Automated Blob Detection and Identification of Spotted Lanternfly Eggs

Group Number: MEM-31

Senior Design Project III

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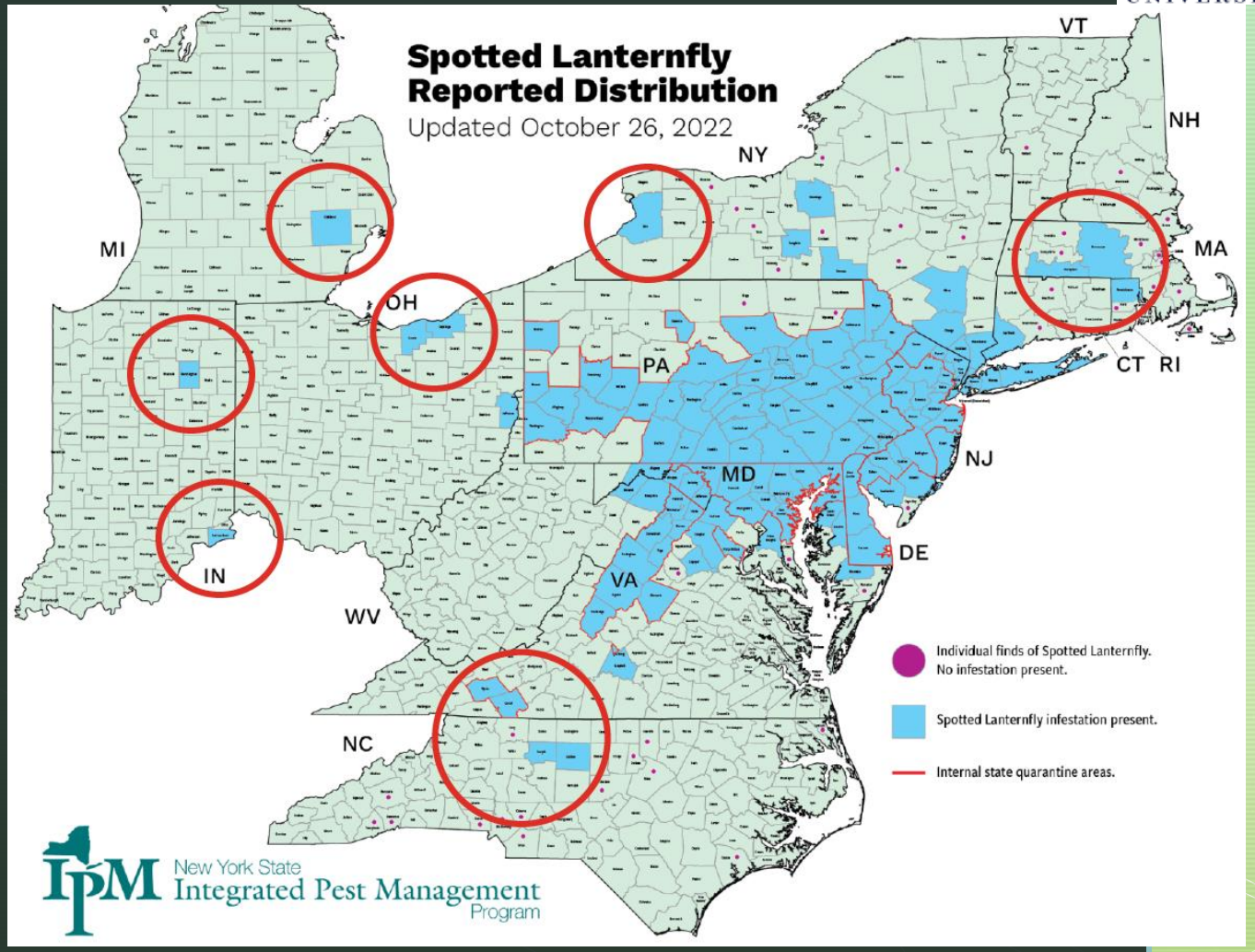
Date: 22nd May 2023

The Problem

The population and spread of the invasive Spotted Lanternfly (SLF) is growing.

