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

Annual Report
2021-2022

Cover Photo: The DIRS laboratory small unmanned aircraft systems (sUAS) fleet of DJI Inspire 2 aircraft equipped with Zemuse X5S imaging payloads capable of RAW 6K 30fps 12-bit video collection in Adobe CinemaDNG format. All of these aircraft were flown simultaneously to collect data for the geometric reconstruction and volume estimation of condensed water vapor plumes emanating from a power plant's mechanical draft cooling towers in support of Department of Energy research [Photo credit: Nina Raqueno].

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Foreword

Carl Salvaggio

Foreword

The 2021-2022 academic year has come and gone, and all of us in the Digital Imaging and Remote Sensing laboratory have enjoyed another great year. Life on the RIT campus has felt like it is back to normal in almost every way, and that is especially true here in the laboratory. The dedication of each and every one of our students, administrative staff, research staff, and faculty continues to make this such an amazing place to work and thrive in our pursuits of academic and applied research, as well as sharing all of our many and varied skills with the larger remote sensing community through our fee-for-service Enterprise Center.

Growth is always a wonderful thing to talk about, and if you have ever been part of the DIRS laboratory, you may never have realized the size of the organization. We are 25 members strong at this point, plus the many other faculty, staff and students across the university who are critical collaborators on many of our research programs. We are 13 research staff, 7 tenured/tenure-track faculty, 3 research faculty, 2 administrative staff, and 1 post-doctoral researcher. At the time of this writing, we are in the process of adding our 26th member to our group.

We pride ourselves on carrying out our mission with the great students in our undergraduate and gradualte programs in Chester F. Carlson Center for Imaging Science. This year our own Jan van Aardt was the recipient of the Eisenhart Award for Outstanding Teaching. This prestigious award is RIT's highest honor for tenured faculty and recognizes faculty who excel at teaching and enhancing student learning. We could not be prouder of Jan for the work he does to educate the next generation of Imaging Science graduates.

This year James Albano, David Conran, Serena Flint, and Amirhossein Hassanzadeh have all joined the DIRS laboratory. This brings to us some great expertise in the areas of synthetic aperture radar (SAR), radiometric systems calibration and characterization, and some much-needed additional expertise and support in the areas of DIRSIG, machine/deep learning, and spectral processing.

We did have to say farewell to 2 of our laboratory research staff members this year, Tania Kleynhans took a great opportunity at Hydrosat and Philip Salvaggio moved on to join Descartes Labs. 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 them both the best and always consider them a part of the DIRS family.

Dedication and longevity are wonderful attributes in so many aspects of life, and when it comes to members of organizations such as ours, it always amazes me to see how much of their lives our members have given to this group. I would like to point out two such people. This year is Scott Brown's 28th year with us in the DIRS group and Nina Raqueño is just finishing up her amazing 35th year. It is the commitment of people like Scott and Nina that make this laboratory as successful as it has been all of these years – essentially since the beginning.

Resilience is another factor that amazes me about our group. We have had to restructure our laboratory's financial model and operational budget this year due to policy changes at the University, but despite these dramatic changes imposed upon us, we have made the necessary financial adjustments to continue on the same path we have always been and have seen continued growth accross our research and Enterprise Center offerings. We all can't thank our Associate Director for Research and Business Development, Joe Sirianni, enough for providing the leadership that has brought us to a fiscally stronger point than we have ever been.

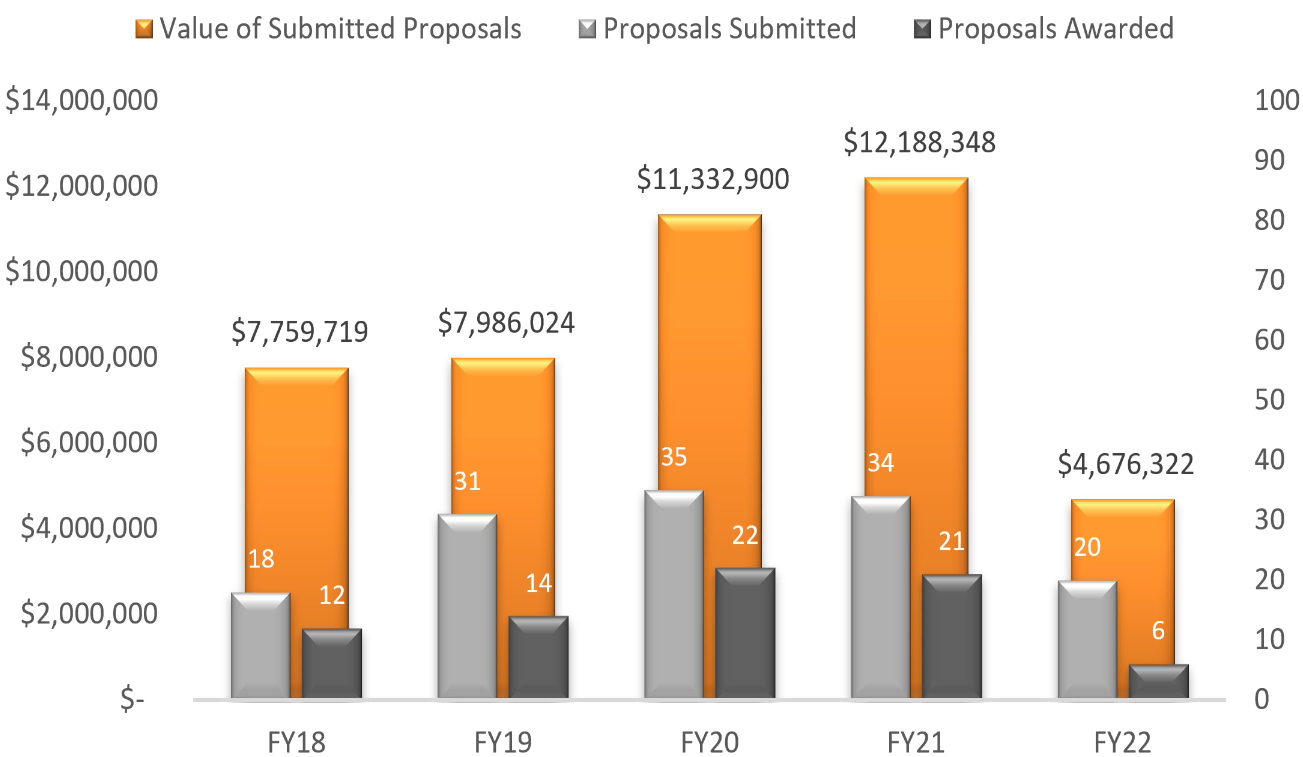
I am always grateful for the support we get each year from the many organizations that are needed to run a research laboratory on a university campus. Here at RIT, I want to thank many individuals that help us out every day, and forgive me if I miss any individual as there are so many. Jim Bodie and Brett Matzke, from our Center for Imaging Science computing support team, for their countless hours working to enable our unique and endless requests for computing capabilities to support all of our ever-changing research demands. Katherine Clark, Denis Charlesworth, and David Harrison 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, 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.

Of course, the support of our Center Director, David Messinger and our College Dean, Sophia Maggelakis are always so generous. Both of these individuals will be moving on to the next big things in their respective careers this coming year and we wish them both the best and will miss them dearly. 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 goals and continue to challenge us to be better each and every year. Thanks to all for giving us such a great academic environment in which to thrive.

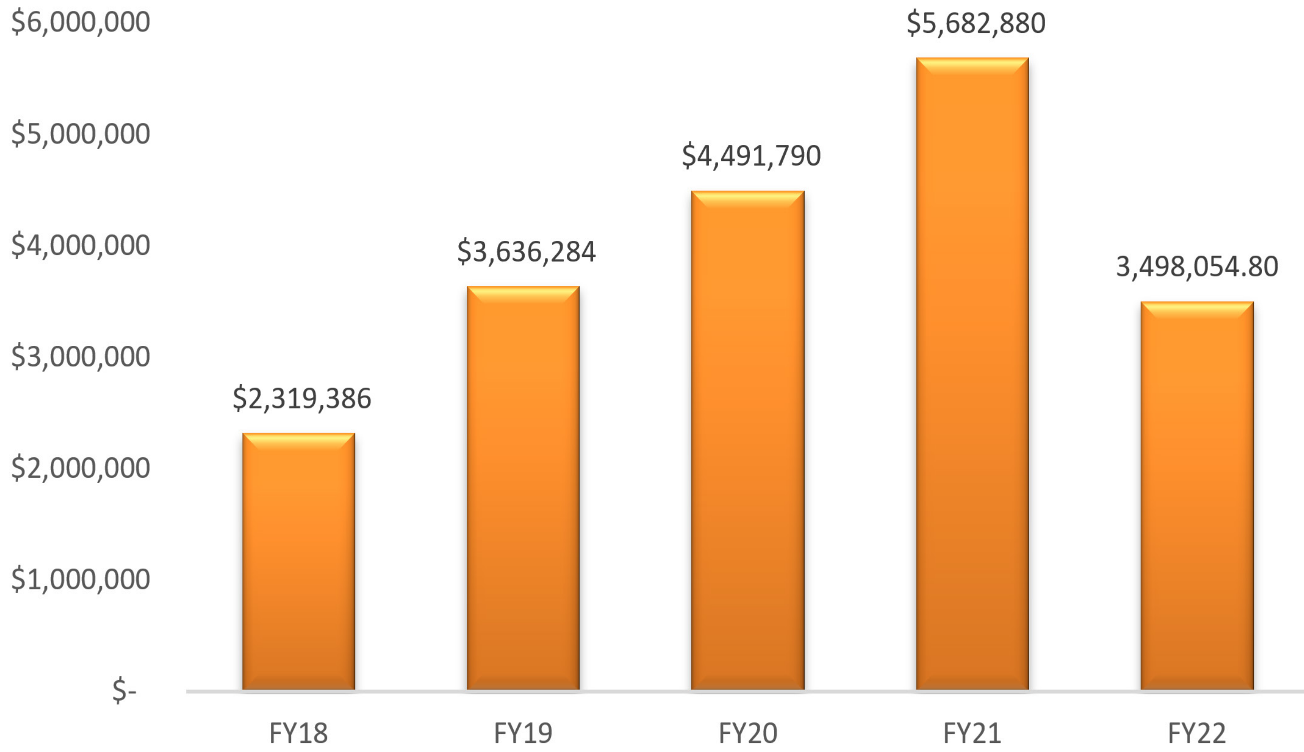
My warmest regards,

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 2021-2022 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

Project Description

The continuous development of the DIRSIG5 model has a few overarching goals: improve performance, improve user experience, modernize tools to keep up with technological advances, and remove dependencies on the old (DIRSIG4) codebase. With the help of our external partnerships and collaborations, many improvements were made to the model this year to bring us closer to these goals.

Figure 1: Output from a new capability within the ChipMaker plug-in for DIRSIG. Inputs include three targets (white Nissan Fairlady, red Nissan Infinity, green Toyota Corolla) and two backgrounds (grass, parking lot). This new capability produces randomized pairings of targets and backgrounds while also randomizing standard ChipMaker parameters such as view/source angles.

Project Status

DIRSIG5 performance was improved through many changes this year. The process of running DIRSIG5 in parallel was simplified, allowing better use of cloud computing resources. The ray-tracing core received a number of upgrades, further increasing the gap in performance of DIRSIG5 vs. DIRSIG4. Support for the THERM temperature prediction model was added to DIRSIG5 and performance improvements were integrated. A new capability was added to the ChipMaker plug-in which enables easier randomization between a set of targets and a set of miniature background scenes. A new method for reading raster image inputs was added; improving runtime performance.

A DIRSIG plug-in to upgrade the level of integration between DIRSIG and ThermoAnalytics' MuSES temperature prediction software has been developed. The synchronization between the two software packages now includes geographic location and orientation, date and time, weather, and material emissivities. The user supplies the plug-in a MuSES specific CAD model and gives it a location and orientation for placement in the DIRSIG simulation. Then the plug-in runs MuSES on the fly to predict the temperatures for the model given the environment conditions set up for the DIRSIG simulation.

Numerous changes to the DIRSIG documentation and Graphical User Interface (GUI) were added to improve the user experience. A large overhaul of the documentation and manuals was conducted to address any inconsistencies or gaps and reflect the fact that the majority of use cases are best handled by the modern DIRSIG5 tools. Other improvements were added, such as the ability to output additional debug information, quickly scale output resolution, edit DIRSIG5-era simulation files in the (DIRSIG4-era) GUI, convert output files with a more powerful image analysis tool, and easily assign objects or materials from a set of pre-built assets.

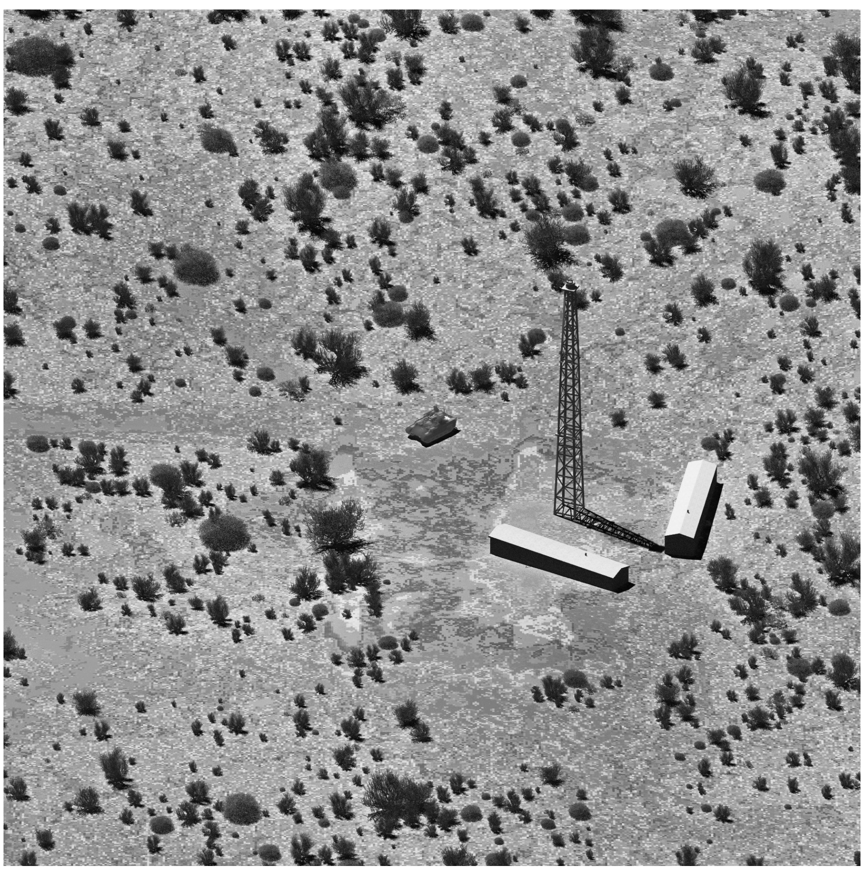


Figure 2: Output from the new MuSES plug-in for DIRSIG. The DesertHighway DIRSIG scene is used as a background for a BMPT Terminator tank. The tank's temperature was modeled at runtime using the MuSES temperature prediction software. The temperature for the rest of the scene was modeled using the THERM model. This coupling between the DIRSIG and MuSES models will allow high accuracy thermal targets to be placed into scenes of high complexity.

High-fidelity Scene Modeling and Vehicle Tracking Using Hyperspectral Video

Principal Investigator: Matthew Hoffman

Team: Anthony Vodacek, Chris Kanan, Tim Bauch, Don McKeown, Aneesh Rangnekar, Zachary Mulhollan

External Collaborators: Angel D. Sappa, ESPOL Polytechnic University Ecuador & Computer Vision Center Campus UAB, Barcelona, Spain

Project Description

The ability to persistently track vehicles and pedestrians with video imagery requires complex computation and imaging for best performance. Spectral cameras at low video rates have the ability to leverage additional phenomenological features to enhance robustness across varying environments, illumination, and occlusions. This project involves 1) collecting and annotating novel hyperspectral datasets of vehicle movement that will be released to the community, 2) developing a framework for efficiently extracting and exploiting spectral information from this large dataset using deep learning methods and 3) leveraging DIRSIG to support rapid and dynamic construction of physics-based scene models for tracking applications.

Project Status

The vehicle tracking dataset collected from the rooftop of the Center for Imaging Science building was annotated and used as a challenge dataset for semi-supervised hyperspectral object detection. The dataset included images 2890 frames with average pixel dimensions of 1600 x 192 pixels, and 51 spectral bands from 400 nm to 900 nm. 989 images were for training, 605 images were for validation, and 1296 images for testing. 10% of the images were labeled to provide the semi-supervised learning task. Challenge results were presented in a conference publication and suggest the Cascade R-CNN approach is the most effective for this semi-supervised problem.

(a) Vehicles occluded by trees in the scene.

(b) Vehicles occluded by other vehicles in the scene. The second figure from the left also shows the image perturbations caused by glint in the scene.

Figure. 1: (a) A set of individual natural color frames from the challenge video demonstrating occlusion by trees. (b) A set of individual natural color frames from the hyperspectral challenge video demonstrating vehicle occlusion by other vehicles and demonstrating glint as a confuser.

Partnership for Skills in Applied Sciences, Engineering and Technology

Principal Investigator: Anthony Vodacek

External Collaborators: Emmanuel Ndashimye, University of Rwanda; Damien Hanyurwimfura, 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 project is in the initial stages. The field microphones will feature AudioMoth open source hardware with the development board option. This will allow the integration of the audio system with GPS for timing and localization, edge processing featuring machine learning, and a low power data transmission solution. Network design and machine learning method development will be critical tasks in the project. The system integration and machine learning development for edge computing will take place at the University of Rwanda as Ph.D. projects.

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 an effort to reasonably match real world imagery in the visible and NIR regions of the electromagnetic spectrum under a variety of atmospheric, surface, target, bottom and water composition conditions. This last stage of the Phase II project has focused on comparative studies between real world collects and simulated imagery. Explorative studies into fully entrained bubble distributions during the previous year were turned into simulation tools. We also found that the main source of disparity between measured and modeled data was the presence of structured cloud fields above the water, particularly at longer wavelengths when the reflected signal was stronger than the upwelled radiance. To address this difference, we developed several cloud field irradiance models and settled on an approach that uses a simple "fisheye" type capture of actual (or representative) conditions, bringing the simulated data into close alignment with measurements.

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.

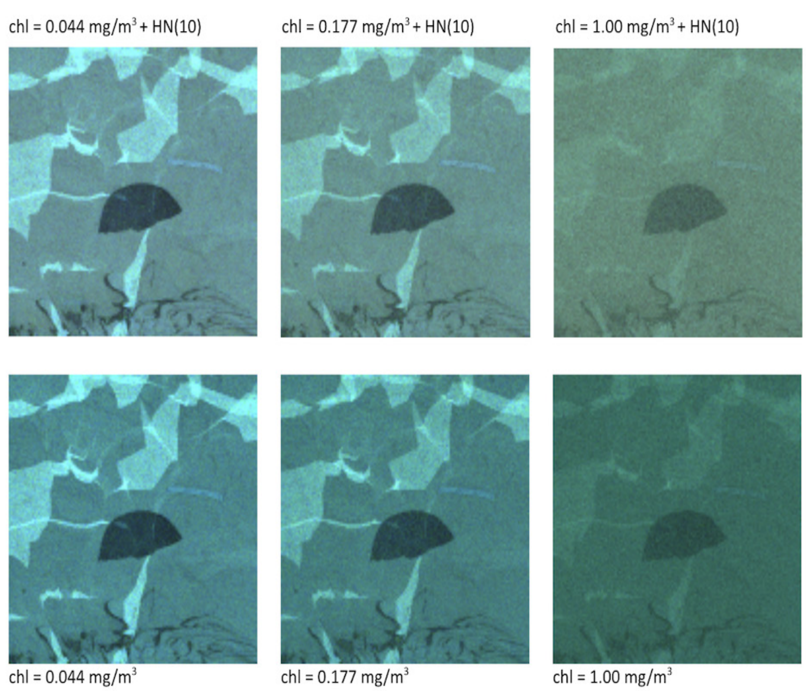


Figure 1: Simulations demonstrating the impact of entrained bubbles on the overall radiance signal (using a Hall-Novarini (HN) size distribution parametrized by a 10 m/s wind speed). The top row shows the qualitative influence of the bubbles on both magnitude and color on the simulated shallow water images.

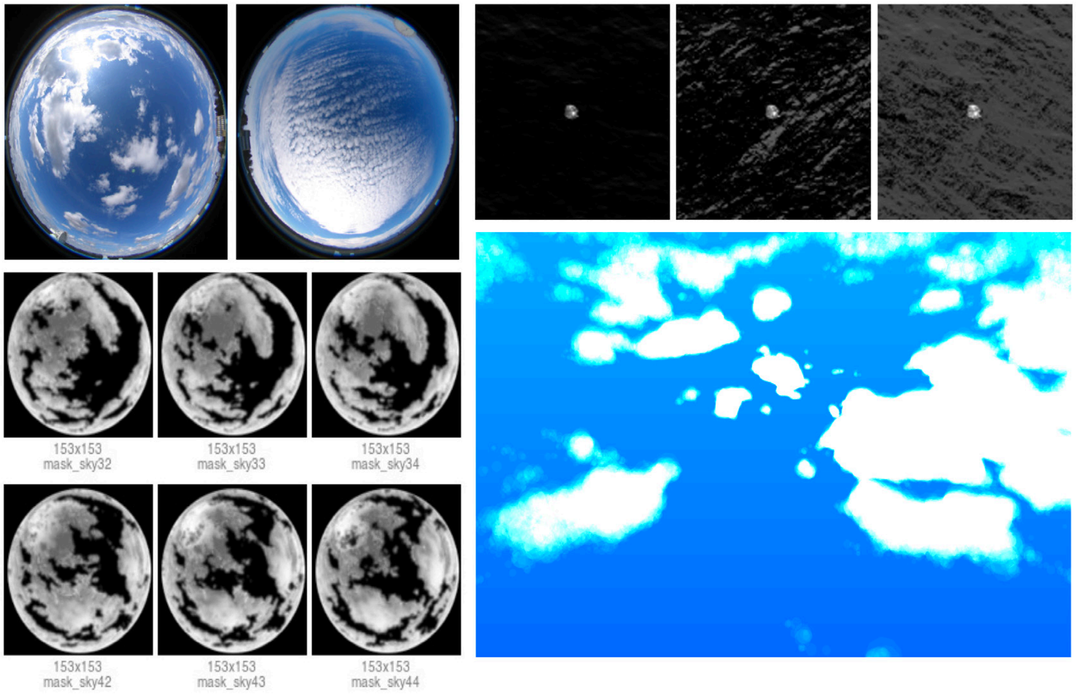


Figure 2: The example sky dome images at the top left are from the RAPACE (Récepteur Automatique Pour l'Acquisition du Ciel Entier) instrument and similar images were used to construct the time series of fractional cloud maps shown below. The final solution uses the fractional cloud cover map and a spectral irradiance model based on Bartlett, et al [1998] to modify the downwelled sky irradiance. The three images in the upper right highlight the impact on the same surface using the two example sky domes (the left most assumes a cloudless sky). The cloud field below it is a visualization of a three-dimensional cloud field generated from one of the dome masks that might be used in the future.

