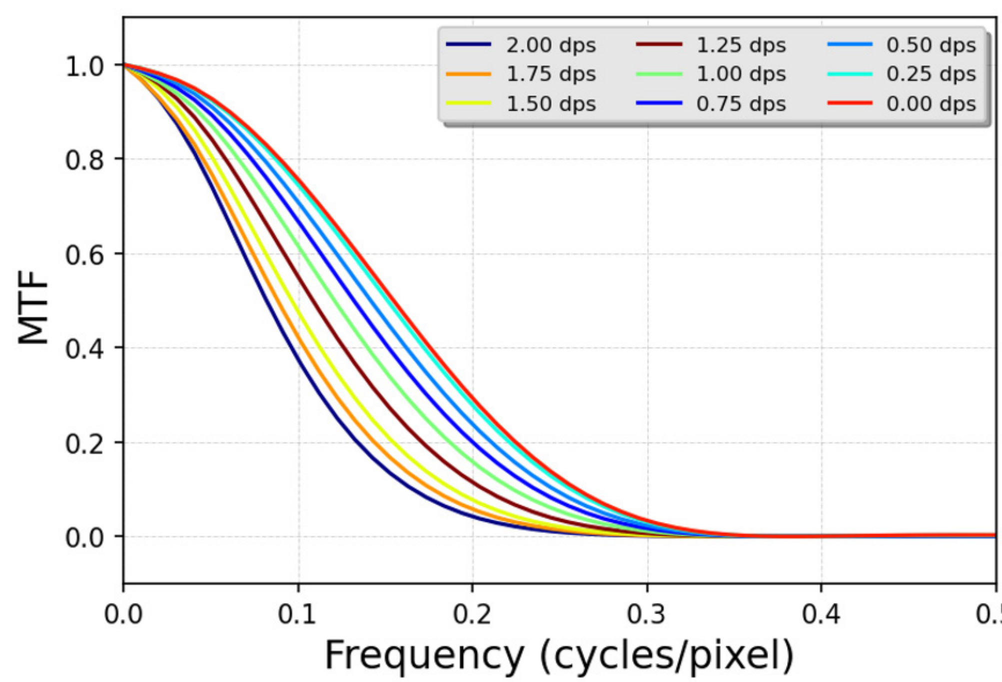


Figure 3: The measured MTF at different motion rates.

Towards An Optimized Sensor Specification Corn Yield Assessment

Principal Investigator: Jan van Aardt

Team: Nate Burglewski, Emmett Ientilucci, John Kerekes

External Collaborators: Quirine Ketterings, Subhashree Srinivasagan, Manual Marcaida III, Juan Carlos Ramos Tanchez

Project Description

This project aims to define the spectral and spatial properties of corn, Zea Mays, which are correlated with grain and/or silage yield. Using this, we intend to design several space-based remote sensing systems for the express purpose forecasting corn yield. These systems will have varied spatial resolutions, spectral resolutions (as well as band centers/widths), and will each occupy a survey of orbits designed to have access to the largest possible collection area. These systems will be tested upon custom built simulated imagery which has been statistically validated with real hyperspectral data collected in the Finger Lakes region of New York.

Project Status

Nate Burglewski recently published in the SPIE Defense+Commercial Sensing (DCS) Proceedings, where the team compared several different traditional regression and machine learning (ML) corn yield forecast models using high resolution hyperspectral imagery (HSI), as well as low resolution multispectral imagery. We are currently in the data collection and analysis phase. We have successfully compared the performance of several linear and exponential regression models, in addition to ML models, and found that both a fully-connected convolutional neural network (CNN) and support vector regression (SVR) models are adequate for our purposes. The CNN permits full access to spatial and spectral information, while the SVR model uses spectral content only. Both are warranted as we intend to further investigate dependencies on spatial resolution.

Figure 1: A corn plant at an early growth stage (V2). HSI imagery collected of this field (and one other at the same growth stage) will be used to evaluate the feasibility of detecting corn plant emergence from different remote sensing platforms

Figure 2: A fully-matured corn field used for yield forecast model analysis and comparison.

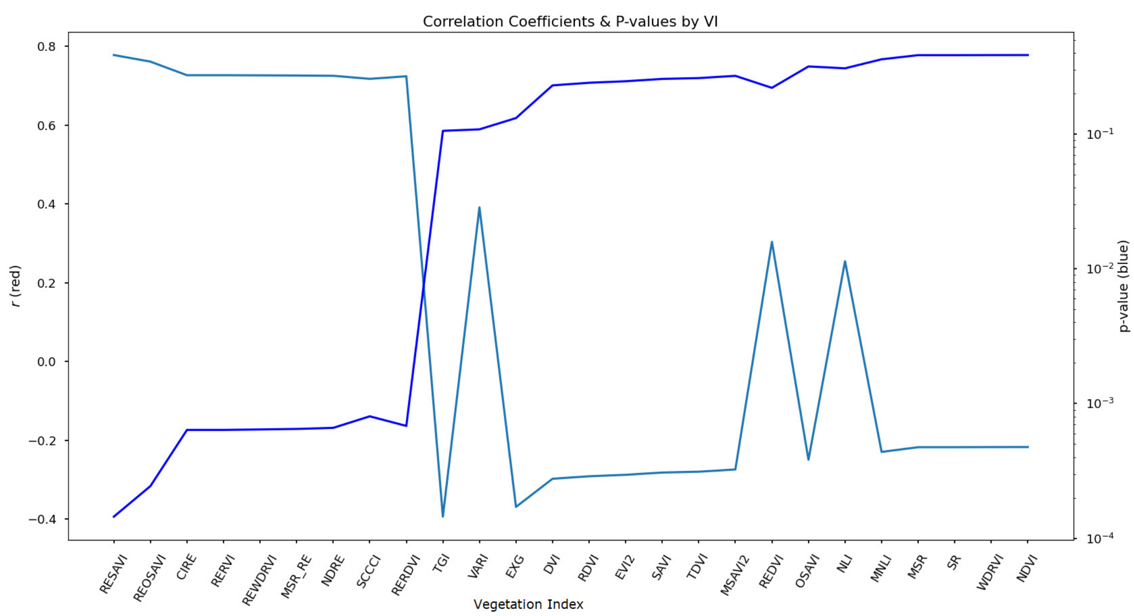


Figure 3: The results of a correlation analysis between 26 different spectral reflectance indices with yield. Both the Pearson correlation coefficient and the p-value are displayed.

Radiative Transfer Simulation and Validation of Structural and Spectral Properties of Cape Vegetation

Principal Investigator: Jan van Aardt

Team: Manisha Das Chaity, Grady Saunders, Byron Eng, Jacob Irizzary

External Collaborators: Jasper Slingsby (University of Cape Town, South Africa), Glenn Moncrieff (South African Ecological Observation Network)

Project Description

The Greater Cape Floristic Region (GCFR) in South Africa is a hyper-diverse region, compasses two global biodiversity hotspots, threatened by habitat loss and fragmentation, invasive species, altered fire regimes, and climate change. Managing and mitigating these threats requires regularly updated, spatially-explicit information for the entire region, which is currently only feasible using satellite remote sensing. However, detecting the signal change over the spectral and structural variability of ecosystems in the region is highly challenging due to the exceptionally high ecosystem diversity and the confounding influence of structural variables at the leaf, stem, and whole-crown scales. This complexity is exacerbated by the fact that GCFR contains spectacular plant diversity.

The objective of this study is to build a simulated scene using a combination of fynbos trait measurements and radiative transfer modeling in a biophysically- and physics-robust simulation environment and then validate the scene with high spectral resolution and LiDAR remote sensing NASA data from the BioSCape project's aircraft campaigns. This will provide a mechanistic linking of structure/spectra-to-traits, and an ability to track biodiversity as a function of post-fire recovery. Achieving this goal could significantly improve our understanding of interactions of light within the fynbos biophysical traits and inform innovative uses of remote sensing data for highly diverse ecosystems at all scales, from airborne to satellite levels. Overall, this study presents a novel approach to resolving the challenge of simulating land surface reflectance spectra in a region with high ecosystem diversity, which could have important implications for the management and conservation of the GCFR.

Project Status

Our approach involves using RIT's DIRSIG simulation package to simulate hyperspectral and LiDAR data, captured over the "virtual" Greater Cape Floristic Region. (GCFR) These data then will be used to develop a better understanding of the correlations between structure metrics and spectral reflectance from hyperspectral data, as well as structure-trait cause-and-effect relationships differences for such a highly diverse ecosystem, and evaluating observed post-fire recovery regimes, and embedding those in DIRSIG for an assessment of monitoring approaches.

We have begun simulating a virtual replica of the Grootbos Nature Reserve (South Africa) area within the GCFR (see Figure 1), using 3D models of plants. Terrestrial Laser Scanner (TLS) and iPad LiDAR scanner data were used to capture the structural variability of different plant species and the terrain of the study area. We then used these collected data to develop digital elevation models (DEM) to feed into the DIRSIG simulator. We also have embedded optical properties (reflectance and transmittance curves), based on our recent field collection to Grootbos, South Africa, in October 2022. Our simulations are based on the AVIRIS-NG hyperspectral imaging spectrometer.This virtual scene will expand our ability to simulate different variants of our hyper diverse fynbos scene and test the imaging instrument's ability to capture it.

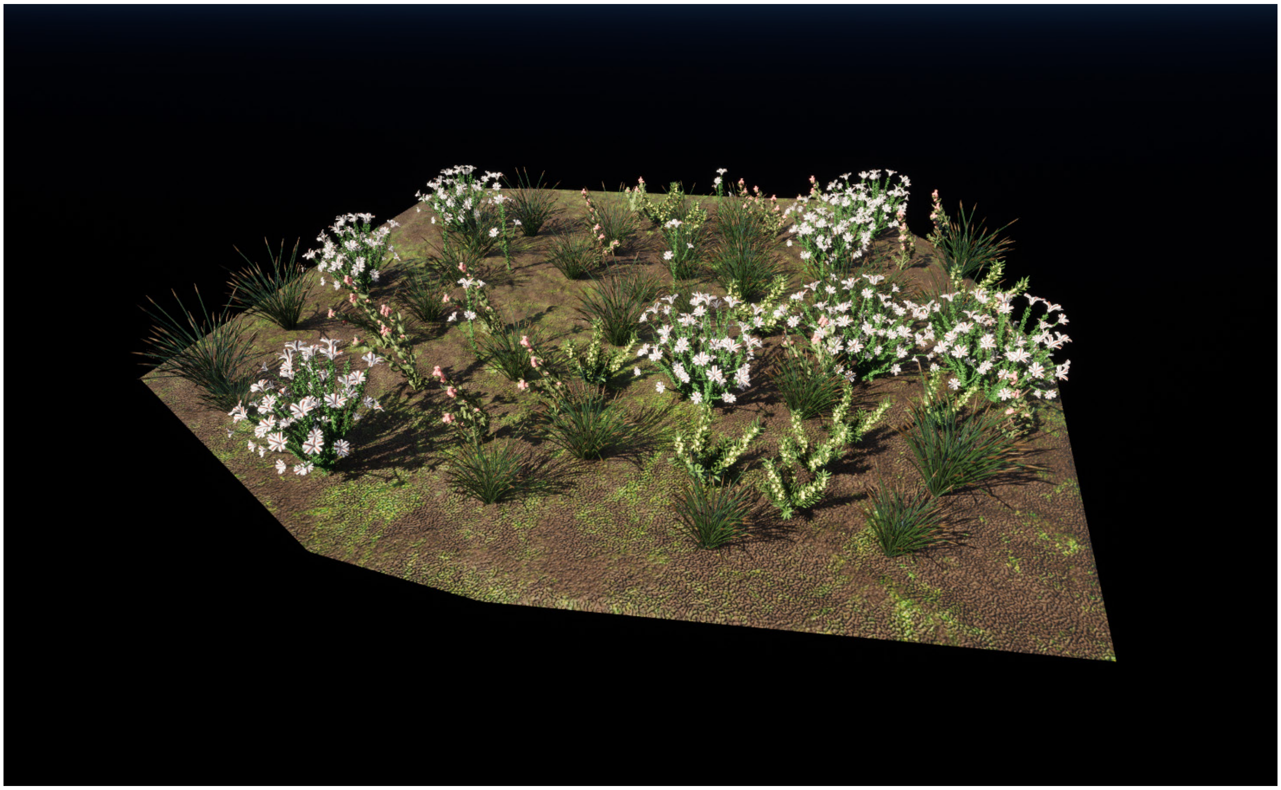


Figure 1: An early rendering of the virtual scene of the fynbos developed for the DIRSIG simulator.

Fundamental Research on Detection and Classification Limits in Spectral Imagery

Principal Investigator: John Kerekes

Team: Chase Cañas, Colin Maloney, Scott Brown, Emmett Ientilucci

Project Description

RIT continued to conduct research to understand the fundamental limits of multi- and hyperspectral imagery for the detection of surface objects and land cover classification. For over 50 years, spectral imagery from aircraft and satellites have been used in these applications and have demonstrated high levels of performance. But as technology and imaging system performance capabilities improve, a fundamental question remains: what are the physical limits in the use of passive remote optical observations to detect objects and classify surface areas? This project is pursuing answers to that question through the use of a previously developed analytical spectral imaging performance prediction tool.

Project Status

Initiated in July 2021 the project has completed its second year. In September of 2022 a second empirical data collection experiment was conducted (see figures) and during the subsequent period the data analyzed to support modeling development and validation. Also, a bottoms-up software rewrite of an analytical modeling approach was continued with a preliminary version undergoing extensive testing. This new software uses portions of and is compatible with DIRSIG software to allow self-consistent modeling of spectral imaging systems from both an analytical and physics-based simulation viewpoint.

Figure 1: Imaging Science students Micah Ross (left) and Colin Maloney (right) collect ground truth reflectance spectra during a UAS collection at the RIT Tait Preserve in September 2022.

Figure 2: Novel subpixel detection targets deployed during September 2022 collection along with shadowing and reflector panels designed to explore nonlinear mixing effects in hyperspectral imagery.

The Influence of Canopy Structure & Foliar Chemistry on Remote Sensing Observations: Radiative Transfer Modeling Interactions of Light Within the Canopy & Inform Innovative Uses of Remote Sensing Data

Principal Investigator: Jan van Aardt

Team: Kedar Patki, Rob Wible, Grady Saunders

External Collaborators: Keith Krause (Battelle), Scott Ollinger (University of New Hampshire; UNH), Andrew Ouimette (UNH), and Jack Hastings (UNH)

Project Description

The objectives of this project are to i) better understand the correlations between spectral reflectance and structural metrics and structure-trait cause-and-effect relationships; ii) propose a data fusion approach (LiDAR + Hyperspectral) to trait prediction; and iii) apply the fusion approach to mitigate scaling issues (leaf-level, stand-level, forest-level). We are currently focusing our efforts towards understanding impact on spectral and structural metrics due to variation in leaf angle distributions (LAD). Leaf angle is a key factor in determining arrangement of leaves, and directly impacts forest structural metrics, such as leaf area index (LAI), which in turn is an important variable for a variety of ecological processes, such as photosynthesis and carbon cycling.

Project Status

Previously we showed the impact of varying leaf angle distributions on important vegetation indices (NDVI and PRI). We observed that lower LADs (peak 0° (planophile) and peak 30°) show different behavior in terms of change in VI values, as compared to higher LADs (peak 60° and peak 90° a.k.a. erectophile). We also showed results related to impact of changing LAD on two LiDAR penetration metrics - canopy height and intensity ratio (directly related to gap fraction used in LAI estimation). Next, we showed how the red edge inflection point (REIP), defined as the maximum change in the red edge portion of the vegetation spectrum. The REIP slope and wavelength parameters are well known to be good predictors of chlorophyll, so it is worth investing the changes it undergoes due to variation of LAD conditions. We observed that there is no significant impact on the wavelengths; however, the slope distributions do change with LAD. Shown in Figure 1 is the histogram of the red edge slope parameter for the four LADs – peak 0° degree, peak 30°, peak 60°, and peak 90°. We notice that the 0° and 30° curves have similar spread and average value of slope, however the center shifts toward lower values as we increase the LAD peak to 60° and then 90°. We currently are working on quantifying the change induced in LAI, as well as chlorophyll, (directly related to nitrogen content), since both important biophysical traits are used extensively in ecological modeling. Creating prediction models requires ground truth data, and our approach to obtain ground truth LAI is to divide our 3D scene into voxels and algorithmically count all leaf elements (made of triangular primitives) and accumulate the element surface areas within each voxel. We then further accumulate the leaf areas in each voxel column and divide by the voxel face area (pixel size) to obtain LAI. This is the mathematically accurate approach given the 3D model of the forest.

Our approach to obtain the chlorophyll ground truth values over Harvard Forest area is similar. We obtain leaf areas by the process described above, but for each plant species individually. The distinction between species is in the form of spectral reflectance characteristics. We then use the PROSPECT model, a tool that predicts the reflectance curve given several leaf and canopy parameters, including chlorophyll concentration. We invert this model to go from reflectance information to an estimation of chlorophyll concentration (grams/cm2). This gives us the ability to find reasonable estimates for ground truth chlorophyll concentration for any species, given its spectral signature information. The spectral information is already available as we use it for our DIRSIG simulations. Finally, we multiply leaf area and chlorophyll concentration for each species to obtain the total chlorophyll content per species, and then we accumulate this value across all species to obtain a chlorophyll content map. Figure 2 shows this simulated ground truth chlorophyll content map of Harvard Forest. We are working on using regression methods, e.g., partial least squares (PLS) method to build prediction model for chlorophyll and LAI, and show if and how these models vary with introduction of leaf angles. Our next goal is to exploit machine learning techniques to fuse discrete LiDAR data with hyperspectral imagery data and create a prediction model that robust against the potential errors due to LAD variation.

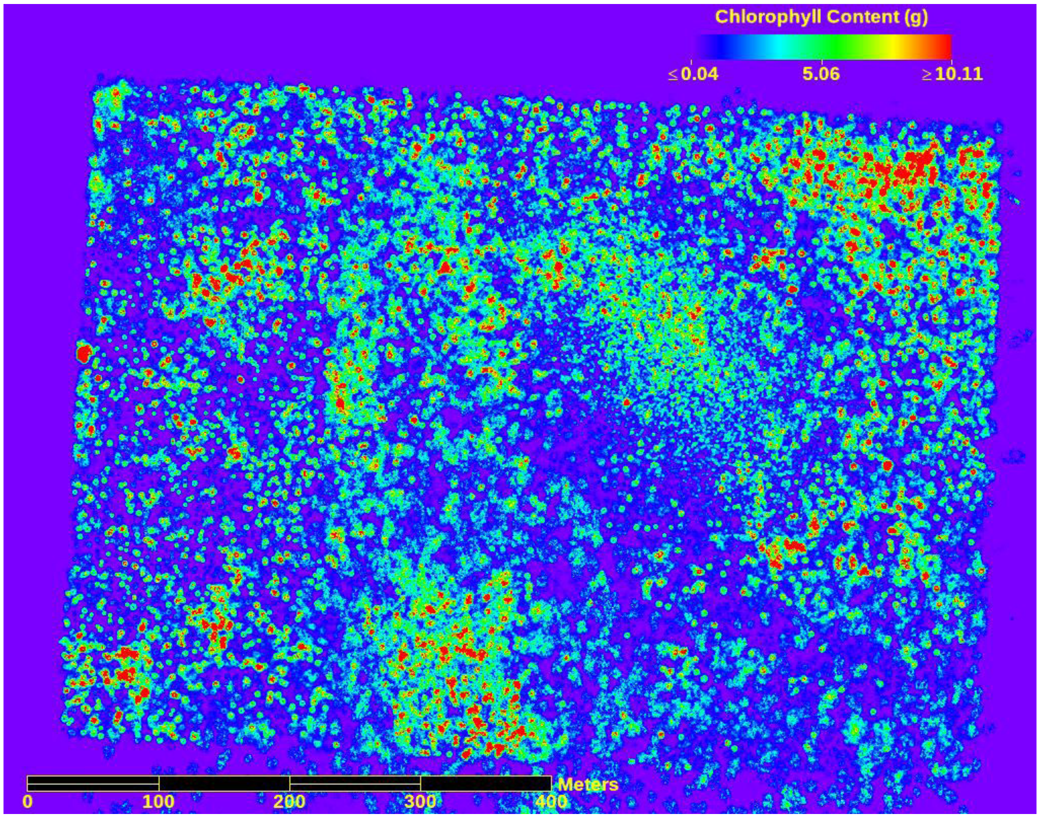


Figure 1: Change in distribution of REIP slope due to variation in Leaf Angle Distribution

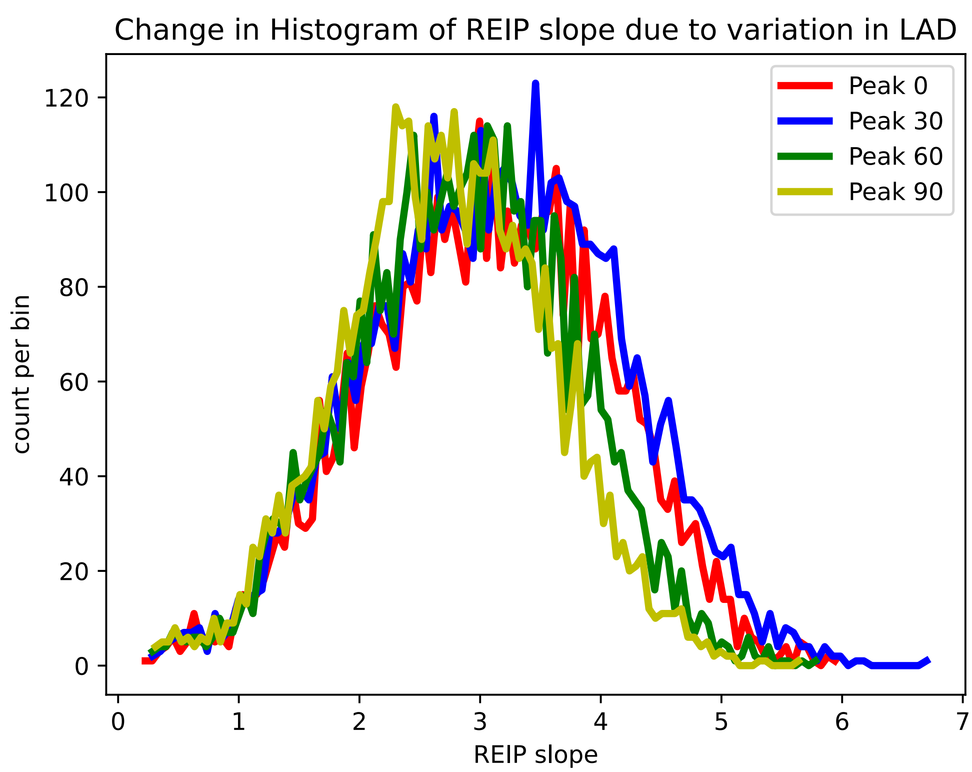


Figure 2: Chlorophyll Ground Truth obtained from Harvard Forest 3D model

Globally-Derived Measures of Structure Informed by Ecological Theory and Observation

Principal Investigator: Jan van Aardt

Team: Tahrir Siddiqui, Grady Saunders

External Collaborators: Keith Krause (Battelle), Chris Gough (VCU)

Project Description

The objectives of this project are to i) Identify existing and novel vegetation structural metrics, akin to leaf area index (LAI), that are strongly correlated with ecosystem function and broadly useful to advancing ecological knowledge at multiple spatial scales; ii) design and develop the suite of "next generation" LiDAR instruments and processing algorithms for deriving ecologically significant vegetation structural metrics; iii) assess the capabilities and limitations of current LiDAR systems to produce ecologically meaningful next generational data products; and iv) evaluate the accuracy and uncertainty of next generation data products across several spatial scales including change with time.

