AC 2007-2433: RICH LEARNING EXPERIENCES FOR MINORITY UNDERGRADUATE STUDENTS THROUGH INQUIRY-BASED PROJECT ACTIVITIES IN THE FIELD AND LABORATORY SETTINGS

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Rich Learning Experiences for Minority Undergraduate Students thru Inquiry Based Project Activities in the Field and Laboratory Settings

Abstract

With support from HBCU-UP (Historically Black College and University Undergraduate Program) at National Science Foundation (NSF), the ACTION (Advanced Curriculum and Technology-Based Instructional Opportunities Network) program at University of Maryland Eastern Shore (UMES) is promoting inquiry based active learning and research projects among undergraduate STEM (Science, Technology, Engineering and Mathematics) majors. Field based experiential learning efforts titled (i) AIRSPACES: Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship and (ii) ECPA: Environmentally Conscious Precision Agriculture, provided a perfect setting for STEM undergraduates to interact with UMES farm personnel, graduate students, NASA and USDA researchers collaborating with the faculty members in the project. In the summer of 2006 ACTION program supported three undergraduate students to work with the principal author to work on a chosen aspect of the ongoing effort. For this ACTION project students decided to focus on aspects of yield monitoring and remote sensing for the precision agriculture project at UMES. This paper will highlight the student efforts related to the ACTION project for 2006 summer and discuss how the out of classroom, field, and laboratory based activities enhanced learning.

1. Introduction

Undergraduate research projects offer students with opportunities that provide motivation for them to learn and refine their knowledge independently in the same vein as a research scientist or engineer,[1] increases student participation in interdisciplinary, authentic problem solving,[2] and help universities move from teaching oriented to learning centered.[3] Undergraduate research is a way of focusing, guiding and enhancing the undergraduate experience, rather than just a preparation for graduate school. It also provides a major opportunity to demonstrate to accreditation agencies and other organizations that students are performing at enhanced levels. [4] A substantial number of universities have begun to realize that undergraduate research is a real asset, thus they are identifying more resources and expanding opportunities to involve more students [5]. The work reported in this paper is based on the efforts devoted by three undergraduate students that were integrated with the AIRSPACES (Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship) and ECPA (Environmentally Conscious Precision Agriculture) experiential learning and research projects, ongoing at UMES campus. These student participations were made possible with support from NSF HBCU-UP ACTION grant. The students worked along with an interdisciplinary team of faculty members, graduate students, and farm personnel on specific aspects of the project for eight weeks of summer. The students focused on three major aspects involving (i) error analysis, filtering, and spatial interpolation of yield monitor data and (ii) georeferencing and mosaicking of images collected using a color infrared (CIR) digital remote sensing camera mounted on Cessna 172 airplane, (iii) preliminary investigations for program development and path planning of a robotic helicopter (UAV) equipped with a monochrome IP camera for agricultural applications.

Increased profits, environmental concerns, and effective farm management have been the primary motivators for the adoption of "Precision Agriculture (PA)" in the United States over the last decade. PA is a convergence of agronomy, advanced engineering technologies, and geo-spatial information technology (GIT)". At UMES synergy between two ongoing multidisciplinary projects ECPA(Environmentally Conscious Precision Agriculture) and AIRSPACES (Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship) have provided the platform to undertake experiential learning and research endeavors in this advanced technology driven environmentally friendly agricultural practice. Participation is open to all undergraduate and graduate STEM majors. A graduate student supported through the AIRSPACES project coordinates the student activities while maintaining appropriate interfaces with the faculty investigators. Some of the preliminary results of the ECPA and AIRSPACES project at UMES have been documented in scholarly articles and presented at various conferences nationwide[7 -10].

2. Error Analysis, Filtering, and Spatial Interpolation of Yield Monitor Data

At the onset of the ECPA project a "Yield Monitor" was installed in the UMES combine to gather spatially distributed yield data from the UMES farms (see Figure 1(a, b, c)). The "Yield Monitor" has a GPS unit associated with a yield sensor and allows the combine to gather spatially distributed yield data during harvest. A properly calibrated yield monitor not only allows appropriate documentation of overall yield but also provides insight into field characteristics and possible yield enhancement techniques that can be applied to specific locations of the field by observing the spatial variation of the yield.