Condensed Water Vapor Plume Volume Estimation

Principal Investigator: Carl Salvaggio

Team: Ryan Connal, Tim Bauch, Nina Raqueno, Imergen Rosario, Meg Borek, Micah Ross

External Collaborators: Brian d'Entremont, Alfred Garrett

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

An ongoing campaign involving the collection of plume imagery from permanent ground stations deployed at the test site, as well as several simultaneous small unmanned aircraft systems (sUAS), has provided a significant amount of data across various meteorological conditions. This dataset has been utilized to train convolutional neural network implementations of semantic segmentation algorithms, such as Mask R-CNN and U-Net. The training of these models has led to an automatic method for segmenting condensed plumes to assist in the generation of 3D volumetric models.

A space carving methodology has been adapted from the simultaneous captures across ground and aerial perspectives. Combined with segmentation provided by the neural networks, and visual localization to determine position and orientation of the instruments, the space carving implementation has generated 3D volumetric models.

Figure 1: Trained Mask R-CNN model inference on imagery captured by drones at mechanical draft cooling tower test site.

DIRS Internal Research and Development

Principal Investigator: Luke DeCoffe

Team: David Conran, Timothy Bauch, Emmett Ientilucci, Carl Salvaggio, Nina Raqueno

External Collaborators: Daniel Kaputa, RIT Department of Electrical and Computer Engineering Technology

Project Description

This project consists of the design, implementation, and operational testing of an onboard, small unmanned aircraft system (sUAS)-based hardware and software reflectance conversion system that can be applied to any spectral sensor. The system uses the at-altitude radiance ratio (AARR) method for reflectance conversion of remote sensing data. Unlike the popular and more commonly used empirical line method (ELM), AARR does not require in-scene calibration targets and has the ability to adapt to dynamic changes in scene brightness throughout a flight. AARR has been moderately investigated for use with multispectral imagery in the past, however, this project explores its application to hyperspectral imagery for the first time.

Project Status

The newly designed and fabricated hardware system, referred to as the RIT downwelling irradiance sensor (DIS), has been successfully implemented and operated during multiple data collects. It has gone through several hardware and software revisions and is nearing the end of its prototype phase. Initial performance in multispectral applications has been remarkably promising and has helped identify various features that would benefit from additional improvements, both in hardware implementations, and more importantly, the implemented reflectance conversion approach. Results for hyperspectral imagery will soon be available, pending data processing. The project is to be completed by late Q3/early Q4 of 2022 and the system will be place in full operation at that time.

Figure 1: The RIT DIS (Version 1) mounted on top of a DJI Wind 8 sUAS platform that carries the DIRS MX2 sensor. This sensor package includes multispectral, hyperspectral, longwave infrared, and LIDAR imaging sensors.

Hyperspectral Video Imaging and Mapping of Littoral Conditions

Principal Investigator: Charles Bachmann

Team: Rehman Eon, Christopher Lapszynski, Gregory Badura

Project Description

This project focused on the development of retrieval algorithms to map littoral conditions from short time-scale series of hyperspectral imagery. Critical underlying factors impacting littoral zone conditions include sediment density, moisture content, grain size distribution, material composition, and roughness. Our modeling efforts have considered radiative transfer models that incorporate hyperspectral time series and multi-view imagery to retrieve these critical geophysical variables. Hyperspectral imagery sources have included a state-of-the-art integrated mast-mounted hyperspectral imaging system developed by Dr. Bachmann, his students, and RIT staff as well as the DIRS UAS-based hyperspectral imaging systems. The mast-mounted hyperspectral system includes the Headwall visible and near-infrared (VNIR) E-Series micro-Hyperspec High-Efficiency (micro-HE) imager, a General Dynamics maritime-rated high-speed pan-tilt unit, and an onboard Applanix GPS-IMU system for pointing, georeferencing, and precision timestamps. At maximum operating rates, the system can produce a low-rate hyperspectral video imagery time series at about 1.5 Hz. Details of the system and purpose are further described in a recent journal article that was featured on the cover of the Journal of Imaging (https://www.mdpi.com/2313-433X/5/1/6).

Project Status

This past year, we published a validation study of a relatively new radiative transfer model for retrieving soil moisture content from hyperspectral imagery. This study considered both laboratory analysis of hyperspectral directional reflectance data froma our hyperspectral goniometer system, the Goniometer of the Rochester Institute of Technology-Two (GRIT-T) (https://dx.doi.org/10.1117/1.JRS.11.046014), as well as the first known field validation of the approach using hyperspectral imagery from the DIRS UAS-based hyperspectral imaging systems acquired contemporaneously with ground truth data (see Eon and Bachmann, https://www.nature.com/articles/s41598-021-82783-3). The field validation campaign took place on a barrier island at the Virginia Coast Reserve LTER site (Figure 1). Using both our mast-mounted hyperspectral system (https://www.mdpi.com/2313-433X/5/1/6) and our hyperspectral goniometer system GRIT-T, our team similarly has developed and validated other retrieval algorithms for sediment geophysical properties based on radiative transfer models in both laboratory and field settings. In these studies, we have used multi-view and multi-temporal hyperspectral imagery from our mast-mounted hyperspectral imaging system to directly estimate the sediment filling factor, which is directly related to sediment bulk density (https://doi.org/10.3390/rs10111758). The study described in this article documents a comprehensive field campaign to validate the methodology using multi-view and multi-temporal hyperspectral imagery of a tidal flat on a barrier island. This work builds on an earlier article (https://dx.doi.org/10.3390/rs10111758) in which we adapted a radiative transfer model inversion approach that we originally developed and validated in our laboratory using our GRIT-T hyperspectral goniometer system. The extended method allows retrieval of the sediment filling factor from multi-view hyperspectral imagery in field settings. In this earlier article, we used both airborne hyperspectral imagery from the NASA G-LiHT sensor suite as well as multi-spectral satellite imagery from GOES-R. Using our GRIT-T hyperspectral goniometer system, we have also published laboratory analyses quantifying the accuracy of a methodology that determines the degree of surface macroscopic roughness from spectral imagery and accounts for its impact on observed directional reflectance (https://dx.doi.org/10.1109/JSTARS.2019.2896592). This article quantified the limitations of a popular current approach to this problem, and for this work, our article received the prestigious IEEE Geoscience and Remote Sensing Society 2020 JSTARS Prize Paper Award. In related work, we have also developed a method to quantify the degree of surface roughness from a direct measure of the variability of spectral response with angle (https://dx.doi.org/10.1109/TGRS.2019.2908170). This work also used the GRIT-T hyperspectral goniometer system (https://dx.doi.org/10.1117/1.JRS.11.046014), a system which received the 2017 Best Paper Award, Photo-optical Instrumentation and Design, in the Journal of Applied Remote Sensing (https://spie.org/about-spie/press-room/press-releases/spie-journal-of-applied-remote-sensing-honors-three-with-best-paper-awards?SSO=1).

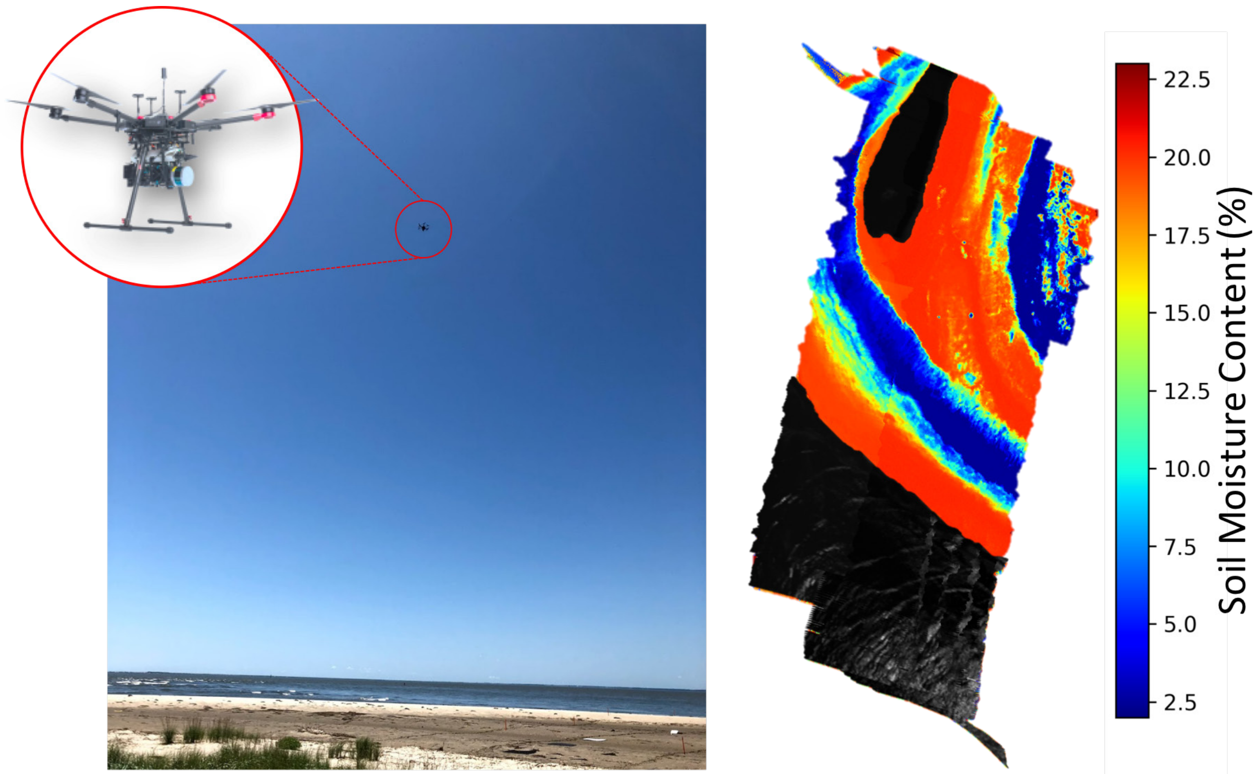


Figure 1: Hyperspectral retrieval of soil moisture content retrieval using a radiative transfer model of hyperspectral imagery from the DIRS UAS-based hyperspectral imaging systems described in our recent publication (Eon and Bachmann, https://www.nature.com/articles/s41598-021-82783-3). The field validation campaign was undertaken at the Virginia Coast Reserve LTER site.

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, Carlos Barrios, Reed Terdal, Austin Martinez

External Collaborators: Tania Kleynhans, Hydrosat; Larry Leigh, South Dakota State University; Jeff Czapla-Myers, University of Arizona; Simon Hook, NASA's Jet Propulsion Laboratory

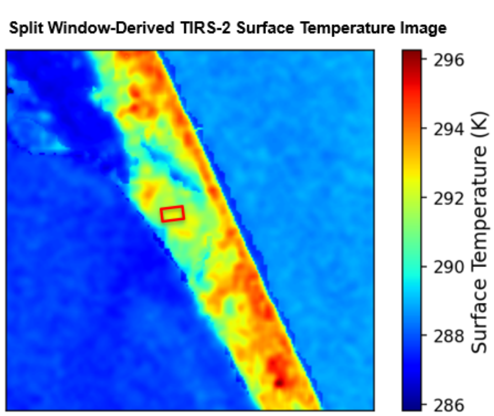
Project Description

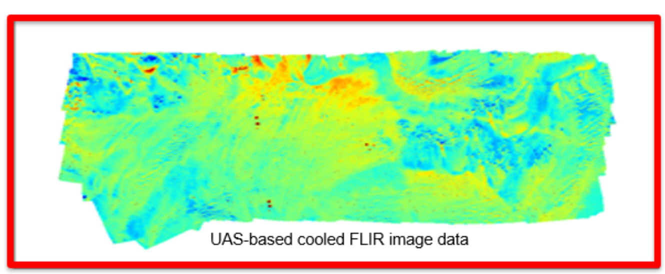
The United States Geological Survey at EROS is committed to providing calibrated Landsat flight data to support consistent and traceable higher-level science outcomes. As a research institution, RIT is committed to investigating techniques and methodologies to support the sponsor's goals of providing users with high-quality, calibrated image data and validated higher-level science products. Through simulation and modeling, the Landsat group at DIRS continues to provide high-quality reference data to support the calibration of spaceborne thermal sensors, specifically the TIRS-class sensors onboard Landsat 8 & 9 for this work. To address a deficiency in ground-reference data necessary for product validation, specifically surface temperature validation, RIT continues to develop and characterize a prototype radiometer that would significantly enhance validation efforts.

Project Status

Landsat 9 was launched on 27 September 2021, making this a significant year for the Landsat group within DIRS. In addition to the nominal efforts described above, RIT was involved in the planning and execution of several experiments designed to provide an initial characterization of the TIRS-2 instrument and its associated higher-level thermal products. Most notably, a comprehensive ground-campaign was conducted during the Landsat 9 under-flight of Landsat 8 in the Outer Banks, North Carolina. To support this inter-comparison opportunity, RIT acquired full-spectrum reference data with its ground-based spectrometers and its extensive UAV-based sensors.

While the main thrusts of this program continue to mature (i.e., our forward modeling process to support calibration and our thermal radiometer design to support validation), an emphasis will be placed on data-dissemination during year 4 of this five-year effort. The desired product at the end of this five-year effort is a website that houses (unscrubbed) data-driven reference data to support spaceborne thermal sensor calibration and validation data acquired from the RIT radiometer network. All work in on schedule and progressing nominally.





Site	UAS FLIR (K)	FTIR (K)	TidBit (K)	L8 SW (K)	L9 SW (K)
OBX Dunes	289.9	290.3	-	291.8	291.9
OBX Bay-side Water	287.5	-	286.7	287.5	287.8
OBX Ocean-side Water	-	-	288.2	288.4	288.7

Figure 1: Landsat 9 image of the Outer Banks, NC (left) where a ground campaign was conducted to acquire reference data to support underflight activities. The maiden flight of RIT's cooled FLIR sensor was successful and its image data (top right) used for comparison to satellite measurements. The table (bottom right) shows comparisons of reference measurements to L8 and L9 image data. Results of this study provide insight into the early behavior of Landsat 9.

Simulation & Modeling to Support the Definition of Requirements for Future Landsat Payloads

Principal Investigator: Aaron Gerace

Team: Rehman Eon, Amir Hassanzadeh, Lucy Falcon, Gabriel Peters, Ethan Poole

External Collaborators: Tania Kleynhans; Hydrosat

Project Description

The Sustainable Land Imaging (SLI) program is committed to extending the nearly fifty-year data record of space-borne measurements of the Earth's surface collected from Landsat's reflective and thermal instruments. Through the development of a system of space-borne sensors, and perhaps the inclusion of alternative data sources, the SLI program is interested in identifying cost-effective solutions to acquiring consistent and continuous data to support science applications related to the monitoring of Earth's natural resources. To support these interests, the Rochester Institute of Technology is performing studies that investigate the impact of potential system requirements on corresponding science applications.

Project Status

Several studies were conducted by RIT in the final year of this effort to inform future Landsat sensor designs. Considering the proposed band-combination for Lnext (Landsat Next), existing lossless compression schemes need to be modified to accommodate the quantity of data that will be acquired with Lnext. As such, a study was conducted to investigate the impact of image data compression on science fidelity. Conclusions of this study indicate that several levels of (lossy) compression may be applied with minimal impact of science. Additionally, and based on simulated studies conducted in Year 1 of this effort, flight data acquired during the Landsat 9 underflight of Landsat 8 were used to assess the impact of 12- vs. 14-bit systems on higher-level science. Finally, to support modelling efforts for future Lnext systems & cross-comparisons of existing sensors, a comprehensive ground campaign was conducted during the L9 underflight of L8.

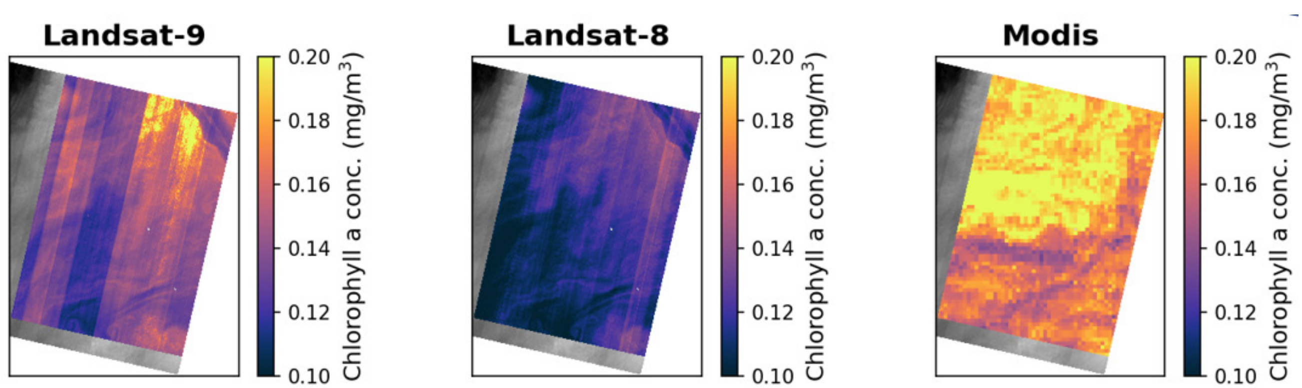


Figure 1: Visual comparison of Chlorophyll-a retrievals associated with Landsat 9 (left), Landsat 8 (middle), and Terra-MODIS (right). Note that these data were collected during the L9 underflight of L8. In general, for the image data used in this study, Chlorophyll-a retrievals for the L9 14-bit system 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.

Development and Validation of Landsat's Thermal Products

Principal Investigator: Aaron Gerace

Team: Rehman Eon, Amir Hassanzadeh

External Collaborators: Tania Kleynhans; Hydrosat

Project Description

The Rochester Institute of Technology has a long history of supporting the calibration of thermal spaceborne sensors and, in recent years, developing and validating associated higher-level surface temperature products. The focus of this five-year effort was to enhance existing, and develop alternative, methodologies for deriving surface temperature products for Landsat's thermal archive. Accordingly, RIT developed two workflows to derive surface temperature for Landsat's broadband and dual-band suite of thermal sensors. A significant finding in this work indicates that care must be taken with respect to sensor design to leverage the split-window algorithm for surface temperature derivation. Significant aliasing, resulting from the offset of the two bands on the focal plane, may occur in the final image product if not properly handled.

Project Status

This five year effort closed 1 August 2022 and was funded by USGS with additional follow-on work by KBR. The single-channel workflow that can be used for Landsat's broadband systems has been integrated into the USGS' Landsat product generation system and is currently offered to users as a Level-2 product. The split-window workflow that is appropriate for Landsat's TIRS-class sensors has been implemented as intended and is ready for production.

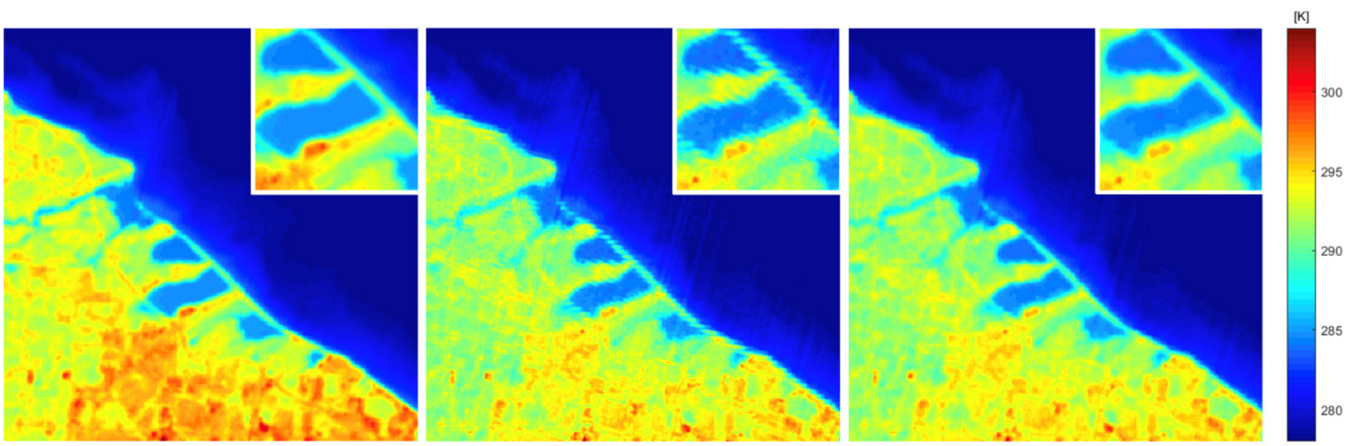


Figure 1: Comparison of the Landsat surface temperature products developed and validated (ongoing) by RIT. The single channel workflow (left) is currently implemented in the Landsat product generation system (LPGS) and is offered to users on EarthExplorer. Aliasing artifacts in the nominal split-window product (middle-zoom) arise due to the offset of the two relevant bands on the focal plane. A simple smoothing technique can be applied without impact on radiometry to mitigate these geometric artifacts (right).

Analysis of NOx Blast Fumes with Drones

Principal Investigator: Emmett Ientilucci

Team: Bob Kremens, Nina Raqueno, Vedant Anand Koranne

Project Description

A private company 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. The company is seeking research into the ability to image these plumes so as to estimate concentration (using image processing and/or 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, generated more smoke grenade data with video cameras at RIT, created visualizations of NOx concentration and synced video data from UAS's into a spatial environment (GIS) for spatial and temporal analysis, and developed smoke segmentation algorithms ready for publication.

