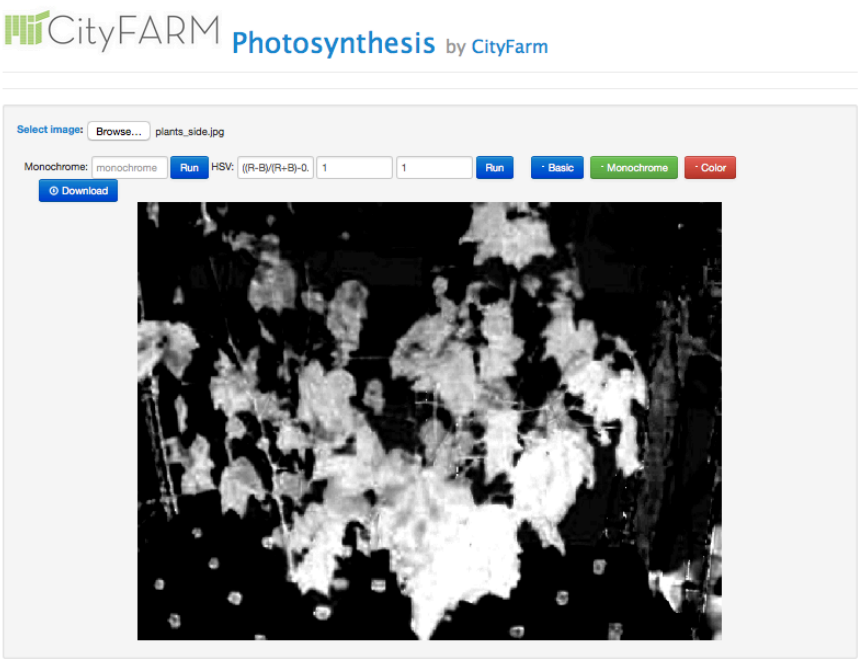
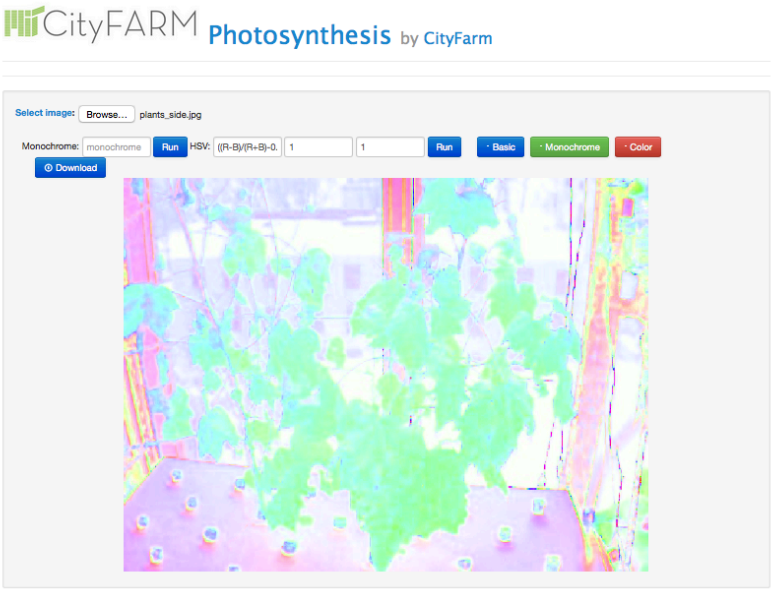
Photosynthesis by CityFarm Edible Bytes





Background to the Application

This application was created as part of the class MAS.S64 Edible-Bytes at MIT http://mitcityfarm.media.mit.edu/ediblebytes/

The idea behind the application was that in a “CityFarm” or any other farm for that matter you need to know how effective your growing techniques are. You

want to know if a batch of plants is as healthy as the one that came before it. You want to be able to establish some kind of metric in order to judge whether one growing combination is more effective than the other. You want to be able to compare a set of plants in the same bay to see if some plants are growing better than others, figure out why this is occurring, and adjust accordingly.