Errors creep into yield monitor data due to operator error, GPS malfunction, field conditions, sensitivity of yield monitor instrumentation and variety of other reasons. The raw yield data obtained from the monitor data card incorporates these errors. One of the undergraduate students supported by the ACTION program in summer of 2006 was directed to work with the yield monitor data using the newly acquired SMS Advanced software [11] and filter the raw yield data obtained from the wheat harvest in the Bozman field at UMES to eliminate erroneous information as much as possible. Figure 2 shows an aerial image of the UMES campus in which some of the agricultural fields including the Bozman (light green) are identified.

(1a) 1(b)

Figure 1a and 1 b: Yield Monitor Inside the Combine Driver's Cabin

Figure 1c: UMES Combine during Crop Harvest

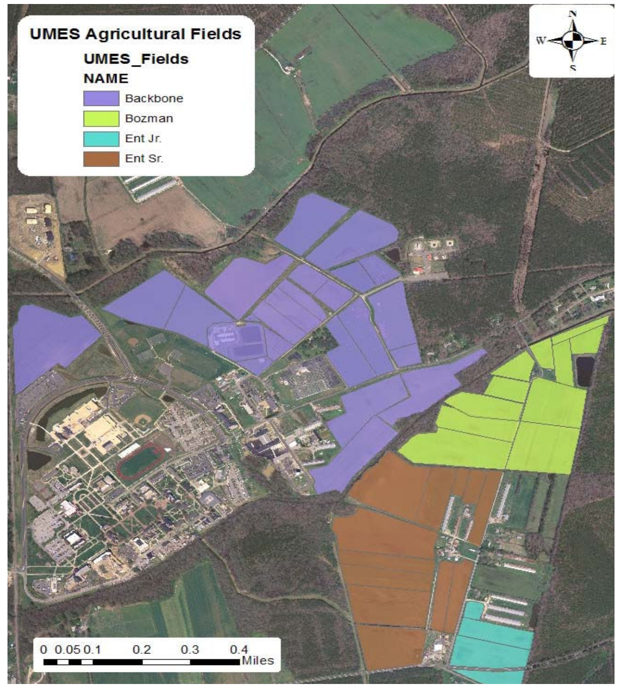

Figure 2: UMES Campus and Agricultural Fields

At the initiation of the summer project, the undergraduate student got familiarized with the UMES combine and the basics of the yield monitor system. The data card that recorded the yield in various agricultural fields during spring harvest was then taken out from the cab and inserted into the PCMCIA slot of a laptop computer and downloaded into the computer memory. The data sets corresponding to spring-wheat harvest from the "Bozman field" were isolated and mapped using SMS Advanced. SMS Advanced provides user friendly tools for developing the yield maps to document the spatial variation of the yield across the field. Upon extensive investigation of the raw yield data the student identified the chief sources of error including (i) inappropriate yield records at the edges of the field due to inability to utilize the entire "swath width"; (ii) recording yield data over the same location by driving the cab over an already harvested region without deactivating the GPS and yield sensing by raising the "harvest head", (iii) random sensor noise, (iv) GPS malfunction and other errors. Appropriate scholarly articles relevant to "yield data" filtering [12-15] was consulted before filtering the data for spring-wheat harvest. A minimum and maximum yield filter was set-up to eliminate yield values that were too low or too high. Regions of yield data error due to operator mistakes and other reasons identified above were cleaned up manually, finally outliers that is data that were outside the three times the standard deviation band were identified and eliminated. Filter tools available from USDA website [16] and features integrated with SMS Advanced were utilized for the purpose. Figure 3 and Figure 4 show the raw and filtered yield data mapped using SMS Advanced software. Careful inspection of the figures will reveal, the differences in yield data legend categories and histogram before and after filtering.