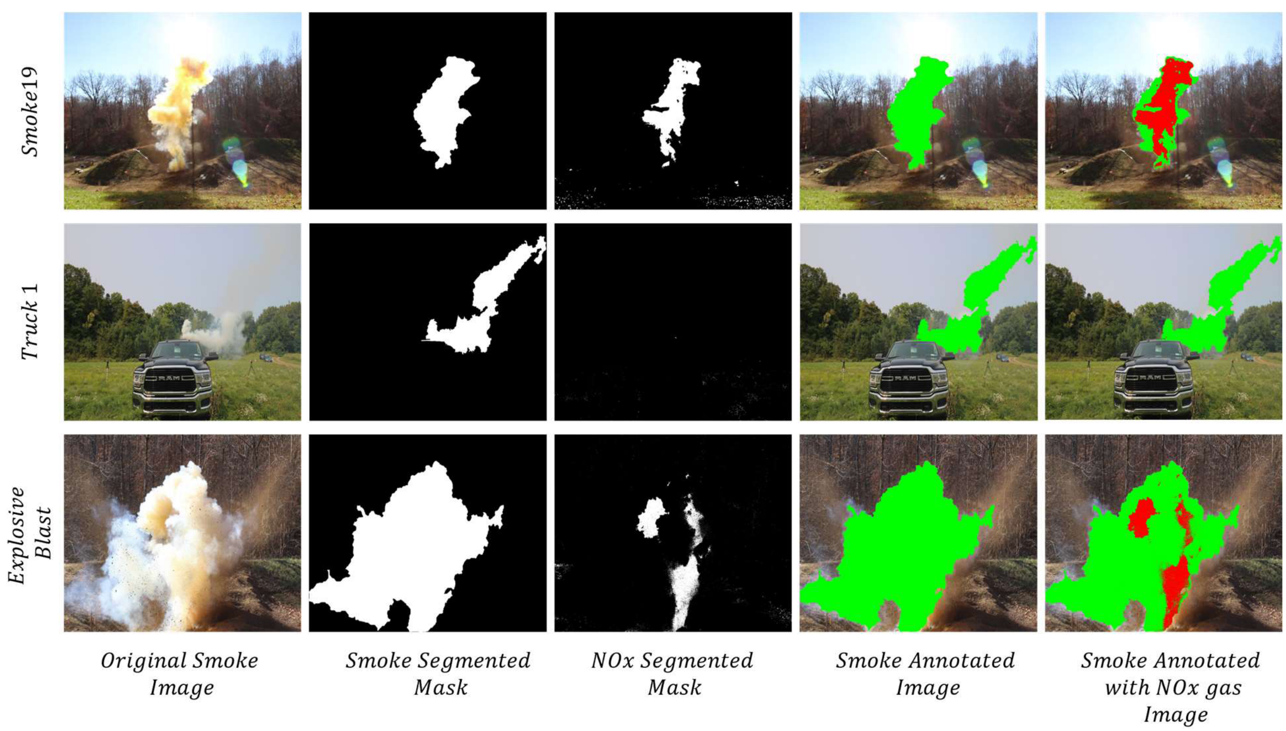


Figure 1: Results of post-blast smoke analysis showing smoke segmented and NOx segmented plumes from various example imagery.

NASA Goddard Space Flight Center

Principal Investigator: Matthew Montanaro

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 final instrument and observatory checkouts for TIRS-2 and Landsat 9 at Vandenberg Space Force Base. The Landsat 9 mission successfully launched and achieved final orbit in the Fall of 2021. The PI led the TIRS-2 instrument calibration commissioning phase during the first four months on-orbit. This work involved the successful power-up and activation of the instrument, initial image data flows and quality checks, acquisition of characterization data to verify instrument requirements, updates and delivery to USGS of detector calibration coefficients, final assessment of stray light, and troubleshooting and resolution of anomalies. The PI represented the Calibration team at mission handover reviews and presented characterization data and requirement close-out data. Since the observatory has become fully operational, the PI continues to assist the Flight Operations Team with routine operations and recovery from instrument anomalies. Additionally, the PI led an effort to acquire a special image acquisition of the May 2022 total lunar eclipse with Landsats 8 and 9 that was featured as a NASA Image of the Day (https://earthobservatory.nasa.gov/images/150043/landsat-looks-at-the-moon).

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. Team members also supported the Landsat 9 underfly of Landsat 8 during the Landsat 9 commissioning by performing field measurements and comparing to on-orbit image data for calibration and validation purposes. The team also continued to provide input for future Landsat thermal band architecture studies and the PI began a new role defining requirements and assessing instrument concepts for the future Landsat Next mission.

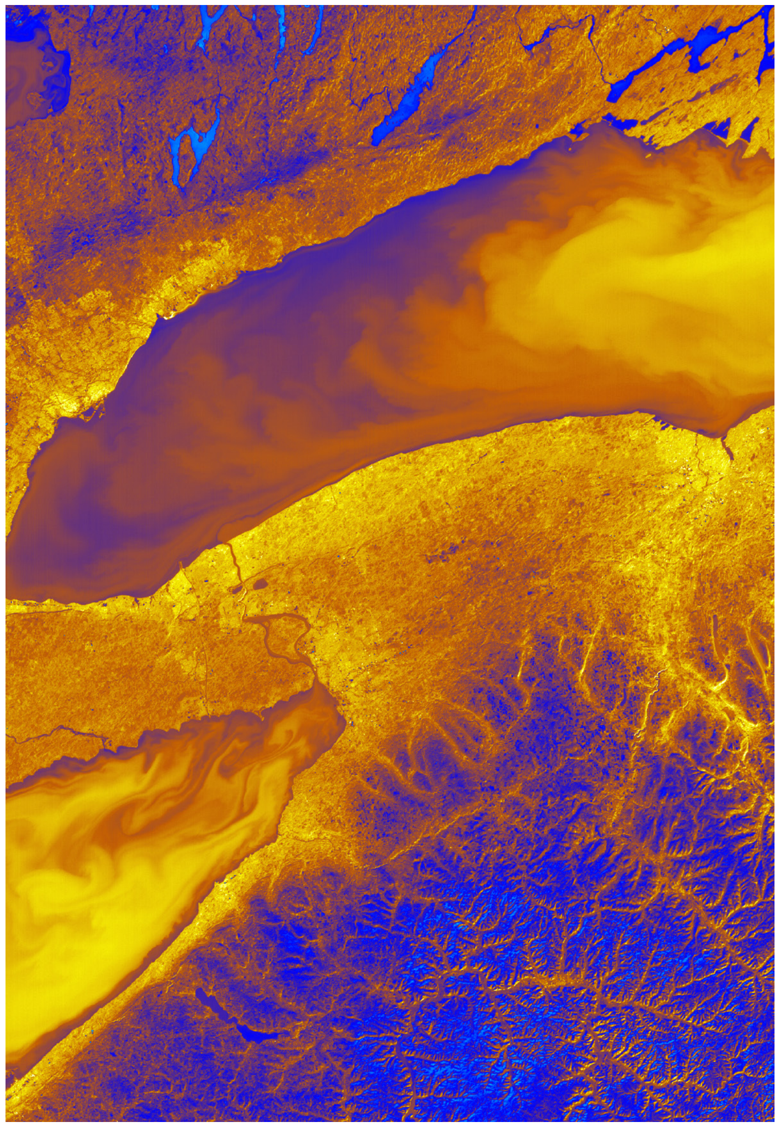


Figure 1: Thermal infrared (10.8 micron) image of western New York from the new Landsat 9 / TIRS-2 instrument acquired on 2021-12-13 during observatory commissioning. Contrast stretched between temperatures of 272 Kelvin (blue) to 283 Kelvin (yellow). Image width is 185 km with a pixel ground resolution of 100 meters. North is toward the upper left.

Vicarious Radiometric Calibration of Satellites using Mirrors

Principal Investigator: Emmett Ientilucci

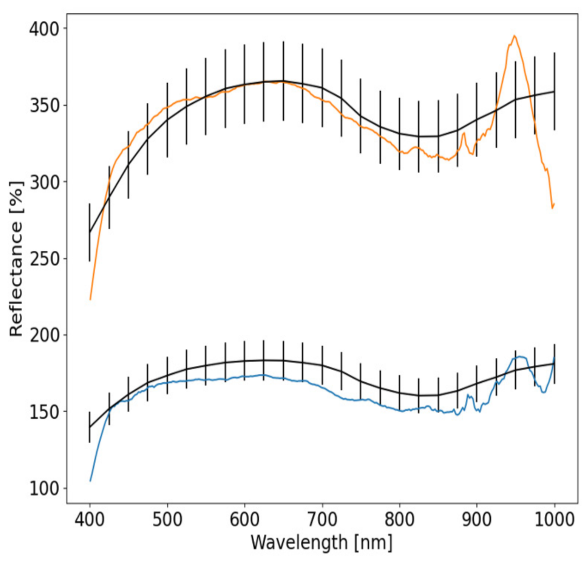
Team: David Conran

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. Laboratory based studies on the radiometric, spatial and spectral performance of HSI systems is currently in development.



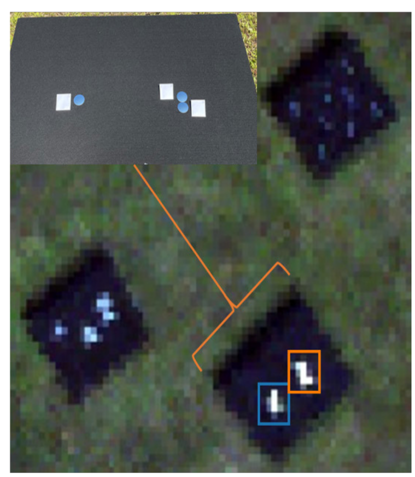


Figure 1: (Left) Surface reflectance validation of the mirrors highlighted in the right image. The orange and blue curves are extracted signals from a calibrated image using a two-point ELM with Permaflect targets. The black curves are predicted surface reflectance estimates from the SPARC equations with an estimate of the uncertainty. (Right) The image used in this analysis. These results were published and presented at IGARSS 2022.

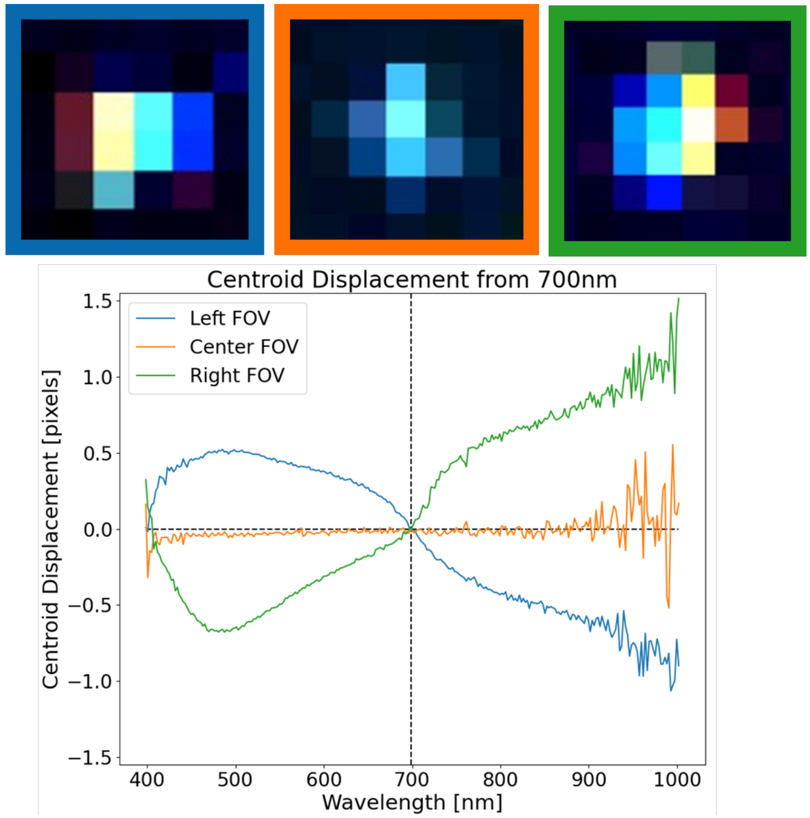


Figure 2: False color composite image (R-900nm, G-700nm, B-500nm) of the Headwall Nano's SPSF. Using the three selected wavelengths, the spectral separation can be easily identifiable with unique field-of-view dependencies. Performing this analysis under field conditions provide the best estimate for overall spatial performance of the HSI system.

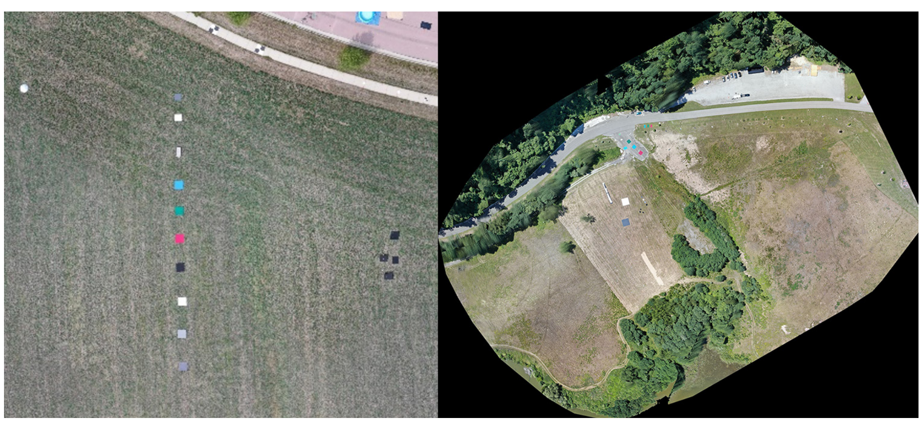


Figure 3: (left) USGS EROS hosted a multi-agency field campaign (BigMAC) between August 30 and September 3, 2021 in Brookings, South Dakota, USA, at the Research Park for South Dakota State University (SDSU). This overview image highlights the area under investigation (alfalfa field) where reflective targets were deployed for calibration and validation. The BigMAC campaign was designed to understand different technologies (i.e., spectrometer and drone based HSI) for surface reflectance calibration/validation of current and future Landsat missions. (right) An overview image of the Ground to Space CALibration Experiment (G-SCALE) which was a large field campaign conducted at the Tait Preserve in Rochester, NY on July, 2021 in cooperation with RIT, the National Research Council of Canada (NRC), Labsphere, Inc., and MAXAR Technologies. G-SCALE was a campaign designed to calibrate and validate drone, airplane, and satellite based imaging systems using SPARC technology. Results in Figure 1 stemmed from this highly successful field campaign.

Shadow Detection and Mitigation in Satellite Imagery

Principal Investigator: Emmett Ientilucci

Team: Mike Gartley, Scott Couwenhoven

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 simple 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. We are getting ready to submit this algorithm, along with results, to a journal. On the ML front, we have proposed a weakly-supervised, multitask framework for training a convolutional neural network to solve the problem of cloud shadow mitigation given only cloud and shadow masks as labels. The network minimizes the Wasserstein distance between shadows and their proximal sunlit neighborhoods, generating a supervisory signal directly from within the input image. We extract further utility from the shadow mask through multitask learning by introducing an auxiliary task of shadow segmentation. Our approach is advantageous since it performs mitigation in an end-to-end framework which requires only a shadowed image for inference. We apply this process to the Landsat 8 OLI SPARCS validation data set and demonstrate plausible results. This work has been published in IEEE IGARSS 2022.

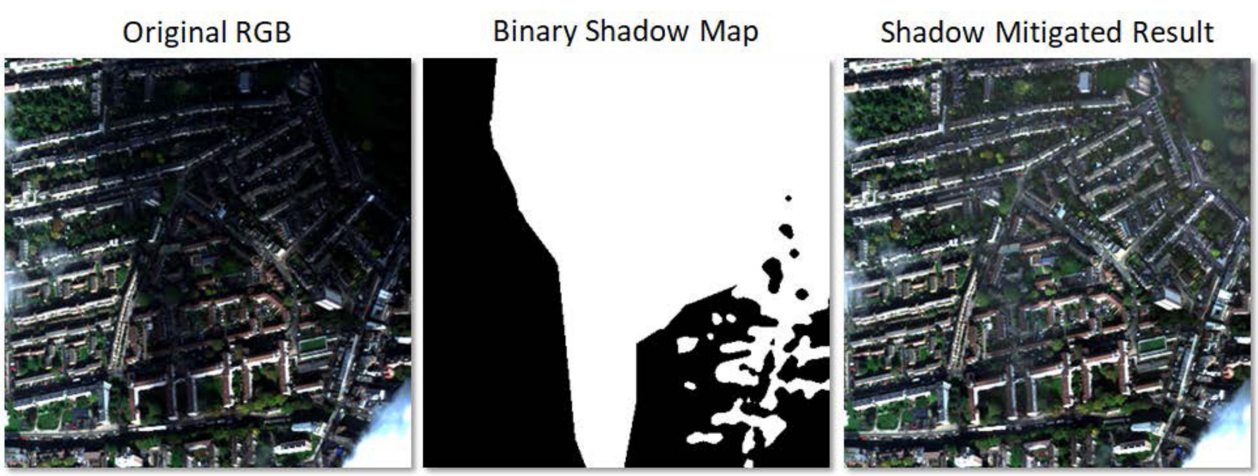


Figure 1: Images showing (left) original RGB, (center) original binary cloud shadow mask, and (right) shadow mitigated result for an urban Worldview-2 scene.

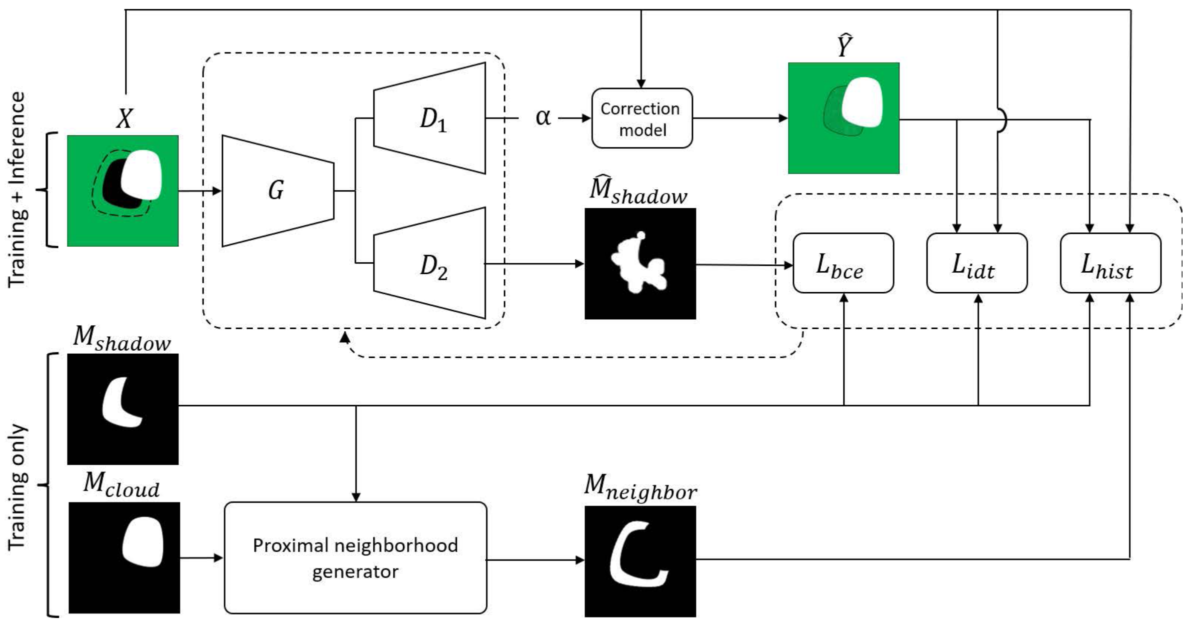


Figure 2: Schematic of our framework used to train the CNN. The three major loss terms computed are binary cross-entropy L_bce, identity L_idt, and histogram L_hist.

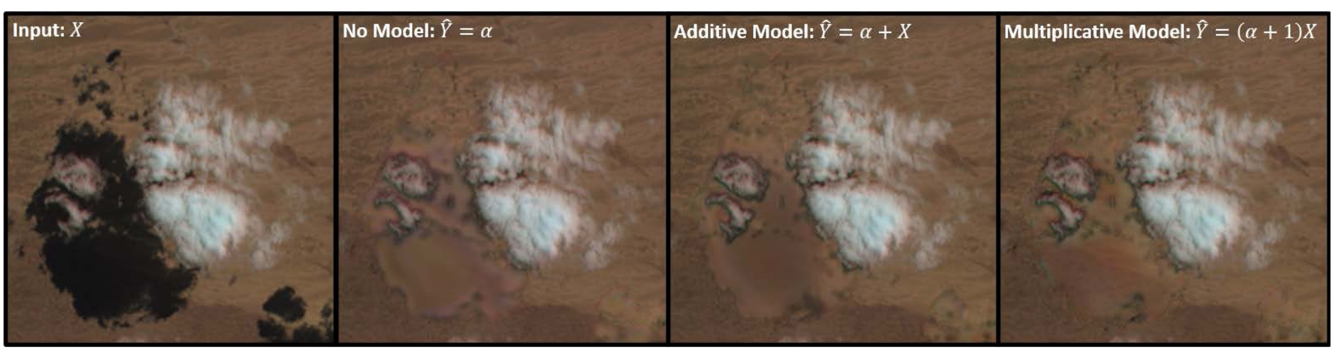


Figure 3: A comparison of results from identical experiments using different correction models. All solutions yield similar histogram matches despite massive differences in mitigation quality.

Multi-spectral, Multi-temporal, Space-based, Atmospheric Compensation

Principal Investigator: Emmett Ientilucci

Team: Mike Gartley, James Albano, Sarvani Bhamidi

Project Description

In many applications, ground-leaving reflectance data is needed to fully understand the desired phenomenology in the obtained observations. Of course, measured sensor data is altered by spectrally dependent effects due to the atmosphere, particularly molecular absorption and Rayleigh and aerosol scattering (e.g., haze, smoke, fog). Thus, an atmospheric compensation approach is warranted to remove these effects. Most existing atmospheric compensation algorithms, such as Landsat's LaSRC and Sentinel's Sen2Cor, are specifically designed to operate on single image products and do not leverage information collected over time. Leveraging a co-registered temporal series of images can be used to understand changing atmospheric effects over non-changing ground materials or objects. This can lead to a general improvement in surface reflectance retrievals as compared to retrievals from a single image. This work aims to develop a multi-spectral, multi-temporal, space based atmospheric compensation algorithm called, TAAC (temporally adjusted atmospheric compensation).

