AG2PI SEED GRANT PROPOSAL

Title of Proposal: Sharing Unoccupied Aerial System (UAS) based High-Throughput Plant Phenotyping Data via Public Cloud

Lead PI (Name, Title, Affiliation(s), email)

Jinha Jung, Assistant Professor, Lyles School of Civil Engineering, Purdue University, jinha@purdue.edu

Co-PI (Name, Title, Affiliation(s), email)

Zhou Zhang, Assistant Professor, Biological Systems Engineering, University of Wisconsin – Madison, zzhang347@wisc.edu

Collaborator (Name, Title, Affiliation, email):

Alison Derbenwick Miller, Vice President, Oracle for Research, alison.derbenwick@oracle.com

Grant Administrator:

Matthew Claxton

Sponsored Program Services

765-496-1464

mclaxto@purdue.edu

Keywords:

Unoccupied Aircraft System, High Throughput Phenotyping, Open Data, Data Sharing

1. Objectives/aims

The main goal of this project is to develop online educational material for managing and sharing Unoccupied Aircraft System (UAS) High Throughput Plant Phenotyping (HTPP) data using public cloud services. Recent advancements in sensor technologies make it possible to integrate advanced sensors into UAS platforms. UAS has unique advantages over traditional full-scale airborne and spaceborne systems: 1) flexible deployment options, 2) faster data turn-around time, 3) lower operational cost, and 4) acquire high spatial and temporal resolution data. The UAS is rapidly becoming the platform of choice for acquiring remote sensing data for agriculture applications, such as quantifying biotic and abiotic stresses (Oh et al., 2021; Bhandari et al., 2021; Pugh et al., 2018), estimating crop yield (Chang et al., 2021; Ashapure et al., 2020; Anderson et al., 2019), and quantifying plant phenotypes in a field-scale (Oh et al., 2020; Ashapure et al., 2019). Although the UAS-based HTPP system is getting adapted in many agriculture applications, the massive data volume acquired from the UAS platform and lack of software packages customized for processing these data make it challenging to develop interdisciplinary research collaboration around this data.

In the early development of the UAS based HTPP system, most efforts focused on integrating various imaging sensors into various UAS platforms such as multirotor, fixed-wing, and vertical take-off and landing (VTOL) vehicles. More recently, developing standard data collection procedures and establishing streamlined data processing pipelines to generate high-quality geospatial data products are gaining more attention in agriculture communities. Indeed, AG2PI previously funded the "Empowering HTP using UAVs" project whose primary focus was to address the issues mentioned above – identifying obstacles among research groups and developing standardized best practices for UAV data collection and processing. Although Wilkinson et al. (2016) highlighted the importance of the FAIR (Findable, Accessible, Interoperable, and Reusable) principles in data-intensive science, little attention has been paid to management and sharing of the big geospatial data generated from the UAS imageries yet. We propose to develop online educational material to provide tutorials on how to share the geospatial data products generated from the UAS data with the general public as web services. Having access to appropriate on-premises computing infrastructure to develop web services can be a daunting task, especially for research scientists who do not have experience and background in computer engineering. We will use public cloud infrastructure, especially the Oracle Cloud Infrastructure (OCI) in this project, to develop the training material so that users can implement web services without capital investment on on-premises computing infrastructure. The training material will cover three main modules:

Module 1. Configuring a web server using an OCI instance: This module will cover the basics of creating a new OCI instance, installing a Linux operating system, and configure a web server for sharing various geospatial data products. Oracle Research will provide free Cloud tenancies to support this training.

Module 2. How to share raster geospatial data products as a web service: UAS based HTP system can generate various raster geospatial data products such as orthomosaic images, Digital Surface Model (DSM). This module will cover the basics of how to create tile maps and upload the tile maps to the web server for visualization. Users will be able to share the URL with other research scientists, and others will be able to visualize various raster geospatial data products without downloading big files.

Module 3. How to share 3D point cloud data as a web service: One of the geospatial data products generated from the UAS data is 3D point cloud data when they are processed with the Structure from Motion (SfM) algorithm. This module will cover the basics on how to convert the 3D point cloud data into Potree (https://github.com/potree/potree) format using open-source tools so that the converted 3D point cloud data are uploaded to the web server for 3D visualization. Users with the URL will be able to visualize 3D point cloud data without downloading big files, and additional tools will be available for performing certain measurements such as distance, height, and line transects.

We will create a public GitHub repository to disseminate the developed training material to the public. In addition, we will also work with the PhoneForce group (https://phenome-force.github.io/PhenomeForce/) to provide an online workshop to reach a larger audience.

2. Furthering the aims of the AG2PI

The Agricultural Genome to Phenome Initiative (AG2PI) was created to address the challenges of agriculture, from genome to phenome, by building a cross-kingdom and multi-disciplinary research community. Among various program scope areas, this proposal addresses priority area "1. Identify best practices, tools, and techniques for AG2P data sharing and storage" by creating online educational material that uses public Cloud services to share UAS based phenotyping data with the public to encourage the FAIR principle within agriculture research communities.