Project Status

We are using RIT's DIRSIG simulation software to simulate LiDAR collections of various airborne laser scanning (ALS) systems on a spectrally and structurally accurate virtual scene of Harvard Forest, Massachusetts. We identified three canopy structural complexity (CSC) metrics, derived from terrestrial LiDAR data, that are strongly correlated with forest carbon cycling processes at stand to landscape scales: Canopy Rugosity, Top Rugosity, and Rumple. Robust estimation of these metrics using airborne LiDAR data is essential to scaling and modeling ecological processes at large spatial scales. Due to the high cost of collection, current ALS systems fly a limited number of times at fixed configurations. Therefore, we cannot investigate the impact of using various collection settings on the derivation of such structural products. We therefore simulated multiple flights of NEON's (National Ecological Observatory Network) AOP (Airborne Observatory Platform) in order to simulate various ALS collection settings. Simulated datasets varied in terms of LiDAR footprint size, pulses per square meter, and full-width-at-half max (FWHM) of the outgoing pulse, which respectively determine the sampling area, sampling density, and range resolution. Using the exact leaf area in the voxelated DIRSIG scene, we computed highly precise ground truth of each metric coincident with the simulation transects.

Figure 1 illustrates the simulation of a NEON AOP flight over a transect using the first of 36 different configurations. We developed methods for processing simulated full-waveform LiDAR data to derive the three identified structural metrics, and then investigated the effects of the selected LiDAR parameters on the estimation of each metric using linear correlation analysis and other appropriate statistical tests. Based on our results, we will perform a tradeoff analysis and recommend the optimal range of collection settings for robustly estimating each metric. The results of this study will be presented in Silvilaser 2023.

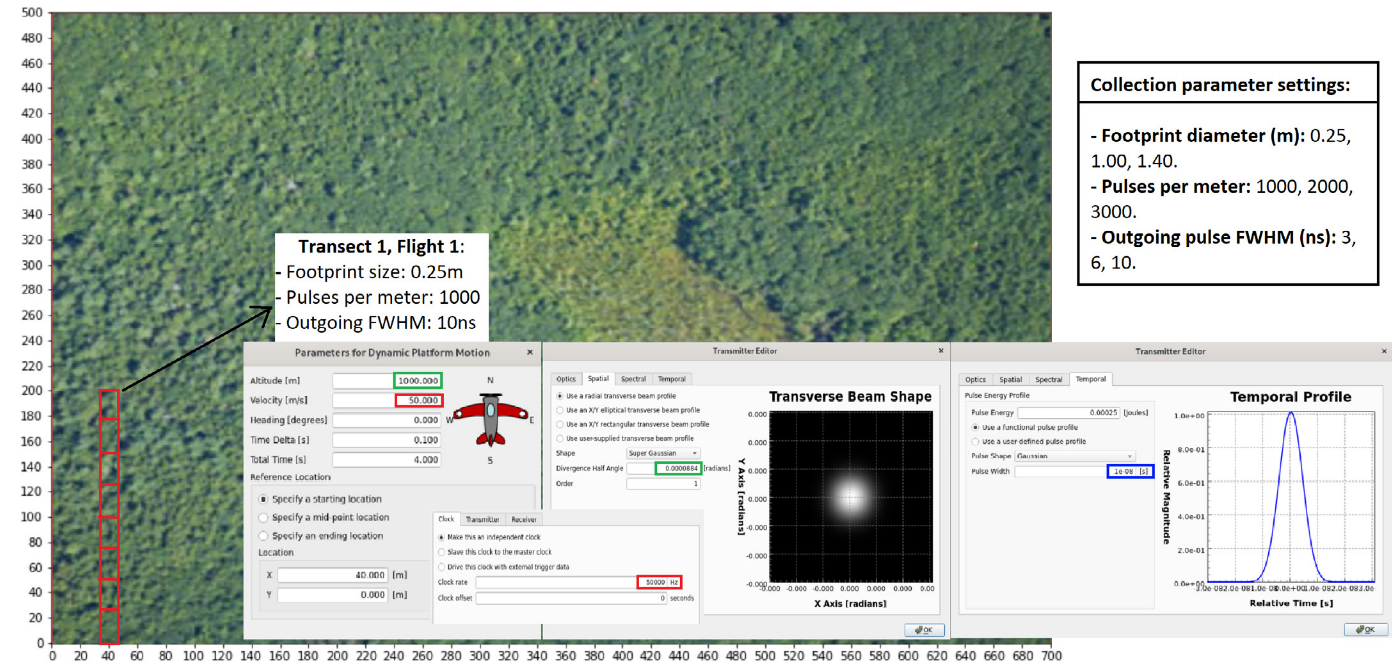


Figure 1: An example of the DIRSIG simulation tool, where we can simulate LiDAR data for a virtual scene of Harvard Forest, MA. This approach allows us to test the impact of different system configurations on the collected data and eventual structural metrics, derived from these data.

Vicarious Radiometric Calibration of Satellites using Mirrors

Principal Investigator: Emmett Ientilucci

Team: David Conran

Project Description

The Specular Array Radiometric Calibration (SPARC) method employs convex mirrors to create field deployable radiometric and spatial calibration targets for remote imaging sensors. Recent research has been invested into understanding the use of convex mirrors to assess the image and data quality of drone mounted hyperspectral imaging (HSI) systems. To fully understand our scientific applications with such instruments, radiometric and spatial characterizations need to be conducted under similar field conditions which makes convex mirrors an optimal target for extracting pixel level discrepancies. A radiometric study between standard Lambertian calibration panels and convex mirrors demonstrated their use as calibration targets by recovering comparative surface reflectance estimates. Simultaneous spatial analysis experiments were conducted where a complex sampled point spread function (SPSF) exists across the field-of-view of the hyperspectral instruments.

Project Status

Surveying different hyperspectral imaging systems using convex mirrors to highlight similarities/differences. This includes how the HSI system is mounted (i.e., fixed or gimballed), different instrument manufacturers and post-processing efforts. At the same time, we published our paper on the Ground to Space CALibration Experiment (G-SCALE) experiment. The objective of the experiment was to demonstrate the use of convex mirrors as a radiometric and spatial calibration and validation technology for Earth Observation assets, operating at multiple altitudes and spatial scales. Specifically, a point source with NIST-traceable absolute radiance signal was evaluated for simultaneous vicarious calibration of multi- and hyperspectral sensors in the VNIR/SWIR range, aboard Unmanned Aerial Vehicles (UAVs), manned aircraft, and satellite platforms. Our journal paper looked at the intercomparison between sensor technologies and remote sensing applications utilizing the mirror-based calibration approach. The G-SCALE represents a unique, international collaboration between commercial, academic, and government entities for the purpose of evaluating a novel method to improve vicarious calibration and validation for Earth Observation.

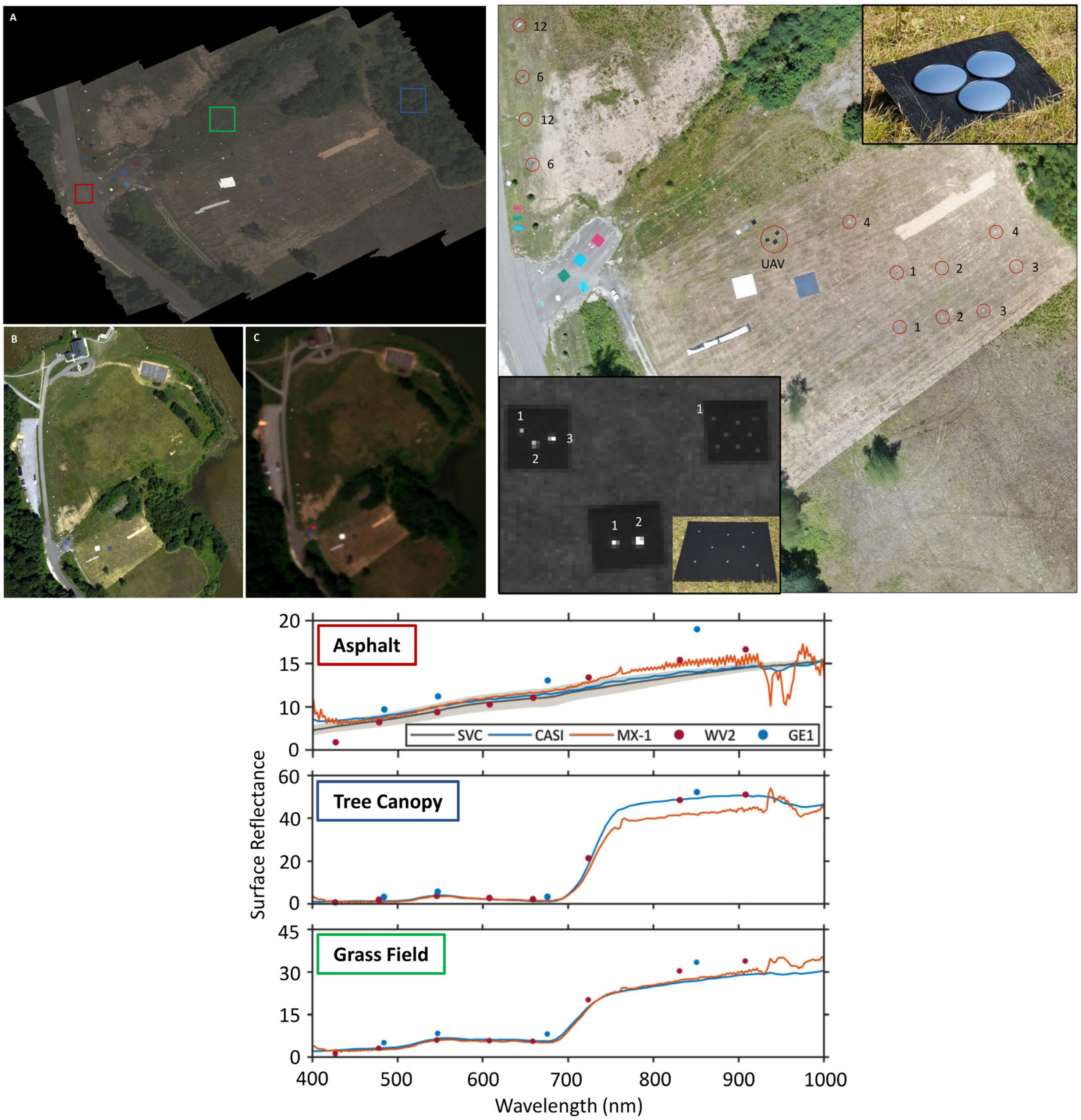


Figure 1:(right top) Primary target area. SPARC targets for airborne and satellite assets are circled and labeled with the number of mirrors (upper right inset) deployed for that target, with additional arrays of 6 and 12 mirrors positioned North of the main area. A separate type of SPARC target was dedicated to the UAV sensors (bottom left inset). Greyscale and colored diffuse reflectance targets are also visible in the middle of the image. UAV, airborne, and satellite sensors successfully observed the target area simultaneously. (left top) Flightline imagery of the Tait Preserve and primary target area from (A) UAV MX-1 VNIR overpass mosaic, (B), airborne CASI system and (C), space-based satellite WorldView-2 can be used for an ideal cross comparison between remote sensing platforms in the VISNIR and SWIR. Pixels extracted from the highlighted areas (A) were used in comparison of surface reflectance retrievals across all platforms. (bottom) Surface reflectance measurements from all platforms showed good agreement for asphalt, tree canopy, and grass field common target areas. While all assets viewed the area virtually simultaneously, airborne and UAV sensors had a nadir geometry while satellite sensors observed from up to ~30 deg off-nadir. Differences are potentially explained by the impacts of the Bidirectional Reflectance Distribution Function (BRDF) of the AOI targets themselves. UAV and airborne sensors were calibrated using in-scene targets, while satellite imagery was processed to surface reflectance using the AComp algorithm. By contrast to diffuse targets, the SPARC mirrors deployed during G-SCALE were tailored to all asset classes. Using the mirrors the retrieved surface reflectance of each AOI can be simultaneously calibrated using in-scene data, improving cross-platform agreement.

Condensed Water Vapor Plume Volume Estimation

Principal Investigator: Carl Salvaggio

Team: Ryan Connal

External Collaborators: Brian d'Entremont, Alfred Garrett, Christopher Sobecki

Project Description

The goal of this research is to develop a methodology for volume estimation of condensed water vapor plumes emanating from mechanical draft cooling towers for thermodynamic and hydrodynamic modeling purposes.

Modern 3D reconstruction is typically performed using techniques referred to as structure-from-motion, a process involving building the scene with correspondences found between multiple images. However, plumes are a dynamically changing physical form and the spatial features either within the plume, or forming the boundaries, are neither significant nor consistent.

Project Status

The visual localization approach utilizing [1] began by loading images for the ground and aerial data sets separately. Similar to the approach described in [2] SuperPoint was selected as the feature extractor where images were converted to grayscale and resized to square 1024 x 1024px. Superglue initialized with outdoor trained weights was utilized as the feature matcher. The cameras associated with each of the captured images for either collect were implemented with radial camera models, where two radial distortion parameters were estimated during the PnP procedure. Features are extracted and tracked by exhaustively matching features across all images, and incremental Structure from Motion triangulates 3D world points while estimating and optimizing the camera parameters. Model files are written to be loaded when query image parameters are to be estimated at a later time. Successful estimation of camera parameters and pose is demonstrated through tracked features with Figure 1, where features determined as inliers from the epipolar geometric verification procedure are shown. A significant observation is the difference in background, camera position, and shadow on the cooling tower in the query image with respect to the environment in which the reference images were collected. Utilizing SuperPoint and SuperGlue for the outdoor localization task demonstrates how robust this implementation is towards camera pose estimation over an application such as Metashape. However, this implementation still requires properly exposed imagery of the scene, where targeted regions will fail to provide features that can be extracted and matched. Figure 2 demonstrates this situation, where saturation from the sun within the field of view produces an improperly exposed image for the cooling tower. The DN values for any part of the scene aside from the sky are too low to detect reliable features, and relevant information cannot be extracted. Under different meteorological conditions, properly exposed images from the same camera stations can be captured, and the camera pose can be extracted. Provided that the ground stations looking upwards can experience this saturation phenomenon when the sun is in view, reference camera pose parameters could be substituted. Considering captures where the plume is still clearly visible against the background and where the ground station cameras remain locked in place, the pose estimated under conditions observed in Figure 3 could be utilized in Figure 2. Therefore, the proposed work will include additional functionality to substitute camera projection matrices in the space carving procedure instead of outright disregarding capture instances where the pose of one or more cameras cannot be estimated. The clear advantage of the aerial perspective providing significantly more reference from observation of ground objects over the camera stations was recognized with the hloc aerial localization model. The overall number of detected keypoints and tracked features was greater than those in the ground model, where features were found not only in the mechanical draft cooling towers but within the surrounding site as well. The apparent disadvantage of the aerial data is that the plume can obstruct the view of regions which could provide reference and could confuse the feature detection and matching procedure. However, the visible plume proved to not be a hindrance to the localization procedure, as ample feature inliers were tracked from the query images to the reference set without the plume interfering. Figure 5 demonstrates the successful registration of an aerial image with the sun present in the background, as control of the focus and exposure during the flight avoided the observed phenomenon with ground imagery (Fig. 2) where the saturation dominated the exposure of the entire image.

The estimation of the camera pose and intrinsic parameters is required for all capture instances in order for space carving to generate a 3D volume of a condensed water vapor plume. Provided that the ground and aerial imagery captured at the test site not only suffer the complications associated with performing computer vision tasks in outdoor environments but experience various meteorological and lighting conditions across the 17 months of the collection campaign, a robust localization technique was sought out. Packaged 3D reconstruction software implementing Structure from Motion such as Agisoft Metashape are assumed to use hand-crafted feature detectors and matchers such as SIFT or SURF. While effective in generating scene reconstructions from 2D images captured within a short duration to reduce the variation induced by changing outdoor conditions, typical feature detection and matching outright fails under drastic changes that would occur across a collection campaign. This was observed where properly exposed ground station images captured at mid-day without a plume present could not become registered to the Metashape model without manual intervention in the form of selecting and tracking tie points across images.

The hierarchical visual localization implementation effectively registers query plume images for both the ground-based and aerial models developed through incremental Structure from Motion. The utilization of self-supervised feature detectors and matchers such as SuperPoint and SuperGlue proved to be extremely effective in tracking features across various illumination and meteorological conditions. The exposure of the scene remains important, as ground-based imagery, whose dynamic range was dominated by saturation from the sun cannot detect features on the cooling towers.

In addition, the implementation of hloc does not include any methodology toward including ground control points in the scene. Therefore the estimated camera projection matrices are determined for the arbitrary model scale, whose distances are not metric.

Figure 1: Query plume image with successful registration and (b) reference image with highest count of matched feature inliers tracked to the query image. Green lines show tracked feature inliers, where red designates outliers.

Figure 2: Query plume image with a failed registration and (b) incorrect reference image.

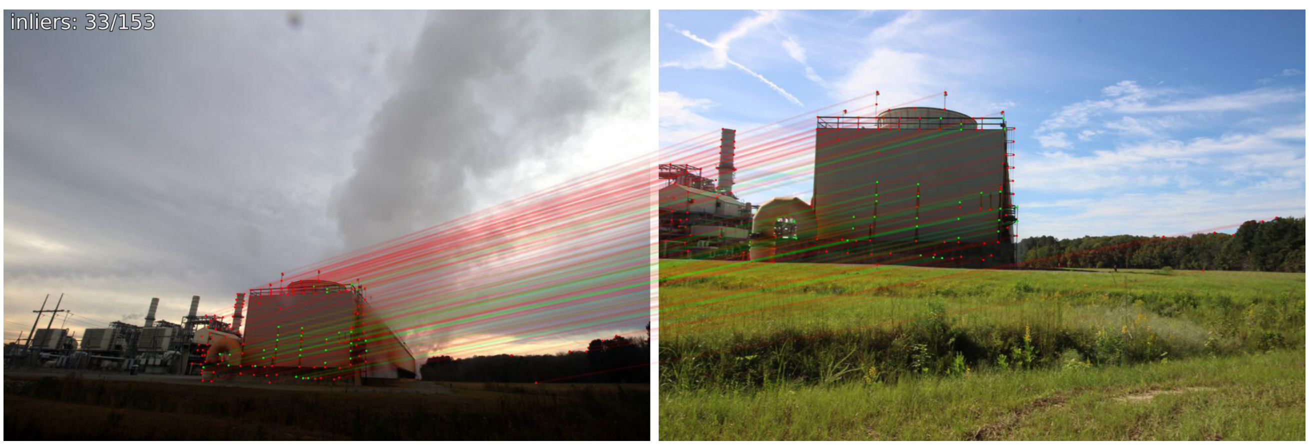


Figure 3: Query plume image with successful registration and (b) reference image with highest count of matched feature inliers tracked to the query image. Green lines show tracked feature inliers, where red designates outliers.

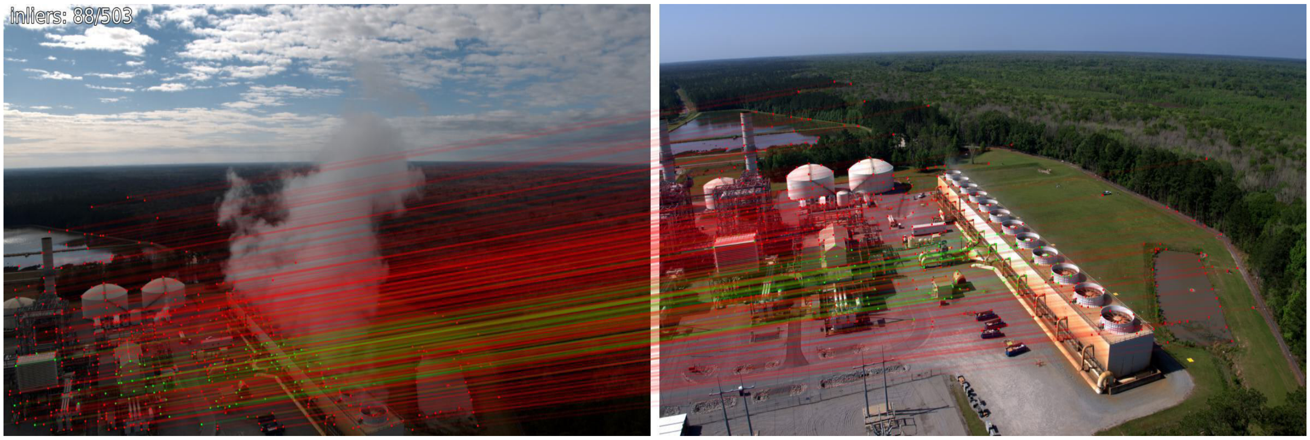


Figure 4: Query sUAS plume image with successful registration and (b) reference image with highest count of matched feature inliers tracked to the query image. Green lines show tracked feature inliers, where red designates outliers.

Figure 5: Query sUAS plume image with successful registration and (b) reference image with highest count of matched feature inliers tracked to the query image. Green lines show tracked feature inliers, where red designates outliers.

Accelerating Use of Geologically-driven Engineering and Reclamation

A Predictive Approach to a Sustainable Critical Minerals Industry

Principal Investigator: Charles Bachmann

Research Team: Chris Lee, Nayma Nur, Tim Bauch, Nina Raqueno, Brian Benner, Robert Chancia

External Collaborators: Karin Olson Hoal (Cornell University, PI); Louisa Smieska (Cornell University, Co-PI); Anthony Balladon (Phoenix Tailings, Co-PI); Jessica Stromberg (CSIRO, Co-PI); Greg Ray (Cornell University); Sriramya Duddukuri Nair (Cornell University)

Project Description

This Phase 1 project brings together two critical technology areas, hyperspectral imaging (HSI) and x-ray fluorescence (XRF) to inform both better planning and re-use of mineral resources and associated byproducts such as mine tailings. The project builds on expertise in material characterization using XRF at the Cornell High Energy Synchrotron Source (CHESS) and RIT expertise within DIRS related to both drone hyperspectral imaging for environmental characterization as well as lab hyperspectral characterization of materials. The goal is to better link these complementary technologies at the micro-scale in order to benefit what is discoverable at remote sensing scales from hyperspectral imaging. From these improved insights into material characterization, the goal then is to more effectively identify mineral resources and hazards at the beginning stages of site exploration, plan for better use of all discovered resources and thus promote a paradigm shift within the minerals resource industry. This same approach can be used to characterize mine waste (tailings) to repurpose materials, promoting sustainable end-use of byproducts. The long-term goal is to develop a resource toolkit that will support the mineral resources industry to promote more efficient use of site resources as well as repurposing of byproducts.

