2006-519: AERIAL IMAGING AND REMOTE SENSING EFFORTS AT UNIVERSITY OF MARYLAND EASTERN SHORE

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Aerial Imaging and Remote Sensing Efforts at University of Maryland Eastern Shore

Abstract

The aerial imaging and remote sensing efforts that were initiated on UMES campus in collaboration with NASA Wallops Flight Facility with the undergraduate experiential learning project titled UMESAIR (Undergraduate Multidisciplinary Earth Science Airborne Imaging Research) have recently been integrated with ASTI (Airborne Science and Technology Institute) project and AIRSPACES (Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship) project. The ASTI project focuses on training undergraduate students to fly remote controlled fixed wing model aircrafts, as well as, acquire aerial images with analog video and digital cameras in the infrared, thermal, and, visible regions of electromagnetic spectrum. AIRSPACES project focuses on aerial imaging of agricultural fields for yield estimation, weed detection, and crop health monitoring efforts. Initial efforts undertaken at UMES campus for ASTI and AIRSPACES project are highlighted in the paper. Efforts involving rectification and geo-referencing of acquired aerial images are described. Preliminary results of mosaicking geo-referenced images using ARCMAP and MATLAB software are also provided. Future expansion of the projects using UAV (Uninhabited Aerial Vehicle) helicopters and manned airplanes equipped with color infrared digital cameras are also advanced.

1. Introduction

UMES-AIR (Undergraduate Multidisciplinary Earth Science-Airborne Imaging Research) project was partially funded by NASA Goddard Space Flight Center (GSFC) in the fall of 1999. The project initiated remote sensing efforts involving undergraduate STEM (Science, Technology, Engineering, and Mathematics) majors using helium filled tethered blimp on UMES campus. The students designed a payload for the blimp consisting of cameras, transmitters, filters, and power systems for remote imaging from a height of upto 2500 ft. University System of Maryland Board of Regents supplemented the seed grant from NASA to continue to support student involvement with the project for subsequent years. The following references [1-4] document student achievement and successes with the UMESAIR project. UMESAIR project has paved the way for projects such as AIRSPACES (**A**erial **I**maging and **R**emote **S**ensing for **P**recision **A**gri**c**ulture and **E**nvironmental **S**tewardship) which has been partially funded by Maryland Space Grant Consortium and ECPA (**E**nvironmentally **C**onscious **P**recision **A**griculture) [5] supported through United States Department of Agriculture (USDA) Evans Allen grant, to explore applications of geospatial information technology and remote sensing for environmentally friendly agricultural practices. Through the Airborne Science and Technology Institute (ASTI) project, NASA engineers, and technicians from Instrumentation Science Branch at Wallops Flight Facility (WFF) of Goddard Space Flight Center (GSFC) provides training to UMES STEM undergraduates to learn to fly remote controlled UAV platforms. As part of the project the remote controlled platforms are also equipped with small digital cameras as well as analog micro-video cameras to acquire remote images in the visible, near infra-red, and far infrared bands, of the UMES agricultural fields, thereby supporting and complementing efforts of ECPA and AIRSPACES project. Graduate students working in the AIRSPACES and ECPA projects are also involved in the ASTI project and contribute to the image acquisition and analysis efforts.

This paper focuses on Phase-I of AIRSPACES project which has been conducted in concert with the ASTI project. The paper also describes image acquisition, frame selection, rectification, geo-referencing, and mosaicking of aerial images to capture an entire agricultural field with the objective of correlating image data with spatial variation of the yield data using a yield monitor. The strength and shortcomings of the aerial imaging efforts and future plans are also discussed. Integration of the remote sensing component with the overall project goals in environmental stewardship and precision agriculture [6] is also advanced. Student involvement in the project is discussed to provide an overview of the academic vitality of the project.

2. ASTI Project and Aerial Imaging

There is a growing interest in using small remote controlled and autonomous fixed wing aerial platforms for aerial imaging applications in natural resource management and precision agriculture [7]. Autonomous UAV platforms are capable of performing this task; however, they are relatively expensive compared to small remote controlled airplanes. ASTI project provides training to interested UMES students and faculty to acquire skills to fly fixed wing remote controlled airplanes. This also provides an avenue to introduce fundamentals of flight, including roll, pitch, yaw of aerial platforms and their control elements aileron, elevator, and rudder, as well as, fundamentals of communication technology associated with remote control. Once students achieve the necessary dexterity to control these fixed wing aerial platforms, they are qualified to fly the r/c airplanes integrated with a digital camera and /or analog video-camera over UMES agricultural fields, under appropriate supervision, to acquire remote images of the field for scientific analysis. Over and above the significant educational value of the ASTI project especially for Aviation Science, Environmental Science, Agriculture, Engineering, and Technology majors it also provides a platform for experiential learning and discovery of important aspects pertaining to aerial imaging, photogrammetry and geo-informatics [8]. Figure [1] shows UMES undergraduate and graduate students, NASA personnel and UMES Aviation Science faculty actively participating in ASTI project related efforts on UMES campus.

