PROJECT NO.__RU-2

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE:
Development of Real-time Monitoring and Early Detection System for Insect Activity in Rice during Storage

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OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

Objectives:

The goal of this research project was to develop and study the feasibility of real-time insect monitoring and early detecting system for insects in rice storage facilities using an imaging technique. To achieve the goal, we identified the following specific objectives:

1. Design a real-time insect monitoring and early detecting system using an imaging technique for a commercial scale of rice storage facility.

2. Evaluate the effectiveness and accuracy of the new system for monitoring and detecting insect activity in stored rice.

3. Provide recommendations for feasibility of real-time monitoring and early detecting system for infested rice during storage.

Experimental Procedures

<u>Design a real-time insect monitoring and detecting system using an imaging technique for a commercial scale of rice storage facility</u>

A new system consisting of traps, USB cameras, LEDs, a raspberry Pi, sever, and user interface, was developed and tested. Three traps (each has diameter of 4.5 cm and length of 32 cm) were designed and built. Each trap was equipped with a brightness camera and two LEDs connected to the raspberry Pi to remotely provide users with access to images of the captured insects through a server. The server processes the images with identification algorithm to count the insects captured per trap and stores the images and numerical data over time. The user interface was designed to allow the user to easily visualize the data.

1. Trap design

The trap consists of three main parts, cap, perforated area, and collecting chamber. To choose proper diameter and length for the trap, four diameters (6.3, 5.1, 4.5, 3.3 cm) and four lengths (21, 27, 32, 40 cm) were tested in a rice storage facility (Fig. 1 and Table1). During the teste, the dimensions were marked as A, B, C and D (Table 1). The tested traps were inserted into the grain mass by a same person using the same force. The diameter of 4.5 cm and length of 32 cm were chosen based on appropriate force required to insert the trap into the rice mass, and enough space to fit the camera in the cap. Three traps were made from stainless steel perforated sheet with 0.8 mm of thickness and 2.4 mm of hole diameter (Figs. 2 and 3). Each trap was equipped with a brightness camera (Sensor 1/2.7" CMOS, OV2710, 2.0 megapixel) and two LEDs (5 mm Clear LEDs w/resistors) contacted to the raspberry Pi (Model B Quad-Core 1.2 GHz 1 GB RAM).

Fig. 1. Trap dimension test at rice storage facility.

Table 1. Tested diameters and lengths of trap.

Dimension (cm)	A	B	C	D
Diameter	6.3	5.1	4.5	3.3
Length	21	27	32	40

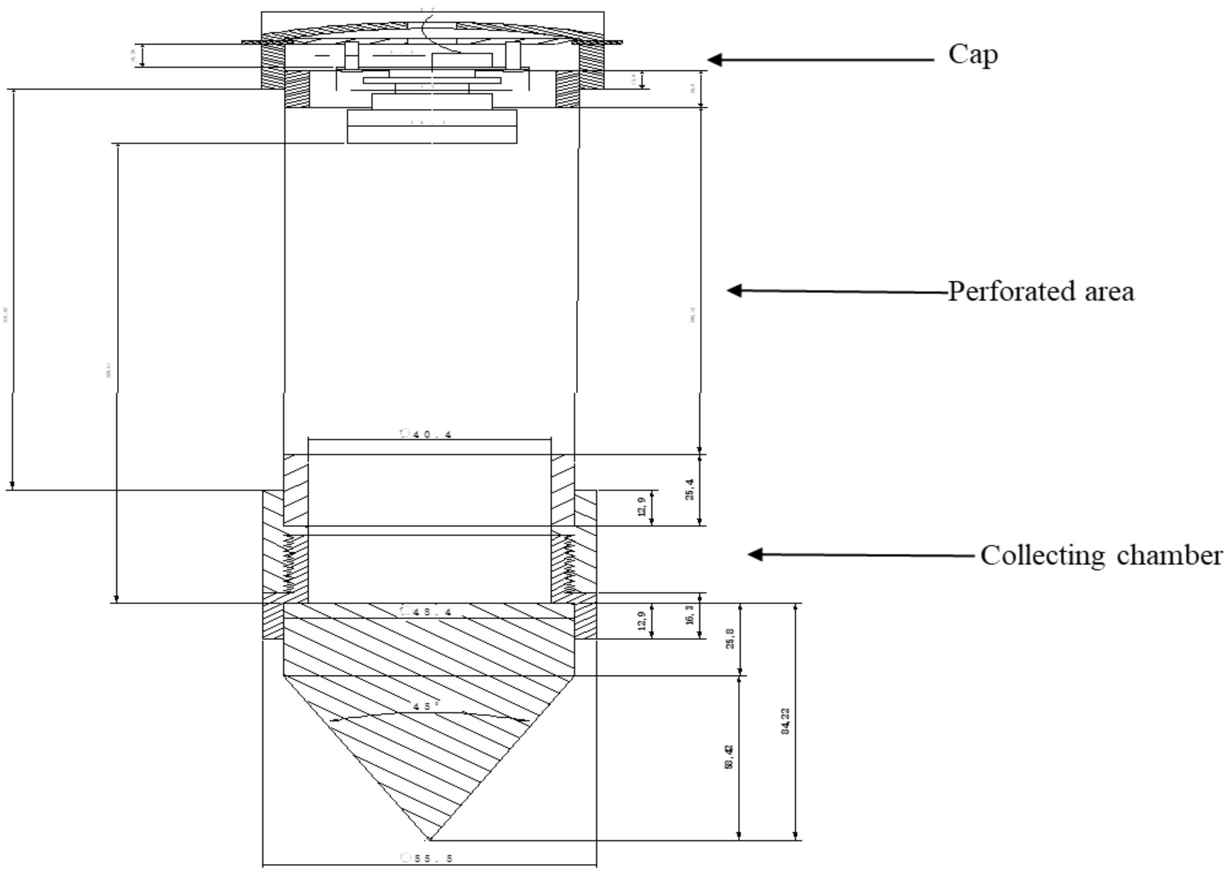


Fig.2. Schematic diagram for the insect trap. (Dimensions in mm)

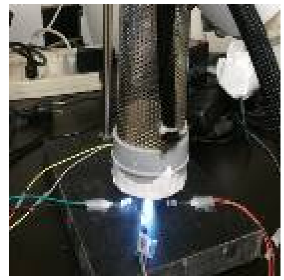
Fig. 3. Designed traps with installed LEDs, camera, and raspberry Pi.

The cap was made from a 2.4-inch ID PVC cap fitting. A ¼-inch aluminum disk was machined to mount the camera and LEDs flat and perpendicular to the base. The camera wires ran through a hole in the aluminum disk, and through a strain relief out of the top of the cap. The perforated cylinder (diameter of 4.5 cm and length of 32 cm) was made by rolling and spot welding 0.8 mm thick stainless steel with 2.4 mm diameter perforations. The cylinder was connected to its end components by a PVC annulus matching the inner diameter. The base collection chamber was created using a straight threaded PVC connection. The male piece was sealed at the bottom with a solid PVC nose cut to shape on the lathe, and a rubber O-ring was added to the connection. The base of the collecting chamber was painted with a white color to create contrast against the insects in captured images. The LEDs were connected to the Raspberry Pi by a set of soldered wires including resistors and jumper cables.