Project Status

To date, we implement the code to pre-process multi-spectral, space-based imagery from sensors such as Landsat, Sentinel, and Worldview. We are now able to convert all sensors to top of atmosphere (TOA) radiance, which is needed as input to TAAC. We have developed the necessary MODTRAN look-up-tables (LUT's) required to help estimate bottom of atmosphere (BOA) surface reflectance. We have implemented a technique to retrieve aerosol optical depth (AOD) based on the dark dense vegetation (DDV) technique. We have also implemented spatial interpolation algorithms to fill in the missing AOD values. Initial surface reflectance's have been computed and are on-par with those retrievals from Landsats LaSRC and Sentinels Sen2Cor algorithms. We are now working on the temporal aspect of the algorithm. To do this we need to find (pseudo) invariant features (PIF) across a temporal stack of images (i.e., non-changing surface reflectances). This initial code has been written and under test. We also are testing and evaluating spectral band adjustment factors so we can utilize multiple sensor types.

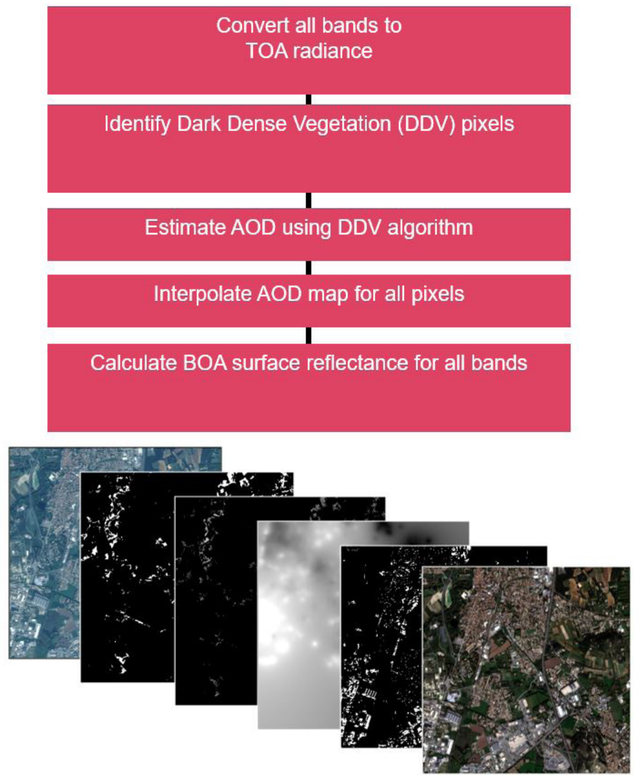


Figure 1: Initial workflow of the TAAC algorithm. We first pre-process satellite imagery to TOA radiance followed by location of dark dense vegetation pixels, followed by estimation of aerosol optical depth (AOD) and in-painting of missing AOD values, spatially, across the image. Lastly we use MODTRAN LUT's, water vapor estimates, and AOD retrievals to estimate BOA surface reflectance.

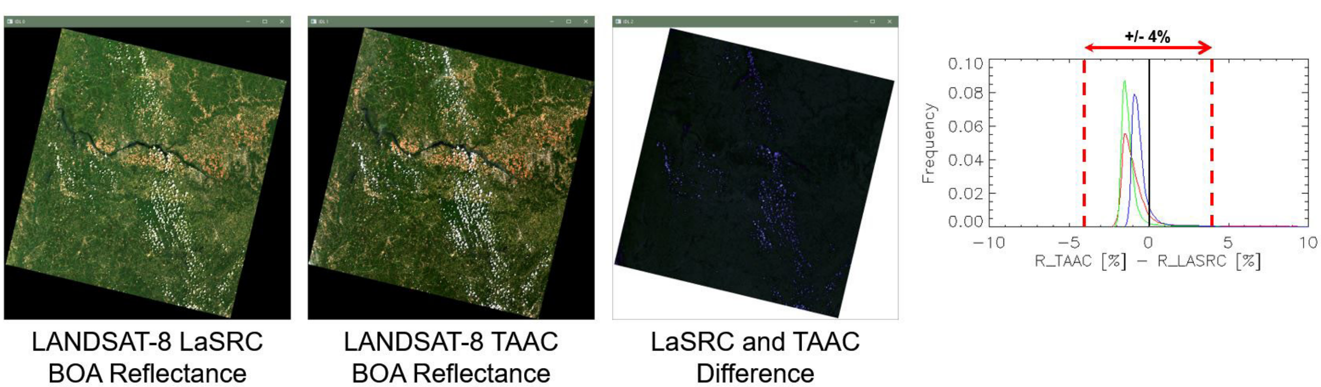


Figure 2: Results of the TAAC algorithm (w/o the temporal aspect yet). Here we see a single temporal image BOA reflectance retrieval by TAAC followed by a BOA reflectance retrieval by LaSRC followed by an image difference. From the residual difference histogram, we can see that we are easily within 4% of LaSRC. We assume LaSRC retrievals are good. We are currently working on comparing to ground truth through the RadCalNet images.

Hyperspectral Target Detection Using Neural Networks

Principal Investigator: Emmett Ientilucci

Team: Emmett Ientilucci, Eddie Lo

External Collaborators: Eddie Lo, Susquehanna University; Department of Mathematics and Computer Science

Project Description

The field of remote sensing involves the study of extracting information about an object without coming into physical contact with it. This definition often includes many disciplines. Remote sensing today is leveraged in a variety of applications, such as environmental mapping, global change research, geological research, wetlands mapping, assessment of traceability, abundance estimation, classification, gas detection, anomaly detection, and target detection. In particular, the area of hyperspectral target detection, using optical remote sensing data, has gained substantial attention in the last decade in various applications such as defense, security, surveillance, and agriculture to name a few. We think of target detection, in this context as the identification of a sparse set of known objects or materials. There have been many publications over the years detailing the variety of detection approaches. Some use vector algebra without statistics to describe the target and background while other rely on first and second-order statistics (i.e., means and covariance, for example). Some algorithms, like the Adaptive Coherence Estimator (ACE), have shown significant promise and seem to outperform many other detection schemes today. However, we note that the field is still evolving. In this research, we take a different approach by illustrating that a single layer neural network can detect subpixel targets in hyperspectral data.

Project Status

We have already finished the development of a statistical TES algorithm (called S-ISSTES) and implemented it into FASSP as well as a cotangent detector which is equivalent to ACE. This resulted in a publication in IEEE Geoscience and Remote Sensing Letters (GSRL). We then integrated this work into the overall FASSP model and showed how the model could be used for trade studies. This work results in a publication in IEEE Transactions on Geoscience and Remote Sensing (TGRS).

Figure 1: Cooke City hyperspectral image with spatial dimensions of 280 × 800 and spectral dimension of 125 channels (i.e., 0.453μm–2.50μm). The target area of interest is highlighted by a red circle

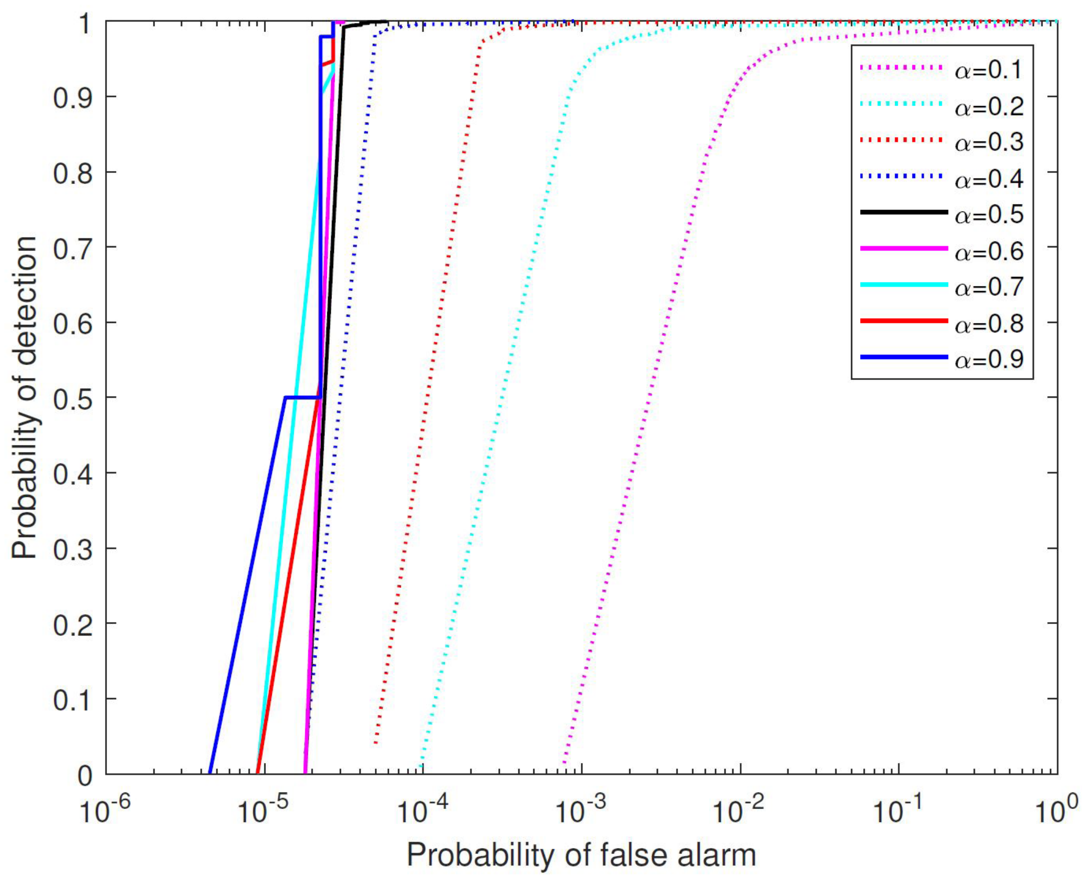


Figure 2: ROC curves generated by iterating the gradient descent method for 100 epochs at different target fill factors alpha.

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

Principal Investigators: Emmett Ientilucci , Susmita Ghosh

Team: Vedant Anand Koranne, Abhishek Dey, and 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 Chapter 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

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 includes shadowed targets, material types over a variety of backgrounds, RGB, VNIR hyperspectral, SWIR, thermal, LiDAR and more recently, SAR. We have flown our MX1 and SWIR instruments coincidental with each other followed by our new IMSAR Ku-band SAR instrument.

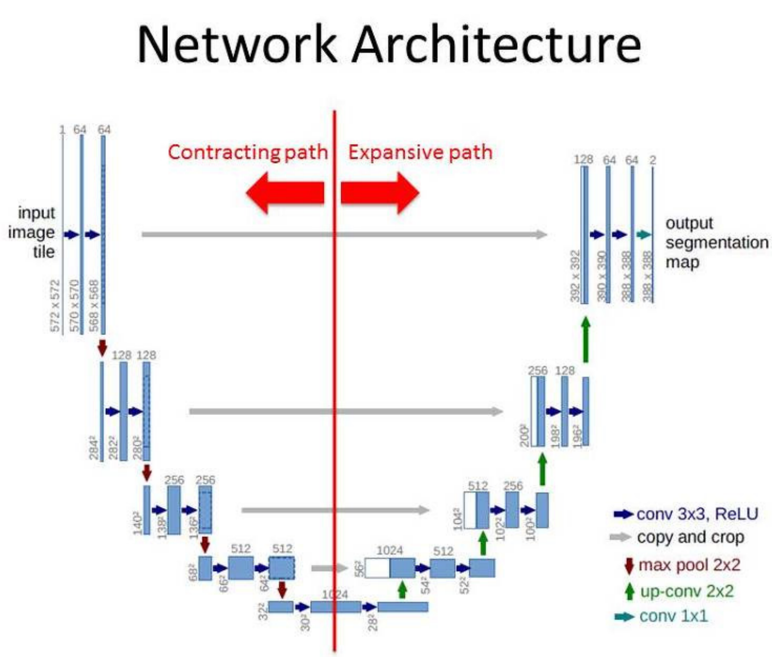


Figure 1: Architecture of our UNet model.

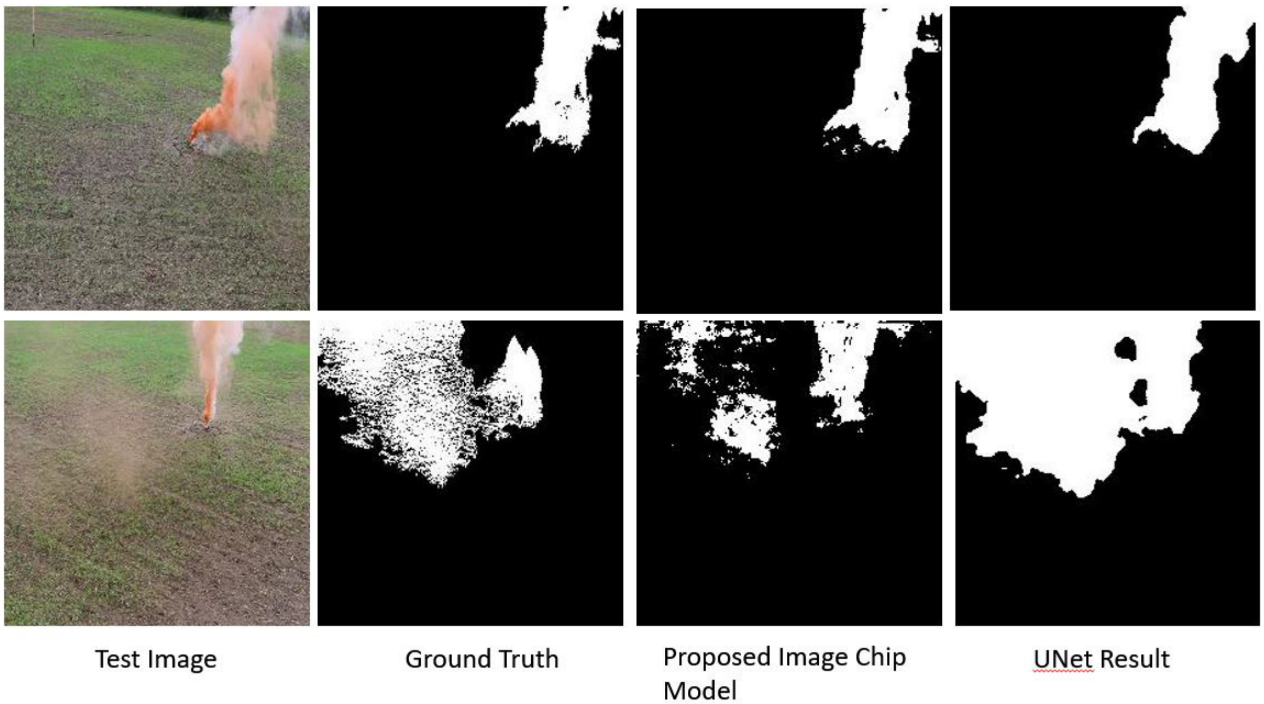


Figure 2: Result of prediction on example images when the proposed model and UNet are trained with 20% of the total images.

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

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

RIT has developed a simulated environment to assess the impact of radiometric error on higher-level science products (surface temperature in this context). A total of 42,000 different simulated condition was established to assess the accuracy of VanZyl-1 in retrieving land surface temperature (LST) using the Split Window (SW) algorithm. The LST error budget as a result of the radiometric and emissivity error is shown in Figure 1. The total LST error budget is derived based on impacts of the radiometric error of the thermal sensor and error associated with emissivity calculation for the SW algorithm.

The research team at RIT is also developing a simulation environment in DIRSIG to better understand the orbital performance of VanZyl-1. We want to observe how the MTF, NEΔT and time delayed integration (TDI) of the sensor affects the imagery collected by the TIR sensor. Figure 2 shows a simulated imagery of the VanZyl-1 thermal sensor (with calibration targets) simulated using DIRSIG.

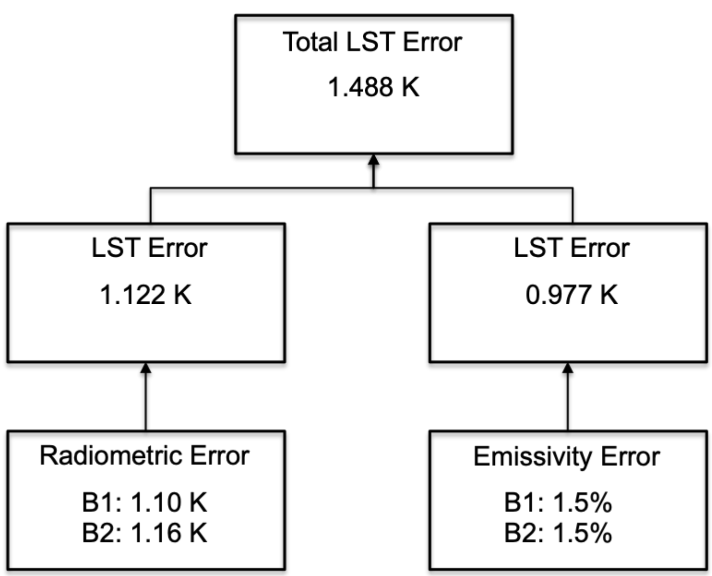


Figure 1: LST error budget for VanZyl-1 due to radiometric and emissivity error.

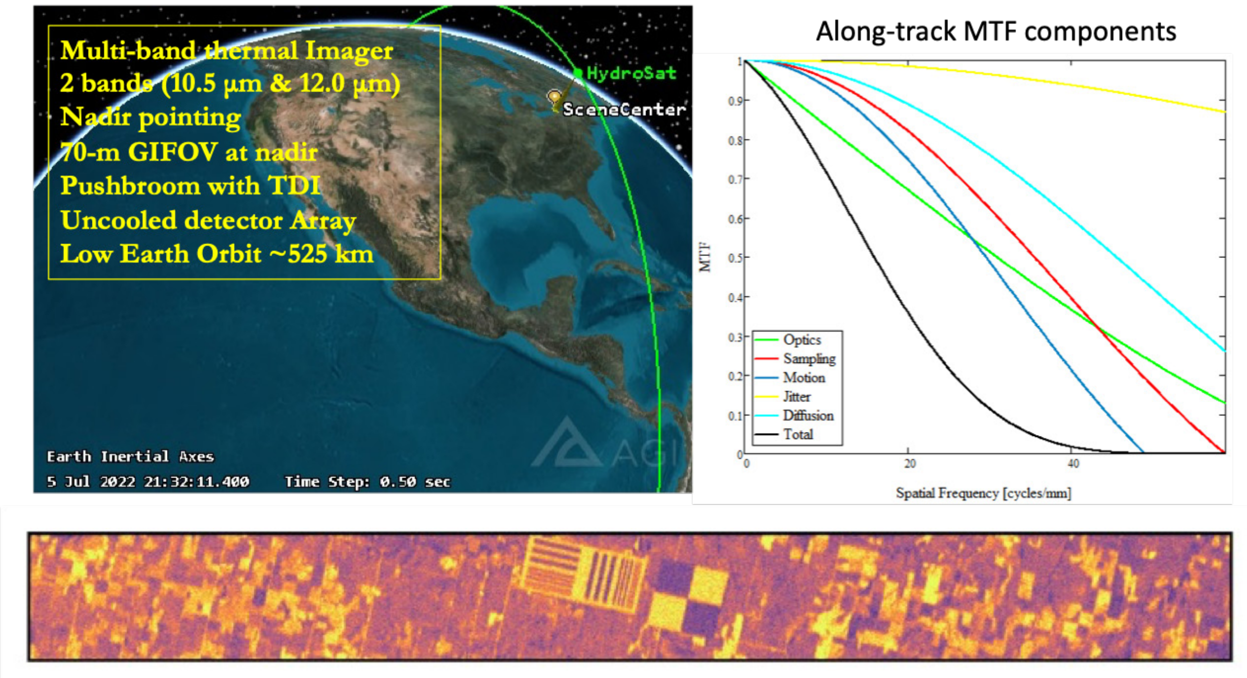


Figure 2: DIRSIG simulated imagery of the Vanzyl-1 thermal sensor.

Model Based Design Tool Development for AI, UAV & Embedded Vision Applications

Principal Investigator: Dan Kaputa

Team: Krystian Derhak

Project Description

As the performance of embedded processors continues to increase and their size, weight, and power [SWaP] continue to decrease, each year ushers in new capabilities and applications that were only dreamed about in years past. Some limiting factors to realizing these new applications are the complex and multi-faceted tool flows that are required to program these new compute devices. For example, a small unmanned aerial vehicle [UAV] can contain C code, VHDL code, linux drivers, and make use of various libraries such as OpenCV and artificial intelligence [AI] constructs. Cobbling these somewhat disparate languages, constructs, and tool flows together can be a daunting task and ultimately result in significant 'churn' as requirements, design concepts, and implementations bounce between systems engineering, software engineering, electrical engineering, etc. This project focuses on enhancing the capabilities of the Mathworks tool ecosystem by baselining the existing tools for various applications as well as extending the tools based upon lessons learned during specific use case implementations. The major focus areas of this project are stereo vision, artificial intelligence, and unmanned aerial vehicles. Extensive use of the code generation tools [Simulink Coder, HDL Coder] will be used as well as HDL Verifier and the newer hardware targeting tool flows for AI and streaming video. This project will make use of the Xilinx Zynq 7020 SoC which is featured on the Snickerdoodle 7020 SOM [www.krtkl.com] compute engine for all three core technologies mentioned above.

Project Status

The Mathworks Vision HDL Toolbox and HDL Coder tool flows have been extensively used to demonstrate an FPGA-based real time stereo vision rectification and undistortion algorithm. Images of a calibration checkerboard [Figure 1] were first captured from an FPGA-based stereo camera system and were then used to generate the camera intrinsic and extrinsic matrices. These camera properties were then fed into the Simulink model where the raw images where successfully rectified and undistorted as can be seen in Figure 2. The Simulink algorithm was then converted into FPGA code and successfully run in real time on the FPGA-based stereo camera. Stereo image rectification and undistortion is a necessary step for any stereo imaging system and this simulation and hardware targeting tool flow will greatly ease the development of any new stereo algorithm.

