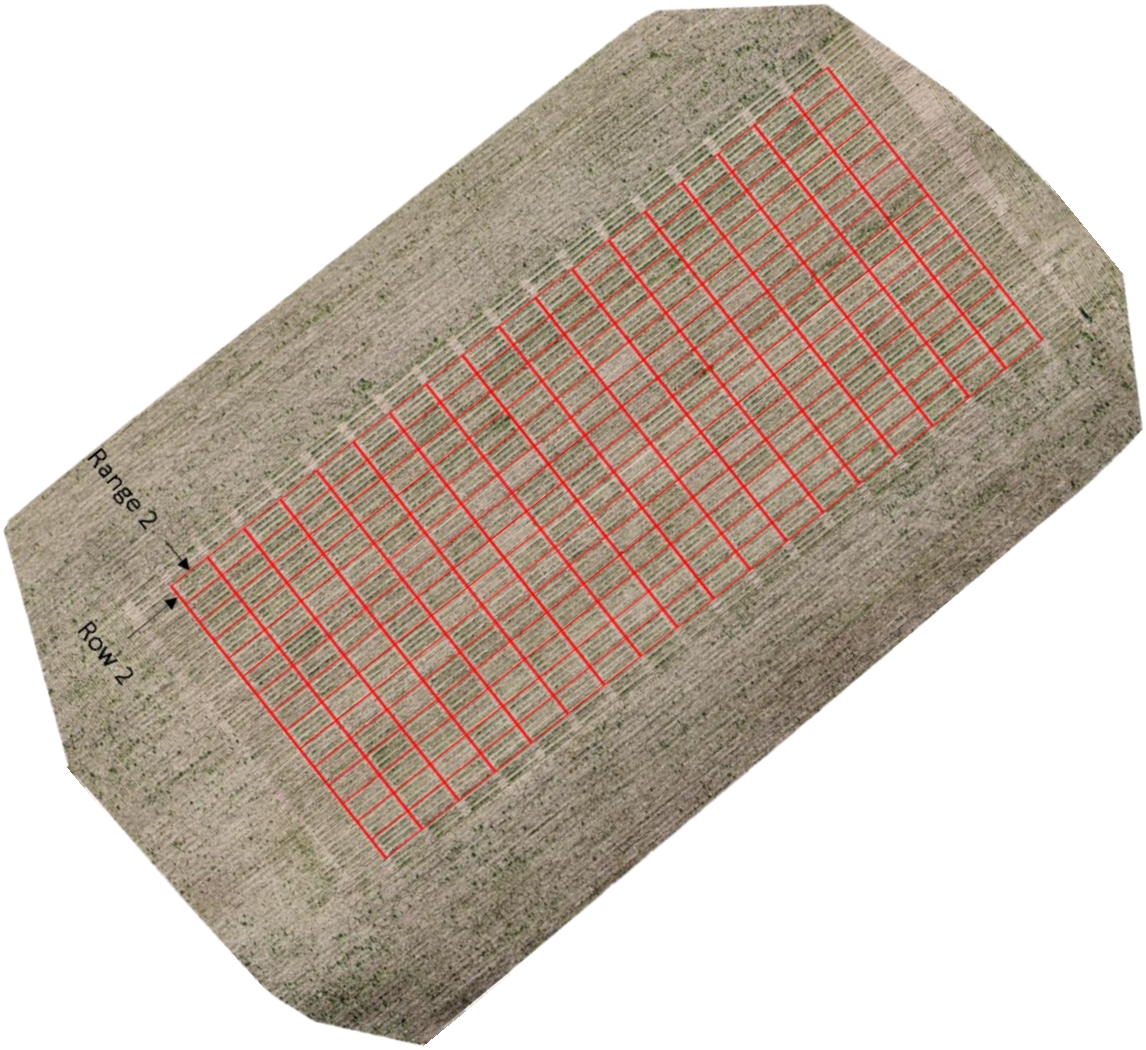
Introduction

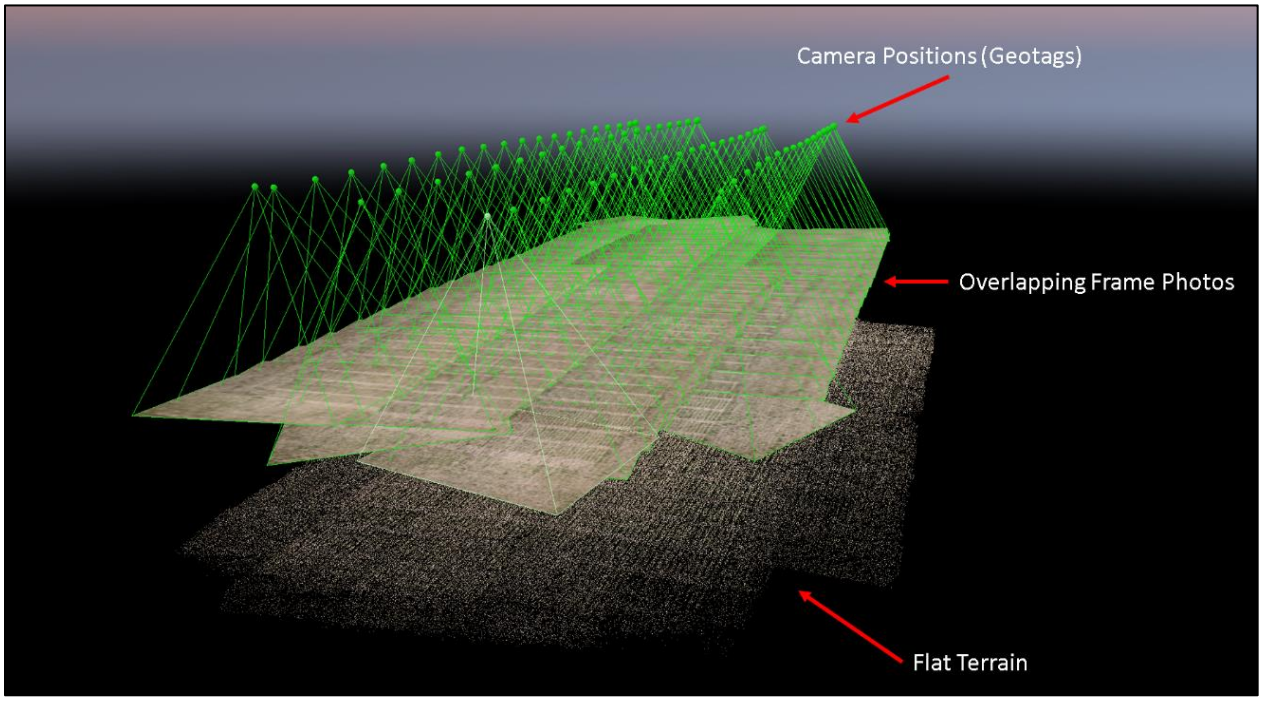
Progeny software was designed to rapidly extract replicate ortho-images and metrics of small agronomic research plots from raw overlapping drone imagery **without requiring internet connectivity, Real-Time Kinematic (RTK) GPS, ground control points, shapefiles, high-performance computing, or programming expertise**. This dramatically reduces the cost, turnaround time, and difficulty of drone-based small plot research while allowing researchers to process their own data locally and maintain data privacy. Here we summarize the user scenario, inputs, user interface, outputs, and system requirements for Progeny.