1.1 Installation of LDEs

Three installation methods to locate the LEDs (two) were tested and the light uniformity was observed. The installation methods included positioning the LEDs above the insect collecting chamber, around the camera, and below the insect collecting chamber (Table 2). The best light uniformity was obtained when the LEDs were positioned around the camera. Consequently, for the final design, the LEDs were placed around the camera.

Table 2. Installation locations of LEDs and corresponding light uniformities.

Installation place	LEDs above collecting chamber	LEDs around the camera	LEDs below collecting chamber
LED Location			
Light uniformity			

1.2 Adjustment of camera's parameters

After determining the appropriate position for installing the LEDs, parameters of camera listed in Table 3 were tested and adjusted. Through the preliminary tests, we found that brightness, contrast and gamma had a significant influence on image quality. Consequently, brightness, contrast and gamma were chosen to be adjusted.

Table 3. The parameters of the cameras.

Parameter	Range
Brightness	-64~64
Contrast	0~64
Gamma	72~500
Backlight Compensation	0~2
Gain	0~100
Hue	-40~40
Sharpness	0~6
Exposure (Absolute)	1~5000
White Balance Temperature	2800~6500
Saturation	0~128

The images shown in Fig. 4 were taken with brightness values of -32, -16, 0, 16, 32, 48. Image number 6 is the brightest one but the reflection of insects is very harsh and does not possess good contrast. Consequently, the brightness value (32) of image number 5 was chosen to give the best results.

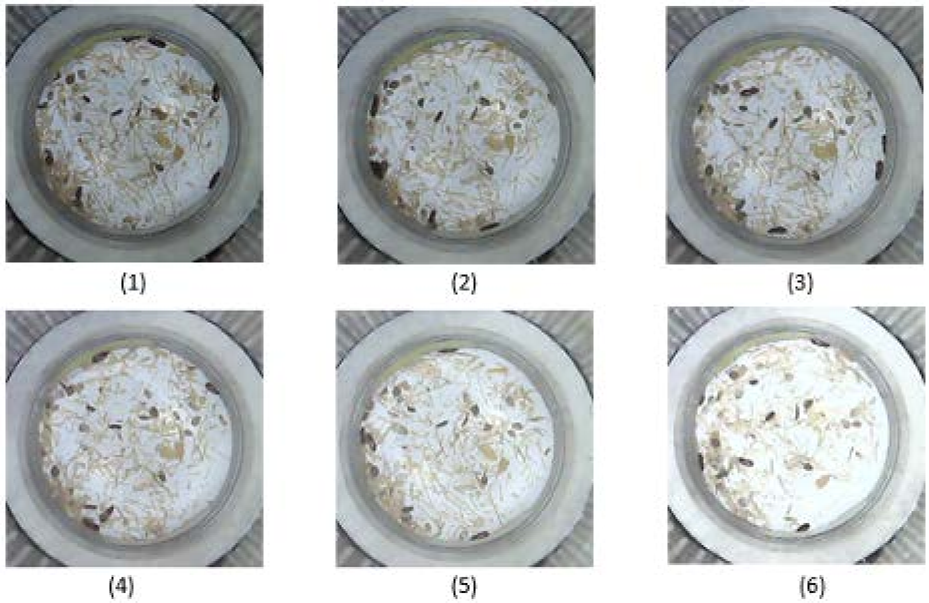


Fig. 4. Images taken at different values of brightness.

The images shown in Fig. 5 were taken with the following contrast values: 0, 16, 32, 48, 64. The highest value (64) resulted in the best contrast between the insects and background (image 5).

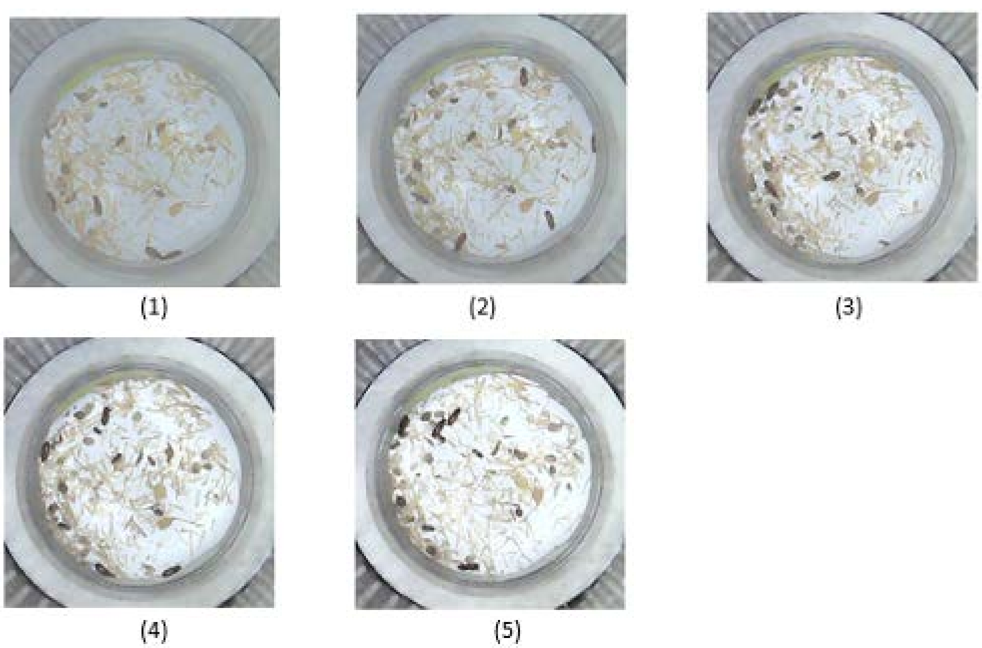


Fig. 5. Images taken at different values of contrast.

The images shown in Fig. 6 were taken with gamma values of 100, 125, 150, 175, 200. Images (4) appeared to be brighter than images pictures (1), (2), and (3). additionally, image (4) had a better contrast compared to image (5). Therefore, a value of 175 was selected for the gamma parameter.

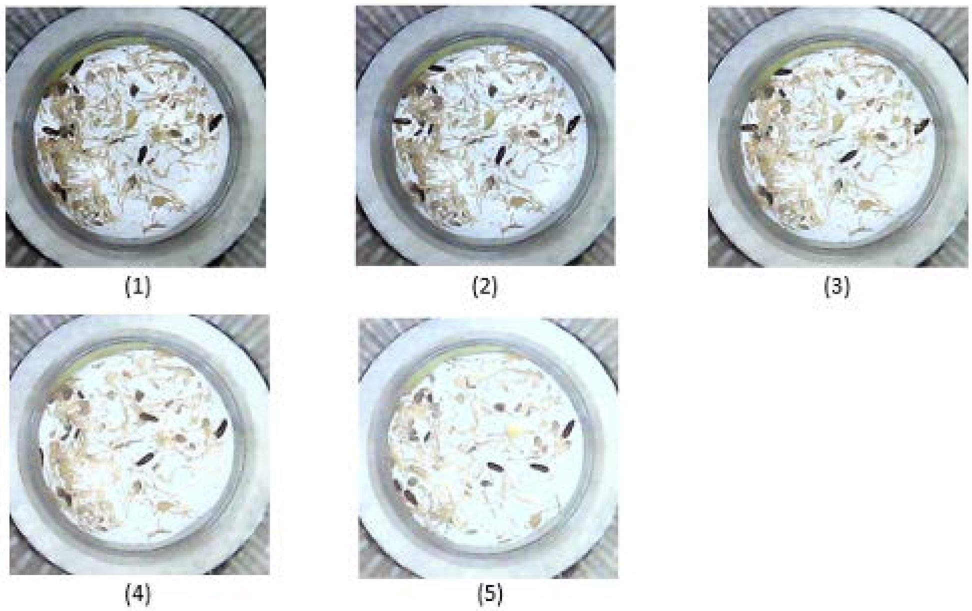


Fig. 6. Images taken at different values of gamma.