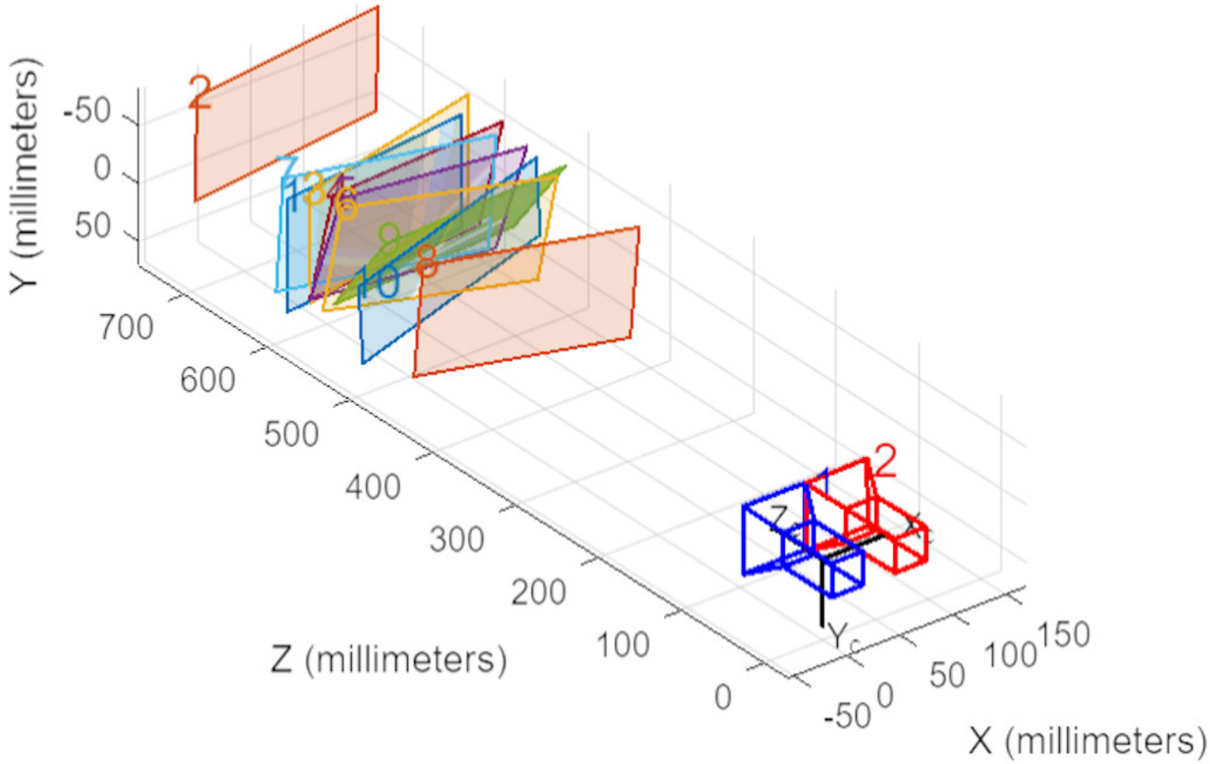


Figure 1: Stereo Camera Calibration with the Matlab Stereo Camera Calibrator App.

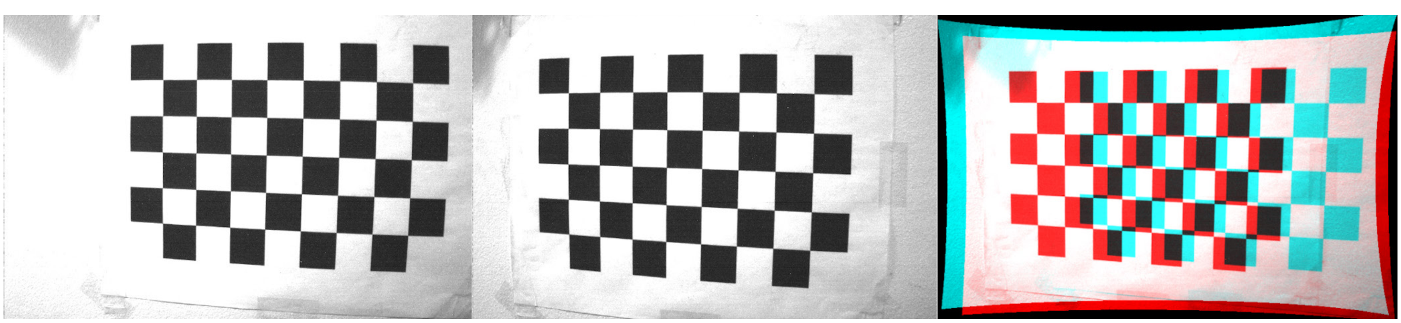


Figure 2: Left Input Image [Left], Right Input Image [Middle], Output Anaglyph [Right]

Air Quality Mapping in Asunción, Paraguay

Principal Investigator: John Kerekes

Team: Yuwei Zhou

External Collaborators: Lauren Prox, Duke University; Guillermo Pallarolas, Aire Paraguay; Richard Baldauf, Environmental Protection Agency

Project Description

Through connections made during Dr. Kerekes' service as a Jefferson Science Fellow at the U.S. Department of State in 2019-2020, a project was organized to augment a ground-based network of air quality sensors with continuous maps of air quality across the city of Asunción, Paraguay derived from satellite imagery. An objective was to understand the spatial and temporal variability of particulate matter 2.5 (PM2.5) across the city as part of an effort to identify suitable locations for placement of a regulatory grade PM2.5 monitor by the U.S. Embassy. PM2.5 data compiled by researchers at Washington University in St. Louis from satellites, ground monitors, and global chemical transport models were analyzed and maps produced to show the spatial and temporal variability of PM2.5 concentration for the region. These data complemented and were compared with point measurements made by the low-cost sensor network operated by AireParaguay.

Project Status

The project was completed in the spring of 2022 with an article documenting the project to be published in EM: The Magazine for Environmental Managers in the July 2022 issue.

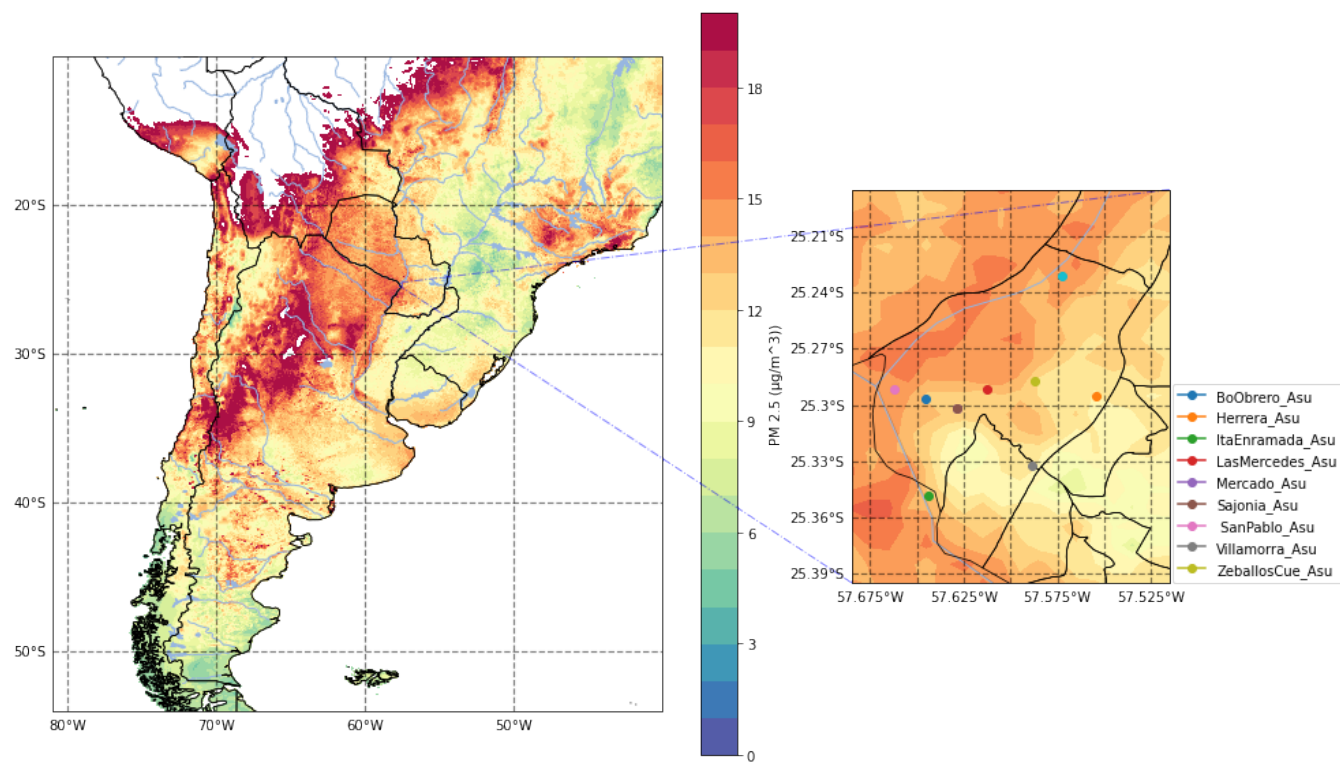


Figure 1: Average surface PM2.5 concentration during February 2020 for a region in South America including Paraguay and is capital Asunción. Data were obtained from the Atmospheric Composition Analysis Group at the Washington University in St. Louis headed by Prof. Randall Martin. The colored dots on the inset are the locations of low-cost sensors operated by the AireParaguay PM2.5 measurement network.

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

With support from an NGA University Research Initiative award RIT has begun exploring research tools 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 first year. During this time an empirical data collection experiment was conducted and the data analyzed to support modeling development and validation. Also, a bottoms-up software rewrite of the analytical modeling approach was initiated and a preliminary version completed. 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.

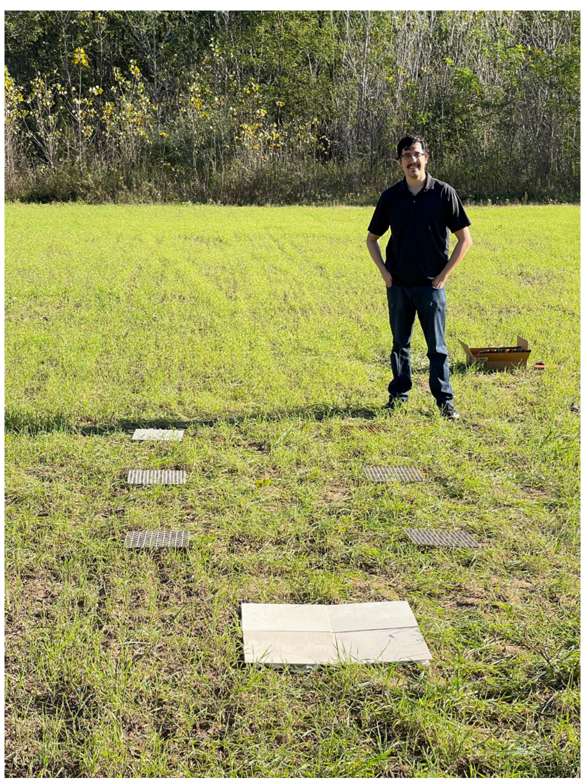


Figure 1: Imaging Science PhD student Chase Cañas observes a set of novel subpixel targets designed by him and deployed during a UAS collection at the RIT Tait Preserve in October 2021.

Autonomous Learning for Full-Spectrum Simulations

Principal Investigators: Alexander Loui, Carl Salvaggio

Team: Byron Eng, Timothy Bauch, Nina Raqueno, Rajiv Mandya Nagaraju, Rudram Joshi, Jacob Irizarry, Jordan Beaupre

External Collaborators: Emmanuel Arzuaga, University of Puerto Rico Mayaguez; Juan Figueroa, University of Puerto Rico Mayaguez

Project Description

When generating synthetic imagery using a model such as DIRSIG, the bulk of the effort is often spent on constructing the scene. The fidelity of the 3D geometry, material definitions, and location accuracy (when modeling a real location) all directly impact the quality of the synthetic data. Advances in the fields of data science and remote sensing have led to new techniques in depth estimation, automated point registration in both 2D and 3D, and semantic segmentation. Combining these techniques can provide estimates for the necessary components of a DIRSIG scene. The goal of this project is to develop algorithms to automatically generate full-spectrum 3-dimensional synthetic scenes using only single band imagery as an input.

Project Status

Researchers from the RIT drone team and UPRM conducted a six-day data collection campaign at the UPRM campus. This multimodal drone data will be used to train and test algorithms and provide input data for the creation of a new UPRM DIRSIG scene. The DIRSIG output data will be used as truth data for algorithm training. A new process was developed in support of this project to convert a set of DIRSIG output images into a 3D point cloud. During this process, DIRSIG truth outputs are used as classifiers to generate semantic labels.

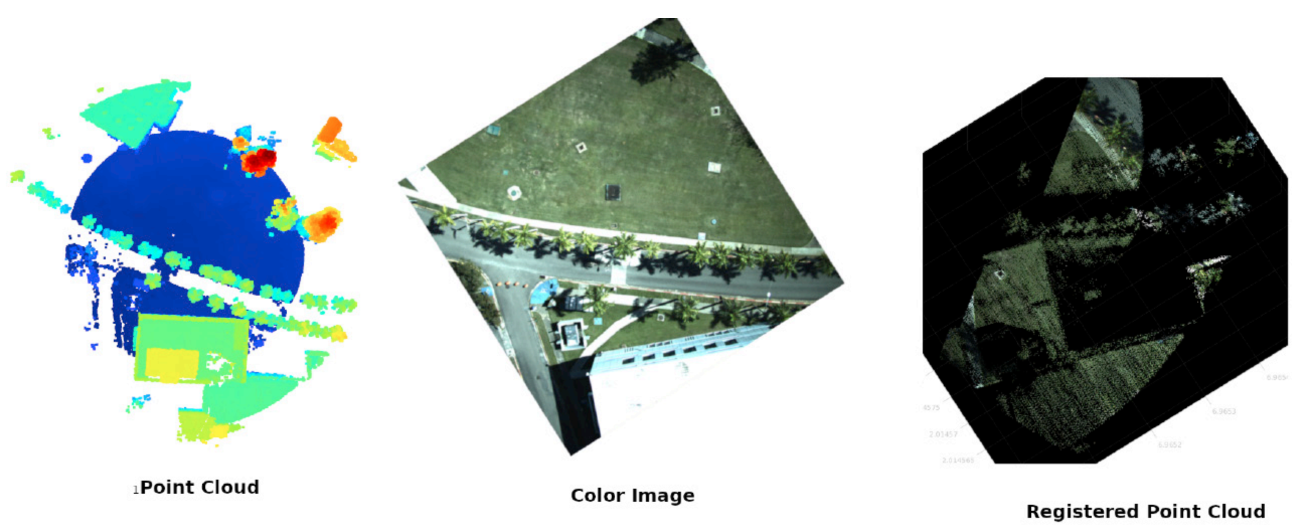


Figure 1: Preliminary output from 2D-to-3D Registration algorithm. The LIDAR point cloud (left) was combined with the RGB image (center) to create a 3D registered point cloud (right

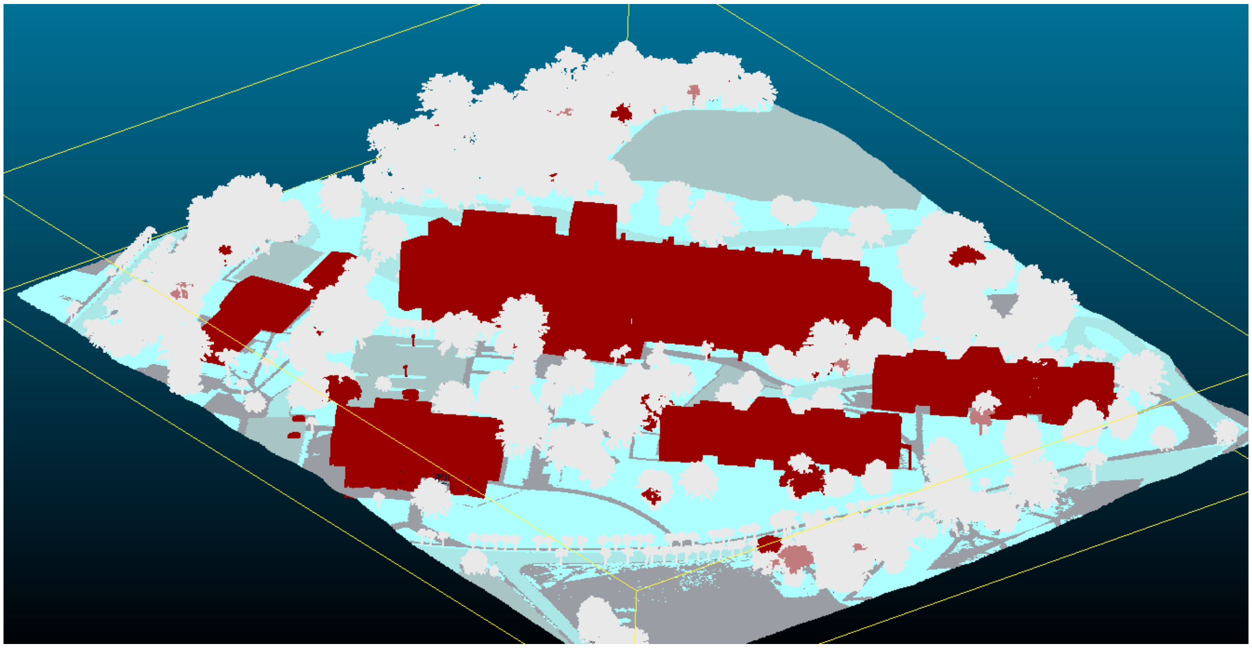


Figure 2: 3D semantically labeled point cloud of DIRSIG truth data from a subset of the UPRM regions of interest.

Estimation of Beet Yield & Leaf Spot Disease Detection

Principal Investigator: Jan van Aardt

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. A total of seven flights have been executed during summer 2021. Hyperspectral imagery, ranging from 400-2500 nm, were collected at seven different stages of plant growth. We currently are working to determine which wavelengths can estimate the yield parameters and at what stages of the growth are they useful. We are looking at narrow band wavelength indices to find the most suitable model. Figure 3.a shows the "heat map" for wavelengths obtained from normalized difference reflectance indices (NDRI), while Figure 3.b shows normalized difference texture indices (NRTI); flight dates are listed in Table 1. NDRI is a placeholder for spectral characteristics, while NDTI reflects texture characteristics. Finally, various feature selection approaches are being investigated to obtain the most suitable model. Concurrently, we have also started collecting data for summer 2022. We are planning to use these data to further validate our approaches.

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.

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

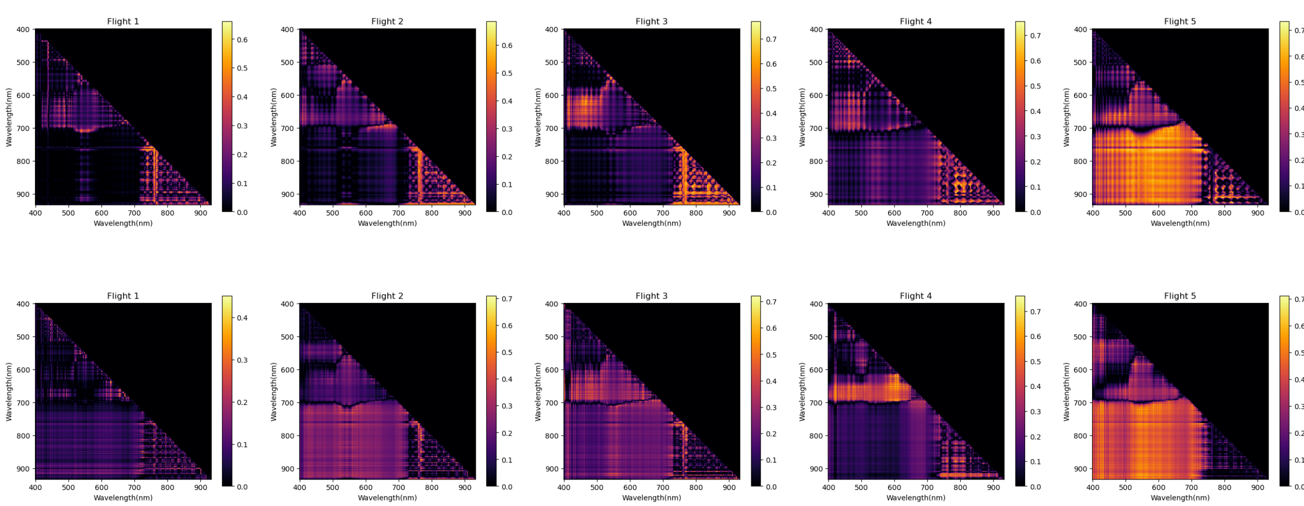


Figure 3: Predictive wavelength index pairs for different seasonal flights; (a; top) shows NDRI and (b; bottom) shows NRTI heat maps. The flight dates are listed in Table 1.