There are abnormalities in the spread that may be caused by trains.



https://nysipm.cornell.edu/environment/invasive-species-exotic-pests/spotted-lanternfly/spotted-lanternfly-ipm/introduction-native-range-and-current-range-us/

The Problem Statement

Spotted lanternflies have been spreading through the region causing harm to the local infrastructure, economy and wildlife. We intend to identify these egg masses beneath train cars using a camera and Python's blob detection to limit their spread.

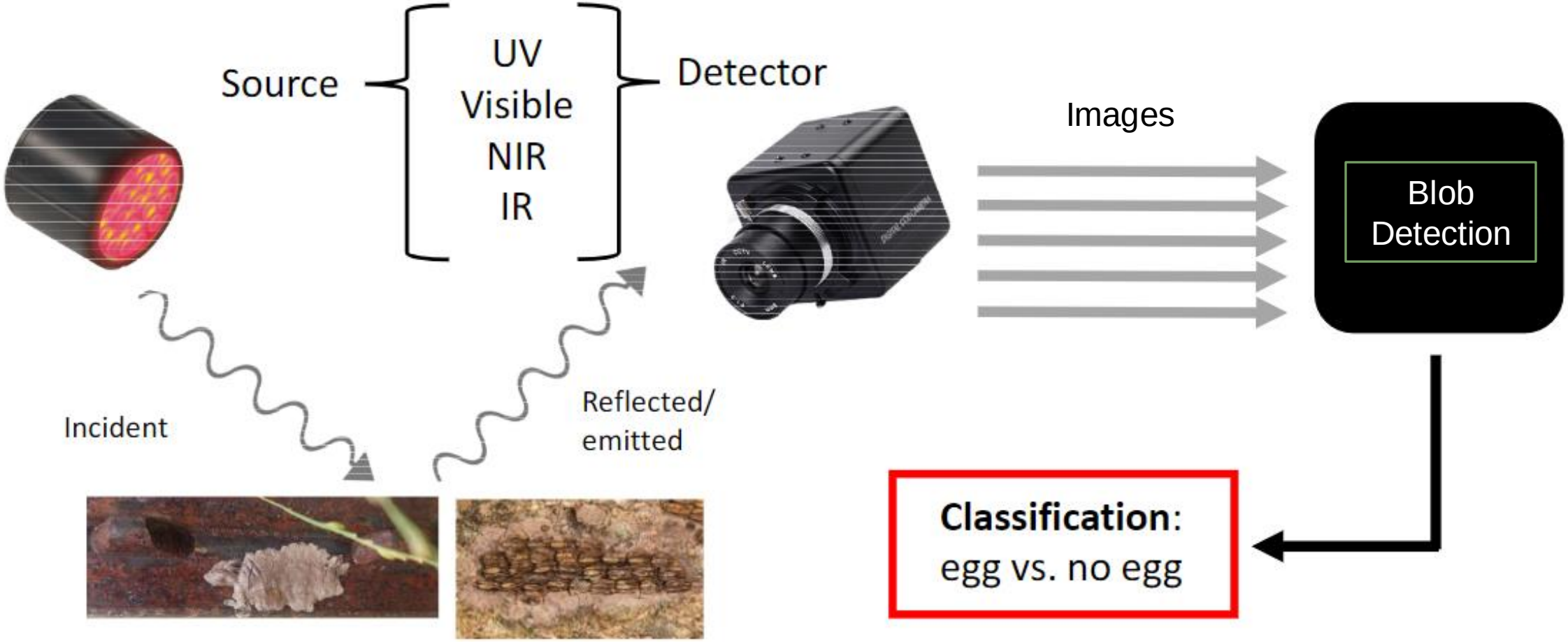
Our Stake Holders

- Amtrak
- Septa
- Other Train Companies
- Local Farmers
- Plant Nurseries
- USDA
- General Public

Our Stakeholder Needs

NO.	NEED	IMPORTANCE
1	The design can positively identify egg clusters	5
2	The design is automated	5
3	The design is capable of long-term wear	4
4	The design can maintain optimal conditions	5
5	The design requires minimal effort to install	3
6	The design uses renewable materials	2
7	The design can scan while the car is moving	4
8	The design can transfer data remotely	5
9	The design can process the data quickly	4
10	The system is easy to use	3
11	The design fits within available area	5

