FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM SEGREGATION USING ARDUINO MEGA 2560 WITH ESP 32 FOR WIRELESS NOTIFICATION

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In Partial Fulfilment of the Course Requirements for the Degree of

Bachelor of Science in Electronics Engineering

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ABSTRACT

Styrofoam, also known as polystyrene, is one of the products that fall under the umbrella term of white pollution. A single cup of Styrofoam takes roughly 500 years to decompose, making it one of the world's long-term problems. With this, the research project's primary goal is to create a system that biodegrades polystyrene by containing and maintaining mealworms capable of degrading Styrofoam. This project will have two adjoining components: the hardware and the web app. The life forms will be placed, segregated, and collected in one of the units. Another application of the said device is the IoT-enabled control and monitoring of lifeforms. Through Arduino, this effective and environmentally friendly device was achieved. The system's programmed temperature and humidity, as well as the control feature of the actuators, motors, fan, and food dispenser for manual override, performed well in the functional testing. With a 300 percent population growth rate and an estimate of 25,000 mealworms for a year of deployment, the system promotes an effective habitat for the mealworms to degrade polystyrene (PS) or Styrofoam. By integrating the hardware and web app, the system not only creates an artificial environment for mealworms but also reduces the risk of mealworm handling errors and the time and effort required to convert polystyrene into a less harmful material.

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CHAPTER 1

THE PROBLEM AND ITS BACKGROUND

1.1 Background of the Study

A non-biodegradable material is a substance that cannot be broken down by natural organisms and is thus a source of pollution or contamination. Non-biodegradable wastes, unlike biodegradable wastes, are challenging to manage. Non-biodegradable wastes cannot be decomposed or dissolved by natural agents. They will exist on earth for thousands of years without deteriorating. Many plastics and Styrofoam containers made of polystyrene are non-biodegradable (Mathur, 2021). Polystyrene degrades so slowly that it cannot be considered a biodegradable material. According to the Environmental Action Association, most polystyrene that ends up in landfills will still be there in 500 years (Korpella, 2019).

Mealworms are the larvae of the beetle Tenebrio molitor, a darkling beetle organism. Mealworms are commonly fed to reptiles and birds as a staple food. They are often put out in bird feeders for wild birds, particularly during the nesting season, when birds are raising their young and appreciate a ready supply of food. Also, they're sometimes used as bait for fishing. Mealworm frass has a high fertilizer capacity, according to chemical analysis. Unlike traditional mineral fertilizer, frass produced small amounts of micronutrients (such as Cu and Zn), which could benefit crops (Houben, 2020). Eggs, larvae, pupae, and adults are the four stages of development for mealworm beetles. The time it takes for insects to progress through these stages is affected by the temperature of their surroundings and the food availability ("Mealworm Beetle Life Cycle," 2018). With a retention period of fewer than 24 hours, Styrofoam can be efficiently degraded in the

larval gut. Over a month, larvae fed only with Styrofoam survived just as well as those fed a regular diet or bran (Yang et al., 2015).

Automating the rearing, collecting, and handling of insects is a vital step toward making insect mass production more appealing, cost-effective, and competitive. With little to no human intervention, an automated mass rearing system may promote mass organism growth from egg hatching to full adults or some stages, such as the larvae rearing process. Deaths and developmental disorders may be reduced by automating the rearing and transportation of these organisms. Various techniques and apparatuses are used in this automation to cause the least amount of disruption to the organisms during growth which would optimize the organisms' survival rate and health (Massaro, 2016).

The observation that mealworms can biodegrade polystyrene is now a building block toward decomposing a non-biodegradable waste into decomposable. This research will be effective by using an automated technology providing a system that will continuously biodegrade Styrofoam by providing a rearing mechanism for the beetle's life cycle.

1.2 Statement of the Problem

Every year, over fourteen million tons of polystyrene products are produced and taken into the trash after a single use. It amounts to 38,400 tons, equivalent to approximately thirteen thousand trucks. Furthermore, Styrofoam is a polystyrene-based substance that takes up to 500 years or more before decomposition. These single-used materials are left in oceans, landfills, and our surroundings.

Not only does Styrofoam pose a danger to the environment, but it also has a severe effect on human health. Benzene, one of the components of Styrofoam, was listed on the

most hazardous substances list as it contains mutagen, a carcinogen that is flammable and extensive exposure may cause cancer. (Occupational Health and Safety Administration, 2015). Short-term exposure to other chemicals used in producing Styrofoam, such as styrene, may cause dizziness, headaches, vomiting, and convulsions. Aside from this, long-term levels of exposure have been known to cause skin scaling, leukemia, plastic anemia, and worst, death.

Furthermore, this material can cause harm to animals that scavenge food from landfills and oceans. Marine life, such as marine mammals and turtles, mistake Styrofoam for their food since it easily breaks apart into small pieces making it a choking hazard.

1.3 Objectives of the Study

1.3.1 General Objective

This study aims to develop a fully automated system for mealworm rearing that will biodegrade polystyrene and serve as artificial habitat for their whole life cycle.

1.3.2 Specific Objectives

The specific objectives are the following:

1. To develop a segregation module utilizing modified mesh screens, vibrating motor, servo motor, linear actuators, and tilting containers combined with a collection module.
2. To develop a GUI-based program for remote monitoring, control and notification system of the food dispensing, ventilation system, and weight using Arduino microcontroller and ESP 32.

3. To determine the organisms' population growth to ensure the system's efficiency and effectiveness as an artificial habitat for their entire life cycle.
4. Test and evaluate the prototype using the ISO Standard 25010.

1.4 Significance of the Study

The researchers see an opportunity to develop a fully automated polystyrene biodegrading system for mealworm segregation.

This study should make an essential contribution to the following sectors:

End-Users. The primary end users of this technology are the Material Recovery Facilities (MRF) of the Local Government Units. This technology will provide a solution to one of the community's most challenging problems in terms of white pollution, specifically Styrofoam since this study takes less time and energy to break down Styrofoam than other methods. Furthermore, this will benefit breeders by creating a fully automated artificial habitat for mealworms that does not require much effort.

Environment. Polystyrene, also known as Styrofoam, has an impact on the environment and ecosystem. Biodegradation has long been a global issue due to the non-biodegradability of such materials. When Styrofoam is burned, toxic gasses are released, causing harm to people, animals, and the environment. This research represents the application of electronics engineering to the environment. Typically, the technologies that are being developed are harmful to the environment in some way. The researchers wanted to create something that could aid it.

Engineering Community. This study will serve as an example to the Engineering body of how electronics engineering can be applied to the environment. Providing a solution to one of the country's major problems using engineering methods while keeping the environment in mind.

Researchers. The proposed project will provide the researchers with the opportunity to apply their knowledge and skills to the development of technology that will benefit humanity.

Future Researchers. The ideas presented may be used as a reference for future researchers to test the validity, improve the project or conduct new research.

1.5 Scope and Limitation

This study aims to develop a fully automated device that will biodegrade polystyrene through the utilization of yellow mealworms. The control system of the device will be based on the integration of Arduino Mega 2560 for the automation of the segregation module, collection module, exhaust fans, and food dispensing. The device is focused on the segregation of mealworms per life stage, including their wastes.

In the notification system, ESP 32 will be used for the wireless data transfer of the temperature, humidity, and weight sensor installed inside the prototype. This will help the user to monitor the temperature, humidity, and weight of larvae and frass and be notified once the mealworms and frass are ready for harvest and when a refill of Styrofoam is needed in the food dispenser. Furthermore, from the web app, the user can override the system's automation by manually controlling the linear actuator and vibrating motor of the segregation module, the linear actuator of the collection module, exhaust fans, and food dispenser.

Expanded Polystyrene (EPS) will only serve as food for the mealworms for biodegradation, turning the non-biodegradable polystyrene into decomposable. Failure to maintain the temperature may significantly affect mealworms' fecundity, growth, and metabolism.

1.6 Definition of Terms

For clarification, the following were the definition of words used in the paper:

Collection Module

A small component of a larger device or an arrangement that is designed to be installed, replaced, or serviced independently, this module is composed of a tilting container connected to a linear actuator.

EPS (Expanded Polystyrene)

A white foam plastic substance made of solid polystyrene particles. It is generally used for packing, insulation, and other similar purposes.

ESP 32

A highly integrated Wi-Fi system on a chip which is used as an external Wi-Fi module to give complete internet access.

Mealworm

Mealworms are the larval stage of a darkling beetle species called Tenebrio Molitor. Young larvae can be as small as 1.5 cm in length and reach a maximum size of 2.5

cm. They are typically used as a food source for reptiles, birds, and captive mammals.

Polystyrene

A naturally transparent thermoplastic that comes in both solid and rigid foam forms. PS plastic is widely utilized in a wide range of consumer products and is specifically suitable for commercial packaging.

Segregation Module

A small component of a larger device or an arrangement that is designed to be installed, replaced or serviced independently consists of beetle, pupae, mealworm, egg, and frass containers.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

2.1 Related Literature

Economically, *Tenebrio molitor* larvae, popularly known as mealworms, are considered to be one of the most, if not the primary species used for massive conversion of biomass into protein. These tiny creatures are deemed the best option as reducing meat-based diets will benefit environmental, health, and economic factors (Grau et al., 2017). Moreover, the nutritional components of mealworms can be classified as "high in" and "source of" based on the thresholds for World Health Organization and Food and Agriculture Organization of the United Nations food labels. Mealworms have a high protein and fat content apart from a large amount of polyunsaturated fatty acids (Nowak et al., 2016) and have a considerably higher nutritional content than beef and chicken and are not significantly less nutritionally balanced as compared to traditional meats (Payne et al., 2016).

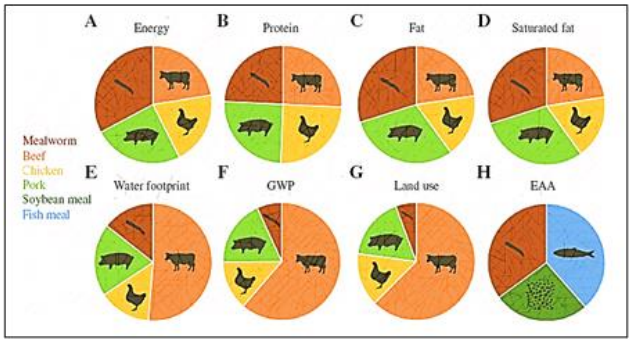


Figure 1. Nutritional Values and Sustainability of Mealworms and Conventional Feed (degruyter.com, 2017)

2.1.1 Mealworms

Mealworms are elongate and cylindrical, hard-bodied, and yellow to golden brown crop, flour, and vegetable organisms distributed worldwide. They are simple to breed, and their protein content remains constant regardless of their diet, implying that *T. molitor* larvae can be reliably produced. Consequently, they have been developed as a commercial feed for dogs, zoo animals, and even production animals like fish, pigs, and poultry (Ramos et al., 2002).

Figure 2. *Tenebrio Molitor* Larvae (Mealworm) (freepik.com)

2.1.2. Life Cycle of Mealworms

Tenebrio molitor, a species of darkling beetle, is a holometabolous insect that goes through four life stages of development: egg, larva, pupa, and adult. Female *T. molitor* specimens lay about 500 eggs, which hatch after 4–18 days and transition into larvae at 25°C. The larva period is 9-13 weeks, followed by a pupal stage of 6–18 days at 18°C and 8-12 weeks for the darkling beetle stage (Utah Education Network, 2018). Adult beetles weigh approximately 130 mg (Dellinger, 2018).

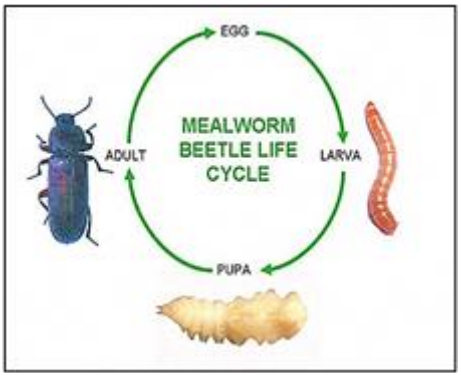
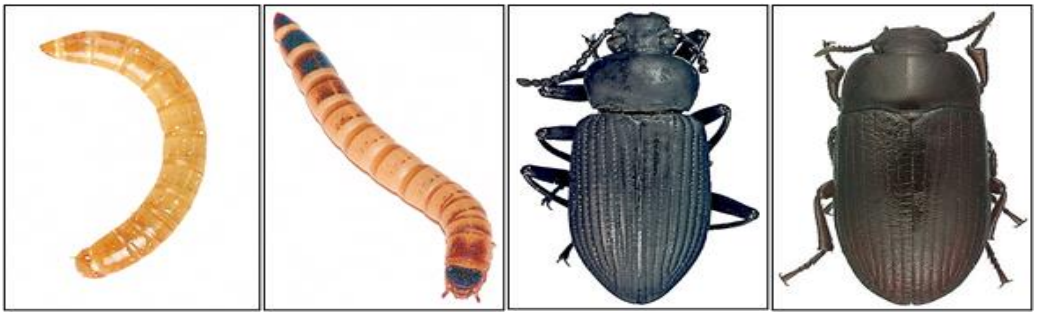


Figure 3. Mealworm-Beetle Life Cycle (uen.org, 2013)

2.1.3. Types of Mealworms

Tenebrio molitor L. commonly known as yellow mealworm, *Zophobas morio/atratus* (giant mealworm/giant mealworm beetle), and *Alphitobius diaperinus panzer* (lesser mealworm) are the three species of mealworms. The first kind, *Tenebrio molitor L*., has a tremendous potential to replace widely used protein sources in poultry diets; a fresh one contains around 15% fat and 20% protein (Jones et al., 1972; Finke, 2002). *Zophobas morio* and *Zophobas atratus* are reared for commercial purposes as live animal feed; the beetle is a good animal feed resource for its high protein content and healthy nutrients. Conversely, the characteristics of its life stages have not been clearly defined, particularly those of the larval stage that can be used as commercial products; its body length gradually increased with each successive instar and reached a limit at the 18th instar; larvae were white at first instar and gradually turned brown after the second (Kim et al., 2015). *Alphitobius diaperinus panzer* (lesser mealworm) adults, on the other hand, are narrowly oval, mildly convex, black or brownish-black in color, and generally shiny. The color of lesser mealworms varies based on age or 'strain.' The length

ranges from 5.8 to 6.3 mm. Tiny yellowish hairs cover the antennae, with the terminal segment appearing lighter in color. The front of the head is deeply emarginate, with a distinct clypeal groove and a coarsely punctured surface. (Dunford and Kaufman, 2006).



a) b) c) d)

Figure 4. a) Yellow Mealworm, b) Giant Mealworm, c) Giant Mealworm Beetle, d) Lesser Mealworm Adult (entnemdept.ufl.edu, 2006)

2.1.4. Factors that affect the Mealworms

Mealworms are, after all, living creatures, and their importance has risen as technological and environmental impacts have increased. As it has been discovered that they consume polystyrene foam, understanding the factors that affect them would be highly beneficial.

2.1.4.1 Temperature

Since mealworms are cold-blooded, just like most other organisms, environmental changes influence the rate at which physical changes occur. Typically, as the temperature rises, the rate of transition accelerates. Increased

temperature improves metabolism and hormone production, resulting in faster development. At 27.5°C, it indicates that within the optimum temperature of this species (22° - 28°C). Also, the length of exposure was not a critical factor at 25°C. In addition, there was no significant overall mortality at extreme temperature values with 52% - 75% moisture levels. Therefore, 27.5°C represents a non-critical temperature under all humidity conditions, and 52% - 75% represents non-stressful moisture conditions at all test temperatures for mealworms. It is important to note that there is significantly higher mortality at extreme temperatures of 10° and 35° and more extended periods of exposure (24 and 48 hours). The results of the study also indicate that under dry conditions (12%), low-temperature extremes (10°C) result in a slightly higher mortality rate than high-temperature (35°C) extremes for the early larval stage of this species. Thus, it is more critical for this species to be subjected to higher temperatures. In conclusion, mealworms survive best when the optimum temperature in their environment does not exceed 27.5 °C (Devine, et al, 2016).

2.1.4.2 Moisture and Humidity

Most millipedes, centipedes, arachnids, and insects can regulate their body temperature for brief periods with evaporative cooling; as a result, they can tolerate higher temperatures in an arid climate than in one with high relative humidity. This condition has already been experimentally tested in *Tenebrio molitor* larvae; if these larvae are held at a relative humidity of 80%, they can gain weight. This weight gain is due to a rise in the body's water content (Punzo, 1975).

2.1.4.3 Amount of Sunlight/Light

Due to their nocturnal behaviors, mealworms are considered ectothermic animals that are most active at night. Since mealworms behave this way, their metabolic rate would be higher without the presence of light. Consequently, it is confirmed that when mealworms were exposed to light, they released more CO_2 into the air, implying that they did so as they were in a different environment and likely under a lot of stress. Mealworms' metabolic rate improves due to all of these factors (Braeden et al., 2019).

2.1.4.4 Environment Adaptability

T. molitor's behavioral immunity included antiparasitic activities that resulted in three different infectious outcomes (de Roode and Lefèvre, 2012). First, temporal avoidance of remotely infectious locations, people, or food, in addition to hygienic conduct like grooming and adapted social contacts; when *T. molitor* is exposed to a rodent parasite that makes use of the mealworm beetle as an intermediary host, this variety of activity was observed (Pappas et al., 1995). Second, parasite replication-inhibiting host activities may provide resistance. There seem to be no reports of therapeutic medication in the mealworm beetle; thus, additional research regarding this part of mealworm behavioral immunity is required (de Roode and Lefèvre, 2012). Lastly, the host may survive infections if the harmful effects on their reproductive success are kept to a minimum. It is accomplished mainly by increasing their breeding effort; however, this is also at the cost of their lifespan (Vigneron et al.,2019).

2.1.4.5 Suffocation of Mealworms

Mealworms thrive in a large container because providing more space will help dissipate heat and prevent overheating, which improves their survival rate. An excessive number of mealworms stored in a container will cause the worms to suffocate, get compressed, overheat, and die. It is recommended that mealworms should be no more than 1 ½ inches deep. Furthermore, it is recommended for the container of darkling beetles to keep a tight-fitting, removable lid or cover on the container to prevent infestation of mice, rats, cockroaches, spiders, flour, and grain moths. Good ventilation in the containers helps prevent mold growth. (Exotic Nutrition, 2018).

2.1.4.6 Cannibalistic Behavior

Cannibalism shows an impact on population dynamics as well as competitive relationships among species. It is more prevalent in stressful situations, including when population density is high, or food is low, and cannibals thus gain a nutritional advantage for this reason (Ichikawa, 2009). Furthermore, cannibalism of pupae by flour beetle, the latter being a member of the genus Tenebrio, was verified to exist and ranged from moderate to extreme (Park et al., 1968).

2.1.5. Polystyrene and its Components for Decomposition

2.1.5.1 Characteristics of Polystyrene

Styrofoam is a trademarked brand name referred to the application of polystyrene (PS), including the utilization of expanded polystyrene (EPS), which is commonly used in automobile parts, road bank stabilization systems, food containers, insulation, packing, and extruded polystyrene (XPS) also known as the blue board, often used in building insulations and water barriers (Krueger M.C. et al., 2015). Polystyrene (PS) is a petroleum-based plastic made from styrene monomers. Styrene monomers are obtained by reacting ethylene with benzene in the presence of aluminum chloride to yield ethylbenzene. The polymerization of styrene has been known since 1839, when German pharmacist Eduard Simon reported its conversion into a solid named metastyrol (Britannica, 2018). Moreover, PS is highly degradable and is resistant to photo-oxidation (Bandyopadhyay and Basak, 2007). In the 1950s, synthetic plastic materials were widely used commercially and economically in electronic products, drainage pipelines, and containers. One of the most common single-used synthetic products is Styrofoam, made available and manufactured in 1947 by the Dows Chemical Physics Company led by Ray McIntire (Dows Chemical Physics Lab, 1948). PS products are inexpensive, durable, and lightweight, with good thermal insulation and high impact resistance. These are why several million tons of PS items are produced per year (Maul, J et al., 2007).

2.1.5.2 Decomposition of polystyrene materials

Decomposition of polystyrene (PS) materials is extremely long since it is relatively chemically inert, which makes it resistant to breakdown by many acids and bases, waterproof, and only disintegrates into smaller fragments due to the intervention of sunlight, water, and weathering. Since PS products are composed of 98% air, they never lose their inherent chemical properties, making them intact for centuries. (J.A Brydson, 1999).

2.1.6. POLYSTYRENE BIODEGRADATION OF MEALWORMS

2.1.6.1 Behavior of Mealworms utilizing Styrofoam as their Sole Diet

It has recently been proven that the larvae of *Tenebrio molitor Linnaeus* can consume polystyrene wastes. This organism is an efficient depolymerization substitute for Styrofoam or polystyrene products because of the microorganisms found in their microbial gut and analyses proving that Styrofoam was successfully depolymerized after being consumed by the said organisms.

In the experiment conducted to determine the survival rate of mealworms for 30 days with Styrofoam as their sole diet, with a total number of mealworms used in the device was 2,500 individuals that consume approximately 0.644 mg of polystyrene a day per worm, the survival rate of the conventional diet (bran)-feeding mealworms was not significant with an average of 85 percent. Similar results were achieved

using different batches of mealworms from Harbin, China, Compton, California, and USA. The survival rate of Styrofoam-feeding mealworms tested in Harbin and California were approximately 81.3 ± 2.5% and 86.7 ± 3.3%, respectively. Hence, consuming Styrofoam for mealworms and maintaining their survival rate optimum concludes that Styrofoam could be their diet for a considerable extended amount of time.

Furthermore, the retention time of ingested Styrofoam in a mealworm's gut is estimated to be 12-15 hours. Styrofoam-eating mealworms can be characterized based on the changes in physical and chemical properties of egested residues of the mealworms deposited in their frass (Yang et al., 2015).

In another experiment conducted by Wrobel, mealworms were subjected to biodegrade three different types of food packaging plastics: polystyrene (PS), polyvinyl chloride (PVC), and polylactide (PLA). The factors to be evaluated are mass loss, dry matter content, and the biochemical composition of mealworms. Bradford method was used to determine the protein concentration in homogenates of the larvae, while the Anthrone method was utilized for the level of hydrolyzed carbohydrates. The experiment concluded that all three types of plastics were consumed by the mealworms proving that they are a key feature in degrading polymers in the environment (Wrobel et al., 2017).

2.1.6.2 Polystyrene depolymerization by the particular microbes inside a Mealworm's gut

Polystyrene depolymerization and biodegradation can be characterized by conducting several analyses such as Gel permeation chromatography (GPC), Fourier Transform infrared spectroscopy (FTIR), solid-state C-cross polarization/magic angles spinning nuclear magnetic resonance (C-CP/NMR) and liquid-state H nuclear magnetic resonance (H-NMR) (Yang et al., 2015b). By conducting this analysis on the frass excreted by the mealworms after consuming Styrofoam, it was significantly asserted that the residual polymer in frass decreased significantly from those of the original Styrofoam material indicating that depolymerization of the PS is occurring. Furthermore, the release of C-labeled CO2 from the mealworms confirmed the biodegradation and mineralization of polystyrene (Yang et al., 2017).

Yang et al. (2015a) devised a set-up that screens the microbes on the guts of *Tenebrio molitor* and *Zophobas morio*, which can digest polystyrene. By utilizing a pre-sensitized plate and pre-sensitized turbidity system, Yang estimated that 47.7% of the ingested Styrofoam carbon was converted into CO2, and the residue (49.2%) was excreted in feces (frass), with a minimal fraction incorporated into biomass (ca. 0.5%). In the following experiments, they proved the unique role of gut bacteria in the biodegradation process. The strains collected were named TM1 and ZM1 using 16s rDNA sequencing. Tang et al. (2017) claimed that they isolated

two bacterial strains, TM1 and ZM1 (cocci-like and short rod-shaped Gram-negative bacteria), from mealworm gut, which grew in a medium with PS as the sole carbon source. They isolated a PS-degrading bacterial strain, Exiguobacterium sp. strain YT2, which was able to form a biofilm on PS and create pits and holes in the plastic (Yang et al., 2015b). Furthermore, it was shown that antibiotics could suppress gut microbiota and inhibit PS biodegradation indicating that PS degradation is gut-microbe dependent (Peng et al., 2019; Yang et al., 2018b, 2018a; Yang et al., 2015b).

Therefore, mealworms, and their gut bacteria, seem to be a promising 'tool' for the degradation of PS waste. However, factors including temperature, humidity, and population density still directly influence the development of larvae.

2.1.6.3 Polystyrene-Eating Mealworms as Food for Other Animals

The future of potentially dangerous plastic additives has recently gotten much attention. On that account, a group of researchers at Stanford discovered that mealworms could eat numerous types of plastic, particularly plastic foam, without it building up in their body and still be used as a protein-rich feedstock for other animals. Hexabromocyclododecane is a flame retardant found in plastic foam. This component is used to enhance its manufacturing qualities while reducing flammability. Mealworms excreted half of the polystyrene they ate as partly decomposed pieces and the other half as carbon dioxide, implying that the chemicals in the plastic

end up in the environment. By 24 hours, 90% of the HBCD was gone, and within 48 hours, it had completely decomposed. The worms fed a constant diet of HBCD-laden polystyrene were just as healthy as those given a normal diet after the experiment (Brandon et al., 2019).

2.2 RELATED STUDIES

2.2.1 Semi-Automated Biodegradation System for Polystyrene-Eating Mealworms

Around the world, 14 million tons of polystyrene are produced yearly, which correlates to 38.4 thousand tons per day, making it one of the products that cause "white pollution." It is a term used to describe a product that becomes a problem due to its non-biodegradability since it takes about 500 years for a single cup of Styrofoam to decompose. Besides its detrimental effects on the environment, it also causes harm to humans and even animals due to the chemical Styrene (Alonzo et al., 2020). A biodegrading technology system that takes advantage of polystyrene-eating mealworms is now available, but since it is semi-automated, it still requires human intervention.

Based on the findings of the previous study, the semi-automated biodegradation system can be an artificial habitat for mealworms to increase their population and continually biodegrade polystyrene waste. It is a better solution than depending on the existing ways of decomposing polystyrene. The whole system was built initially by integrating different ideas from existing technologies. The

data from the biodegradation system can also be monitored via the Blynk application through ESP 8266 (Alonzo et al., 2020).

In this study, the development of a fully automated biodegrading system is what the researchers want to achieve, exploiting the full potential of the entire segregation process. This system can be accomplished by incorporating a collector module that will take over the job previously performed by humans and advancing the features of each container into tilting ones with an addition of a collector module. The collector module will be incorporated by a linear actuator that will transport the organisms to the topmost container for segregation, allowing the entire system to run automatically while solving one of the country's major issues.

2.2.2 Linear Actuator

An automated manual transmission is a new type of transmission that combines the advantages of manual and automatic transmissions. The study devised an appropriate experiment that allows for the precise determination of the parameters of the actuators that control the transmission. The goal was to use existing actuators and understand their behavior under extreme operating conditions to ensure their success as a part of the AMT. (Krishnaraj, 2013).

The primary motivation for determining efficiency is that the linear actuator contains many small moving parts that are interconnected with one another. The actuator efficiency tests were designed to closely resemble the various loads the transmission and actuator would encounter during a drive cycle. The actuators were put through their paces with various loads and input voltages, ranging from 0 to 45

pounds (lbs.), and an input voltage varied between 6 and 13 volts. The tests showed that the actuators were pushed to their limits while still ensuring they performed their duty reliably. On a side note, the actuator tested with 100lbs and 10-13V still managed to perform its functions, although in a rather sluggish and non-linear manner. (Krishnaraj, 2013).

This linear actuator will also be integrated into the system's segregation and collection module. It will be in control of raising and tilting the containers in the segregation module to transfer the life forms to the collection module, which will also be operated using two linear actuators. The linear actuators will primarily become the main variable of the entire system, making it fully automated and capable of performing segregation work independently.

2.2.3 Segregation of Mealworms using Mesh Screen and Vibrating Motor

Several processes are used in the mining industry to extract minerals from the ground. Shovels, pickaxes, chisels, hammers, and other tools are used in mining. The mining industry's machinery is still evolving today. High-tech equipment is being used to improve new mining machinery. Vibrating screen machines play an important role in mineral processing and mining machinery. These vibrating screen machines aided in the advancement of mineral extraction from the ground. This equipment extracts minerals from the ground because its primary purpose is to separate things from each other. This type of segregation can be used to create a biodegradation system. (Makinde et al., 2015).

This vibrating screen could also be used to separate mealworms at different stages of life for efficient polystyrene biodegradation. The containers will be designed to fit different mesh sizes to a sifting screen. They are separated based on the sizes of their developmental stages. The vibrating motor will also help with separation, causing the containers to move back and forth for filtering.

2.2.4 Temperature-Based Automatic Fan Speed Controller

It was discovered that the increase in electricity usage has become crucial nowadays. From 1980 to 2015, India's average electricity consumption value was 15.1 billion kilowatts/hour (Baligar et al., 2019). Failure to control the fan rate level whenever the temperature changes can increase electricity consumption. In line with this problem, an automatic fan speed controller was introduced in the industry. Its primary goal is to develop a temperature-based automatic fan speed controller that will reduce power consumption and assist individuals unable to control the fan rate level. A DHT11 Temperature sensor that can sense both temperature and humidity was programmed using Arduino UNO. The fan speed is controlled using Pulse Width Modulation (PWM) technique which is based on the temperature sensor (Baligar et al., 2019).

In this study, a temperature-based automatic fan speed controller will be applied. However, instead of DHT11, DHT22 will be used to automatically maintain the temperature and humidity inside the machine since temperature and humidity would significantly affect the metabolism and reproduction of the mealworms.