The Influence of Canopy Structure & Foliar Chemistry on Remote Sensing Observations

Principal Investigator: Jan van Aardt

Team: Kedar Patki, Rob Wible, Grady Saunders

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

Project Description

The objectives of this project are to i) better understand the correlations between spectral reflectance and light detection and ranging (LiDAR) 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

Our approach is to use RIT's DIRSIG package to simulate hyperspectral and LiDAR capture over a virtual forest scene, followed by derivation of various spectral indices and structural metrics for analysis. We built a virtual replica of the Prospect Hill area of Harvard Forest, MA, using 3D models of trees from Onyxtree software suite. We embedded optical properties (reflectance and transmittance curves), based on Ecosis and NEON vegetation spectra databases, as well as data from a field collection to Harvard Forest. Our simulations are based on NEON AOP hyperspectral (NASA NIS Imager) and LiDAR (Optech Gemini) imaging instruments. We developed software (Python) to modify 3D models from Onyxtree to conform to desired leaf angle distributions, as well as desired leaf size distributions. We added the ability to apply two or more leaf angle distributions in the same tree model, in order to reflect real tree species, where the LAD changes from top of the canopy to the bottom. Finally, we are capable of simulating different variants of our forest scene, each with a particular leaf angle distribution for deciduous (broadleaf) trees and obtaining spectral and LiDAR data. Figures 1 and 2 show how varying the leaf angle distribution impacts important vegetation indices (NDVI and PRI) and LiDAR penetration metrics (canopy height Figure 3 and intensity ratio). For NDVI (650nm and 850nm) and PRI (570nm and 531nm), we show log histograms of NDVI and PRI "pixels" corresponding to variations in LADs (each relative to peak 45° plagiophile LAD). The change in peaks at 0 values indicate no change for a majority of areas, which covers coniferous regions, swamps, and dead tree regions. For both NDVI and PRI, we observe the peak 0° and 30° curves close together and distinct from the 60° and 90° curves. For PRI, the differences are consistent, whereas for NDVI, differences are most visible around -1 and +1.5. Intensity ratio (defined here as the ratio between sum of return intensities of ground hits and sum of all return intensities) is typically used as a proxy for gap fraction, which is used to estimate LAI via the Beer Lambert's law for forest canopies. Beer Lambert's law assumes a "typical" leaf angle distribution, hence the observed variation due to leaf angle distribution can impact LAI estimation. We observe a similar trend where the ratio values of peak 0° and 30° are close together and distinct from peak 60° and peak 90° curves. The intensity ratio for 0° and 30° curves shows rapid decline, whereas those for 60° and 90° peaks are low and decrease gradually. Overall canopy penetration does not exceed 0.4. As shown in Figure 3, we show a comparison between tree heights (obtained from canopy height maps for each LAD variation and sampled at individual deciduous tree locations) with ground truth heights from tree model information. The mid-range gap in this height distribution indicates more trees in the higher range (20 – 35m) and in the sub-canopy range (0-5m). Otherwise, height distributions are similar for all leaf angle distribution types, except for the peak 90° LAD, which happens due to greater canopy penetration. We are currently working on quantifying the change induced in nitrogen percentage, a key biophysical trait that indicates plant productivity. Here we make use of PROSPECT to estimate ground truth foliar nitrogen content, based on known spectral reflectance curves for various species in our DIRSIG simulated vegetation. We will evaluate how well-known methods, such as models based on wavelength ranges that are highly correlated with nitrogen concentrations (derived from step-wise regression), change in their predictions under varying LAD conditions.

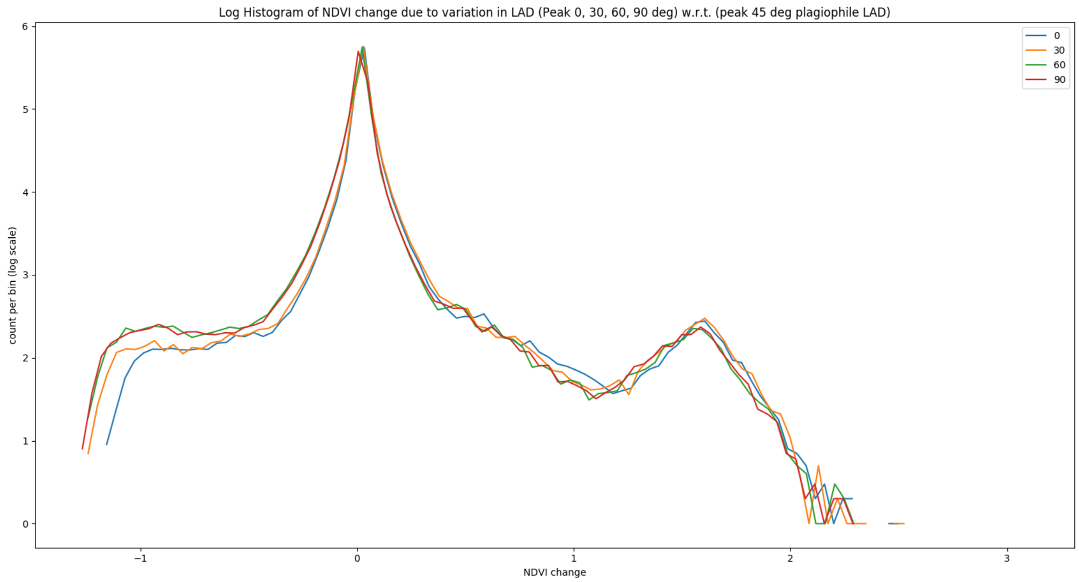


Figure 1: Log histogram of NDVI corresponding to variation in LADs (each relative to peak 45° plagiophile LAD).

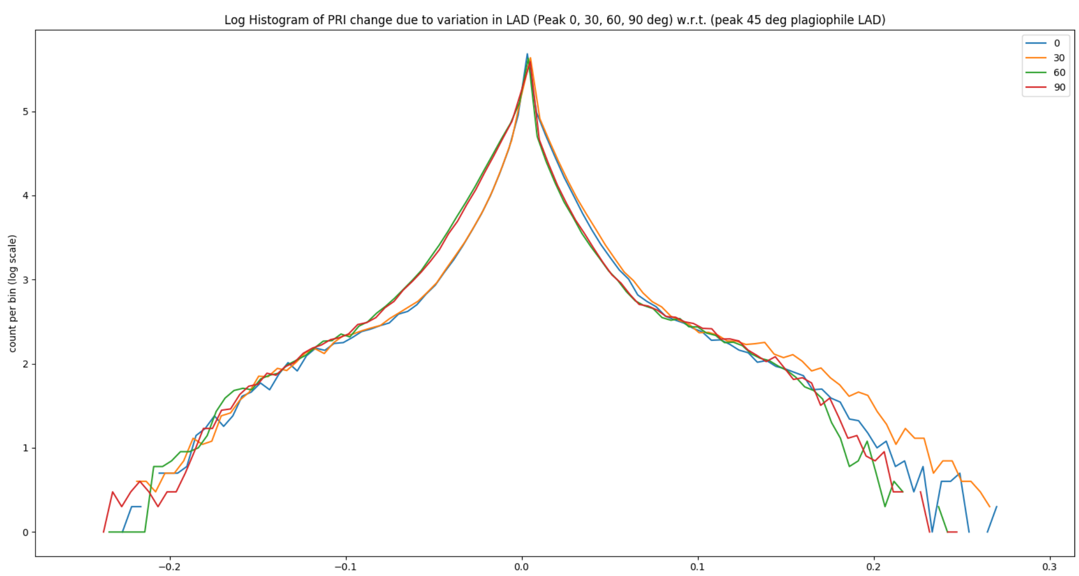


Figure 2: Log histogram of PRI corresponding to variation in LADs (each relative to peak 45° plagiophile LAD).

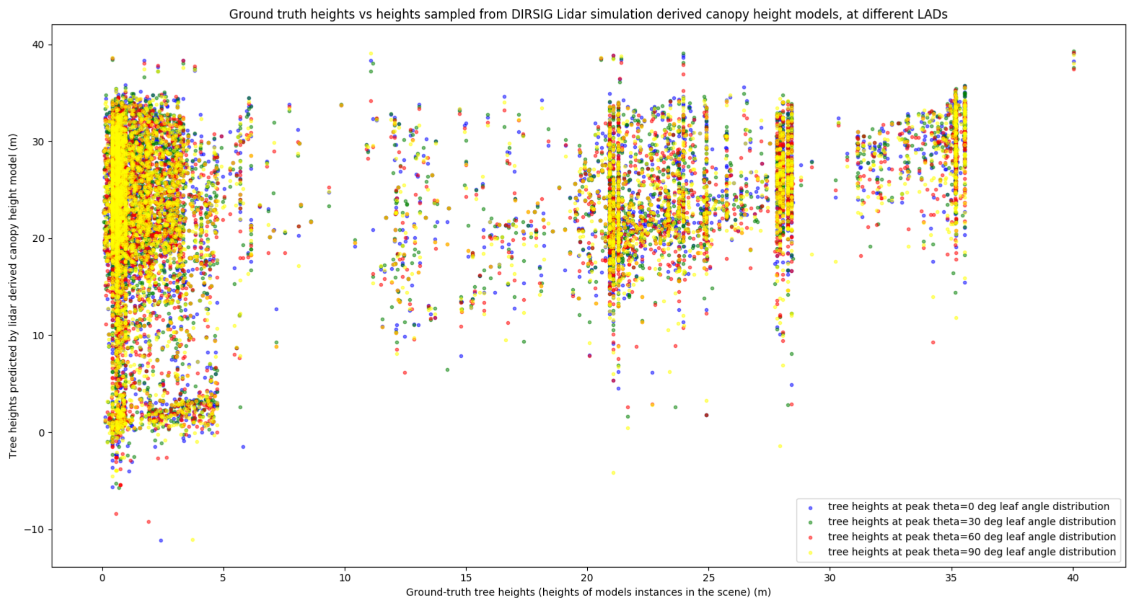


Figure 3: Height distribution comparison between canopy height maps for each LAD variation vs ground truth 3D model heights.

Support to DeepFrame: A Deep-learning Framework for Modeling and Simulation

Principal Investigators: John Kerekes, Scott Brown

Project Description

Modeling and simulation (M&S) are being increasingly used to assist in the development and evaluation of system solutions on faster and more cost-effective timelines. RIT supported I-A-I (now BlueHalo) on an AFRL SBIR to develop a framework for machine learning assisted ingestion of simulation modules to model the performance of surveillance and reconnaissance imaging systems. During this effort RIT provided direct support in the use and application of the DIRSIG simulation tool and its use as a surrogate for imaging system performance modeling as part of I-A-I's DeepFrame modeling and simulation framework. Assistance and examples were provided to assist I-A-I in generating appropriate input files and digesting DIRSIG output files for use in DeepFrame.

Project Status

RIT completed its support in early 2022 and provided a final report to I-A-I.

Enhanced 3D Sub-Canopy Mapping via Airborne/Spaceborne Full-Waveform LiDAR

Principal Investigator: Jan van Aardt

Team: Robert Wible, Yuval Levental, Kedar Patki, Grady Saunders,

External Collaborators: Dr. Keith Krause, Battelle

Project Description

This 3D modeling effort aims to better understand how light detection and ranging (LiDAR) laser light propagates through tree canopies. LiDAR has seen widespread use in measuring 3D vegetation structure, but it is not abundantly apparent how laser light propagates through a multi-layered forest canopy and, critically, which portions of the 3D space have been adequately sampled or remain unsampled. For the first phase of this project, a physics-based, first-principles radiometric model simulation tool (DIRSIG), combined with remote sensing data collected from Harvard Forest, MA, will be used to create a detailed virtual scene of a northeastern forest that accurately models reflectance, transmission, and absorption (380-2500nm) for multispectral, hyperspectral, and LiDAR sensing modalities. The scene will be used for numerous research efforts to include examining the effects of various LiDAR parameters, e.g., wavelength, beam geometry, etc., on sub-canopy detection and using simulated LiDAR as training data for CNN classification of the scene.

Project Status

Scene updates, LiDAR simulations, and early CNN waveform research were conducted over the past year. The latest version of the simulation, Harvard Forest scene v2.6, fixed canopy density issues that led to unrealistic simulated LiDAR outputs. Previous tree canopy models were too dense (twig, branch and bough level objects), thus resulting in high leaf are index (LAI) and leaf angle distribution (LAD) readings. Unrealistic tree gaps in the scene, caused by simple tree models and the inability to accurately place diseased trees, led to very high ground point densities. The ability to realistically model a tree canopy's interactions with lasers is extremely important to the follow-on research projects. Therefore, new models of the trees were created, tested, and placed in the scene, to ensure that their mean LAI value fell within the 1-5 range. The new scene (Figures 1 and 2) has a better overall mean LAI and standard deviation, which has resulted in more realistic LiDAR simulations.

Simulations with varying parameters have been generated for airborne, drone, and terrestrial LiDAR systems. The Gemini ALTM flown on the NEON airborne platform, the VLP16 flown on RIT's MX1 drone, and RIT's SICK LMS-151 terrestrial scanner have all been simulated in DIRSIG and validated against real data (Figure 3). Other sensors, such as the AVIRIS hyperspectral imager and the AccuPAR LP-80 have also been simulated in DIRSIG. We have also created a new process to analyze simulated discrete LiDAR outputs (Figure 4). Initial research into LiDAR parameter optimization for sub-canopy modeling has started. Changes in flight patterns (single pass, crisscross, and spotlight) are currently being modeled. A next logical step involved a machine learning process to classify scene component based on LiDAR returns.

We thus have developed a novel method for using full-waveform LiDAR data to classify sub-canopy areas. This method uses a voxelized Harvard Forest scene to provide classifications based on dominant material IDs within each voxel. The "voxelizer tool", created by Grady Saunders, allows a user to voxelize any portion of a DIRSIG scene. Simulated waveform sensor data from DIRSIG are processed and normalized to provide an intensity map of the scene. The waveform intensity data then are overlaid onto the voxelized scene and assigned a classification. This serves as the training data for the CNN, developed by Yuval Lenvental. The CNN then classifies the voxels into leaves, bark, ground, objects, or background. Initial results are encouraging, as the overall recall was 70% and precision was 66%. Our next steps will involve expanding the data set to increase the training data for each classification and testing the CNN on real airborne data.

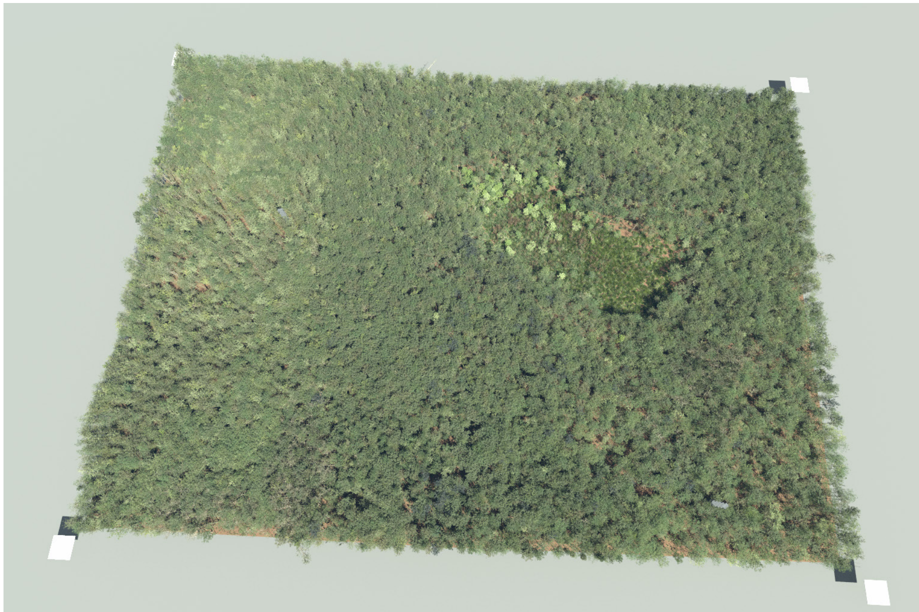


Figure 1: A simulated RGB image of the mega plot scene version 2.6 – oblique view.

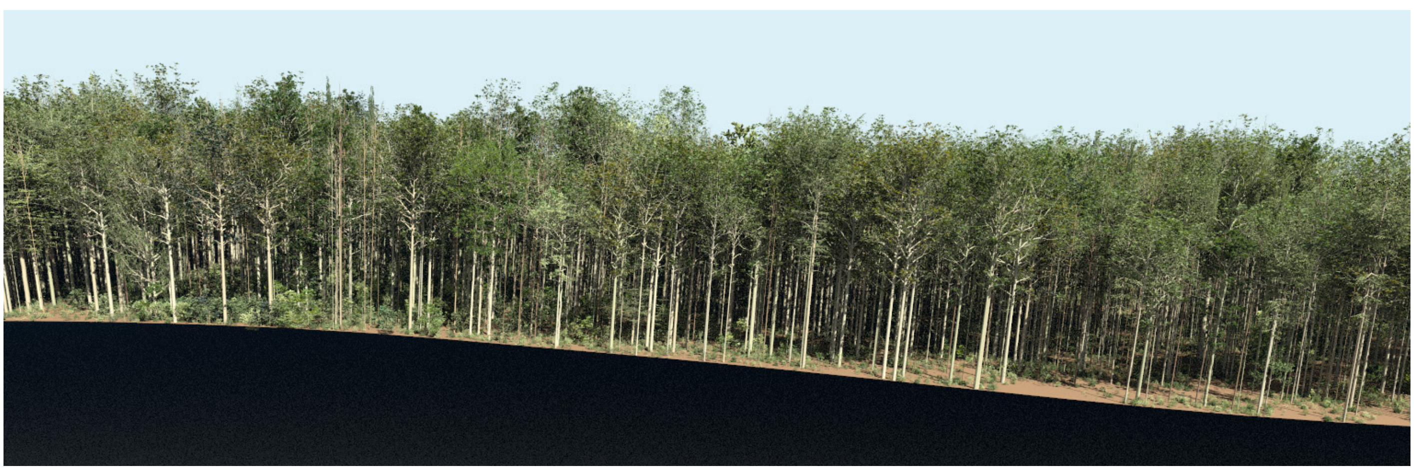


Figure 2: A simulated RGB image of the mega plot scene version 2.6 – side-view.

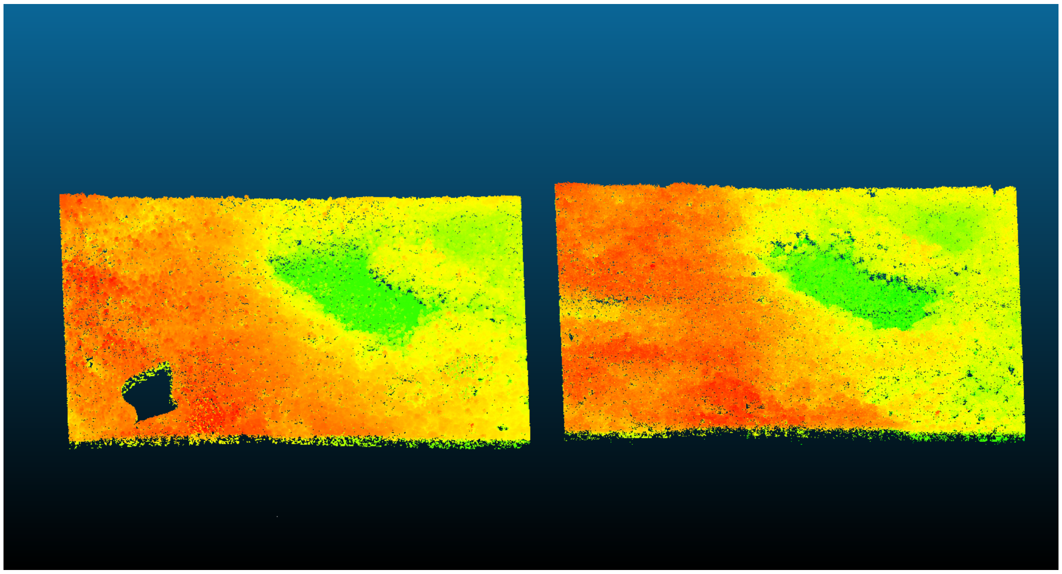


Figure 3: Real (left) and simulated (right) Gemini ALTM LiDAR point clouds of the mega plot scene.

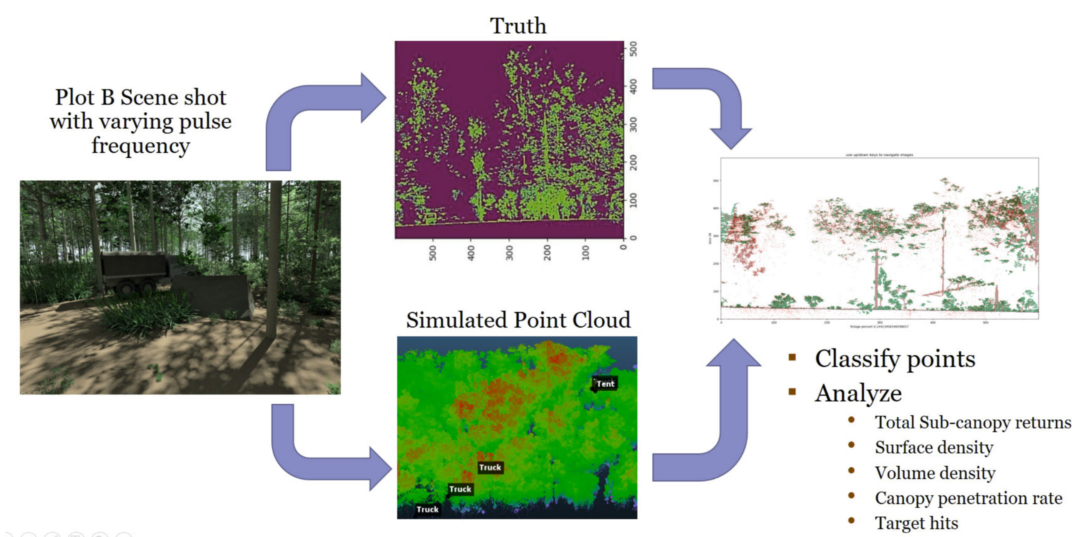


Figure 4: Process for analyzing discrete LiDAR point clouds.

On the Use of Terrestrial Laser Scanning for Structural Assessment of Complex Forest Environments

Principal Investigator: Jan van Aardt

Team: Rob Chancia, Ali Rouzbeh Kargar

External Collaborators: Richard Mackenzie

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

We have begun implementing our existing mangrove surface elevation change procedure into a graphic user interface (GUI) with tools based on open-source Python point cloud libraries (Figure 1). After using our defined scanning protocol, this simple tool can automatically register point clouds and calculate surface elevation change, with no user interaction beyond loading the desired datasets. This will allow forest engineers to offload data from the TLS equipment, upload new data to a data drive or the cloud, and retrieve the desired surface elevation change output automatically.