In summary, the camera parameters were adjusted at values listed in Table 4.

Table 4. Parameters of camera and their adjusted values.

Parameters	Value
Brightness	32
Contrast	64
Gamma	175
Backlight Compensation	2
Gain	0
Hue	0
Sharpness	6
Exposure (Absolute)	5000
White Balance Temperature	2800
Saturation	96

1.3 Adjustment of background color of collecting chamber

Three different background colors (white, green and yellow) for the collecting chamber were tested (Fig. 7). Fifteen images for each background color were taken. It was found that there was no significant difference between the different colors. The white color was chosen as the background color for the following reasons: (A) the visual effect of white is good, (B) the white color is a definite color, and (B) unlike green and yellow, white color does not have shade effect.

Yellow background   Green background   White background

Fig. 7. Images taken at different colors for background of collecting chamber.

2. Developed imaging system

The imaging system that we developed includes the following components: three trapes equipped with LEDs and USB cameras, raspberry Pi, server, interface, micro USB cables, and USB charger, as it is shown in Fig. 8. The Raspberry Pi serves as the trap's central processing computer. It is used to control LEDs and the cameras to take images for the insects trapped in the collecting chamber by running a Python code periodically. The images taken are time stamped and saved into a folder and named by their date and time. With the images saved in a specific folder, the Raspberry Pi could run a Python code that calls the Macro code used to program images by using an insect counting algorithm (ImageJ) to count the insects in each image and save the data. To count the insects, ImageJ is used to refine the image to eliminate grain particles in the background and highlight the dark colored insects. The Raspberry Pi uses apache2 to host a server that allows the Raspberry Pi to receive and send data. The server essentially allows communication between the Raspberry Pi and the mobile application. The mobile application could access a gallery displaying all the images in the folder of the Raspberry Pi. The user could also press a button to request images to be taken at any time. When there is an increase in the number of insects, a notification will pop up on the phone to alert the user as well. The mobile application essentially allows the user to monitor insect activity off site through images in the gallery. In order to conserve energy, the algorithm was devised to power the Raspberry Pi only when a new command is issued. When a command is received, it is added to the queue of commands. Then, after the command is accepted, the sensors are activated and start gathering data. Then, the image is processed and the analog signals from the sensors are converted into digital values. The data are then bundled together and sent to the server, thereby finishing the command.

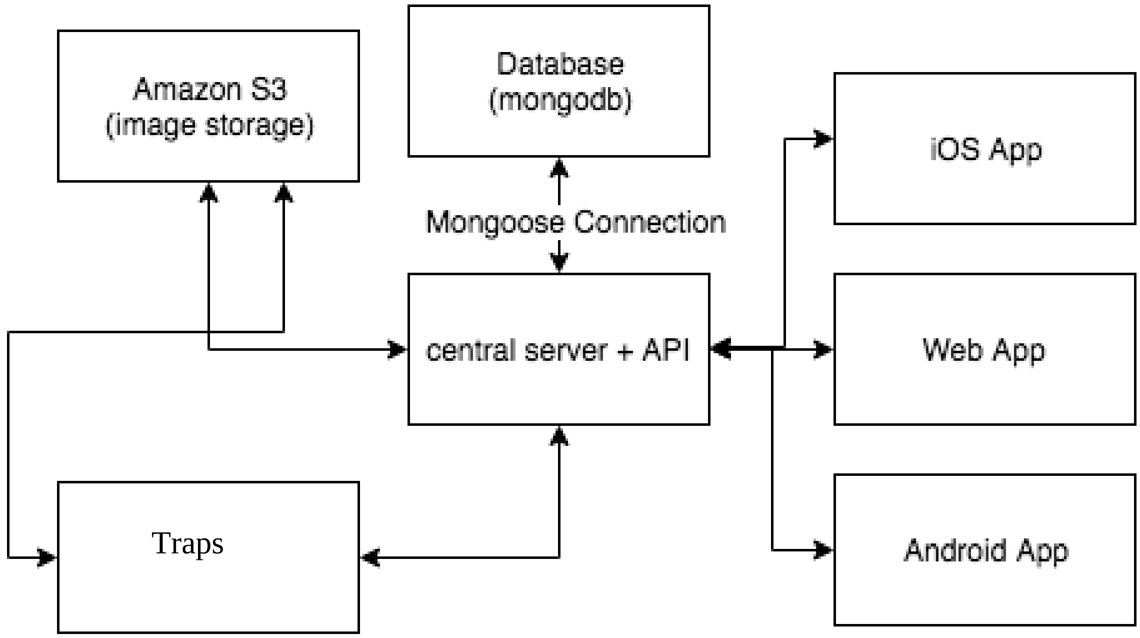


Fig. 8. Schematic diagram presenting function follow of the imaging system.

<u>Evaluate the effectiveness and accuracy of the new system for monitoring and detecting insect activity in stored rice.</u>

To evaluate the effectiveness and accuracy of the new imaging system, experiments were conducted in our lab and a commercial rice storage facility. The experiments were designed to provide quantitative information on effectiveness and accuracy of the insect detection using the new system. In the lab experiment, the set-up involved filling a cylindrical container (a diameter of 20 cm and a height of 48cm) with 8 kg of infested rice (Fig. 9). The rice was infested with red flour beetles. The system was tested under different infestation concentrations (4 insects/8 kg rough rice, 8 insects/8 kg, 16 insects/8 kg rough rice, 24 insects/8 kg rough rice) which is equal to (0.5/kg, 1/kg, 2/kg, 3/kg). For each concentration, three replicates were conducted. In the commercial storage test, the new system including three traps was installed in a commercial storage facility (Sutter Basin Growers Cooperative) in Knight Landing city, CA. The rice stored in the facility was visually inspected before and after system installation (Fig. 10). During the test, the temperature and relative humidity of ambient air inside and outside of the storage were measured. The rice temperature and moisture were measured as well (Fig. 11).

Fig. 9. Set up for lab test: (1) clear cylinder, (2) clean rice, (3) rice sampling, (4) sample infesting, (5) rice mixing, (6) developed traps, (7) trap assembling, (8) final set up.

Fig. 10. Set up for the commercial storage facility test.

Temperature and relative humidity meter | Moisture content meter | Rice temperature meter

Fig. 11. Measurements of temperature and relative humidity of ambient air, moisture content and temperature of rice in the commercial storage facility.

The detection rate of insects was defined and calculated using the following question:

$$DR(\%) = \frac{NID_{24hr}}{TNI_{8kg}} X100$$

where DR is detection rate (%), NID_{24hr} is number of insects detected after 24 hours, TNI_{8kg} is total number insects infested in 8kg of rice.

The accuracy rate of the new system was calculated using the following equation:

$$AR(\%) = \left(1 - \frac{\Delta D}{NIVC}\right) X100$$

where AR is accuracy rate (%), ΔD is difference between number of insects visually counted and those counted by the system, and NIVC is the number of insects visually counted.