2.2.5 Automatic Pet Feeder (Using Relay and Servo Motor)

In today's generation, almost every household has become entranced with having their pets. It is necessary to prevent the pets from starving and feeding them at the exact time interval. Nevertheless, there are some instances where the pet owners are busy with their scheduled work and routines at the office, business, or even school. For this reason, an automatic pet feeding system was developed to ensure that pets can get food at a specific time interval. The machine is connected to a real-time clock for real-time monitoring and is integrated with a servo motor to deliver food from the storage to the feeding bowl. An Arduino UNO was used to control this pet feeding system. (Tiwari et al., 2018).

This study will also develop an automatic feeding system wherein polystyrene will serve as food for the mealworms. In the food dispenser, an MG995 servo motor connected to a real-time clock will be used to deliver polystyrene materials to the mealworm and beetle containers. It will be programmed to function using an Arduino Mega 2560.

2.2.6 Notification System (ESP 32)

Weather stations mainly calculate the prediction and estimation of environmental conditions through the scientific calculation of weather parameters. That is why individuals depend highly on the official weather station forecasting. There are possibilities that the estimation of weather conditions is unreliable due to uncontrolled conditions like different atmospheric conditions for every location. That is why a weather monitoring and controlling system was developed to oversee

the weather conditions in remote areas. An ESP 8266 Node MCU was used as a Wi-Fi module that sends the data sensed by the temperature sensor and displayed in the NET PI web server (Mahmood et al., 2020).

With this study, ESP 32 will also be used as Wi-Fi Module so that the end-users can monitor the temperature and humidity of the machine. Also, the weight sensors for specific containers will be connected to the ESP 32 to notify the users whether each container is already overpopulated based on the measured weight. The data will then be displayed in a web app developed through HTML, CSS, PHP, and MySQL to provide a platform for remote monitoring and control of the system, accessed via the Internet.

2.2.7 Control System

ESP Wi-Fi module is used for accessing and controlling devices anywhere and anytime to deployed ESP stations. This work shares the data of air quality, temperature, and humidity gathered through the DHT11 sensor module and MQ-2 gas sensor module, respectively, in three food stores at three remote locations where two control actions are taken automatically with the temperature and air purity output results of the area through ESP 8266. The air cooler is turned on to cool the foods in stores, while the air puller is turned on to extract contamination in certain areas. Also, manual control actions can be taken by the web server administrative person (Aziz, 2018).

In this study, ESP 32 Wi-Fi module will also be utilized to monitor and display data gathered from the sensors installed in the system through a web app.

Also, on the web, the user can manually override the time-based automation of the system and control the specific motors inside the device: linear actuators, vibrating motor, exhaust fans, and servo motor for the food dispenser.

2.3 PATENT CHECK

2.3.1 Automated Insect Separation System

This prior art titled "Automated Insect Separation System" has a grant date of September 27, 2011, from the applicants of the United States of America, specifically the Secretary of Agriculture, is related to the technology in terms of automated segregation or separation system. The focus of the technology is its segregation of a specific organism which are the "mealworms" while this prior art is an automated insect separation device that separates selected insects from the rest of the mixture by processing accumulated insects and other materials. Also, its system flows vertically through a series of vibrating screens, similar to our technology's process.

2.3.2 Yellow Mealworm and Pupa Separation Method

This prior art, titled "Yellow Mealworm and Pupa Separation Method," granted September 4, 2014, and submitted by the applicants from Sichuan Agriculture University in China, is about the technological field of separation devices that deals with the yellow mealworm and pupa separation process. In the prior art, a long-strip-shaped mesh screen separator is also utilized as a screening tool. After screening, the pupas will remain on a mesh screen while the yellow mealworms will fall from the mesh. According to this yellow mealworm and pupa

segregation method, since separation is rapid and accurate, both time and labor are saved while maintaining a convenient operation. This prior art and the technology share a common mechanism of separation but differ in technique since a fully automated mechanism for the technology will be developed.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter outlines the research methods and techniques used in implementing the project. The study specifically integrated multiple modules into the system by adding a linear actuator to lift these containers. This section also discusses the design flow process, hardware construction, software development, materials and equipment needed, overall system evaluation procedures, and the implementation plan for the conduct of the study while in the pandemic.

3.2 Theoretical Framework

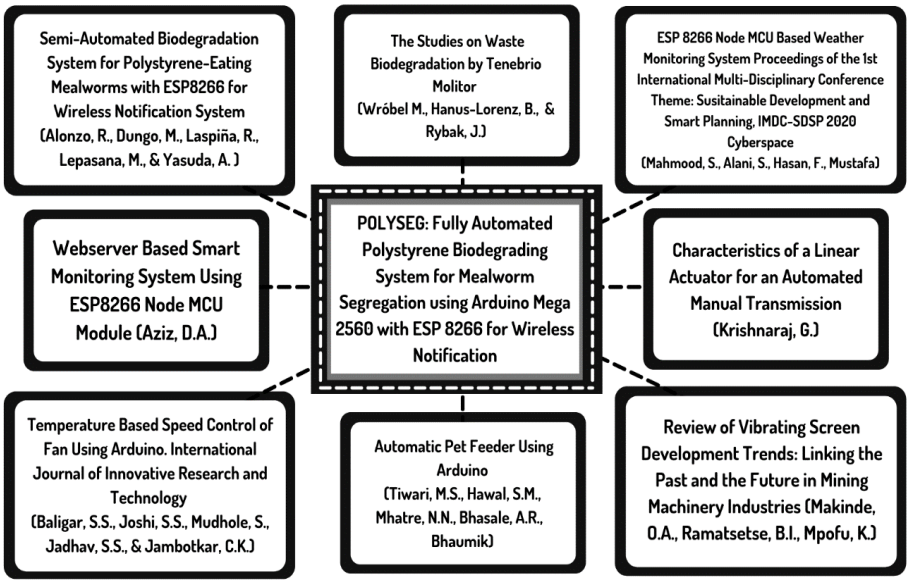


Figure 5. Block Diagram of Related Studies

Figure 5 shows recent studies that were used as a guide and support for the proposed research. These related studies include information on how mealworms biodegrade

polystyrene, semi-automation of the prior technology, vibration and mesh screen system analysis, automation using linear actuators, fan speed control, and user notification.

3.3 Conceptual Framework of the Study

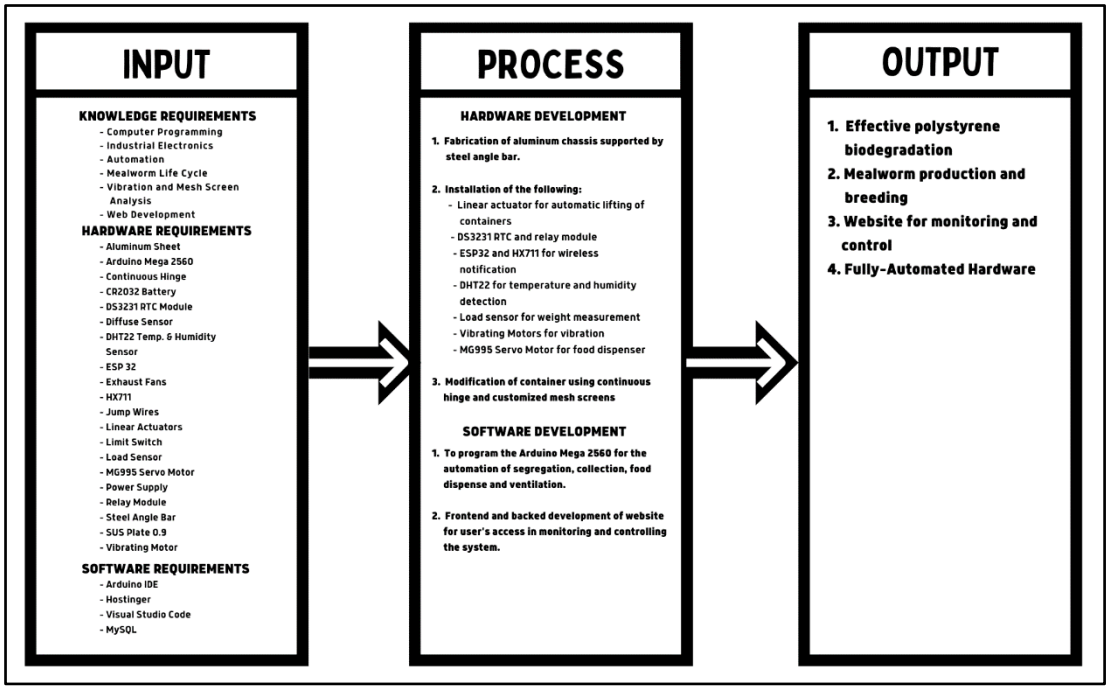


Figure 6. Input-Process-Output Diagram

The input-process-output diagram is shown in Figure 6. The project's primary goal is to create a habitat for mealworms that will let them effectively biodegrade polystyrene. The system is fully automated to aid mealworms in having an environment where they can grow and efficiently biodegrade polystyrene. The knowledge and general information required for this project are the following: mealworm's life cycle and the specific parameters and factors that affect its growth and survival, web development, programming, and automation. Linear actuators, Arduino Mega Board 2560, ESP32 Wi-Fi Module, a DS3231 RTC with a CR2032 battery, exhaust fan, power supply, MG995 servo motor, DHT22 temperature and humidity sensor, load cell with HX711 amplifier, and a vibrating

motor are the main components of this machine. The process of the whole project involves both hardware and software development. The hardware comprises the fabrication of the prototype, mesh screen, and vibration analysis, integration of components and motors in the prototype. Software constitutes the programming for automation of the motors in the system, frontend, and backend development of the web for monitor and control.

3.4 Research Design

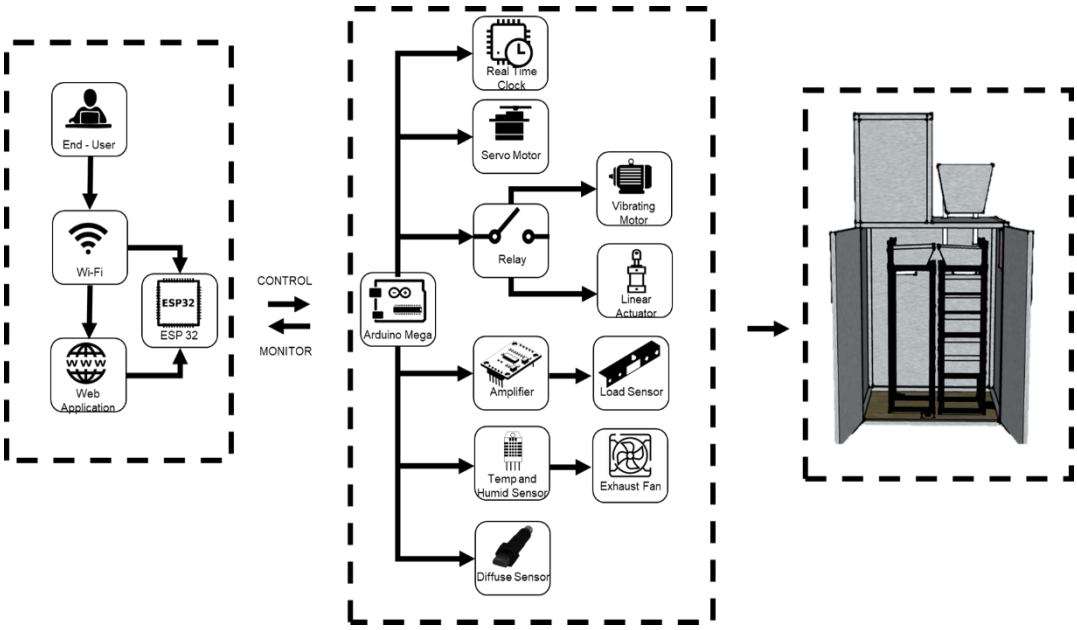


Figure 7. One-Line Diagram

Figure 7 shows the system's one-line diagram. It is composed of the overall development of the project, including the fabrication of the prototype using materials that are cost-efficient and suitable for the organisms, programming of Arduino Mega 2560 board for automation of the integrated motors for segregation, and collection of the organisms and ventilation. All these subsystems in the segregation and collection module were used to separate the different developmental stages of beetle, pupae, mealworm, and

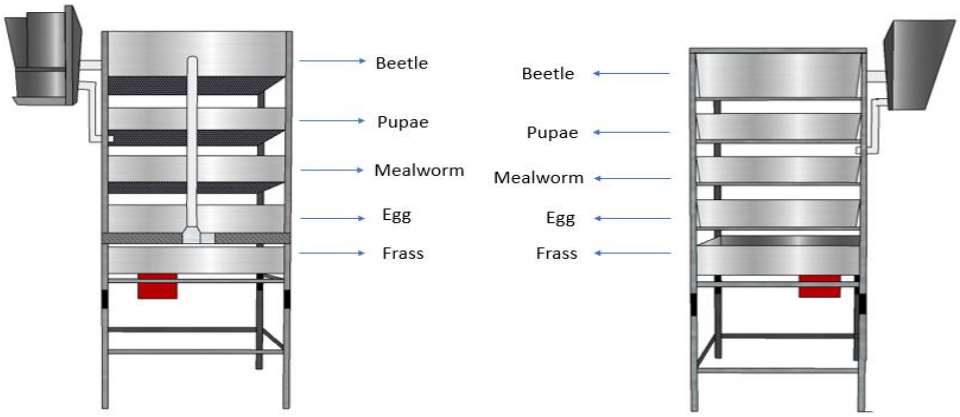
egg to avoid cannibalism and suffocation. Furthermore, the ESP32 module was used for collecting data from the sensors and sending it into the web server, displayed on the web app developed using HTML, CSS, and PHP. Manual control features were applied on the web where the user may manually override the function of motors in the prototype.

3.5 Hardware Construction

The proponents constructed the hardware by integrating the devices and components. These include servo motors and a vibrating motor that were integrated to develop the feeding and segregation mechanism of the system. Angled steel bars were used for the main frame or chassis of the prototype and SUS plate 0.9 for the cover. Furthermore, linear actuators facilitated the tilting of segregation module and the lifting of collection module. Finally, the installation of the ESP 32 is responsible for establishing the connection to the Wi-Fi network and notification, exhaust fans for ventilation, DHT22 for temperature and humidity sensor, load cell and HX711 in specific containers for weight measurement, vibrating motor for segregation, a linear actuator for both segregation and collection module.

(a) (b)

Figure 8. Segregation Module: (a) Internal Front View and (b) Internal Back View of the Hardware Design



(a) (b)

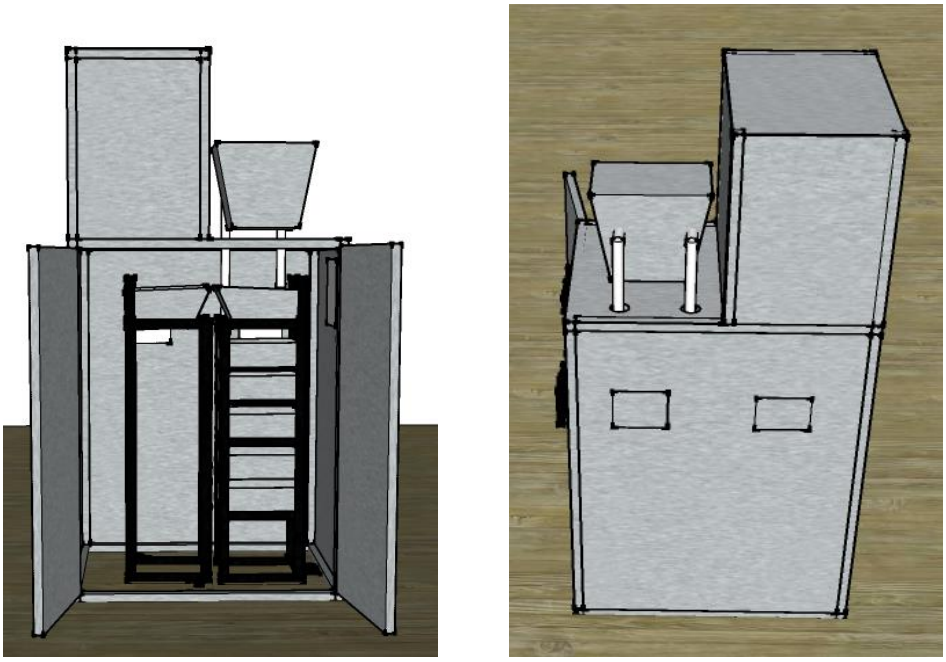
Figure 9. Segregation Module: (a) Internal Left-side View and (b) Internal Right-side View of the Hardware Design

(a) (b)

Figure 10. Collection Module: (a) Internal Front View and (b) Internal Back View of the Hardware Design

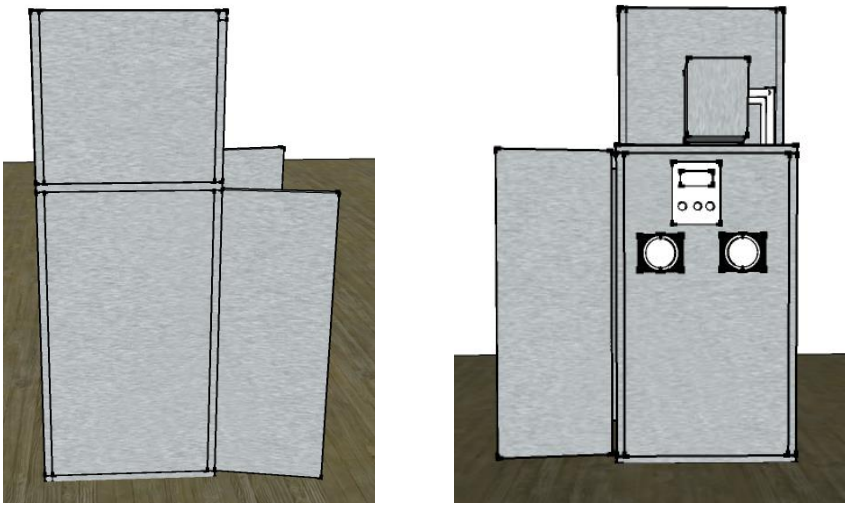
(a) (b)

Figure 11. Collection Module: (a) Internal Left-side View and (b) Internal Right-side View of the Hardware Design



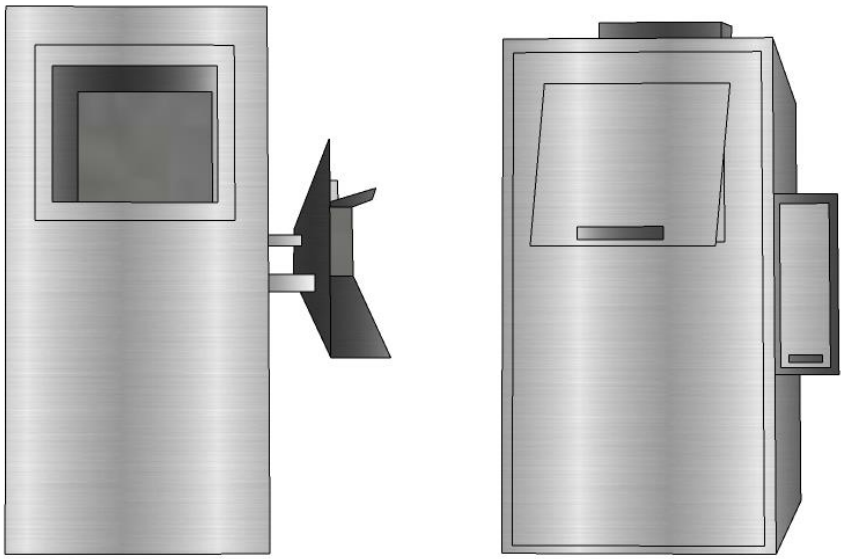
(a) (b)

Figure 12. (a) External Front View and (b) External Back View of the Hardware Design



(a) (b)

Figure 13. Hardware Design: (a) Outer Left-side and (b) Right-side view



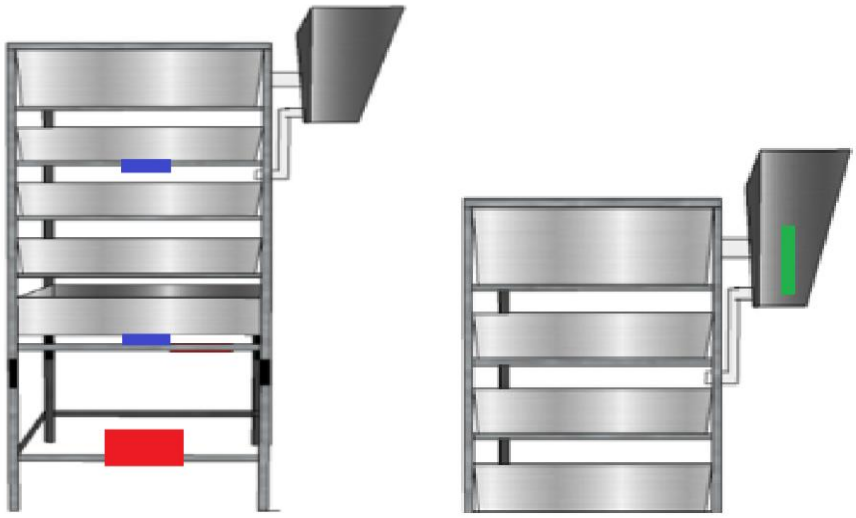
(a) (b)

Figure 14. Hardware Design: (a) Inner and (b) Outer Top View

The proposed project is approximately 35 in long, 24 in wide, and 67 in tall. The measurements of the components are as follows:

Table 1. Dimension of the different segments of the Prototype

Dimension	**Length**	**Width**	**Height**
Container (Beetles)	10 in	7 in	4.5 in
Container (Pupa)	10 in	7 in	2.5 in
Containers (Mealworm)	10 in	7 in	2.5 in
Container (Egg)	10 in	7 in	2.5 in
Container (Frass)	10 in	7 in	2.5 in
Container (Collection)	10 in	7 in	4.5 in
Food dispenser	Short base: 3 in Long base: 8 in	Short base: 3 in Long base: 5 in	11 in
Control Panel	8 in	8 in	12 in
Skeletal Frame	25 in	7 in	30.5 in
Extension for the collection module	10 in	7 in	30 in
Chassis	30 in	14 in	40 in
Cover	35 in	24 in	60 in



(a) (b)

Figure 15. Placement of the Main Components

In Figure 15a, the blue boxes represent the load sensors placed under the mealworm and frass containers. The red box is the vibrating motor located under the frass container. While in Figure 15b, the green box represents the MG995 servo motor inside the food dispenser.

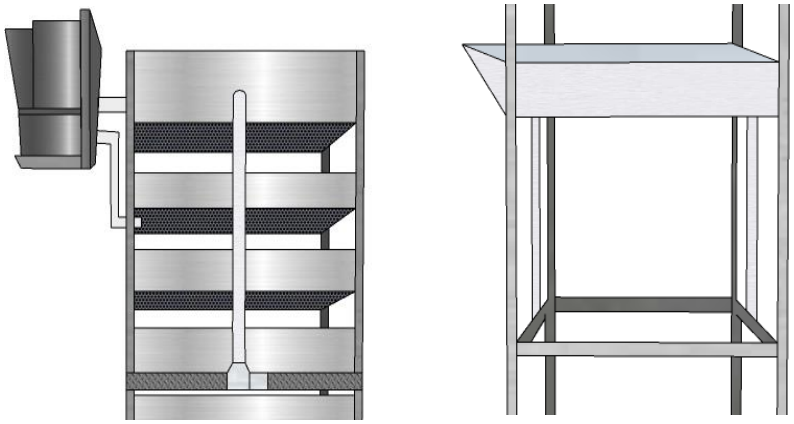


Figure 16. Placement of linear actuators

Figure 16 shows the placement of linear actuators in the segregation module. Each container is connected to the side of the linear actuator that tilts them once it moves. The two linear actuators support both the end sides of the container in order to raise it. The actuator on the right side is extended longer than the left side to facilitate tilting. The sizing of mesh screens in the containers of mealworms and frass is represented in Table 2, which is based on size of the organism to be segregated.

Table 2. The sizes of the mealworm and frass and their respective standard mesh screens for segregation (Zong, 2015)

Order	Life Forms	Growth (days)	Insect length (mm)	Insect diameter (mm)	Size of screen hole in the mesh screen (mm)
1	Beetle	8-12 weeks	19 – 35	2.3-5	4
2	Pupae	6-18 days	20 – 25	1-2.5	3
3	Mealworm	9-13 weeks	15 – 20	1-1.5	1
4	Egg	4-18 days	2	0.9	< 1
5	Frass	-	< 0.2	< 0.2	None

3.6 Software Development

The software design of the program is primarily constituted of an Arduino Mega 2560 microcontroller board linked to a Real Time Clock (RTC), which makes the system time-based.

The system is divided into two subcategories: the segregation and the collection module. During the collection process, when the real-time clock reaches the programmed time, the segregation module's containers are tilted towards the collection module through the linear actuator. Then, the collection module is raised to the topmost container of the segregation module to pour all the gathered life forms. After the collection process, the organisms at the topmost container are segregated using the vibrating motor. For the food dispenser, the servo motor is programmed to rotate for a set amount of time, which is responsible for dispensing the appropriate amount of Styrofoam into the beetle and mealworm containers.

Figure 17 shows the flowchart of the sequence of segregation and collection of the organisms, automating the motors integrated into the system.

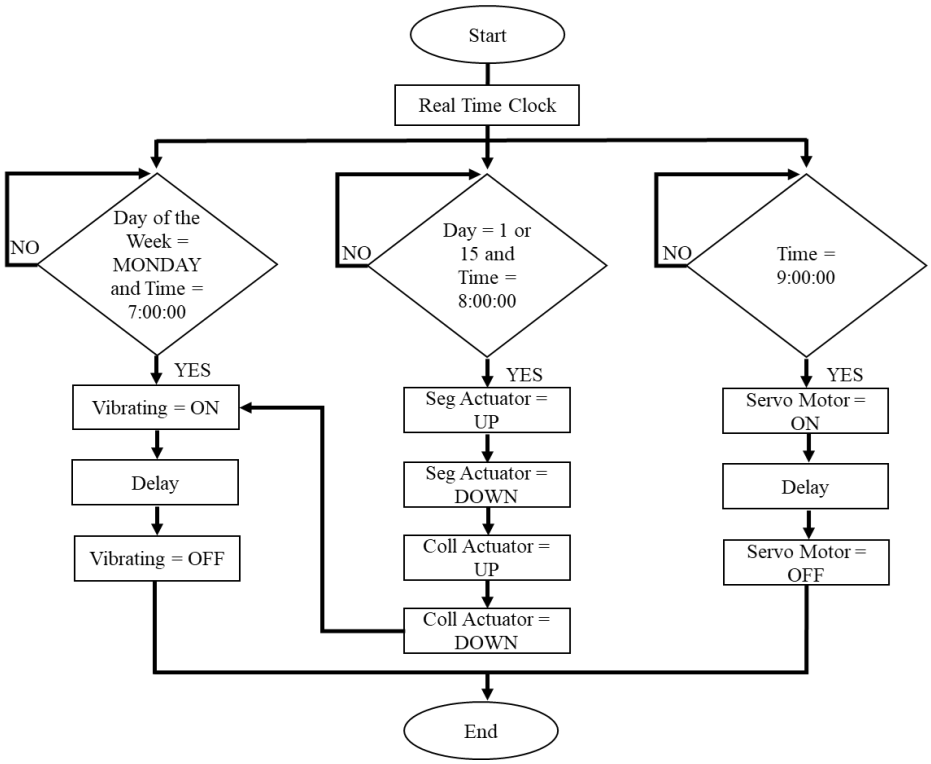


Figure 17. Flowchart for the sequence in the automation of the motors

ESP32, which has Wi-Fi networking capabilities, allows data transfer for the notification, monitor, and control system. The data is displayed in the web app designed and constructed with HTML and CSS. This web application has a home, about us, contact, and login pages. Upon logging in to the login page, the user is directed to the database programmed using MySQL and PHP, where the weight of mealworm and frass will be displayed, along with the temperature and humidity of the system. The user can send a signal to the web to control its mechanism in case of a manual override. Furthermore, the user is notified of the time of the harvest of mealworm and frass or food refill via a pop-up notification on the web. Figure 18 shows the flowchart for the frontend and backend development of the web app that is connected to the system.

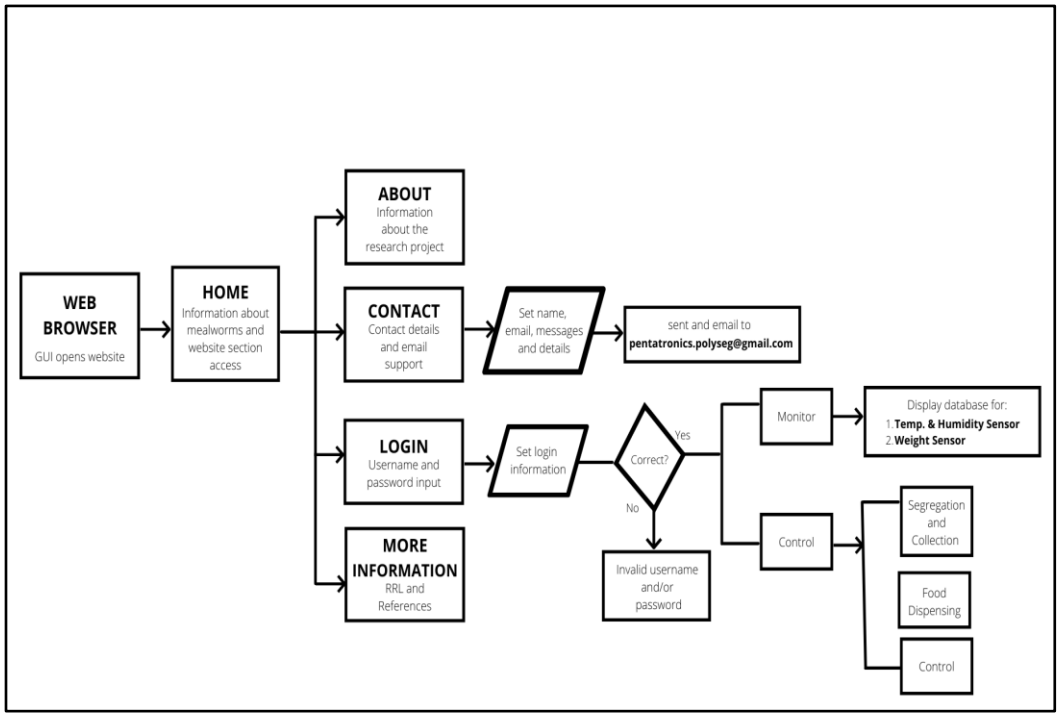


Figure 18. Flow chart for frontend and backend development of the web app

Notification to the user for the harvest of the mealworm larvae and frass is triggered when specific weight measurements are reached. The computation of the weight threshold

for each container is stated below. Also, weight sensors were calibrated to ensure that exterior parameters aside from the weight of organisms were eliminated.