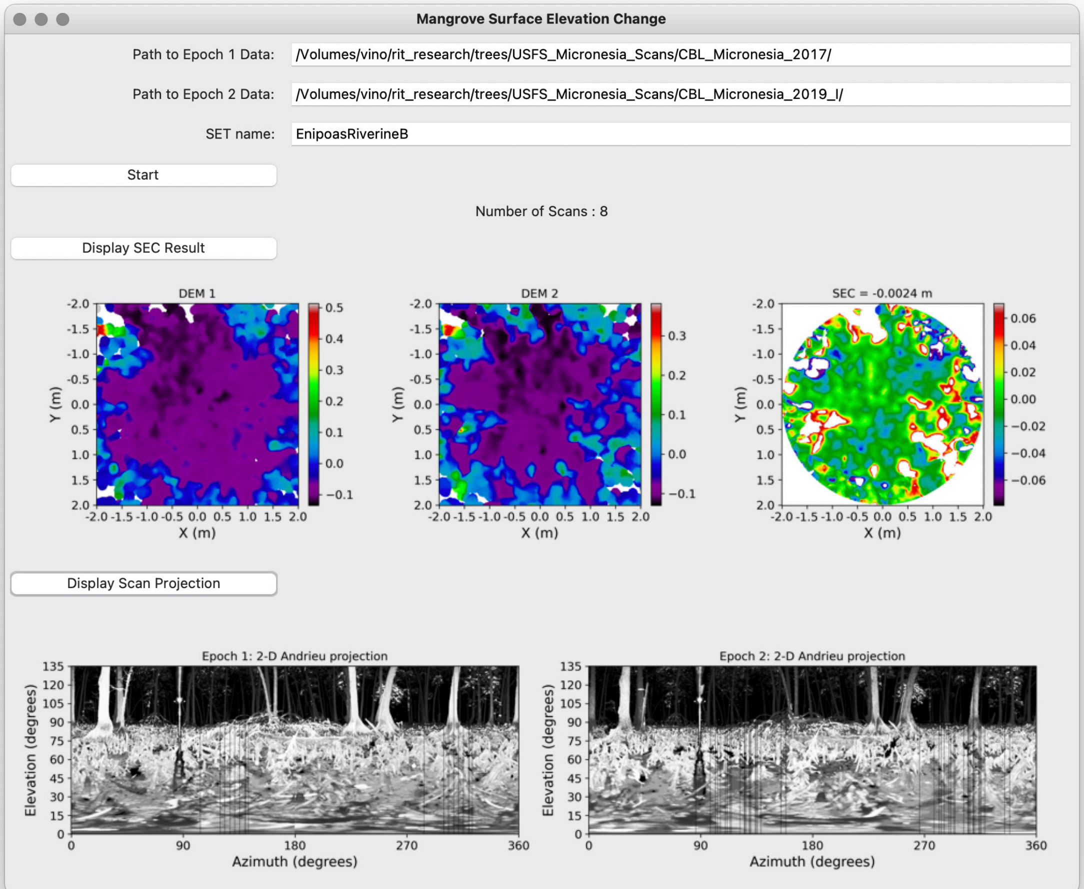


Figure 1: An early iteration of a graphic user interface to completely process two sets of TLS scans, compute surface elevation change, and display the results.

Partnership for Skills in Applied Sciences, Engineering and Technology

Principal Investigator: Anthoy 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

The project is in the initial stages. The hardware will feature Hamamatsu mini-spectrometers configured to measure down and upwelling radiation from just above the surface of a lake. The sky blocked approach will be used, in part to make the measurement with two sensors, rather than three. System integration and testing will be done at the University of Rwanda. A poster describing this work was presented at IGARSS 2022.

HiRes Vineyard Nutrition

Principal Investigator: Jan van Aardt

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

External Collaborators: Terry Bates, Cornell University; Justine Vanden Heuvel, Cornell University; Manushi Trivedi, Cornell University

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 satus 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 two primary sites in Portland, NY and Lansing, NY for the 2022 project year. This year, we also began visiting a new commercial wine vineyard located in Romulus, NY, with increased sample numbers (Table 1). All imagery was captured in coordination with field leaf sampling studies, conducted by Terry Bates at the Cornell Lake Erie Extension Laboratory (CLEREL), and Justine Vanden Heuvel and Manushi Trivedi at Cornell University. Our potassium model, based on imagery and samples from 2020 and 2021, successfully predicted extensive potassium deficiency in the CLEREL Railroad block (Figure 1) before symptoms of deficiency became visually obvious later in the season.

Location	Block	Variety	Area (ha)	# of Vines approx.	Growth Stages	Nutrient Samples per
Portland	Railroad	Concord	2.7	4058	Veraison 2020, Bloom 2021, Veraison 2021, Bloom 2022	12
Portland	Martin	Concord	0.5	567	Veraison 2020, Bloom 2021, Veraison 2021, Bloom 2022	100
Ovid	West	Riesling	1.8	5756	Bloom 2021, Veraison 2021	4
Ovid	East	Pinot Grigio	2.7	4173	Bloom 2021, Veraison 2021	4
Lansing	Riesling	Riesling	0.3	340	Bloom 2021, Veraison 2021, Bloom 2022	31
Romulus	North	Cabernet, Merlot, Valvin Muscat, Zweigelt	3.4	TBD	Bloom 2022	72

Figure 1: The vineyard study sites located in New York State include juice/jelly and wine grape varieties. To date, we have imaged more than 20,000 different vines and sampled ~600 individual vines (Concord) or groups of neighboring vines (wine varieties) over the course of two growing seasons.

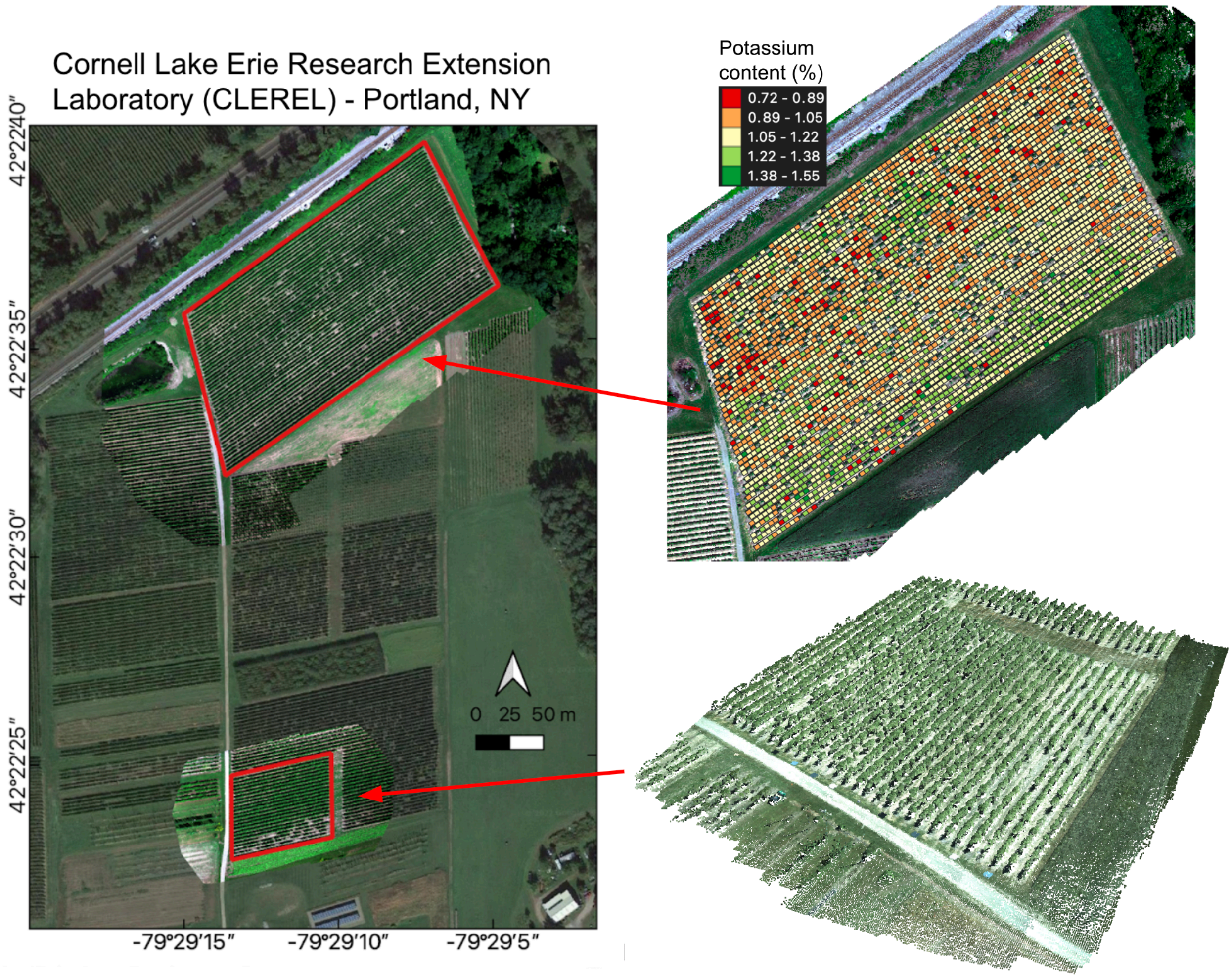


Figure 2: The primary study site located in Portland, NY (left) has provided the majority of our ground truth nutrient data. Nearly half of our data set is comprised on imagery and sampling of the deficiency-induced small southern block, pictured as a 3D structure-from-motion point cloud (lower right). A successful potassium deficiency prediction map (upper right), reveals an extensive region of deficiency even before symptoms of deficiency were obvious later in the season.

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

Principal Investigator: Jan van Aardt

Team: Dr. Carl Savaggio, Amir Hassanzadeh, Fei Zhang

External Collaborators: Dr. 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, namely 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 project section, Part I, focuses on addressing the above-mentioned objectives via hyperspectral UAS-based sensing.

Over the past year we have concluded this study by comparing and contrasting the results of a greenhouse study with the UAS-based field study. We showed that yield and maturity assessment of snap bean is feasible using hyperspectral sensing. The timeframe of 44-55 days after planting (DAP) was found to be of importance for both crop management objectives. Moreover, we identified that the maturity assessment of snap bean, in terms of pod maturity classification, is only feasible for large sieve cultivars (e.g., Huntington). A product of this study was a feature selection library that was released under the name of Jostar, which helps scientists with identifying most discriminating spectral features from a larger set of features.

Due to the complex system properties of hyperspectral sensors, atmospheric effects, UAS equipment influence, etc., we have also determined it is mandatory to remove the unwanted noise after data are collected. We developed a deep learning method, called deep HypeMemNet, for denoising of hyperspectral data, by taking advantage of GPUs for shorter processing times.

Project Status

Our findings have been published in multiple journals as follows:

- Hassanzadeh, A., Lu, G., Zhang, Z., van Aardt, J., Zhang, F., & Chancia, R. (2022). On the Application of Memory Networks for Spectral Denoising - Bridging the Traditional and State-of-the-Art. Ready for Submission
- Hassanzadeh, A., Zhang, F., Murphy, S. P., Pethybridge, S. J., & van Aardt, J. (2021). Toward Crop Maturity Assessment via UAS-Based Imaging Spectroscopy—A Snap Bean Pod Size Classification Field Study. IEEE Transactions on Geoscience and Remote Sensing, 60, 1-17.
- Hassanzadeh, A., Zhang, F., van Aardt, J., Murphy, S. P., & Pethybridge, S. J. (2021). Broadacre crop yield estimation using imaging spectroscopy from unmanned aerial systems (UAS): A field-based case study with snap bean. Remote Sensing, 13(16), 3241.
- Hassanzadeh, A., Murphy, S. P., Pethybridge, S. J., & van Aardt, J. (2020). Growth Stage Classification and Harvest Scheduling of Snap Bean Using Hyperspectral Sensing: A Greenhouse Study. Remote Sensing, 12(22), 3809.
- Hassanzadeh, A., van Aardt, J., Murphy, S. P., & Pethybridge, S. J. (2020). Yield modeling of snap bean based on hyperspectral sensing: a greenhouse study. Journal of Applied Remote Sensing, 14(2), 024519

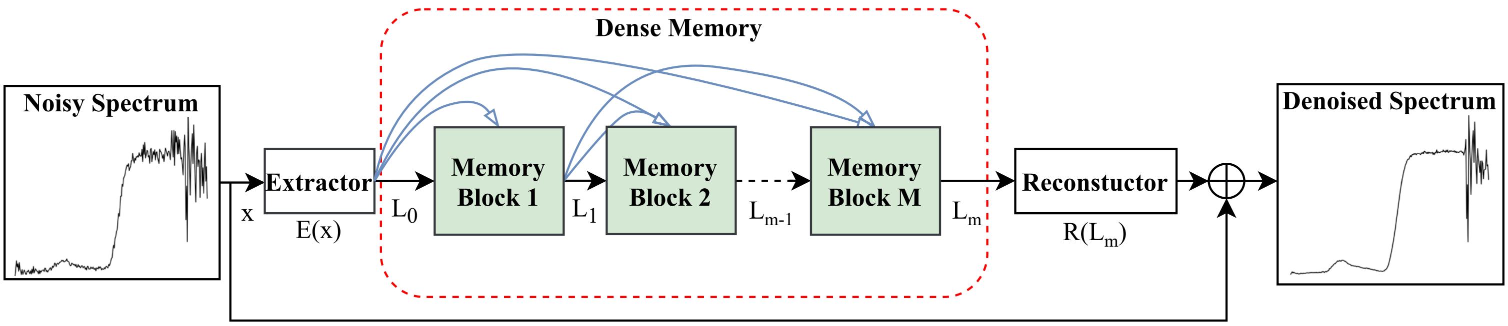


Figure 1: The hyperspectral denoising deep learning approach (deep HypeMemNet) developed in order to speed up the denoising process.

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

Principal Investigator: Jan van Aardt

Team: Carl Savaggio, Amir Hassanzadeh, Fei Zhang

External Collaborators: Sarah Pethybridge, Cornell University

Project Description

We 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.

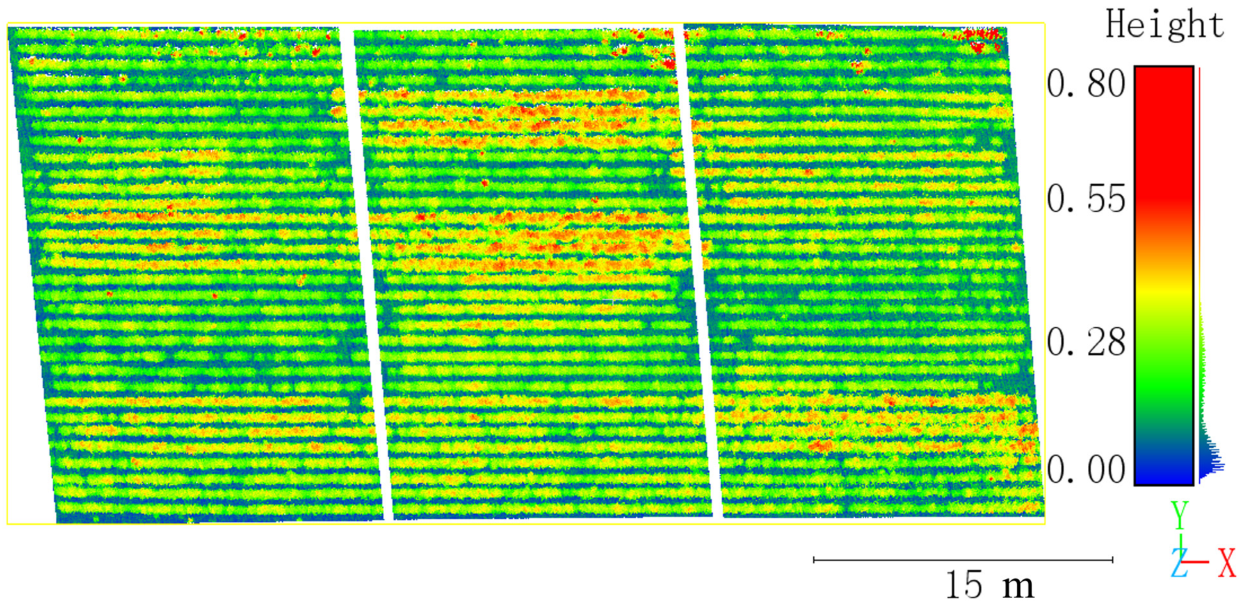


Figure 1: A crop height model generated from the LiDAR point cloud of a snap beans field.

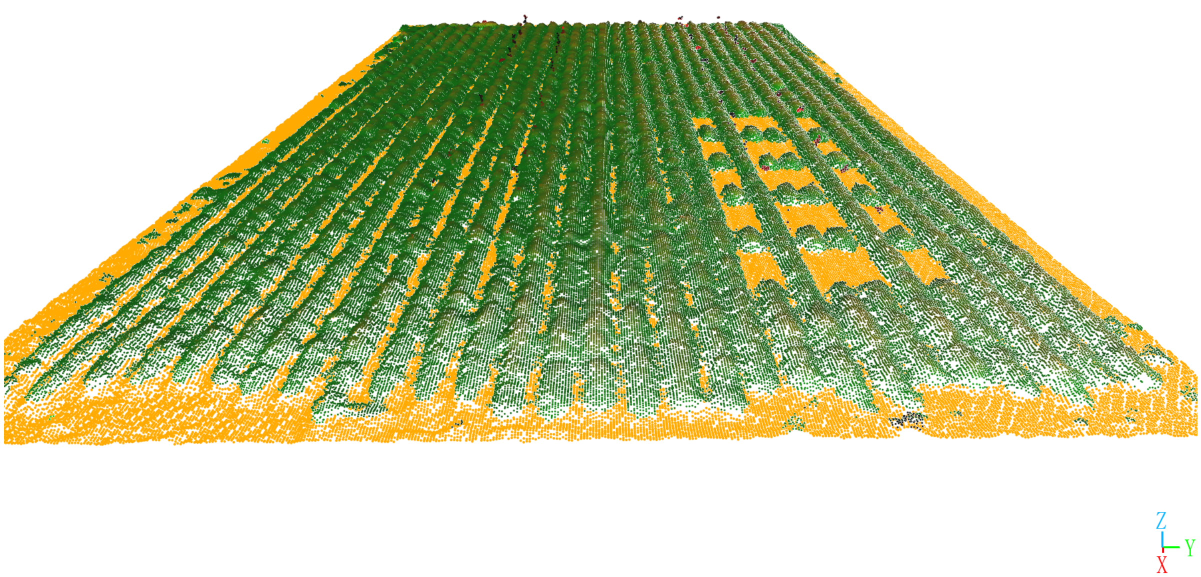


Figure 2: Filtering result of a SfM point cloud of a snap beans field

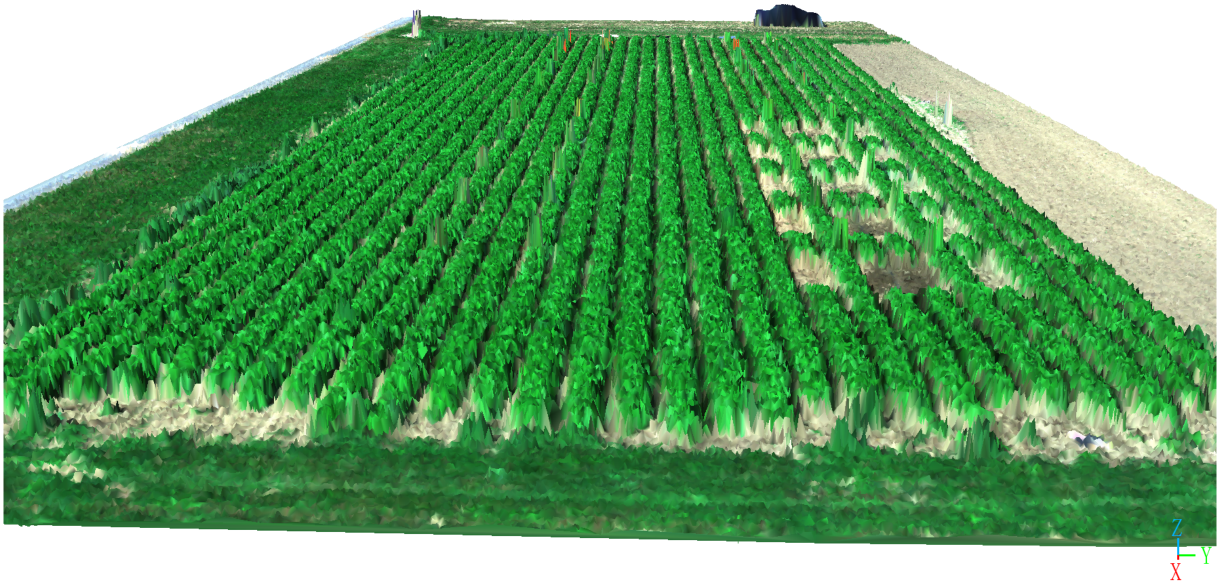


Figure 3: A SfM point cloud coloured by corresponding pixel values in mosaicked multispectral imagery.

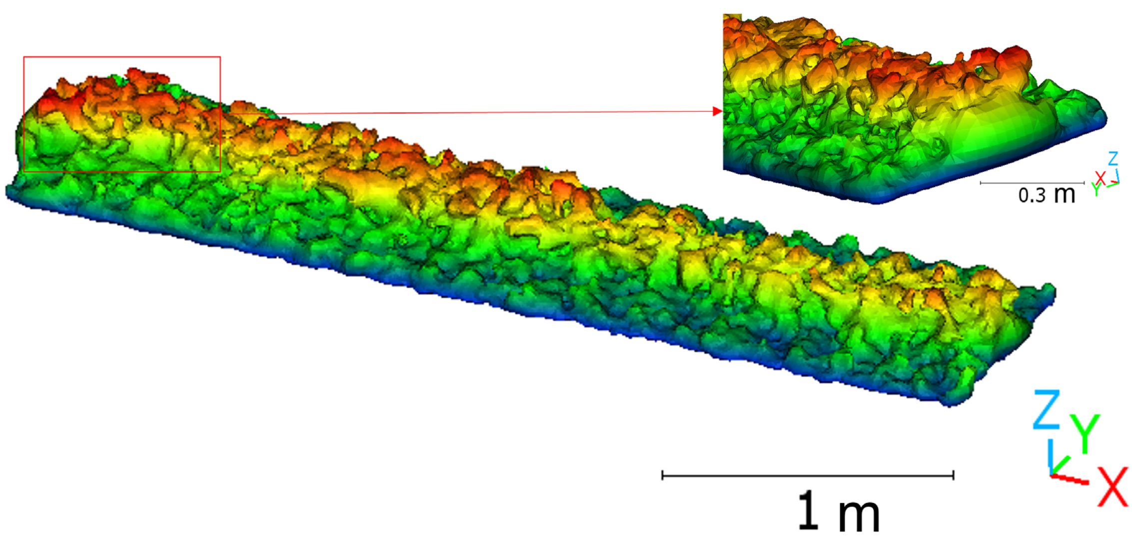


Figure 4: An example of the Poisson reconstruction surface of a row segment in the snap bean field.

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 includes shadowed targets, material types over a variety of backgrounds, RGB, VNIR hyperspectral, SWIR, thermal, LiDAR and more recently, SAR. We have flown our MX1 and SWIR instruments coincidental with each other followed by our new IMSAR Ku-band SAR instrument.

