Counting adults of the black soldier fly

Background and Rationale

Waste processing by Black Soldier Fly (BSF) larvae is seen as a promising organic waste treatment technology, due to the high waste reduction potential while producing valuable products. Young BSF larvae are placed on organic waste where they feed for about two weeks, reducing the biomass by up to 70%. The grown larvae will be harvested and sold as a component of animal feed for fish and poultry or pet food.

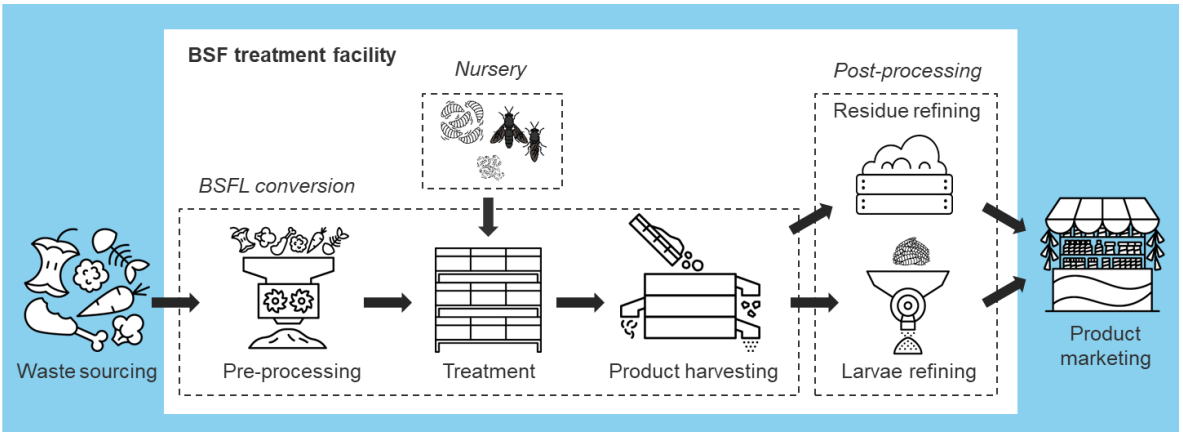


Figure 1: Illustration of a BSF facility

For waste treatment, trays are filled with substrate and stocked with a clearly defined number of young larvae. The production of stocking larvae in constant quality and quantity is therefore a crucial point in every BSF facility. For the production of young larvae, a nursery is operated with nets in which the flies mate and lay eggs. These nets, the so-called love cages, are temporarily connected to other nets (dark cages) from where flies fly into the love cages. The number of these flies should be counted with a sensor.

Adult of the Black Soldier Fly, Hermetia illucens

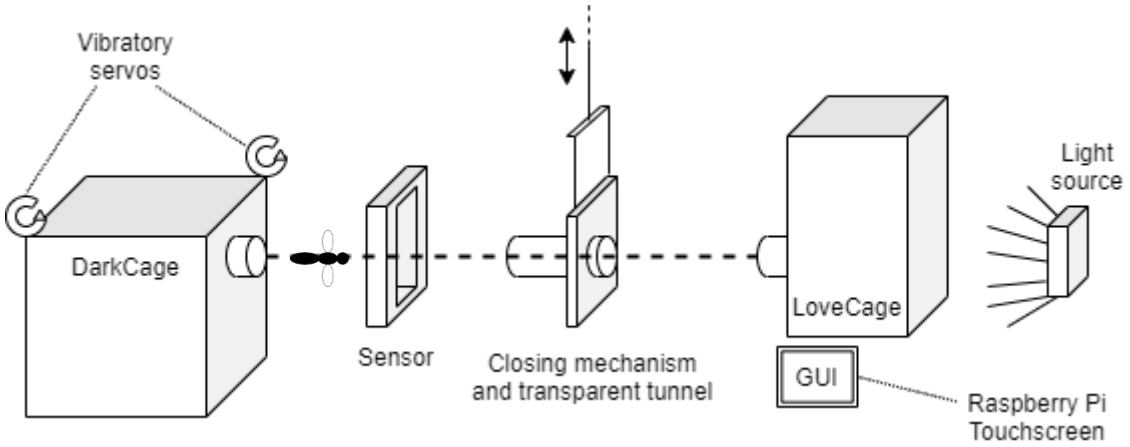
BSF Larvae

BSF Prepupa

The objectives of the assignment are:

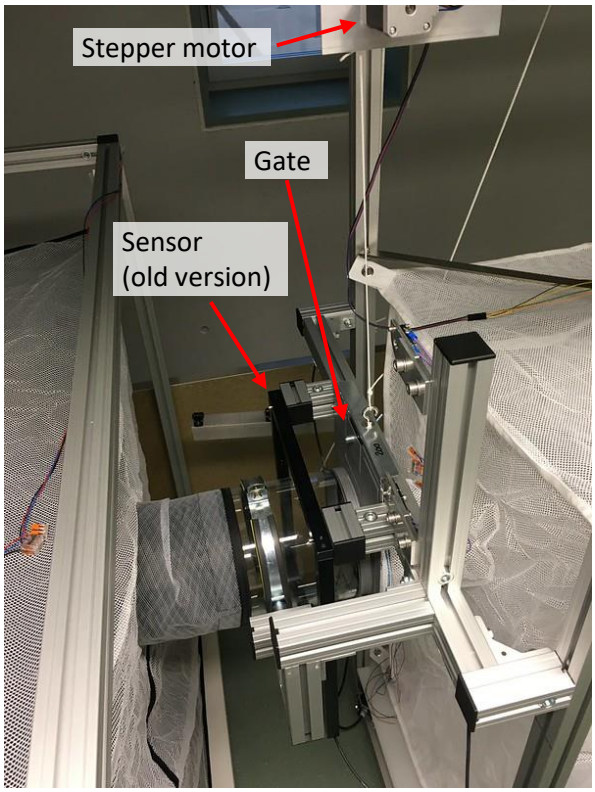
- **i) to write the code for the Raspberry Pi 4 which reads the sensor and controls the set-up (closing mechanism, vibratory sensors) for the counting of adult flies migrating from the dark cage to the love cage.**
- **ii) to design and program the GUI which leads the operator through the filling process.**

The set-up and procedure are as follows:



- The operator scans the ID of love cage LC-X1 via QR code.
- He connects love cage LC-X1 with dark cage DC-X1.
- He scans the QR code of dark cage DC-X1 and starts the process.
- A slider opens the connection between the two cages.
- The flies fly from the dark cage into the love cage.
- The sensor detects and counts the flies in the passage.
- As soon as one of the conditions for closing the slider is reached, the slider closes.
    - Total number of flies reached
    - Number of flies per dark cage reached
    - Time limit
    - Number of flies/time unit falls below threshold
    - Manual stop
- The operator moves love cage LC-X1 to the next dark cage DC-X2.
- He scans the QR code of DC-X2 and continues the process.
- This scenario is repeated until the love cage contains the target amount of flies.

Dark cage (left) and love cage (right)



The tunnel connecting the two cages.

Elements

Raspberry Pi:

The controller used is the Raspberry Pi 4 model B with 8GB RAM. The Raspberry Pi is used with its official touchscreen with case where the GUI (graphical user interface) is visualized and with the official PiCamera that is used to scan the cages' QR codes. A printed circuit board (PCB) was designed which contains components needed for the interface between R-Pi and the external devices (see "Printed Circuit Board"). The PCB is directly positioned on the top of the Raspberry Pi as a hat covering the GPIO pins and everything is then integrated inside the touchscreen case.

GPIO 19 =	Indicator LED
GPIO 22 =	Black push button
GPIO 27 =	Red push button
GPIO 11 =	Servo motor for cage agitation
GPIO 10 =	Direction of the stepper motor of the gate
GPIO 9 =	Stepper motor of the gate
GPIO 17 =	Upper switch key to stop the opening gate
GPIO 2 =	Lower switch key to stop the closing gate

Table 1: Allocation of the GPIO pins

Sensor:

The sensor is a light grid LF 48/5 270 T/S with 48 infrared light beams, each 5mm apart (see "Manual light grid"). It consists of two separate elements: the transmitter (TX) and the receiver (RX). They are both connected to a control unit (FAW). Its output for the communication with the Raspberry Pi is a serial interface. The status of every beam can be transmitted (see "Manual controller FAW" and "Data sheet and configuration FAW") through RS232 (TxD, RxD). Since there is a PCB attached to the Raspberry Pi, access to the GPIO pins is limited. However, one could use the screw terminals J3 and J7 which are foreseen for the push buttons (black and red). Or, one would use an RS232 to USB adapter.