Figure 1 : Glimpses of ASTI project activities on UMES Campus

Initial efforts enabled project participants to quickly realize that it would be necessary to mosaic selected frames from the collected video streams to get a panoramic view of the entire field. Also, that lot of the acquired frames will not be usable owing to significant distortions introduced due to instantaneous roll and pitch configuration of the aerial platform. Only frames with relatively low roll and pitch distortions could be rectified for tilt and digitally stitched/ mosaicked using appropriate ground control points [8]. For spatially meaningful data mining efforts, these images also needed to be georeferenced. Orthotiles (orthorectified and georeferenced base images) were purchased for the entire UMES campus area. These orthobases provided the base image with respect to which the acquired images obtained from the aerial platforms used in the ASTI project were referenced, subsequent to appropriate rectification. Once georeferenced and rectified, each pixel of the acquired image could be associated with a x,y value or a latitude and longitude value with respect to the center of the earth.

3.0 Results

Figure [2] shows an acquired image frame overlaid at an appropriate location over the orthobase image of a portion of a UMES farm after rectification and geo-referencing. As may be noticed, each frame of the camera captures only a small portion of the field. The camera lens, diameter, and height of the aerial platform at the point of capturing the images are important variables that determine the size of the captured frame and resolution of the image, in all practical situations, however, images acquired from r/c platforms had to be digitally mosaicked to obtain a view of the entire field. This also necessitated that appropriate flight patterns are followed so that overlapping frames with visible ground controls can be selected for mosaicking purposes. UMES agricultural fields are divided into several farm units. Bozman, a 50 acre farm, has been selected for the preliminary investigations involving the ECPA and AIRSPACES project. Figure [3a] shows several frames that have been mosaicked together to get a significant portion of the Bozman field. These images were taken in November, 2005, prior to

Figure 2: Rectification and Geo-referencing of Acquired

harvesting corn that was cultivated in the field. Although, the Ent farm has not been set aside for this study, images were also captured from a r/c airplane attached with a analog video camera and a transmitter from over the Ent farm before wheat harvest in the summer of 2005. Appropriate frames were selected and mosaicked to obtain the view of a large portion of the Ent farm as shown in Figure [4a]. Both the MATLAB mapping toolbox [9] and ARCGIS 9.0 software tools [10] have been used for rectification, georeferencing and mosaicking operations. The Figures [3a] and [4a] show the results obtained using the ARCGIS 9.0 software.

Both Figures [3a] and [4a] demonstrate the procedure followed, as well as, the refinements that will be necessary in the future for improved results. It may be observed that while qualitative information can be garnered from the figures, quantitative information pertaining yield estimation, weed detection, and crop health monitoring will require higher resolution in the camera. It may also be observed even with a great deal of expertise and practice, it is difficult to make r/c platforms follow the planned path exactly, moreover, it is difficult to keep the platform

Figure 3a: Bozman Farm (Mosaic)

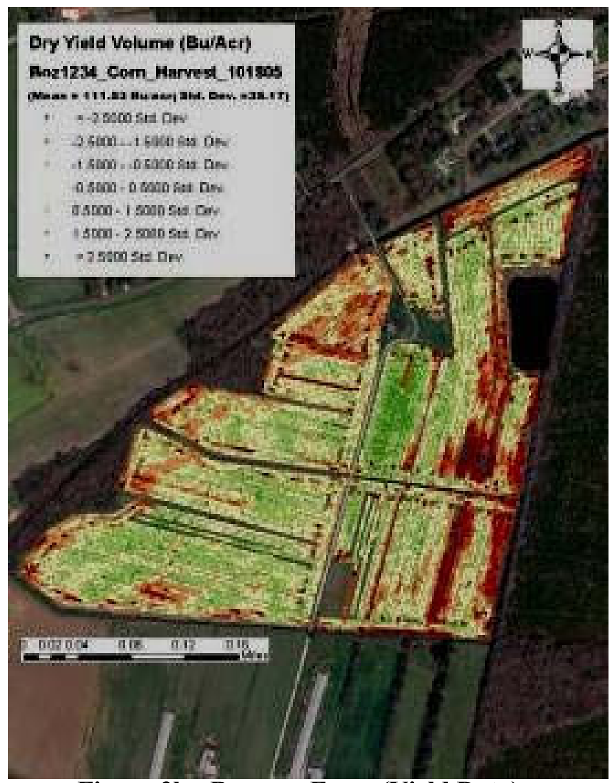

Figure 3b: Bozman Farm (Yield Data)