3. Expected outcomes & deliverables

Tutorials that cover the three modules mentioned above (Module 1: Web Server configuration, Module 2: Raster data sharing, and Module 3: Point cloud data sharing) will be the main deliverables of this project. PIs will create a public GitHub repository to host the developed tutorial so that anyone can have access to the material. PIs will work with the Phenome Force to provide a series of workshops to disseminate the online educational material to a larger audience. These workshops will be recorded and uploaded to the PhenomeForece YouTube channel so that audience who cannot attend the workshop will have access to the workshop material in the future.

4. Qualifications of the project team

Dr. Jinha Jung (PI), Assistant Professor of Civil Engineering, is the Geospatial Data Science Lab Director at Purdue University. Dr. Jung is noted for his work in high-performance computing for advanced remote sensing data processing and WebGIS software development using Free and Open Source Software (FOSS). He has developed various cloud-based data portals for managing big geospatial data, including UAV and satellite images. Dr. Jung will take the lead on developing the online educational material.

Dr. Zhou Zhang (co-PI), Assistant Professor with Biological Systems Engineering at the University of Wisconsin-Madison, has expertise in UAS-based imaging platform development and data analysis, including hyperspectral, RGB, and LidAR. Also, Dr. Zhang has developed various machine learning models for estimating different crop traits using UAS-based imagery. Dr. Zhang will work with the PI to assist Module 2 and Module 3 of the educational material by providing her expertise in remote sensing data analysis.

Alison Derbenwick Miller (collaborator), Vice President of Oracle for Research, has a proven track record of innovative cross-functional team leadership that maximizes efficiencies and revenues. Alison will work with the PI to assist Module 1 of the educational material by providing OCI tenancy credits and OCI technical supports.

5. Proposal timeline

Task	Q1 2022	Q2 2022	Q3 2022	Q4 2022
Module 1 education material development	■			
Module 2 education material development		■		
Module 3 education material development			■	
Phenome Force workshop				■

6. Engaging AG2P scientific communities & underrepresented groups

Online educational material will provide level ground to anyone who would like to utilize the UAS based HTP technology for their research program.

Bibliography/References cited

Wilkinson, M., Dumontier, M., Aalbersberg, I. *et al.* The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data* **3,** 160018 (2016). https://doi.org/10.1038/sdata.2016.18

S. Oh, D. Lee, C. Gongora, A. Ashapure, J. Carpenter, A. Cruz, M. Fernandez-Campos, B. Lane, D. Telenko, **J. Jung**, C. Cruz, "Tar Spot Disease Quantification Using Unmanned Aircraft Systems (UAS) Data," Remote Sensing, 13 (13), https://doi.org/10.3390/rs13132567, 2021.

M. Bhandari, S. Baker, J. Rudd, A. Ibrahim, A. Chang, Q. Xue, **J. Jung**, J. Landivar, B. Auvermann, "Assessing the Effect of Drought on Winter Wheat Growth Using Unmanned Aerial System (UAS)-Based Phenotyping," Remote Sensing, 13 (6), https://doi.org/10.3390/rs13061144, 2021.

N.A. Pugh, X. Han, S.D. Collins, J.A. Thomasson, D. Cope, A. Chang, **J. Jung**, T.S. Isakeit, L.K. Prom, G. Carvalho, I.T. Gates, A. Vree, G.C. Bagnall, W. Rooney, "Estimation of plant health in a sorghum field infected with anthracnose using a fixed-wing unmanned aerial system," Journal of Crop Improvement, DOI: 10.1080/15427528.2018.1535462, 2018.

A. Ashapure, **J. Jung**, A. Chang, S. Oh, J. Yeom, M. Maeda, A. Maeda, N. Dube, J. Landivar, S. Hague, W. Smith, "Developing a machine learning based cotton yield estimation framework using multi-temporal UAS data", ISPRS Journal of Photogrammetry and Remote Sensing, vol. 169, pp. 180-194, 2020.

A. Chang, **J. Jung**, J. Yeom, M. Maeda, J. Landivar, J. Enciso, C. Avila, J. Anciso, "Unmanned Aircraft System based High Throughput Phenotyping for Tomato Yield Estimation," Journal of Sensors, vol. 2021, https://doi.org/10.1155/2021/8875606, 2021.

S.L. Anderson, S.C. Murray, L. Malambo, C. Ratcliff, S.C. Popescu, D. Cope, A. Chang, **J. Jung**, J.A. Thomasson, "Prediction of Maize Grain Yield Before Maturity Using Improved

Temporal Height Estimates of Unmanned Aerial Systems," The Plant Phenome, doi:10.2135/tppj2019.02.0004, 2019.

S. Oh, A. Chang, A. Ashapure, **J. Jung**, N. Dube, M. Maeda, D. Gonzalez, J. Landivar, "Plant Counting of Cotton from UAS Imagery Using Deep Learning-Based Object Detection Framework", Remote Sensing, 12(18):2981, DOI: 10.3390/rs12182981, 2020.

A. Ashapure, **J. Jung**, J. Yeom, A. Chang, M. Maeda, A. Maeda, J. Landivar, "A novel framework to detect conventional tillage and No-tillage cropping system effect on cotton growth and development using multi-temporal UAS data," ISPRS Journal of Photogrammetry and Remote Sensing, 152, pp. 49-64, 2019.