SUMMARY OF 2012 RESEARCH (major accomplishments), BY OBJECTIVE:

Design a real-time insect monitoring and detecting system using an imaging technique for a commercial scale of rice storage facility.

Through this project, we have successfully designed and built an imaging system for real-time monitoring and early detection of insect activity in stored rice (Fig.12). The new system includes traps, USB cameras, LEDs, a raspberry Pi, sever, and user interface. The USB cameras and LEDs were installed inside insect traps to remotely provide users with access to images of the captured insects through a server. The system was programmed to take images periodically and additional images could also be requested through a “take picture” button on the mobile app or website. When the images were taken, the onboard Raspberry Pi processed the images to count the number of insects and sent the data, along with the image, to an Amazon S3 bucket. Amazon S3 is cloud storage service to upload various types of data in virtual databases called (buckets). The server processes the images and counts the insects captured per trap and stores the images and numerical data over time. A website and a mobile application were developed to act as user-interface for the user to view an image gallery for each trap, view a graph of the insects collected over time, and request images to be taken at any time. The general flow for software and insect counting algorithm are as follow:

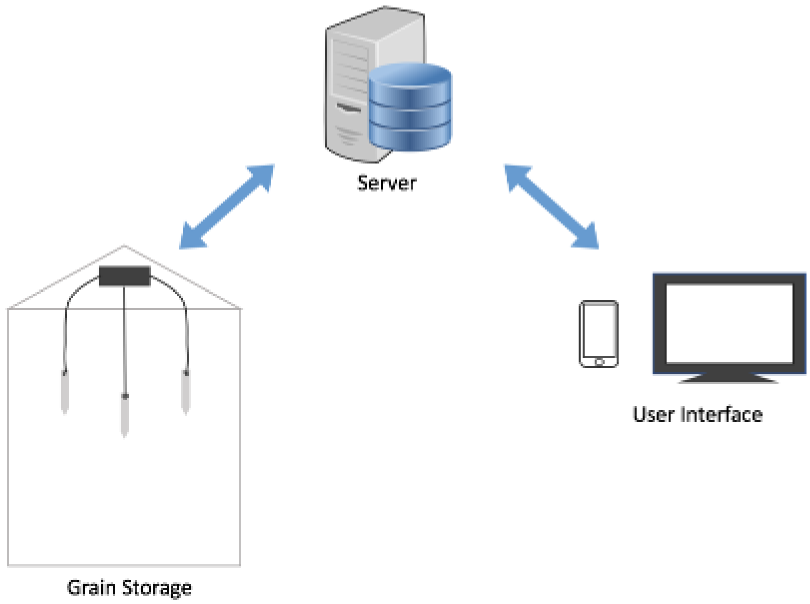


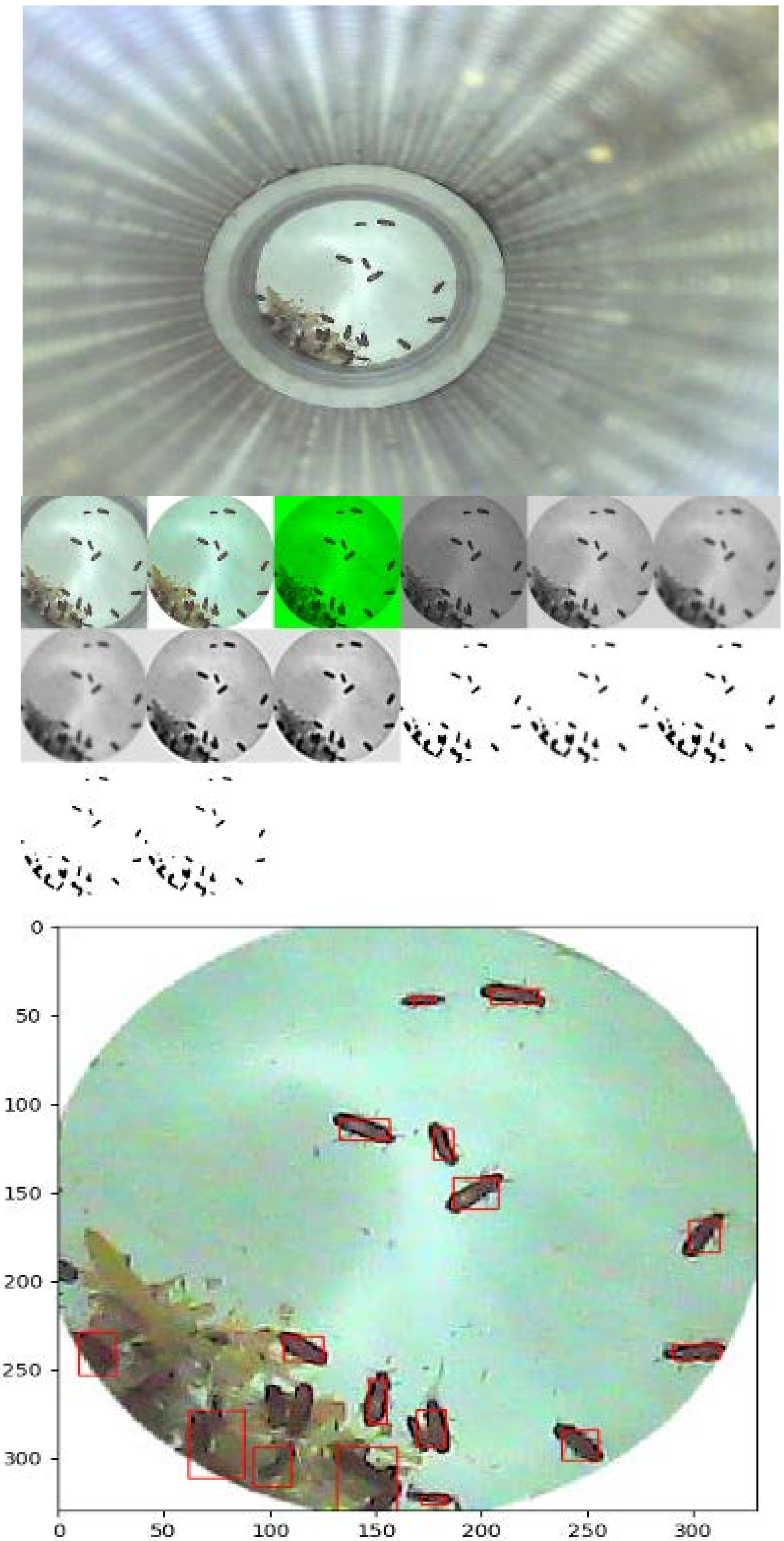
Fig. 12. The main components of the new the imaging system.

General software flow:

i. A command is sent by a user to the trap to take an image.
ii. The Raspberry Pi acknowledges the command and commands the camera to take an image.
iii. The image is passed through the counting algorithm which is described in details below.
iv. The cropped image produced by the previous step is uploaded to a cloud file host and the link is extracted.
v. This link along with the insect count and timestamp are packaged and sent to the web-server.
vi. The web-server parses the incoming data and stores a copy of the information in a database.
vii. If the original command was from a user and not the internal timer, then the web-server sends the data as a response. Otherwise it is cached for later use.
viii. The interface provides a user-friendly way to access this internal database which contains the insect count trends.
ix. The web-server holds a few other helper methods such as setting the delay between subsequent image captures and configurable alerts.