The weight threshold for mealworm containers to avoid overpopulation is set at 650 grams. For the frass, the set threshold is 600 grams.

Calculation of the weight threshold for mealworm container to avoid overpopulation:

145 mg (Finke, 2002) * 1500 mealworms [0.5 in deep] (Alonzo, et. al, 2020) = 217.5g

217.5g/0.5in deep * 1.5 inch deep (Exotic Nutrition, 2018) = 652.5g

The following illustrations demonstrate the flowchart for the sensors – DHT22 temperature and humidity sensor and load cell for the pop-up notification on the web once the set threshold for mealworm and frass containers is reached.

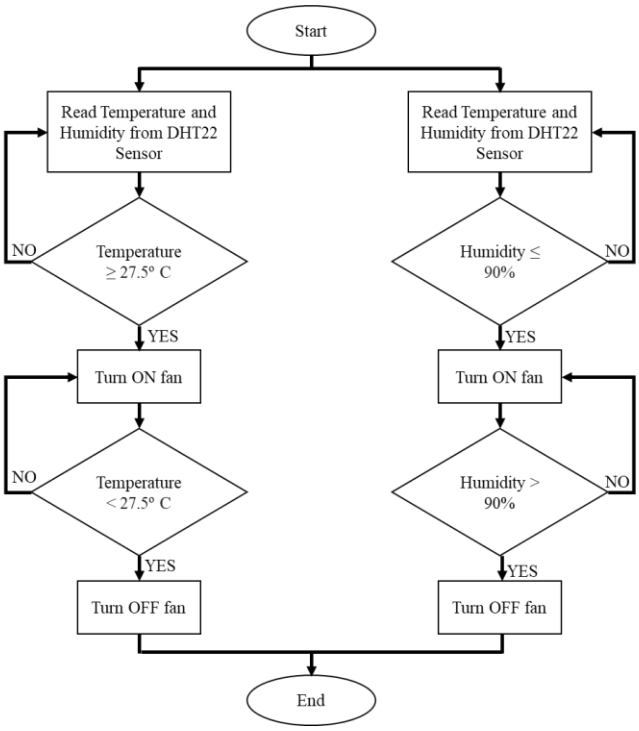


Figure 19. Flow Chart for the Temperature and humidity sensor that controls the exhaust fans

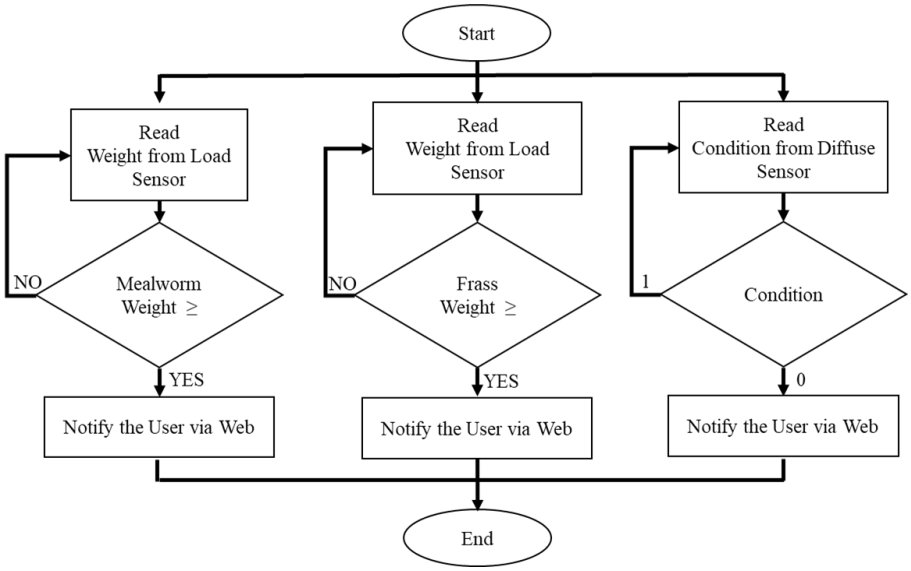


Figure 20. Flow Chart for the Weight Sensors and Diffuse Sensor that controls notification

3.7 Materials and Equipment

3.7.1 Aluminum Sheet

Aluminum is a metal that has a wide range of applications, including industrial, residential, and commercial. This metal is light in weight, corrosion resistant, sturdy, suitable for welding, and a good heat conductor.

Figure 21. Aluminum Sheet (Almetals, 2015)

3.7.2 Arduino Mega 2560

The Arduino MEGA 2560 is a microcontroller board with 54 digital input/output pins and 16 analog inputs that requires more input/output, sketch memory, and RAM. Arduino software is used to program it (IDE).

Figure 22. Arduino Board (Aqeel, 2018)

3.7.3 Continuous Hinge

These are piano hinges, which are made of thin stainless steel. Slightly bendable to accommodate a variety of applications. The hinge is also available without holes, allowing the consumer to weld it directly to the surface.

Figure 23. Continuous Hinge (Amazon, 2020)

3.7.4 CR2032 Battery

The CR2032 Lithium button cell battery provides dependable, long-lasting power for specialty devices. It is found in calculators, electronic devices, watches, and other items.

Figure 24. CR2032 Battery (Duracell, 2020)

3.7.5 DS3231 RTC Module

The DS3231 is a low-cost, high-precaution Real Time Clock module that counts hours, minutes, seconds, days, months, and years. It can operate on either 3.3 or 5 volts, making it suitable for a wide range of development platforms and microcontrollers. Furthermore, it includes automatic compensation for leap years and months with fewer than 31 days. An integrated temperature compensated crystal oscillator that communicates via the i2c protocol. It is used in various electronic devices such as computers, laptops, and GPS for high accuracy. It has a crystal resonator for long-term device accuracy and reduces the piece-cart count on the manufacturing line. Furthermore, this circuit board has a reset output and can switch to backup mode automatically if necessary.

Figure 25. DS3231 RTC Module (Nedelkovski, 2016)

3.7.6 ESP 32

The ESP 32 is a device with Wi-Fi networking capabilities. This device can be programmed using Arduino and can also be linked to a sensor used in notification systems. Because of its Internet of Things applications, this Wi-Fi module is beneficial and popular.

Figure 26. ESP32 (Makerlab Electronics, 2020)

3.7.7 Exhaust Fan

Exhaust fans remove odors, fumes, and moisture from space by venting them outside. The fan's blades are turned on by a motor pulling air out of the space. The stale, humid, or contaminated air is expelled through the exhaust vent.

Figure 27. Exhaust fan (Twinkle Bay, 2020)

3.7.8 HX711

HX711 is a load cell amplifier used for signal conditioning for the signal to be amplified and converted into an output value. It is used after the load or force has been measured by the load cell.

Figure 28. HX711 (NightShade Electronics, 2020)

3.7.9 Jump Wires

Jumper wires are used to connect items on a breadboard or the header pins of an Arduino board.

Figure 29. Jump Wires (Blum, 2020)

3.7.10 Linear Actuator

Simply put, an actuator is a device that converts energy, which can be electric, hydraulic, pneumatic, or other, to mechanical energy that can be controlled. The amount of input is determined by the type of converted energy and function of the actuator. In industrial mechatronics systems, linear actuators are solely responsible for ensuring that a device, such as a robotic arm, can move when electric input is provided.

Figure 30. Linear Actuator (Alibaba, 2020)

3.7.11 Load Sensor

Load cells measure pressure and convert it into an electrical signal. These components are made of aluminum alloy, can withstand up to three kilograms, and can measure pressure unilaterally.

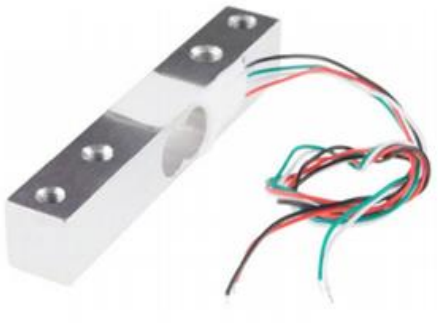


Figure 31. Load Cell (Marketlab Electronics, Straight Bar Load Cell 3Kg, 2020)

3.7.12 MG995 Servo Motor

The MG995 servomotor is metal-geared, which provides better torque and wear gear strength. Its size is typical, making it compatible with most servo attachments like a servo horn, a servo bracket, and more. This servo operates on a 4.8V to 6V power supply. This servo's torque or lifting power is determined by its power supply. With a 4.8V to 6V power source, it can lift from 9.4kg to 11kg. The motor speeds are 0.20 and 0.16 seconds per 60 degrees, respectively. The user can adjust the angle of this motor using a PWM signal from the Arduino board. Only the PWM, PWR, and GND pins are required.

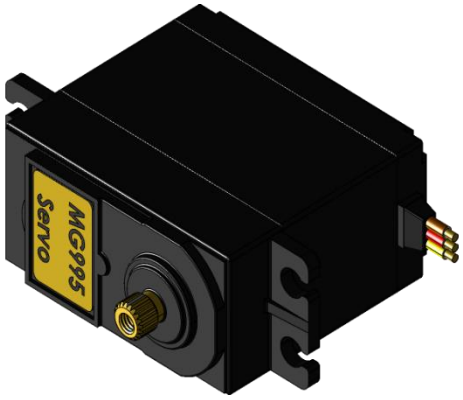


Figure 32. MG995 Servo Motor (CircuitRocks, 2022)

3.7.13 Power Supply

A power supply is an electrical device that supplies electrical power to an electrical load. It converts electric current from a source to the required voltage, current, and frequency to power the load. Power supplies are available in various ratings depending on their intended use.

Figure 33. 12V 15A Power Supply (Alibaba, 2022)

3.7.14 Relay Module

Relays are electronic switches that use electromagnetism to activate a mechanical switch. This application allows for the control of high current equipment while using a relatively low voltage, low current to control the relay's trigger, allowing it to be used with Arduino or similar devices.

Figure 34. 8-Channel 5V Relay Module (Makerlab Electronics, 2020)

3.7.15 Steel Angle Bar

Steel angle bars are ideal for structural, general fabrication, and repair applications. Angle bar is also known as an "L-bar," a "L-bracket," or an "angle iron." A steel metal in the shape of a right angle.

Figure 35. Steel Angle Bar (Anping Lingus Steel Grating Factory, 2020)

3.7.16 DHT22 Temperature and Humidity Sensor

A basic digital temperature and humidity sensor is the DHT22. It measures the ambient air with a capacitive humidity sensor and a thermistor and outputs a digital signal on the data pin, with no analog input pins required.

Figure 36. DHT22 (Adafruit, 2020)

3.7.17 Vibrating Motor

Its purpose is to create or generate vibration. The unstable mass on its driveshaft is the source of the vibration.

Figure 37. Vibrating Motor (Yoycart.com, 2020)

3.7.18 End stop Limit Switch

A limit switch is a switch mechanically operated by the machine's motion that acts as a trigger to prevent the travel of an object once the machine has reached a predetermined point. End stop limit switch is a contact-based manual switch that determines the end of an object's linear movement.

Figure 38. Endstop Limit Switch (Amazon, 2020)

3.7.19 Diffuse Sensor

Diffuse sensors use an IR sensor that can measure a distance between 3 to 80 cm. It features an easy-to-mount chassis, making prototyping much more uncomplicated.

Figure 39. Diffuse sensor (Makerlab Electronics, 2020)

3.8 Testing Procedure

The system is linked to the Real Time Clock (RTC), making the system time-based. Mealworms must be placed in the larva container. Based on the temperature and humidity sensor reading, the measured values determine the opening of the exhaust fan. To ensure that each life form is separated effectively, the automatic segregation of the life forms is conducted weekly, while the collection process is twice a month.

Following that, the vibrating motor assists in filtering and segregating the larvae, pupae, eggs, beetle, and frass. Following segregation, the automatic food dispenser will release Styrofoam to the mealworm and beetle containers daily.

As a result of the continuous cycle, old beetles are released from the device; new beetles will lay eggs; the eggs will hatch and grow into mealworms. The mealworm develops into a pupa, which will hatch into a new beetle. To avoid overpopulation of mealworms and beetles, the population is closely monitored through the load sensors placed underneath the mealworm container.

3.9 Evaluation Procedure

One of the most prevalent ways a quantity can grow is exponentially (Mathews, 2013). The population of species that grows exponentially over time can be modeled by

$$P = \boldsymbol{P_0 e^{rt}}$$

Where:

P = total population after time t

$\boldsymbol{P_0}$ = initial population size

e = Euler's number ≈ 2.71828 (unitless constant)

r = % rate of growth

t = time, in years

An exponents formula, similar to the one used to calculate compound growth for superannuation and interest-bearing investments, may be used to determine the population of humans, animals, and bacteria (Passy, 2013). In this instance, it is used to calculate mealworm population growth.

Table 3. Sample Table for Data Gathering from Weighing Scale, Load Sensor, and Manual Counting

Week	WEIGHT OF MEALWORMS (g)		NUMBER OF SURVIVING MEALWORMS		
	From Weighing Scale	From Load Sensor	From Weighing	From Load Sensor	Manual Counting
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Microsoft Excel's *Forecast Sheet* tool and Exponential Smoothing (ETS) algorithm was utilized to calculate or predict a future value based on existing historical data. The predicted value is a continuation of the historical values at the selected target date, which should follow the timeline (Treacy, n.d.).

Formulas used in forecasting data:

- Column of historical time (time-based data series)
- Column of historical values (corresponding values data series)
- Column with expected values (calculated using *FORECAST.ETS*). *FORECAST.ETS* function predicts a value based on existing values that follow a seasonal trend.
- Two columns represent the confidence interval (calculated using *FORECAST.ETS.CONFINT*). *FORECAST.ETS.CONFINT* function is used to calculate the confidence interval for a forecasted value.

To determine the amount of biodegraded polystyrene is to compare the initial weight of polystyrene to its remaining weight. The rate of polystyrene consumption is evaluated once a week after the weekly segregation. Also, the number of mealworms per week is monitored. The initial and remaining weight are based on the gathered data displayed in the web app. The formula for biodegraded polystyrene is given below.

$$Formula:$$

$$Biodegraded\ Polystyrene = (Initial\ Weight) - (Remaining\ Weight)$$

Table 4. Sample Table for Biodegraded Polystyrene of Mealworms

WEEK	Initial Weight (g)	Remaining Weight (g)	Biodegraded Polystyrene (g)
1			
2			
3			
4			
5			
6			
7			
8			
9			

10			
11			
12			

In most experiments, it is necessary to include the overall accuracy of experimental values by calculating the percent error (Scuro, 2004). The formula for the percent error is given below.

$$\%\ Error = \frac{|Experimental\ Value - True\ Value|}{True\ Value} x\ 100\%$$

Table 5. Sample table for percent error

WEEK	n_t	n_e	$\%\ Error$
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

3.10 Technical Evaluation

To determine the functionality and reliability of the prototype and its application, the proponents gathered the user's responses regarding the performance of the Fully Automated Mealworm Segregation System for Polystyrene Biodegradation using Arduino Mega 2560 with ESP 32 for Wireless Notification. Table 6 shows the evaluation assessment form given to the respondents consisting of professionals and machine automation experts. This evaluation assessment form served as an assessment form for

future prototype improvements. The evaluation is based on different factors/requirements following the ISO 25010 to determine the quality of the software and a technical evaluation using a 5-point Likert scale.

Table 6. Evaluation Form using a 5-point Likert scale

Mealworm Segregation with Wireless Notification					
Introduction: The students involved in the completion of this study needs to conduct an evaluation questionnaire regarding the different factors and parameters, entitled *"Fully Automated Mealworm Segregation System for Polystyrene Biodegradation using Arduino Mega 2560 with ESP 32 for Wireless Notification."*					
Instruction: Please rate each of the parameters and check one response if your review suffice to this rating. Check 1- if Strongly Disagree, 2- if Disagree, 3- if Neutral, 4- if Agree, and 5- if Strongly Agree.					
Survey Statements	Rating				
	1	2	3	4	5
Functional Suitability					
1. The automated segregation of the mealworms is more efficient than the manual or traditional method.					
2. The collection of the life organisms for segregation is more efficient than the manual or traditional method.					
3. The notification for the harvest of organisms if they are overpopulated in the container is effective.					

4. The notification for the harvest of frass in the application is effective.					
5. The information in the application's interface for monitoring is clearly displayed and in real-time.					
Usability					
6. The whole system including the application is easy to navigate and learn					
7. The whole system needs minimum supervision during its entire operation.					
8. The design and structure of the whole system is pleasing to the eye of the user.					
Maintainability					
9. The device does not require special handling during the operation.					
10. The instructions on the usage of the system are easy and simple to understand.					
Safety and Reliability					
11. The prototype does not have health safety risk or physical risk in the entire operation.					
12. The inlets, outlets, and wiring are intact and properly organized.					

3.11 Gantt Chart

Table 7. Project Work Plan

	2021										2022							
ACTIVITIES	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Brainstorming	■																	
Gathering of Research Facts	■	■																
Topic Defense		■																
Interview with Stakeholders		■																
Formulation of Chapter 1-3 And preparation for Title Defense			■															
Consultation with Adviser			■	■														
Title Defense				■														
Planning and Design				■														
Purchase of Materials					■													
Fabrication of Prototype					■	■	■	■	■	■	■							
Website Development						■	■	■	■	■	■	■	■	■				
Calibration of Sensors, Motors, and other components							■	■										
Establishing Connection of ESP32 module to the Web Server over the Internet								■	■	■	■	■	■	■	■			
Progress Defense									■									
Send values from Load Cell to the database (monitoring)									■	■								

Send data from web to Arduino (controlling)																		
Revision, Evaluation and Testing of Prototype																		
Preparation for Pre-Final Defense																		
Pre-Final Defense																		
Data Gathering																		
Finalization of Document																		
Preparation for Final Defense																		
Final Defense																		
Finalization of Thesis Paper																		
Revision of Thesis Paper																		

3.12 CoVid-19 Implementation Plan

Table 8. CoVid-19 Implementation Plan for Research Project Management

Objective	**Personnel**	**Location**	**Responsibilities**		**Communication**	
			Action	**Timeline**	**Pre-Visit**	**When to report**

To assess the previous prototype and salvage usable materials. Also, to visit the deployment area and initiate communication with the head of the Materials Recovery Facility.	Maximum of two team members which are near the area.	Brgy. Baranga Valenzuela City	Assess the previous prototype.	2nd week of June (June 9)	Contact the head of the facility and schedule the visit of the team members.	Update team leader regarding the assessment.
To acquire the materials and tools needed in building the prototype.	Maximum of three team members which are near the area.	Manila City	Canvass and buy the materials which are available on-site.	3rd week of June (June 16)	Procure a list of materials needed.	The team members must be stayed in contact with each other during the entire process.

To conduct a safe and systematic purchase of the customized chassis of the prototype in the manufacturing company.	Maximum of three members	Laguna	Visit the manufacturer for kickstarting the construction of prototype	4th week of June (June 21)	Contact the head of the facility and schedule the visit of the team members.	Update the team of the visit.
To conduct a second visit for checking the construction progress of the prototype.	Maximum of three members near the area.	Laguna	Check the progress of the prototype.	5TH week of June (June 28)	Contact the head of the facility and schedule the visit of the team members	Update the team of the visit.
To acquire the finished prototype.	All of the members	Laguna	Receive the prototype.	2nd week of July	Contact the head of the facility and schedule the visit of the team members.	The team members must be stayed in contact with each other during the entire process.

					Rent a vehicle for transporting the prototype.	
To modify the prototype in line with the methodology of the study. To assess the overall functionality of the prototype along with the GUI.	All of the members	Laguna	Prototype Modification Software Development Testing	2nd week of July (July 6-13)	All members are mandated to have a RT-PCR Swab Test. If the result returns positive for most of the members, the plan will be delayed until majority of the members are cleared of Covid.	

Table 9. Research Team Contact Information

Each of the members must have a copy of the team's contact numbers so there would be an ease in contact tracing for emergent situations.

Name	Phone Number	Address	Email address
Rey Mark Migullas	09272591208	B4 L1 Dreamland Heights Brgy. UB San Pedro Laguna	reymark.migullas@tup.edu.ph
Rael Beatriz Nabong	09156042790	860 Anahaw St. A. Bonifacio Rd. Balingasa, Quezon City	raelbeatriz.nabong@tup.edu.ph
Queen Venus Andrea Oriol	09776001402	KS15, Santiago St., Lancaster New City, Brgy. Navarro, Gen. Trias Cavite	queenvenusandrea.oriol@ tup.edu.ph
Micah Daniela Santos	09565122010	#11 Lakbayan St. Central Signal Village Taguig City	micahdaniela.santos@tup.edu.ph
Czarina Mae Talde	09672580310	#319 Gaffud St., Madarang Norte, Poblacion Sur, Maddela, Quirino	czarinamae.talde@tup.edu.ph

Table 10. Protocol to be Followed During the Team's Visit

	PROTOCOL
1	Wear a mask and a face shield during the entire visit. ● Wash your hands or use hand sanitizer before putting on your mask. ● Wear your mask over your nose and mouth and secure it under your chin. ● Fit the mask snugly against the sides of your face, slipping the loops over your ears or tying the strings behind your head.
2	Stay at least 6 feet (about 2 arms lengths) apart from others.
3	Clean and disinfect.
4	Avoid crowds and poorly ventilated spaces. ● Avoid indoor spaces that do not offer fresh air from the outdoors as much as possible. ● If indoors, bring in fresh air by opening windows and doors, if possible.

5	Maintain cleanliness of the hands by spraying alcohol every once in a while. ● Before eating or preparing food ● Before touching your face ● After using the restroom ● After leaving a public place ● After blowing your nose, coughing, or sneezing ● After handling your mask ● After changing a diaper ● After caring for someone sick ● After touching animals or pets ● Avoid touching your eyes, nose, and mouth with unwashed hands.
6	Cover coughs and sneezes ● Immediately wash your hands with soap and water for at least 20 seconds. If soap and water are not readily available, clean your hands with a hand sanitizer that contains at least 60% alcohol.

7	Daily monitor your personal health. ● Be alert for symptoms. Watch for fever, cough, shortness of breath, or other symptoms of COVID-19. ● Especially important if you are running essential errands, going into the office or workplace, and in settings where it may be difficult to keep a physical distance of 6 feet. ● Take your temperature if symptoms develop. ● Do not take your temperature within 30 minutes of exercising or after taking medications that could lower your temperature, like acetaminophen. ● Follow CDC guidelines if symptoms develop.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Project Technical Description

PolySeg is an automated system that biodegrades polystyrene by containing and maintaining mealworms capable of degrading Styrofoam. This project has two adjoining components: the hardware and the web app. The life forms are placed, segregated, and collected in one of the units. Another application of the said device is the IoT-enabled control and monitoring of lifeforms. By linking these two, the system not only serves as an artificial habitat for mealworms but also decreases potential mistakes in mealworm handling and the time and effort required to turn polystyrene into a less toxic material.

The hardware consists of two modules: a collection and a segregation module. Each life form is separated into several containers (egg, mealworm, pupa, beetle) using different sizes of mesh screens, along with another container for its frass. It also includes a food bin and a dispenser where mini cubes of Styrofoam are stored. The web app is programmed to control and monitor the device based on the user's intended availability and preferences. The prototype can then be accessed via the Internet provided that users have the web application's link and login credentials, which include the user ID and password.

4.2 Project Structural Organization

4.2.1 Device

(a) (b)

Figure 40. (a) External Front View and (b) Internal Front View of the Hardware Design

(a) (b)

Figure 41. Hardware Design: (a) Outer Left-side and (b) Outer Right-side view

(a) (b)

Figure 42. Internal System: (a) Segregation Module and (b) Collection Module

Figure 43. Hardware Design: Food Dispenser

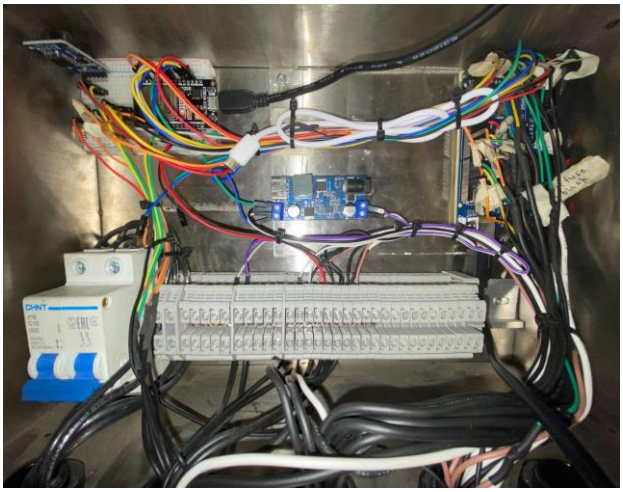


Figure 44. Hardware Design: Control Panel

(a) (b)

Figure 45. Placement of Sensors: (a) Load Sensor and (b) Temperature and Humidity Sensor

The prototype's final structure is shown in Figure 40 to Figure 45, with an overall dimension of 35x24x60in. The prototype is divided into two parts, the segregation and collection module, shown in Figure 40. The components used for the system were arranged and wired inside the control panel.

4.2.2 Graphical User Interface

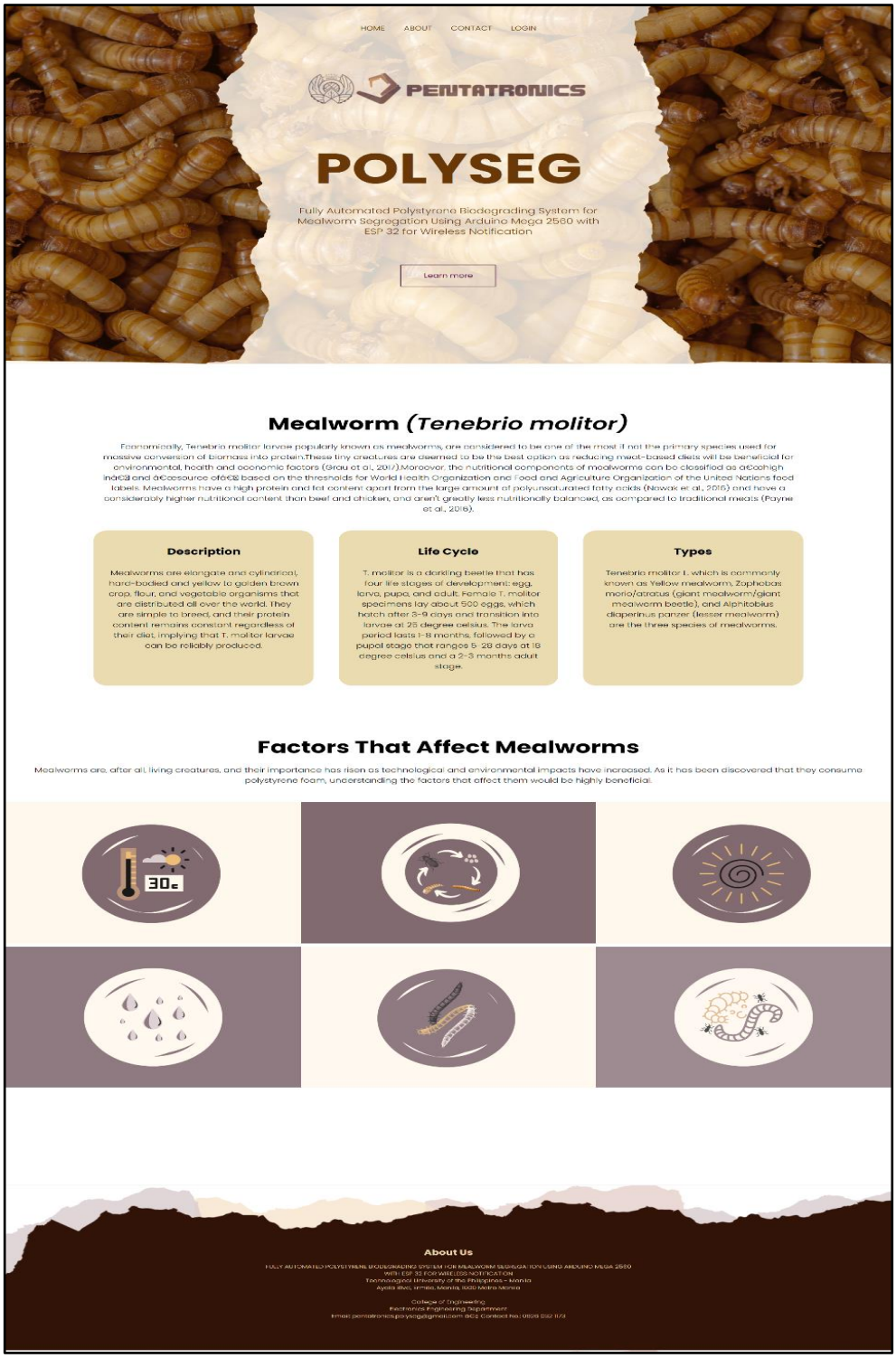
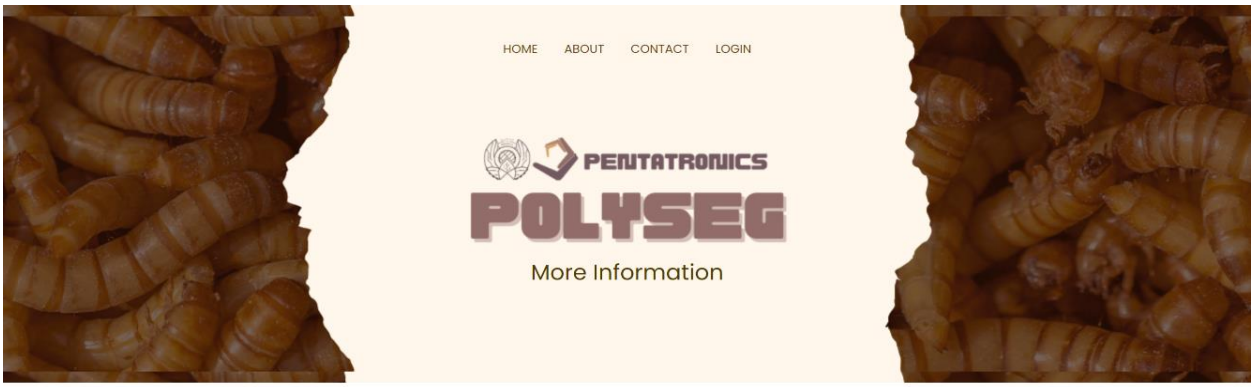


Figure 46. Home Page



Characteristics of Polystyrene

Decomposition of polystyrene materials

Behavior of Mealworms utilizing Styrofoam as their Sole Diet

Polystyrene depolymerization by the special microbes inside a Mealworm's gut

Polystyrene-Eating Mealworms as Food for Other Animals

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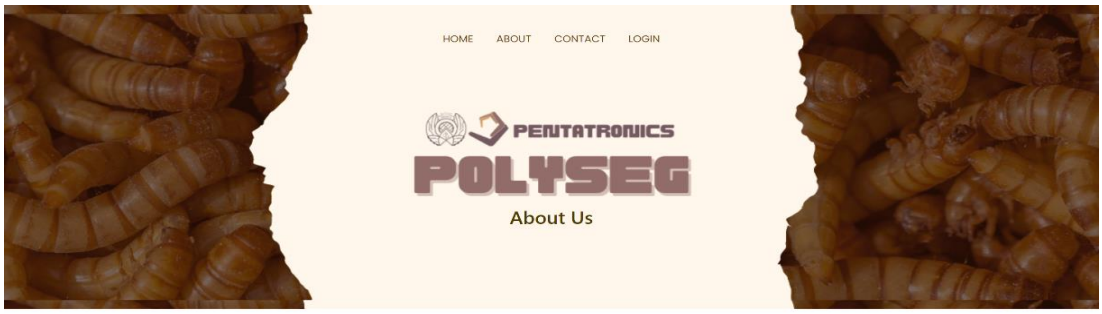
Figure 47. Learn More Page



FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM SEGREGATION USING ARDUINO MEGA 2560 WITH ESP 32 FOR WIRELESS NOTIFICATION

A non-biodegradable material is a substance that cannot be broken down by natural organisms and is thus a source of pollution or contamination. Non-biodegradable wastes, unlike biodegradable wastes, are difficult to manage. Wastes that are non-biodegradable cannot be decomposed or dissolved by natural agents. They will exist on earth for thousands of years without deteriorating. Many plastics and Styrofoam containers made of polystyrene are non-biodegradable (Mathur, 2021). Polystyrene degrades so slowly that it cannot be considered as a biodegradable material. According to the Environmental Action Association, most polystyrene that ends up in landfills will still be there in 500 years (Korpella, 2019).