Project Status

In addition to technical work, team members interviewed stakeholders in the mineral resources industry as well as effected communities to determine the key parameters and analyses needed to develop a resource toolkit based on key technologies such as XRF and hyperspectral imaging. These interviews informed the technical goals that we have pursued in experimental work in both field and laboratory settings over the course of this project. As part of this effort, our RIT team undertook an initial experiment at a former mine site in Mineville, NY, flying our drone-based imaging payloads to collect hyperspectral imagery, LiDAR, and thermal imagery. In additional, 3D site models were also constructed from orthorectified stereo RGB imagery. A mast-based hyperspectral imaging system was also deployed, and extensive ground truth measurements were undertaken. Site samples have been brought back from the experiment and added to the samples being used in laboratory analysis with our hyperspectral goniometer; these measurements are being coordinated with XRF measurements by our partners at Cornell CHESS and CSIRO in Australia. Data from these and ongoing efforts will eventually populate a database and scientific computing toolkit that the team hopes to develop in a phase 2 effort. The RIT PI has also collaborated with Cornell CHESS to plan integration of hyperspectral data collection into the experimental configuration being used for XRF analysis of samples at CHESS.

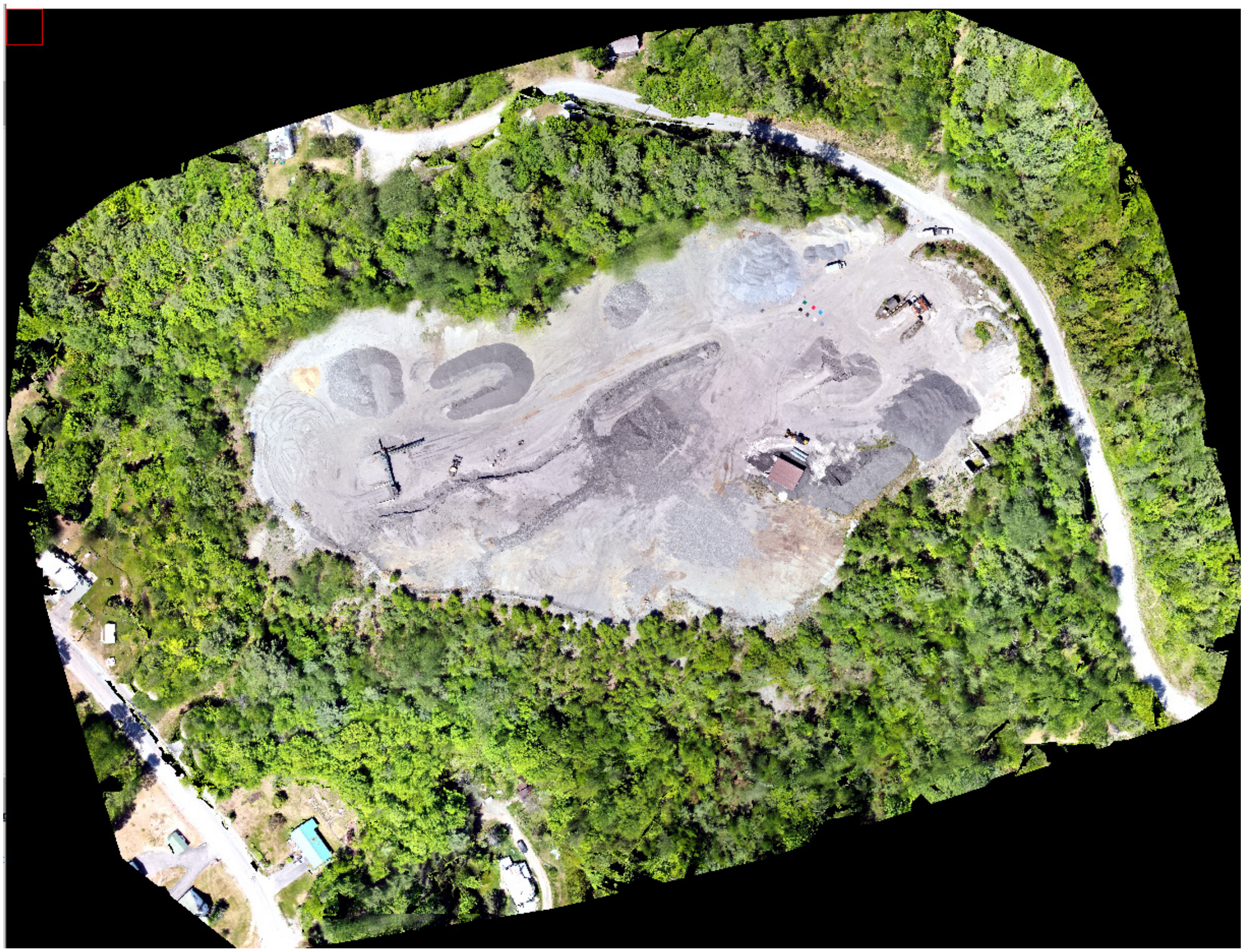


Figure 1: Drone imagery from the RIT field experiment in May 2023 at a former mining site in Mineville, NY.

Synthetic Aperture Radar (SAR) Image Formation and ATR Studies

Principal Investigator: James Albano

Project Description

This program consists of three technical areas: generalized phase history modeling and simulation, SAR image formation processor limitations on target recognition, and the impact of target model fidelity on neural-based automatic target recognition (ATR) algorithms. This program has resulted in a SAR phase history simulation capability which has been instrumental in addressing the latter two topic areas. Some of its features include the ability to simulate both spotlight and stripmap modes, quadrature and dechirp-on-receive demodulation, radiometrically correct data, accounts for antenna beampattern, and works with Xpatch scattering centers that accurately model a target at a given center frequency and polarization. Scenes can be composed of multiple targets placed at user-defined locations and orientations.

The Polar Format Algorithm (PFA) is a popular technique for SAR image formation due to its low computational complexity when compared to other algorithms like Backprojection. While Backprojection implements a perfect matched filter to the image, its computational complexity is N^3 where N is the total number of pixels in the image. This is compared to $N \log_{10} N$ computational complexity for PFA. The disadvantage of PFA is that it neglects wavefront curvature which results in spatial-variant image distortion and defocus artifacts that decrease the performance of ATR systems. This program has surveyed several methods to correct both artifacts and is currently developing a computationally efficient algorithm to increasing the performance of target recognition. This algorithm is outlined in Figure 1 below. Figure 2 provides a demonstration of the algorithm. Figure 2a shows an image of a point target that has not been corrected for wavefront curvature. Figure 2b is the output of the algorithm that predicts and corrects the residual phase error, resulting in a focused image of the point target. Figure 2c shows the gain in signal-to-noise ratio accomplished which also contributes to an increase in ATR performance.

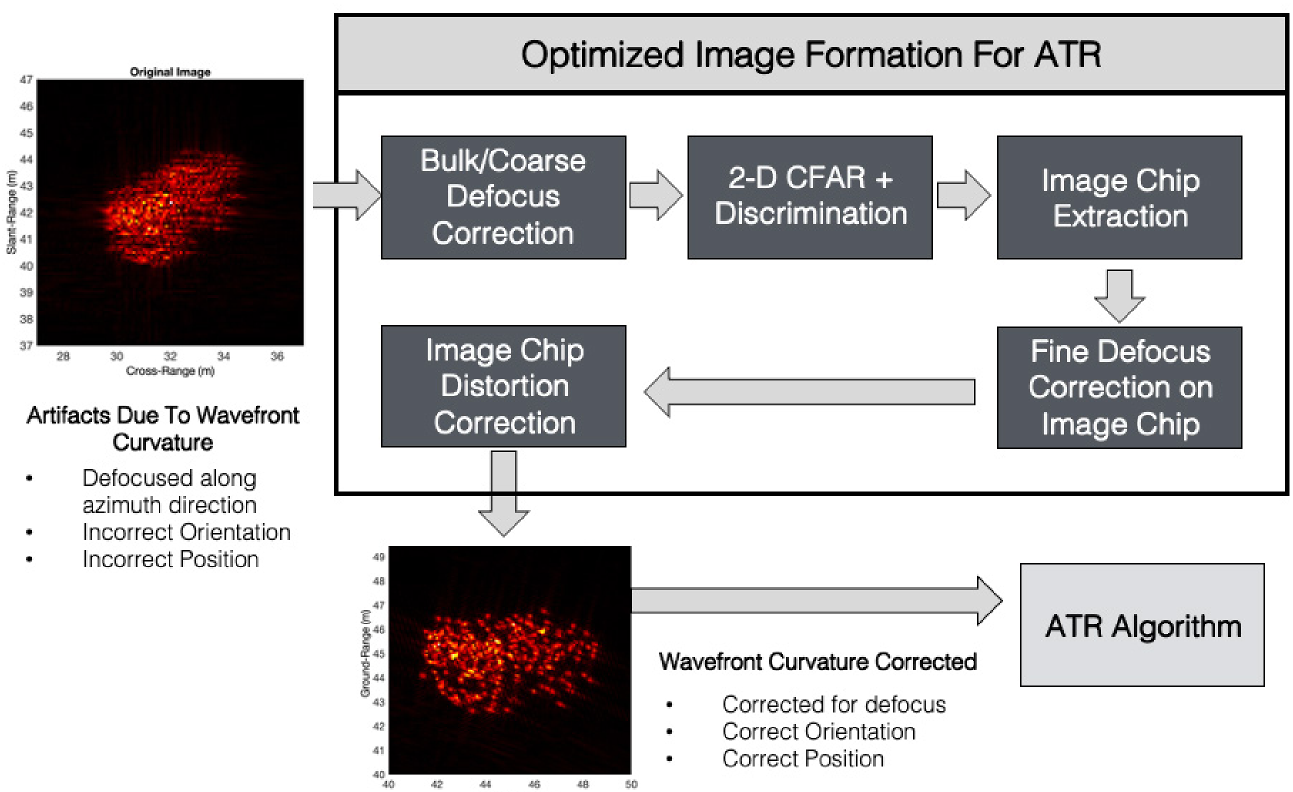


Figure 1: Efficient pre-processing algorithm for automatic target recognition applications that corrects for wavefront curvature.

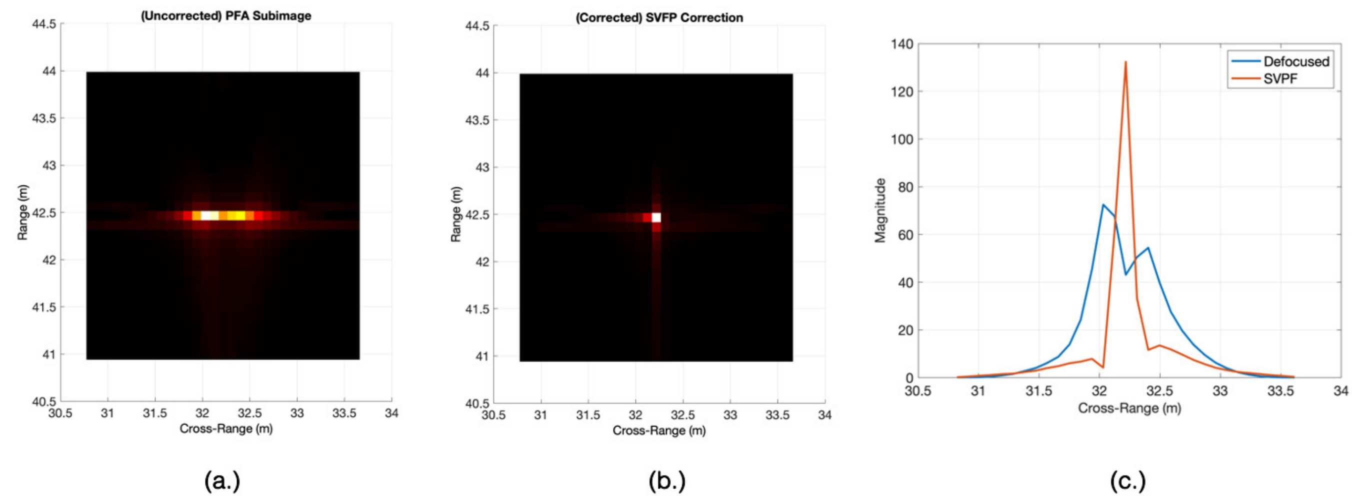


Figure 2: (a) Image of a point target using PFA that has not been corrected for wavefront curvature, (b) phase corrected image of the point target, and (c) a cross-range profile showing a drastic increase in signal-to-noise ratio once phase corrected.

Improved Strategies to Enhance Calibration and Validation of Landsat Thermal Data and Their Associated Higher-Level Products

Principal Investigator: Aaron Gerace

Team: Eon Rehman, Nina Raqueno, Amir Hassanzadeh, Gabriel Peters, Reed Terdal, Austin Martinez, Christian Secular, Sebastian Steigerwald, Zachary Steigerwald

Project Description

This research effort leverages existing techniques to support persistent calibration of Landsat's operational thermal instrumentation and to continue the development of their corresponding surface temperature products. Considering the scarcity of thermal reference data due to insufficient ground-based equipment, significant effort has been placed on the development of a multichannel thermal radiometer to support Landsat Surface Temperature product validation.

Project Status

In Year 4 of this five-year effort, RIT worked with USGS-EROS to implement an operational (near real-time) surface temperature workflow in their Landsat Product Generation System (LPGS) that uses data acquired from the Thermal infrared Sensors (TIRS-1 and TIRS-2) onboard Landsat 8 (9). Once active, Landsat products that leverage the split window algorithm (tailored for TIRS) for deriving surface temperature will be made freely available to users worldwide, see Figure 1.

Several studies that use existing ground-based equipment for reference continue to be conducted to ensure the fidelity of the Landsat surface temperature products. To address the scarcity of thermal reference data in the community, RIT continues to investigate the feasibility of a lost-cost thermal radiometer design to potentially increase the reference measurements available for validation. In Year 4, the radiometer electronics were finalized and fabrication of the units completed. Results from in-lab calibration indicate that the units are performing as expected, see Figure 2. Field-placement of the experimental radiometers will take place in Year 5 to assess the utility of these instrumentation for thermal product validation for image data derived from spaceborne platforms.

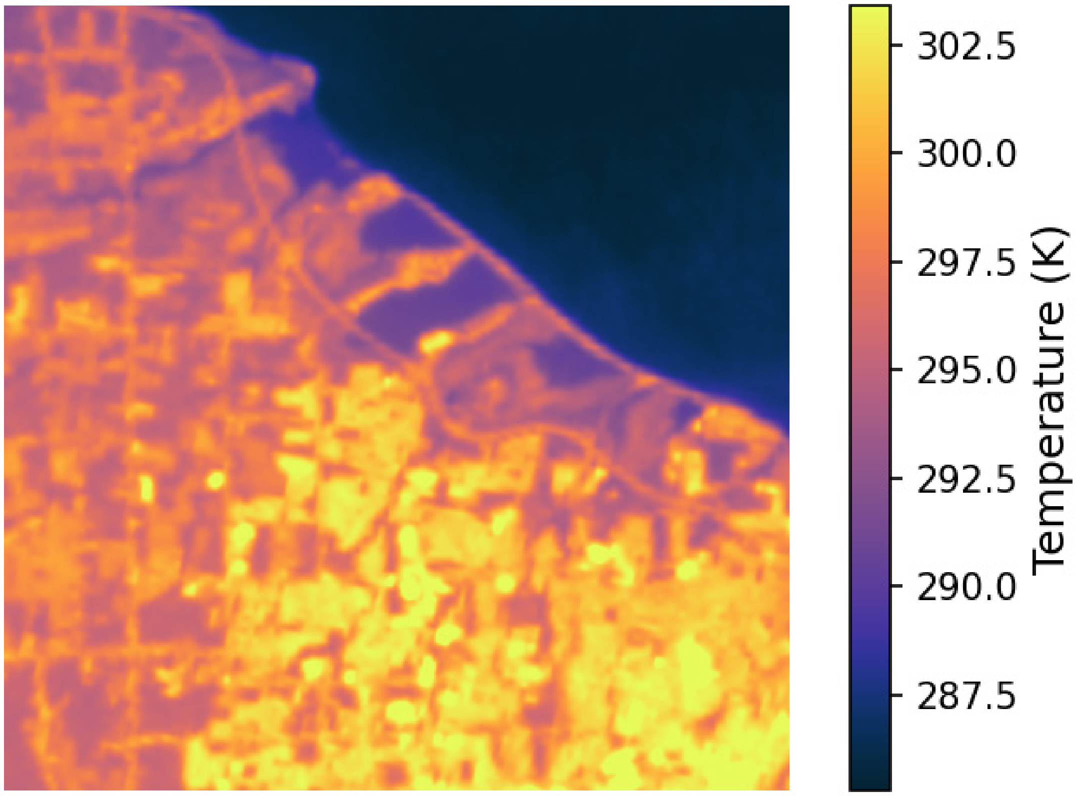
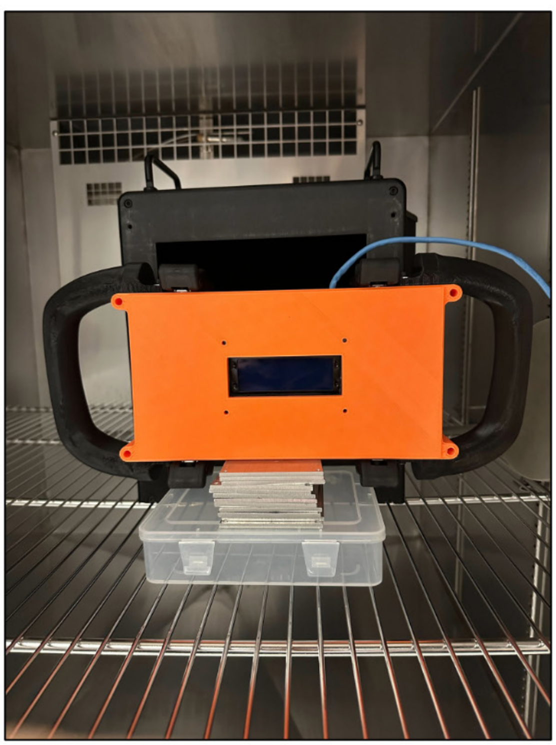


Figure 1: Split window derived surface temperature product using Landsat 9 Thermal Infrared Sensor data acquired over Rochester, New York.



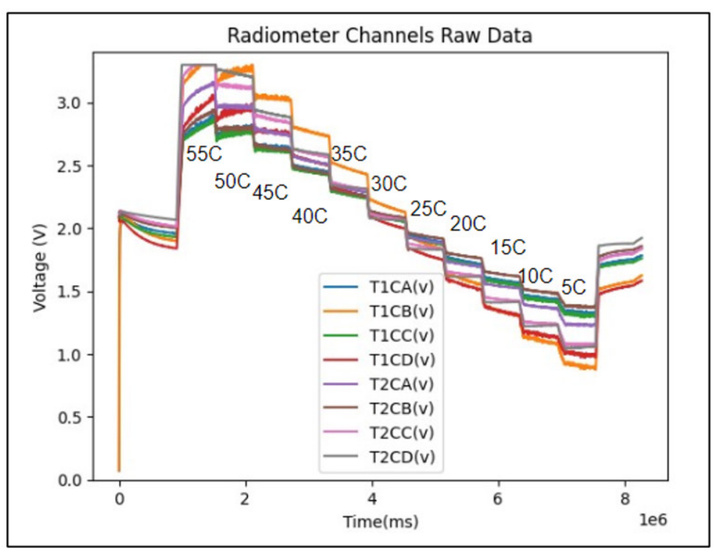


Figure 2: (Left) Thermal radiometer developed at RIT for measuring kinetic surface temperature to support Landsat surface temperature product validation and (right) voltage data acquired from chamber sweep used for calibration.

Analysis of NOx Blast Fumes with Drones

Principal Investigator: Emmett Ientilucci

Team: Bob Kremens, Nina Raqueno, Xuesong Liu

Project Description

Austin Powder manufactures, distributes, and applies industrial explosives for industries including quarrying, mining, construction, and other applications. Although it's unusual, these massive explosions can release a foreboding yellowish-orange cloud that is often an indicator of nitrogen oxides—commonly abbreviated NOx. Austin Powder is seeking research into the ability to image these plumes so as to estimate concentration (using image processing and sensors on drones) and potentially estimate volume. We also seek to identify NOx in the plume itself.

Project Status

We have made field-deployable NOx ground sensors, in-lab controlled spectral measurements of NOx gas, participated in Austin Powder customer blast data collections, created visualizations of NOx concentration and synced video data from UAS's into a spatial environment (GIS) for spatial and temporal analysis. We have deployed our custom NOx sensors at customer sites to measure NOx in units of ppm. We have published papers on an image processing technique to plume segmentation.

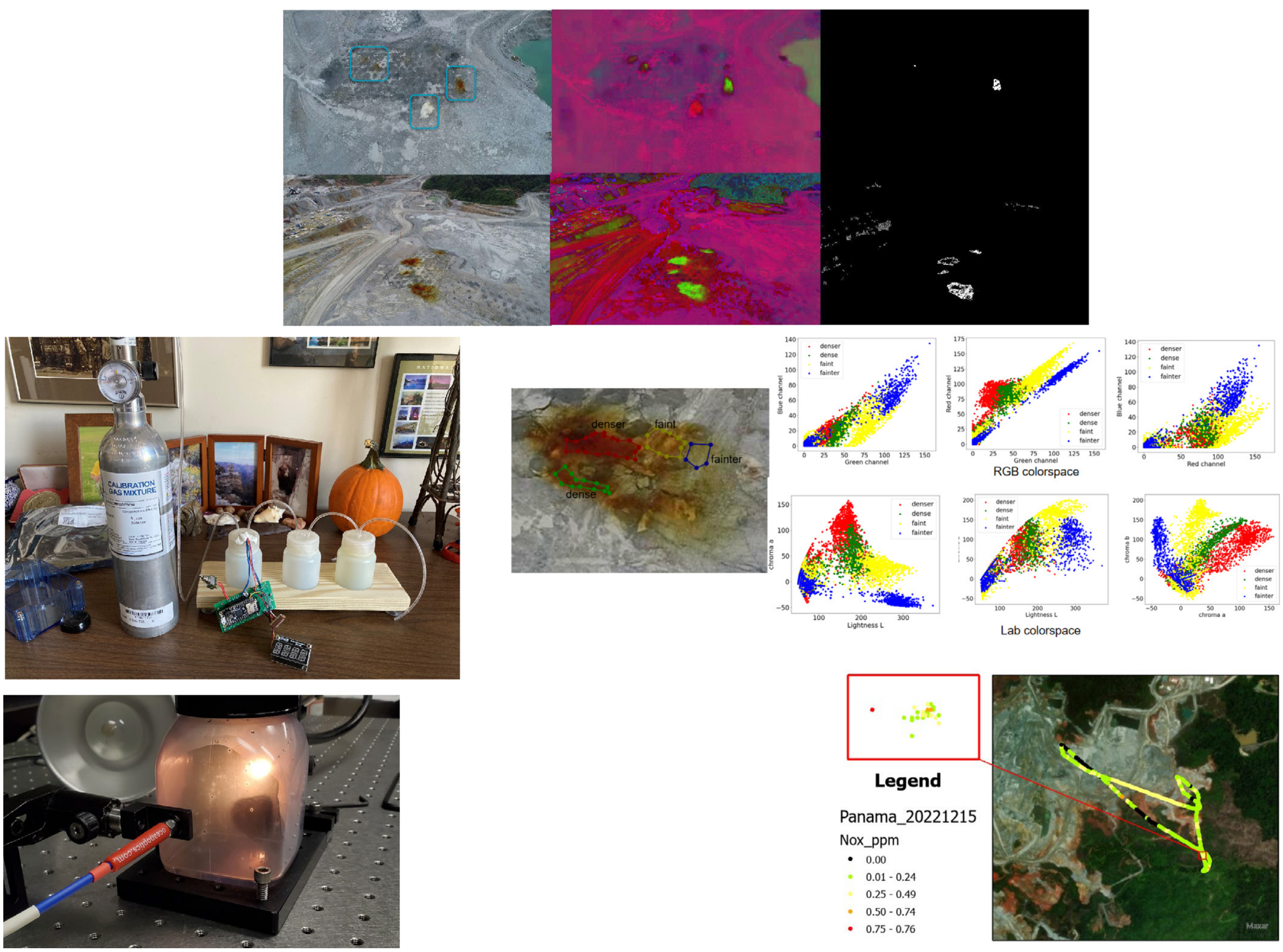


Figure 1:(top) Show image processing results to segment and detect NOx gas in blast plumes. (center left) Calibrating our custom made NOx, drone mounted sensors. (center right) Approaches to classify the various levels of NOx in imagery. (bottom left) measuring the transmission of a small sample of NOx gas under a hood with a spectrometer, (bottom right) overlaying NOx readings from our NOx drone sensor in a GIS environment.