User Scenario

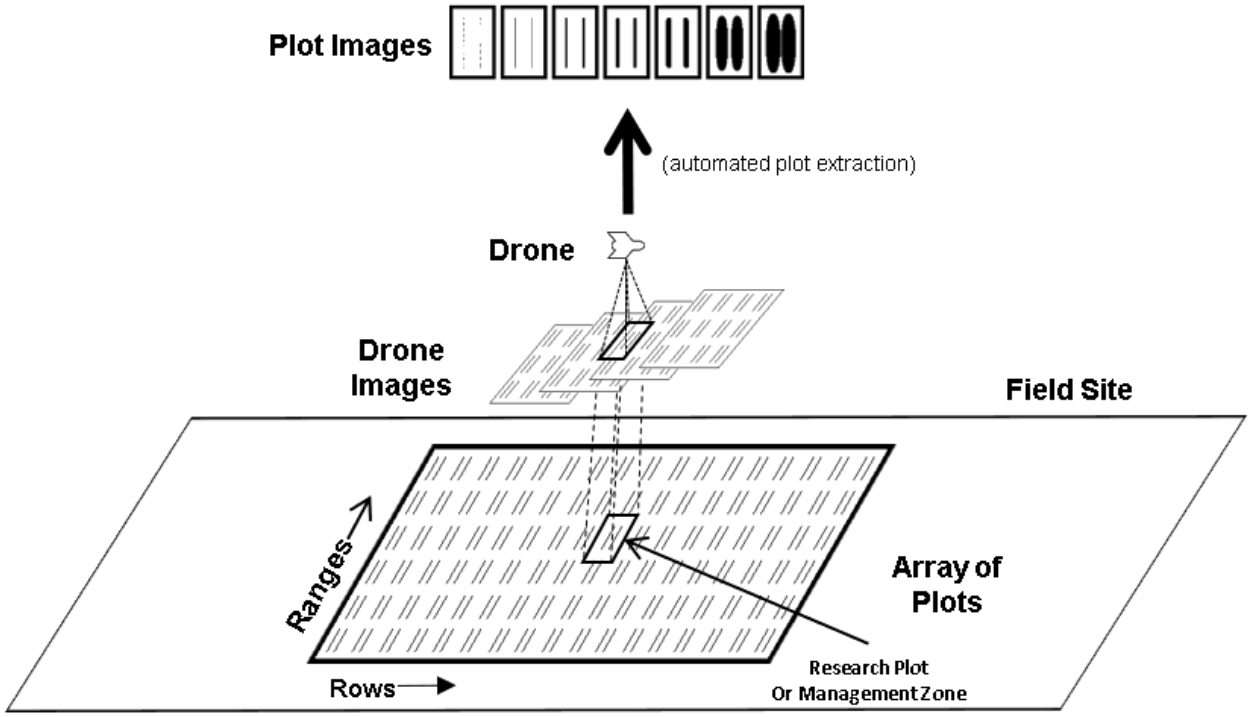
A researcher has a flat, rectangular experimental crop field on the order of 1 square kilometer in area. The field is gridded into rows and ranges of small agronomic research plots of fixed size (on the order of 1 square meter in area) with roughly constant spacing and arbitrary orientation. For example, an experiment may contain 4-row plots with 4 rows of border on all sides.



The researcher has collected high-resolution, overlapping, nadir-view, geo-tagged images of the entire field experiment using a low-cost drone with a digital camera and low-grade GPS sensor.



The researcher wants to convert the imagery into replicate ortho-images and metrics of individual research plots labelled by row and range number on a low-cost laptop within 30 minutes while in the field without internet, RTK-GPS, ground control points, or shapefiles.



Inputs

- A folder of raw drone imagery of small agronomic research plots

- A text file describing the basic layout of the plots

locn_exp_plot_layout.txt

```
rows per plot: 4
measurement rows: 2,3
vertical stagger (ft): 0.000000
starting row and range number: 2,2
total number of rows and ranges of plots to be processed: 18,15
bottom left corner latitude and longitude from Google Earth (decimal degrees): 46.705477,-118.998372
top left corner latitude and longitude from Google Earth (decimal degrees): 46.706557,-118.997504
top right corner latitude and longitude from Google Earth (decimal degrees): 46.706481,-118.997310
bottom right corner latitude and longitude from Google Earth (decimal degrees): 46.705402,-118.998174
```