Mealworms are the larvae of the beetle Tenebrio molitor, a darkling beetle organism. Mealworms are commonly fed to reptiles and birds as a staple food. They are often put out in bird feeders for wild birds, particularly during the nesting season, when birds are raising their young and appreciate a ready supply of food. Also, they're sometimes used as bait for fishing. Mealworm frass has a high fertilizer capacity, according to chemical analysis. Frass, unlike traditional mineral fertilizer, produced small amounts of micronutrients (such as Cu and Zn), which could be beneficial to crops (Houben, 2020). Eggs, larvae, pupae, and adults are the four stages of development for mealworm beetles. The length of time it takes for insects to progress through these stages is affected by the temperature of their surroundings and the food availability (â€œMealworm Beetle Life Cycleâ€, 2018). With a retention period of less than 24 hours, Styrofoam can be efficiently degraded in the larval gut. Over the course of a month, larvae that are fed only with Styrofoam survived just as well as those fed a regular diet or bran (Yang et al., 2015).

Automating the rearing, collecting, and handling of insects is a vital step toward making insect mass production more appealing, cost-effective, and competitive. With little to no human intervention, an automated mass rearing system may promote mass organism growth from egg hatching to full adults or some stages in between, such as the larvae rearing process. Deaths and developmental disorders may be reduced by automating the rearing and transportation of these organisms. Various techniques and apparatuses are used in this automation to cause the least amount of disruption to the organisms during growth which would optimize the organisms' survival rate and health (Massaro, 2016).

The observation that mealworms can biodegrade polystyrene is now a building block toward decomposing a non-biodegradable waste into a biodegradable one. This research will be effective by using an automated technology providing a system that will continuously biodegrade Styrofoam by providing a rearing mechanism to the beetle's life cycle.

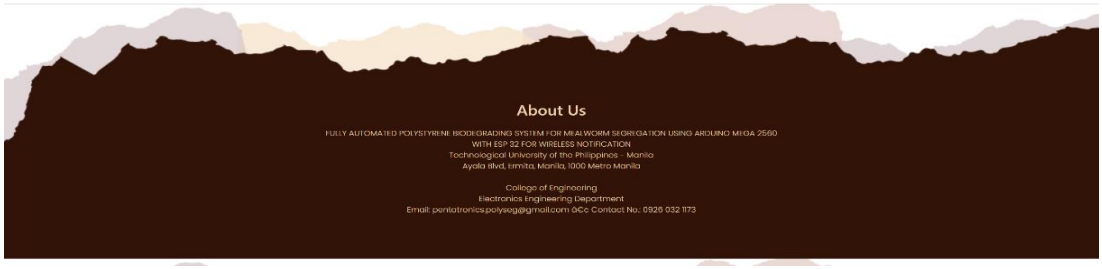
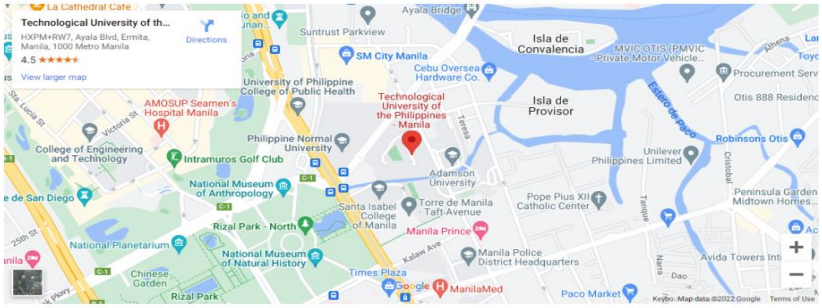


Figure 48. About Page



Name

Email Address

Message

Additional details

Submit

Ayala Blvd, Ermita, Manila, 1000 Metro Manila
Address

0926 032 1173
Phone no.

pentatronics.polyseg@gmail.com
Email Address

About Us

FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM SEGREGATION USING ARDUINO MEGA 2560 WITH ESP 32 FOR WIRELESS NOTIFICATION
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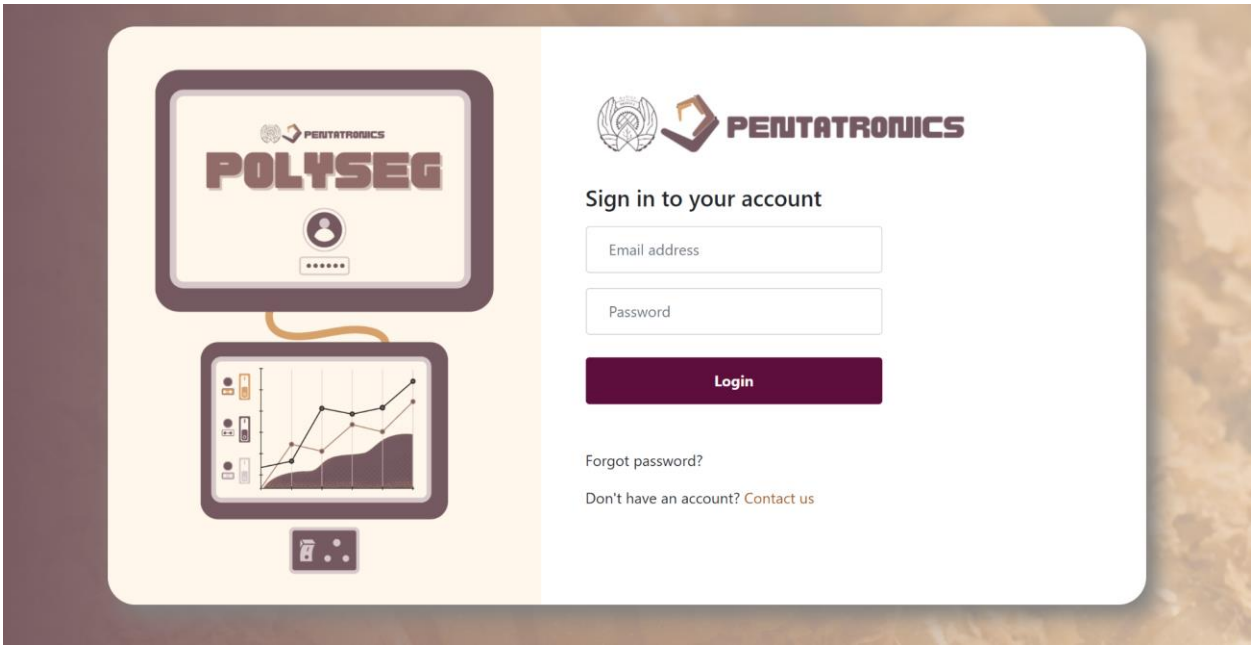
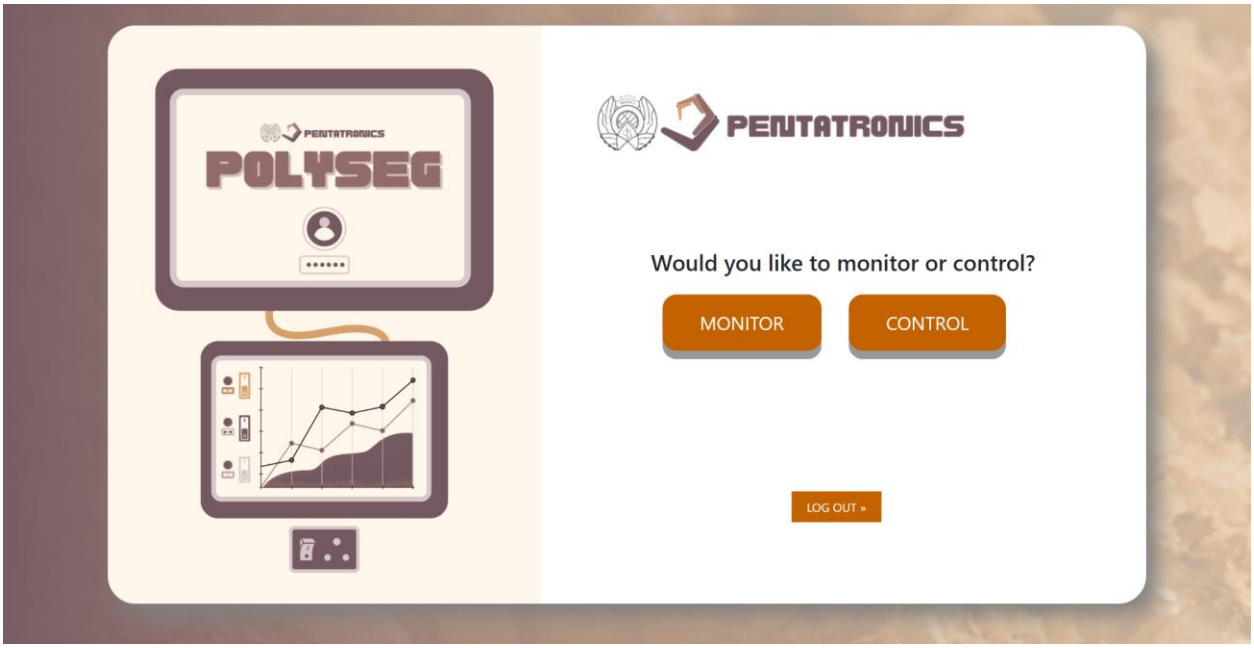
Ayala Blvd, Ermita, Manila, 1000 Metro Manila

College of Engineering
Electronics Engineering Department
Email: pentatronics.polyseg@gmail.com ✆& Contact No.: 0926 032 1173

Figure 49. Contact Page

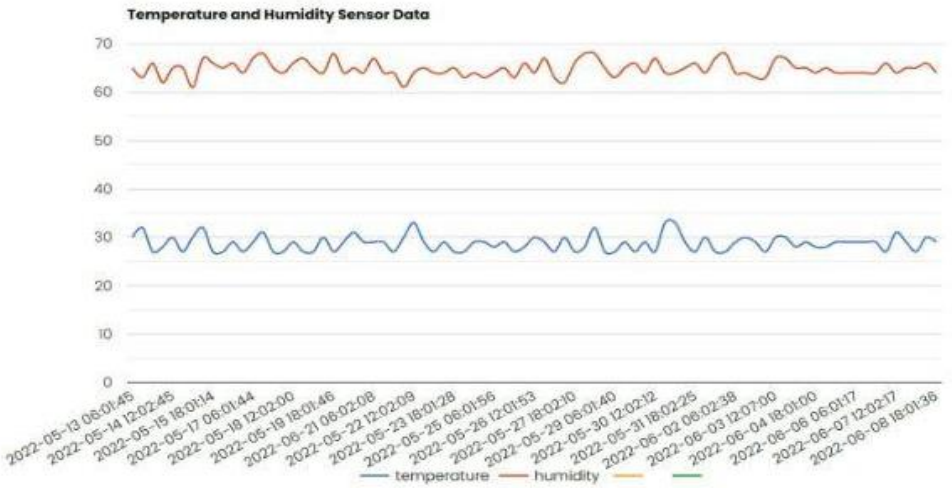


(a)



(b)

Figure 50. (a) Login Page (b) Monitor and Control Button Page



TEMPERATURE & HUMIDITY SENSOR DATA

ID	Date & Time	Temperature °C	Humidity %
81	2022-06-08 18:01:36	29.6	64.5
80	2022-06-08 12:02:05	30.4	66.1
79	2022-06-08 06:02:01	27.1	65
78	2022-06-07 18:01:25	29.3	65.3
77	2022-06-07 12:02:17	31	64
76	2022-06-07 06:00:06	27.4	68
75	2022-06-06 18:01:04	29.3	64.6
74	2022-06-06 12:02:03	29.3	64.6
73	2022-06-06 06:01:17	29.3	64.6
72	2022-06-05 18:02:08	29.3	64.6
71	2022-06-05 12:00:57	29	64
70	2022-06-05 06:01:11	28.7	65.3
69	2022-06-04 18:01:00	28.3	64
68	2022-06-04 12:02:02	29	65.7
67	2022-06-04 06:00:00	28.4	65.8
66	2022-06-03 18:01:00	30	67
65	2022-06-03 12:07:00	30	67
64	2022-06-03 06:02:03	27	63.2
63	2022-06-02 18:02:50	29	63.4
62	2022-06-02 12:01:43	30	64.7
61	2022-06-02 06:02:38	29	64.3
60	2022-06-01 18:02:32	27.3	68
59	2022-06-01 12:02:29	27.4	67
58	2022-06-01 06:01:30	30	64.7
57	2022-05-31 18:02:25	27.1	66.8
56	2022-05-31 12:02:20	29	65.5

Figure 51. Monitoring Page (Temperature and Humidity)

Figure 52. Monitoring Page (Weight)

Figure 53. Control Page

The web app displays the monitored weight, temperature, and humidity through graphs and tables. Buttons were allotted for controlling the segregation, collection, food dispenser, and exhaust fan. The red button indicates that the button is inactive or currently OFF, while the green indicates that it is active (ON). Credentials must be provided on the

login page to access the monitor and control pages. Aside from that, necessary information about mealworms was provided in the web app. Information about the project study and contact details were also presented.

4.3 Project Limitation and Capabilities

The system was built to notify the users and to monitor and control the device remotely. The capabilities of the study were as follows:

1. The system automatically dispenses food and segregates each lifeform into its designated areas.
2. The system proved quite convenient for deployment at homes and MRFs.
3. The system could determine if the organisms are ready for harvest and when the food dispenser needs a refill.
4. The system was able to alert the users through web app notifications.

The limitations of the study were as follows:

1. Reliance on the internet connection to check the status of the technology remotely.
2. The only synthetic substance that can be disposed of with this technology is EPS or Expanded Polystyrene.
3. It is intended for indoor usage only and should not be exposed to direct sunlight or rain.
4. A higher level of maintenance is needed than with a manually operated machine.

4.4 Project Evaluation

4.4.1 Data Gathering

The population of species that grows exponentially over time can be modeled by

$$\textit{Total Population After t } (P) = \textit{Initial Population Size } (P_0)$$

$$e^{\textit{rate of growth } (r) * \textit{time,in years } (t)}$$

Table 11. Data Gathered from Weighing Scale, Load Sensor, and Manual Counting

Week	Date	WEIGHT OF MEALWORMS (g)		NUMBER OF SURVIVING MEALWORMS		
		From Weighing Scale	From Load Sensor	From Weighing Scale	From Load Sensor	Manual Counting
0	May 13	207.9	209	1386	1393	1440
1	5-13 to 5-20	209.7	211.3	1398	1408	1454
2	5-21 to 5-27	223	228.1	1486	1520	1543
3	5-28 to 6-3	245.7	249.4	1638	1662	1687

The table above shows the data from the weighing scale, load sensor, and manual counting over 21 days of data gathering.

Table 12. Population Growth Rate from Weighing Scale vs. Manual Counting

21 Days (May 13 to June 3)	
FROM WEIGHING SCALE	**MANUAL COUNTING**
$P_0e^{rt} = P(t)$ $1386e^{rt} = 1638$ $1386e^{r(21/365)} = 1638$ $e^{r(0.0575)} = 1.1818$ $ln(e^{r(0.0575)}) = ln(1.1818)$ $r(0.0575) = 0.1670$ $r = 2.9043$ $\mathbf{r = 290.43\%}$	$1440e^{rt} = 1687$ $1440e^{r(21/365)} = 1687$ $e^{r(0.575)} = 1.1715$ $ln(e^{r(0.0575)}) = ln(1.1715)$ $r(0.0575) = 0.1583$ $r = 2.7530$ $\mathbf{r = 275.30\%}$

With a nearly 300 percent growth rate, this is a strong indication that the system was able to increase mealworm reproduction, demonstrating its efficiency. After a year of breeding, the calculation estimates there will be approximately 25,000 mealworms.

4.4.2 Forecasting Polystyrene Consumption of Mealworms

Utilizing Microsoft Excel's Forecast Sheet tool and Exponential Smoothing (ETS) algorithm, it is possible to easily calculate or predict a future value based on existing historical data. The results are shown in the following table, which consists of mealworms' polystyrene consumption for 70 days. Referring to the data, an average of 1541 mealworms consume 9.6 grams of polystyrene per week. Hence, it calculates a 0.623 mg-mealworm per day rate. Subsequently, it increased to a daily average of 1.6g or an equivalent of 115 grams of Styrofoam in two months, which is a remarkable outcome considering the size of the mealworms and the trouble of degrading this type of waste.

Table 13. Daily Throughput (Consumed Styrofoam)

Date	Initial Weight (Styro)	Remaining Weight (Styro)	Daily Throughput (g)	Weekly Throughput (g)
27/03/2022	2.4g	1.2	1.2	
28/03/2022	2.4g	1	1.4	
29/03/2022	2.4g	1	1.4	
30/03/2022	2.4g	0.6	1.8	
31/03/2022	2.4g	1.2	1.2	
01/04/2022	2.4g	1.4	1	
02/04/2022	2.4g	1	1.4	9.4
03/04/2022	2.4g	1.2	1.2	
04/04/2022	2.4g	0.8	1.6	
05/04/2022	2.4g	1.2	1.2	
06/04/2022	2.4g	0.6	1.8	
07/04/2022	2.4g	1	1.4	
08/04/2022	2.4g	1	1.4	
09/04/2022	2.4g	1	1.4	10
10/04/2022	2.4g	1.2	1.2	
11/04/2022	2.4g	1	1.4	
12/04/2022	2.4g	0.8	1.6	
13/04/2022	2.4g	1.2	1.2	
14/04/2022	2.4g	0.8	1.6	
15/04/2022	2.4g	1.2	1.2	
16/04/2022	2.4g	1.2	1.2	9.4
17/04/2022	2.4g	1.1	1.3	
18/04/2022	2.4g	1.2	1.2	
19/04/2022	2.4g	0.9	1.5	
20/04/2022	2.4g	1	1.4	
21/04/2022	2.4g	1	1.4	
22/04/2022	2.4g	1.2	1.2	
23/04/2022	2.4g	1.3	1.1	9.1
24/04/2022	2.4g	1	1.4	
25/04/2022	2.4g	1.2	1.2	
26/04/2022	2.4g	1.1	1.3	
27/04/2022	2.4g	1.1	1.3	
28/04/2022	2.4g	1	1.4	
29/04/2022	2.4g	0.8	1.6	
30/04/2022	2.4g	1.3	1.1	9.3

Date	Initial Weight (Styro)	Remaining Weight (Styro)	Daily Throughput (g)	Weekly Throughput (g)
01/05/2022	2.4g	1.1	1.3	
02/05/2022	2.4g	1.1	1.3	
03/05/2022	2.4g	0.9	1.5	
04/05/2022	2.4g	1.2	1.2	
05/05/2022	2.4g	0.8	1.6	
06/05/2022	2.4g	0.8	1.6	
07/05/2022	2.4g	1.3	1.1	9.6
08/05/2022	2.4g	1.2	1.2	
09/05/2022	2.4g	1.2	1.2	
10/05/2022	2.4g	1	1.4	
11/05/2022	2.4g	0.8	1.6	
12/05/2022	2.4g	0.8	1.6	
13/05/2022	3.0g	1.1	1.9	
14/05/2022	3.0g	0.9	2.1	11
15/05/2022	3.0g	0.9	2.1	
16/05/2022	3.0g	1	2	
17/05/2022	3.0g	0.7	2.3	
18/05/2022	3.0g	0.9	2.1	
19/05/2022	3.0g	1	2	
20/05/2022	3.0g	1.1	1.9	
21/05/2022	3.0g	1.1	1.9	14.3
22/05/2022	3.0g	0.8	2.2	
23/05/2022	3.0g	0.8	2.2	
24/05/2022	3.0g	0.9	2.1	
25/05/2022	3.0g	0.7	2.3	
26/05/2022	3.0g	0.8	2.2	
27/05/2022	3.0g	0.6	2.4	
28/05/2022	3.0g	0.6	2.4	15.8
29/05/2022	3.0g	0.6	2.4	
30/05/2022	3.0g	0.7	2.3	
31/05/2022	3.0g	0.5	2.5	
01/06/2022	3.0g	0.6	2.4	
02/06/2022	3.0g	0.6	2.4	
03/06/2022	3.0g	0.7	2.3	
04/06/2022	3.0g	0.8	2.2	16.5

Table 14. Forecasted Daily Throughput (21 Days)

Date	Daily Throughput (g)	Forecast (Daily Throughput (g))	Lower Confidence Bound (Daily Throughput	Upper Confidence Bound (Daily Throughput
27/03/2022	1.2			
28/03/2022	1.4			
29/03/2022	1.4			
30/03/2022	1.8			
31/03/2022	1.2			
01/04/2022	1			
02/04/2022	1.4			
03/04/2022	1.2			
04/04/2022	1.6			
05/04/2022	1.2			
06/04/2022	1.8			
07/04/2022	1.4			
08/04/2022	1.4			
09/04/2022	1.4			
10/04/2022	1.2			
11/04/2022	1.4			
12/04/2022	1.6			
13/04/2022	1.2			
14/04/2022	1.6			
15/04/2022	1.2			
16/04/2022	1.2			
17/04/2022	1.3			
18/04/2022	1.2			
19/04/2022	1.5			
20/04/2022	1.4			
21/04/2022	1.4			
22/04/2022	1.2			
23/04/2022	1.1			
24/04/2022	1.4			
25/04/2022	1.2			
26/04/2022	1.3			
27/04/2022	1.3			
28/04/2022	1.4			
29/04/2022	1.6			
30/04/2022	1.1			
01/05/2022	1.3			
02/05/2022	1.3			
03/05/2022	1.5			
04/05/2022	1.2			
05/05/2022	1.6			
06/05/2022	1.6			
07/05/2022	1.1			
08/05/2022	1.2			
09/05/2022	1.2			
10/05/2022	1.4			
11/05/2022	1.6			

Date	Daily Throughput (g)	Forecast (Daily Throughput (g))	Lower Confidence Bound (Daily Throughput	Upper Confidence Bound (Daily Throughput
12/05/2022	1.6			
13/05/2022	1.9			
14/05/2022	2.1			
15/05/2022	2.1			
16/05/2022	2			
17/05/2022	2.3			
18/05/2022	2.1			
19/05/2022	2			
20/05/2022	1.9			
21/05/2022	1.9			
22/05/2022	2.2			
23/05/2022	2.2			
24/05/2022	2.1			
25/05/2022	2.3			
26/05/2022	2.2			
27/05/2022	2.4			
28/05/2022	2.4			
29/05/2022	2.4			
30/05/2022	2.3			
31/05/2022	2.5			
01/06/2022	2.4			
02/06/2022	2.4			
03/06/2022	2.3			
04/06/2022	2.2	2.2	2.20	2.20
05/06/2022		2.262210595	1.97	2.55
06/06/2022		2.285218228	1.92	2.65
07/06/2022		2.30822586	1.89	2.73
08/06/2022		2.331233493	1.86	2.81
09/06/2022		2.354241125	1.83	2.88
10/06/2022		2.377248758	1.81	2.94
11/06/2022		2.40025639	1.79	3.01
12/06/2022		2.423264023	1.78	3.07
13/06/2022		2.446271656	1.76	3.13
14/06/2022		2.469279288	1.75	3.19
15/06/2022		2.492286921	1.74	3.24
16/06/2022		2.515294553	1.73	3.30
17/06/2022		2.538302186	1.73	3.35
18/06/2022		2.561309818	1.72	3.40
19/06/2022		2.584317451	1.71	3.45
20/06/2022		2.607325083	1.71	3.51
21/06/2022		2.630332716	1.71	3.56
22/06/2022		2.653340348	1.70	3.60
23/06/2022		2.676347981	1.70	3.65
24/06/2022		2.699355613	1.70	3.70
25/06/2022		2.722363246	1.70	3.75

Table 15. Weekly Throughput Based on the Forecasted Daily Throughput

Date	Forecast	Weekly Throughput
05/06/2022	2.382280471	
06/06/2022	2.399119379	
07/06/2022	2.415958287	
08/06/2022	2.432797196	
09/06/2022	2.449636104	
10/06/2022	2.466475012	
11/06/2022	2.483313921	17.02958037
12/06/2022	2.500152829	
13/06/2022	2.516991737	
14/06/2022	2.533830646	
15/06/2022	2.550669554	
16/06/2022	2.567508462	
17/06/2022	2.584347371	
18/06/2022	2.601186279	17.85468688
19/06/2022	2.618025187	
20/06/2022	2.634864096	
21/06/2022	2.651703004	
22/06/2022	2.668541912	
23/06/2022	2.68538082	
24/06/2022	2.702219729	
25/06/2022	2.719058637	18.67979339

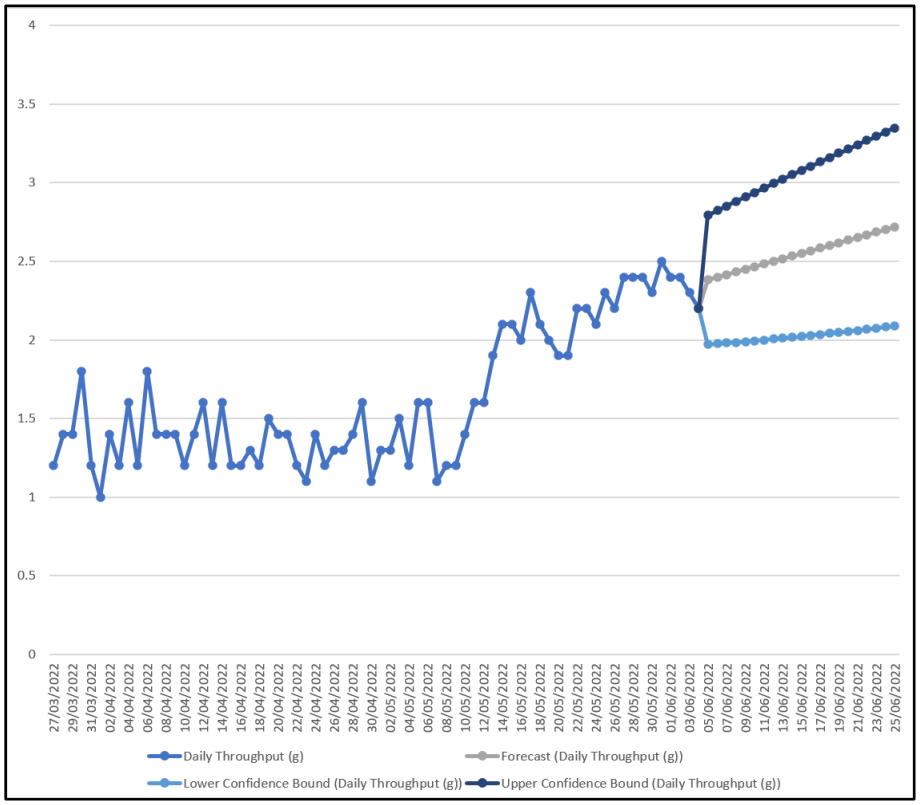


Figure 54. Forecasted Daily Throughput Graph (21 Days)