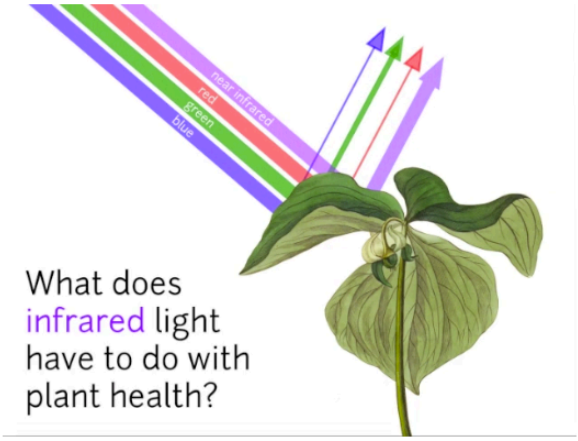
How the Imaging Occurs

The Camera

This technique derived from Public Labs uses a modified digital camera to capture near-infrared and blue light in the same image, but in different color channels. We then post-process the image to attempt to infer how much it is photosynthesizing. This allows us to better understand and quantify how much of the available light plants are metabolizing into sugar via photosynthesis.

Infrared/visible photography has a variety of applications. We are focused on the following uses:

- Take pictures to examine plant health in CityFarms and farms of users of the CityFarm open source software.
- Generate an image that allows you to generate data on how effective your plant growth is
- Generate an image that allows you to generate data that allows you to compare how two different plant batches differed
- Check progress of plants as they grow
- Discover unhealthy plants and be able to analyze when its health shifted and why

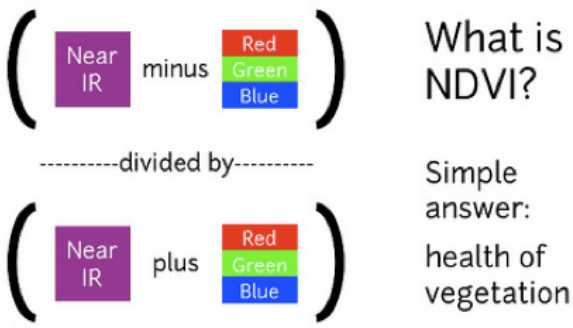


Plants absorb red and blue light but not infrared.

Vegetation is green because plant leaves reflect green light -- they don't use much of it for photosynthesis. Instead they use lots of the blue and red wavelengths in sunlight. The pigments in leaves absorb this light to power photosynthesis which converts CO_2, water, and nutrients into carbohydrates (food).

In general, you can estimate the productivity or vigor of vegetation by how much blue and red light it is absorbing. Photosynthetic pigments do not use the longer, invisible wavelengths of near infrared light and reflect almost all of it away (this helps prevent the leaves from overheating).

Healthy vegetation absorbs blue- and red-light energy to fuel photosynthesis and create chlorophyll. A plant with more chlorophyll will reflect more near-infrared energy than an unhealthy plant. Thus, analyzing a plants spectrum of both absorption and reflection in visible and in infrared wavelengths can provide information about the plants' health and productivity.



A good basic equation to start off with is (R-B)/(R+B) because it draws out an index of blue to red that makes it easier to quantify what areas have more infrared light and therefore more photosynthesis.

http://publiclab.org/wiki/near-infrared-camera
http://missionscience.nasa.gov/ems/08_nearinfraredwaves.html

Applications

Imaging:

- You could change the imaging equations accordingly to make it easier to create indexes and metrics of plant health.
- You could alter the equations to make hotspots of photosynthesis stand out.
- You can soften the emphasis on photosynthesis to make it easier to compare photosynthesis over a wide array of plants.

Automation:

- Automating the photo taking and processing process in order to build up a repository of images over a given amount of time
- Automate the process of creating an index based on a filter in order to quantify plant health and plot it on a time graph

CityFarm:

- Make it easier to discover what combination of variables increase plant growth efficiency
- Figure out if plant are not growing properly due to poor light placement or a chemical discrepancy

Individuals:

- Play around with the filters in order to find insights on how your plants are growing
- Create your own filters based on pre-existing ones to create your own unique insights
- Create filters that make certain photosynthetic characteristics stand out over those of others.