Closing mechanism:

A stepper motor is used to open and close the gate. Two switch keys are used to indicate the end of the opening/closing (see video “closing gate”). The stepper motor is steered by a driver (see “Data sheet Driver stepper motor”). The driver is integrated in the printed circuit board.

Cage agitation:

To motivate the flies to leave the dark cage, two agitation mechanisms are installed (servo motors). Speed, time of activation and interval shall be set through the GUI (graphical user interface). The model of the servomotors used is the 360° High Torque Servo MG996R 10 kg/cm and they can be controlled with a PWM signal. The servomotors have their own power supply and thus only the signal from the Raspberry Pi is required. Servo jitter should be avoided with adding a code/library.

Push buttons:

There are two push buttons (black and red) installed on the front of the touchscreen case. They can be used to confirm actions (e.g. scanning of QR codes, starting the task) or to cancel or abort tasks (e.g. reset program, finish the filling).

LED:

There is a red LED placed on the front of the touchscreen case which can be used.

Specifications

User interface:

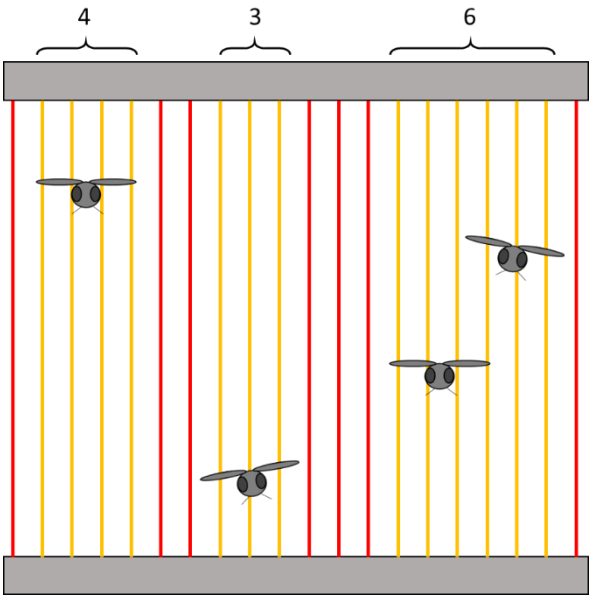
The operator should be able to control the process via the touch screen. This means that the programme starts automatically when the Raspberry Pi is switched on and shows a start screen which gives the operator the possibility to set the parameters or to start counting.

Fly counting:

When flies cross the sensor, they will interrupt several adjacent beams at the same time. The distance between the beams is 5mm. Since the fly’s wingspan is bigger than 5mm, one fly will cover probably four adjacent beams. That means, when more than this threshold of four adjacent beams is interrupted at the same time, it should be counted as multiple flies. However, this threshold needs to be verified and its value has to be a parameter that can easily be changed in the menu “Settings” in the GUI. The calculation for the number of flies is thus:

 # flies = round up #beams/threshold

For an example, see Figure 2.



Adjacent beams	Threshold	Calculated result	# flies
3	4	0.75	1
4	4	1	1
6	4	1.5	2

Figure 2: Different scenarios how the number of interrupted light beams may vary and how the number of flies are calculated

Conditions to close the gate:

The gate should close as soon as one of the following events occur:

- Total number of flies in the love cage reached
- Number of flies from individual dark cage reached
- Time limit
- Number of flies/time interval falls below threshold
- Manual stop

The operator must be able to change these values in the settings via the GUI.

The ranges for the values may be as follows:

Total number of flies in love cage	10-20,000
Number of flies from individual dark cage	5-20,000
Time limit	5-30 minutes
Number of flies/time interval	1-60 flies/minute
Time interval	20-120 seconds

Output files:

The data of every filling session should be stored on a USB stick in a .csv-file containing the actual date, identification codes of all cages involved, starting and finishing time of the filling from each dark cage, number of flies from each dark cage and total number of flies in the love cage at the end.

A second data file should list the time for every detection event (date/time and number of flies). This will be used to test and calibrate the counter.

Agitation motors:

The operating mode for the cage agitation motors should also be selectable via the settings. Interval between operation 0-5 minutes and operating times of 1-5 minutes. There should be a button (either on the touchscreen or one of the push buttons to manually agitate the cage.