Egg Detection Method



Design Specifications

Metric No.	Need Nos.	Metric	Importance	Units
1	7, 9	Train car scan time	4	seconds
2	1, 4	Wavelength of the light used	5	nm
3	9, 2	Processing power of the design	4	Mb/sec
4	3, 4	Design can withstand extreme temperatures	4	°F
5	11, 10, 5	Simple install	3	components
6	8, 2	Distance of data transfer	5	ft.
7	1, 2, 4	Field of view	5	pixels
8	6, 3	Renewable or recycled materials used	2	% renewable materials
9	1, 4	Light intensity	4	foot-candles
10	1, 4, 7	Aperture size	5	f-stops
11	1, 4, 7	Focal length	5	ft.

Our Design Plan

-Train passes over the camera

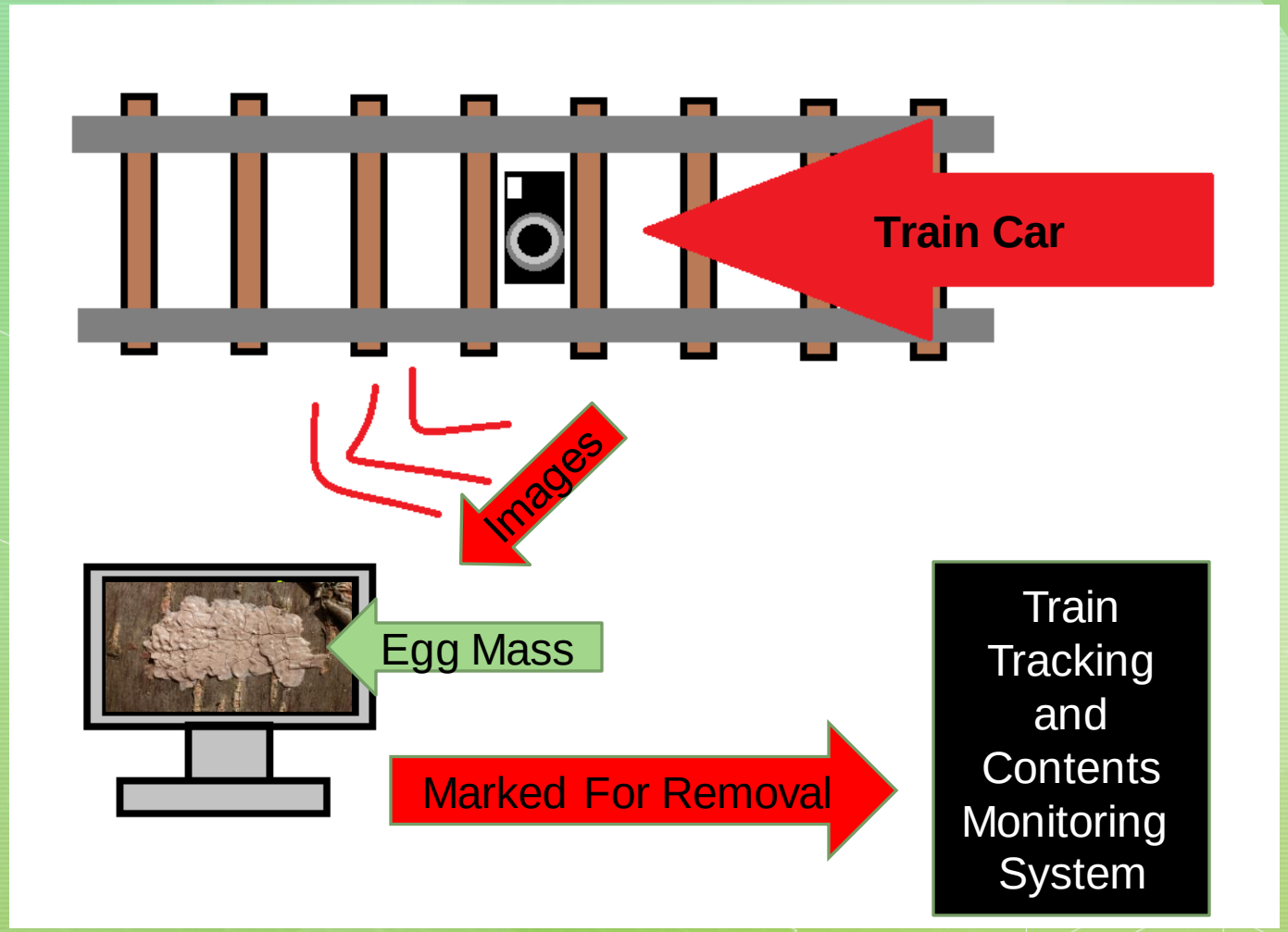
-Photos are taken

-The photos are transmitted into the program

-The program scans the images using blob detection

-Each train car has personal information and history

-The positive results are marked and the train cars are tagged.



Above: The experimental set up

Below: Camera Results

Software Design

- **Connected Component Analysis (CCA) Method**
- **Methodology:** CCA is used to label distinct objects or regions in an image based on connectivity or spatial relationships.
- **Process:** Pixels in an image are grouped into connected sets or components, based on predefined criteria.
- **Output:** A labeled image where each distinct object is assigned a unique label or value. This is used for further analysis like size, shape, orientation, texture, or intensity of each object.

Implementation of the Connected Components Analysis

Algorithm: A for-loop iterates through the image files, applying a blur to reduce noise, binarizing the image relative to a set threshold, and comparing potential objects to a minimum area value.

Function Parameters: Filename, sigma (for Gaussian filter), threshold (for binarization), connectivity (for object classification), and min_area (for size detection).

Image Optimization: Cropping strategically focuses on egg mass-prone areas, enhancing detection efficiency and reducing resource usage for the algorithm's speed and accuracy.

Validation: The algorithm is validated and has performed as intended under optimal conditions. There were some inconsistencies due to varied conditions in the sample data, but overall, the results prove the algorithm is functioning correctly.