Simulation & Modeling to Support the Definition of Sustainable Land Imaging (SLI) System Requirements

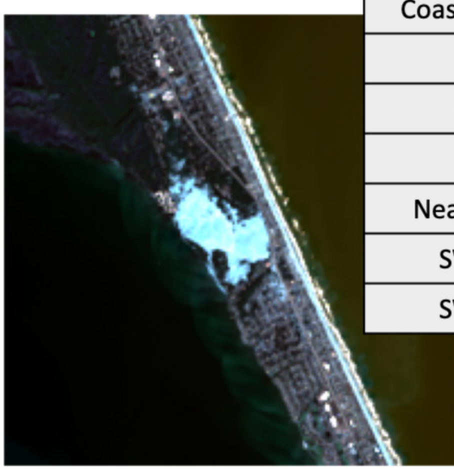
Principal Investigator: Aaron Gerace

Team: Rehman Eon, Amir Hassanzadeh, Tim Bauch, Nina Raqueno, Lucy Falcon, Ethan Poole

Project Description

This three-year research grant focused on supporting the definition of requirements for the next Landsat Earth-observation system using simulation and modeling. Over the period-of-performance of the project, RIT conducted studies to help define Landsat's next band combination, radiometric sensitivity, and potential compression workflow. With the launch of Landsat 9 on September 27, 2021, data acquired during its commissioning phase was used to assess the impact of 12-bit vs. 14-bit quantization on science applications, to perform an on-orbit assessment of its edge response, and to perform an early-assessment of its radiometric sensitivity relative to its predecessor, Landsat 8.

A major ground campaign was conducted by RIT during the Landsat 9 underflight of Landsat 8 in the Outer Banks, North Carolina to acquire ground reference data to support calibration of both Landsat 9's sensors: The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Figure 1 shows a comparison of surface reflectance of the Jockey Ridge Dunes System for Landsat 8, Landsat 9, and a drone-based Headwall Nano sensor (resampled to the OLI bands). Ground-based measurements indicated that the Landsat 9 sensors were performing as expected early on in the mission.



Band Name	UAS SR	L8 SR	L9 SR
Coastal Aerosol (430-450 nm)	0.140	0.134	0.133
Blue (450-510 nm)	0.168	0.162	0.162
Green (530-590 nm)	0.273	0.250	0.253
Red (640-670 nm)	0.338	0.317	0.318
Near Infrared (850-880 nm)	0.414	0.406	0.404
SWIR1 (1570-1650 nm)	0.544	0.494	0.492
SWIR2 (2110-2290 nm)	0.560	0.471	0.474

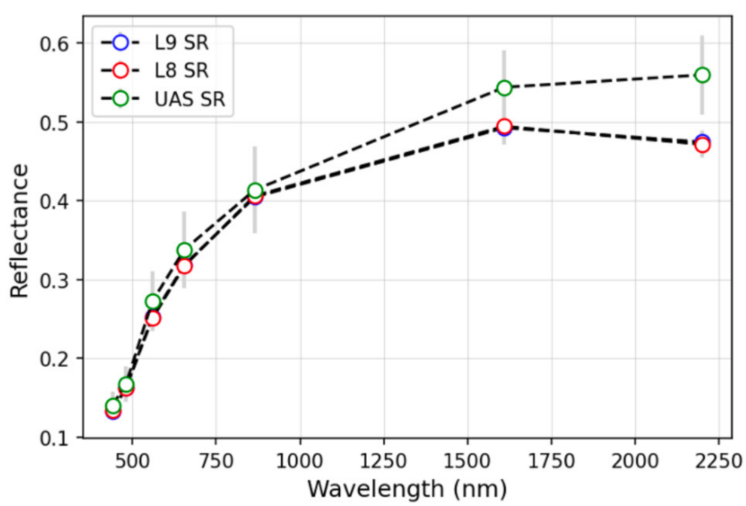


Figure 1: Visual comparison of Chlorophyll-a retrievals associated with Landsat 9 (left), Landsat 8 (middle), and Terra-MODIS (right). Note that these data were collected during the L9 underflight of L8. In general, for the image data used in this study, Chlorophyll-a retrievals for the L9 14-bit system are closer, on average, to MODIS reference than the Landsat 8 12-bit system. This study will be revisited once a proper flat-field is conducted with L9.

Estimation of Beet Yield & Leaf Spot Disease Detection

Principal Investigator: Jan van Aardt & Sarah Pethybridge (Cornell U.)

Team: Mohammad Shahriar Saif, Rob Chancia, Tim Bauch, Nina Raqueno, Imergen Rosario

External Collaborators: Sarah Pethybridge, Cornell University; Pratibha Sharma, Cornell University; Sean Patrick Murphy, Cornell University

Project Description

The Rochester, NY area is home to a growing economy of table beet root growers and production facilities for various organic beet products, headed by Love Beets USA. Since 2018, Love Beets has been working with the RIT DIRS group and Cornell AgriTech to explore the application of UAS remote sensing imagery for yield estimation, plant count, and root size distribution forecasting. In the summer of 2021, in addition to the above-mentioned yield parameters, root weight, root number, and dry weight foliage were collected. The goal will be to develop models based on the spectral signatures acquired from UAS. This will equip farmers with tools to forecast their harvest. Models developed from the previous season's data will be tested on the summer 2022 data in order to assess the robustness of models. Figure 1 shows a ground image of a beet root field during harvest, while Figure 2 shows the picture of UAS as it is collecting data for summer 2022. Both images were compiled from the blue, green, and red channels taken from a MicaSense RedEdge-M five-band multispectral visible-near-infrared (VNIR) camera system, mounted on a DJI Matrice 600. For the summer flight we used a DJI Wind 8 platform.

Project Status

Rob Chancia published an article in Remote Sensing, reporting on the model developed for 2018 and 2019 seasons' imagery (see previous DIRS annual report for 2021-2022). Seven flights were conducted during the summer of 2021, capturing hyperspectral imagery from 400-2500 nm at different stages of plant growth. Wavelength indices linked to beet yield prediction were identified. Results from the 2021 data were published, and a yield model map is shown in Figure 3. Seven flights were also carried out in the summer of 2022, and the data are currently being processed to validate and expand on the 2021 results. Additionally, a potential five-band multispectral solution is being explored for beet yield prediction. In both 2021 and 2022, Cercospora Leaf Spot (CLS) disease trials were conducted, and the disease severity was assessed by the Cornell AgriTech team. Figure 4 displays a table beet leaf infected with CLS. The potential use of UAS for severity determination is currently under investigation.

Table 1. Data collection milestones for the 2021 flight season.

DATE	MILESTONE
20-May	Beets planted
16-Jun	1st Flight
7-Jul	2nd Flight
15-Jul	3rd Flight
20-Jul	4th Flight
2-Aug	5th Flight
5-Aug	Harvest

Figure 1: An example of a typical beet crop during harvest.

Table 2. Data collection milestones. All data collected in 2022.

DATE	MILESTONE
28-May	crop planted
10-Jun	1st Flight
28-Jun	2nd Flight
7-Jul	3rd Flight
15-Jul	4th Flight
26-Jul	5th Flight
10-Aug	6th Flight
18-Aug	7th Flight
15-Aug	Harvest
18-Aug	Harvest
24-Aug	Harvest

Figure 2: First flight of summer 2022 using RIT's MX-2 UAS.

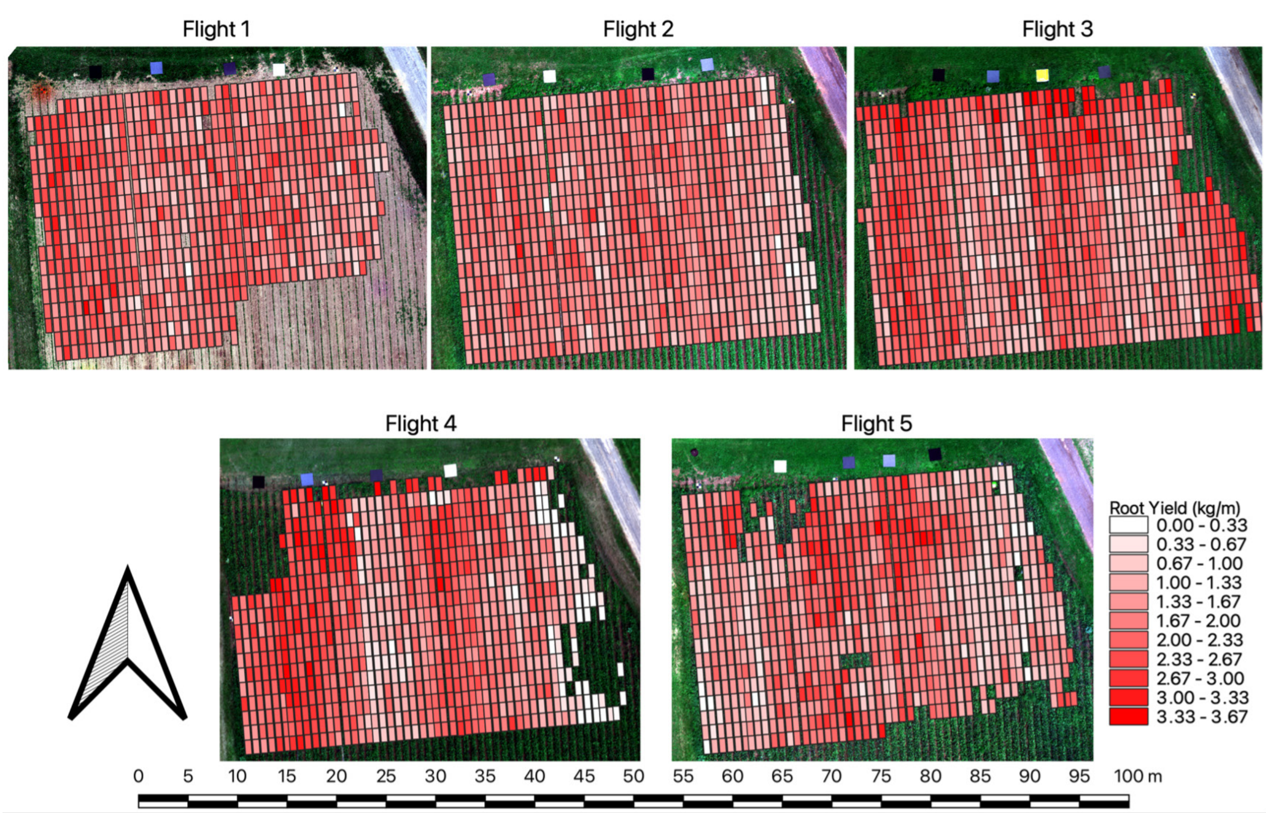


Figure 3: An example of field-level estimated root yield using the best performing model for each flight.

Figure 4: A leaf sample affected with CLS.

Partnership for Skills in Applied Sciences, Engineering and Technology

Principal Investigator: Anthony Vodacek

External Collaborators: Gerard Rushingabigwi, University of Rwanda; Louis Sibomana, University of Rwanda

Project Description

Tools for East African Lakes (TEAL). The aim of this project is to assemble and test a relatively inexpensive set of devices to support the creation of Internet of Things sensor networks for measuring optical properties and temperatures of East African lakes. Sensor networks developed for this project will be piloted in Cyohoha North and Mugesera lakes, in Rwanda. Successful creation and practical deployment of these types of sensor networks at scale, and the satellite remote sensing measurements they enable, will improve the knowledge of lake managers about lake conditions in East Africa. This project also aligns with the goals of the African Center for Aquatic Research and Education (ACARE) lake monitoring committee, of which Dr. Vodacek is a member.

Project Status

A paper describing the design of the system was published in the IGARSS 2022 proceedings. Assembly of the prototype system with occur in the coming year.

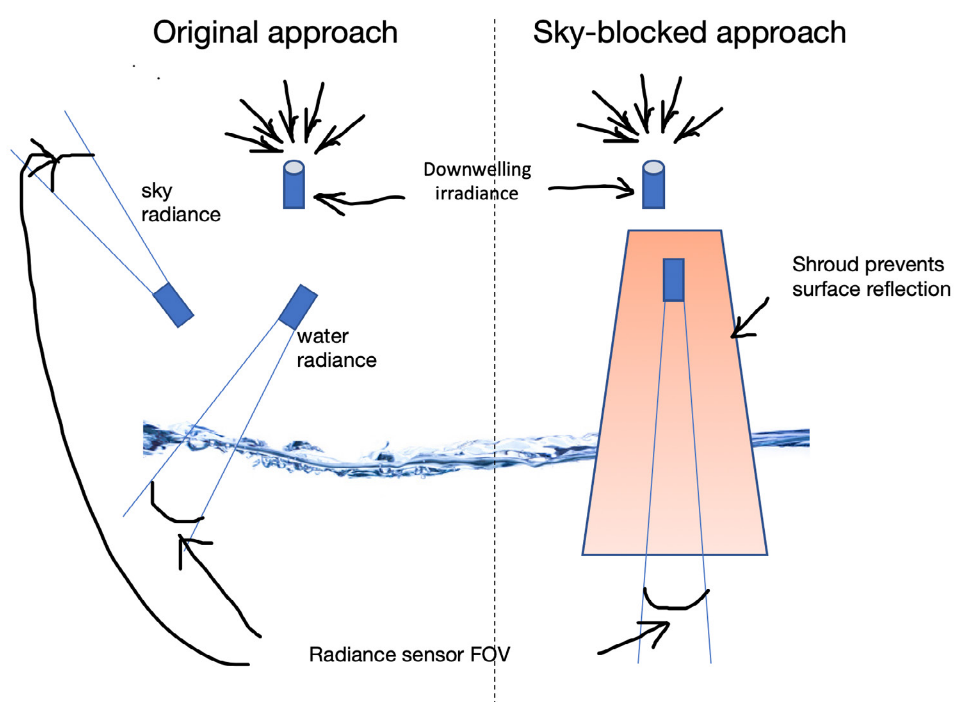


Figure 1: Drawing of the two methods of collecting water leaving radiance. The original approach requires 3 sensors while the sky-blocked approach requires 2 sensors. The sky-blocked approach is described in the International Ocean Color Coordinating Group (IOCCG) protocol series.

Integrating TES and Modern Target Detection Capabilities into a Forecasting Model

Principal Investigator: Emmett Ientilucci

Team: Runchen Zhao

Project Description

A material's (say a powder) surface emissivity can be affected by many things including particle size, for example. Increasing or decreasing the particle size can vary the dominant scattering sources between surface scattering and volume scattering. Thus, how the particle size impacts target detection performance is a valuable question, especially in the LWIR domain. To analyze this, parameter trade-off studies focusing on particle size can be studied using Forecasting and Analysis of Spectroradiometric System Performance (FASSP) model. FASSP is an end-to-end system performance forecasting analysis tool which uses first and second order statistics associated with targets and background. The current FASSP model does not have a temperature/emissivity separation (TES) algorithm which is needed to perform realistic analysis in the LWIR. In addition, a state-of-the-art and wildly used detection algorithm called adaptive cosine estimator (ACE) is to be implemented. Due to the nature of FASSP (i.e., propagating statistics), ACE cannot be directly coded into the model. An alternative and equivalent algorithm called the cotangent detector will be utilized instead

Project Status

We have already finished the development of our TES algorithm (called S-ISSTES) and implemented it into FASSP. We tested this and published it in the IEEE Transactions on Geoscience and Remote Sensing (TGRS). We have implemented and validated the implementation of both the ACE and equivalent cot detectors. Our last phase is to implement a covariance matrix generator based on the Hapke model and Monte-Carlo simulations for particle size studies.

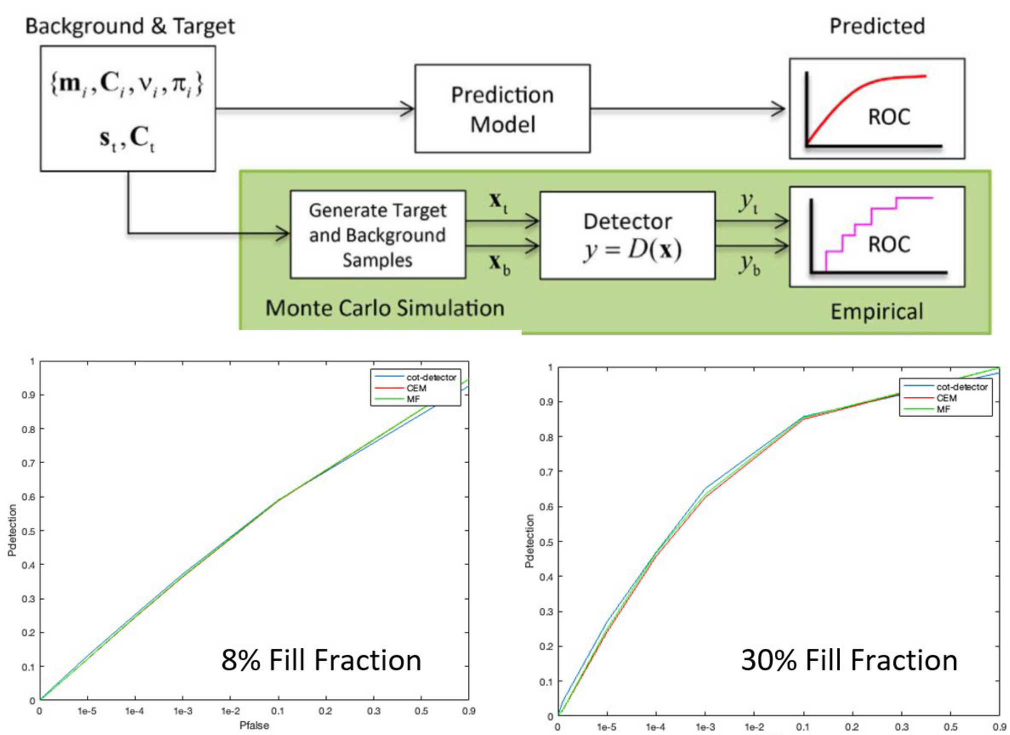


Figure 1: ROC curves drawn from (left) 8% and (right) 30% target fill fraction for the ACE and cot-detectors. We see high agreement with our implementations of both ACE and the equivalent cot detector.

Unmanned Aerial System Data Collections

Principal Investigator: Emmett Ientilucci

Team: Nina Raqueno, Tim Bauch

Project Description

RIT has been working work ORNL to provide them with a variety of data sets with heavy focus on varying sensor modality (i.e., both active and passive), number of spectral bands (i.e., multi- and hyper-spectral), and imaging scenarios.

Project Status

We have been collecting and processing data related to a variety of scenarios that can be used for input to various ORNL algorithms. Recently, this has included the collection of SAR date with our IMSAR Ku-band UAV. These UAS data collections are in direct support of EO / SAR fusions algorithmic development.

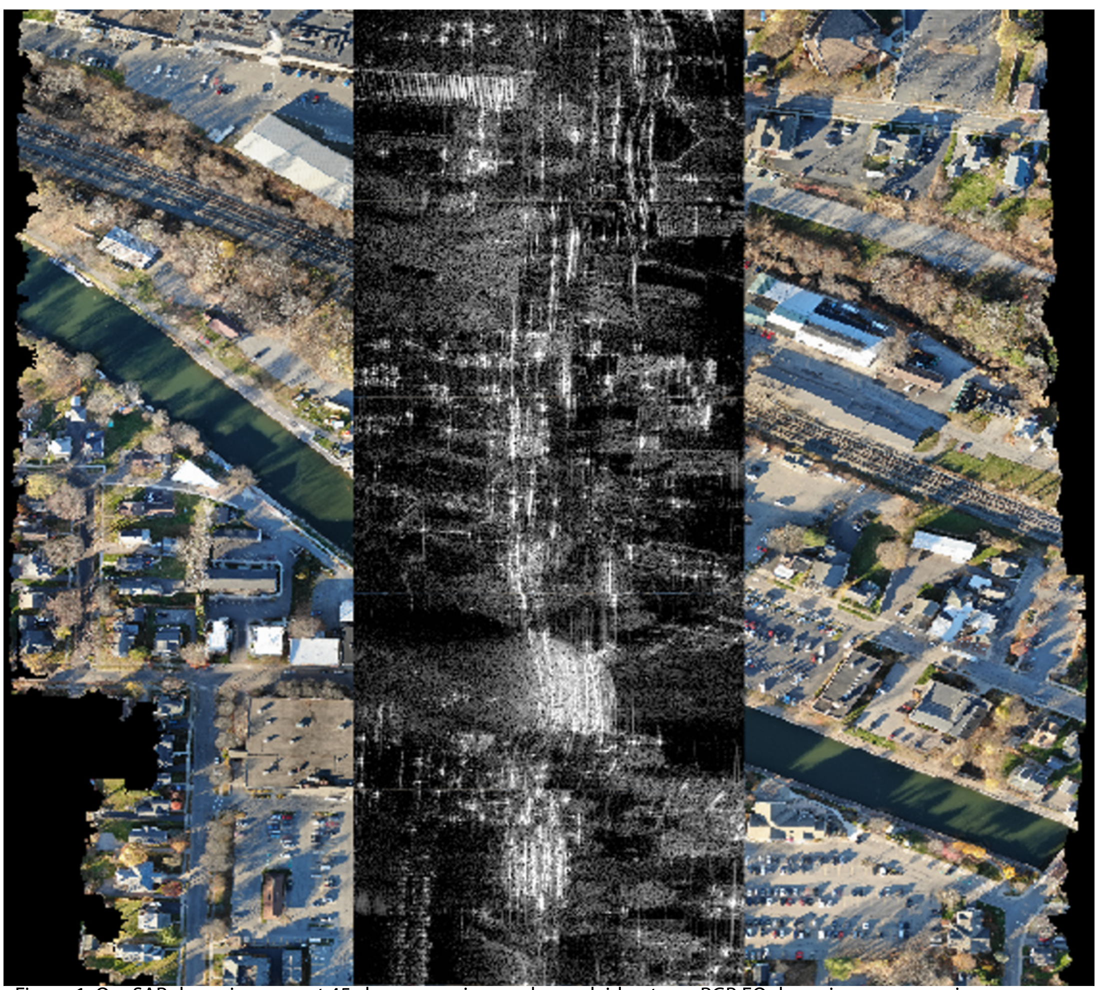


Figure 1: OneSAR drone imagery at 45-degree grazing angle overlaid onto an RGB EO drone imagery mosaic

L’RALPH In Flight Instrument Characterization

Principal Investigator: Matthew Montanaro

Project Description

The in-flight characterization and calibration of NASA’s Lucy Ralph (L’Ralph) instrument is essential to a successful science mission. The L’Ralph instrument will provide spectral image data of the Jupiter Trojan asteroids from visible to mid-infrared wavelengths from two focal planes sharing a common optical system. The Multispectral Visible Imaging Camera (MVIC) acquires high spatial and broadband multispectral images in the 0.4 to 0.9 micron region. The Linear Etalon Imaging Spectral Array (LEISA) provides high spectral resolution image data in the 1 to 3.8 micron spectral range. The Lucy observatory is currently in flight (phase E) after a successful launch in October 2021 and is in-route to the Jupiter Trojan swarms via multiple Earth Gravity Assists (EGAs). The overall objective of this work is to assist in the continuing characterization and radiometric calibration of the L’Ralph instrument through processing and analyses of in-flight image data. These image datasets are assessed for radiometric and spatial quality. Calibration algorithms are updated as needed to correct for any artifacts or radiometric errors found during these image assessments.