Subsequent to filtering the yield data which is in the point or vector data format, spatial interpolation techniques such as "inverse distance weighting" and "kriging" [17] were explored to convert the “vector data” into “raster data” to allow for correlation studies with aerial images of the crop field prior to harvesting. Figure 5 shows raster data obtained after preliminary spatial interpolation efforts. Given the constraints on time, this is the extent to which the undergraduate student devoted to this effort over the summer could proceed. Further investigations are underway to improve spatial interpolation results and techniques utilized.

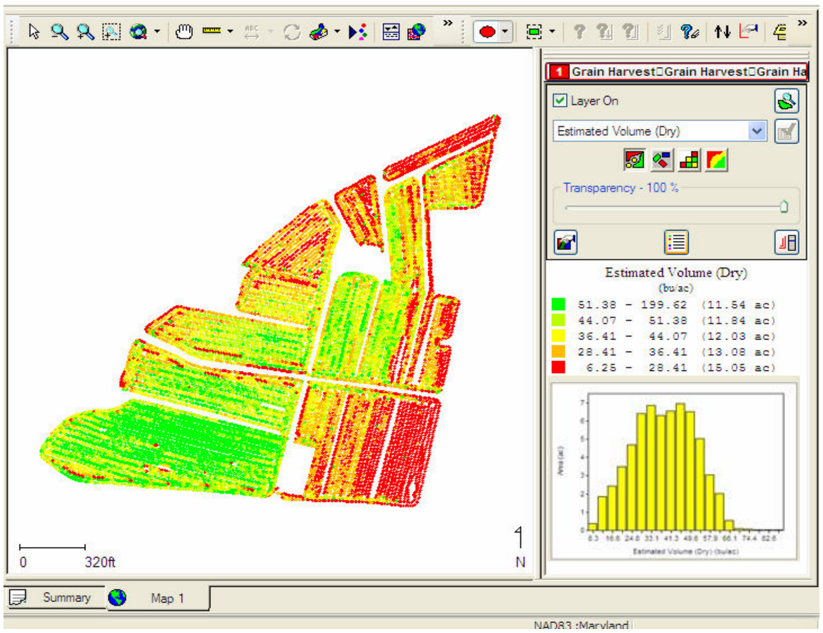

Figure 3: Raw Data Yield Map in SMS Advanced

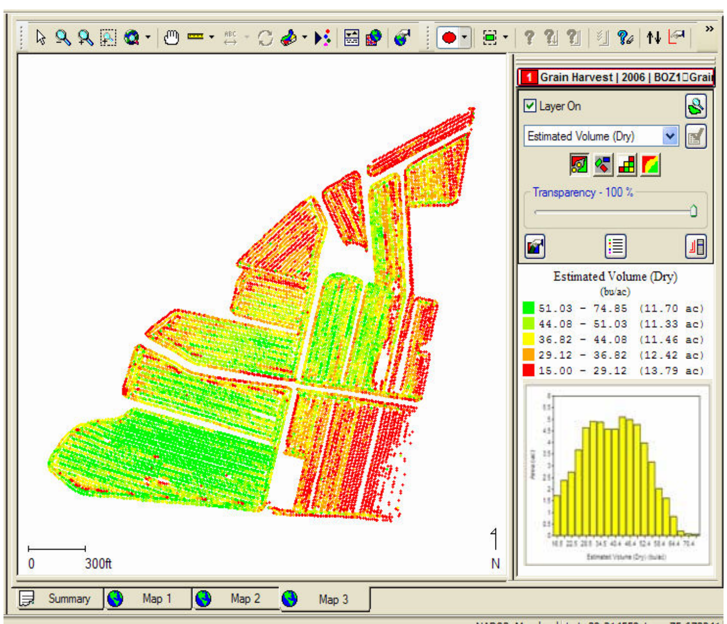

Figure 4: Filtered Data Yield Map in SMS Advanced

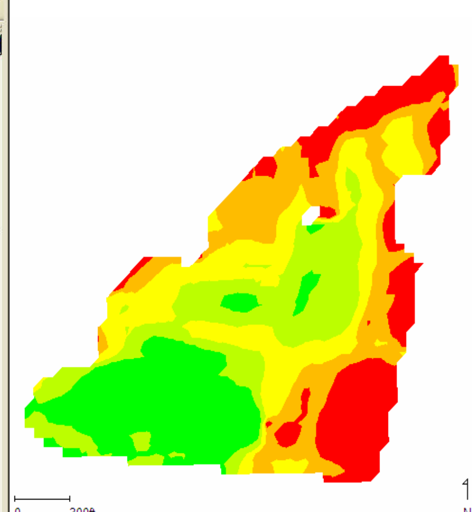

Figure 5: Interpolated Yield Map

3. Georeferencing and Mosaicking of Remote Images

A second undergraduate student was assigned the responsibility of georeferencing images acquired using a new camera system that was installed in a Cessna 172 airplane[see Figure 6a and 6b]. The Terrahawk camera system [18] can acquire high resolution digital infrared images formed by fusing three independent bands (i) near infrared; (ii) red; and (iii) blue/green. The red and infrared bands can be utilized to develop NDVI (Normalized Difference Vegetation Index) following equation (1) provided below:

$$(NIR - RED) / (NIR + RED) \quad (1)$$

Figure 6a: Cessna 172 Airplane

Figure 6b: Terrahawk System installed in Cessna 172

NDVI has several applications in crop health analysis and early detection of crop stress through remote sensing. Several preliminary issues needed to be addressed before such analysis could be performed. The Terrahawk imaging system integrates a Color Infrared (CIR) Digital camera with a gimball attachment, microcomputer, and a GPS unit. The camera is installed looking down through the belly of an airplane. A shapefile of the field boundary or shapefiles of region boundaries to be imaged is loaded in the computer memory. As the pilot flies the aeroplane over the field, the GPS unit recognizes that it has crossed into the field boundaries, and starts snapping images at pre-determined intervals of time without any pilot intervention. The pilot focuses on covering the region using