Connected Components Algorithm Implementation

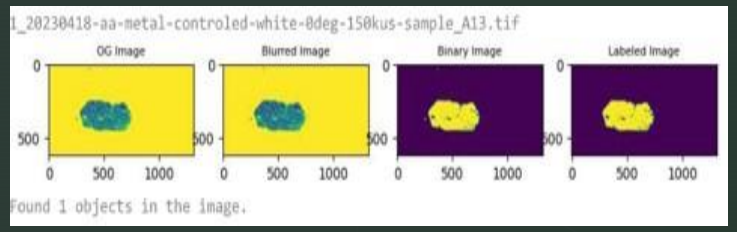


Figure: An egg sample on a metal

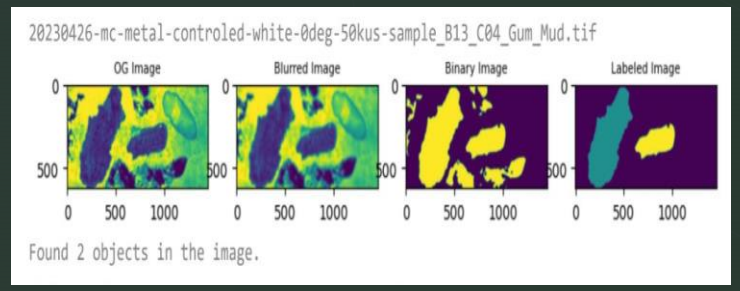


Figure: Two egg samples with both gum and dirt results

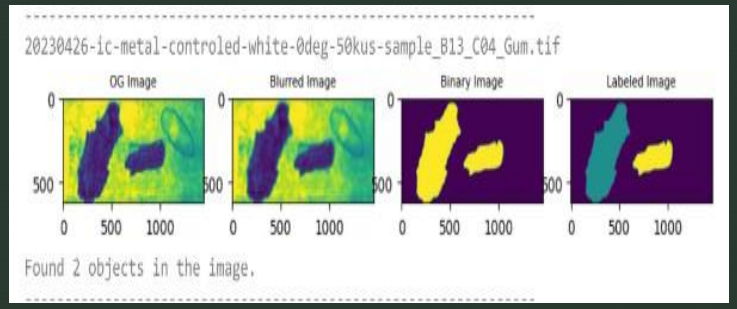


Figure: Two egg samples and a piece of gum results

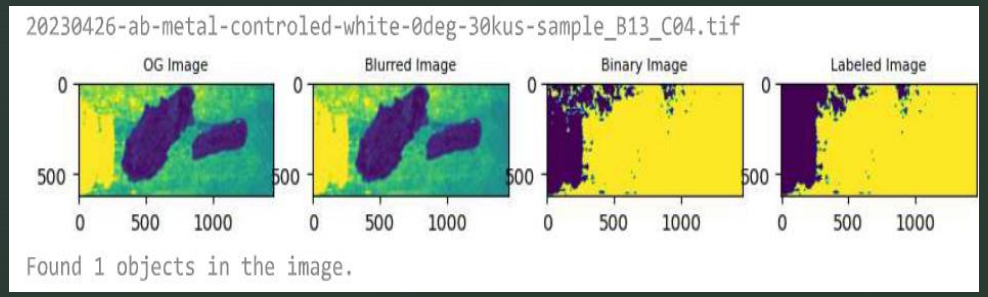
```python
def enhanced_connected_components(filename, sigma=1.0, t=0.5, connectivity=2, min_area=0):
    fig, ax = plt.subplots(1,4,figsize=(10,5))
    image = iio.imread(filename)
    ax[0].imshow(image)
    ax[0].set_title('OG Image',fontsize=8)
    blurred_image = skimage.filters.gaussian(image, sigma=sigma)
    ax[1].imshow(blurred_image)
    ax[1].set_title('Blurred Image',fontsize=8)
    binary_mask = blurred_image < t
    ax[2].imshow(binary_mask)
    ax[2].set_title('Binary Image',fontsize=8)
    object_mask = skimage.morphology.remove_small_objects(binary_mask,min_area)
