UNMANNED AERIAL SYSTEM (UAS)-BASED ASYMMETRIC COTTON GROWTH MODEL FOR HIGH THROUGHPUT PHENOTYPING

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Introduction

UAS, mounted with advanced sensors onboard, enables the acquisition of crop data at spatial and temporal scales previously unobtainable via traditional remote sensing methods. A novel framework to monitor cotton growth using asymmetric models from a series of UAS data collected over the growing season is proposed in this study. Canopy Cover (CC), Canopy Height (CH), and Canopy Volume (CV) measurements were extracted from the UAS data and these measurements were fitted with non-linear growth models including 3-parameter logistic model, 4-parameter logistic model, 5-parameter logistic model, and 4-parameter Richard model. Growth rate curves will be generated from growth curves by calculating first derivatives. Various phenotypic features will also be extracted from the growth rate curves which includes: 1) maximum growth rate, 2) days after emergence at maximum growth rate, 3) increasing growth rate slope, 4) decreasing growth rate slope, 5) increasing growth rate duration, 6) decreasing growth rate duration, and 7) days above half maximum growth rate. These features will be used to develop models to estimate crop yield from the UAS data. The framework developed in this study is expected to serve as an important tool for cotton breeders.

Materials and Methods

UAS data were collected over the cotton experiment trial using various UAV systems including DJI Phantom 2 Vision Plus, DJI Phantom 4, 3DR Iris Plus, and 3DR X8 Plus. Raw images collected from the UAV platforms were processed using a Structure from Motion (SfM) algorithm to generate three geospatial data products - orthomosaic image, 3D point cloud data, and digital surface model (DSM). These geospatial data sets were then used to calculate Canopy Cover (CC) and Canopy Height (CH) based on multiple UAV flights over the full growing season. In this study, CC values were calculated for every 1-m^2 grid and summarized by individual row. Average value of CC values for each row was fitted with four non-linear growth models including 3-parameter logistic model, 4-parameter logistic model, 5-parameter logistic model, and 4-parameter logistic model as follow.

3-parameter logistic model:
$$f(x) = \frac{a}{1 + e^{\frac{-(x-c)}{b}}}$$

4-parameter logistic model:
$$f(x) = d + \frac{a-d}{1 + (\frac{x}{c})^b}$$

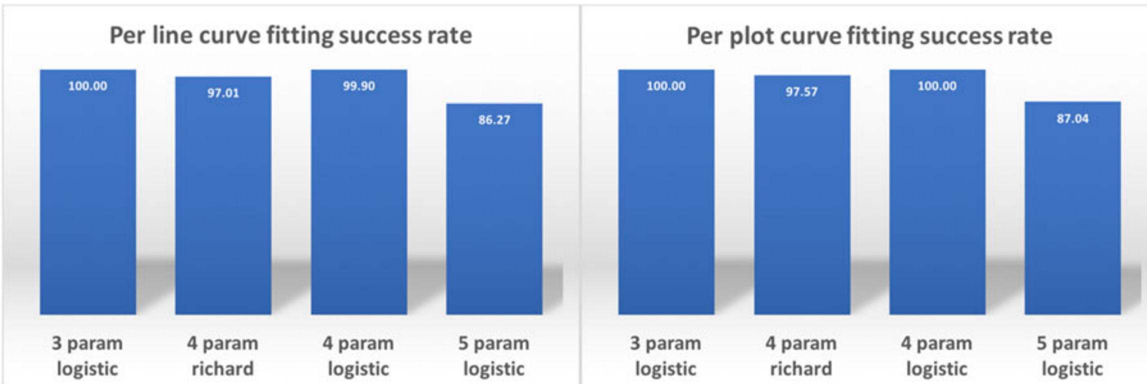
5-parameter logistic model:
$$f(x) = d + \frac{a-d}{\left[1 + (\frac{x}{c})^b\right]^g}$$

4-parameter Richard model:
$$f(x) = \frac{\alpha}{\left(1 + \beta e^{-kx}\right)^{\frac{1}{m}}}$$

Among four growth models, 3-parameter logistic model is symmetric, while the others are asymmetric growth model.

Results and Discussion

There were total of 980 rows in the cotton experiment field, where each variety was planted in two rows. Two experiments were conducted to assess effectiveness of each growth model: 1) fitting growth models per row (980 rows in total) and 2) fitting growth models per plot (490 plots in total). Success rate of the growth model fitting was then calculated for each growth model (Figure 1).



(a) (b)

Figure 1. Success rate of growth model fitting when (a) the fitting is done per-row and (b) the fitting is done by-plot

Results indicated that the symmetric growth model (3-parameter logistic model) was most stable (100 % success rate) in terms of fitting success rate, while 5-parameter logistic model was least stable (~ 87 % success rate). Other asymmetric growth models were reliable (4-parameter Richard model = ~ 97% and 4-parameter logistic model ~ 99%) but not as good as the symmetric growth model in terms of fitting success rate. Based on these results, 4-parameter logistic model seems the most appropriate growth model for cotton growth analysis since it can model asymmetric growth characteristics while maintaining reliable fitting success rate.

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