Insect counting algorithm (Fig. 13):

1. The image is first cropped to size to isolate only the area of interest. The color of the circle is chosen as it provides good contrast between the insects themselves and the rest of the construction.
2. A white mask is applied to further bring out the area of interest.
3. The image is broken down into separate colors and the green channel is extracted. This is done as we discovered that we get better processing results rather than using the entire RGB image.
4. The green channel is converted into a luminosity channel (black & white image).
5. A Gaussian blur is applied to soften out the smaller imperfections in the image.
6. We then apply sharpening to the image to bring back the larger details and ignore the smaller imperfections.
7. The process is repeated two more times to bring the image to a state where it only contains larger regions of contrast.
8. The contrast value is then increased until the image only contains purely black and white pixels.
9. The Gaussian blur/unsharp mask step is repeated one more time to remove any artifacts produced by the previous steps.
10. Then the regions of contrast are flagged and are compared against set area and eccentricity constants.
11. If the region is found to pass both tests, the insect counter is incremented by one.



(b)

Fig. 13. Image processing algorithm stages and final image processing output.

Evaluate the effectiveness and accuracy of the new system for monitoring and detecting insect activity in stored rice.

The imaging system was tested in our lab under different concentrations of insects. The results revealed that the new system could detect emergence of the fist insect within a short time. Under insect concentration of 0.5(insects)/kg, the new system could detect emergence of the first insect within 60, 15, and 15 minutes for replicate 1, 2 and 3, respectively (Table 5). The corresponding values for detection rates of insets were 75%, 75% and 75%, respectively. Under concentration of 1(insect)/kg, the new system could detect emergence of the first insect within 15, 15, and 15 minutes, for replicate 1, 2 and 3, respectively (Table 5). The corresponding values for detection rates of insets were 75%, 75% and 50%, respectively. While under concentration of 3/kg, the new system could detect emergence of the first insect within 15, 15, and 30 minutes, for replicate 1, 2 and 3, respectively. The corresponding values for detection rates of insets were 70.8%, 71% and 83.3%, respectively. Additionally, the accuracy rate of the system was tested in the lab under concentrations of 4 insects/kg and 5 insects/kg. The new system achieved high accuracy of 88.7% and 87.8% under of 4/kg and 5/kg, respectively, (Table 6). The obtained results clearly revealed that the new system was able to detect the emergence of the first inset within short time with a good accuracy.

Moreover, the effectiveness and accuracy of the new system were tested in a commercial rice storage facility under two approaches. In the first approach, the three developed tarps were buried in the rice mass and left for one week. Before trap burial, the rice was inspected by the conventional method. The samples were taken from eight different locations and inspected by the storage operator using screening method and he reported the rice is not infested (Fig. 14). After 7 days, the traps were inspected, and the trapped insects were counted. There were 15 insects, 17 insects, and 23 insets trapped in trap number 1, 2, 3, respectively. This mean the developed trapes have high effectiveness to trap insects compared to the conventional method. In the second approach, the rice was inspected by the storage operator in the same way followed in the first approach. It was inspected and confirmed that the rice is not infested by grain storage operator. Then the system was installed, and the insect activity was remotely monitored. It was found that the system was able to detect the emergence of the firs insect within 34 minutes and the second inset within 85 minutes. After four days, the system detected 5, 9 and 13 insets in traps 1, 2, and 3 with accuracy rates of 75%, 100% and 82% (Fig. 15 and Table 7). The average ambient temperatures inside and ousted the storage were 25.7± 2.6 °C and 28.1 ±3.6 °C, respectively. The corresponding values for relative humidity were 52.9± 4.3% and 45.4 ±5.6%. The average temperature and moisture content of stored rice were 24.7±0.7 °C and 11.8±0.5%, respectively.

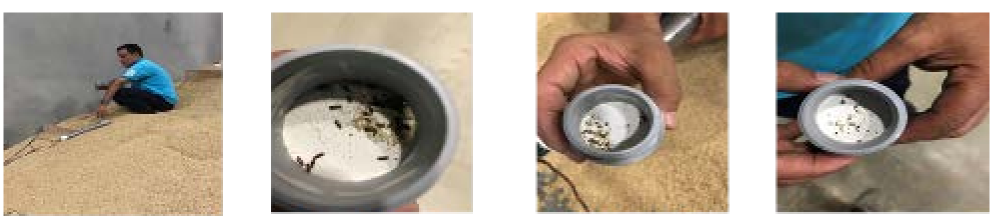
It is important to notice that the results obtained from the lab test were consistent with those obtained from the commercial storage test. Additionally, the obtained results revealed that the new system was able to detect the emergence of the first insect within a short time. It took only 35 minutes to detect the insect activity during the lab and commercial storage test (Fig.16).

Table 5. Effectiveness and detection rate of the new system during lab test.

Infestation concentration	Total (Insects/8 kg rough rice)	Replicate	Time to detect first insect (min)	Insects detected after 24hr	Detection rate (%)
0.5/kg	4.0	R1	60.0	3.0	75.0
		R2	15.0	3.0	75.0
		R3	15.0	3.0	75.0
		Average	30.0	3.0	75.0
1/kg	8.0	R1	15.0	6.0	75.0
		R2	15.0	6.0	75.0
		R3	15.0	4.0	50.0
		Average	15.0	5.3	66.7
2/kg	16.0	R1	30.0	9.0	56.3
		R2	15.0	9.0	56.0
		R3	45.0	11.0	68.8
		Average	30.0	9.7	60.3
3/kg	24.0	R1	15.0	17.0	70.8
		R2	15.0	17.0	71.0
		R3	30.0	20.0	83.3
		Average	20.0	18.0	75.1

Table 6. Accuracy rate of the new system during lab test.

Concentration	Time (hr)	Detected insects (visually counted)	Detected insects (counted by system)	Accuracy rate (%)
4/kg	0.25	6.0	7.0	83.3
	1.25	8.0	7.0	87.5
	2.00	9.0	10.0	88.9
	2.75	10.0	12.0	80.0
	12.00	14.0	14.0	100.0
	16.75	16.0	14.0	87.5
	22.25	17.0	19.0	88.2
	24.00	17.0	16.0	94.1
5/kg	0.25	5.0	7.0	60.0
	1.00	7.0	8.0	85.7
	1.25	8.0	8.0	100.0
	1.50	9.0	10.0	88.9
	2.00	10.0	11.0	90.0
	2.25	11.0	11.0	100.0
	2.75	12.0	11.0	91.7
	3.50	13.0	10.0	76.9
	14.00	18.0	18.0	100.0
	24.00	20.0	17.0	85.0



Insects trapped by the trapes installed in the rice storage facility

Convectional insect inspection

Fig. 14. Evaluation of trap effectiveness in rice storage facility.