Project Status

Over the past year, the Lucy spacecraft continued its out-bound cruise from Earth. The L’Ralph instrument acquired multiple calibration datasets to confirm the health of the instrument. Images of star fields served as ‘first light’ images and verified the pointing and spatial quality of the MVIC detector arrays. The LEISA array is still too warm for valid image data. Additionally, MVIC acquired several datasets of the Earth and of the Moon during the EGA1 fly-by of the Earth-Moon system in October 2022. The PI supported the image processing and analyses of these datasets and specifically characterized optical scattering and electrical cross-talk in the image data. Scattering and cross-talk magnitudes were found to be generally consistent with pre-flight characterization measurements. These results were documented for presentation to the Lucy Science Team.

Figure 1: Image of the Moon acquired by the L'Ralph MVIC detector arrays during the Lucy Earth Gravity Assist 1 in October 2022. Color composite created from the MVIC violet, green, and near-infrared channels. Image originally processed by Dr. Amy Simon, NASA GSFC, for the article: https://www.nasa.gov/image-feature/goddard/2022/nasas-lucy-spacecraft-eyes-the-moon-again/

NASA Goddard Space Flight Center

Principal Investigator: Matthew Montanaro

Research Team: Aaron Gerace, Rehman Eon, Amir Hassanzadeh

External Collaborators: NASA Goddard Space Flight Center; U.S. Geological Survey, Earth Resources Observation and Science Center

Project Description

This project provides general image calibration and systems support for the Landsat thermal band instruments for NASA. Specifically, this involves the continuing on-orbit characterization and calibration of the Landsat 8 / Thermal Infrared Sensor (TIRS) and the Landsat 9 / Thermal Infrared Sensor 2 (TIRS-2) instruments. It also involves instrument concept and requirements assessments for the upcoming Landsat Next mission. The PI serves as the Deputy Calibration Lead for the TIRS-2 project, the Deputy Instrument Scientist for the Landsat Next project, and is a member of the Calibration and Validation team for the Landsat program. Team members also provide technical expertise and guidance on Landsat thermal image products to the Landsat Science team and the US Geological Survey (USGS).

Project Status

Over the past year, the PI has been involved in finalizing instrument requirements for the Request for Proposals (RFP) for the Landsat Next Instrument Suite. He contributed to efforts to model the trade space for potential instrument configurations and helped refine constraints on the instrument design. The PI continued to support the on-going operations of the TIRS instruments onboard Landsat 8 and Landsat 9 through analyses of in-flight calibration data with the Landsat Cal/Val team and by assisting the Flight Operations team with recovering from instrument anomalies.

Team members continued to support USGS efforts to field a Landsat land surface temperature product by providing USGS engineers with requested test data and algorithms. The team also continued to provide modeling support and expertise for Landsat Next architecture studies.

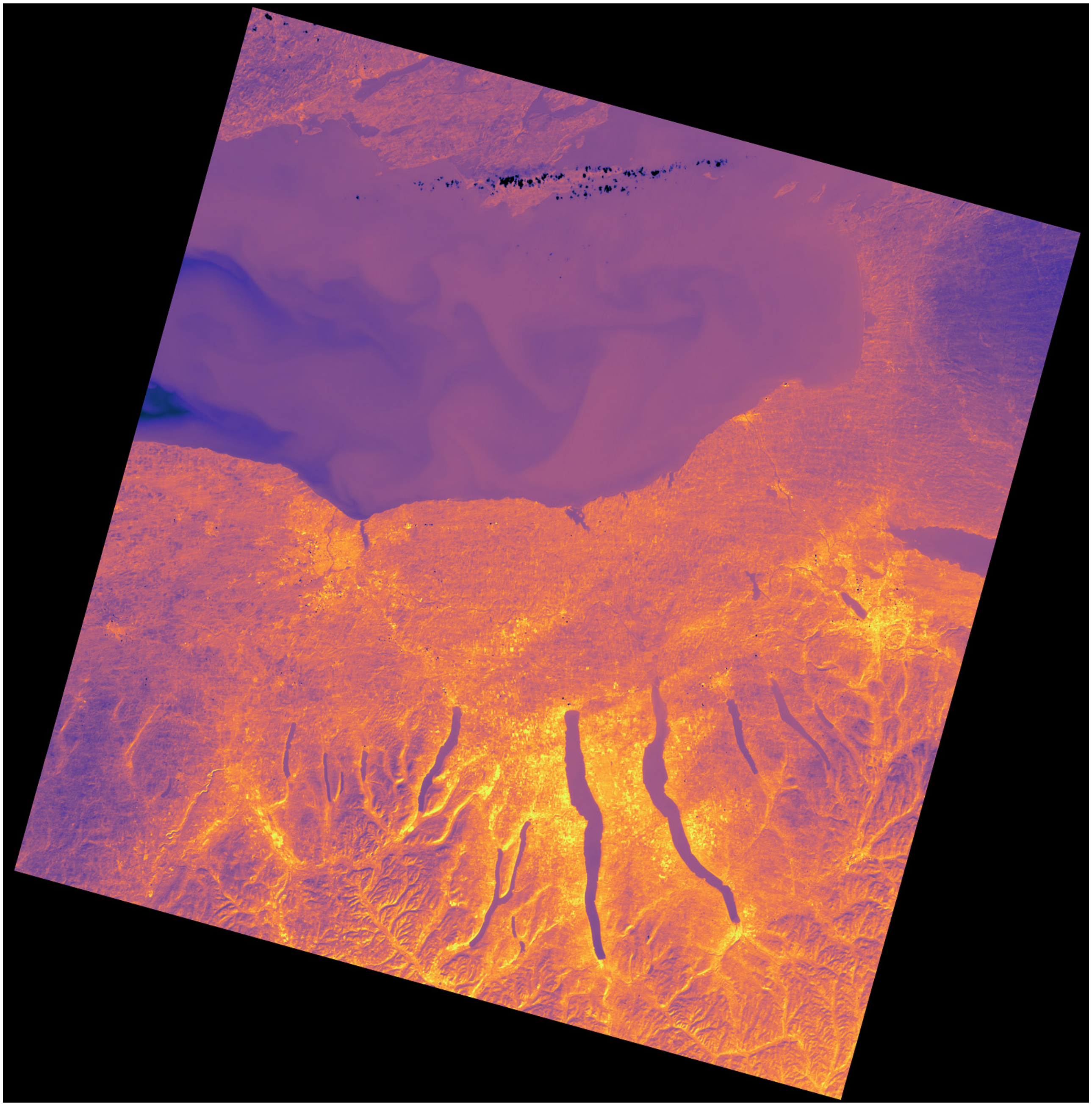


Figure 1: USGS product image of western New York from the Landsat 9 / TIRS-2 instrument (10.8 microns) acquired on 2022-11-07. Image contrast is stretched between temperatures of 272 Kelvin (dark purple) to 288 Kelvin (bright orange). Image width is 185 km with a pixel ground resolution of 30 meters (resampled from 100 meters). North is straight up.

Shadow Detection and Mitigation in Satellite Imagery

Principal Investigator: Emmett Ientilucci

Team: Mike Gartley, Tolga Furkan Aktas

Project Description

Shadows are present in a wide range of aerial images from forested scenes to urban environments. The presence of shadows degrades the performance of computer vision algorithms in a diverse set of applications, for example. Therefore, detection and mitigation of shadows is of paramount importance and can significantly improve the performance of computer vision algorithms. This work assumes as input a multispectral image and co-registered cloud shadow maps which are used to calculate shadowed pixel spectral statistics and adjusting to match the statistics of spectrally similar sunlit pixels resulting in a shadow mitigated multispectral image. ORNL also seeks to advance machine learning (ML) approaches to in-paint these cloud shadows.

Project Status

We have further developed our imaging processing shadow mitigation algorithm. We present an image processing techniques for brightening the content within cloud shadows to improve both visualization and algorithm performance. The approach assumes that both a cloud and a cloud shadow mask is available and accurate. Using these masks, we estimate the sunlit brightness of materials within a scene that are either spectrally and/or spatially close to materials within the shadowed regions and brighten each individual shadow accordingly while maintaining spatial detail. We assessed the shadow mitigation performance using a directional gradient metric across each cloud shadow edge and subsequently determined specific algorithm configurations that are better suited for specific scene content. At the same time, we are exploring the use of machine learning approaches to shadow mitigation through exploration of shadow transformers.

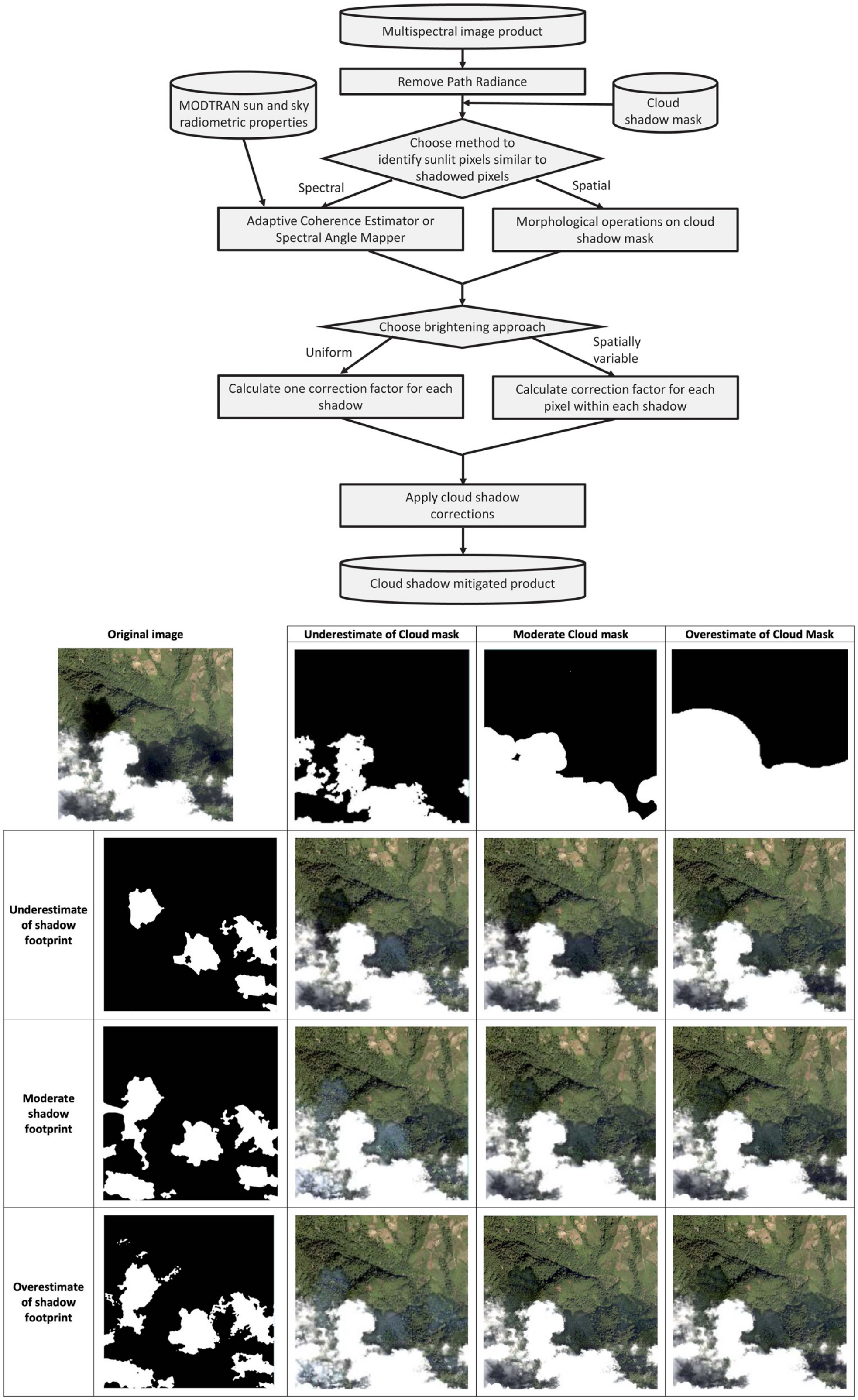


Figure 1: (top) Cloud shadow mitigation algorithm flow diagram and (bottom) images demonstrating how cloud and shadow mask size influence algorithm output. Overestimating the size of both the cloud and shadow masks yielded best shadow mitigation results as seen in the bottom right.

EO / SAR Data Fusion

Principal Investigator: Emmett Ientilucci

Team: Mike Gartley, Matt Murphy

Project Description

Most fusion of EO and SAR imagery has been of data collected on different platforms and at different times. RIT can collect EO and SAR data at nearly the same time over the same landscape area with both platforms covering the same position in space. RIT will develop algorithms for fusing SAR and EO data for the case in which both the scene positions and the sensor positions nearly coincide or overlap. We are also looking into more quantitative evidence of algorithm performance using developed quantitative metrics.

Project Status

The team continues to study data collected from the Fairport, NY Fall and spring collections. To detect buildings using the collected SAR imagery, a technique using constant false alarm rate (CFAR) for the original SAR imagery combined with similar processing for the SAR CCD products is being employed. Examples of CFAR outputs from the team's CFAR algorithm are shown in the accompanying figure. The morphology outputs shown on the bottom row of the figure, will be combined with the processed SAR CCD products to produce an enhanced SAR building detection algorithm. The outputs of this algorithm will then be combined with optical building detection outputs to remove false alarms and present an enhanced SAR-optical fused building detection tool.

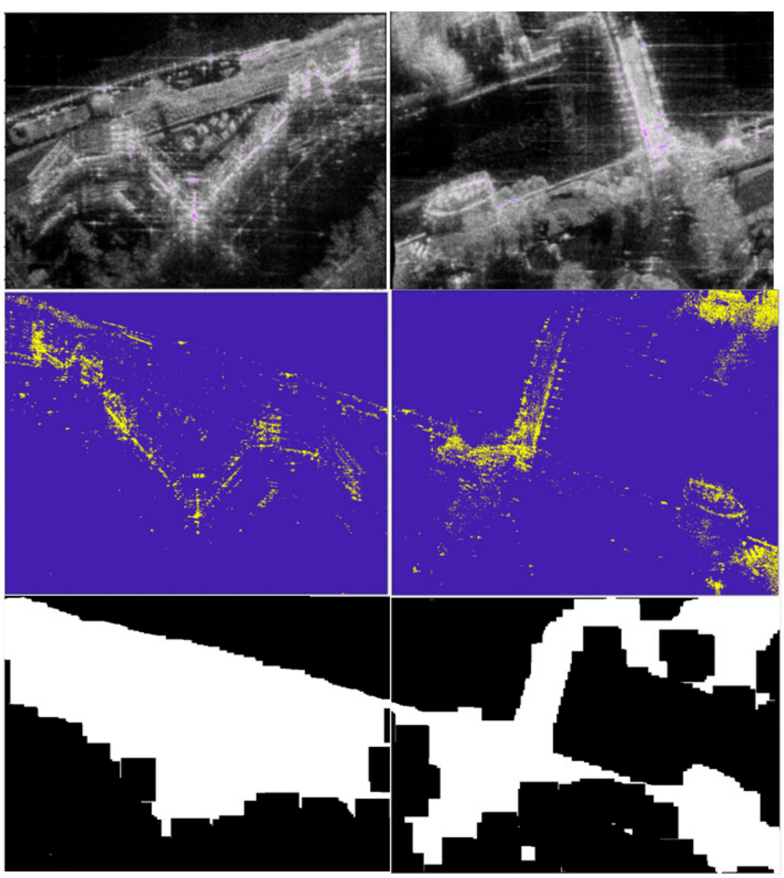


Figure 1: Left and right show two different SAR image examples and algorithm steps (top is original SAR image in log scale, middle is CFAR detections output binary image, bottom is output from image morphology).

Segmenting Smoke Plume from Background Clutter in Video Imagery using Machine Learning Tools

Principal Investigator: Emmett Ientilucci and Susmita Ghosh

Team: Xuesong Liu, Abhishek Dey, Aloke Datta

External Collaborators: Western New York IEEE GRSS Chapter and the GRSS Kolkata, India Chapter

Project Description

This is a collaborative project between the Western New York IEEE GRSS Chpater and the GRSS Kolkata, India Chapter. It is funded through an initiate called ProjNET with facilitate networking between global GRSS chapters. The objective of this project is to segment smoke plumes in video data captured from a remote sensing drone platform and/or ground-level video cameras from surrounding background clutter (i.e., trees, rock, road, etc.). Modern machine learning techniques will be used for this task. The ultimate objective would be to perform this task in real time using video cameras.

Project Status

Our latest algorithm to segmentation involves a region growing-based mask generation process and classification using deep features. At first, ground truth masks are generated from smoke plume images using an unsupervised approach. This is achieved through thresholding and a series of morphological operations such as connected component extraction and an active contour region growing algorithm. In the next step, a pre-trained deep neural net namely, VGG16 is used to extract deep features from the images. This is followed by Random Forest classification for smoke plume detection. The performance of the proposed model, unlike the existing literature, has been investigated with real-time smoke data sets. Comparative analysis is done in terms of evaluation metrics like accuracy, precision, recall, Intersection-Over-Union and F1-Score. Results of segmentation using the proposed method have been compared with another deep learning model U-Net, which is used for both feature extraction from smoke plume images and subsequently classification. Qualitative and quantitative analysis of results shows that the proposed model, unlike U-Net, can detect smoke plumes with high accuracy even with a small number of images used for training. Hence, the proposed method is robust as it can produce good results when the number of labelled images is scarce.

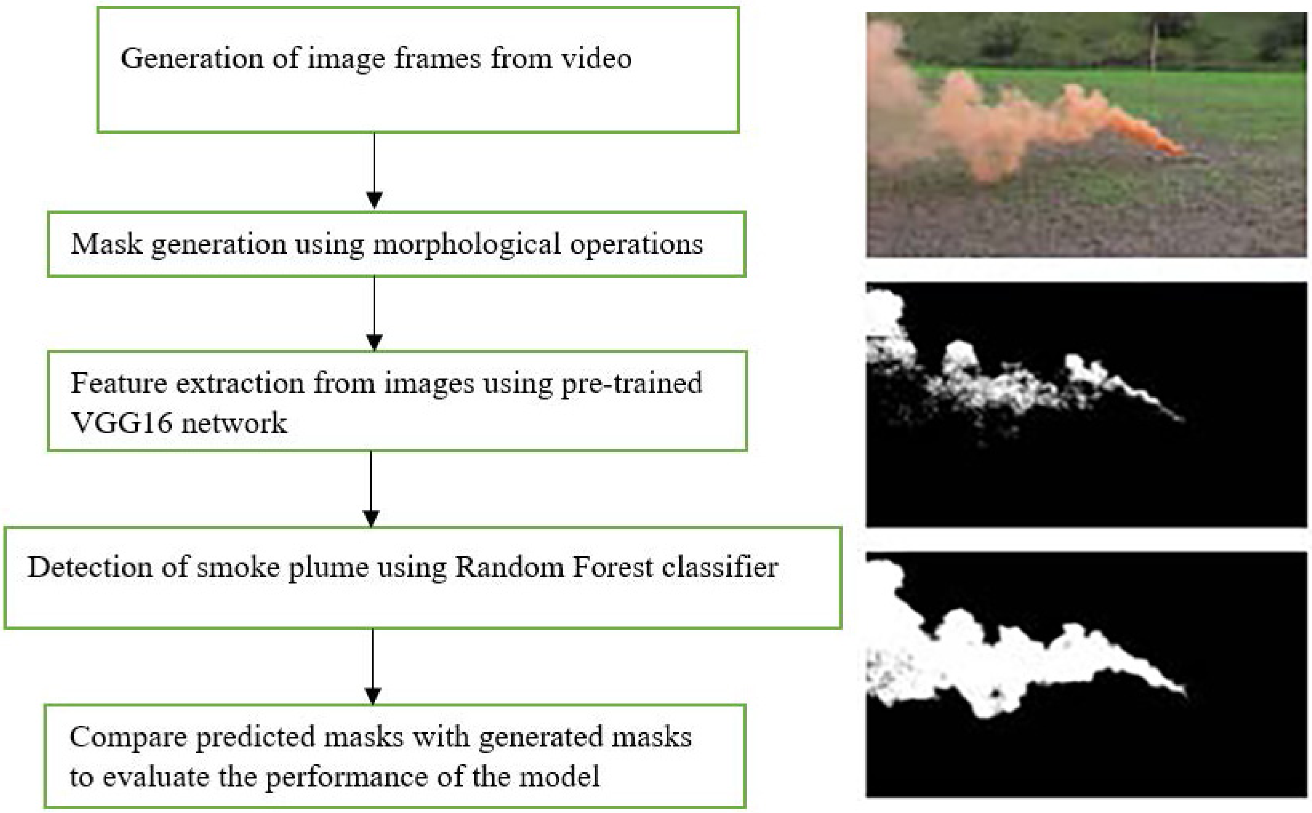


Figure 1: (left) Block diagram of the proposed workflow highlighting the overall testing and evaluation methodology used to assess our algorithm's performance and (right) test image results.