flat with respect to the ground. This makes frame selection arduous. Autonomous UAVs will improve path following efforts, and rotary winged aerial platforms (helicopters) will allow hovering while acquiring images, thereby, providing improved management of aerial imaging efforts.

Also, it may be clearly observed from Figures [3a] and [4a] that significant normalizing and color balancing efforts will need to be performed on the individual frames to integrate them into a seamless whole picture.

Figure 4a : Ent Farm (Mosaic)

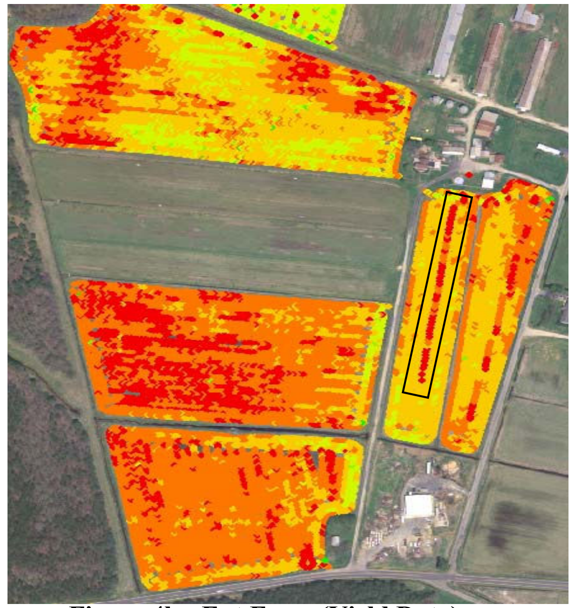

Figure 4b: Ent Farm (Yield Data)

The existing combine at UMES as shown in Figure [5] has been retrofitted with a yield monitor and GPS unit to acquire spatial variation of the yield data during harvest. The yield monitor has been calibrated following appropriate guidelines and Figures [3b] and [4b] show examples of the appropriately processed yield maps of the Bozman farm and Ent farm overlaid on the orthobase images. The yield maps correlate well with the qualitative information obtained from the images, however, as previously observed, more resolution is necessary in the images for a more meaningful correlation study. For example, in Figures [4a] by closely inspecting the boxed region it can be readily observed the captured images do not have enough resolution to reveal the low yielding region as evidenced from the yield monitor data in Figure 4[b]. In Figure [4b] red regions indicate low yield. In general, the yield of Ent farm was low, the orange and yellow regions, however, indicate moderate yield.

Figure 5: UMES Combine

4.0 Future Plans

Based on the lessons learned in implementing Phase-I efforts of the AIRSPACES project in concert with the ASTI project the following plans will be implemented in Phase-II:

(i) In recognition of the strong educational value of the ASTI project UMES faculty and staff will continue to participate in the ASTI project in collaboration with NASA GSFC WFF Observation Science Branch personnel. Imaging will be performed in various bands within and outside the visible frequencies over UMES agricultural fields to complement the AIRSPACES project.

(ii) A robotic helicopter [11] has been acquired which is equipped with a high resolution monochrome camera. This platform will provide additional means of collecting aerial images. The desired path and hovering stations for image acquisition can be preprogrammed for overcoming limitations of image acquisition efforts documented in the previous section.

(iii) In collaboration with lecturers in the Aviation Program at UMES who are also trained pilots, imaging efforts will be conducted from a manned airplane. In this regard, the project leaders have worked with a local aviation company who has allowed installation of a high resolution color infrared digital camera [12] on the belly of a CESSNA 172 airplane. Infrared images provide valuable information for crop health analysis for early intervention and disease prevention. Bayland Aviation will allow appropriately authorized UMES personnel to fly the airplane at a negotiated hourly rate for the AIRSPACES project and other aerial imaging research projects in the future.

(iv) Research will be conducted to develop normalizing techniques to seamlessly integrate frames for mosaicking efforts. Capabilities of commercially available software tools to perform such tasks will also be explored.