a predetermined flight path that is developed following basic photogrammetry principles [19] and fine-tuned using simulation software. Since each image as shown in Figure: 7a covers only a small portion of the 50 acre field (Bozman) several images have to be mosaicked and georeferenced to develop a full field view. Since the first band which is reserved for red in an RGB image, is infrared in this hyperspectral camera, followed by a red, and user selectable blue or green as the 3rd band, the images acquired look different from a regular RGB image. Infrared frequencies of the solar radiation get reflected by healthy vegetation giving rise to the red color in the image corresponding to regions of healthy vegetation. Stressed vegetation although it may look green to the naked eye will not reflect infrared properly, which can be captured using CIR camera and enhanced using the NDVI.

The installation of the camera system on the airplane was completed in early summer and only one test run and two preliminary trials could be completed in the 2006 summer. The undergraduate summer intern working on this aspect of the project was given an overview of all the imaging devices that were being used in the project but her focus was on learning the fundamentals of linear algebra, photogrammetry, remote sensing, georeferencing and mosaicking. She used the ARCGIS 9.0 software extensively in georeferencing and mosaicking the frames acquired during the trial runs of the airplane with the Terrahawk imaging device. Figure 7b shows mosaic view of the acquired frames around the Bozman farm region overlaid on an ortho-rectified base image. It may be observed that there are gaps in the image frames. This may have resulted from inaccurate path planning, wind gusts, loss of GPS signal that triggers the camera, speed of travel, height of airplane or other relevant variables that determine image overlap or lack thereof. More fine-tuning will need to be done on subsequent runs. During the summer of 2006 the project team also acquired a software tool for normalizing and color balancing image frames so that the mosaic view appears seamless. This aspect could not be addressed due to time limitations in the summer, but will be integrated with future efforts. A seamless mosaic of the field prior to harvesting will be correlated with appropriately interpolated yield map.