Table 1 Comparative performance obtained using U-Net and the proposed model for testimage1 with varying number of images (N) used for training

N	U-Net							Proposed Model						
	OA	**PR**	**RE**	**IoU**	**F1-score**	**AUC_ROC**	**AUC_PR**	**OA**	**PR**	**RE**	**IoU**	**F1-score**	**AUC_ROC**	**AUC_PR**
50	90.25%	0.56	0.04	0.04	0.08	0.52	0.35	**97.91%**	**0.88**	**0.92**	**0.81**	**0.90**	**0.95**	**0.90**
100	91.20%	0.70	0.19	0.17	0.29	0.59	0.49	**98.17%**	**0.90**	**0.92**	**0.83**	**0.91**	**0.95**	**0.91**
150	96.81%	0.77	**0.97**	0.75	0.86	**0.96**	0.87	**98.24%**	**0.90**	0.93	**0.84**	**0.91**	**0.96**	**0.92**
200	97.02%	0.78	**0.97**	0.76	0.87	**0.97**	0.88	**98.14%**	**0.89**	0.92	**0.83**	**0.91**	0.95	**0.91**

Table 2 Comparative performance obtained using U-Net and the proposed model for testimage2 with varying number of images (N) used for training

N	U-Net							Proposed Model						
	OA	**PR**	**RE**	**IoU**	**F1-score**	**AUC_ROC**	**AUC_PR**	**OA**	**PR**	**RE**	**IoU**	**F1-score**	**AUC_ROC**	**AUC_PR**
50	92.67%	0.65	0.11	0.10	0.18	0.56	0.41	**98.46%**	**0.89**	**0.91**	**0.82**	**0.90**	**0.95**	**0.90**
100	93.65%	0.73	0.27	0.25	0.40	0.63	0.53	**98.40%**	**0.88**	**0.91**	**0.81**	**0.90**	**0.95**	**0.90**
150	98.11%	0.82	**0.96**	0.80	0.89	**0.97**	0.89	**98.61%**	**0.91**	0.91	**0.83**	**0.91**	0.95	**0.91**
200	97.77%	0.79	**0.96**	0.77	0.87	**0.97**	0.88	**98.58%**	**0.91**	0.91	**0.83**	**0.91**	0.95	**0.91**

Figure 2: (top) Comparative performance obtained using U-Net and the proposed model for an orange smoke image in a field and (bottom) smoke plume coming from a truck, with varying number of images (N) used for training.

Spatial Resolution of Hyperspectral Imagery for Improved Exploitation

Principal Investigator: David Messinger

Team: Sihan Huang, Rey Ducay, Mike Gartley

Project Description

The remote sensing community has a long history of developing methods to fuse the high spatial resolution information from panchromatic sensors with the spectrally diverse information, but generally of lower spatial resolution, from spectral sensors. This process is referred to as either panchromatic sharpening or spatial resolution enhancement. However, these methods have typically had as their primary motivation the creation of color imagery of high visual quality for visual interpretation. These methods do not in general seek to preserve the quantitative spectral information in the data and can sacrifice the radiometric fidelity of the spectral sensor. Several approaches exist and have been used to produce high resolution color imagery, however empirical evidence indicates that algorithmic performance is dependent on scene and sensor characteristics. This project investigates the area of spectrally accurate spatial resolution enhancement of hyperspectral imagery, with a goal of ensuring good performance from spectral exploitation algorithms such as target detection.

This research project seeks to address the challenging problem of sharpening remotely sensed hyperspectral imagery with higher resolution multispectral or panchromatic imagery, with a focus on maintaining the radiometric accuracy of the resulting sharpened imagery. Traditional spectral sharpening methods focus on producing results with visually accurate color reproduction, without regard for overall radiometric accuracy. This is done primarily to support exploitation through visual interpretation. However, hyperspectral imagery (HSI) is not exploited through purely visual means. Instead, HSI is processed through (semi-) automated workflows to produce various resulting products. Tasks of interest include material classification and identification, anomaly detection, and target detection. For many of these applications, individual pixel spectra are compared against either other in-scene spectral signatures, or library signatures. Consequently, maintaining radiometric accuracy is a key goal of spatial resolution enhancement of hyperspectral imagery. Here, our focus will be in characterizing the issues related to accurate sharpening, and in particular understanding how the scene spatial - spectral content and complexity impact the ability to sharpen a particular image, or portion of an image. We also present results from a novel algorithm developed to address part of the problem: sharpening of Vis-NIR HSI (400 \nm - 1000 \nm) with multispectral imagery. Our assessment metrics are based on per-pixel signatures and the quantitative results of algorithmic performance, in particular target detection. Novel algorithms for sharpening Vis-NIR-SWIR HSI with multispectral imagery, based on an Unsupervised Cascade Fusion Network have been developed, as well as approaches that leverage knowledge of the scene spatial content into the sharpening processes.

Project Status

This year was the fourth out of five years of funding for this project. To date, the project has funded two Ph.D. students, Dr. Sihan Huang, who defended in the summer of 2022, and Rey Ducay, who is anticipated to complete his degree in the fall of 2023. The fifth year of funding has already been approved and we will be continuing this work, focusing on fusing and sharpening hyperspectral imagery from two hyperspectral sensors, one a Vis-NIR imager and the other a SWIR imagers, flown on separate platforms and collecting data at two different resolutions. Again, the focus will be on maintaining the radiometry as well as possible. We are also using DIRSIG to perform system level trade studies on how limitations in point accuracy, and other system errors, affect our ability to fuse and sharpen these data sets.

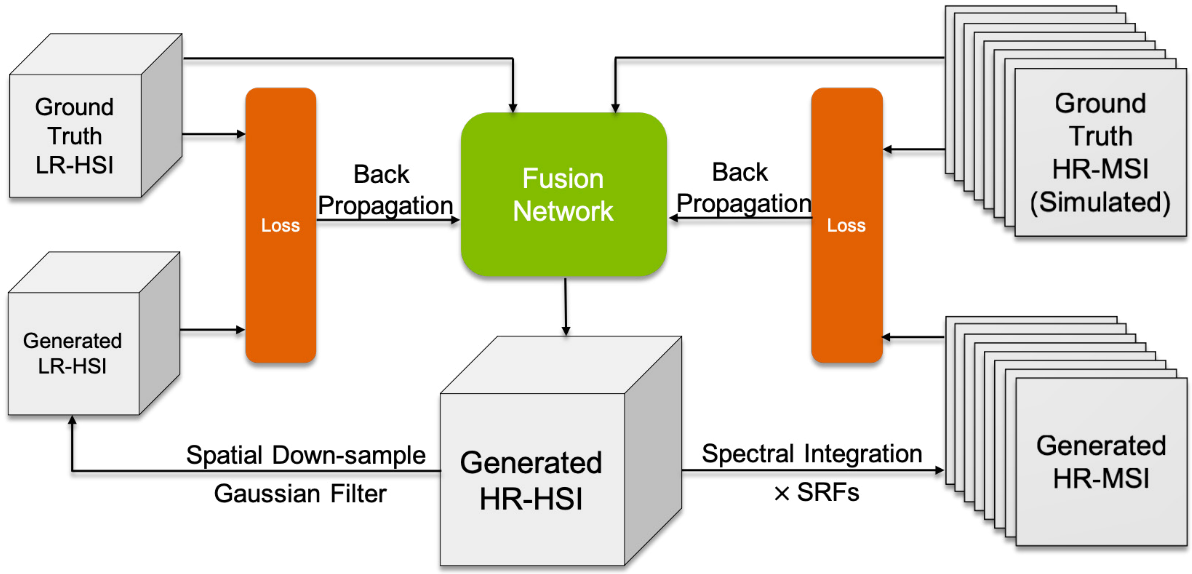


Figure 1: The Unsupervised Cascade Fusion Network developed for sharpening Vis-NIR-SWIR hyper- spectral imagery.

High Resolution Vineyard Nutrition Management

Principal Investigator: Jan van Aardt

Team: Dr. Rob Chancia, Tim Bauch, Nina Raqueno, Mohammad Shahriar Saif

External Collaborators: Terry Bates (Cornell U.), Justine Vanden Heuvel (Cornell U.), Manushi Trivedi (Cornell U.)

Project Description

The USA annual grape production value exceeds $6 billion across as many as 1 million acres (>400,000 ha). Grapevines require both macro- and micro-nutrients for growth and fruit production. However, inappropriate application of fertilizers to meet these nutrient requirements could result in widespread eutrophication through excessive nitrogen and phosphorous runoff, while inadequate fertilization could lead to reduced grape quantity and quality. It is in this optimization context that unmanned aerial systems (UAS) have come to the fore as an efficient method to acquire and map field-level data for precision nutrient applications. We are working in coordination with viticulture and imaging teams across the country to develop new vineyard nutrition guidelines, sensor technology, and tools that will empower grape growers to make timely, data-driven management decisions that consider inherent vineyard variability and are tailored to the intended end-use of the grapes. Our primary goal on the sensors and engineering team is to develop non-destructive, near-real-time tools to measure grapevine nutrient status in vineyards. The RIT drone team is capturing hyper and multispectral imagery over both Concord (juice/jelly) and multiple wine variety vineyards in upstate New York.

Project Status

We are continuing UAS-based hyperspectral (400-2500 nm, Headwall Nano & SWIR) and five-band VNIR (MicaSense) image acquisitions at our primary site in Portland, NY, for the 2023 project year. All imagery was captured in coordination with field leaf sampling studies, conducted by Dr. Terry Bates at the Cornell Lake Erie Extension Laboratory (CLEREL). This year, the team is collecting additional samples in the large CLEREL Railroad block (see Figure 1) that has been used as a testing ground for our remote sensing based nutrient models. This year, we've also obtained Planet Labs Dove and/or SuperDove 3-meter resolution multiband satellite imagery for all previous nutrient sample dates and will continue for sampling dates in 2023. We also collected our first data with the DJI Mavic 3M, a drone with native 4-band multispectral capability. In June 2023, we presented a performance comparison of satellite, drone, and proximal multispectral sensing data for nutrient status assessment to the American Society for Enology and Viticulture that received much interest from the viticulture community. We've developed streamlined procedures for structuring satellite and drone imagery into modeled nutrient prediction point data for integration with a cloud-based GIS application specific to vineyard monitoring called myEfficientVineyard (myEV tool: my.efficientvineyard.com). While only drone imagery allows for the precise isolation of vineyard canopy pixels to develop the most accurate nutrient models, small satellite constellation imagery offers what is likely the most cost-effective and adoptable solution to mapping relative vineyard nutrition.

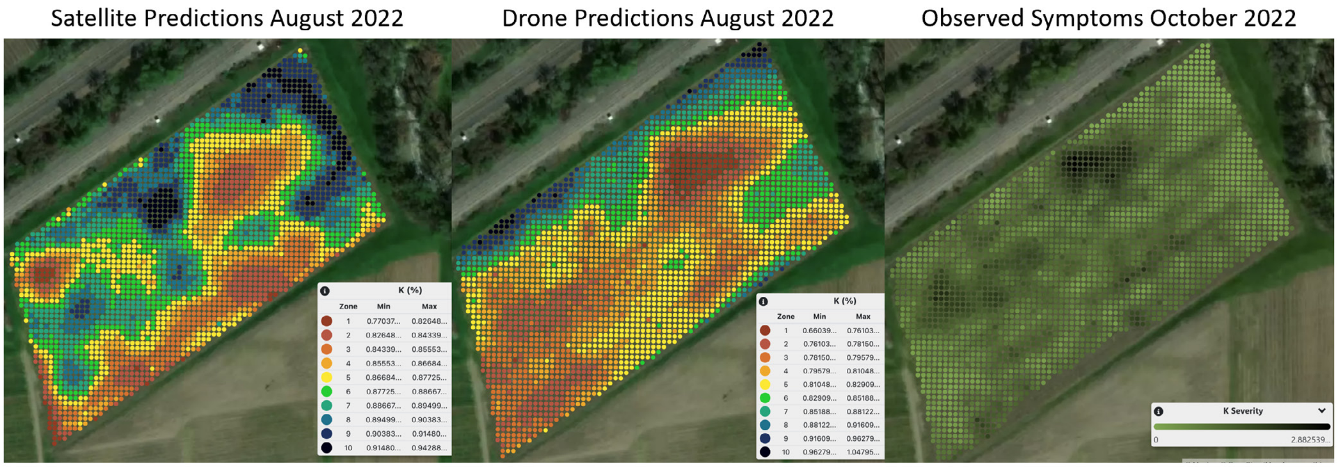


Figure 1: We applied our multispectral potassium status models to imagery of a 3-hectare concord vineyard block (CLEREL Railroad block), unseen during model development. Shown are the model predictions displayed in myEV for Planet Labs 4-band (B, G, R, NIR) satellite imagery (left) alongside MicaSense 5-band (B, G, R, RE, NIR) drone-based imagery (center), both taken in August of 2022. Finally, at the right we've mapped the vineyard manager's observations of potassium deficiency symptoms (blackleaf) that developed in October 2022.

International Research Malaysia

Principal Investigators: Anthony Vodacek

Team: Joe Casale, Josie Clapp, Katelynn Carlson, Greg Herdzik, Lilly Rowland, Kamron Gonzales

External Collaborators: Badli Esham Ahmad, Muhammad Fuad Abdullah, and Zulklifee Abd Latif, Universiti Teknologi MARA, Malaysia (UiTM)

Project Description

Vodacek led an international research experience for RIT undergraduate students to Malaysia. This collaboration with UiTM took the six students to the rainforest of the Taman Negara National Park in the center of peninsular Malaysia and the UiTM research station. Microphone clusters were placed at several sites near the research station to use the audio data to assess the characteristics of the biodiversity at each site. Four days of acoustic monitoring data were obtained and the students explored concepts in audio monitoring and various machine learning methods for automated analysis.

Project Status

The research experience took place at the end of the spring semester. Data collected during the project is being used for developing sound classification, localization, and counting using machine learning techniques.

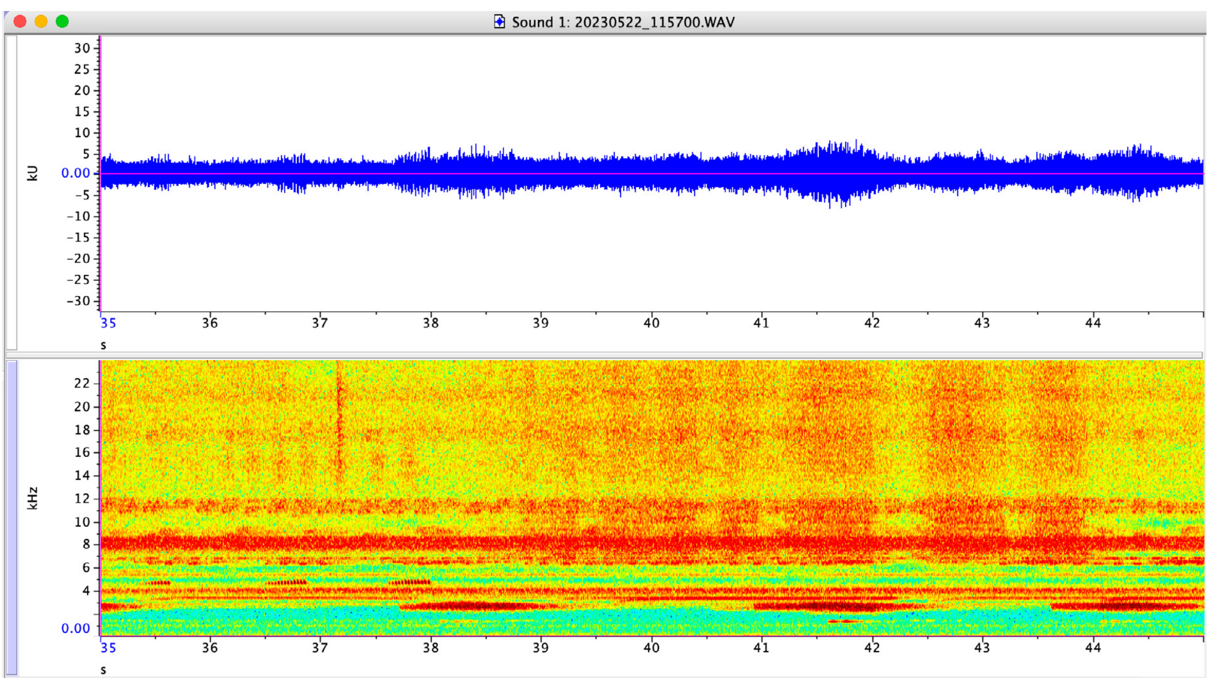


Figure 1:Waveform (top) and spectrogram (bottom) of one 10 s recording, illustrating the complex overlapping acoustic signals present in the Malaysian rainforest.

Figure 2: Team members at the UiTM research station in Taman Negara National Park.

Partnership for Skills in Applied Sciences, Engineering and Technology

Co-Principal Investigator: Anthony Vodacek

External Collaborators: Emmanuel Ndashimye (PI) and Damien Hanyurwimfura (Co-PI), University of Rwanda

Project Description

Agricultural Data from Acoustic Monitoring (ADAM). The aim of this project is to investigate the use of passive acoustic sensors for monitoring agricultural phenomena and activities that produce sound. Some examples of phenomena and activities related to agricultural production that have an associated sound include farm animals, rain, plants moving in the wind, flowing water, machinery, people, and pest animals, insects, and birds. All of these processes can impact agricultural production and value-added activities over the 24 hours of the day and across the whole area of a farm. Farmers do not have the ability to monitor all these processes in person, but a low-cost network of acoustic sensors might give the farmer the ability to collect and analyze sound information about their farm, even when no one is there to hear.

Project Status

The first year of work on this project has taken two directions. First, a survey of farmers in Bugasera District, Rwanda was performed to assess the farmers' perceptions of the acoustic environment and the application of technological solutions to their major problems. One major finding is the ability to monitor various animal pests is the main concern of the farmers, with a clear consensus that birds are the most important pest. This is encouraging because of the obvious capacity to monitor the presence of birds via sound, which can then trigger some action to scare the birds away. A second major finding is the strong majority of farmers would like to receive an alert to the presence of pests via a simple SMS text. The second research direction is to seek effective algorithms for classifying sounds at the edge, e.g., in an environment with low computational resources. Preliminary work in this area used acoustic data collected from farms in Bugasera District and has been successful in applying the open source LightGBM framework to processing the acoustic data and extract bird calls.

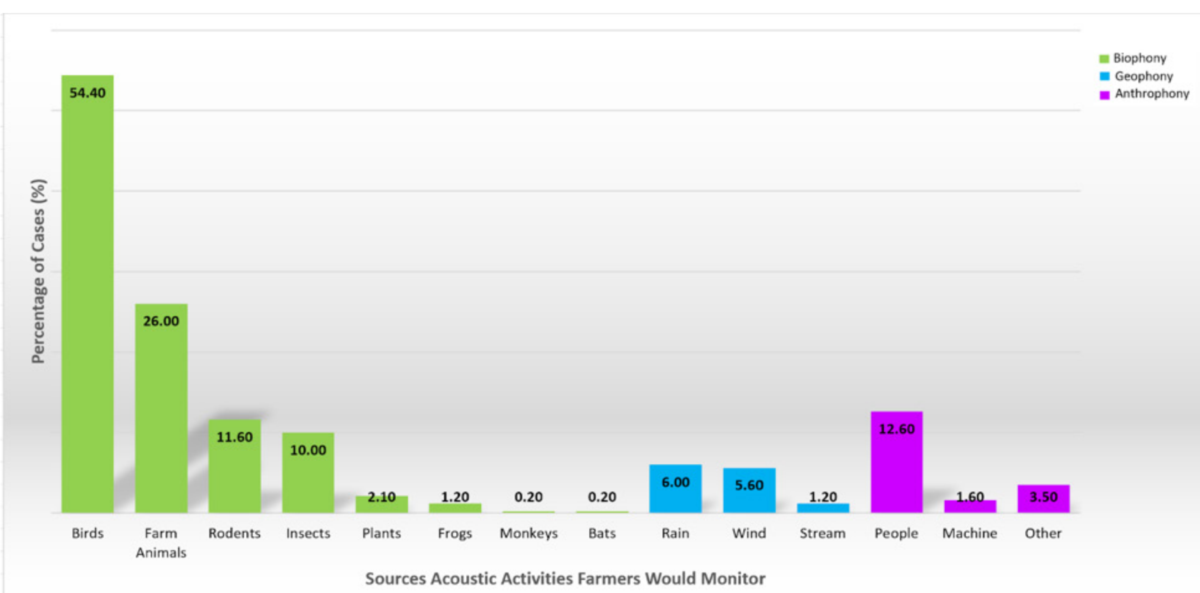


Figure 1: Percentage distribution of specific acoustic sources farmers would like to monitor if they had access to a listening technology. Farmers could list more than one source so the total percentage of cases sums to more than 100.

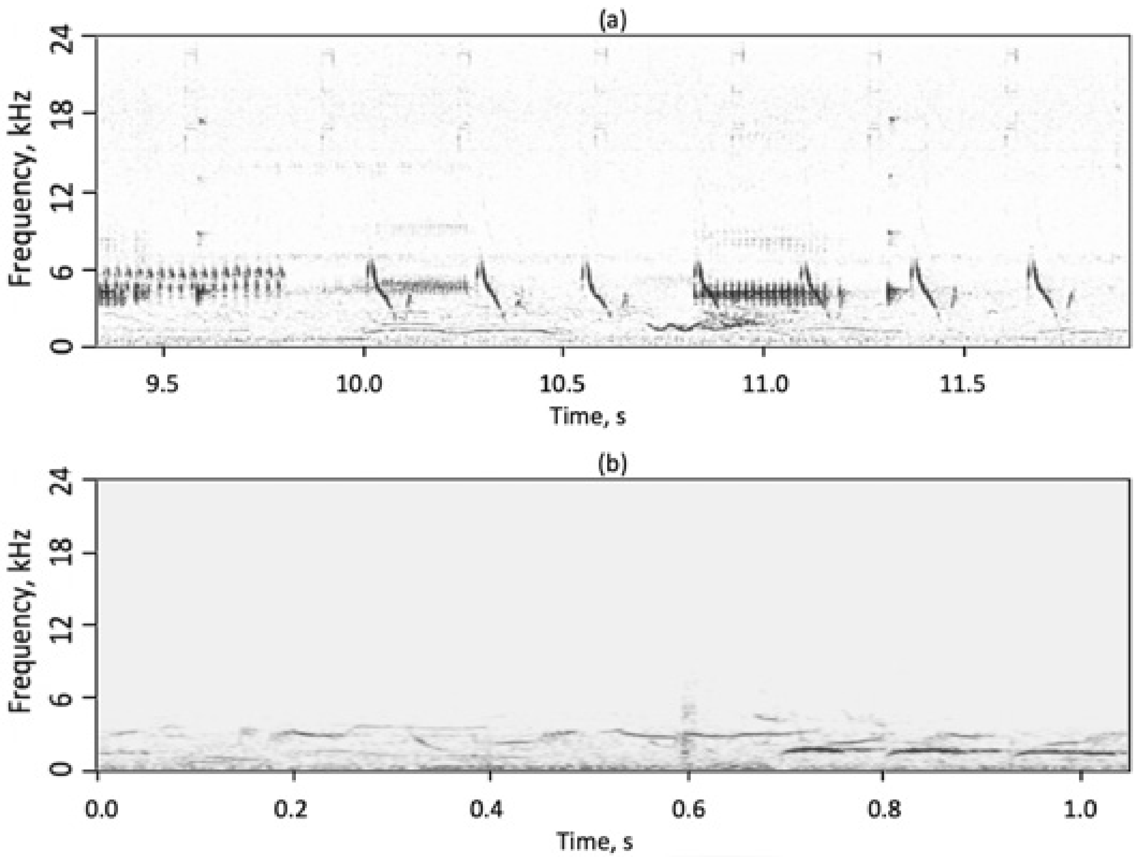


Figure 2: Audio spectrogram of a nightingale, and (b) audio spectrogram of a mousebird collected in the field using an open source AudioMoth microphone. These two birds were identified by local farmers as pests eating crops nearing maturity.