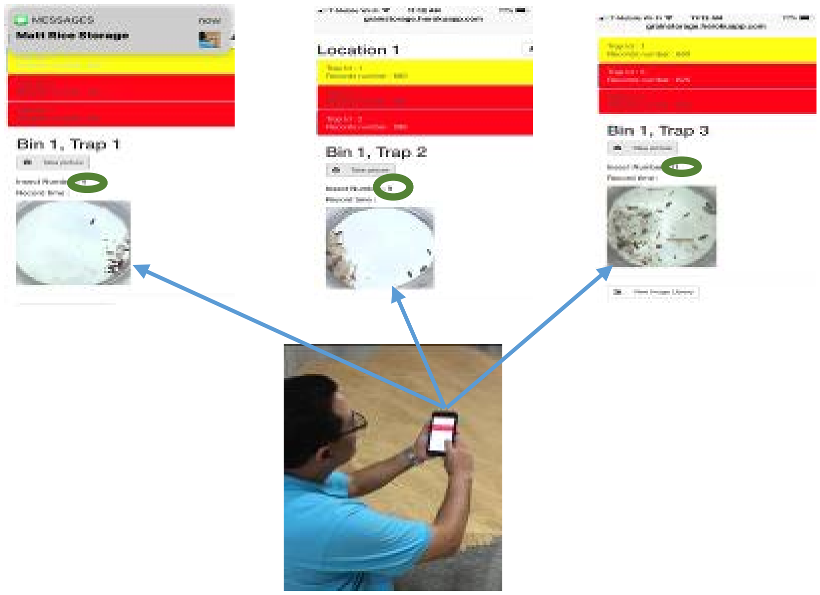


Fig. 15. Final output of the new system representing the detected insects in the commercial storage facility.

Table 7. Accuracy rate of new system during storage test.

Trap number	Detected insects (visually counted)	Detected insects (counted by system)	Accuracy rate (%)
1	5	4	75
2	9	9	100
3	13	11	82

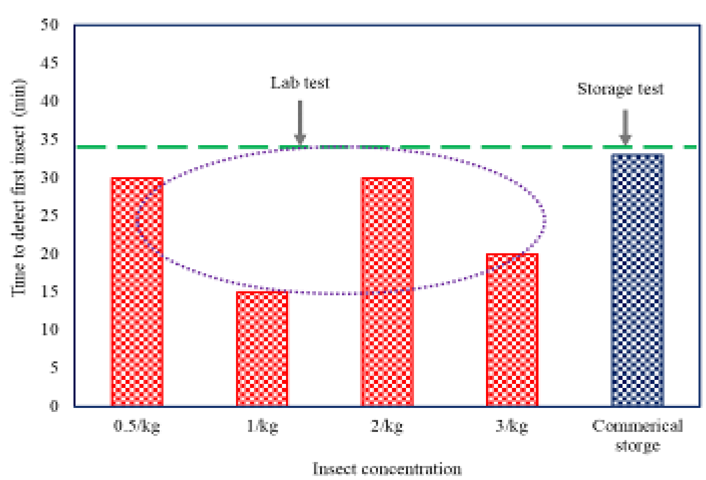


Fig. 16. Time to detect the emergence of the first insect during the lab and commercial storage tests.

Conclusions and recommendations

The obtained results from lab and commercial storage tests were consistent and revealed that the new system had high effectiveness and accuracy for real-time monitoring and early detection of the insect activity in stored rice. For the lab test, the results related to effectiveness of insect detection indicated that the new system could detect the emergence of the first insect within 30, 15, 30, and 20 minutes under infestation concentrations of 0.5/kg, 1/kg, 2/kg and 3/kg, respectively. The corresponding values for detection rates of insects were 75%, 66.7%, 60.3% and 75.1%. The average of accuracy rate of the new system was 88.2 %. During the storage test, the new system was able to detect the emergence of the first insect within 34 minutes. After four days, the system detected 5, 9 and 13 insets in traps 1, 2, and 3 with accuracy rates of 75%, 100% and 82%. The results clearly revealed that it took only less than 35 minutes to detect the insect activity during the lab and commercial storage tests. It can be concluded that the new system could be used to early detect insect activity in stored rice with a good accuracy, reliability and low cost and labor.

It is recommended that a further study is needed to upgrade and improve the ease of use and performance of the system before its commercialization. The upgrade approach of the new system will improve its handling, customization, effectiveness, accuracy and reduce energy use.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESEARCH

The objective of this research was to develop a real-time monitoring and early detection system for insect activity in rice during storage. A new system consisting of traps, USB cameras, LEDs, a raspberry Pi, sever, and user interface, was developed and tested. Three traps (each has diameter of 4.5 cm and length of 32 cm) were designed. The appropriate diameter and length for the trap design were chosen based on the appropriate force required to insert the trap into the rice mass, and enough space to fit the camera in the cap. Each trap was equipped with a brightness camera and two LEDs. The USB cameras and LEDs were installed inside insect traps to remotely provide users with access to images of the captured insects through a server. The system was programmed to take images periodically and additional images could also be requested through a "take picture" button on the mobile app or website. When the images were taken, the on-board Raspberry Pi processed the images to count the number of insects and sent the data, along with the image, to an Amazon S3 bucket. Amazon S3 is cloud storage service to upload various types of data in virtual databases called (buckets). The server processes the images and counts the insects captured per trap by using an insect counting algorithm and stores the images and numerical data over time. A website and mobile application were developed to act as user-interface for the user to view an image gallery for each trap, view a graph of the insects collected over time, and request images to be taken at any time. The new system was evaluated through experiments conducted in our lab and a commercial rice storage facility.

The obtained results from lab and commercial storage tests were consistent and revealed that the new system had high effectiveness and accuracy for monitoring and early-detection of the insect activity in stored rice. For the lab test, the results related to effectiveness of insect detection indicated that the new system could detect emergence of the first insect within 30, 15, 30, and 20 minutes under infestation concentrations of 0.5/kg, 1/kg, 2/kg and 3/kg, respectively. The corresponding values for detection rates of insects were 75%, 66.7%, 60.3% and 75.1%. The average of accuracy rate of the new system was 88.2 %. During the storage test, the new system was able to detect emergence of the first insect within 34 minutes. After four days, the system detected 5, 9 and 13 insets in traps 1, 2, and 3 with counting accuracy rates of 75%, 100% and 82%. It can be concluded that the new system could be used to detect insect activity in the early stage in stored rice with a reasonable effectiveness and accuracy.

Further research is needed to upgrade the system and improve its handling, customization, effectiveness, accuracy and reduce energy use before its commercialization. The design of traps needs to be upgraded by providing each trap with wireless Wi-Fi system, sensors to measure temperature and relative humidity and an independent power source by using chargeable batteries. The accuracy of insect counting algorithm needs to be improved as well. This will lead to a full development and implement of the new system for real-time monitoring and early detection of insect activity in rice storage facilities with high accuracy, reliability, safety and low cost and labor.