(v) Efforts will be expanded to involve more participation of undergraduate and as well as graduate STEM majors.

5.0 Integration with Broad Project Goals

This paper is primarily devoted to the aerial imaging and remote sensing efforts ongoing at UMES campus in conjunction with the ASTI and AIRSPACES project. The broad goals of the AIRSPACES and ECPA project are to provide an experiential learning and research platform at UMES that will generate, disseminate, and promote improved nutrient management for environmentally friendly agricultural practices through community engagement. UMES personnel will play a key role in providing support services to local farmers as they adopt this technologically intensive farming practice, and in particular, their future needs for remote sensing and aerial imaging. At UMES appropriate run-off monitoring efforts are already underway to generate data to identify suitable nutrient management plan in concert with implementation of precision agriculture. Figure [6] shows UMES students monitoring the nutrient status of the watershed adjacent to the Bozman farm using a YSI unit.

Figure 6: Nutrient Monitoring of Watershed

6. Student Participation in the Project

The project provides an ideal platform to promote merits of experiential learning[13] and teamwork[14]. The out of classroom activities are designed to provide participating students with an enriching learning experience. A graduate student in the system wide Marine Estuarine and Environmental Sciences (MEES) leads the project efforts in consultation with participating faculty and NASA personnel. The participating NASA personnel from Wallops Flight Facility of Goddard Space Flight Center come to weekly team meetings at UMES campus as well as to direct ASTI project activities. All participating students attend the team meeting and share their experiences whenever convenient through formal or informal presentations. These presentations provide exposure to the participating students in a variety of fields that include aerial imaging and remote sensing, geospatial information technology, communications technology, precision agriculture, environmental sciences and other aspects of STEM disciplines. The students who are more inclined to fieldwork participate in the aerial imaging, and, agricultural and environmental monitoring aspects of the project. Hand-held GPS units are extensively utilized for spatial information on all data that are collected. ARCGIS 9.0, MATLAB, SST Toolbox, and Spatial Management Software (SMS) are software tools that provide the mapping capabilities and data analysis capabilities for the project. Participating students have access to Marine Ecology and Environmental Science, Mechatronics, and GIS laboratory on campus where these software tools and computer workstations are available. A graduate student in the Applied Computer Science program currently works for software development efforts of the project, and in particular, for the remote sensing efforts involving a robotic helicopter.

STEM undergraduate students are kept informed of the project activities by participating faculty and encouraged to take up class projects that address different aspects of the broad scope of the project. While graduate students working on the project are supported by research funds the undergraduates are participating out of their own interest and desire. Project goals and objectives have been structured in such a way that the scientific and research goals of the project are not dependent on undergraduate students but they provide vitality to the project and advance the educational goals. Currently, efforts are underway to identify support for interested STEM undergraduates to get involved in more responsible roles as undergraduate research assistants for the project.

UMES farm manager and other farming personnel work closely with the project leaders and student participants to advance the project goals. Their support has been invaluable during activities involving yield monitor calibration and harvesting. Exposure to these efforts is also of significant educational value to the participating students.

The merits of out of classroom experiential and problem based learning paradigm are well recognized in academia. However, within the academic framework it becomes difficult to integrate students from several different majors to cohesively work together as a team. Primary difficulty comes in identifying an appropriate time in which all participants can meet, discuss, and set future goals. Electronic mail, cellular phones, synchronous electronic communication environments and other means of communication have to be utilized more effectively to keep the teams together despite scheduling conflicts.

7. Conclusion

Environmental concerns and agricultural needs are two of the most relevant issues for the eastern shore region of the Delmarva Peninsula. The rural environment of the region and the proximity to Chesapeake Bay provide a special significance to projects such as AIRSPACES and ECPA in the area. The activities involving remote sensing and precision agriculture have steadily gathered momentum at UMES. UMES administration has strongly supported the activities and provided significant funds for equipment necessary to conduct the research and educational projects. Related activities have also received support from NASA and USDA. Proposals have been generated to support graduate students to work in the area towards their master's thesis. Consistent with the historical mission of UMES efforts are already underway for inspiring more women and minority students to participate in the endeavor. In this regard, faculty members involved with the project are beginning to introduce activities related to this effort in project requirements in undergraduate courses they offer at UMES so that a large number of students get exposed to, as well as, get involved with the project. Efforts are also underway to find support for STEM undergraduates to take up more responsible roles as undergraduate research assistants.

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