PURDUE UNIVERSITY | Agricultural and Biological Engineering

CAPSTONE/SENIOR DESIGN EXPERIENCE 2020

YY-1: Image System for Plant Phenotyping

Lingxi Shi (MSE), Bryant Hartanto (MSE)

1. Problem Statement

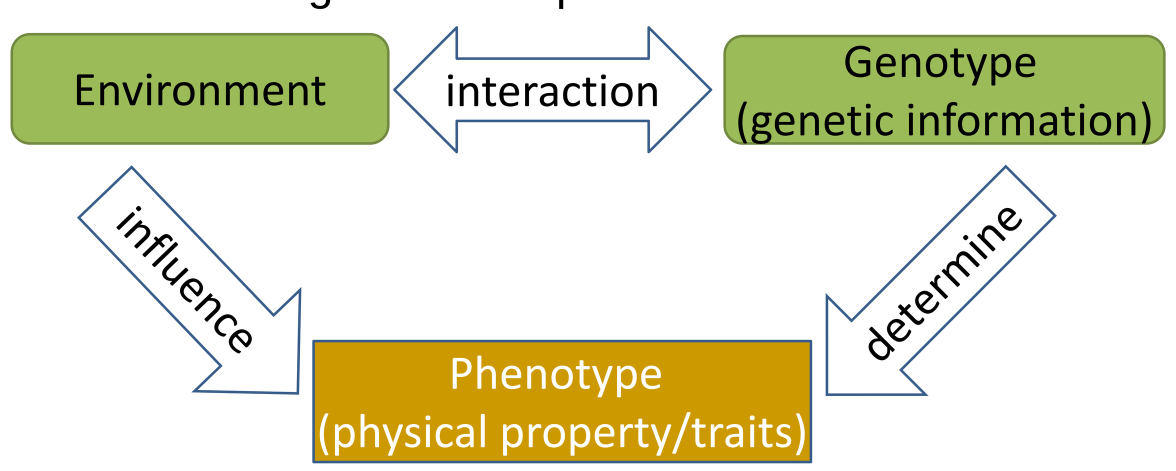
Current imaging systems in phenotyping research are either too expensive or too cumbersome for small and medium size plant imaging. Handmade systems available at low costs usually have inadequate functionalities to accommodate the needs in different researches. The limitation has quickly become a key bottleneck for the development and application of high throughput plant phenotyping technologies in biological research.

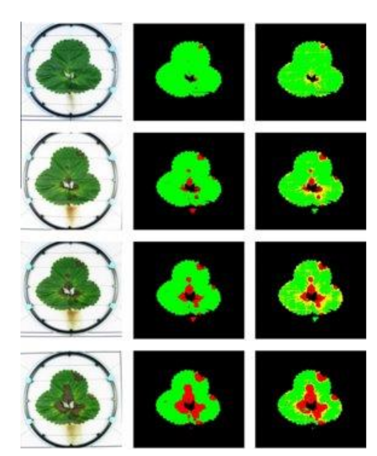
The major outcome of our design is a low-cost, versatile multispectral imaging system.

2. Background

Plant Phenotyping: a quantitative analysis of the plant's properties. Plant phenotyping is an emerging science that links genomics with plant ecophysiology and agronomy. Image-based phenotyping develops rapidly today. The characterization of the plant performance can be achieved from image analysis, including but not limited to plant size, leaf angle, and nutrition factor.

Impact: Improving plant productivity is key to address major economic, ecological and societal challenges. It's necessary and urgent to increase the capacity of the plant science community to analyze the plant's performance with quantitative tools. Advances in plant phenotyping are therefore a key factor for success in modern breeding and basic plant research.





- The relation and reaction among environment, genotype and phenotype
- Example image for a strawberry plant in image-based phenotyping analysis

3. Factors Considered

Considered Factors	Yes/ No	Yes, it is important, and why; or No, it is not important, and why
Public Health	No	Product is used only by researchers.
Public Safety	No	Product is used only by researchers.
Public Welfare	Yes	Life would be better if more scientist can use an imaging system.
Global Factors	Yes	With less cost, our product lets wider range for researchers to conduct plant phenotypical analysis.
Cultural Factors	No	Any researchers with any background can use this product freely.
Social Factors	Yes	The product is used by Agricultural-related people.
EnvironmentalFactors	Yes	Our product has to be environmentally friendly.
Economic Factors	Yes	Our goal is to compete in the market.

4. Constrains & Criteria

Constrains:

- Size: adequate for small to medium size plant (e.g. Arabidopsis, tomato seedlings)
- Weight: bearable by a normal lab bench
- Functionality:
  - multispectral with at least five color channel including R G B
  - Capable of acquiring images from top and side view

Criteria:

- Adaptability
- Cost:
  - Prototype Phase: Purchase + Labor
  - Quantity Production: Price + Delivery
- Versatile functions
- User-friendly
- Safety

5. Alternative Solutions:

The main problem the team must solve is the choice of the camera and lighting system to obtain multispectral images of good quality.

1. Use one multispectral camera with more than 4 color bands filter array.
2. Use a monochrome camera with full-spectrum light and different color filters to adjust the inlet lighting of the camera.
3. Use LED lights with different color channels to achieve multispectral functionality and a monochrome camera.

Decision Matrix: the decision-making tool that help us to chose the final solution. The third solution gives the highest score. It is the final design.