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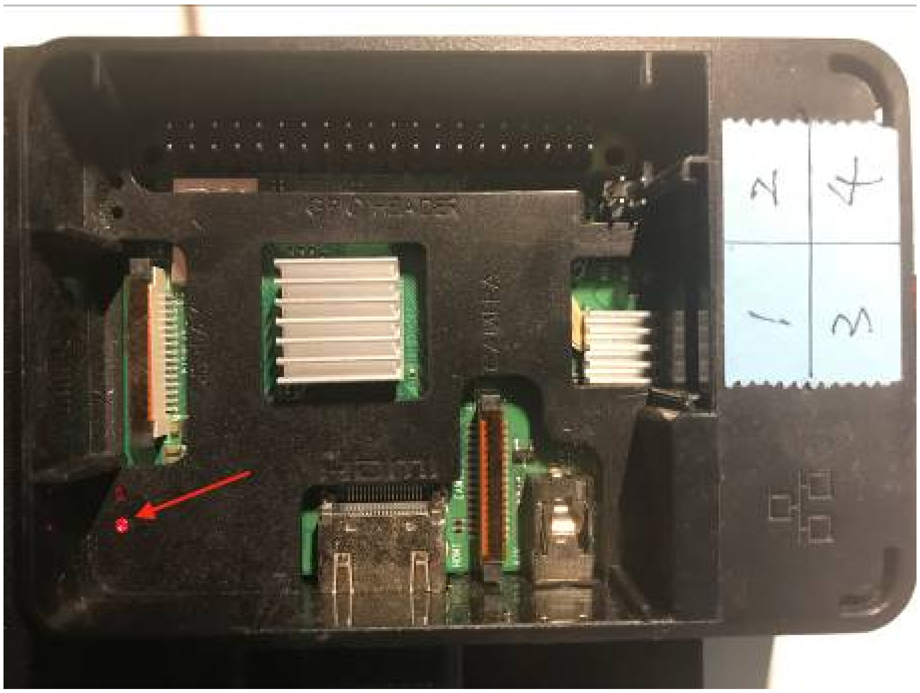
California Rice Research Board
Sutter Basin Growers Cooperative

Appendix: User Manual

GETTING STARTED

1. **Installation and Logging In**

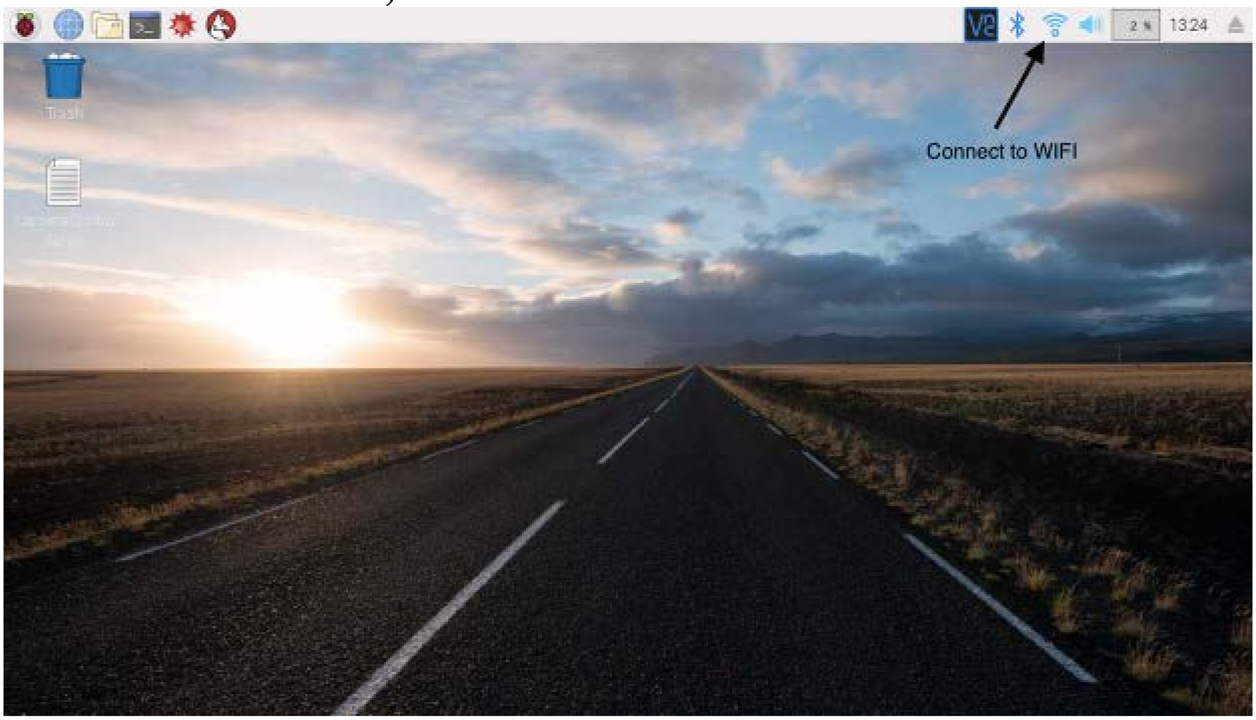
First, connect Raspberry Pi to power. Once you see the red led is on, that means Raspberry Pi is power on successfully.



There are two ways to view Raspberry Pi. One is to use a HTMI cable to connect Raspberry Pi to a display monitor. Alternatively, you can download VNC Viewer at https://www.realvnc.com/en/connect/download/viewer/ to access the Raspberry Pi remotely from your computer.

2. WIFI Connection

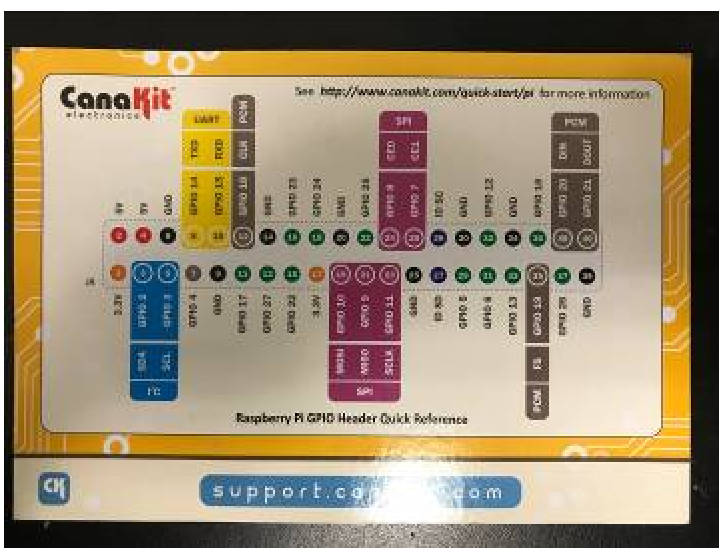
Connecting to WIFI is required for the system to operate. (Be aware, for first time connecting to a WIFI will need a monitor)