Table 16. Forecasted Weekly Throughput (42 Weeks)

Date	Weekly Throughput (g)	Forecast (Weekly Throughput (g)	Lower Confidence Bound (Weekly Throughput (g	Upper Confidence Bound (Weekly Throughput (g
03/04/2022	9.4			
10/04/2022	10			
17/04/2022	9.4			
24/04/2022	9.1			
01/05/2022	9.3			
08/05/2022	9.6			
15/05/2022	11			
22/05/2022	14.3			
29/05/2022	15.8			
05/06/2022	16.5			
12/06/2022	17.02958037			
19/06/2022	17.85468688			
26/06/2022	18.67979339	18.67992428	18.70	18.70
03/07/2022		19.56385338	17.68	21.45
10/07/2022		20.44778248	17.65	23.24
17/07/2022		21.33171158	17.74	24.92
24/07/2022		22.21564068	17.87	26.56
31/07/2022		23.09956977	18.03	28.17
07/08/2022		23.98349887	18.18	29.79
14/08/2022		24.86742797	18.34	31.40
21/08/2022		25.75135707	18.48	33.02
28/08/2022		26.63528617	18.62	34.65
04/09/2022		27.51921527	18.75	36.29
11/09/2022		28.40314436	18.87	37.94
18/09/2022		29.28707346	18.97	39.60
25/09/2022		30.17100256	19.07	41.28
02/10/2022		31.05493166	19.15	42.96
09/10/2022		31.93886076	19.21	44.67
16/10/2022		32.82278986	19.26	46.38
23/10/2022		33.70671895	19.30	48.11
30/10/2022		34.59064805	19.32	49.86
06/11/2022		35.47457715	19.33	51.61
13/11/2022		36.35850625	19.33	53.39
20/11/2022		37.24243535	19.31	55.17
27/11/2022		38.12636445	19.28	56.97
04/12/2022		39.01029354	19.24	58.78
11/12/2022		39.89422264	19.18	60.60
18/12/2022		40.77815174	19.11	62.44
25/12/2022		41.66208084	19.03	64.29
01/01/2023		42.54600994	18.94	66.16
08/01/2023		43.42993904	18.83	68.03
15/01/2023		44.31386813	18.71	69.92
22/01/2023		45.19779723	18.57	71.82
29/01/2023		46.08172633	18.43	73.74
05/02/2023		46.96565543	18.27	75.66
12/02/2023		47.84958453	18.10	77.60
19/02/2023		48.73351363	17.92	79.55
26/02/2023		49.61744272	17.72	81.51
05/03/2023		50.50137182	17.52	83.49
12/03/2023		51.38530092	17.30	85.47
19/03/2023		52.26923002	17.07	87.47
26/03/2023		53.15315912	16.83	89.48

Table 17. Forecasted Weekly Throughput and Total Consumed Styrofoam in a Year

Date	Weekly Throughput (g)	Total Consumed Styro in a Year (g
03/04/2022	9.4	
10/04/2022	10	
17/04/2022	9.4	
24/04/2022	9.1	
01/05/2022	9.3	
08/05/2022	9.6	
15/05/2022	11	
22/05/2022	14.3	
29/05/2022	15.8	
05/06/2022	16.5	114.4
Forecast		
12/06/2022	17.02958037	
19/06/2022	17.85468688	
26/06/2022	18.67979339	
03/07/2022	19.56385338	
10/07/2022	20.44778248	
17/07/2022	21.33171158	
24/07/2022	22.21564068	
31/07/2022	23.09956977	
07/08/2022	23.98349887	
14/08/2022	24.86742797	
21/08/2022	25.75135707	
28/08/2022	26.63528617	
04/09/2022	27.51921527	
11/09/2022	28.40314436	
18/09/2022	29.28707346	
25/09/2022	30.17100256	
02/10/2022	31.05493166	
09/10/2022	31.93886076	
16/10/2022	32.82278986	
23/10/2022	33.70671895	
30/10/2022	34.59064805	
06/11/2022	35.47457715	
13/11/2022	36.35850625	
20/11/2022	37.24243535	
27/11/2022	38.12636445	
04/12/2022	39.01029354	
11/12/2022	39.89422264	
18/12/2022	40.77815174	
25/12/2022	41.66208084	
01/01/2023	42.54600994	
08/01/2023	43.42993904	
15/01/2023	44.31386813	
22/01/2023	45.19779723	
29/01/2023	46.08172633	
05/02/2023	46.96565543	
12/02/2023	47.84958453	
19/02/2023	48.73351363	
26/02/2023	49.61744272	
05/03/2023	50.50137182	
12/03/2023	51.38530092	
19/03/2023	52.26923002	
26/03/2023	53.15315912	1471.545804
		1585.9458

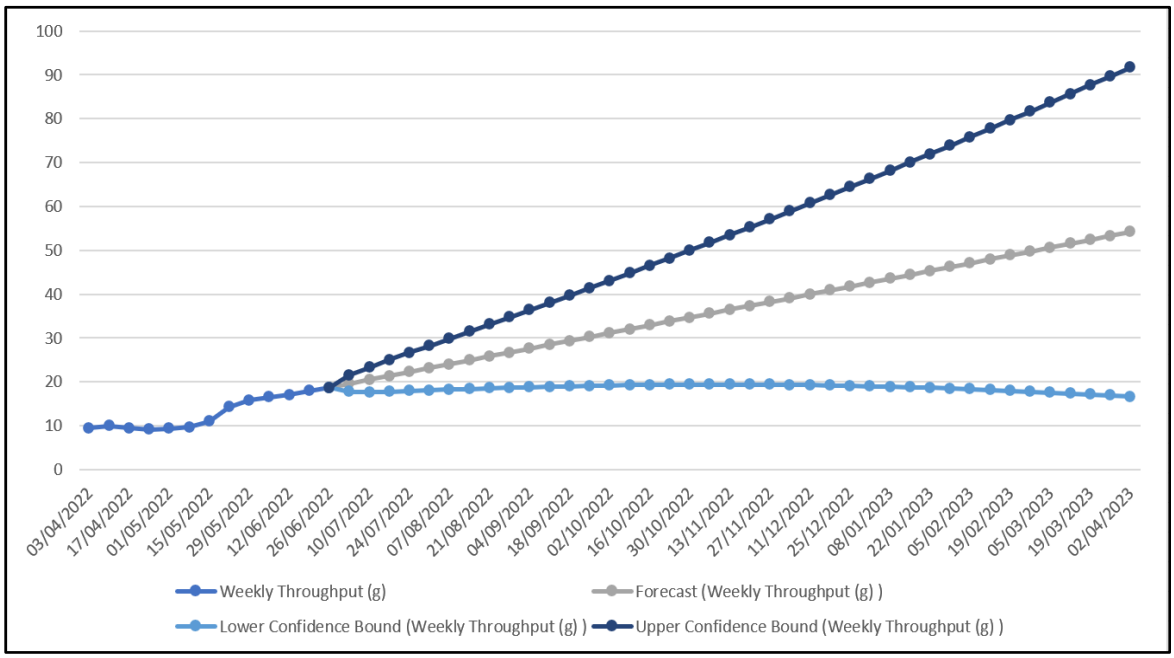


Figure 55. Forecasted Weekly Throughput Graph (42 Weeks)

Figure 55 displays the line graph showing the projected throughput for the entire year based on previously recorded data. This graph implies that polystyrene consumption increases exponentially, demonstrating a data pattern of significant increase as time goes by. Forty-two weeks were forecasted, resulting in an average of 30g and 1585g of Styrofoam consumed each week and year, respectively.

Table 18. Percent Error (From Weighing Scale)

WEEK	n_t	n_e	$\%\ Error$
1	1440	1386	3.75
2	1454	1398	3.851444292
3	1543	1486	3.694102398

4	1687	1638	2.904564315

The percentage error is close to zero, suggesting that the data is extremely close to the targeted value. The population growth rate is determined using these values, as provided in the table below.

Table 19. Percent Error (From Load Sensor)

WEEK	n_t	n_e	$\% \, Error$
1	1440	1393	3.26388889
2	1454	1408	3.163686382
3	1543	1520	1.490602722
4	1687	1638	1.481920569

Table 20 shows the evaluation/assessment of the product quality model using the ISO standard 25010 and a 5-point Likert scale gathered from five individuals consisting of professionals, engineers, and mealworm breeders. Based on the table, it can be inferred that the prototype has high functional completeness, functional correctness, and functional appropriateness, with a 4.56 average for functionality. Moreover, the prototype has a high rating for operability, learnability, and user interface aesthetics, with an average of 4.73 for usability. Furthermore, the system has acceptable testability and modularity with an average of 4.5 for maintainability. Lastly, the wiring, safety and risk precautions of the system

received a decent average of 4.5 for safety and reliability. Overall, the product quality evaluation assessment received an average rating of 4.58 out of 5.

Table 20. Evaluation Form using a 5-point Likert scale

	Evaluators					
	Apolinario Orias Mechanical Engineer	**Richard Albano** Community Development Officer	**Reynaldo Ramos** Mechanical Engineer	**Erson Celestial** Health, Safety, Environment and Quality (HSEQ) Administrator	**Reynaldo Acuyado** Mealworm Breeder	
SURVEY STATEMENTS	**Rating**					**Average**
Functional Suitability						
1. The automated segregation of the mealworms is more efficient than the manual or traditional method.	5	5	5	4	5	**4.8**
2. The collection of the life organisms for segregation is more efficient than the manual or traditional method.	5	5	5	4	5	**4.8**
3. The notification for the harvest of organisms if they are overpopulated in the container is effective.	5	5	4	4	3	**4.2**
4. The notification for the harvest of frass in the application is effective.	5	5	4	4	5	**4.6**
5. The information in the application's interface for monitoring is clearly displayed and in real-time.	5	5	4	5	3	**4.4**
Usability						
6. The whole system including the application is easy to navigate and learn	5	5	5	4	5	**4.8**
7. The whole system needs minimum supervision during its entire operation.	5	5	3	4	4	**4.6**
8. The design and structure of the whole system is pleasing to the eye of the user.	5	5	5	4	5	**4.8**
Maintainability						
9. The device does not require special handling during the operation.	5	4	4	3	5	**4.2**
10. The instructions on the usage of the system are easy and simple to understand.	5	5	5	5	4	**4.8**
Safety and Reliability						
11. The prototype does not have health safety risk or physical risk in the entire operation.	5	4	4	4	5	**4.4**
12. The inlets, outlets, and wiring are intact and properly organized.	5	5	5	3	5	**4.6**

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

This chapter reviews the results of the conducted study, the conclusions drawn from the findings, and recommendations made as a result of the research. This study was pursued to establish an efficient and automated system for mealworm segregation and polystyrene biodegradation with the final objective of notifying users through ESP 32 via Arduino Mega 2560.

5.1 Summary of Findings

PolySeg was developed and programmed to achieve the optimum methods of mealworm breeding that are much more convenient than the traditional ones, to maintain safe polystyrene biodegradation, and to reduce human labor and inaccuracies. This project mainly focused on the automation of the device and how it could instantly inform users to be displayed on the associated web app. This notification system is dependent on the information received from the device.

The project was deployed and ran for 21 consecutive days and has recorded three weeks' worth of data from the sensors. Due to the high population growth percentage, the results showed that the system was efficient in dealing with polystyrene biodegradation, collection, and segregation of the lifeforms while at the same time maintaining a healthy and consistent mealworm reproduction. The outcomes mentioned above demonstrated the project's quality and effectiveness.

5.2 Conclusion

The following conclusions were congregated in pursuance of developing a technology for mealworm breeding and polystyrene biodegradation:

1. The whole system integrates the previous design of a semi-automated system and an original design conceptualized from intensive research of existing technologies relating to the process of segregation and collection of mealworms and the like.

2. The segregation and collection modules for mealworm separation consisting of a vibrating motor, four-layer mesh screen containers, a tilting mechanism, and integrated linear actuators were capable of executing the task via Arduino Mega 2560, reducing human labor and inaccuracies.

3. The developed algorithm for this system uses a time-based and pre-scheduled setup via the real-time clock. Through this program, the system automatically activates the segregation and collection process, ventilation, and food distribution network on the schedule/time optimum for the growth and reproduction of the mealworms.

4. The associated web app displays the gathered data from the configured temperature, humidity, and weight sensors using ESP32. Furthermore, the user could control the collection, segregation, food distribution, and exhaust fan for manual override. Moreover, the user can be notified in the web app to replenish food and harvest mealworms, provided that login credentials were given to the user to gain access, including the user ID and password.

5. Utilizing Microsoft Excel's Forecast Sheet tool and Exponential Smoothing (ETS) algorithm, data gathered from polystyrene consumption of mealworms for 70 days resulted in a projection of 30g and 1585g of Styrofoam consumed each week and year,

respectively. This result calculates a 2.5 mg-mealworm per day rate. Hence, it can be inferred that the mealworms were able to digest polystyrene (EPS) more safely and efficiently.

6. Using the Exponential Growth formula, data collected from the weight and manual counting of mealworms for 21 days resulted in a nearly 300 percent growth rate, with a projection of approximately 25,000 mealworms after a year of breeding. Hence, the system becomes an ideal artificial habitat for the optimum growth and increased reproduction of the mealworms.

Overall, the development of this fully automated technology for polystyrene biodegradation using mealworms with the application of IoT for remote monitoring and controlling was successfully conducted. The system serves as an efficient artificial habitat for the optimum growth and separation of the mealworms, as well as a beacon for safer and healthier polystyrene biodegradation.

5.3 Recommendations

To further improve the study, researchers recommend that the weight sensor be repositioned, or a different arrangement be considered for more accurate readings. It is also recommended that the egg and frass containers be combined since their sizes are indistinguishable and part of the collecting process to ensure the survival of eggs. It is advised to build a larger prototype for increased throughput for industrial use. Furthermore, the researchers suggest using button restrictions rather than the current way to prevent system errors. The improvement of the user interface could also be considered. Lastly, additional research is highly recommended about improving the mealworms' diet better than pure Styrofoam for more effective population growth.

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APPENDIX A

Program Codes

I. AUTOMATION OF THE DEVICE

```
#include <HX711_ADC.h>
#include <EEPROM.h>
#include <Wire.h>
#include <DS3231.h>
#include "DHT.h"
#include <SoftwareSerial.h>
#include <ArduinoJson.h>
DHT dht;
DS3231 clock;
RTCDateTime dt;
SoftwareSerial linkSerial(15,14);
#define vMotor 2
#define segAUP 3
#define segADOWN 30
#define collAUP 5
#define collADOWN 6
#define collBUP 7
#define collBDOWN 53
#define dynamoM 9
#define dynamoM1 10
#define fanM 11
const byte lswSUP = 12;
const byte lswSDOWN = 22;
const byte lswCUP = 52;
const byte lswCDOWN = 24;
const byte diffSensor = 34;
const int HX711_dout_1 = 25;
const int HX711_sck_1 = 26;
const int HX711_dout_2 = 27;
const int HX711_sck_2 = 28;
byte button_SPON = 31;
byte button_CPON = 32;
byte button_FPON = 33;
byte button_EFON = 34;
byte button_SPOFF = 35;
byte button_CPOFF = 36;
byte button_FPOFF = 37;
byte button_EFOFF = 38;
HX711_ADC LoadCell_1(HX711_dout_1, HX711_sck_1);
HX711_ADC LoadCell_2(HX711_dout_2, HX711_sck_2);
unsigned int cur_avg = 0;
unsigned int cur_avg1 = 0;
const int calVal_eepromAdress_1 = 0;
const int calVal_eepromAdress_2 = 4;
unsigned long t = 0;
float TEMP,HUM,FDIFFUSE,Loadcell1,Loadcell2;
int lswSUPout,diffOut,lswSDOWNout,lswCUPout,lswCDOWNout,ard_esp,EndSeq;
int button_SP,button_CP,button_FP,button_EF,buttonSP_OFF,buttonCP_OFF,buttonFP_OFF,buttonEF_OFF;
```

```
int segP,collP,AP=1,foodP,Efan,DAO,DAO1,lswSUO,lswSDO,lswCUO,lswCDO,sp;

int delayTime=20000,delayTime1=6000,delayTime2=3000,delayTime3=30000;

void setup()

{

 clock.begin();

 pinMode(vMotor,OUTPUT);

 pinMode(segAUP,OUTPUT);

 pinMode(segADOWN,OUTPUT);

 pinMode(collADOWN,OUTPUT);

 pinMode(collAUP,OUTPUT);

 pinMode(collBUP,OUTPUT);

 pinMode(collBDOWN,OUTPUT);

 pinMode(dynamoM,OUTPUT);

 pinMode(dynamoM1,OUTPUT);

 pinMode(fanM,OUTPUT);

 pinMode(lswSUP,INPUT);

 pinMode(lswSDOWN,INPUT);

 pinMode(lswCUP,INPUT);

 pinMode(lswCDOWN,INPUT);

 pinMode(diffSensor,INPUT);

 pinMode(button_SPON,INPUT);

 pinMode(button_CPON,INPUT);

 pinMode(button_FPON,INPUT);

 pinMode(button_EFON,INPUT);

 pinMode(button_SPOFF,INPUT);

 pinMode(button_CPOFF,INPUT);

 pinMode(button_FPOFF,INPUT);

 pinMode(button_EFOFF,INPUT);

 //clock.setDateTime(__DATE__, __TIME__);

 dht.setup(4);

 digitalWrite(vMotor,HIGH);

 digitalWrite(segAUP,HIGH);

 digitalWrite(collAUP,HIGH);

 digitalWrite(collBUP,HIGH);

 digitalWrite(segADOWN,HIGH);

 digitalWrite(collADOWN,HIGH);

 digitalWrite(collBDOWN,HIGH);

 digitalWrite(dynamoM,HIGH);

 digitalWrite(dynamoM1,HIGH);

 digitalWrite(fanM,HIGH);

 Serial.begin(9600);

 linkSerial.begin(1200);

 WeightSensor_begin();

 while (!Serial) continue;

 if(lswSDOWNout==0){

     digitalWrite(segAUP,HIGH);

     digitalWrite(segADOWN,LOW);

if(lswSDOWNout==1){digitalWrite(segAUP,HIGH);

     digitalWrite(segADOWN,HIGH);}}

 if(lswCDOWNout==0){

     digitalWrite(collBUP,LOW);
```

```
digitalWrite(collBDOWN,HIGH);
      digitalWrite(collAUP,HIGH);

digitalWrite(collADOWN,LOW);
if(lswCDOWNout==1){digitalWrite(
collBUP,HIGH);

digitalWrite(collBDOWN,HIGH);
      digitalWrite(collAUP,HIGH);

digitalWrite(collADOWN,HIGH);}}
  delay(delayTime2);
}
void loop()
{
 LSW();
 segregationP();
 collectionP();
 foodDP();
 eFan();
WeightSensor();
 uartTemp();
}
void segregationP(){
dt = clock.getDateTime();
if(dt.dayOfWeek==1 && dt.hour==7
&& dt.minute==0 && dt.second==0
|| button_SP ==
1){sp=1;ArdtoESP();}
if(sp==1){
Stop();
digitalWrite(vMotor,LOW);
delay(delayTime);
Stop();
digitalWrite(vMotor,HIGH);
delay(delayTime2);
sp=0;EndSeq=1;
EndSequence();}}
void collectionP(){
dt = clock.getDateTime();
if(dt.day==1||15 && dt.hour==8 &&
dt.minute==0 && dt.second==0
|| button_CP == 1){collP=1;ArdtoESP1();}
if(lswSDOWNout==1 && DAO==1 &&
lswCDOWNout==1 && collP==1){AP=1;}
switch (AP){
  case 1:
      Stop();
      collP=0;
      collP=0;
      digitalWrite(segAUP,LOW);
      digitalWrite(segADOWN,HIGH);
      DAO=0;lswSDO=0;
      Serial.print("lswSDO=");
      Serial.println(lswSDO);
if(lswSUPout==1){digitalWrite(segAUP,HI
GH);digitalWrite(vMotor,LOW);
      digitalWrite(segADOWN,HIGH);
DAO=0;lswSDO=0;delay(delayTime);AP=2
;}
```

```
        Stop();
        break;
  case 2:
        Stop();
        digitalWrite(vMotor,HIGH);
        digitalWrite(segAUP,HIGH);

digitalWrite(segADOWN,LOW);
        if(DAO==2){
        digitalWrite(segAUP,HIGH);

digitalWrite(segADOWN,HIGH);
        delay(delayTime2);
        AP=3;}
        Stop();
        break;
  case 3:
        Stop();
        if(lswCDOWNout==1){
        digitalWrite(collAUP,LOW);

digitalWrite(collADOWN,HIGH);
        digitalWrite(collBUP,HIGH);

digitalWrite(collBDOWN,LOW);
        }
if(lswCUPout==1){digitalWrite(collAUP,HIGH);
digitalWrite(collADOWN,HIGH);delay(delayTime3);lswCDO=0,AP=4;}
        Stop();
        break;
  case 4:
        Stop();
        digitalWrite(collBUP,LOW);
        digitalWrite(collBDOWN,HIGH);
        delay(delayTime3);
        digitalWrite(collAUP,HIGH);
        digitalWrite(collADOWN,LOW);
        delay(delayTime2);
        AP=5;
        Stop();
        break;
  case 5:
        Stop();
        if(DAO1==2){
        digitalWrite(collAUP,HIGH);
        digitalWrite(collADOWN,HIGH);
        digitalWrite(collBUP,HIGH);
        digitalWrite(collBDOWN,HIGH);
        digitalWrite(vMotor,LOW);
        delay(delayTime);
        digitalWrite(vMotor,HIGH);
        delay(delayTime2);

AP=0,lswSUO=0,lswCUO=0,collP=0,DAO1=0;}
        Stop();
        EndSeq=2;
        EndSequence();
```

```
      break;
case 6:AP=0,lswSUO=0,lswCUO=0,collP=0,DAO1=0;
      if(lswSDOWNout==0){
       digitalWrite(segAUP,HIGH);
digitalWrite(segADOWN,LOW);
if(lswSDOWNout==1){digitalWrite(segAUP,HIGH);
digitalWrite(segADOWN,HIGH);}}
       if(lswCDOWNout==0){
       digitalWrite(collBUP,LOW);
digitalWrite(collBDOWN,HIGH);
       digitalWrite(collAUP,HIGH);
digitalWrite(collADOWN,LOW);
if(lswCDOWNout==1){digitalWrite(collBUP,HIGH);
digitalWrite(collBDOWN,HIGH);
       digitalWrite(collAUP,HIGH);
digitalWrite(collADOWN,HIGH);}}
       break;}}
void foodDP(){
dt = clock.getDateTime();
if(dt.hour==9 && dt.minute==0 && dt.second==0 || button_FP == 1){foodP=1;ArdtoESP2();}
if(foodP==1){
digitalWrite(dynamoM,LOW);
digitalWrite(dynamoM1,LOW);
Stop();
delay(delayTime1);
Stop();
digitalWrite(dynamoM,HIGH);
digitalWrite(dynamoM1,HIGH);
foodP=0;EndSeq=3;
EndSequence();}}
void eFan(){
  delay(dht.getMinimumSamplingPeriod());
  float humidity = dht.getHumidity();
  float temperature = dht.getTemperature();
  if(temperature>=27.5 || humidity<=90){
  Efan=1;
  digitalWrite(fanM,LOW);
  if(button_EF==1){Efan=1;
  digitalWrite(fanM,LOW);}
  if(buttonEF_OFF==1){Efan=0;
  digitalWrite(fanM,HIGH);}}
  if(temperature<27.5 && humidity>90){
  Efan=0;
  digitalWrite(fanM,HIGH);
  if(button_EF==1){Efan=1;
  digitalWrite(fanM,LOW);}
```

```
 if(buttonEF_OFF==1){Efan=0;
 digitalWrite(fanM,HIGH);}}
 }
 void LSW(){
   lswSUPout=digitalRead(lswSUP);
lswSDOWNout=digitalRead(lswSDOWN);

lswCUPout=digitalRead(lswCUP);
lswCDOWNout=digitalRead(lswCDOWN);

button_SP=digitalRead(button_SPON);

button_CP=digitalRead(button_CPON);

button_FP=digitalRead(button_FPON);

button_EF=digitalRead(button_EFON);
buttonSP_OFF=digitalRead(button_SPOFF);
buttonCP_OFF=digitalRead(button_CPOFF);
buttonFP_OFF=digitalRead(button_FPOFF);
buttonEF_OFF=digitalRead(button_EFOFF);
   if(lswSUPout==1){lswSUO=1;}
   if(lswSDOWNout==1){lswSDO=1;}
   DAO=lswSUO+lswSDO;
   if(lswCUPout==1){lswCUO=1;}
   if(lswCDOWNout==1){lswCDO=1;}
   DAO1=lswCUO+lswCDO;
   diffOut=digitalRead(diffSensor);
   if(diffOut==0){FDIFFUSE=0;}else{
     FDIFFUSE=1;
   }
 }
void Stop(){
 if(buttonCP_OFF==0){
   AP=6;}
 if(buttonSP_OFF==0){
   SP=0;
   digitalWrite(vMotor,HIGH);}
 if(buttonFP_OFF==0){
   foodP=0;
   digitalWrite(dynamoM,HIGH);
   digitalWrite(dynamoM1,HIGH);}
}
```

II. WEIGHT SENSOR

```
void WeightSensor_begin(){
 Serial.println("Starting...");
  float calibrationValue_1;
  float calibrationValue_2;
```

```
EEPROM.get(calVal_eepromAdress_1, calibrationValue_1);

EEPROM.get(calVal_eepromAdress_2, calibrationValue_2);
  LoadCell_1.begin();
  LoadCell_2.begin();
  unsigned long stabilizingtime = 2000;
  boolean _tare = true;
byte loadcell_1_rdy = 0;
  byte loadcell_2_rdy = 0;
  while ((loadcell_1_rdy + loadcell_2_rdy) < 2) {
    if (!loadcell_1_rdy) loadcell_1_rdy = LoadCell_1.startMultiple(stabilizingtime, _tare);
    if (!loadcell_2_rdy) loadcell_2_rdy = LoadCell_2.startMultiple(stabilizingtime, _tare);
  }
  if (LoadCell_1.getTareTimeoutFlag()) {
    Serial.println("Timeout, check MCU>HX711 no.1 wiring and pin designations");
  }
  if (LoadCell_2.getTareTimeoutFlag()) {
    Serial.println("Timeout, check MCU>HX711 no.2 wiring and pin designations");
  }
LoadCell_1.setCalFactor(calibrationValue_1);
LoadCell_2.setCalFactor(calibrationValue_2);
  Serial.println("Startup is complete");
}
void WeightSensor(){
  int avg[10]={0};
  int avg1[10]={0};
  int i=0;
  long wholesum  = 0;
  long wholesum1  = 0;
  dt = clock.getDateTime();
  if(dt.minute==50 && dt.second==0){
  ArdtoESP4();
  static boolean newDataReady = 0;
  const int serialPrintInterval = 0;
  if (LoadCell_1.update()) newDataReady = true;
  LoadCell_2.update();


  if ((newDataReady)) {
    if (millis() > t + serialPrintInterval) {
      Loadcell1 = LoadCell_1.getData();
      Loadcell2 = LoadCell_2.getData();
```

```
    for(i=0;i<10;i++){
      avg[i]=Loadcell1;
      avg1[i]=Loadcell2;
      delayMicroseconds(200);
    }
    for(i=0;i<10;i++){
      wholesum += avg[i];
      wholesum1 += avg1[i];
    }
    cur_avg = wholesum / 10;
    cur_avg1 = wholesum1 / 10;
    Serial.print("Load_cell 1 output val: ");
    Serial.print(cur_avg);
    Serial.print("    Load_cell 2 output val: ");
    Serial.println(cur_avg1);
    newDataReady = 0;
    t = millis();
      uartWeight();
    }
  }
  if (Serial.available() > 0) {
    char inByte = Serial.read();
    if (inByte == 't') {
      LoadCell_1.tareNoDelay();
      LoadCell_2.tareNoDelay();
    }
  }
  if (LoadCell_1.getTareStatus() == true) {
    Serial.println("Tare load cell 1 complete");
  }
  if (LoadCell_2.getTareStatus() == true) {
    Serial.println("Tare load cell 2 complete");
  }
}else{ard_esp=0;}}
```