- A text file describing basic parameters of the camera on the drone

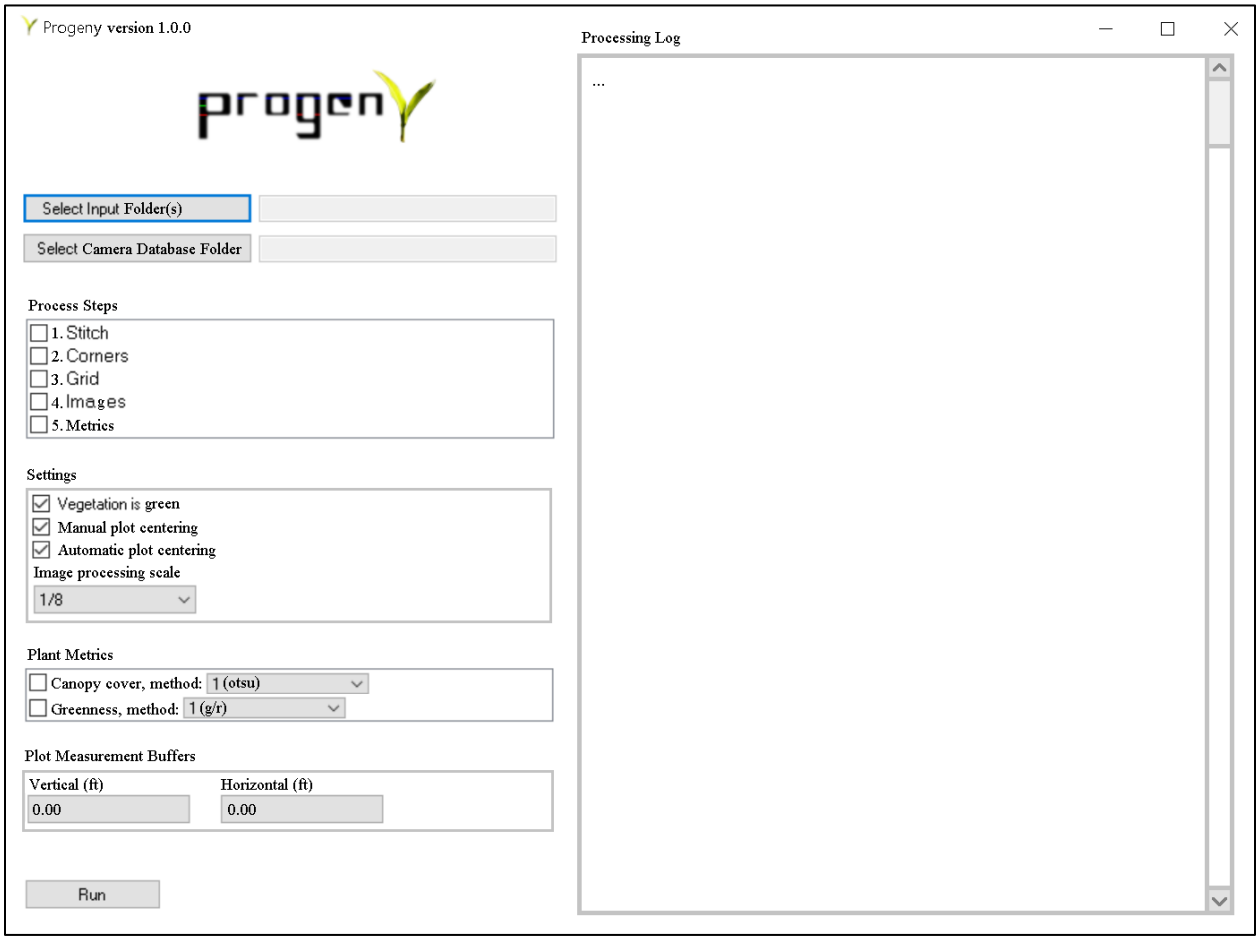
djifc220.txt

```
total number of color bands captured by your camera: 3
red band number: 1
green band number: 2
blue band number: 3
nir band number: 0
sensor width that corresponds to the image pixel width (mm): 6.3
```

User Interface

Progeny allows the user to select the following inputs:

- A folder containing raw drone images and an associated plot layout file
- A camera database folder containing camera parameter files
- The desired processing steps to run



The user must also select processing options appropriate for the imaging conditions and accuracy requirements. Finally, the user must select desired output metrics of crop growth and health and measurement buffers to restrict measurements to the desired measurement zone within each plot.