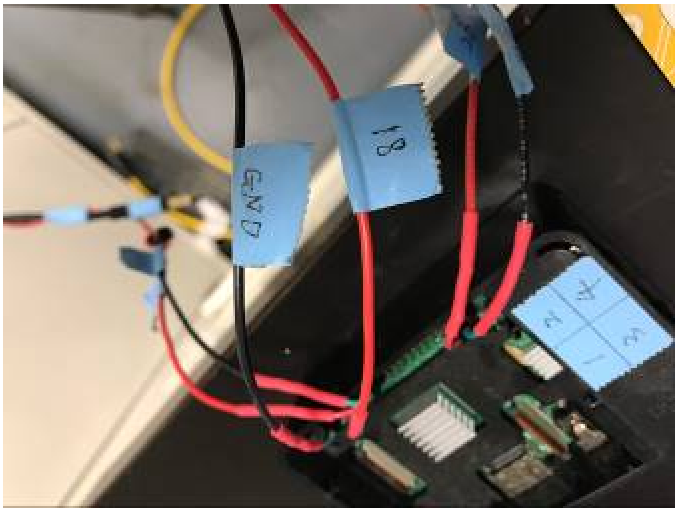
SETTING SENSORS

1. LED Connection

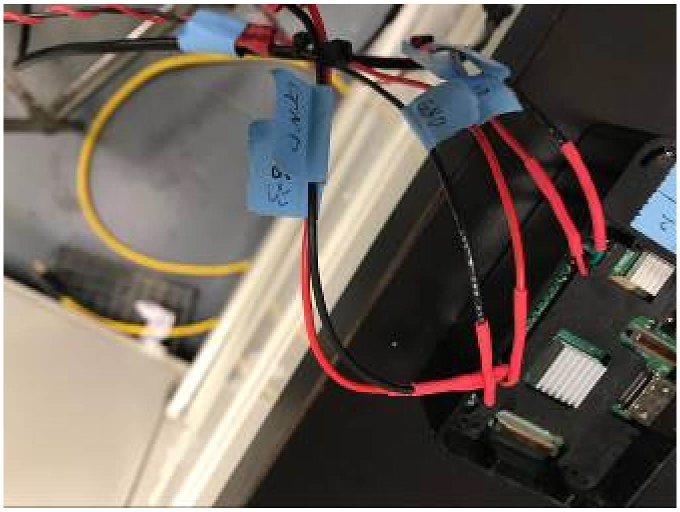
Each trap has two wires, the red wire connects to the right pin (the pin number is indicated on the wire) and the black wire connect to any GND pin on the Raspberry Pi. Using the instruction card to determine which one the right port.



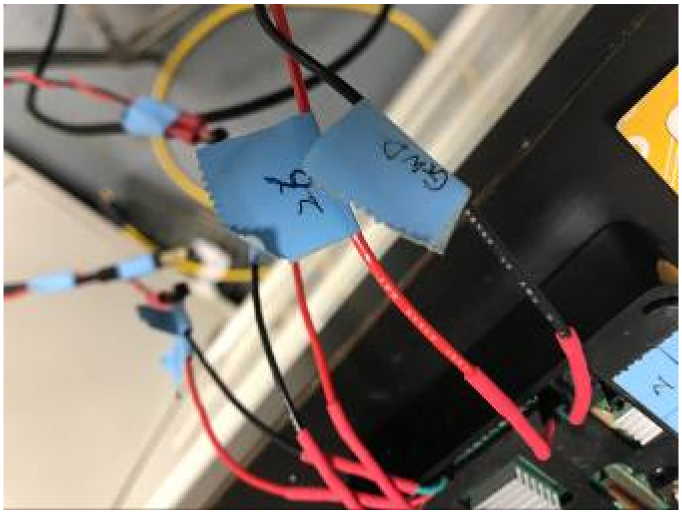
Trap one:



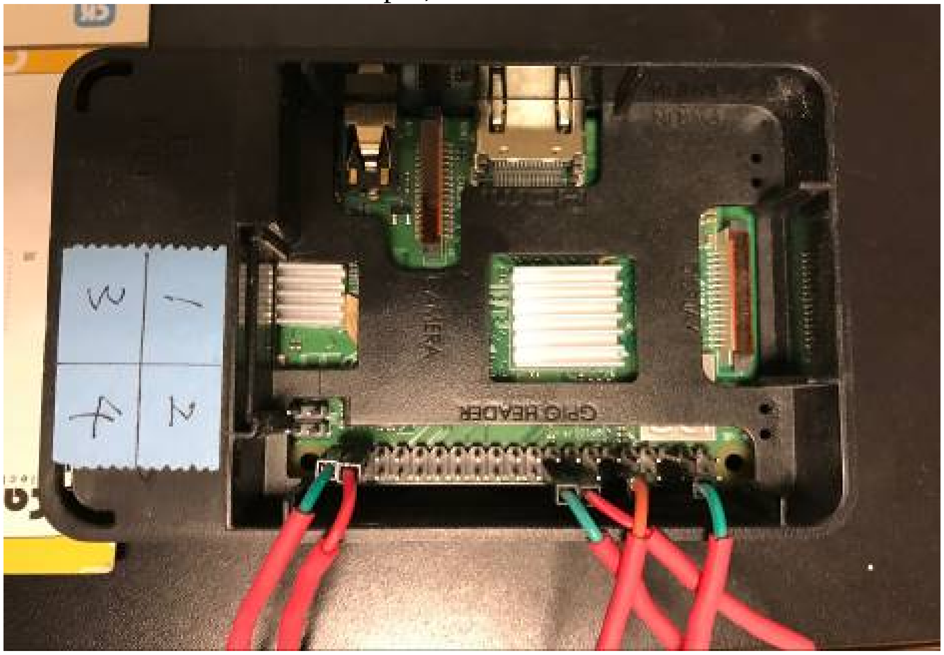
Trap two:



Trap three:



Once connect all wires to the pin, it will look like this



2. Camera Connection

First, we connect trap one (the one mark 18) camera to a USB port on Raspberry Pi. After it connected, open the terminal window in Raspberry Pi and input:

```
pi@raspberrypi:~ $ cd DavisGrainSensorProject/client0
pi@raspberrypi:~/DavisGrainSensorProject/client0 $
```

After pressing enter, input:

```
pi@raspberrypi:~/DavisGrainSensorProject/client0 $ ./webcam.sh
```

Make sure the LED is on for trap one and check if the photo is clear in **/home/pi/DavisGrainSensorProject/client0/example.jpg**

Then, input following to get back to home directory:

```
pi@raspberrypi:~/DavisGrainSensorProject/client0 $ cd
pi@raspberrypi:~ $
```

Second, we connect trap two (the one mark 23) camera to a USB port on Raspberry Pi. After it connected, open the terminal window in Raspberry Pi and input:

```
pi@raspberrypi:~ $ cd DavisGrainSensorProject/client1
```

```
pi@raspberrypi:~/DavisGrainSensorProject/client1 $
```

After pressing enter, input:

```
pi@raspberrypi:~/DavisGrainSensorProject/client1 $ ./webcam.sh
```

Make sure the LED is on for trap one and check if the photo is clear in **/home/pi/DavisGrainSensorProject/client1/example.jpg**

Then, input following to get back to home directory:

```
pi@raspberrypi:~/DavisGrainSensorProject/client1 $ cd
pi@raspberrypi:~ $
```

Third, we connect trap two (the one mark 26) camera to a USB port on Raspberry Pi. After it connected, open the terminal window in Raspberry Pi and input:

```
pi@raspberrypi:~ $ cd DavisGrainSensorProject/client2
pi@raspberrypi:~/DavisGrainSensorProject/client2 $
```

After pressing enter, input:

```
pi@raspberrypi:~/DavisGrainSensorProject/client2 $ ./webcam.sh
```

Make sure the LED is on for trap one and check if the photo is clear in **/home/pi/DavisGrainSensorProject/client2/example.jpg**

Then, input following to get back to home directory:

```
pi@raspberrypi:~/DavisGrainSensorProject/client2 $ cd
pi@raspberrypi:~ $
```

CONECT TO SERVER

1. **Run Code**

Type in following command in the terminal and waiting for connection:

```
pi@raspberrypi:~ $ ./run.sh
22:30:51: begin checking...
22:30:51: checking client0.py
22:30:51: client0 disconnected, restarting...
22:30:51: checking client1.py
22:30:51: client1 disconnected, restarting...
22:30:51: checking client2.py
22:30:51: client2 disconnected, restarting...
```