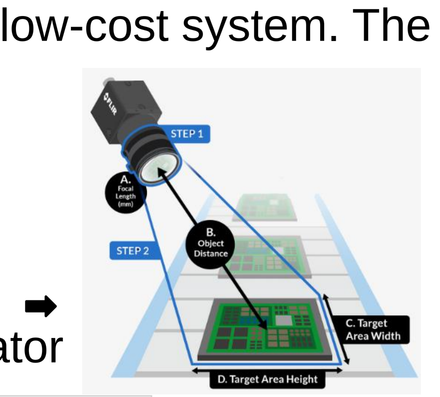
Score scale: 1 to 5:

	Criteria	Adaptable	Cost	Versatility	Safety	Simplicity	Noise	Sum
Solution	Weight	0.2	0.3	0.2	0.2	0.05	0.05	1
1	Score	2	1	5	5	5	5	0.64
2	Score	4	4	4	5	2.5	3	0.81
3	Score	4	5	4	5	4	4	0.90

6. Tools and Design of Solution

We use several tools for the design.

- The 3D modeling has been built in Creo Parametrics.
- The lens calculator is used to help us find the best parameters of the lens with the proper mounting type, focal length and sensor size.
- The budget analysis is one of the most important part of the design of solution as our goal is a low-cost system. The budget will be around 2,200 dollars.
- The LEDs are chosen based on their wave length and price.



➡ Lens Calculator

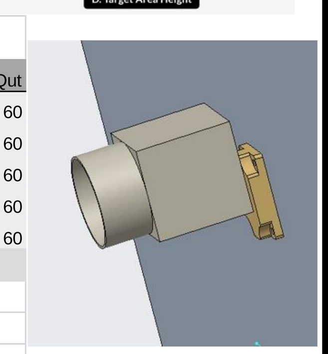
⬇ Budget analysis

Budget Analysis for Group YY-1 - Bench-top Image System for Plant Phenotyping

Camera expenses				
	LR: Blackfly USB	$	519.00	
	Lens	$	300.00	
	total	$	819.00	
Frame expense				
T-slotted framing — from McMaster	Rail	$	135.00	-$10.6/3ft * 8
	Bracket	$	192.00	$8/ea *24
	Roller	$	35.00	
	Panel	$	300.00	
	Screw on	$	24.00	$6 * 4
	Felt	$	50.00	
	total	$	736.00	

Lighting				unit price	Qut
LEDs	400nm	$	44.70	$ 0.75	60
	532nm	$	32.40	$ 0.54	60
	blue	$	3.00	$ 0.05	60
	660nm	$	10.80	$ 0.18	60
	880nm	$	20.52	$ 0.34	60
	total			$ 111.42	
Signal transition					
	Cable & Wire	$	70.00		
	Other	$	70.00		
	total			$ 140.00	
Other					
	Delivery	$	80.00		
	Tax	$	138.00		
	Other	$	100.00		
	total			$ 318.00	

Total $ 2,124.42



⬆ Creo modeling of the top side adaptor

7. Final Design

- **Camera**

The final choice of camera is model BFLY-U3-23S6M-C from FLIR.

- **Lens**

The final choice of lens is model V1226-MPZ from Computar.

- **Physical structure**

The physical device implement the T-slotted framework. Acrylic felt will be used to cover all the side board to create the light-proof environment.

- **Lighting system**

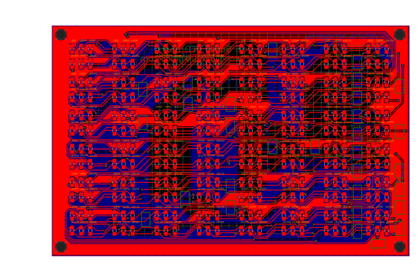
There are five types of LED lights providing five different wave length of lighting to achieve the multispectral functionality. The LED circuit board resembles the design shown below. The lens is implemented at the hole in the middle of the LED board, the lights going around the lens to provide lighting with no shade. And a layer of Teflon covers the LED board to make the lighting symphonious.

- **Operation context**

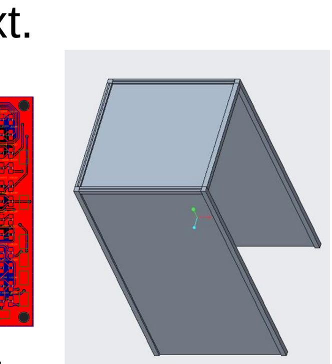
The entire system will work under the Visual Studio context using C language as the programming context.

- FLIR Camera

- Computar Lens



- Designed Circuit



- 3D Model of the structure

8. Process Implement Plan

There are several steps for the future implement:

Step 1: Purchase everything on the list. The items that already delivered are the camera and red LED lights.

Step 2: Assemble the rails and brackets to build the physical frame and structure

Step 3: Weld the LEDs on the circuit as designed. Make adjustment for optimal brightness and clearness.

Step 4: Continue to finish the program and interface for the operation of the camera.

Step 5: Test the camera with the program under LED lighting. Refer to the photo result, make adjustment and optimization.

Step 6: Install the components into the structure. Design the pattern of the entrance and exit of the plant.

Step 7: Arrange all the cables and wires to make it integrate and invisible on the outside.

Step 8: Finish the prototype.

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