III. COMMUNICATION: ARDUINO TO ESP

```
void uartTemp(){
  dt = clock.getDateTime();
  if(dt.minute==45 && dt.second==0){
  ArdtoESP5();
  for(byte i = 0; i <= 5; i++){

delay(dht.getMinimumSamplingPeriod());
  float humidity = dht.getHumidity();
  float temperature = dht.getTemperature();
  StaticJsonDocument<256> doc;
  doc["TEMP"] = TEMP;
  TEMP=temperature;
  doc["HUM"] = HUM;
  HUM=humidity;
  Serial.println(humidity);
```

```
  Serial.println(temperature);
  humidity++;
  temperature++;
  serializeJson(doc, linkSerial);
  delay(1000);}}else{ard_esp=0;}}
void uartWeight(){
  for(byte i = 0; i <= 5; i++){
  StaticJsonDocument<1000> doc;
  doc["Loadcell1"] = Loadcell1;
  doc["Loadcell2"] = Loadcell2;
  Loadcell1=cur_avg;
  Loadcell2=cur_avg1;
  Serial.println(Loadcell1);
  Serial.println(Loadcell2);
  serializeJson(doc, linkSerial);
  delay(500);}
}
void ArdtoESP(){
if(sp=1){
  for(byte i = 0; i <= 2; i++){
  ard_esp=1;
  StaticJsonDocument<256> doc;
  doc["ard_esp"] = ard_esp;
  Serial.println(ard_esp);
  serializeJson(doc, linkSerial);
  delay(500);}}
  else{ard_esp=0;}
}
void ArdtoESP1(){
  for(byte i = 0; i <= 2; i++){
  ard_esp=3;
  StaticJsonDocument<256> doc;
  doc["ard_esp"] = ard_esp;
  Serial.println(ard_esp);
  serializeJson(doc, linkSerial);
  delay(500);}
}
void ArdtoESP2(){
  for(byte i = 0; i <= 2; i++){
  ard_esp=5;
  StaticJsonDocument<256> doc;
  doc["ard_esp"] = ard_esp;
  Serial.println(ard_esp);
  serializeJson(doc, linkSerial);
  delay(500);}
}
void ArdtoESP4(){
  for(byte i = 0; i <= 2; i++){
  ard_esp=7;
  StaticJsonDocument<256> doc;
  doc["ard_esp"] = ard_esp;
  Serial.println(ard_esp);
  serializeJson(doc, linkSerial);
  delay(500);}
}
void ArdtoESP5(){
```

```
  for(byte i = 0; i <= 2; i++){
  ard_esp=8;
  StaticJsonDocument<256> doc;
  doc["ard_esp"] = ard_esp;
  Serial.println(ard_esp);
  serializeJson(doc, linkSerial);
  delay(500);}
}
void EndSequence(){
  for(byte i = 0; i <= 2; i++){
  ard_esp=8;
  StaticJsonDocument<256> doc;
  doc["EndSeq"] = EndSeq;
  Serial.println(ard_esp);
  serializeJson(doc, linkSerial);
  delay(500);
```

IV. COMMUNICATION: ESP TO WEB

For Control

```
<?php

$value = $_GET['value'];                //Get the value
$column = $_GET['column'];              //Which coulumn of the database, could be the RECEIVED_BOOL1, etc...

//connect to the database
include("database_connect.php"); //We include the database_connect.php which has the data for the connection to the database

//Select Database
mysqli_select_db($con,'u750376384_polyseg') or die('Cannot select the DB');

// Check the connection
if (mysqli_connect_errno()) {
   echo "Failed to connect to MySQL: " . mysqli_connect_error();
 }

 //Now update the value sent from the post (ON/OFF, change or send button)
 $query = "UPDATE ESPtable2 SET $column = '{$value}'
 WHERE id=2";
 $esptable2 = mysqli_query($con,$query) or die('Errant query:  '.$query);
?>
```

For monitoring of weight sensors

```
<?php
```

```
$servername = "localhost";
$username = "u750376384_pentatronics";
$password = "w/4jT0owsDD";
$dbname = "u750376384_polyseg";

/*For Weight */
$api_key_value = "cyZVzpr5zwK5QutQ1T4cdA";

$api_key = $sensor = $location = $value1 = $value2 = $value3 = $value4 = "";

if ($_SERVER["REQUEST_METHOD"] == "POST") {
    $api_key = test_input($_POST["api_key"]);
    if($api_key == $api_key_value) {
        $sensor = test_input($_POST["sensor"]);
        $location = test_input($_POST["location"]);
        $value1 = test_input($_POST["value1"]);
        $value2 = test_input($_POST["value2"]);
        $value3 = test_input($_POST["value3"]);
        $value4 = test_input($_POST["value4"]);

        // Create connection
        $conn = new mysqli($servername, $username, $password, $dbname);
        // Check connection
        if ($conn->connect_error) {
            die("Connection failed: " . $conn->connect_error);
        }

        $sql = "INSERT INTO weightData (sensor, location, value1, value2, value3, value4)
```

```
        VALUES ('" . $sensor . "', '" . $location . "', '" . $value1 . "', '" . $value2 . "', '" . $value3 . "', '" . $value4 . "')";


        if ($conn->query($sql) === TRUE) {
            echo "New record created successfully";
        }
        else {
            echo "Error: " . $sql . "<br>" . $conn->error;
        }


        $conn->close();
    }
    else {
        echo "Wrong API Key provided.";
    }

}
else {
    echo "No data posted with HTTP POST.";
}

function test_input($data) {
    $data = trim($data);
    $data = stripslashes($data);
    $data = htmlspecialchars($data);
    return $data;
}
?>
```

Getting the status

```
<?php

$column = $_GET['column'];            //Which coulumn of the database, could be the RECEIVED_BOOL1, etc...

//connect to the database
include("database_connect.php"); //We include the database_connect.php which has the data for the connection to the database

//Select Database
mysqli_select_db($con,'u750376384_polyseg') or die('Cannot select the DB');

// Check the connection
if (mysqli_connect_errno()) {
   echo "Failed to connect to MySQL: " . mysqli_connect_error();
 }

   $sql      =   "SELECT $column FROM ESPtable2 LIMIT 1";
   $result   =   $con->query($sql);

   if ($result->num_rows > 0) {

   while ($row = $result->fetch_assoc())
   {
      echo $row["$column"];
   }

   } else {
```

```
        echo "Error:" . $sql . "<br>" . $con->error;
    }

    $con->close();
?>
```

V. WEB APPLICATION

Monitoring page 1

```
<?php
session_start();

if ($_SESSION["status"] != true){

    header("Location: login-page.php");
}
?>

<!DOCTYPE html>
<html>
<head>
    <!--<meta http-equiv="refresh" content="5" > -->
    <meta name="viewport" content="with= device-width, initial-scale= 1.0">
    <link rel="stylesheet" type="text/css" href="monitoring-style.css" media="screen"/>
        <title> POLYSEG </title>
    <link rel="preconnect" href="https://fonts.googleapis.com">
<link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
<link
href="https://fonts.googleapis.com/css2?family=Poppins:ital,wght@0,100;0,200;0,300;0,
400;0,700;1,600&display=swap" rel="stylesheet">
```

```
</head>


<body>
<section class="sub-header">
   <h1>Monitor</h1>
   <a href="monitoring-page1.php" style="color: rgb(80, 59, 0); font-size: 13px; text-decoration: none;" name='temp-link'>> Temperature & Humidity</a><br>
   <a href="monitoring-page2.php" style="color: rgb(80, 59, 0); font-size: 13px; text-decoration: none;" name='weight-link'>> Weight</a>
   </section>
   <div class = "sensors-box">


<!--For Temp and Humidity notification-->
<?php
$servername = "localhost";
$username = "root";
$password = "";
$dbname = "polyseg";

// Create connection
$conn = mysqli_connect($servername, $username, $password, $dbname);

// Check connection
if (!$conn) {
   die("Connection failed: " . mysqli_connect_error()."<br>");
}
//echo "Connected successfully <br>";
mysqli_select_db($conn,$dbname);
```

```
$qry1 = mysqli_query($conn, "SELECT * FROM tempData");

while($result1= mysqli_fetch_array($qry1)){

   //echo $result["value1"];

   if ($result1['value1']>=27.5)

   echo "NOTICE: ".$result1['reading_time']."., temperature is ".$result1['value1']." C.
<script type='text/javascript'> alert('Temperature: Reached the 27.5 C
limit');</script><br>";

}


$qry2 = mysqli_query($conn, "SELECT * FROM tempData");

while($result2= mysqli_fetch_array($qry2)){

   //echo $result["value2"];

   if ($result2['value2']>=90)

   echo "NOTICE: ".$result2['reading_time']."., humidity is ".$result2['value2']." %.
<script type='text/javascript'> alert('Humidity: Reached the 90% limit');</script><br>";

}

mysqli_close($conn);

?>


<!--For Temp and Humidity chart-->

<!doctype html public "-//w3c//dtd html 3.2//en">

<html>

<body >

<?Php

require "config-pdo.php";// Database connection

$query="SELECT reading_time,value1,value2

 FROM tempData";

$step=$dbo->prepare($query);

if($step->execute()){
```

```
$php_data_array=$step->fetchAll();
//print_r($php_data_array);
echo "<script>
     var my_2d= ".json_encode($php_data_array)."
                              </script>";
}
?>
<div id='curve_chart'></div>
<script type="text/javascript"
          src="https://www.gstatic.com/charts/loader.js"></script>
<script type="text/javascript">
google.charts.load('current',{packages:['corechart']})
google.charts.setOnLoadCallback(tempChart);
function tempChart(){
          //var data=new google.visualization
          var data=new google.visualization.DataTable();
          data.addColumn('string','reading_time');
          data.addColumn('number','temperature');
          data.addColumn('number','humidity');
          data.addColumn('number','');
          data.addColumn('number','');
          for(i=0;i<my_2d.length;i++)
data.addRow([my_2d[i][0],parseInt(my_2d[i][1]),parseInt(my_2d[i][2]),
parseInt(my_2d[i][3]),parseInt(my_2d[i][4])]);

var options = {
 title: 'Temperature and Humidity Sensor Data',
 curveType: 'function',
```

```
width: 1230,
 height: 600,
            legend: { position: 'bottom' },
              animation:{'startup':true,
        duration: 5000,
        easing: 'out',
      },
 };
 var chart=new
 google.visualization.LineChart(document.getElementById('curve_chart'))
chart.draw(data,options);
}
</script>
</body>
</html>
<br><br><br><br>

<!--For Temp and Humidity Table-->
    <h1 class = "sensor-title">TEMPERATURE & HUMIDITY SENSOR DATA</h1>
<?php
$servername = "localhost";
$username = "root";
$password = "";
$dbname = "polyseg";

// Create connection
$conn = new mysqli($servername, $username, $password, $dbname);
// Check connection
```

```
if ($conn->connect_error) {
   die("Connection failed: " . $conn->connect_error);
}

$sql = "SELECT id, value1, value2, reading_time FROM tempData ORDER BY id DESC"; /*select items to display from the Temp data table in the data base*/

echo '<table cellspacing="5" cellpadding="5">
     <tr>
       <th>ID</th>
       <th>Date & Time</th>
       <th>Temperature &deg;C</th>
       <th>Humidity &#37;</th>
     </tr>';

if ($result = $conn->query($sql)) {
   while ($row = $result->fetch_assoc()) {
       $row_id = $row["id"];
       $row_reading_time = $row["reading_time"];
       $row_value1 = $row["value1"];
       $row_value2 = $row["value2"];

       // Uncomment to set timezone to - 1 hour (you can change 1 to any number)
      // $row_reading_time = date("Y-m-d H:i:s", strtotime("$row_reading_time - 1 hours"));

       // Uncomment to set timezone to + 4 hours (you can change 4 to any number)
       //$row_reading_time = date("Y-m-d H:i:s", strtotime("$row_reading_time + 4 hours"));
```

```
        echo '<tr>
                <td>' . $row_id . '</td>
                <td>' . $row_reading_time . '</td>
                <td>' . $row_value1 . '</td>
                <td>' . $row_value2 . '</td>

              </tr>';
    }
    $result->free();
}

$conn->close();
?>
</table>
</div>
<br>
<a href="login-choose.php" style="text-decoration: none;padding: 8px 16px;
background-color: #ddd;color: black; margin-left: 2%; font-size: 13px">Back
&raquo;</a>
<a href="logout.php" style="text-decoration: none;padding: 8px 16px;
background-color: #C46200;color: white; margin-left: 2%; font-size: 13px">LOG OUT
&raquo;</a>
<br>
</body>
<br>
<!--Footer-->
<footer class="footer">
    <h4>About Us</h4>
```

```
   <p>FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM
      SEGREGATION USING ARDUINO MEGA 2560 <br> WITH ESP 32 FOR WIRELESS
      NOTIFICATION<br>Technological University of the Philippines - Manila<br>
      Ayala Blvd, Ermita, Manila, 1000 Metro Manila<br><br>
      College of Engineering<br>
      Electronics Engineering Department<br>
      Email: pentatronics.polyseg@gmail.com • Contact No.: 0926 032 1173
   </p>
</footer>
</html>



<!----------php----------->
<?php
if(isset($_POST["logout"])){
   header("Location: logout.php");
}
?>
```

Monitoring page 2

```
<?php
session_start();

if ($_SESSION["status"] != true){

   header("Location: login-page.php");
}
```

```
?>


<!DOCTYPE html>
<html>
<head>
   <!--<meta http-equiv="refresh" content="5" > -->
   <meta name="viewport" content="with= device-width, initial-scale= 1.0">
   <link rel="stylesheet" type="text/css" href="monitoring-style.css" media="screen"/>
        <title> POLYSEG </title>
   <link rel="preconnect" href="https://fonts.googleapis.com">
<link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
<link
href="https://fonts.googleapis.com/css2?family=Poppins:ital,wght@0,100;0,200;0,300;0,
400;0,700;1,600&display=swap" rel="stylesheet">
</head>


<body>
<section class="sub-header">
   <h1>Monitor</h1>
   <a href="monitoring-page1.php" style="color: rgb(80, 59, 0); font-size: 13px; text-
decoration: none;" name='temp-link'>> Temperature & Humidity</a><br>
   <a href="monitoring-page2.php" style="color: rgb(80, 59, 0); font-size: 13px; text-
decoration: none;" name='weight-link'>> Weight</a>
   </section>
   <div class = "sensors-box">


<!--Weight notification-->
<?php
$servername = "localhost";
$username = "root";
```

```
$password = "";
$dbname = "polyseg";

// Create connection
$conn = mysqli_connect($servername, $username, $password, $dbname);

// Check connection
if (!$conn) {
   die("Connection failed: " . mysqli_connect_error()."<br>");
}
//echo "Connected successfully <br>";
mysqli_select_db($conn,$dbname);

$qry2 = mysqli_query($conn, "SELECT * FROM weightData");
while($result2= mysqli_fetch_array($qry2)){
   //echo $result["value1"];
   if ($result2['value1']>=652)
   echo "NOTICE: ".$result2['reading_time']." , the weight of mealworms is ".$result2['value1']." g. <script type='text/javascript'> alert('Mealworm: Reached the 652g limit');</script><br>";
}

$qry3 = mysqli_query($conn, "SELECT * FROM weightData");
while($result3= mysqli_fetch_array($qry3)){
   //echo $result["value2"];
   if ($result3['value2']>=200)
   echo "NOTICE: ".$result3['reading_time']." , the weight of frass is ".$result3['value2']." g. <script type='text/javascript'> alert('Frass: Reached the 200g limit');</script><br>";
}
```

```
$qry4 = mysqli_query($conn, "SELECT * FROM weightData");
while($result4= mysqli_fetch_array($qry4)){
   //echo $result["value3"];
   if ($result4['value3']==0)
   echo "NOTICE: ".$result4['reading_time']." , the weight of food is ".$result4['value3']." g. <script type='text/javascript'> alert('Food: Needs to be refilled');</script><br>";
}

mysqli_close($conn);
?>

<!--For Weight chart-->
<!doctype html public "-//w3c//dtd html 3.2//en">
<html>
<body >
<?Php
require "config-pdo.php";// Database connection
$query="SELECT reading_time,value1,value2,value3
 FROM weightData";
$step=$dbo->prepare($query);
if($step->execute()){
$php_data_array=$step->fetchAll();
//print_r($php_data_array);
echo "<script>
     var my_2d= ".json_encode($php_data_array)."
                              </script>";
}
```

```
?>
<div id='curve_chart'></div>
<script type="text/javascript"
        src="https://www.gstatic.com/charts/loader.js"></script>
<script type="text/javascript">
google.charts.load('current',{packages:['corechart']})
google.charts.setOnLoadCallback(weightChart);
function weightChart(){
        //var data=new google.visualization
        var data=new google.visualization.DataTable();
        data.addColumn('string','reading_time');
        data.addColumn('number','mealworm');
        data.addColumn('number','frass');
        data.addColumn('number','food');
        data.addColumn('number','');
        for(i=0;i<my_2d.length;i++)
data.addRow([my_2d[i][0],parseInt(my_2d[i][1]),parseInt(my_2d[i][2]),
parseInt(my_2d[i][3]),parseInt(my_2d[i][4])]);

var options = {
 title: 'Weight Sensors Data',
 curveType: 'function',
width: 1230,
 height: 600,
          legend: { position: 'bottom' },
            animation:{'startup':true,
       duration: 5000,
       easing: 'out',
```

```
    },
};
var chart=new
google.visualization.LineChart(document.getElementById('curve_chart'))
chart.draw(data,options);
}
</script>
</body>
</html>
<br>
<br>
<br>
<br>


<!--weight table-->
<div class = "sensors-box">
<h1 class = "sensor-title">WEIGHT SENSORS DATA</h1>
<?php
$servername = "localhost";
$username = "root";
$password = "";
$dbname = "polyseg";

// Create connection
$conn = new mysqli($servername, $username, $password, $dbname);
// Check connection
if ($conn->connect_error) {
```

```
    die("Connection failed: " . $conn->connect_error);
}

$sql = "SELECT id, value1, value2, value3, value4, reading_time FROM weightData
ORDER BY id DESC"; /*select items to display from the weight data table in the data
base*/

echo '<table cellspacing="5" cellpadding="5">
      <tr>
        <th>ID</th>
        <th>Date & Time</th>
        <th>Mealworm</th>
        <th>Frass</th>
        <th>Food</th>
      </tr>';

if ($result = $conn->query($sql)) {
    while ($row = $result->fetch_assoc()) {
        $row_id = $row["id"];
        $row_reading_time = $row["reading_time"];
        $row_value1 = $row["value1"];
        $row_value2 = $row["value2"];
        $row_value3 = $row["value3"];



        // Uncomment to set timezone to - 1 hour (you can change 1 to any number)
       // $row_reading_time = date("Y-m-d H:i:s", strtotime("$row_reading_time - 1
hours"));
```

```
        // Uncomment to set timezone to + 4 hours (you can change 4 to any number)
        //$row_reading_time = date("Y-m-d H:i:s", strtotime("$row_reading_time + 4 hours"));

        echo '<tr>
                <td>' . $row_id . '</td>
                <td>' . $row_reading_time . '</td>
                <td>' . $row_value1 . '</td>
                <td>' . $row_value2 . '</td>
                <td>' . $row_value3 . '</td>

              </tr>';
    }
    $result->free();
}

$conn->close();
?>

</table>
</div>
<br>
<a href="login-choose.php" style="text-decoration: none;padding: 8px 16px;
background-color: #ddd;color: black; margin-left: 2%; font-size: 13px">Back &raquo;</a>
<a href="logout.php" style="text-decoration: none;padding: 8px 16px;
background-color: #C46200;color: white; margin-left: 2%; font-size: 13px">LOG OUT &raquo;</a>
<br>
```

```
</body>
<br>
<!--Footer-->
<footer class="footer" style="transform: scale(1.15)">
   <h4>About Us</h4>
   <p>FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM
      SEGREGATION USING ARDUINO MEGA 2560 <br> WITH ESP 32 FOR WIRELESS
      NOTIFICATION<br>Technological University of the Philippines - Manila<br>
      Ayala Blvd, Ermita, Manila, 1000 Metro Manila<br><br>
      College of Engineering<br>
      Electronics Engineering Department<br>
      Email: pentatronics.polyseg@gmail.com • Contact No.: 0926 032 1173
   </p>
</footer>
</html>
<!-----------php----------->
<?php
if(isset($_POST["logout"])){
   header("Location: logout.php");
}
?>
```

Monitoring stylesheet

```
/*body {
   background: #f5efe0;
   box-sizing: border-box;
```

```
    color: #000;
    font-size: 1.8rem;
    letter-spacing: -0.015em;
    text-align: center;
    font-family: 'Poppins', sans-serif;
}*/
*{
    margin: 0;
    padding: 0;
    background-position: center;
    background-size: auto;
    background-repeat: repeat-x;
    font-family: 'Poppins', sans-serif;
    overflow-x: hidden;
    box-sizing: border-box;
    text-align: center;
}
nav{
    display: flex;
    padding: 2% 6%;
    justify-content: space-between;
    align-items: center;
}
nav img{
    width: 100px;
}
.nav-links{
    flex: 1;
```

```
    text-align: center;
}
.nav-links ul li{
    list-style: none;
    display: inline-block;
    padding: 8px 12px;
    position: relative;
}
.nav-links ul li a{
    color: rgb(105, 63, 14);
    text-decoration: none;
    font-size: 13px;
}
.nav-links ul li::after{
    content: '';
    width: 0%;
    height: 2px;
    background: #660541;
    display: block;
    margin: auto;
    transition: 0.5s;
}
.nav-links ul li:hover::after{
    width: 100%;
}
.sub-header{
    height: 55vh;
    width: 100%;
```

```
    background-image:url(images/background.png);
    background-position: center;
    text-align: center;
    color: rgb(80, 59, 0);
    /*linear-gradient(rgba(4,9,30,0.7),rgba(4,9,30,0.7)),*/
}
.sub-header h1 {
    margin-top: 245px;
    font-weight: 600;
}
table {
margin-left: auto;
margin-right: auto;
width: 80%;
}

th {
font-family: 'Poppins', sans-serif;
font-size: 15px;
background: #986960;
color: #FFF;
padding: 2px 6px;
border-collapse: separate;
border: 1px solid #FFF;
}

td {
font-family: 'Poppins', sans-serif;
```

```
font-size: 10px;
text-align: center;
border: 1px solid #DDD;
}
.sensor-title {
    text-align: center;
}
.sensors-box {
    padding: 5%;
}
.chart-box{
    padding: 100px;
    border-color: black;
    width:400px;
}
.footer{
    background-image: url(images/Footer.png);
    width: 100%;
    text-align: center;
    padding: 60px 0px;
    color: rgb(235, 213, 172);
    margin-top: 60px;
}
.footer h4{
    margin-bottom: 0px;
    margin-top: 70px;
    font-weight: 600;
}
```

```
.footer p{
    font-size: x-small;
    line-height: 15px;
}
```

Control page

```
<?php
session_start();

if ($_SESSION["status"] != true){

    header("Location: login-page.php");
}

?>
<?php
//This line will make the page auto-refresh each 60 seconds
$page = $_SERVER['PHP_SELF'];
$sec = "60";
?>

<!DOCTYPE html>
<html>
<head>
    <!--<meta http-equiv="refresh" content="5" > -->
    <meta name="viewport" content="with= device-width, initial-scale= 1.0">
    <link rel="stylesheet" type="text/css" href="control-style.css" media="screen"/>
        <title> POLYSEG </title>
```

```
   <link rel="preconnect" href="https://fonts.googleapis.com">

<link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>

<link
href="https://fonts.googleapis.com/css2?family=Poppins:ital,wght@0,100;0,200;0,300;0,
400;0,700;1,600&display=swap" rel="stylesheet">

</head>

<body>

<section class="sub-header">

   <h1 style="font-size:x-large">Control</h1>

   </section>

        <br><br><br>

        <div style="width: 500px; padding: 10px; border: 5px solid #F3F5F6; font-size:
15px; color: black; margin: 0; margin-left: 33%">

        GUIDELINES: Once a button is ON, other buttons will not be visible. Turning
ON two or more buttons at the same time is prohibited. This is to prevent possible
complications to the system.</div>

        <br><br><br>

</body>

</html>


<html>

<head>

<!--<meta name="viewport" content="with= device-width, initial-scale= 1.0">-->

<!--//I've used bootstrap for the tables, so I import the CSS files for that as well...-->

<meta http-equiv="refresh" content="<?php echo $sec?>;URL='<?php echo $page?>'">


<!-- Latest compiled and minified CSS -->

<link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/3.4.0/css/bootstrap.min.css">

<!-- jQuery library -->

<script src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jquery.min.js"></script>
```

```
<!-- Latest compiled JavaScript -->

<script
src="https://maxcdn.bootstrapcdn.com/bootstrap/3.4.0/js/bootstrap.min.js"></script>

<title> POLYSEG </title>

<link rel="stylesheet" type="text/css" href="control-style.css" media="screen"/>

<link rel="preconnect" href="https://fonts.googleapis.com">

<link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>

<link
href="https://fonts.googleapis.com/css2?family=Poppins:ital,wght@0,100;0,200;0,300;0,
400;0,700;1,600&display=swap" rel="stylesheet">

</head>


<body>

<!-- For Button Table-->

<?php

include("database_connect.php"); //We include the database_connect.php which has the
data for the connection to the database


// Check the connection

if (mysqli_connect_errno()) {

  echo "Failed to connect to MySQL: " . mysqli_connect_error();

}

//Again, we grab the table out of the database, name is ESPtable2 in this case

$result = mysqli_query($con,"SELECT * FROM ESPtable2");//table select


//Now we create the table with all the values from the database

echo "<table class='table' style='font-size: 30px; color:white;'>


    <tbody>

      <tr class='active'>
```

```
        <td style='color:#F3F5F6;'>Collection</td>
        <td style='color:#F3F5F6;'>Segregation</td>
                    <td style='color:#F3F5F6;'>Food Dispenser</td>
                    <td style='color:#F3F5F6;'>Exhaust Fan</td>
      </tr>
                    ";

//loop through the table and print the data into the table
while($row = mysqli_fetch_array($result)) {

   echo "<tr class='success'>";
    $unit_id = $row['id'];
    //echo "<td>" . $row['id'] . "</td>";

    $column1 = "RECEIVED_BOOL1_2";
    $column2 = "RECEIVED_BOOL2_2";
    $column3 = "RECEIVED_BOOL3_2";
    $column4 = "RECEIVED_BOOL4_2";

    $current_bool_1 = $row['RECEIVED_BOOL1_2'];
          $current_bool_2 = $row['RECEIVED_BOOL2_2'];
          $current_bool_3 = $row['RECEIVED_BOOL3_2'];
          $current_bool_4 = $row['RECEIVED_BOOL4_2'];

          if($current_bool_1 == 1){
    $inv_current_bool_1 = 0;
          $text_current_bool_1 = "Collection";
          $color_current_bool_1 = "#33cc33";
```

```
        }
        //elseif($current_bool_1 == 1 && ($current_bool_2 == 1 || $current_bool_3 == 1
|| $current_bool_4 == 1)){
        //$inv_current_bool_1 = 0;
        //$text_current_bool_1 = "OFF";
        //$color_current_bool_1 = "#efdecd";
        //}
        else{
    $inv_current_bool_1 = 1;
        $text_current_bool_1 = "Collection";
        $color_current_bool_1 = "#cc0000";
        }


        if($current_bool_2 == 1){
    $inv_current_bool_2 = 0;
        $text_current_bool_2 = "Segregation";
        $color_current_bool_2 = "#33cc33";
        }
        else{
    $inv_current_bool_2 = 1;
        $text_current_bool_2 = "Segregation";
        $color_current_bool_2 = "#cc0000";
        }


        if($current_bool_3 == 1){
    $inv_current_bool_3 = 0;
        $text_current_bool_3 = "Food";
```

```
        $color_current_bool_3 = "#33cc33";
        }
        else{
    $inv_current_bool_3 = 1;
        $text_current_bool_3 = "Food";
        $color_current_bool_3 = "#cc0000";
        }


        if($current_bool_4 == 1){
    $inv_current_bool_4 = 0;
        $text_current_bool_4 = "Fan";
        $color_current_bool_4 = "#33cc33";
        }
        else{
    $inv_current_bool_4 = 1;
        $text_current_bool_4 = "Fan";
        $color_current_bool_4 = "#cc0000";
        }

        if($current_bool_2 == 0 && $current_bool_3 == 0 && $current_bool_4 == 0){
        echo "<td><form action= update_values.php method= 'post'>
        <input type='hidden' name='value2' value=$current_bool_1   size='15' >
        <input type='hidden' name='value' value=$inv_current_bool_1  size='15' >
        <input type='hidden' name='unit' value=$unit_id >
        <input type='hidden' name='column' value=$column1 >
        <input type= 'submit' name= 'change_but' style=' margin-left: 0%; margin-top:
10%; margin-bottom: 10%; font-size: 20px; padding: 10px; text-align:center;
background-color: $color_current_bool_1' value=$text_current_bool_1></form></td>";
```

```
}

if($current_bool_1 == 0 && $current_bool_3 == 0 && $current_bool_4 == 0){
echo "<td><form action= update_values.php method= 'post'>
<input type='hidden' name='value2' value=$current_bool_2   size='15' >
<input type='hidden' name='value' value=$inv_current_bool_2  size='15' >
<input type='hidden' name='unit' value=$unit_id >
<input type='hidden' name='column' value=$column2 >
<input type= 'submit' name= 'change_but' style=' margin-left: 5%; margin-top: 8%; margin-bottom: 10%; font-size: 20px; padding: 10px; text-align:center; background-color: $color_current_bool_2' value=$text_current_bool_2></form></td>";
}

if($current_bool_1 == 0 && $current_bool_2 == 0 && $current_bool_4 == 0){
echo "<td><form action= update_values.php method= 'post'>
<input type='hidden' name='value2' value=$current_bool_3   size='15' >
<input type='hidden' name='value' value=$inv_current_bool_3  size='15' >
<input type='hidden' name='unit' value=$unit_id >
<input type='hidden' name='column' value=$column3 >
<input type= 'submit' name= 'change_but' style=' margin-left: 5%; margin-top: 10%; margin-bottom: 10%; font-size: 20px; padding: 10px; text-align:center; background-color: $color_current_bool_3' value=$text_current_bool_3></form></td>";
}

if($current_bool_1 == 0 && $current_bool_3 == 0 && $current_bool_2 == 0){
echo "<td><form action= update_values.php method= 'post'>
<input type='hidden' name='value2' value=$current_bool_4   size='15' >
<input type='hidden' name='value' value=$inv_current_bool_4  size='15' >
<input type='hidden' name='unit' value=$unit_id >
<input type='hidden' name='column' value=$column4 >
```

```
        <input type= 'submit' name= 'change_but' style=' margin-left: 5%; margin-top: 10%; margin-bottom: 10%; font-size: 20px; padding: 10px; text-align:center; background-color: $color_current_bool_4' value=$text_current_bool_4></form></td>";

        }


        echo "</tr>

          </tbody>";

}

echo "</table>

<br>

";

?>


<br>

<a href="login-choose.php" style="text-decoration: none;padding: 8px 16px;

background-color: #ddd;color: black; margin-left: 2%; font-size: 13px">Back &raquo;</a>

<a href="logout.php" style="text-decoration: none;padding: 8px 16px;

background-color: #C46200;color: white; margin-left: 2%; font-size: 13px">LOG OUT &raquo;</a>

<br>

<br>



<!DOCTYPE html>

<html>

<head>

   <!--<meta http-equiv="refresh" content="5" > -->

   <meta name="viewport" content="with= device-width, initial-scale= 1.0">

   <link rel="stylesheet" type="text/css" href="control-style.css" media="screen"/>
```

```
        <title> POLYSEG </title>
   <link rel="preconnect" href="https://fonts.googleapis.com">
<link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
<link
href="https://fonts.googleapis.com/css2?family=Poppins:ital,wght@0,100;0,200;0,300;0,
400;0,700;1,600&display=swap" rel="stylesheet">
</head>
<!--Footer-->
<footer class="footer">
   <h4>About Us</h4>
   <p>FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR
MEALWORM
      SEGREGATION USING ARDUINO MEGA 2560 <br> WITH ESP 32 FOR
WIRELESS
      NOTIFICATION<br>Technological University of the Philippines - Manila<br>
      Ayala Blvd, Ermita, Manila, 1000 Metro Manila<br><br>
      College of Engineering<br>
      Electronics Engineering Department<br>
      Email: pentatronics.polyseg@gmail.com • Contact No.: 0926 032 1173
   </p>
</footer>
</html>

<!----------------php----------------->
<?php
if(isset($_POST["logout"])){
   header("Location: logout.php");
}
?>
```