Possible Metrics

Monochrome

- Area
    - If you use the “Black&White” filter under “Monochrome” you can make the image purely black and white instead of different shades of gray
        - The White area showcases that there is photosynthesis occurring there - by taking the area of the white sections you can quantify the amount of photosynthesis in a batch - since all the bays are the same size you can make this into a metric

- Black and White Gradient
  - Create an index for the different shades of gray. Use that to quantify plant batch health per image.

Color

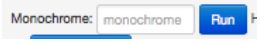
- Target A Specific Color Intensity
- Analyze How Much of an Image is above a certain color intensity
- Create a filter that draws out a certain color if there is photosynthesis above a certain intensity. Take areas of all spots of this color from an image to quantify batches above this photosynthesis threshold

---

Things To Keep In Mind

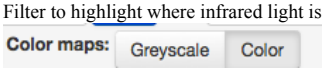
- This Type of imaging is based on infrared light therefore if there are reflective surfaces in your image then you may get hotspots that show up in your image even though they are not plants undergoing photosynthesis
- You may want to change and modify the equations based on the amount of infrared light in your environment.

Documentation

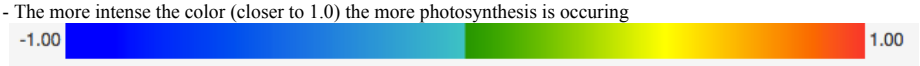
- Adding Images
  - To Add Images click on the “Browse” button - click on the image of your choosing in your computer that has been taken with an Infragram camera
    - Infragram cameras are cameras that have had the infrared filter taken out and an infragram filter put in- we use the Infragram red filter
- Creating Your Own Equations/Filters
  - Because Infrared depends heavily on the environment you are in sometimes you need to create your own filters to either increase or decrease the emphasis on photosynthesis in the image. For example, their may be more infrared light outdoors while little indoors.
  - Monochrome
    - 

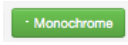
    - Click on the monochrome input
    - A good basic equation to start off with is (R-B)/(R+B)
    - To increase the intensity of R or B multiply it by a factor greater than 1
  - HSV
    - 

    - I would recommend working mostly in the “H" section and leaving the “S” and “V” sections blank
    - A good basic equation to start off with is (R-B)/(R+B)
    - To increase the intensity of R or B multiply it by a factor greater than 1. When creating your own filter feel free to play around with multiplication of variables in order to draw out more of a specific color.
- Basic Filters
  - 

  - Raw
    - Original Image
  - NDVI
    - Filter to highlight where infrared light is being reflected off of
    - 

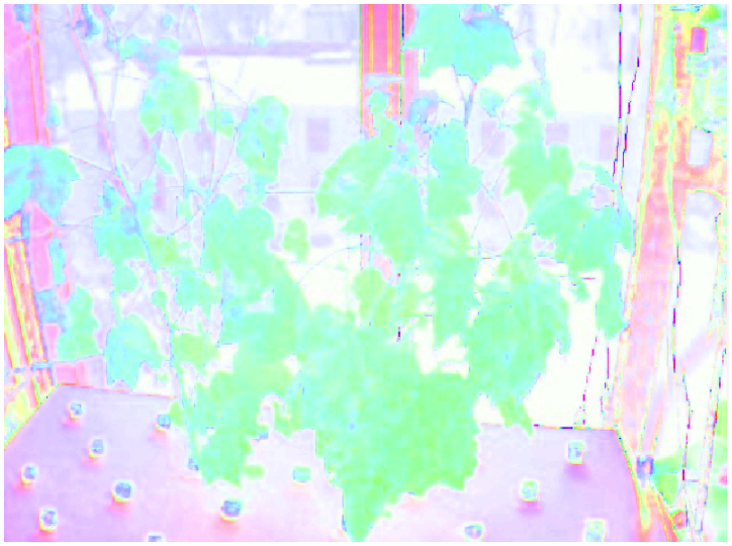
      - After clicking on the NDVI option you will see the buttons above pop up
      - What you want to do is click on one option
        - Greyscale -The more intense the color (closer to 1.0) the more photosynthesis is occurring
        - 