    labeled_image, count = skimage.measure.label(object_mask,
                                                 connectivity=connectivity, return_num=True)
    ax[3].imshow(labeled_image)
    ax[3].set_title('Labeled Image',fontsize=8)

    plt.show()

    return labeled_image, count
```

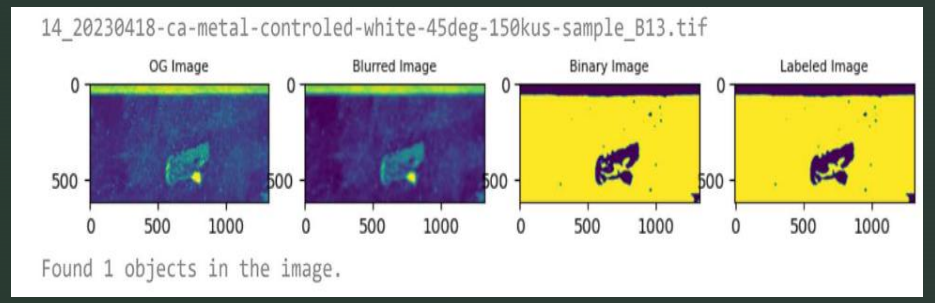
Figure: Connected Components function body

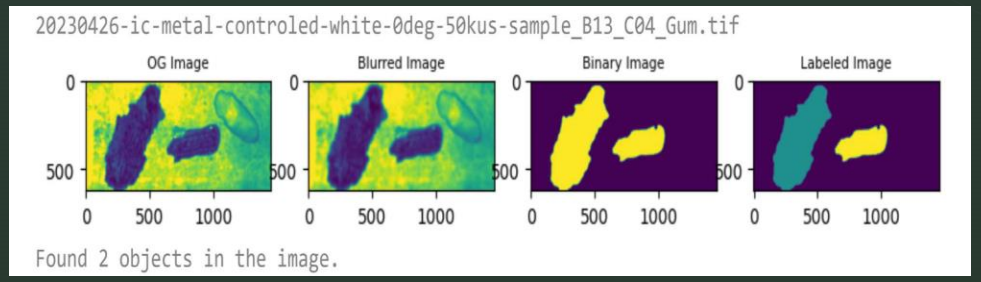
```python
folder_dir = '/content/drive/MyDrive/2023-04-26 Sample Images'
output_dir = '/content/drive/MyDrive/output'

def crop_image(image_path, left, top, right, bottom):
    img = Image.open(image_path)
    img_res = img.crop((left, top, right, bottom))
    return img_res

for images in glob.iglob(f'{folder_dir}/*'):

    print(images.rsplit('/')[-1])

    cropped_image = crop_image(images, 0,370,1456,990)
    cropped_image_path = os.path.join(output_dir, os.path.basename(images))
    cropped_image.save(cropped_image_path)
```