NSF PFI FARMS (Fostering Agricultural ReMote Sensing Alliance) Part II

Principal Investigator: Jan van Aardt

Team: Carl Salvaggio, Amir Hassanzadeh, Fei Zhang

External Collaborators: Sarah Pethybridge, Cornell University

Project Description

We established an academic/industrial innovation ecosystem, called the Fostering Agricultural ReMote Sensing Alliance, or FARMS Alliance, around the technology and data analytics of remote sensing from unmanned aircraft systems (UAS), with precision agriculture (PA) as the targeted application area. We focus on a proxy crop, snap bean, and three proxy applications prioritized by our industry partners as key to their commercial efforts, namely disease risk modeling, harvest timing/scheduling, and yield prediction to propel FARMS into a sustainable innovation ecosystem. This section, Part II, focuses on addressing to above-mentioned topics via LiDAR and structure-from-motion (SfM) UAS-based 3D sensing.

Our premise is that UAS-based tools can be used to meet the farmers' need for enhancing crop productivity and yield. By utilizing imaging sensors carried by drone, we are extracting structure information of the crops from the 3D points cloud created by SfM of multispectral images and by LiDAR, and then develop effective models to evaluate the yield or the disease risk. Our objectives are to i) assess the utility of UAS-based LiDAR and SfM point clouds to accurately map digital elevation models and crop height models of snap bean; ii)) evaluate structural traits (e.g., leaf area index; LAI) of snap beans using the two types of point clouds; and iii) determine the efficacy of LiDAR and SfM-based point clouds and structural metrics to accurately model disease risk and crop yield for snap beans.

Project Status

We have compared SfM and LiDAR point clouds across multiple evaluation criteria, and have evaluated LAI of snap beans using UAS-based LiDAR point clouds and multispectral imagery (see Figures 1-3). We are extracting key structural features of the snap beans for disease risk modelling and yield prediction and building models to evaluate yield and disease risk of the snap beans. We have published two papers in the last two years and are working on two more papers related to the project objectives:

- Zhang, F., Hassanzadeh, A., Kikkert, J., Pethybridge, S. J., & van Aardt, J. (2021). Comparison of UAS-Based Structure-from-Motion and LiDAR for Structural Characterization of Short Broadacre Crops. Remote Sensing, 13(19), 3975
- Zhang, F., Hassanzadeh, A., Kikkert, J., Pethybridge, S.J. and van Aardt, J., 2022. Evaluation of Leaf Area Index (LAI) of Broadacre Crops Using UAS-Based LiDAR Point Clouds and Multispectral Imagery. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 15, pp.4027-4044.

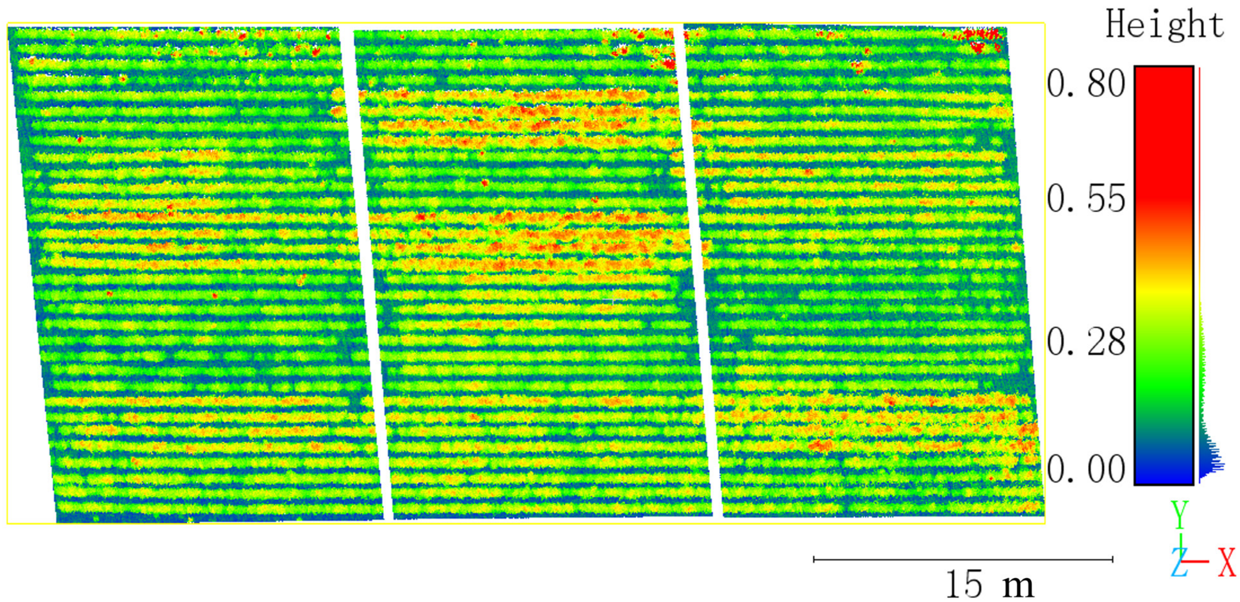


Figure 1: A crop height model generated from the LiDAR point cloud of a snap beans field.

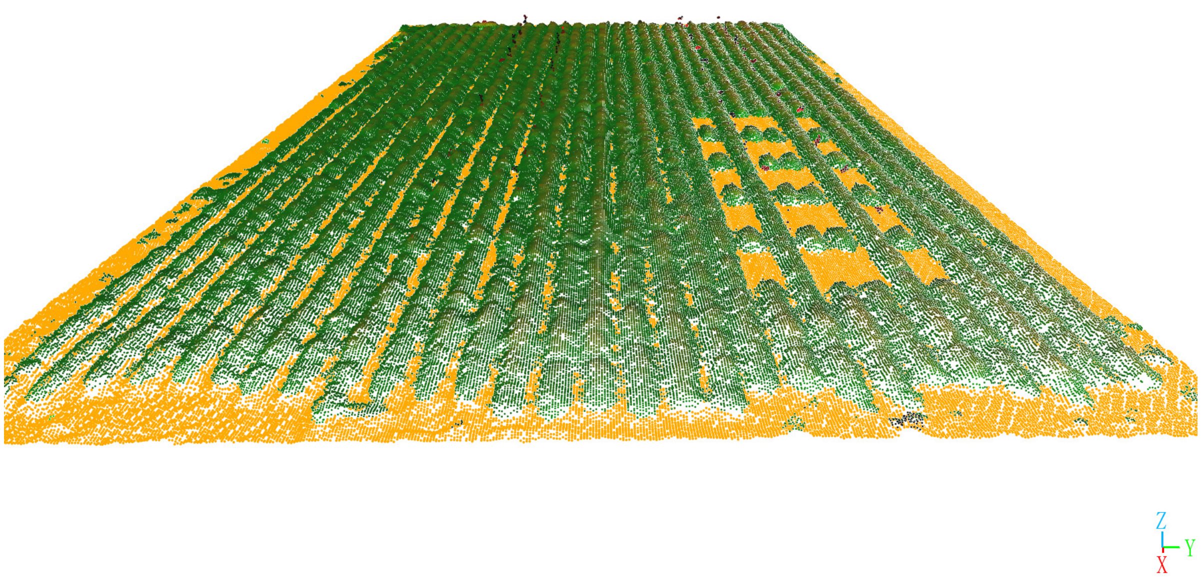


Figure 2: Filtering result of a SfM point cloud of a snap beans field

Terrestrial Laser Scanning for Structural Assessment of Complex Forest Environments

Principal Investigators: Jan van Aardt

Team: Dr. Rob Chancia, Dr. Ali Rouzbeh Kargar

External Collaborators: Dr. Richard Mackenzie (USFS)

Project Description

Mangrove forests attempt to maintain their forest floor elevation through root growth, sedimentation, resistance to soil compaction, and peat development in response to sea level rise. Human activities, such as altered hydrology, sedimentation rates, and deforestation, can hinder these natural processes. As a result, there have been increased efforts to monitor surface elevation change in mangrove forests. Terrestrial lidar system (TLS) data were collected from mangrove forests in Micronesia in 2017 and 2019, using the Compact Biomass Lidar (CBL), developed by scientists at the University of Massachusetts (Boston) and RIT. Sediment accretion was assessed using the lidar data, using Cloth Simulation Filtering (CSF), followed by filtering the points based on angular orientation, which improved the performance of the ground detection. The elevation change between the two years was found by subtracting the Z (height) values of the nearest points, detected using a nearest neighbor search. Extreme elevation changes, attributed to human interactions or fallen logs, were removed using interquartile range analysis. The consistency of TLS-measured elevation changes in comparison to the field-measured ones was found to be 72%, with standard error values being 10-70x lower.

Project Status

Our TLS surface elevation table (SET) assessment python-based GUI has been vetted across PC and Mac platforms. The code is now robust to automatically calculate surface elevation changes (SEC) using temporal pairs of raw TLS datasets at 21 different SET sites in Pohnpei, Federated States of Micronesia (FSM). This is in comparison to the base method's tedious manual processing and calculation of SEC for eight SET sites (early publication - Kargar et al. 2021). We began development of an iPad/iPhone-based LiDAR approach (Figure 1) to take advantage of recent advances in common consumer electronic devices and to simplify the SET data gathering procedure. A modified SET arm and rotation stage have been purchased and tested in the laboratory environment. In June 2023, we will test the iPad LiDAR scanning in conjunction with the proven TLS method at SETs in Cape Cod, MA with the National Parks Service (NPS). This will help in developing a procedure before deploying both sensors in Palau, FSM later in the year. This test will also benefit collaborators at the NPS interested in the applicability of the LiDAR-based SEC method in locations with obstructive ground vegetation.

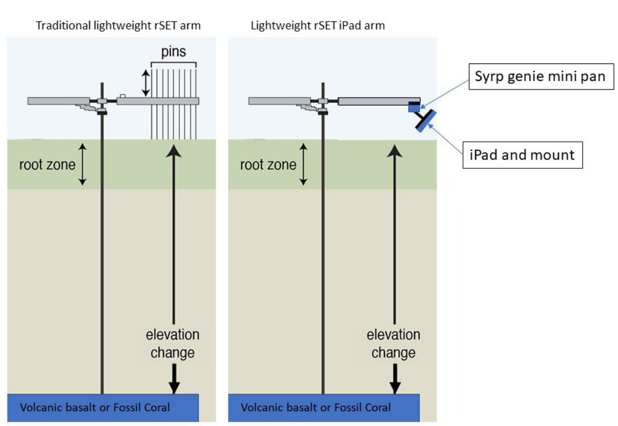


Figure1: Traditional SET arm vs. proposed iPad/iPhone LiDAR SET arm for SEC measurements. The iPad is attached to an app-controlled motorized panning device.

DIRS Enterprise Center

The DIRS laboratory, with deep expertise in drones, imaging and remote sensing technology has been offering its services to the public since late 2019. Through the Digital Imaging and Remote Sensing (DIRS) Enterprise Center, customers can now hire faculty and staff from our Lab to provide training, consulting, data collection, equipment calibration and more. The DIRS Enterprise Center is one of many RIT Enterprise Centers offering fee-for-service as a vendor. We are excited to work with new collaborators outside of academia and expect to support a wide range of industries as we continue to attract new customers and provide high-quality data and services.

DIRS EC By the Numbers (RIT FY23):

30

Total number of quotes submitted.

16

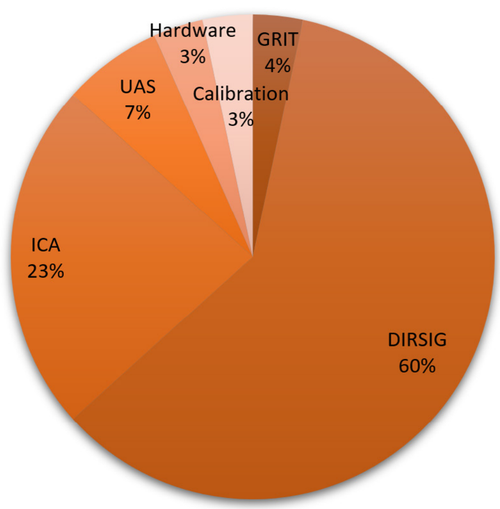
Total number of signed agreements with fee for service provided.

$282K

The value of Competitive quotes submitted.

$773K

The value of Sole Source quotes.



The full list of services the DIRS Enterprise Center offers includes:

DIRSIG Synthetic Image Generation Services

UAS / Drone Collection Services

GRIT - Material Directional Reflectance Measurement Services

Ground Reference - Field Material Measurement Services

Spectro-Radiometric Calibration Laboratory Services

Ground Based LiDAR Measurement Services

Geometric Calibration Laboratory Services

General Image Chain Analysis and Systems Engineering Services

People

The following represents and describes each of our talented list of faculty members, staff, and students. The time and effort from our members allows for the team to be sucessful in our research.

Faculty & Staff

Carl Salvaggio

Director of the Digital Imaging and Remote Sensing Laboratory and Full Professor of Imaging Science, Carl received his Bachelors and Masters degrees in Imaging Science from the Rochester Institute of Technology in 1987 and his Ph.D. in Environmental Resource Engineering from the SUNY College of Environmental Science and Forestry in 1994. Carl teaches and conducts research in image processing, computer vision, remote sensing, and programming. His research interests address the development of solutions to applied, real-world, problems utilizing the appropriate imaging modalities and algorithmic approaches. Carl's expertise are in thermal infrared phenomenology, exploitation, and simulation; design and implementation of novel imaging and ground-based measurement systems; three-dimensional geometry extraction from multi-view imagery; material optical properties measurement and modeling; radiometric and geometric calibration of imaging systems; and still and motion image processing for various applications.

Joesph Sirianni

Associate Director of the Digital Imaging and Remote Sensing Laboratory, Joe received his Bachelors (1992) and Masters (1994) degrees in Imaging Science from the Rochester Institute of Technology. During his 25-year career in the aerospace and defense industry Joe conducted research in image processing algorithms, software development and remote sensing and was a program and business development manager. Joe's continued interest in all-things imaging science, remote sensing and business development drive is a perfect combination for his current role with responsibilities in program management and business development for discovering new sponsored research opportunities for graduate students and research staff.

Jamie Albano

James received his B.S. (2008) and Ph.D. (2014) degrees in Imaging Science from Rochester Institute of Technology. After graduate school, James spent time working in air and missile defense at several locations including MIT Lincoln Laboratory, General Dynamics Mission Systems, and BAE Systems where he primarily focused on the development of advanced radar signal processing algorithms for detection, tracking and identification of air- and space-borne threats. In 2022, he took a position at the Digital Imaging and Remote Sensing Laboratory as a Research Scientist where he is currently researching several areas of radar signal processing including synthetic aperture radar (SAR) image formation processing, SAR automatic target recognition (ATR), moving target indication (MTI), space-time adaptive processing (STAP), multistatic radar signal processing, and multimodal sensor fusion. He currently teaches a special topics course on SAR image formation processing that is offered in the Fall semester.

Chip Bachmann

He received the A.B. degree in Physics from Princeton University, in 1984, and the Sc.M. and Ph.D. degrees in Physics from Brown University in 1986 and 1990, respectively. After a 23-year career at the U.S. Naval Research Laboratory in Washington, DC, Chip joined the RIT Chester F. Carlson Center for Imaging Science faculty as the Frederick and Anna B. Wiedman Chair. Since 2016, he has also served as CIS Graduate Program Coordinator. He holds two U.S. Patents for methods of analysis related to hyperspectral remote sensing imagery. His research interests include hyperspectral and multi-sensor remote sensing applications in coastal and desert environments, BRDF and radiative transfer modeling for retrieval of geophysical and biophysical parameters, field calibration and validation, and the development of advanced instrumentation (goniometers and more recently a mast-mounted hyperspectral video system), as well as abstract models for interpreting hyperspectral and multi-sensor imagery based on manifold descriptions and graph theory.

Tim Bauch

Research Engineer I and sUAS Pilot for the Digital Imaging and Remote Sensing Laboratory, Tim received his Associates degree in Optical Systems Technology from Monroe Community College in 2015 and his Bachelors degree in Imaging Science from Rochester Institute of Technology in 2017. Tim received his Part 107 FAA Pilots license for sUAS Commercial Operations in January 2018. He has performed over 600 flights since that time for many different research projects. His research interests involve using drone technology to solve real world problems to areas such as precision agriculture, infrastructure, environmental science and remote sensing algorithm development. In addition, he has interests in system integration and design for both ground based and UAS Imaging systems. Tim also loves to help and instruct students and is teaching the Freshman Imaging Project in the Chester F. Carlson Center for Imaging Science.

Brian Benner

Coordinator of Admin Lab Operations, Brian received his Bachelor's degree in Mechanical Engineering from Rochester Institute of Technology in 2014. After spending some time in industry, he joined the Chester F. Carlson Center for Imaging Science last year, helping with facilities management, lab safety, swipe/key access, and managing the department's stock room. He received his Part 107 FAA Pilots license for sUAS Commercial Operations in July 2023 and will be starting graduate level courses in the fall.

Karen Braun

Karen is the Associate Director for the Center for Imaging Science, where she received her PhD in 1996. In the meantime, she was a color scientist and area manager at Xerox for 20 years, volunteering with the Xerox Science Consultant Program, FIRST Lego League, and United Way Day of Caring. She received the Rochester Business Journal's Forty Under 40 award. Karen has also received the Golden Brick Award, and the Guiding Star Award.

Scott Brown

Head of the Modeling and Simulation group within the Digital Imaging and Remote Sensing Lab. This group focuses on the modeling of airborne and space-based passive and active EO/IR imaging systems. Scott's specific expertise is the mentoring of student and staff re-search projects and the implementation and integration of complex radiation propagation codes. Since 1994, he has been the lead for the physics-driven image and data simulation model called DIRSIG. This model is elaborate software architecture for radiation propagation across the EO/IR region. The capabilities of the model range from passive temperature calculations to active time-gated, LIDAR predictions. The model consists of nearly a million lines of C++ and is externally distributed to government organizations and contractors. Scott routinely conducts on- and off-site training courses that are attended by the professional community regarding the use of the remote sensing modeling and simulation tools developed at RIT and general remote sensing system design and phenomenology.

Keisha Burton

Senior Analyst, with 25 years of experience in accounting including 10 years in higher education. She earned a Master's in Business Administration from Medaille College in 2012. Keisha joined the Center for Imaging Science in July 2021 providing financial forecasts, budgeting, reporting, best-practice advice and managing the Center's sponsored research grants and contracts to support our faculty and staff.

David Conran

Research/Engineering Support in the Digital Imaging and Remote Sensing Laboratory, David received his B.Sc. degree in Astrophysics and Astronomy with a minor in Mathematics from the Pennsylvania State University in 2018 and is currently pursuing a Ph.D. in Imaging Science at the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology. His Ph.D. research is about investigating new field calibration targets (i.e., convex mirrors) to assess the radiometric and spatial response of hyperspectral/multispectral imaging systems. David joined the Digital Imaging and Remote Sensing Laboratory as a staff member in April 2022 to further develop laboratory procedures in radiometric, spectral and spatial calibration for hyperspectral/multispectral imaging systems.

Jeff Dank

Jeff joined the Digital Imaging and Remote Sensing Laboratory as a Research Enginerr II in August 2021. He earned a Master's in Business Administration and Bachelor's degree in Imaging Science from The Rochester Institute of Technology, as well as a Bachelor's degree in Applied Computer Science from CU Boulder. He has 16 years of experience as a Research Scientist / Systems Engineering and Technical Advisor for both Lockheed Martin and Integrity Applications Incorporated. He is interested in real time rendering of synthetic images and sharing his experience with students and customers to enable them to be DIRSIG power users.

Byron Eng

As a member of the DIRSIG team, Byron helps train and mentor new DIRSIG users. Byron joined the Digital Imaging and Remote Sensing Laboratory as an Assistant Research Scientist in 2019. He earned a Master's degree in Mechanical Engineering from the University of Utah, where he specialized in Heat Transfer, Atmospheric Sciences, and Fluid Mechanics. As the subject matter expert in heat transfer, Byron helps refine the methods in which temperature predictions are made for DIRSIG simulations of thermal imaging systems. Byron is interested in applying his expertise in research topics such as renewable energy, air quality, and atmospheric modeling.

Serena Flint

Serena joined the Digital Imaging and Remote Sensing Laboratory as a Researcher/Engineer I in late June 2022. She earned a Bachelor's degree in Physics and Astronomy earlier this year from the University of Rochester. For the past three years, her research focused on using machine learning to mimic spectropolarimetric inversions in solar physics. Now, she is excited to learn more about the world of imaging science and looks forward to opportunities to work on various projects in the future.

Michael Gartley

Assistant Research Professor in the Center for Imaging Science. Michael received his Bachelors degree in Physics from Binghamton University in 1995, his Masters degree in Materials Science and Engineering from Rochester Institute of Technology in 1997 and his PhD in Imaging Science from Rochester Institute of Technology in 2007. He teaches multiple graduate level courses, one of which he developed to teach practical approaches to system level design trades he learned from his 10 years in industry prior to entering academia. His research often focuses heavily on low level modeling and simulation of various remote sensing modalities such as panchromatic, polarimetric, spectral, and Synthetic Aperture Radar. Michael is also conducting research to improve detection, characterization and monitoring of resident space objects for improved Space Situational Awareness.

Aaron Gerace

Assistant Research Faculty in the Chester F. Carlson Center for Imaging Science. Aaron completed his Bachelors and Masters degree in Mathematics from Brockport College in 2002 and his Ph.D. in Imaging Science from the Rochester Institute of Technology in 2010. His research in the Digital Imaging and Remote Sensing laboratory focuses on calibration of spaceborne thermal sensors and validation of their corresponding higher level products. An upcoming award will enable him to investigate the impact of future Landsat sensor designs on science applications. He is motivated by challenging problems and the wise words of RATM.