Outputs

- A folder of replicate ortho-images of research plots labelled by row and range number

- Excel spreadsheets containing the desired output metrics

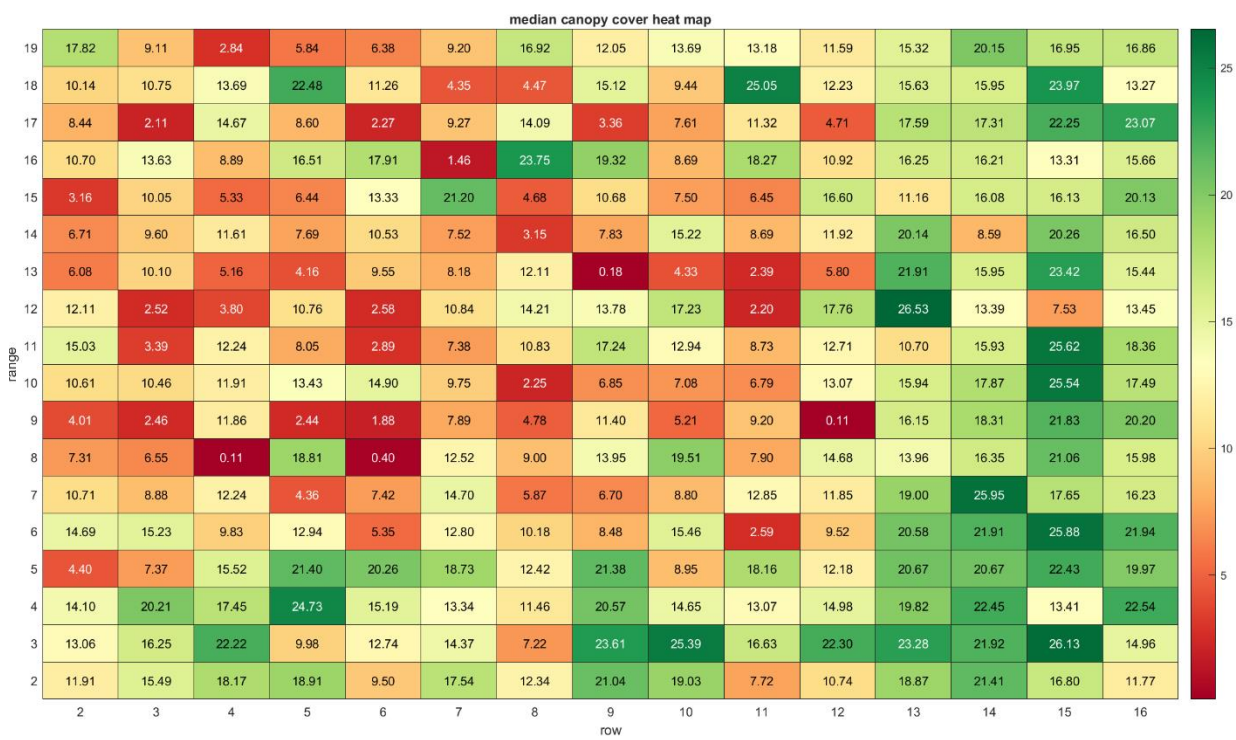
	A	B	C	D	E	F	G	H	I	J
1	location	experiment	flight date	row	range	n reps	median crop cover (m^2)	reference crop cover (m^2)	median G/R ratio	reference G/R ratio
2	laffayatte	soy	180606	2	2	6	2.0493135	2.134933	1.091056	1.09808
3	laffayatte	soy	180606	2	3	7	2.348427	2.348427	1.105727	1.117293
4	laffayatte	soy	180606	2	4	7	2.754763	2.834982	1.128892	1.114134
5	laffayatte	soy	180606	2	5	8	0.9860565	0.972634	1.0683715	1.065476
6	laffayatte	soy	180606	2	6	7	2.260424	2.260424	1.09015	1.091426
7	laffayatte	soy	180606	2	7	8	1.983153	2.105546	1.1090265	1.135468
8	laffayatte	soy	180606	2	8	8	1.672126	1.638688	1.084102	1.077887
9	laffayatte	soy	180606	2	9	8	0.7385695	0.767401	1.056775	1.055729
10	laffayatte	soy	180606	2	10	8	1.4466395	1.520187	1.0675035	1.069511
11	laffayatte	soy	180606	2	11	8	2.0401	2.006424	1.0882015	1.077705
12	laffayatte	soy	180606	2	12	8	2.0730615	2.221983	1.078626	1.074737
13	laffayatte	soy	180606	2	13	8	0.926011	0.883678	1.061797	1.0576
14	laffayatte	soy	180606	2	14	7	0.790751	0.790751	1.067205	1.067205
15	laffayatte	soy	180606	2	15	8	0.6095045	0.598385	1.044362	1.042522
16	laffayatte	soy	180606	2	16	8	1.8588535	1.890147	1.0719365	1.077407
17	laffayatte	soy	180606	2	17	8	1.200662	1.207254	1.08168	1.076523
18	laffayatte	soy	180606	2	18	8	1.723514	1.738922	1.0753835	1.071648
19	laffayatte	soy	180606	2	19	9	2.843719	2.843719	1.114134	1.119063
20	laffayatte	soy	180606	3	2	7	2.718704	2.797335	1.120491	1.127401
21	laffayatte	soy	180606	3	3	7	2.617517	2.55779	1.104525	1.103564
22	laffayatte	soy	180606	3	4	7	3.303905	3.422565	1.122695	1.134504