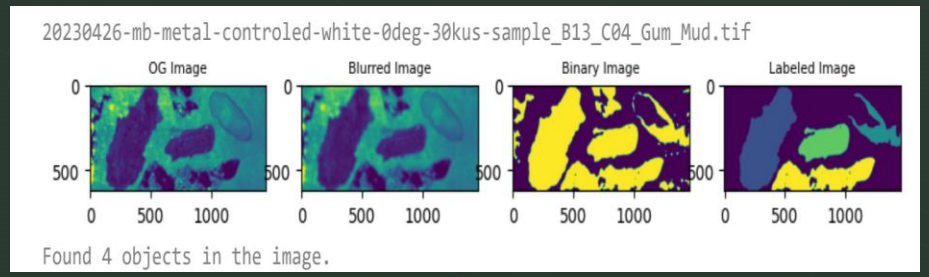
Figure: The crop image function

Output Images









Enviornmental Impact

- Grape, apple, and hop yields, as well as hardwood trees including maple, black walnut, cherry, and birch are affected.
- Native plant species are at risk.
- Higher amounts of pesticides may be used.
- Our design aims to limit these effects and help prevent them from spreading

Economic Impact

- SLF's impacts are greatest in the agricultural and hardwood production industries.
- This threat to the economy has spread to other states such as New Jersey and can effect to others soon.
- Our design could mitigate the spread and prevent other state's economies from being effected..

Source: https://extension.psu.edu/spotted-lanternfly-management-guide
https://www.agriculture.pa.gov/Plants_Land_
Image: https://daily.sevenfifty.com/the-increasing-threat-of-the-spotted-lanternfly/

Social Impact

- Counties are currently being put under quarantines.
- Spotted lanternflies cover trees, swarm in the air, and their honeydew can coat decks and play equipment.
- This system will aid in preventing future infestations of lanternflies from getting this bad.

Ethical Impact

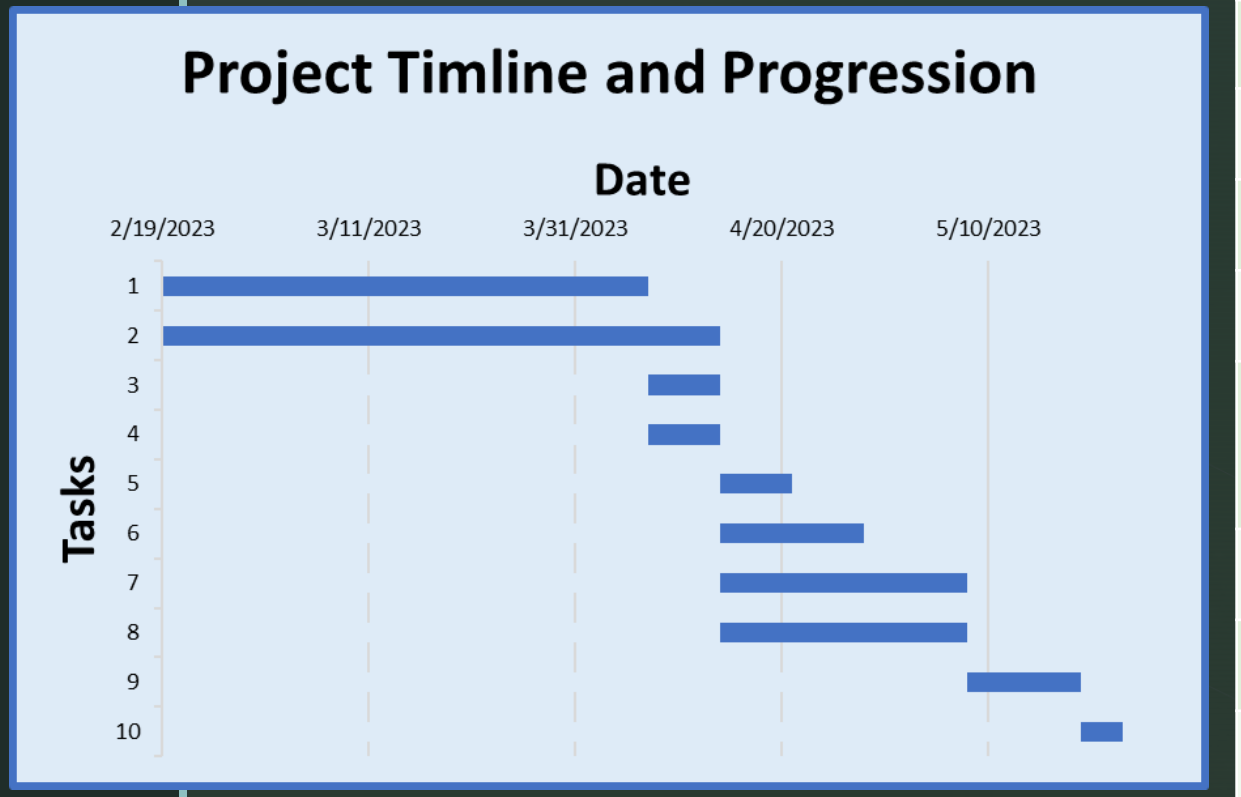
- Our design could prevent the endangerment or extinction of native species affected by SLF.
- The implementation of our design would have a lower environmental impact then using pesticides on the flies.
- Our design will result in easier and safer work for the inspection teams.