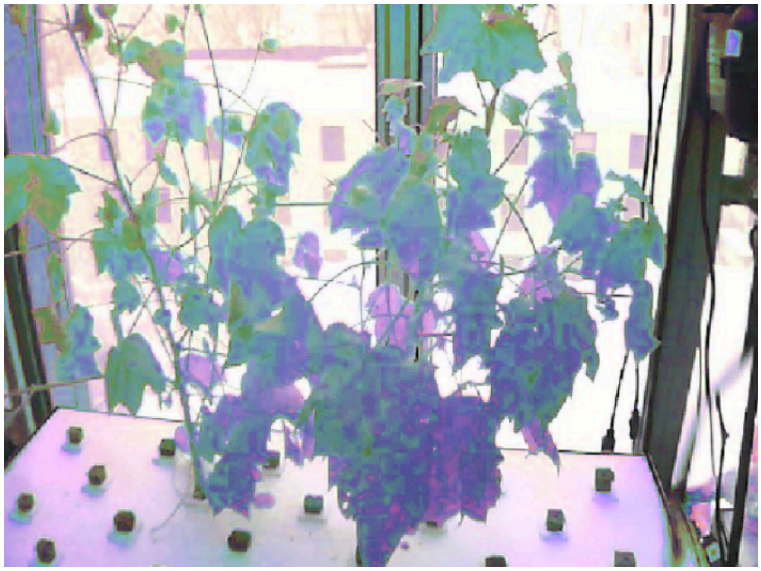
        - Color - The more intense the color (closer to 1.0) the more photosynthesis is occuring
        - 

- Monochrome Filters
  - 

  - There are a variety of monochrome filters
  - They are all slightly similar however they differ in the intensity by which they differentiate photosynthesis
  - The reason behind this is that specifically for infrared imaging - infrared light varies greatly depending on where you are
    - For example CityFarm is indoors near windows

        - Some people may decide to have their plants outdoors.
        - In some places their may be very little infrared light so the intensity will have to be increased even more
- Color Filters
    - 

    - Isolate
        - 
        - The reasoning behind this filter is that sometimes you want to be more specific and see which areas of the plant are more active - this color filter makes the active areas pop out more so that it is a bit easier to see the active areas.
    - Red Emphasis
        - 
        - This filter is designed to really emphasize the more active spots in the plant in red.
    - Active Area

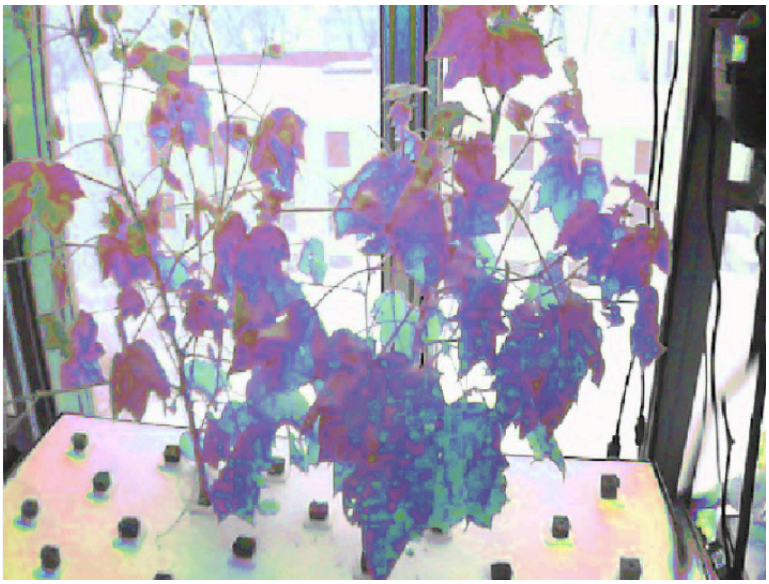


- This filter focuses on finding the active areas of the plant. It is not as specific but it does a good job of showing what areas of the plant are more active (purple).

- Red Highlight

- This filter focuses on showing the more active areas of the plant. It is context based - designed to showcase the more active parts of the plant itself.