- A text file summarizing processing

180606_locn_exp_report.txt

```
Progeny Project Report

1. Summary
Project: 180606_locn_exp
Camera: DJI FC220 (djifc220)
Location: locn
Experiment: exp
Flight date: 06-Jun-2018 09:06:40
Date processed: 20-Feb-2019 11:46:55
Total processing time: 8 minutes and 59 seconds
Processing log filename: progeny_20_Feb_2019_11_37_56.log
Ground sampling distance (cm): 1.051039
Flying height (ft): 97.540578

2. Field Experiment
Rows: 15
Ranges: 18
Starting row: 2
Starting range: 2
Rows per plot: 4
Measurement rows: 2,3
Vertical stagger (ft): 0.000000

3. Quality Check
Frame photos: 77
Calibrated frame photos: 77
Min/max/median matches per frame photo: 144,337,289
Min/max/median replicate images per plot: 4,13,8
Correct number of rows detected: yes,15
Correct number of ranges detected: yes,18

4. Camera Calibration
        Parameters:  sensor_width   sensor height   focal length          p_x           p_y            R1            R2            R3            T1            T2
             Units:           mm              mm             mm           mm            mm      mm^(-3)       mm^(-5)       mm^(-7)       mm^(-3)       mm^(-3)
   Initial values:      6.300000        4.725000       4.700000     3.150000      2.362500      0.000000      0.000000      0.000000      0.000000      0.000000
  Optimized values:      6.300000        4.725000       4.455148     3.076809      2.302852     -0.001237      0.000257     -0.000013     -0.000135     -0.000095
 Percent difference:      0.000000        0.000000       5.209609     2.323520      2.524770      0.000000      0.000000      0.000000      0.000000      0.000000

5. Settings
Vegetation is green: yes
Manual grid adjustment: yes
Automatic grid adjustment: yes
Image processing scale: 0.125
Plant metrics and methods: canopy cover(2),greenness(1)
Vertical measurement buffer (ft): 4.000000
Horizontal measurement buffer (ft): 0.250000

6. System
OS: Microsoft Windows 10 Home
CPU: Intel(R) Core(TM) i7-7820HK CPU @ 2.90GHz
Cores: 4
RAM: 32 GB
```

- Other outputs and data visualizations such as heat maps for the desired output metrics



An example of the software outputs may be downloaded using the following link:

https://drive.google.com/drive/folders/1EOJ9RPdMgCvMbnLV3HDn9GyuCmvVL6Sv?usp=sharing

System Requirements

- Windows 10 64-bit operating system
- 16 GB RAM (8 GB usually enough but not guaranteed)
- 4 Cores

Background

Progeny was developed by researchers in the Department of Agricultural and Biological Engineering and the Department of Agronomy at Purdue University. The technology is owned by Purdue University and licensed by the Purdue Office of Technology and Commercialization to Progeny Drone Inc., a student-faculty startup supported by the Purdue Foundry and dedicated to maintaining and developing the software for public and private researchers. For further information or questions about the software, please contact Anthony Hearst via email ahearst@progenydrone.com or phone (415) 940-1057.