Sources:
https://www.nps.gov/articles/000/slf-in-perpective.htm
https://www.agriculture.pa.gov/Plants_Land_Water/PlantIndu

Future Work

- Though the algorithm does show promise, there is still a lot that can be done to build on the current algorithm and refine the criteria to enhance the accuracy of results using other scikit functions. These functions include sckimage.measure.regionprops and skimage.measure.perimeter which can both provide data on objects found in an image for comparing to an ideal “egg mass case” to help reduce noise in the image. More testing with different objects in the images could and should be done to add noise and ensure no failures occur in the system.

- Once the algorithm is confirmed to be effective, the designing of a physical prototype for field testing would be the next step. From there a final prototype could be designed for testing and proof of concept.



Task	Description	Start Date	End Date
1	Look into camera set up and camera software	2/19/2023	4/7/2023
2	Develop classification algorithm	2/19/2023	4/14/2023
3	Configure camera set up	4/7/2023	4/14/2023
4	Set up controlled lab testing setting	4/7/2023	4/14/2023
5	Create a spreadsheet to track results from the algorithm	4/14/2023	4/21/2023
6	Capture images in the lab	4/14/2023	4/28/2023
7	Run images through algorithm and analyze results	4/14/2023	5/8/2023
8	Adjust the algorithm to be more effective	4/14/2023	5/8/2023
9	Write up final report	5/8/2023	5/19/2023
10	Create slides and prepare for presentation	5/19/2023	5/23/2023

Responsibilities

Each of our roles on the project.

- Samuel Skodi : In charge of the hardware for the system. Responsibilities include the setup, designing, and adjustment of camera, lights and other equipment.
- Atul Mishra : Handling the software part of the system. Responsibilities include developing the algorithm and project management.
- Aravind Rajpurohit : Among the responsibilities include creating the algorithm with Atul, testing the software for errors and it's accuracy, and validating the algorithm's output.
- Ghanath V : Responsible for ensuring that the project met quality standards and specifications. He worked closely with both the hardware and software teams to ensure that the projects communication between teams was always maintained.