- Emphasis


    - This filter focuses on creating a heavy emphasis on active areas (cool blue).
- Download
    - Clicking the download button allows you to download the image into your computer
    - This could be automated later so that it can be uploaded to a file repository later for comparisons.
- Upload To Database
    - Fill out the information under the “Upload to Database” section
    - This form still needs to be integrated into the existing CityFarm system
    - This library allows you to store larger files (images) to your database http://docs.mongodb.org/manual/core/gridfs/

Github: https://github.com/martin-martinez/Photosynthesis-By-CityFarm

---

How The The Open Source Community Can Use The Tool

The Open Source community can use the tool to figure out whether or not their plants are healthy, what sections of the plant are more active, and customize the tool based on their growing environment.

An important aspect to consider about infrared imaging is that it differs based on whether the plants are indoors or outdoors. In order for the imaging to work - there needs to be some infrared light.

The open source community is free to use this application for their own purposes

---

Continuing The Project

- The Upload to Database Section
- Automation
- Adding Filters
- Analysis
    - Creating metrics
    - Software to compare a series of images
    - Software to gather insights on plant health based on a combination of variables - Will make it effective to
- Connect to the Raspberry Pi

Equations Created For This Tool

Basic	Equation

Raw	Raw: "r", "g", "b"
NDVI (Normalized Difference Vegetation Index)	NDVI: "((-(b-r)/(r+b))+1)/2"

Color (HSV)	Equation : “Hue”, “Saturation (Intensity)”, “Value (brightness)"
Isolate	"((R-B)/(R+B))", " ", "1"
Red Emphasis	"(R-5*B)/(R+B)", " ", " "
Active Area	"-(4*R-2*B)/(2*R+B)", " ", " "
Red Highlight	(-(6*R-B)/(2*R+2*B))", " ", " "
Emphasis	"4*(R-B)/(R+B) ", " ", " "

Monochrome	Equation : (Monochrome)
Illuminate	((R+G)-(2*B))/((R+G)+(B))
Radiate	(((R-B)/(R+B))+1/2)
Highlights	4*(R-B)/(R+B)
Black&White	9*(R-B)/(R+B)

Explanation of Image Contexts

Raw

Uses the RGB color channel

NDVI

NDVI stands for "Normalized Difference Vegetation Index". NDVI is a way to visualize the amounts of infrared and other wavelengths of light reflected from vegetation. Because this method compares ratios of blue and red light absorbed versus green and IR light reflected, they can be used to evaluate the health of vegetation. It's a snapshot of how much photosynthesis is happening. This is helpful in assessing vegetative health or stress.

HSV

Stands for **hue, saturation, value**

Hue: Hue is somewhat synonymous to what we usually refer to as "colors". Red, green, blue, yellow, and orange are a few examples of different hues. The different hues have different wavelenghts in the spectrum.

Saturation: Saturation can also be called a color's intensity. It is a measurement of how different from pure grey the color is. Saturation is not really a matter of light and dark, but rather how pale or strong the colour is. The saturation of a color is not constant, but it varies depending on the surroundings and what light the color is seen in.

Value: The value is a measurement of the brightness of a colour. The brighter a colour is, the higher is its value and the more light it emits. For instance, a vivid yellow is brighter than dark blue, therefore its value is higher than that of the blue

http://www.colorsontheweb.com/colorterms.asp

Monochrome

A painting, drawing, or photograph in a single hue

Sources:

This is a tool I referenced - It is the main infragram App - It is useful but none of the code was used
http://infragram.org/sandbox/

For The Infragram-gl Template I worked off of this source code. Most of the UI and code was changed for the purposes of the Photosynthesis App
https://github.com/pfoltyn/infragram-gl

For More Info on the Modified Camera
http://publiclab.org/wiki/near-infrared-camera
https://youtu.be/ZVbC3UxlX8c

For More Info on NDVI and imaging
http://publiclab.org/wiki/ndvi

For The Science Behind The Imaging:
http://publiclab.org/wiki/near-infrared-camera
http://missionscience.nasa.gov/ems/08_nearinfraredwaves.html

Github REPO: https://github.com/martin-martinez/Photosynthesis-By-CityFarm

Developed By Martin Martinez
martin.martinez@mit.edu
MIT Class of 2017
https://github.com/martin-martinez