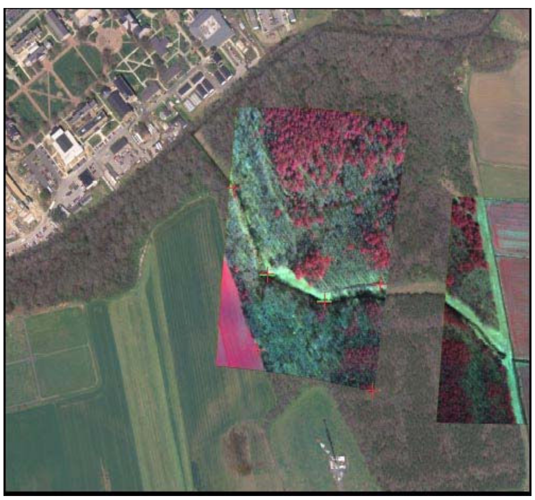

Figure 7a : Individual frames from Terrahawk

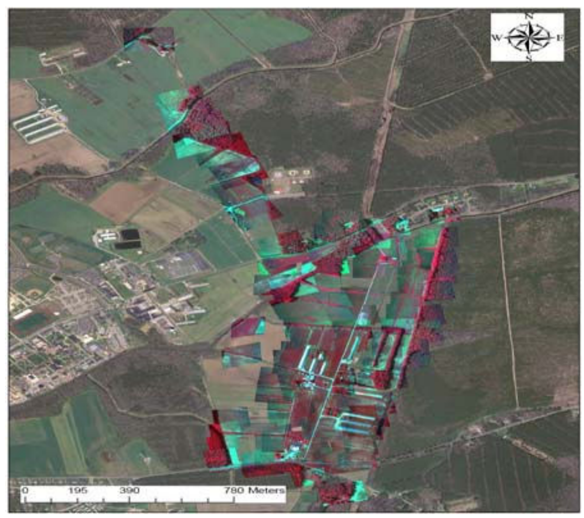

Figure 7b : Mosaic of several frames

4. Program development for Robotic Helicopter

A robotic helicopter equipped with a high resolution monochrome IP camera sensitive to visible and infrared frequencies has also been newly acquired by the project team. This UAV helicopter can be programmed to move to appropriate way-points using GPS locations and capture images of the agricultural fields while hovering at these way-points. The third undergraduate student supported through the ACTION program was tasked with assisting a computer science graduate student whose primary responsibility was code development for the UAV helicopter and the IP Camera. He was assigned the responsibility of studying the IP Camera lens and field of view information at different heights and formulate path planning efforts so as to capture a small portion of Bozman field by mosaicking individual frames.

Figure 8 shows a schematic of the communication system for the robotic (UAV) helicopter [20], IP camera, and base station computer. A Panasonic Toughbook serves as the base station computer and it communicates over an IEEE 802.11 wireless communication channel to an Ethernet hub carried by the robotic helicopter. The IP camera is also carried on a cradle by the robotic helicopter. Microprocessors on the UAV helicopter and IP camera communicate with the base station computer through Ethernet port via the hub.

An operator utilizes the base computer to manipulate the images captured during the flight of the helicopter and provides waypoints to guide the UAV helicopter to appropriate locations to capture aerial images. The UAV helicopter runs on electric power provided by a battery system. Appropriate programming needs to be done to monitor the battery power level so as to safely land the UAV before it runs out of battery power.

During the 2006 summer the undergraduate student assigned to the robotic helicopter project familiarized himself with the fundamentals of a fixed wing and rotary wing aircraft. In this regard a remote controlled(r/c) animation software environment proved very valuable [21]. The student also determined suitable waypoints for the helicopter while taking images with the IP camera so that the images had sufficient overlap for mosaicking. He also interfaced with the programmer and helicopter launcher who was a trained r/c pilot for the helicopter. Before the embedded computer in the robotic helicopter takes over control, an r/c pilot has to raise and hover the UAV several feet above the ground. Once the autopilot is engaged the computer takes over and the program for path following and imaging can be executed.

The program for the UAV path following and the IP camera imaging has been developed, however, the initial field run at the end of summer of 2006 failed due to equipment malfunction. Appropriate communication with the vendor is on going and the problem has been addressed. More effort needs to be devoted before a second trial run is attempted.