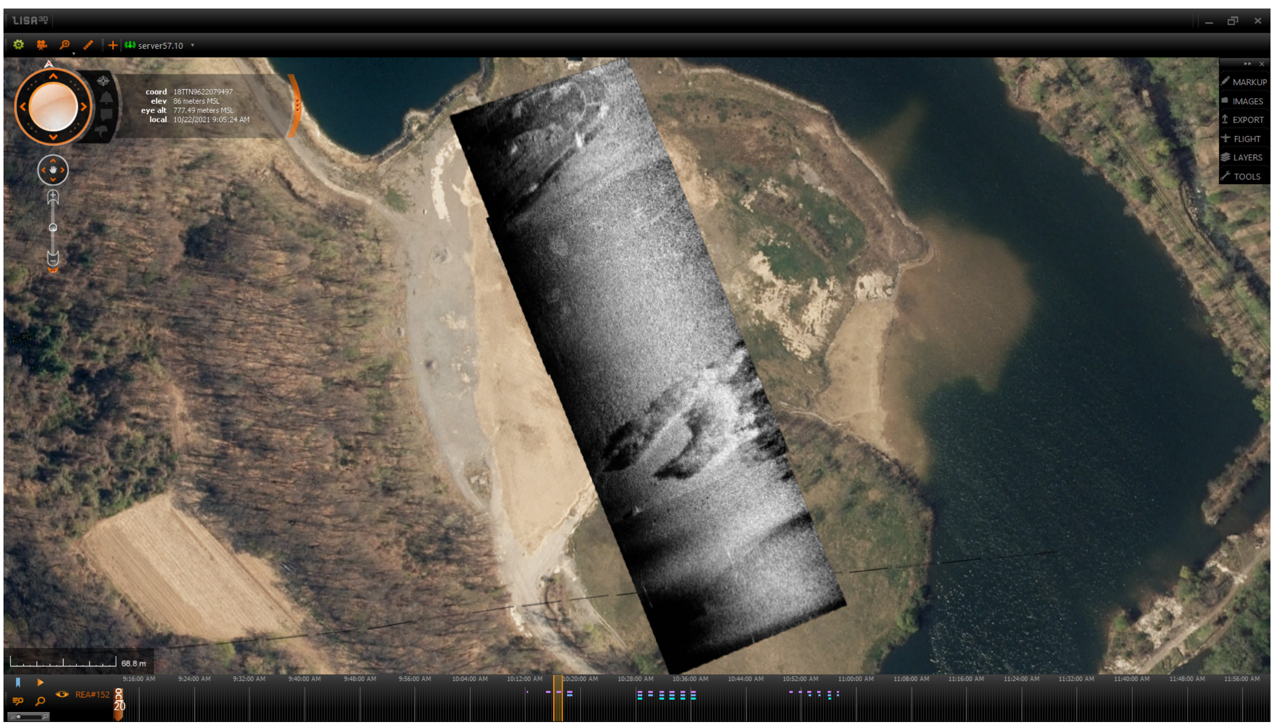


Figure 1: Example image from RIT's Ku-band SAR instrument flown over RIT's Tait Preserve data collection site. Instrument was flown at a 45 degree grazing angle. The region shown was flown in multiple passes.

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 a statistical TES algorithm (called S-ISSTES) and implemented it into FASSP as well as a cotangent detector which is equivalent to ACE. This resulted in a publication in IEEE Geoscience and Remote Sensing Letters (GSRL). We then integrated this work into the overall FASSP model and showed how the model could be used for trade studies. This work results in a publication in IEEE Transactions on Geoscience and Remote Sensing (TGRS).

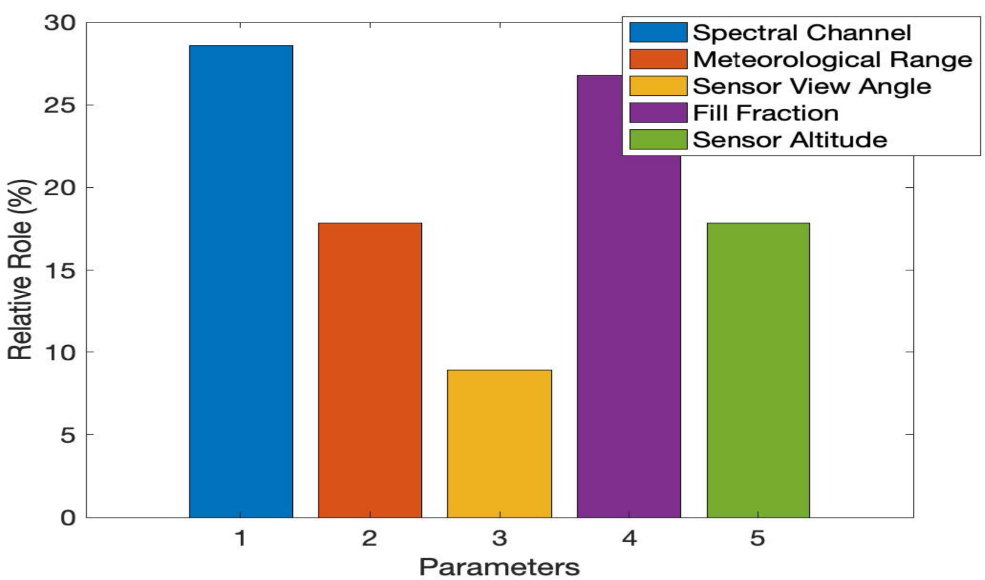


Figure 1: Column result plot showing the relative role or importance of a variety of detection scenario parameters as a percentage. The columns are labeled as, 1: Spectral channel; 2: Meteorological range; 3: Sensor view angle; 4: Target fill fraction; and 5: Sensor altitude.

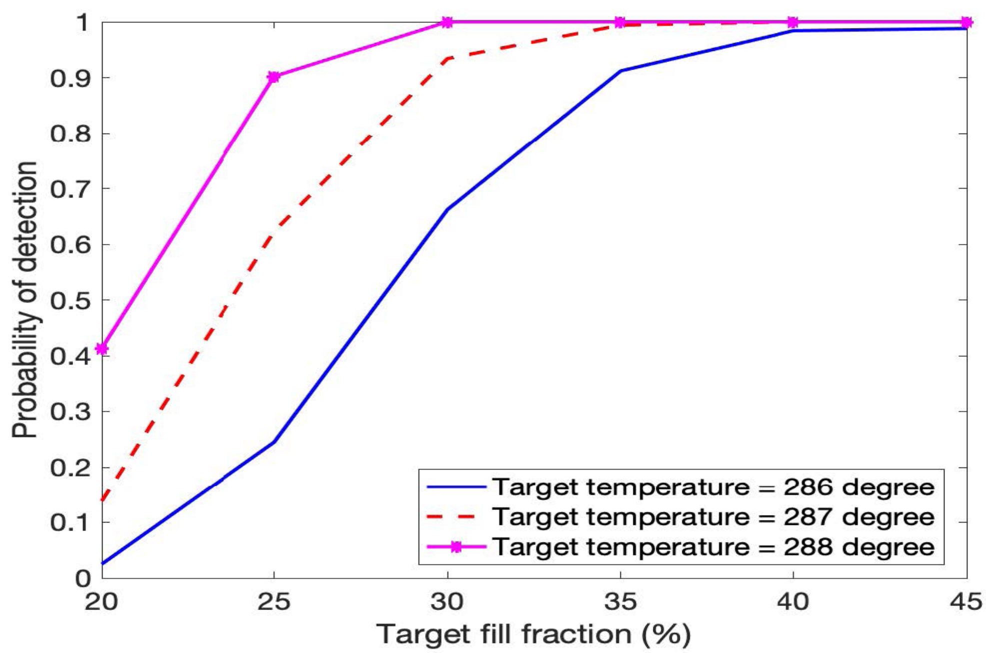


Figure 2: Probability of detection or system performance versus target pixel fill fraction for three target temperatures, relative to a fixed background temperature.

Thermal Image Systems Engineering Support

Principal Investigator: Matthew Montanaro

Team: Tania Kleynhans

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) instrument and the pre-flight characterization of the TIRS-2 instrument for the upcoming Landsat 9 mission (scheduled for launch in September 2021). The PI serves as the Deputy Calibration Lead for the TIRS-2 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 the Landsat 9 observatory-level pre-flight environmental tests at the Northrop Grumman facility in Gilbert, AZ. The PI serves as the Science and Calibration representative for the TIRS-2 project for all observatory-level activities including the electrical integration of the TIRS-2 instrument to the spacecraft bus, comprehensive performance tests of the integrated observatory, electromagnetic interference/susceptibility evaluations, vibration trials, and thermal-vacuum test campaigns. Each activity involved writing and reviewing procedures, processing and evaluating image data files, documenting and reporting results for consent-to-proceed reviews, troubleshooting data stream issues with real-time analyses, and providing custom software tools and instructions to other team members. These efforts contributed to a successful observatory test campaign resulting in NASA's approval to ship the Landsat 9 observatory to Vandenberg Space Force Base to begin launch preparations. The PI is now involved in the final performance tests needed prior to launch and will lead the TIRS-2 instrument commissioning phase during the first 90 days on-orbit.

Additionally, team members contributed to the investigation and recovery of two safe-hold anomalies on the Landsat 8 observatory. The PI helped to coordinate TIRS instrument recovery operations between the instrument Systems engineers and the Flight Operations Team and planned and evaluated image data to assess the health of the instrument after the resumption of normal operations.

Finally, 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 input for future Landsat thermal band architecture studies.

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 FY22):

37

Total number of quotes submitted.

18

Total number of signed agreements with fee for service provided.

$830K

The value of Competitive quotes submitted.

Quotes by Service

- DIRSIG 24%
- UAS 5%
- ICA 4%
- GRIT 3%
- LiDAR 3%

$460K

The value of Sole Source quotes submitted.

Quotes by Service

- DIRSIG 65%
- UAS 13%
- ICA 11%
- GRIT 8%
- LiDAR 1%

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

Research Scientist of the Digital Imaging and Remote Sensing Laboratory, James received his B.S. (2008) and Ph.D. (2014) degrees in Imaging Science from Rochester Institute of Technology. James has spent over 10 years working in air and missile defense at several locations including MIT Lincoln Laboratory, General Dynamics Mission Systems, and BAE Systems. At MIT Lincoln Laboratory, James provided support to the Department of Defense by designing and developing new radar signal processing algorithms to improve the detection and tracking performance of the U.S. Navy's E-2D Hawkeye, U.S. Air force's Airborne Warning and Control System (AWACS) and E-8C Joint STARS platforms. At General Dynamics, his research focused on developing space-based wideband receiver signal processing techniques to detect and identify signals of interest in highly congested signal environments. At BAE Systems, James focused primarily on radar system design and algorithm development for precision guided munitions. This includes both active and passive radar seekers. Other research interests include synthetic aperture radar (SAR) image formation processing and automatic target recognition, moving target indication (MTI), combined SAR-MTI, space-time adaptive processing, multistatic radar signal processing, and multimodal sensor fusion. In 2022, James joined the Digital Imaging and Remote Sensing Laboratory to pursue research in microwave remote sensing. He teaches the synthetic aperture radar image formation processing course currently offered during the Fall semesters.

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

Lab Engineer 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.

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.

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 an Assistant Research Scientist 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

Senior Scientist with the Digital Imaging and Remote Sensing Laboratory and co-devel-oper 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 an Imaging Science PhD graduate (Class of 2022). Throughout his PhD, he worked on solving critical agricultural questions with the use of remote sensing and machine learning. Specifically, modeling yield and evaluating harvest for broad-acre crops. Amir is currently working in the DIRS group as a Researcher/Engineer to provide solutions on different components of Landsat imagery such as validation and land surface temperature estimation. He is taking advantage of statistical models, machine learning, and deep learning algorithms.

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. Prior to his faculty position, he was a Research Faculty and Postdoctoral Research Fellow for the Intelligence Community. 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 taught courses and labs both at RIT and Monroe Community College. He has 70 publications and has served as referee on 14 journals including being an Associate Editor for a special issue of Optical Engineering and current Associate Editor for Geoscience Remote Sensing Letters. 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 currently working on a text book entitled, "Radiometry and Radiation Propagation" with Oxford University Press.

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.

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

Professor of Imaging Science and served as past DIRS Director from 2016-2019. John received his BS, MS, and Ph.D. in Electrical Engineering from Purdue University in 1983, 1986, and 1989, respectively. John teaches courses related to probability, statistics, and system modeling in synergy with his research interests in 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.

Tania Kleynhans

PhD. Researcher / Engineer II at the Chester F. Carlson Center for Imaging Science, Tania received a Bachelor's degree in Mathematics and Honors degree in Operational Research from the University of South Africa, and an M.S. and PhD. in Imaging Science at the Rochester Institute of Technology. She works on various research projects including algorithm development for calculating surface temperature from satellite imagery, thermal sensor calibration and band trade studies, pigment identification of hyperspectral data from paintings with machine learning and AI, and the development of a low cost multispectral imaging system and software for historical document discovery. Tania leads the Rochester Cultural Heritage Imaging, Visualization and Education (R-CHIVE) group that focus on using various imaging modalities to uncover faded, erased or damaged historical texts.

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

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.

Guoyu Lu

Assistant Professor at the Center for Imaging Science. Prior to joining RIT, Guoyu was a research scientist on autonomous driving at Ford Research and computer vision engineer at ESPN Advanced Technology Group. Guoyu finished his Ph.D. and M.S. in Computer Science at the University of Delaware, with the highest honor from the U. of Delaware (UD) Computer Science department. Before coming to UD, he was in European Master in Informatics (EuMI) Erasmus Mundus program. Guoyu obtained his Master degree in Computer Science at University of Trento and Master degree in Media Informatics at RWTH Aachen University. He finished his Bachelor degree in Software Engineering at Nanjing University of Posts & Telecommunications, with a minor in Business Administration and Management. Guoyu has board research interests spreading across computer vision, robotics, and machine learning and deep learning on the applications of computer vision.

Donald McKeown

A Project Manager within the Digital Imaging and Remote Sensing Laboratory, Don received a Bachelor's degree in Aerospace Engineering from the State University of New York at Buffalo in 1982. He spent 20 years in industry at Eastman Kodak supporting operations and leading technology development programs for satellite remote sensing pay loads. Since 2001, Don has supported DIRS with program development, program management, and system engineering for a wide variety of projects with an emphasis on airborne (manned and drone) imaging systems.

Colleen McMahon

Research Program Coordinatorfor Digital Imaging and Remote Sensing Laboratory, with 10 years of experience in an administrative role, Colleen keeps our lab running with support in office management, event coordination, 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

Currently a Professor, the Xerox Chair in Imaging Science, and Director of the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology. David received a BS in Physics from Clarkson University and a Ph.D. in Physics from Rensselaer Polytechnic Institute. He is an Associate Editor of the journal Optical Engineering and a Senior Member of SPIE. He has published over 150 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) from the Rochester Institute of Technology. He is currently a Senior Research Scientist involved in the calibration of thermal infrared imaging instruments through close ties with NASA Goddard Space Flight Center and the US Geological Survey. He specialized in the calibration of the Thermal Infrared Sensor (TIRS) onboard Landsat 8 and was directly involved in the definition of the calibration methodologies, execution of characterization tests, and anal-yses of instrument performance data, both pre-flight and on orbit. He now serves as the Deputy Calibration Lead for the upcoming Landsat 9/TIRS-2 instrument. He has also sup-ported other NASA missions including the SOLARIS sensor and the New Horizons/LEISA instrument. Matt has a number of peer-reviewed scientific journal publications and confer-ence 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

Assistant Research Scientist 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. During this period, 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.

Philip Salvaggio

One of our newest members, Philip joined the Digital Imaging and Remote Sensing Lab-oratory as a Senior Scientist in September 2019. He received dual Bachelor's degrees in Imaging Science and Computer Science from the Rochester Institute of Technology in 2012, as well as his Ph.D. in Imaging Science in 2016. His research involved imaging systems quality modeling, with a focus on systems with exotic apertures, such as sparse aperture telescopes. From 2016-2019, Philip was a Principal Engineer at EagleView, developing a scalable imaging processing workflow centered around the problem of dis-tributed aerial triangulation, as well as orthomosaic generation, dense 3D reconstruction and rolling shutter correction. He has also taught programming as an adjunct professor in the Imaging Science department. Philip is joining the Digital Imaging and Remote Sens-ing Laboratory as a Senior Imaging Scientist, where he will be continuing his research on imaging systems modeling as a member of the DIRSIG team. Philip is also an avid fan of ultimate frisbee, darts, and red pandas.

Marci Sanders

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, and he has published >70 peer-reviewed papers and >80 conference contributions… or rather, his students have.

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. His specific expertise is in spectral phenomenology, image interpretation, aquatic optics including fluorescence lidar, and wildland fire monitoring. He has extensive collaborations in Rwanda and elsewhere in Africa, where he has worked on various teaching and research projects for over ten years. Vodacek is on the Fulbright Specialist roster, 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 Bachelors in Criminal Justice from Niagara University. This included a semester of study abroad at the University of Copenhagen. Melanie 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. Melanie is also the Department Captain for the annual RIT United Way campaign, Go Tigers! Hockey, Football, Rugby, Barrel Racing, are family favorites. As always GO BILLS!!!

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

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.

Chase Canas

Currently a second 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

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.

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.

Amir Hassanzadeh

Amir joined the DIRS group in September 2018 and started working under the supervision of Jan van Aardt. He currently works on yield modeling and harvest scheduling of snap-bean, as a proxy crop using sUAS and remote sensing approaches. His research interests are precision agriculture, remote sensing, hyperspectral data as well as machine learning and deep learning methods. Amir is also keen in bridging remote sensing to deep learning. His research so far, up until summer 2019, involved a greenhouse study in RIT as well as field data collection using sUAS in Geneva, NY. His project is one that focuses on transitioning academia to industry by delivering packages to farmers and growers so they can rent a drone, set up the flight lines, sit and relax while watching the drone fly on its own, uploading the data to the software, have a cup of coffee, and take actions based on the given probability map.

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 Lapszynski

Chris received his bachelors in Imaging Science from the Rochester Institute of Technology in 2013. Prior to returning to academia in 2016 Chris supported research and development efforts as an industry contractor engineering solutions to immediate world problems utilizing the appropriate sensor modalities and algorithmic approaches, while supporting multiple major field campaigns. His current research endeavors (soon to include polarization) seek to exploit hyper spectral data sets to derive geophysical parameters obtaining sediment strength and surface trafficability estimates of a scene. Chris' growing expertise are in visible and near infrared phenomenology; design and implementation of novel imaging and ground based systems; material optical properties measurement and radiative transfer modeling, and radiometric calibration.

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 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.

Jobin Mathew

A Ph.D. student at the Center for Imaging Science. Jobin received his Bachelor's degree from University of Kerala, India and his Master's degree in Electrical Engineering at Rochester Institute of Technology. His past research work includes fast text detection and document imaging/processing, spectral calibration of remote sensing data, human eye motion tracking, and forensic blood detection using hyperspectral imagery. He is currently working on change detection in multi/hyperspectral imagery using novel statistical and graph methods along with the application of machine learning techniques.

Zack Mulhollan

A PhD candidate in Imaging Science, Zack Mulhollan earned his Bachelors degree in Imaging Science from Rochester Institute of Technology in 2016. His research interests include multimodal data integration, estimating three-dimensional structures from two-dimensional images, real-world scene simulation, image segmentation, and dynamic object detection and movement prediction.

Emily Meyers

Emily received her Bachelors degree in Physics from the New College of Florida in 2013 and is currently working on a Ph.D. in Imaging Science at the Rochester Institute of Technology. Her current research interests are in vegetation remote sensing and time-series imaging. For her dissertation, she is investigating how satellite revisit rate impacts our ability to monitor crop growth and predict yield.

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 collaborating with 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.

Ryne Roady

Benjamin Roth

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. His current research focuses on the effects of surface roughness on remote sensing measurements in the VNIR/SWIR and X-band radar domains.

Jason Slover

Cody Webber

Cody is a Ph.D. candidate with the Digital Imaging and Remote Sensing Laboratory. Cody received his Bachelor of Arts in Physics from Skidmore College in 2016, and attended Dartmouth College where he studied engineering, as well as film and media. Currently, Cody is working on assessing environmental applications of a novel uncooled multispectral thermal remote sensing imager, focusing primarily on land surface temperature retrieval and detection of rogue methane emissions.

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

Scott Couwenhoven

A second year MS student in the Applied and Computational Mathematics program. Prior to graduate school, he obtained a BS in Mechanical Engineering from RIT. He is currently working on a machine learning approach to cloud shadow mitigation in overhead imagery under Dr. Emmett Ientilucci and has research interests in Deep Learning and Computer Vision.

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.

Colin Maloney

Jacob Osterberg

Jacob is currently a Master's student at the Center for Imaging Science. He received his Bachelor's degree in Electrical Science and Engineering from MIT in 2009. Before continuing his education at RIT, Jacob spent 9 years in industry as a systems engineer working on multiband and hyperspectral aerial remote sensing payloads. His current primary research interest is in automated no-reference image quality assessment. In his graduate studies with his advisor Dr. Carl Salvaggio, he tested and evaluated a machine learning based automated image sharpness assessment system from his company Aizo Systems utilizing a multiband sUAS payload.

Lucy Zimmerman

Lucy is currently a second year MS student at the Center for Imaging Science. She received her bachelor's degree in physics from the United States Air Force Academy in 2020; her undergraduate research topics included space domain awareness and atmospheric science. She is currently researching how to optimize hyperspectral imagery in order to detect methane emissions by comparing methane's detectability in the LWIR and the SWIR. Her research interests generally lie in remote sensing as it relates to climate change mitigation.

Undergraduate Students

Leanne Robinson

Currently a fifth-year undergraduate student receiving her Bachelor of Science degree in Motion Picture Science from the College of Art and Design at RIT this upcoming May. Leanne is performing research for her senior project with Dr. Emmett Ientilucci relating to spectral radiance calibration. Her current research interests involve radiometry, remote sensing, and computational photography.

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.

Meg Borek

Meg is a senior undergraduate student at the Center for Imaging Science. She has previously conducted research with the DIRS drone lab, working with hyperspectral, multispectral, LIDAR, and thermal imagery for remote sensing applications under Dr. Carl Salvaggio and Timothy Bauch. Meg intends to pursue a graduate degree in Imaging Science with research relating to satellite remote sensing.

Micah Ross

Ethan Snell

Publications

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

Publications

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