Control page stylesheet

```
*{
    margin: 0;
    padding: 0;
    background-position: center;
    background-size: auto;
    background-repeat: repeat-x;
    font-family: 'Poppins', sans-serif;
    overflow-x: hidden;
    box-sizing: border-box;
    text-align: center;
}
nav{
    display: flex;
    padding: 2% 6%;
    justify-content: space-between;
    align-items: center;
}
nav img{
    width: 100px;
}
.nav-links{
    flex: 1;
    text-align: center;
}
.nav-links ul li{
    list-style: none;
    display: inline-block;
```

```
    padding: 8px 12px;
    position: relative;
}
.nav-links ul li a{
    color: rgb(105, 63, 14);
    text-decoration: none;
    font-size: 13px;
}
.nav-links ul li::after{
    content: '';
    width: 0%;
    height: 2px;
    background: #660541;
    display: block;
    margin: auto;
    transition: 0.5s;
}
.nav-links ul li:hover::after{
    width: 100%;
}
.sub-header{
    height: 55vh;
    width: 100%;
    background-image:url(images/background.png);
    background-position: center;
    text-align: center;
    color: rgb(80, 59, 0);
    /*linear-gradient(rgba(4,9,30,0.7),rgba(4,9,30,0.7)),*/
```

```
}
.sub-header h1 {
    margin-top: 280px;
    font-weight: 600;
}
table {
margin-left: auto;
margin-right: auto;
width: 60%;
}

th {
font-family: 'Poppins', sans-serif;
font-size: 30px;
background: rgb(175, 82, 79);
color: #FFF;
padding: 2px 6px;
border-collapse: separate;
border: 1px solid rgb(230, 81, 81);
}

td {
font-family: 'Poppins', sans-serif;
font-size: 15px;
text-align: center;
border: 1px solid #DDD;
}
.footer{
```

```
    background-image: url(images/Footer.png);
    width: 100%;
    text-align: center;
    padding: 60px 0px;
    color: rgb(235, 213, 172);
    margin-top: 60px;
}
.footer h4{
    margin-bottom: 0px;
    margin-top: 70px;
    font-weight: 600;
}
.footer p{
    font-size: x-small;
    line-height: 15px;
}
```

APPENDIX B

Bill of Materials

Description	Qty	Unit	Unit Cost (Php)	Total Cost (Php)
Adhesive Wire Tie Cable (big)	1	set	238	238
Adhesive Wire Tie Cable (small)	1	set	182	182
Arduino Mega	1	pcs	600	600
AWG #18 wire	55	m	20	1100
AWG #22 wire	100	m	7	700
Battery	1	pcs	36	36
Breadboard	2	pcs	65	130
Circuit Breaker	1	pcs	330	330
Converter	1	pcs	225	225
Diffuse Sensor	1	pcs	280	280
Dynamo Motor	2	pcs	250	500
ESP 32	1	pcs	400	400
Exhaust Fan	2	pcs	200	400
Female to Male Jumper Wires	7	set	60	420
Gomo Sim Card	1	pcs	229	229
Hardware Materials with Labor	-	-	-	34350
Lead	2	roll	85	170
Limit Switch	1	set	195	195
Linear Actuator 200mm	1	pcs	1,310.00	1310
Linear Actuator 700mm	1	pcs	3216	3216
Load Cell + HXT711 Amplifier	2	pcs	147	294
Male to Male Jumper Wires	7	set	60	420
Mealworms	250	grams	1	250
Multitester	1	pcs	379	379
Power Supply	1	pcs	2,015.00	2015
Printer Cable	1	pcs	250	250
Pull up Resistors	4	pcs	5	20
Relay (4 channel)	1	pcs	250	250
Relay (8 channel)	1	pcs	300	300
Resistors (10k, 3.3k, 1k: 1/4W)	9	pcs	2	18
Resistors (10k: 1/2W)	10	pcs	2	20

Resistors (3.3k, 1k: 1/4W)	20	pcs	1	20
RTC Module	1	pcs	125	125
Screw	10	pcs	3	30
MG995 Servo Motor	1	pcs	275	275
Shrinkable tube	15	m	40	600
Soldering Iron	1	set	400	400
Spiral Wrap	2	set	239	478
Temperature and Humidity Sensor	1	pcs	315	315
Vibrating Motor	1	pcs	2283	2283
Web Hosting	-	-	-	1008
Wood Works	2	pcs	100	200
			TOTAL	54961

APPENDIX C

Specifications and Data Sheets

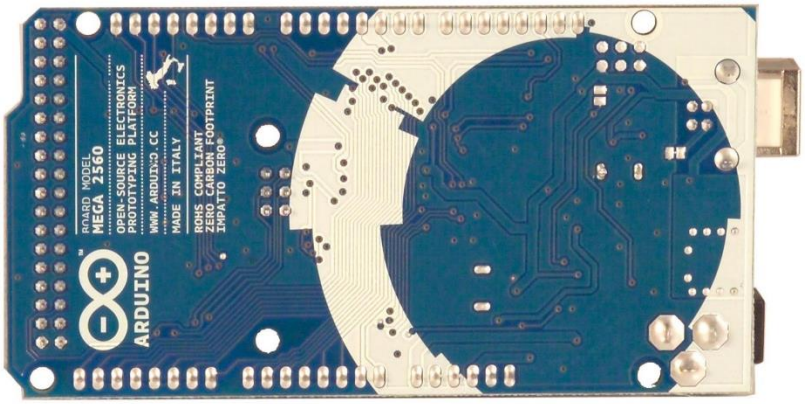
HARDWARE SPECIFICATIONS

Dimension	Length	Width	Height
Container (Beetles)	10 in	7 in	4.5 in
Container (Pupa)	10 in	7 in	2.5 in
Containers (Mealworm)	10 in	7 in	2.5 in
Container (Egg)	10 in	7 in	2.5 in
Container (Frass)	10 in	7 in	2.5 in
Container (Collection)	10 in	7 in	4.5 in
Food dispenser	Short base: 3 in Long base: 8 in	Short base: 3 in Long base: 5 in	11 in
Panel Board	8 in	-	10 in
Skeletal Frame	25 in	7 in	30.5 in
Extension for the collection module	10 in	7 in	30 in
Chassis	30 in	14 in	40 in
Cover	35 in	24 in	60 in

Operating hours	24 hours
Operating system	Arduino Mega 2560

DATA SHEETS

I. ARDUINO MEGA 2560



Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode() , digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH

value, the LED is on, when the pin is LOW, it's off.
- **I2C: 20 (SDA) and 21 (SCL).** Support I2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I2C pins on the Duemilanove or Diecimila.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Mega2560's digital pins.
The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. For SPI communication, use the SPI library.

Programming

The Arduino Mega can be programmed with the Arduino software (download). For details, see the reference and tutorials.
The ATmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).
You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.
This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.
The Mega2560 contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield Compatibility

The maximum length and width of the Mega2560 PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

The Mega2560 is designed to be compatible with most shields designed for the Uno, Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega2560 and Duemilanove / Diecimila. *Please note that I^2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).*

II. DIFFUSE SENSOR

Manual of IR Sensor Switch E18-D80NK-N

IR-Sensor Switch E18 This is Sensor Infrared device for distance detection that can be adjusted in the range of 6 cm.-80 cm.; and Output is Logic TTL; 0 (GND) and 1 (5V).

Specifications -Adjust distance detection in the range of 6 cm.-80 cm. by Adjustable VR and display the status by LED

- Sensing device should be opaque material or any material that allows less light to pass through; black color is the best because Sensor device works well by using reflection of Infrared

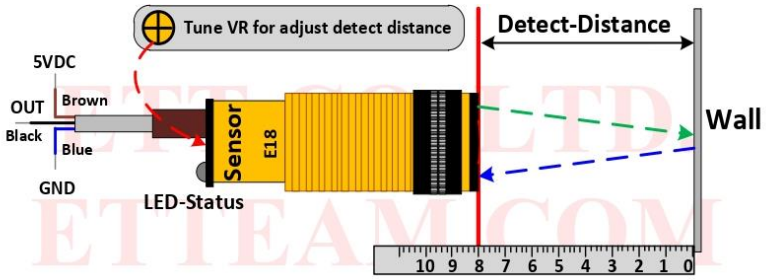
-OUTPUT is Open Collector; it has to connect R 10 K Pull Up at Out Putt

-Signal Output is Digital TTL; 0 = GND and 1 = 5V

-Use Power Supply DC 5V Current 100mA

How to setup distance detection: Before using, it has to setup preferable distance detection for using with Sensor as follows;

1) Provide 5V Power Supply (brown cable) and GND (blue cable) to Sensor
2) Turn the head of Sensor upright to the ground or wall (it is the best if ground or wall is black color)
3) Measure the preferable distance detection from ground or wall to the head of Sensor by ruler; and hold Sensor at the preferable position to detect for awhile
4) Adjust VR at the end of Sensor. Look at the change of LED at the end of Sensor as described below;



- If LED is OFF (OUTPUT = 1), please adjust VR in a clockwise direction until LED becomes ON (OUTPUT = 0) and then stop adjusting VR. The position that LED changes the state is the specified distance detection. This is conditional operation; *if the distance of Sensor is less than or equal to the distance detection*, LED Status is ON and OUTPUT becomes Logic 0; but if the distance of Sensor is greater than the distance detection, LED Status is OFF and OUTPUT becomes Logic 1 instead.

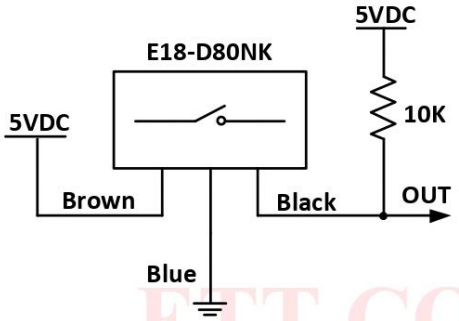
- If LED is ON (OUTPUT = 0), please adjust VR in an anticlockwise direction until LED becomes OFF (OUTPUT = 1) and then stop adjusting VR. The position that LED changes the state is the specified distance detection. This is conditional operation; *if the distance of Sensor is greater than or equal to the distance detection*, LED Status is OFF and OUTPUT becomes Logic 1; but if the distance of Sensor is less than the distance detection, LED Status is ON and OUTPUT becomes Logic 0 instead.

5) Test the operation of Sensor by moving Sensor. When the head of Sensor moves and passes the specified distance detection, LED of Sensor is lit up if the distance of Sensor is less or equal to the specified distance detection; but LED is OFF if the distance of Sensor is greater than or equal to the specified distance detection. If it does not accord with any conditional operation described above, it means that it fails to setup any distance detection for Sensor.

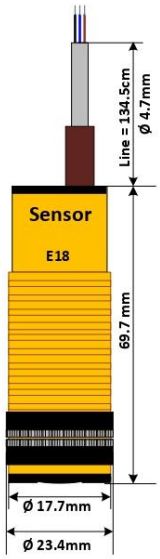
Referred to experiment in use, it found that color of ground or wall or any material that is used to reflect to Sensor is not enough dark. If the wall that is used to reflect is light color, the least distance detection of Sensor is also higher; so, the specified distance detection of user is lower than the least distance detection of Sensor. In this case, it should use wall with the dark color or it may setup the distance detection higher, depend on material of user. User has to test and setup distance detection by self because each color of wall that reflects to Sensor is different; and finally, user needs to return to step 1-5. Referred to experiment, the least distance detection of the black wall that can reflect to Sensor is 6 cm; the operating result accords with step 5, it means that it succeeds and Sensor is ready to use and connect.

How to use Sensor after setup distance detection

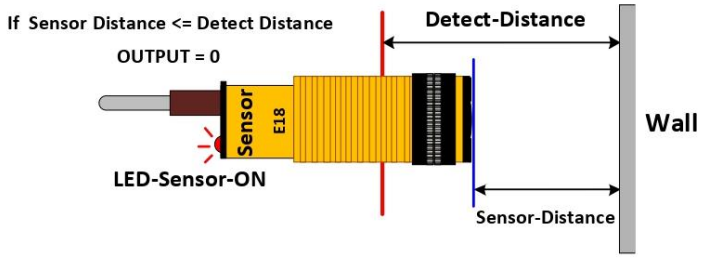
Please look at the circuit below and connect Sensor with Connectors according to the specified color; Brown Cable is 5VDC Power Supply, Blue Cable is GND, and Black Cable is OUTPUT(TTL). Next, please look at the conditional operation of Sensor to write program correctly.



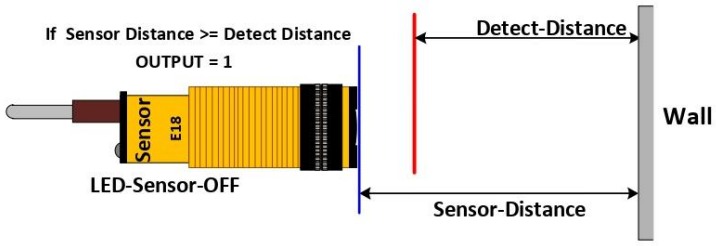
Connector and Circuit



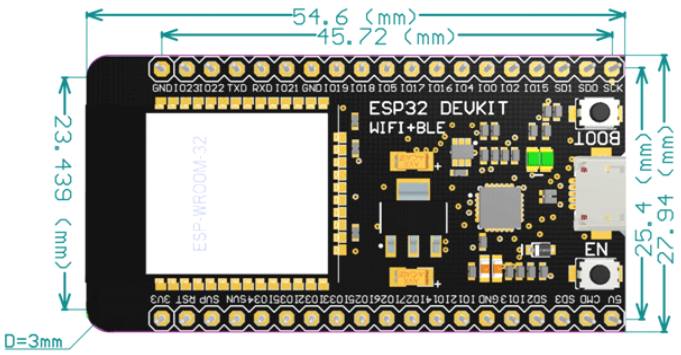
Dimensions of Sensor



When distance of Sensor <= the specified distance detection, LED Status is ON and OUTPUT = 0



III. ESP 32 DEVELOPMENTAL BOARD



Pin Category	Pin Name	Details
Power	Micro-USB, 3.3V, 5V, GND	Micro-USB: ESP32 can be powered through USB port 5V: Regulated 5V can be supplied to this pin which is we be again regulated to 3.3V by on board regulator, to power the board. 3.3V: Regulated 3.3V can be supplied to this pin to power the board. GND: Ground pins.
Enable	En	The pin and the button resets the microcontroller.
Analog Pins	ADC1_0 to ADC1_5 and ADC2_0 to ADC2_9	Used to measure analog voltage in the range of 0-3.3V. 12-bit 18 Channel ADC

DAC pins	DAC1 and DAC2	Used for Digital to analog Conversion
Input/Output Pins	GPIO0 to GPIO39	Totally 39 GPIO pins, can be used as input or output pins. 0V (low) and 3.3V (high). But pins 34 to 39 can be used as input only
Capacitive Touch pins	T0 to T9	These 10 pins can be used as touch pins normally used for capacitive pads
RTC GPIO pins	RTCIO0 to RTCIO17	These 18 GPIO pins can be used to wake up the ESP32 from deep sleep mode.
Serial	Rx, Tx	Used to receive and transmit TTL serial data.
External Interrupts	All GPIO	Any GPIO can be used to trigger an interrupt.
PWM	All GPIO	16 independent channel is available for PWM any GPIO can be made to work as PWM through the software
VSPI	GPIO23 (MOSI), GPIO19(MISO), GPIO18(CLK) and GPIO5 (CS)	Used for SPI-1 communication.
HSPI	GPIO13 (MOSI), GPIO12(MISO), GPIO14(CLK) and GPIO15 (CS)	Used for SPI-2 communication.
IIC	GPIO21(SDA), GPIO22(SCL)	Used for I2C communication.
AREF	AREF	To provide a reference voltage for input voltage.
Pin Category	Pin Name	Details
Power	Micro-USB, 3.3V, 5V, GND	Micro-USB: ESP32 can be powered through USB port 5V: Regulated 5V can be supplied to this pin which

		is we be again regulated to 3.3V by on board regulator, to power the board. 3.3V: Regulated 3.3V can be supplied to this pin to power the board. GND: Ground pins.

Technical Specifications

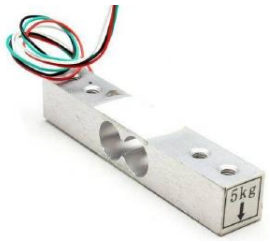
Microprocessor	Tensilica Xtensa LX6
Maximum Operating Frequency	240MHz
Operating Voltage	3.3V
Analog Input Pins	12-bit, 18 Channel
DAC Pins	8-bit, 2 Channel
Digital I/O Pins	30
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
SRAM	520 KB
Communication	SPI(4), I2C(2), I2S(2), CAN, UART(3)
Wi-Fi	802.11 b/g/n
Bluetooth	V4.2 – Supports BLE and Classic Bluetooth

IV. LINEAR ACTUATOR

Material:	Metal
Rated Voltage:	DC 12V
Optional Stroke Length:	200mm and 700mm
Speed:	6mm/s
Max Push Load:	1500N
Connection mode:	Elongation: Positive pole to black line, negative pole to red line. Shorten: Positive pole to red line, negative pole to black line.
Weight:	Approx. 1020-1983g
Input Voltage:	12V DC

V. LOAD SENSOR

YZC-131A Load Cells



How does it work

Strain-gauge load cells convert the load acting on them into electrical signals. The measuring is done with very small resistor patterns called strain gauges - effectively small, flexible circuit boards. The gauges are bonded onto a beam or structural member that deforms when weight is applied, in turn deforming the strain-gauge. As the strain gauge is deformed, it's electrical resistance changes in proportion to the load.

The changes to the circuit caused by force is much smaller than the changes caused by variation in temperature. Higher quality load cells cancel out the effects of temperature using two techniques. By matching the expansion rate of the strain gauge to the expansion rate of the metal it's mounted on, undue strain on the gauges can be avoided as the load cell warms up and cools down. The most important method of temperature compensation involves using multiple strain gauges, which all respond to the change in temperature with the same change in resistance. Some load cell designs use gauges which are never subjected to any force, but only serve to counterbalance the temperature effects on the gauges that measuring force. Most designs use 4 strain gauges, some in compression, some under tension, which maximizes the sensitivity of the load cell, and automatically cancels the effect of temperature.

Installation

This Single Point Load Cell is used in small jewelry scales and kitchen scales. It's mounted by bolting down the end of the load cell where the wires are attached, and applying force on the other end **in the direction of the arrow.** Where the force is applied is not critical, as this load cell measures a shearing effect on the beam, not the bending of the beam. If you mount a small platform on the load cell, as would be done in a small scale, this load cell provides accurate readings regardless of the position of the load on the platform.

Calibration

A simple formula is usually used to convert the measured mv/V output from the load cell to the measured force:

*Measured Force = A * Measured mV/V + B* (offset)

It's important to decide what unit your measured force is - grams, kilograms, pounds, etc.

This load cell has a rated output of 1.0±0.15mv/v which corresponds to the sensor's capacity of 5kg.

To find A we use

*Capacity = A * Rated Output*

A = Capacity / Rated Output

A = 5 / 1.0

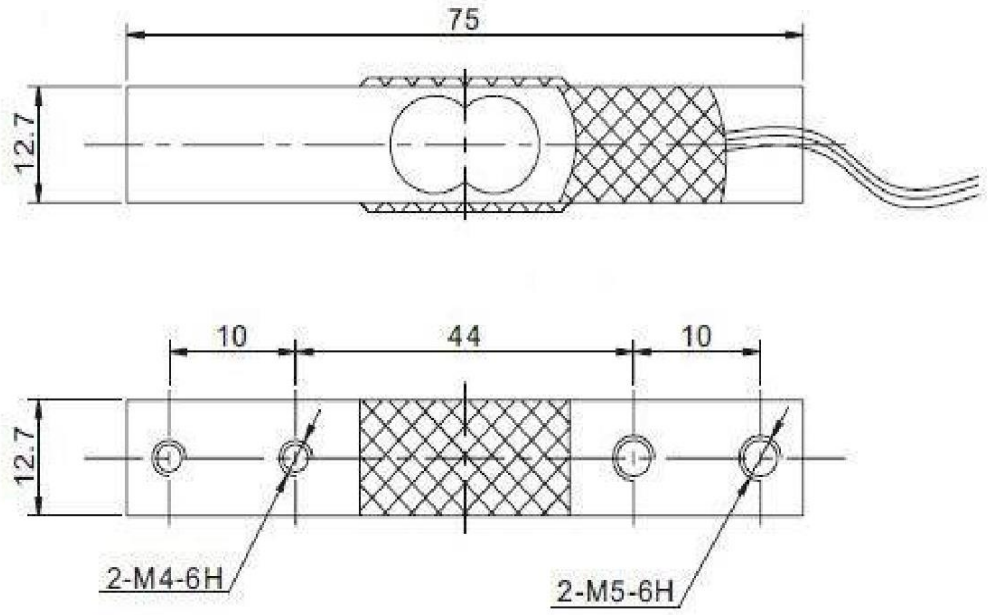
A = 5

Since the Offset is quite variable between individual load cells, it's necessary to calculate the offset for each sensor. Measure the output of the load cell with no force on it and note the mv/V output measured by the PhidgetBridge.

Offset = 0 - 5 * Measured Output

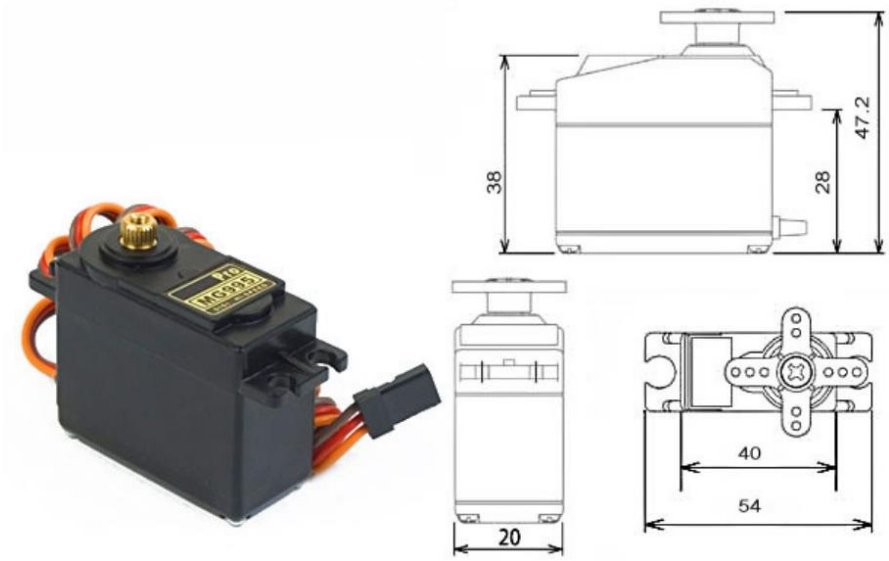
YZC-131A Series Product Specifications	
Mechanical	
Housing Material	Aluminum Alloy
Load Cell Type	Strain Gauge
Capacity	1/2/3/5 kg
Dimensions	Lx12.7x12.7 mm
Mounting Holes	M5 (Screw Size)
Cable Length	210 mm
Cable Size	30 AWG (0.2mm)
Cable - no. of leads	4
Electrical	
Precision	0.05%
Rated Output	1.0±0.15 mV/V
Non-Linearity	0.05% FS
Hysteresis	0.03% FS
Non-Repeatability	0.03% FS
Creep (per 5 minutes)	0.1% FS
Temperature Effect on Zero (per 10°C)	0.02% FS
Temperature Effect on Span (per 10°C)	0.05% FS Zero
Balance	±1.5% FS
Input Impedance	1000±50 Ohm
Output Impedance	1000±50 Ohm
Insulation Resistance (Under 50VDC)	≥2000 MOhm
Excitation Voltage	5 VDC
Compensated Temperature Range	-10 to ~+40°C
Operating Temperature Range	-21 to ~+40°C
Safe Overload	120% Capacity
Ultimate Overload	150% Capacity

Dimensiones



VI. MG995 SERVO MOTOR

MG995 High Speed
Metal Gear Dual Ball Bearing Servo

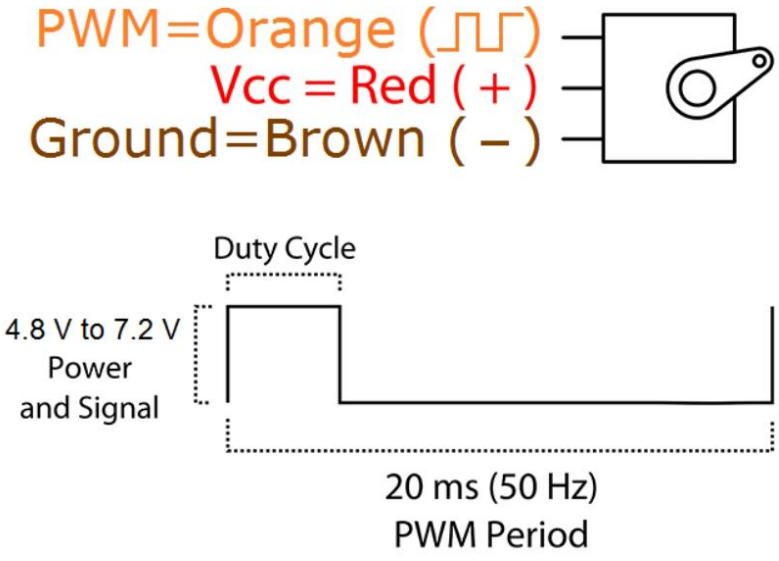


The unit comes complete with 30cm wire and 3 pin 'S' type female header connector that fits most receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum and Hitec.

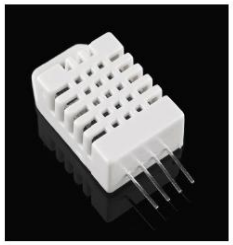
This high-speed standard servo can rotate approximately 120 degrees (60 in each direction). You can use any servo code, hardware or library to control these servos, so it's great for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. The MG995 Metal Gear Servo also comes with a selection of arms and hardware to get you set up nice and fast!

Specifications

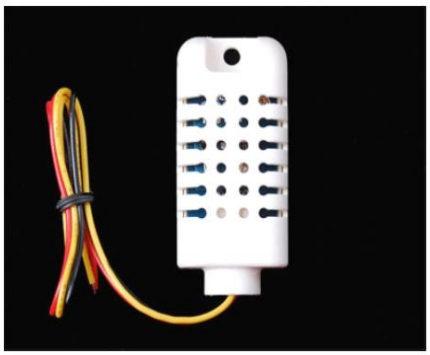
- Weight: 55 g
- Dimension: 40.7 x 19.7 x 42.9 mm approx.
- Stall torque: 8.5 kgf·cm (4.8 V), 10 kgf·cm (6 V)
- Operating speed: 0.2 s/60º (4.8 V), 0.16 s/60º (6 V)
- Operating voltage: 4.8 V a 7.2 V
- Dead band width: 5 µs
- Stable and shock proof double ball bearing design
- Temperature range: 0 ºC – 55 ºC



VII. TEMPERATURE AND HUMIDITY SENSOR



Standard AM2302/DHT22



AM2302/DHT22 with big case and wires

Digital relative humidity & temperature sensor AM2302/DHT22

1. Feature & Application:

*High precision
*Capacitive type
*Full range temperature compensated
*Relative humidity and temperature measurement
*Calibrated digital signal
*Outstanding long-term stability
*Extra components not needed
*Long transmission distance, up to 100 meters
*Low power consumption
*4 pins packaged and fully interchangeable

2. Description:

AM2302 output calibrated digital signal. It applys exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements is connected with 8-bit single-chip computer.

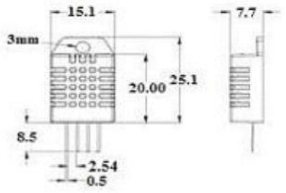
Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(100m) enable AM2302 to be suited in all kinds of harsh application occasions. Single-row packaged with four pins, making the connection very convenient.