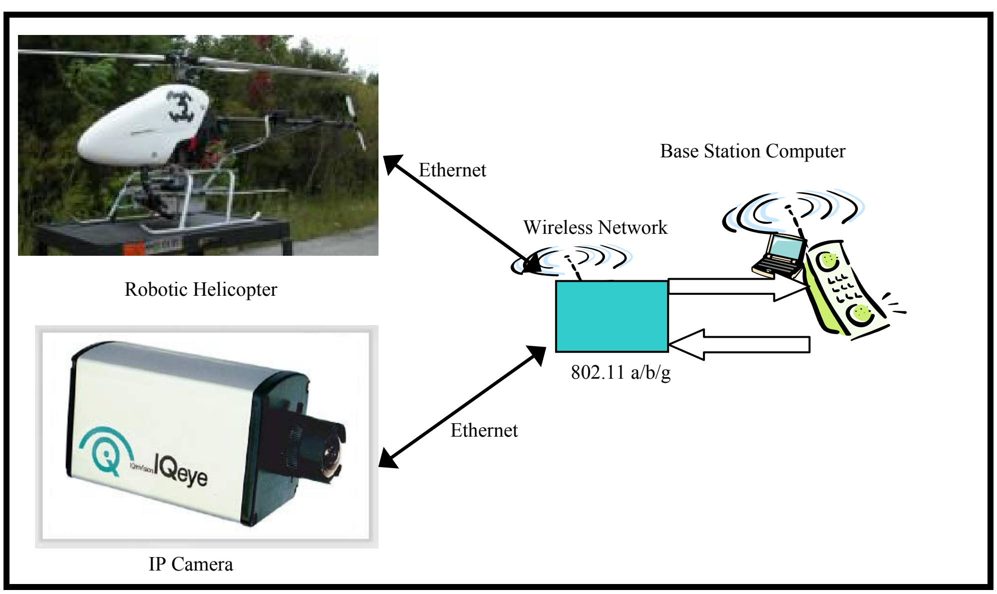

Figure 8: Robotic Helicopter and IP Camera

5. Student Learning Outcomes

All the undergraduate students shared their work with each other to get a glimpse of the big picture in which their individual effort fit together. They interfaced with two graduate students one from the Marine Estuarine and Environmental Systems (MEES) Graduate Program and the other from the Department of Mathematics and Computer Sciences as well as the project investigators in the Department of Engineering and Aviation Sciences and Department of Natural Sciences. Experienced pilots that serve as faculty members in the Aviation Science program who participate in the project, were also available to the students to consult with. The students learned to work in a realistic multidisciplinary team environment and understood the value of effective planning and communication. In addition students also got an opportunity to interface with UMES farm personnel, and NASA and USDA collaborators.

The students associated with the first two projects were juniors in the Mathematics Program in UMES campus and could readily relate to the applied mathematics concepts integrated with their projects particularly with regard to statistics, spatial interpolation and linear algebra. The third student is pursuing an Aviation Science major with a concentration in Aviation Electronics and Software Engineering. The involvement with the UAV helicopter project allowed him to witness first hand the state of the art technology in the field. At the end of the summer each student participant gave a "Powerpoint" presentation of their efforts and developed a report. The graduate students involved with the project assisted with the presentation and report. More effort needs to be devoted to improve the written communication skills of the students, however, the summer experience provided the students with the foundation for them to assess their strengths and limitations with respect to participating in a project similar to what they are likely to encounter in the real world, incorporating both field and laboratory components.

6. Conclusion

Eight weeks of summer is certainly not sufficient time to address all aspects projects that the undergraduates were assigned in the 2006 summer. Their efforts however have provided the foundation and base knowledge for each of the efforts outlined above, all of which required the use of newly acquired software or hardware tool or both. More needs to be done as the project team utilizes these advanced technologies and software tools within the context of the ongoing AIRSPACES and ECPA projects at UMES. The experiential learning and research efforts integrated with the project will continue to encourage multidisciplinary teaming and undergraduate participation from any of the STEM disciplines.

7. Acknowledgment

NSF HBCU-UP ACTION project supported the three undergraduate students and a graduate student over the summer. The second graduate student was supported by funds provided by Maryland Space Grant Consortium (MDSGC) for the AIRSPACES project. Of the three undergraduate students supported by the ACTION project two were females one African American and the other Caucasian, the third undergraduate student was an African American male.

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