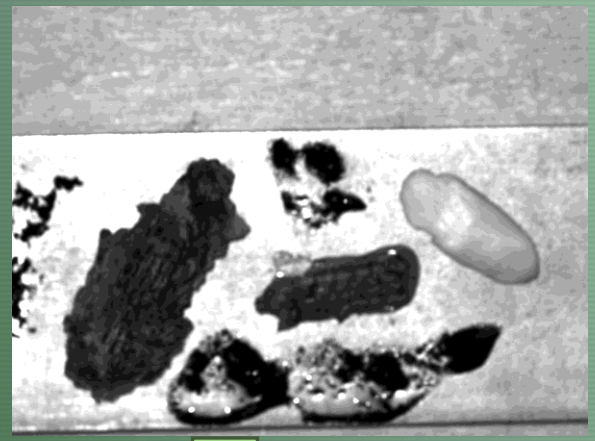
Budget

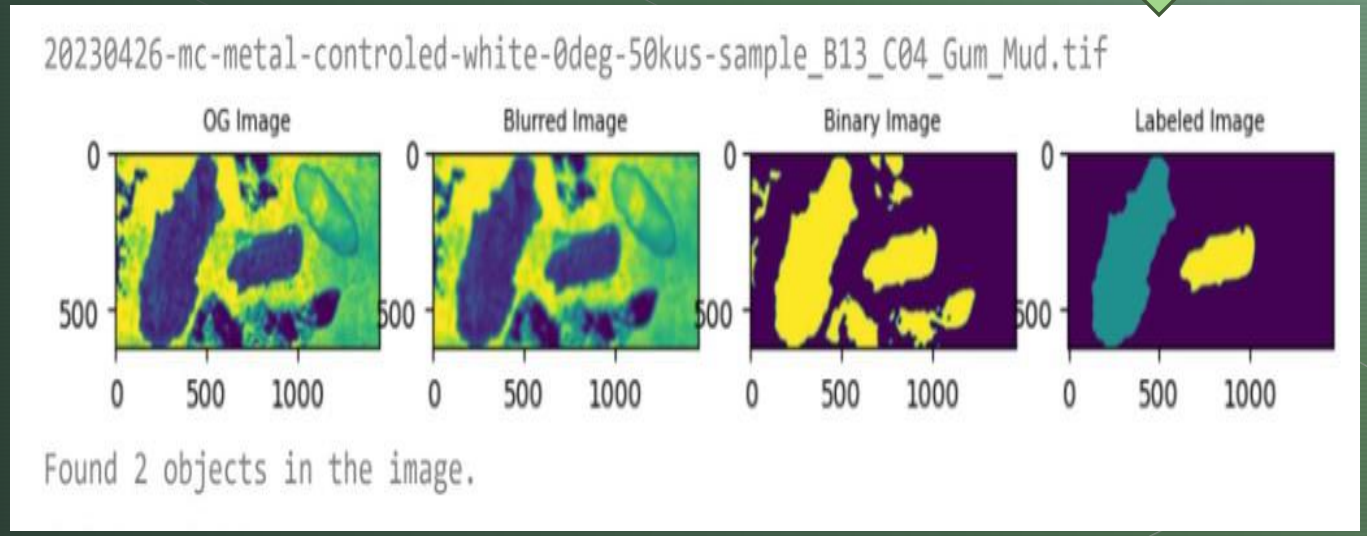
Total funding by USDA	$5,000
Spent funding	$2,838
Remaining funding for future expenses	$2,162

The focus of the prototype was mainly software functionality rather than a physical design

Item	Reason	Cost ($)	Quantity	Item Number	Description
Camera	Collects Images	725	1	AVT-G1-17772	G1-17772 1456x1088 IMX273 GigE 1/2.9 in C-mount 72fps
Lens	Provides better resolution	295	1	MOR-C-ML-M1218	Moritex hi-resolutions lens, 2/3 in, F/1.8, C-mount, 12mm
Cable	Allows for camera connection	70	1	CB-ALY-U3-SL-02M	MV USB3 cable w SL 3M
Mounting plate	Will hold the camera in place	18	1	AVT-UA-12310	Alvium Mounting Plate CSI-2 and USB3 Series
Spotlight Type UV	Lights will help highlight or just illuminate the egg masses	594	1	AI-SL2420-395300	AI medium aimed spot light, 1.5 in O.D., UV 200mm WD Medium FOV, I3
Spotlight Type IR	Lights will help highlight or just illuminate the egg masses	568	1	AI-SL2420-880300	AI medium aimed spot light, 1.5 in O.D., IR 300mm WD medium FOV, I3
Spotlight Type White	Lights will help highlight or just illuminate the egg masses	568	1	AI-SL2420-WHI300	AI medium aimed spot light, 1.5 in O.D., white 300mm WD medium FOV, I3

Accomplishments





Questions?