Adam Goodenough

Research Engineer II with the Digital Imaging and Remote Sensing Laboratory and co-developer of the Digital Imaging and Remote Sensing Image Generation (DIRSIG) tool. Adam received his B.S. and Ph.D. degrees in Imaging Science from the Rochester Institute of Technology (RIT) in 2001 and 2007, respectively. His contributions to the remote sensing community were recently recognized with the 2017 USGIF Achievement Award in Academia. His research interests include modeling and simulation, water quality monitoring, and data visualization.

Amir Hassanzadeh

Amir Hassanzadeh is a Research Engineer II at the center for imaging science. Amir completed his undergraduate studies in engineering at the University of Guilan, Iran, before pursuing a Ph.D. in Imaging Science at the Rochester Institute of Technology (RIT). During his doctoral research, Amir's focus was on yield modeling and harvest scheduling of broad-acre crops, employing drone-based hyperspectral sensing. Amir's broad research interests span across precision agriculture, satellite and drone-based imaging, thermal sensing, machine learning, deep learning, and optimization techniques. research is about investigating new field calibration targets (i.e., convex mirrors) to assess the radiometric and spatial response of hyperspectral/multispectral imaging systems.

Lori Hyde

Lori joined the Chester F. Carlson Center for Imaging Science in December 2021. She earned a Master's in Higher Education from the University of Rochester. Lori pursued research and internships in academic advising and career counseling. While there, Lori joined the staff of RIT's College of Science in 2016 as a scheduling officer and Senior Staff Assistant with Thomas H. Gosnell School of Life Science. Currently, Lori assists the Graduate Program Coordinator and the CIS Director with the administration of the Imaging Science M.S. and Ph.D. programs, including course scheduling, student enrollments, and tracking student progress toward graduation.

Emmett Ientilucci

Associate Professor and Graduate Admissions Chair in the Chester F. Carlson Center for Imaging Science. Emmett has degrees in optics and imaging science. He is the recipient of the 2020-21 Eisenhart Provost's Award for Excellence in Teaching at RIT. His research interests include, spectral image analysis and variability, hyperspectral image processing, target and shadow detection, radiometric calibration, atmospheric compensation and algorithm development. He has 88 publications and has served as referee on 18 journals including being an Associate Editor for a special issue of Optical Engineering (OE) and current Associate Editor for Geoscience Remote Sensing Letters (GRSL). He has been a program reviewer for NASA, the Department of Defense, and is Chair for the SPIE Imaging Spectrometry Conference, the WNY Geoscience and Remote Sensing Society, and the UAS STRATUS Conference. He is senior member of IEEE and SPIE societies and is working on a text book entitled, "Radiometry and Radiation Propagation".

Jacob Irizarry

Joining the DIRSIG team in late 2021, now a Research Engineer/Support Jacob work's as the expert on 3d asset creation. Currently pursuing a Master in Business Administration, and having earned a Bachelor's degree from RIT in 3D Digital Design. I graduated early under the class of 2022, I used my time from graduating early to work on developing a new IP in the 3D world, in addition to continuing work as a contractor for the DIRSIG labs to create custom 3d assets, before formally joining the DIRSIG team as a full time member in August of 2022. I'm excited to learn more about the sciences and, I'm ecstatic that I have been able to bring my expertise in the world of art and design to Imaging Science and connect the two worlds.

Daniel Kaputa

Director of Ravven Labs and Assistant Professor of Computer Engineering Technology, Dan received his Bachelors degree in Computer Engineering [2002] and Masters [2004] and PhD [2007] in Electrical Engineering from the State University of New York at Buffalo. Dan teaches and conducts research in FPGA programming, image processing, computer vision, deep learning, and UAVs. His research interests are broken into two distinct categories namely FPGA based on board video processing for GPS denied navigation and object classification and localization via quantized neural networks. His passion is to combine both domains to create a single FPGA based UAV capable of real time object detection for counter UAS applications.

John Kerekes

Research Professor of Imaging Science. John received his BS, MS, and Ph.D. in Electrical Engineering from Purdue University in 1983, 1986, and 1989, respectively. His research interests include remote sensing system analyses and performance sensitivity studies using simulation and modeling techniques. While his primary expertise is in the area of hyperspectral imaging systems, he has also worked with other remote sensing modalities including thermal imaging, lidar and synthetic aperture radar, with applications ranging from object detection and land cover classification to atmospheric sounding. John is also an active volunteer with the IEEE Geoscience and Remote Sensing Society. Prior to joining RIT, he was a staff member at the MIT Lincoln Laboratory for 15 years.

Robert Kremens

Dr. Kremens is an atomic physicist by education but has spent most of his career as an instrument physicist designer. In addition to a BS, MS and PhD in physics, he obtained a mid-career MS in Environmental Science. He has a strong history of designing and implementing complex experimental apparatus in government, industrial and academic settings. Bob has broad knowledge in measurement techniques including electronics design and fabrication, transducer interfacing, data acquisition and reduction, optical systems, lasers, pulsed power systems, vacuum systems and mechanical assemblies. Recently he has been engaged in designing and deploying portable, inexpensive, fireproof energy flux measurement for observation of wildland fires. Some of this unique equipment includes multi-pleband infrared radiometers, convective flow gauges that operate in high temperature environments, wide dynamic range data acquisition electronics and multiple band in fire camera systems. He has successfully deployed these sensors hundreds of times in the harsh environment of wildland fire.

Patricia Lamb

Senior Staff Assistant for the Chester F. Carlson Center of Imaging and Science since 2018. Prior to coming to RIT, she worked for one of the world's largest distributors of electronic components and embedded solutions. With 30 years of experience in an administrative role at a corporate level. Patty supports faculty, staff, students and post-doctoral researchers. Patty's husband is a proud alumnus of RIT.

Colleen McMahon

Research Program Coordinator for the Digital Imaging and Remote Sensing Laboratory, with 10 years of experience in an administrative role, Colleen keeps our lab running with support in grant management, budgets, and logistics, to name a few. Colleen is pursuing a degree in Business Administration from Rochester Institute of Technology. When she is not putting up with our team's shenanigans, Colleen is an active member of the Seneca Siberian Husky Club.

David Messinger

Dr. Messinger received a BS in Physics from Clarkson University and a Ph.D. in Physics from Rensselaer Polytechnic Institute. He is currently a Professor and the Xerox Chair in Imaging Science at the Rochester Institute of Technology, having served as the Director of the Center for Imaging Science from 2014-2022. He is a Fellow of SPIE and has published over 180 scholarly articles. His research focuses on projects related to image system analysis and spectral image processing using advanced mathematical approaches with applications to remote sensing and cultural heritage imaging.

Matthew Montanaro

Matt holds degrees in Physics (BS, 2005) and Imaging Science (PhD, 2009) and is currently a Senior Research Scientist involved in the calibration of imaging instruments through NASA Goddard Space Flight Center. He specialized in the calibration and characterization of many NASA flight instruments including the Landsat 8/Thermal Infrared Sensor (TIRS), the Landsat 9/TIRS-2, the Lucy/Ralph, the New Horizons/Ralph, and the Solaris pathfinder instrument. He is directly involved in the definition of the calibration methodologies, execution of characterization tests, and analyses of instrument performance data, both pre-flight and on orbit. He is currently supporting the upcoming Landsat Next mission with NASA and the US Geological Survey (USGS). Matt has a number of peer-reviewed scientific journal publications and conference proceedings and has presented at various remote sensing-related conferences. Additionally, he has supported and advised a number of graduate and undergraduate students.

Nina Raqueño

Research Engineer for the Laboratory for the past 20 years. Nina received a Bachelors in Imaging Science from the Rochester Institute of Technology in the 1990s. Nina escaped for several years to SUNY College of Environmental Science and Forestry where she learned practical remote sensing tools, such as GIS, GPS, surveying, flight planning, and many of the skills required for field work. Nina also served as a technical illustrator for "Remote Sensing: The Image Chain Approach". She was eventually lured back to RIT and DIRS by Dr. John Schott with the promise of spending cloud free days on Lake Ontario (which, by the way, is not quite the ocean but at least it's wet). The first project she was assigned to was Landsat 7 thermal calibration which she continues today as part of NASA/USGS's Landsat Calibration Team. Nina continues to coordinate remote sensing field campaigns of all sizes and for a variety of platforms, satellite, aircraft, rooftop, and now from sUAS. Basically, the only thing that has changed in 20 years is now with the advent of sUAS we can fly more often and under those pesky clouds.

Eon Rehman

Rehman Eon received a BSc. from Viterbo University in Mathematical Physics and Chemistry, and his Ph.D. in Imaging Science from the Rochester Institute of Technology (RIT). His research interests include the use of optical remote sensing for the assessment of earth sediments and vegetation, radiative transfer modeling, thermal calibration of air/space-borne imaging sensors, development of surface temperature algorithms, and defining requirements for future Earth Observing systems.

Marci Sanders

Marci Sanders received a Bachelors Degree from RIT in 2020 and is pursuing her Masters in Higher Education form the University of Rochester. Marci Sanders is the student financial assistant, responsible for processing student employment, tuition remission, and stipend payment paperwork. She supports over 100 undergraduate and graduate students. Making sure our students have money for rent and groceries is her top priority.

Michael Grady Saunders

Grady is a member of the Modeling and Simulation team in the Digital Imaging and Remote Sensing Lab. He received his Bachelor's degree with honors from East Tennessee State University in 2017, where he majored in Digital Media and minored in Mathematics. He earned a Master's in Imaging Science here at RIT in 2020. Following his graduation, Grady was happy to join the department as an Assistant Research Scientist. His primary role on the Modeling and Simulation team concerns the creation and management of high fidelity virtual environments to serve as inputs to the 5th edition of the Digital Imaging and Remote Sensing Image Generation model, or DIRSIG5. His scientific interests, revolve around stochastic light-transport simulation and procedural modeling techniques in the context of 3D computer graphics and computer generated environments. Prior to the pandemic, he also frequented nearby trampoline parks to hone his flipping skills.

Jan van Aardt

Full Professor in the Chester F. Carlson Center for Imaging Science. Jan obtained a B.Sc. Forestry degree ("how to grow and cut down trees") from the University of Stellenbosch, South Africa in 1996. He completed M.S. and Ph.D. Forestry degrees, focused on remote sensing (imaging spectroscopy and light detection and ranging), at the Virginia Polytechnic Institute and State University, Blacksburg, Virginia in 2000 and 2004, respectively. This was followed by post-doctoral work at the Katholieke Universiteit Leuven, Belgium, and a stint as research group leader at the Council for Scientific and Industrial Research, South Africa. Imaging spectroscopy and structural (lidar) sensing of natural resources form the core of his efforts, which vary between vegetation structural and system state (physiology) assessment. Or stated differently, the interaction between photons and leaves is what really gets him going. He has received funding from NSF, NASA, Google, and USDA, among others; Jan and his students also have published >90 peer-reviewed papers and >100 conference contributions.

Anthony Vodacek

Full Professor of Imaging Science. Vodacek received his B.S. (Chemistry) in 1981 from the University of Wisconsin Madison and his M.S. and Ph.D. (Environmental Engineering) in 1985 and 1990 from Cornell University. His areas of research lie broadly in multi-modal environmental remote sensing with a focus on the coupling of imaging with environmental modeling for application to monitoring both terrestrial and aquatic systems. He has specific expertise in spectral phenomenology, image interpretation, aquatic optics, and wildland fire monitoring and he has recently begun working with passive acoustic sensing of the environment. He has international collaborations in several African coutries, where he has worked on various teaching and research projects for over ten years, and in Malaysia. Vodacek is an Associate Editor for the Journal of Great Lakes Research, is a Senior Member of IEEE, and supports the IEEE Geoscience and Remote Sensing Society Global Activities Directorate as the regional liaison to Africa.

Melanie Warren

Since 2010, a Senior Staff Assistant for the Digital Imaging and Remote Sensing (DIRS) and the Multidisciplinary Vision Research (MVRL) Laboratories. Melanie received her Bachelor's in criminal justice from Niagara University. Including a semester of study abroad at the University of Copenhagen. Melanie enthusiastically supports faculty, staff, and students with procurement purchases, travel arrangements, processing of reimbursements, lab support, special event coordination, and hospitality. She has served on the committee and chaired the College of Science Staff Advisory Council, COSSAC. Go Tigers! As always Go Bills!

Amanda Zeluff

Amanda Zeluff works for RIT's Sponsored Programs Accounting as a Sr. Staff Accountant. She administers financial aspects of externally funded grants and contract for the Center for Imaging Science. She provides post-award management and direct support to the Principal Investigators. Amanda is a Summa Cum Laude RIT alumni with her BS in Business administration. She has worked for RIT since 2011 and has held several positions on campus. Her favorite aspect to her position is the complexity of the Federal Uniform Guidance/FAR and keeping all the DIRS PI's in line with the policies and procedures of grant and contract management.

Post-Doctoral Researcher

Rob Chancia

Rob is currently a Post Doctoral Researcher at the Center for Imaging Science. He received his PhD in Physics from the University of Idaho in 2019, for his work with outer planet imagery from NASA's Cassini, Voyager 2, and New Horizons spacecraft. He then completed a Master's degree in Imaging Science from RIT in 2021. His research with Dr. Jan van Aardt applies multiple imaging modalities to improve precision agriculture and forest inventory practices.

Graduate Students: PhD Candidates

Tolga Atkas

Sarvani Bhamidi

Sarvani is a second year graduate student pursuing her doctorate degree at the Center for Imaging Science. She received her Bachelor's degree in Electronics and Communication Engineering from Manipal Institute of Technology, India in 2018. Her undergraduate and consequent research was focused on signal processing and computer vision: including fields such as astronomy and biomedical imaging. Her current research work and interests involve remote sensing, atmospheric compensation, spectral image analysis and image processing.

Austin Bergstrom

Nate Burglewski

Currently a third year PhD student, Nate earned a Bachelor's degree in Applied Physics from The Citadel, The Military College of South Carolina. He has since earned a Master of Science in Applied Physics from Wright State University. He has more than ten years' experience in the procurement, testing, and development of spectral and radio frequency remote sensing systems. His research aims to further the understanding of the spectral features correlated with corn yield.

Chase Canas

Currently a third year Ph.D. student at the Center for Imaging Science. Chase received his B.S. in Physics at University of California, Santa Barbara and M.S. in Physics at California State University, Long Beach. His research interests are in remote sensing, with a focus in systems engineering, calibration, and hyperspectral imaging. Chase's current research at the CIS involves investigating fundamental limits of detection in spectral imaging systems.

Joe Carrock

Manisha Das Chaity

Currently a second-year Ph.D. student in Imaging Science, working under the supervision of Dr. Jan Van Aardt. My research interests lie in hyperspectral remote sensing using synthetic data and applying machine learning approaches for remote sensing applications. Currently, I am trying to find a next generation hyperspectral sensor setup that will allow to measure the biodiversity of the Fynbos in South Africa in fine scale resolution. I did a master's in electrical engineering from South Dakota State University and a bachelor's in Electronics and Communication Engineering from Khulna University of Engineering Technology in Bangladesh.

Ryan Connal

Currently a Ph.D. candidate at the Center for Imaging Science. Ryan received his Bachelors degree in Imaging Science from RIT in 2018. In his undergraduate studies, he performed research with Drs. Aaron Gerace and Matthew Montanaro relating to Landsat 8 TIRS calibration. His current research interests involve remote sensing in the visible and thermal infrared, image processing, and computer vision.

David Conran

Received a B.S. in Astrophysics and Astronomy from the Pennsylvania State University in 2018. His research focus involves the spatial assessment of remote imaging sensors using convex mirrors producing ground-based point sources. In partnership with Labsphere, this technology and research is being brought to the satellite community for easy access to an ideal, stable calibration target, both spatially and radiometrically.

Thomas Will Dickinson

Currently a second year PhD student at the Center for Imaging Science. He received his bachelor's degree in physics from the United States Air Force Academy in 2014 with concentrations in lasers, optics, and astronomy and research covering Doppler spectroscopy for exoplanet detection and ground based test and checkout of a space-based imaging payload that launched in 2019. He received his master's degree in applied physics from the Air Force Institute of Technology in 2016 with a concentration in optical science and a thesis on membrane diffractive optic telescope design for space-based, high contrast imaging. He is currently working under Dr. Michael Gartley on modeling and simulation of adaptive optics compensated imagery for Space Domain Awareness applications.

Rey Ducay

Lucy Falcon

Ph.D. candidate at the Center for Imaging Science. Lucy received her Bachelor's degree in Imaging Science from RIT in 2018. Her research is currently focused on calibrating ground based thermal instruments to support validation of Landsat TIRS.

Sihan Huang

Peter Jackson

Currently a Ph.D. Candidate at the Center for Imaging Science and a bachelors in Physics, Peter is performing his research with Dr. Cristian Linte on image-guidance for medical procedures. His current research interests are in areas of medical imaging, registration, and augmented reality.

Ali Rouzbeh Kargar

Ali is a Ph.D. student at Chester F. Carlson Center for Imaging Science. He received his B.E. in Polymer Engineering and Color Science from Amirkabir University of Technology (Tehran Polytechnic) in 2015. Ali's research is focused on structural assessment of complex forest environments using terrestrial laser scanning data. The complexity in these forests introduce challenges to structural evaluation algorithms, thus Ali works on developing approaches to overcome these issues and improve the results acquired from forest inventories in the studied sites.

Vedant Anand Koranne

Currently pursuing MS in Electrical Engineering at the Kate Gleason College of Engineering, RIT. Vedant received his Bachelor's degree in Electronics and Telecommunication Engineering from Yeshwantrao Chavan College of Engineering, India in 2019. In his graduate studies, he performed research with Dr. Amlan Ganguly related to the detection of hardware trojan for multi-core chip processors and Dr. Emmett Ientilucci relating to Smoke Plume Segmentation using Superpixel based Fuzzy C-Mean Clustering. His current research interests involve image processing, image quality tuning, and computer vision.

Chris Lee

Chris is a Ph.D candidate at the Chester F. Carlson Center for Imaging Science since 2019 being advised by Dr. Charles M. Bachmann. He is working on hyperspectral and RGB video capture and analysis techniques for dynamic Earth remote sensing scenes, characterizing the spectral angular reflectance of Spectralon for improved hyperspectral image data calibration, polarimetry of granular media, and directional reflectance spectroscopy of artificial spacecraft materials in support of studying the impact of bright satellite constellations on the night sky for observational astronomy. He obtained a B.S. in Physics and a B.S. in Astronomy from the University of Michigan where he worked on space-related research ranging from galactic astronomy to Space Situational Awareness.

James Liu

Xuesong Liu

Davin Mao

Mathew Murphy

Nayma Binte Nur

Currently enrolled in the third year of a Ph.D. program at the Center for Imaging Science. She earned a Bachelor of Science degree in Electrical and Electronic Engineering and a Master of Science degree in Mathematics. At the moment, she is in the research group of Dr. Charles M. Bachmann. Her current research focuses on hyperspectral remote sensing of coastal areas, as well as radiative transfer modeling for geophysical parameters retrieval.

Kedar Patki

Currently a Ph.D. candidate at the Center for Imaging Science. Kedar received his Master's in Electrical Engineering with a focus on Signal Processing from University of Rochester in 2014. His current research interests are in remote sensing for environmental applications.

Aneesh Rangnekar

A Ph.D. student at Chester F. Carlson Center for Imaging Science. He received his Masters in Electrical Engineering from RIT. His research revolves around dynamic data-driven application for hyperspectral imaging, with focus on aerial object tracking. His research goal is to create an adaptive tracker that can smartly shift between hundreds of spectral bands as required to track an object of specific color and material at real time speed.

Mohammad Shahriar Saif

Currently, a second-year student seeking a Ph.D. in Imaging Science. Mohammad received a Bachelor of Science in Electrical and Electronic Engineering from Bangladesh University of Engineering and Technology in 2017. His current research interest lies in precision agriculture. Under the supervision of Dr Jan van Aardt, he is looking into the applicability of UAS to predict yield and detect disease in crops.

Dylan Shiltz

Dylan is a Ph.D. candidate at the Center for Imaging Science. He received his Bachelor's degree in Mechanical Engineering from Milwaukee School of Engineering in 2014 and his Master's degree in Mechanical Engineering from Massachusetts Institute of Technology in 2016. His previous research involved experimental fluid dynamics, design and modeling of net-zero energy buildings, and optimal control of electrical power systems. He is in the research group of Dr. Charles Bachmann. His current research focuses on the effects of surface roughness on remote sensing measurements in the VNIR/SWIR and X-band radar domains.

Tahrir Siddiqui

Currently, Currently a second-year Ph.D. student at the Chester F. Carlson Center for Imaging Science, Tahrir received his Bachelor's degree in Electrical and Computer Engineering from the University of Mississippi in 2017 and his Master's degree in Computer Engineering from Purdue University Fort Wayne in 2021. Tahrir's research interests lie in remote sensing and deep learning. Under the supervision of Dr. van Aardt, his current project focuses on Light Detection and Ranging (LiDAR) for ecosystem studies as well as sub-canopy target detection.

Jason Slover

Robert Wible

Fei Zhang Ph.D

Fei Zhang received his B.S. degree in Optics from Wuhan University in 2015 and his M.S. degree in Optical Engineering from Zhejiang University in 2018. He is now a Ph.D. candidate at the Center for Imaging Science. His current research interests involve UAS-based 3D point clouds, multispectral imaging, vegetation phenotyping.

Runchen Zhao

Runchen Zhao received his B.S. in applied physics from Xidian University in 2011, and M.S. in material science from the Rochester Institute of Technology in 2014. He is currently a Ph.D. student working under Dr. Ientilucci in the Digital Imaging and Remote Sensing Laboratory, Chester F. Carlson Center for Imaging Science. His current research involves end-to-end LWIR simulations consisting of statistical atmospheric compensation and statistical detection algorithm development.

Yuwei Zhou

Graduate Students: MS Candidates

Luke DeCoffe

Luke DeCoffe is an Aerospace Engineering Officer serving in the Royal Canadian Air Force and is currently working towards his MS in Imaging Science. After receiving his Bachelor's degree in Mathematics from Dalhousie University in 2016, he filled multiple engineering management roles surrounding avionics and defensive electronic warfare systems. The technical material encountered throughout his early career led him to pursue an MS here at the Center for Imaging Science. He is currently researching reflectance conversion techniques for hyperspectral remote sensing and developing a UAS-based spectral downwelling irradiance sensor with Dr. Carl Salvaggio.

Yuval Levental

Colin Maloney

Colin is a MS candidate at the Center for Imaging Science. He received his Bachelor's degree in Physics from the United States Air Force Academy in 2021. His past research has focused on event-based sensors. His current research focuses on the impact of shadowing and multiple reflections on hyperspectral subpixel target detection.

Undergraduate Students:

Oliver Harvieux

Gabriel Peters

Imergen Rosario

Currently a third-year undergraduate student, Imaging Science BS. Imergen graduated from the High School of Art and Design in Manhattan, NY, in 2019. Imergen is fascinated by image processing and the wide range of applications that arise from it.

Micha Ross

Ethan Snell

Yonghuang Wang

Cooper White

Publications

The following publications are from our hardworking staff members and required hours of dedication and commitment.

Publications

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