3. Technical Specification:

Model	AM2302	
Power supply	3.3-5.5V DC	
Output signal	digital signal via 1-wire bus	
Sensing element	Polymer humidity capacitor	
Operating range	humidity 0-100%RH;	temperature -40~80Celsius
Accuracy	**humidity +-2%RH**(Max +-5%RH);	temperature +-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH;	temperature 0.1Celsius
Repeatability	humidity +-1%RH;	temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH	
Long-term Stability	+-0.5%RH/year	
Interchangeability	fully interchangeable	

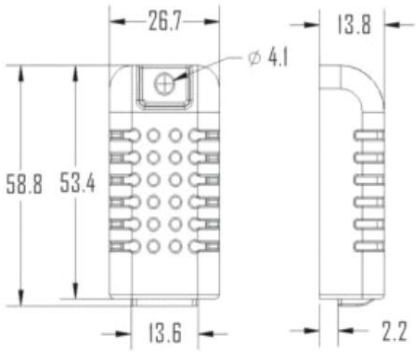
4. Dimensions: (unit—-mm)



Pin sequence number: 1 2 3 4 (from left to right direction).

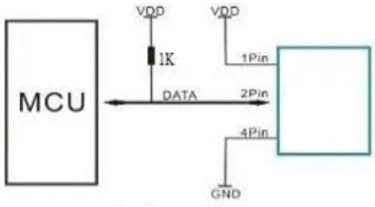
Pin	Function
1	VDD—power supply
2	DATA–signal
3	GND
4	GND

Standard AM2302's dimensions as above



Big case's dimensions as above
Red wire–power supply, Black wire–GND
Yellow wire–Data output

5. Electrical connection diagram:



6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-5.5V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

1-wire bus is used for communication between MCU and AM2302. (Our 1-wire bus is specially designed, it's different from Maxim/Dallas 1-wire bus, so it's incompatible with Dallas 1-wire bus.)

Illustration of our 1-wire bus:

VIII. VIBRATING MOTOR

Technical Specifications:
Color: Orange
Material: Aluminium alloy

- 220V 15W Vibrating Motor - Single Phase
Voltage: 220V
Power: 15W
Current: 0.10A
Force: 10KG
Frequency: 2940Hz (50Hz); 3450Hz (60Hz)
Size: 145x110x75MM (5.7x4.3x3in)

- 220V 30W Vibrating Motor - Single Phase
Voltage: 220V
Power: 30W
Current: 0.13A
Force: 20KG
Frequency: 2940Hz (50Hz); 3450Hz (60Hz)
Size: 145x110x75MM (5.7x4.3x3in)

Features:
【Adjustable Eccentricity Block】Adjust the angle of eccentricity block, can stepless adjust the excitation force, meet all kinds of requirements.
【Vibrator Motor】AC Vibration Motor 15/30W Industrial Vibrating Asynchronous Vibrator 220V 2940RPM.
【Description】Motor adopt of imported bearings, low noise, smooth operation, long service life. High temperature resistance pure copper enameled wire, all copper winding, stator vacuum dip paint, guarantee insulation grade
【Features】Aluminum alloy shell, light quality, fast heat dissipation, fast temperature rise. The motor machine shell is precision casting, with o-ring seal on the edge, fully closed structure design, with dustproof and moisture-proof function.
【Useful】Motor anti vibration special power cable protection cover to prevent long - time cable vibration damage. Apply in Mining, metallurgy, coal, electricity, construction, chemicals, medical equipment, food machinery, etc.

APPENDIX D

Project Manual

PROPONENTS
Migullas, Rey Mark M.
Nabong, Rael Beatriz G.
Oriol, Queen Venus Andrea D.
Santos, Micah Daniela N.
Talde, Czarina Mae M.

ADVISER
Jay Fel C. Quijano

Electronics Engineering Department
Technological University of the Philippines – Manila

Ayala Blvd., Ermita, Manila, 1000, Metro Manila
pentatronics.polyseg@gmail.com

POLYSEG

USER MANUAL

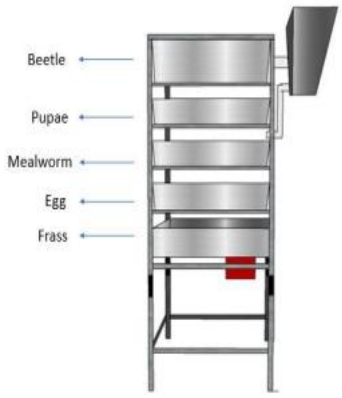


Figure 1. Internal Right-side View of the Hardware Design

HOW TO USE:

INITIAL SETUP

1. Place the beetle, pupae and mealworm in their respective assigned containers as shown in Figure 1.

2. Plug the device to a power source.

3. Securely close all the doors.

Harvesting the frass:

The web app will notify the user when the weight of the frass container reached the limit.

Using the Web App:

1. Browse http://polyseg.online/
2. Log in with the email and password given by the proponents.
3. Temperature, humidity and weight sensors data can be viewed in the monitoring section.
4. Control button for

Monitoring of temperature and humidity:

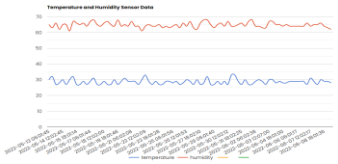


Figure 2. Temperature and Humidity Monitoring

Monitoring of weight sensors:

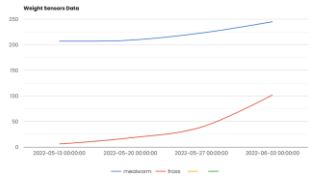


Figure 3. Weight Monitoring

Controlling of motors:

Figure 4. Control Buttons

Loading the Styrofoam:

1. Cut the Polystyrene into 1x1x1 cm cubes.
2. Place the polystyrene into the food dispenser. Make sure the food dispenser is filled.
3. Close the cover.

Safety Reminders:

Do not open the device while the vibrating motor is ON. Always make sure that the control panel is closed/sealed.

Maintenance:

1. Keep the device in a cool, dry and dark place.
2. Avoid placing it in places with extreme temperatures.
3. Always check the containers on a weekly basis.

3. Choose whether to monitor or control.

Figure 12. Web App: Monitor and Control Buttons

4. Temperature, humidity and weight sensors data can be viewed in the monitoring section.

(a) (b)

Figure 13. Web App: (a) Weight Monitoring Page and (b) Temperature & Humidity Monitoring Page

5. Control button for Collection, Segregation, Food dispenser and Exhaust fan. Once a button is ON, other buttons will not be visible. Turning ON two or more buttons at the same time is prohibited. This is to prevent possible complications to the system. Green button indicates "ON" while red button indicates "OFF".

Figure 14. Web App: Control Buttons

HARVESTING THE FRASS

The web app will notify the user when the weight of the frass container reached the limit. Open the chassis and gently take out the frass container.

LOADING THE STYROFOAM

1. Cut the Polystyrene into 1x1x1 cm cubes.
2. Place the polystyrene into the food dispenser. Make sure the food dispenser is filled.
3. Close the cover.

MAINTENANCE

1. Keep the device in a cool, dry, and dark place.
2. Avoid placing it in places with extreme temperatures.
3. Always check the containers on a weekly basis.

SAFETY REMINDERS

Do not open the device while the vibrating motor is ON. Always make sure that the control panel is closed/sealed.

Contact Us

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Ayala Blvd., Ermita, Manila
COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT

POLYSEG
USER MANUAL

FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM SEGREGATION USING ARDUINO MEGA 2560 WITH ESP 32 FOR WIRELESS NOTIFICATION

PROPONENTS

Migullas, Rey Mark M.
Nabong, Rael Beatriz G.
Oriol, Queen Venus Andrea D.
Santos, Micah Daniela N.
Talde, Czarina Mae M.

ADVISER

Engr. Jay Fel C. Quijano

PENTATRONICS

HARDWARE CONSTRUCTION

(a) (b)

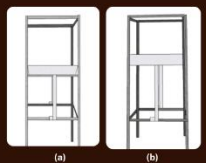
Figure 1. Segregation Module: (a) Internal Front View and (b) Internal Back View of the Hardware Design

(a) (b)

Figure 2. Segregation Module: (a) Internal Left-side View and (b) Internal Right-side View of the Hardware Design

(a) (b)

Figure 3. Collection Module: (a) Internal Front View and (b) Internal Back View of the Hardware Design

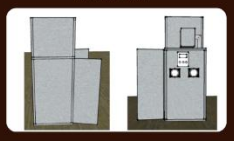


(a) (b)

Figure 4. Collection Module: (a) Internal Left-side View and (b) Internal Right-side View of the Hardware Design

(a) (b)

Figure 5. (a) External Front View and (b) External Back View of the Hardware Design



(a) (b)

Figure 6. Hardware Design: (a) Outer Left-side and (b) Right-side view

(a) (b)

Figure 7. Hardware Design: (a) Inner and (b) Outer Top View

INITIAL SETUP

1. Place the beetle, pupae and mealworm in their respective assigned containers as shown in Figure 1 and Figure 2.

2. Plug the device to a power source.

3. Securely close all the doors.

USING THE WEB APP

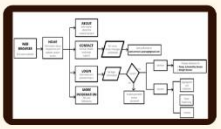


Figure 8. Web App Flowchart

1. Browse http://polyseg.online/

(a) (b)

Figure 9. Web App: (a) Home Page and (b) Additional Information Page

(a) (b)

Figure 10. Web App: (a) About Page and (b) Contact Page

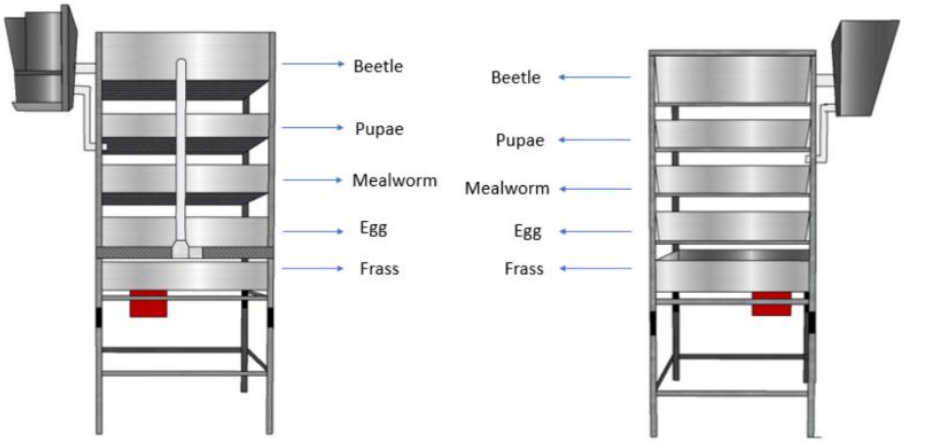
2. Log in with the email and password given by the proponents.

Figure 11. Web App: Log in Page

APPENDIX E

Project Documentation

Project Conceptualization using Sketchup



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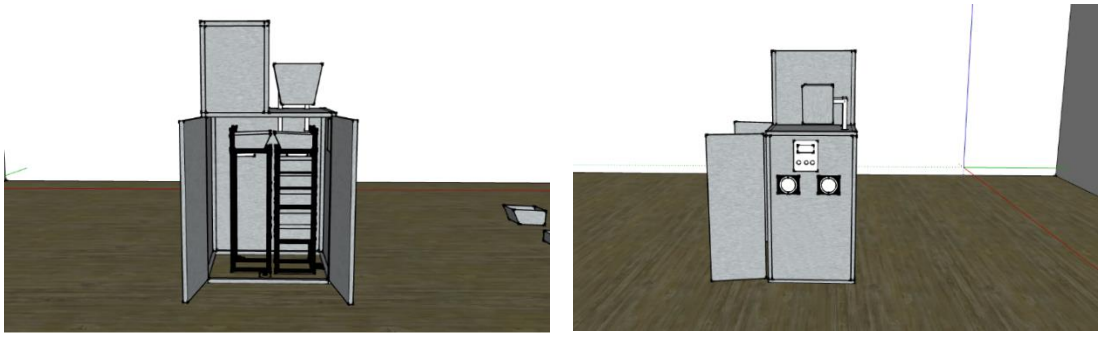
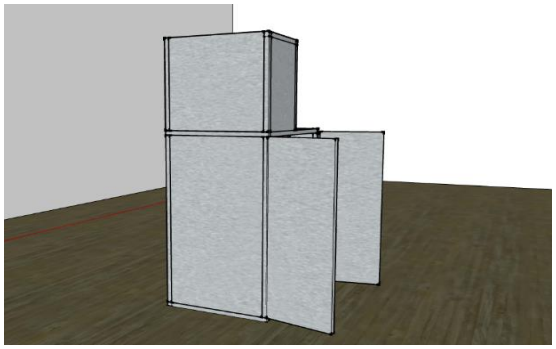
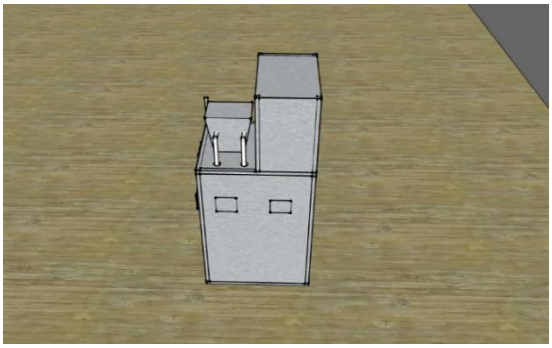
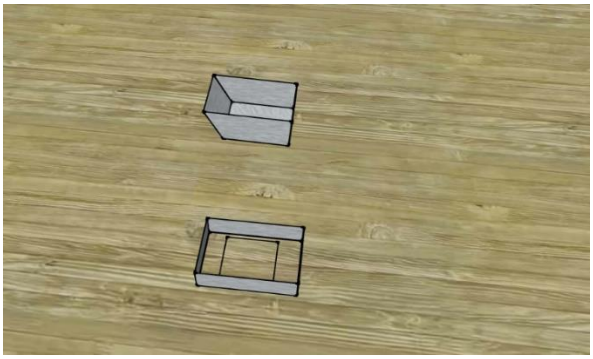
Designing Prototype using AutoCad

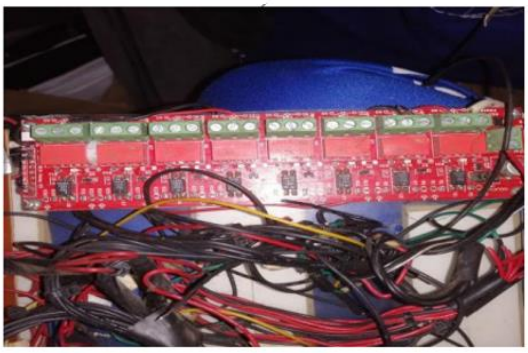






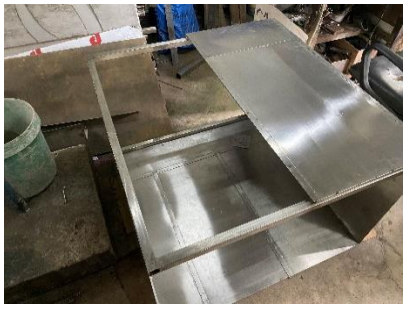


Canvassing and Procurement of Materials



Fabrication of the Prototype

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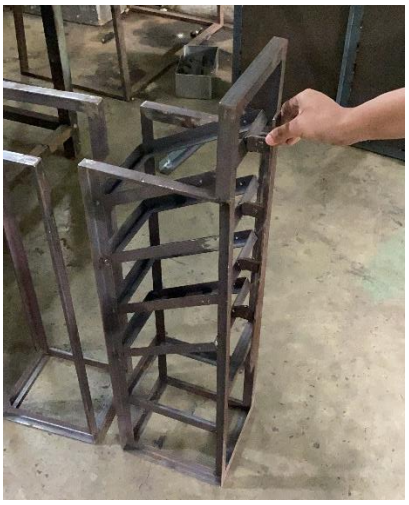
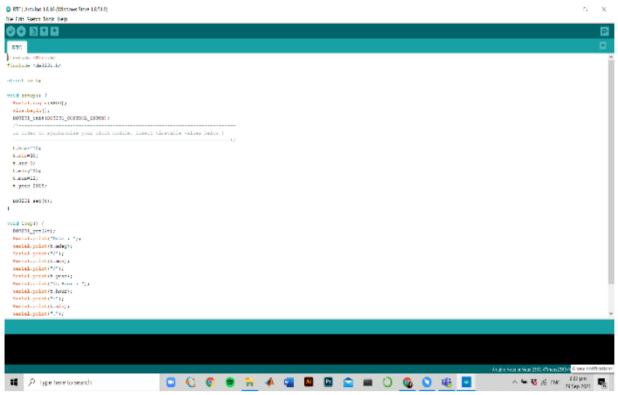
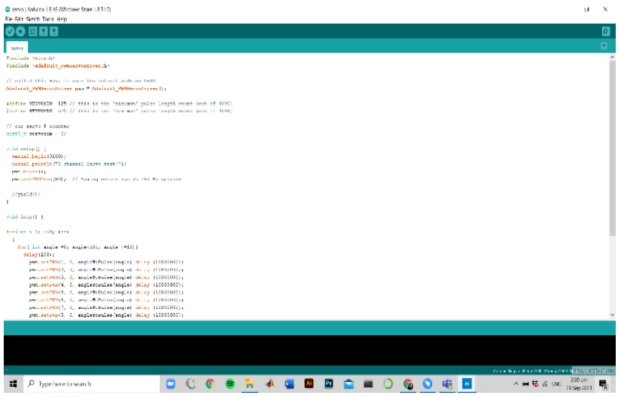
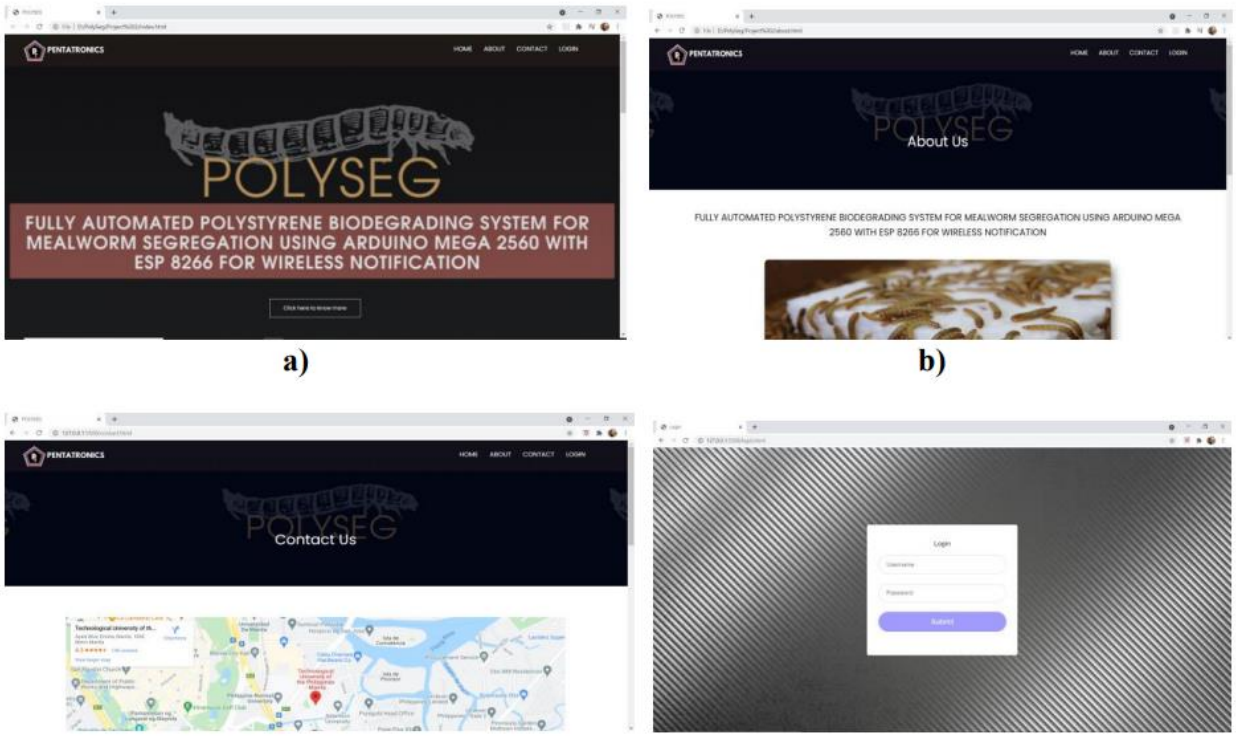


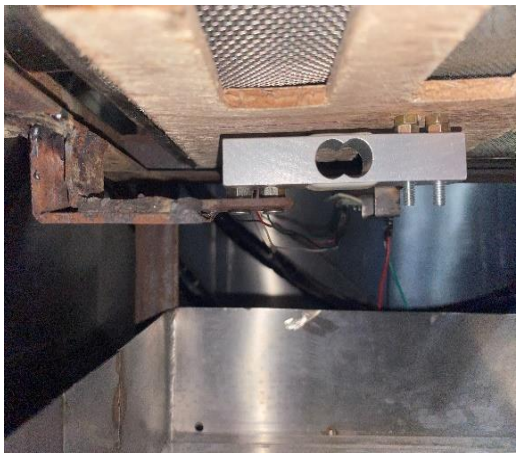
Programming and Initial Front-end development of Web app

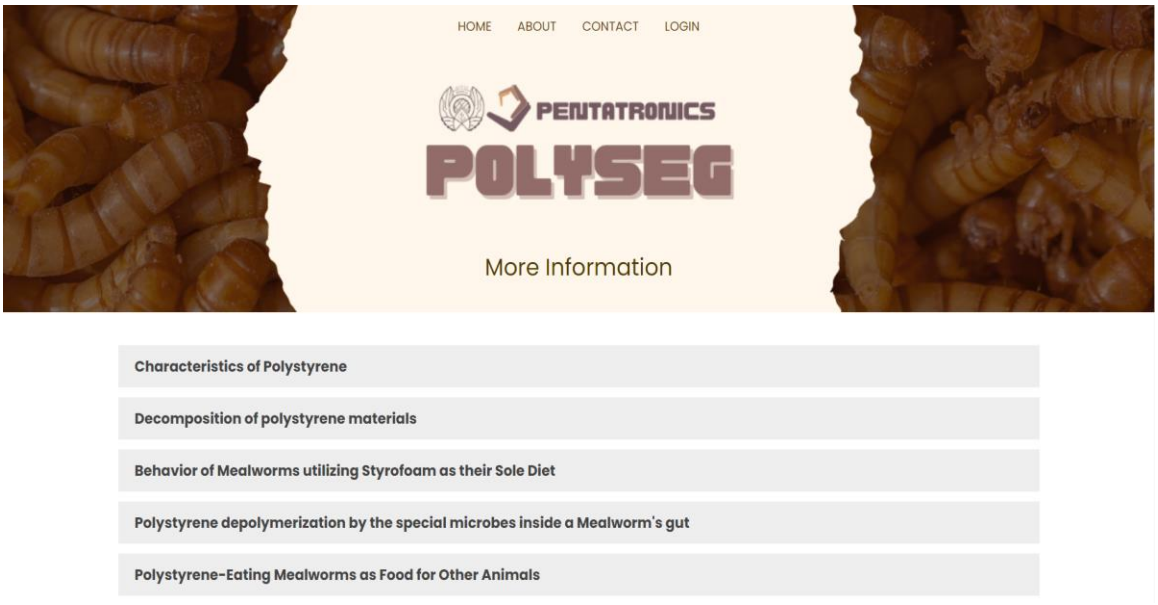


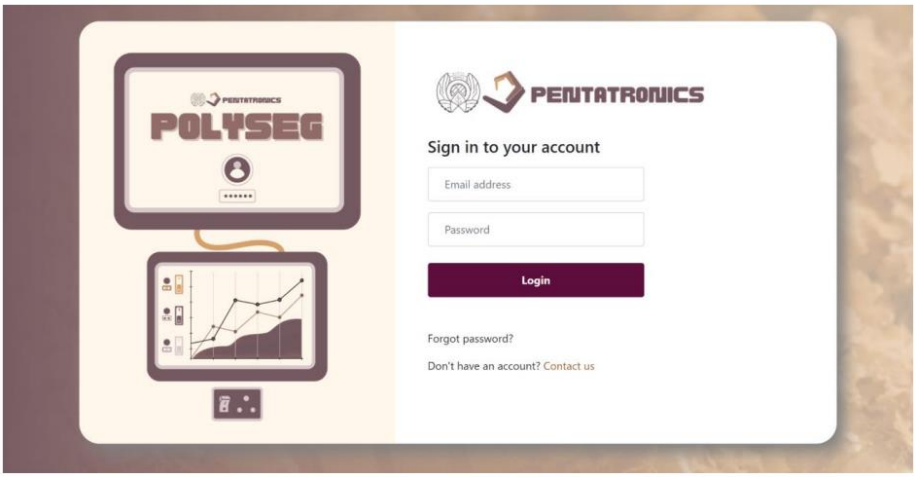
Final Appearance of the Prototype

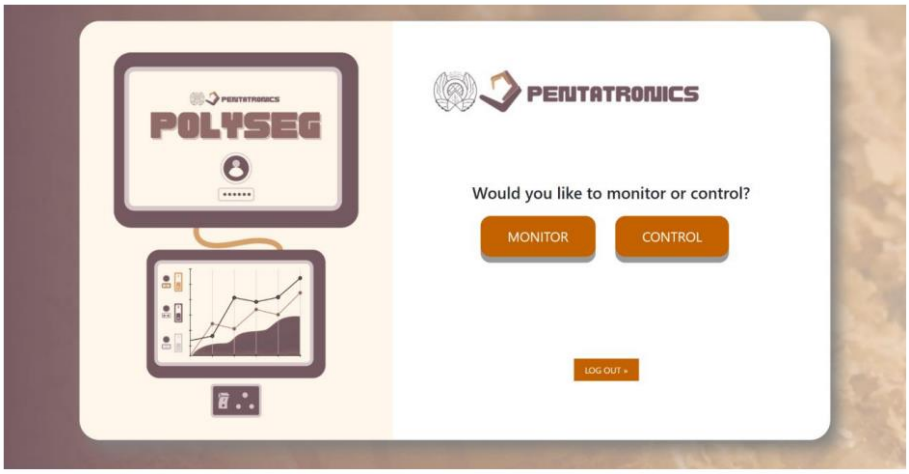

Control panel and other components (temperature, humidity, weight sensors)

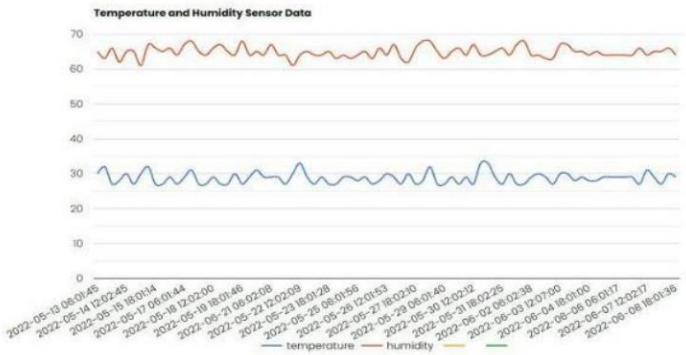

Final Look of the Web App

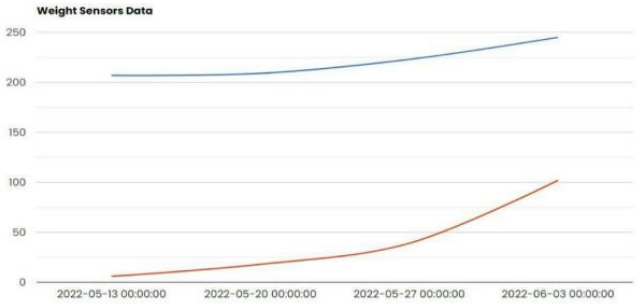



PENTATRONICS
POLYSEG
PENTATRONICS
Sign in to your account
Email address
Password
Login
Forgot password?
Don't have an account? Contact us


PENTATRONICS
POLYSEG
PENTATRONICS
Would you like to monitor or control?
MONITOR
CONTROL
LOG OUT »


PENTATRONICS
POLYSEG
Monitor
› Temperature & Humidity
› Weight


Temperature and Humidity Sensor Data
70
60
50
40
30
20
10
0
temperature
humidity



WEIGHT SENSORS DATA

ID	Date & Time	Mealworm	Frass	Food
4	2022-06-03 00:00:00	245.7	102.4	0
3	2022-05-27 00:00:00	223	39.2	1
2	2022-05-20 00:00:00	209.7	18.7	0
1	2022-05-13 00:00:00	207.9	6.75	1

Back » LOG OUT »

About Us

FULLY AUTOMATED POLYSTYRENE BIODEGRADING SYSTEM FOR MEALWORM SEGREGATION USING ARDUINO MEGA 2560 WITH ESP 32 FOR WIRELESS NOTIFICATION
Technological University of the Philippines - Manila
Ayala Blvd, Ermita, Manila, 1000 Metro Manila

College of Engineering

GUIDELINES: Once a button is ON, other buttons will not be visible. Turning ON two or more buttons at the same time is prohibited. This is to prevent possible complications to the system.

Collection | Segregation | Food | Fan

Back » LOG OUT »

About Us

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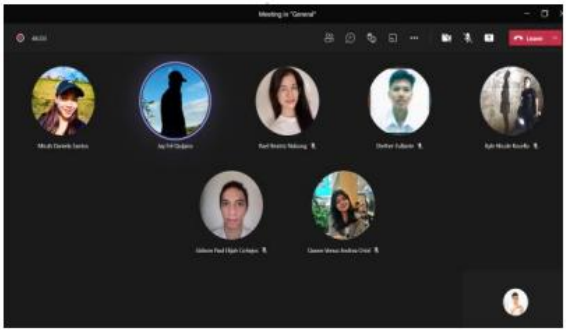
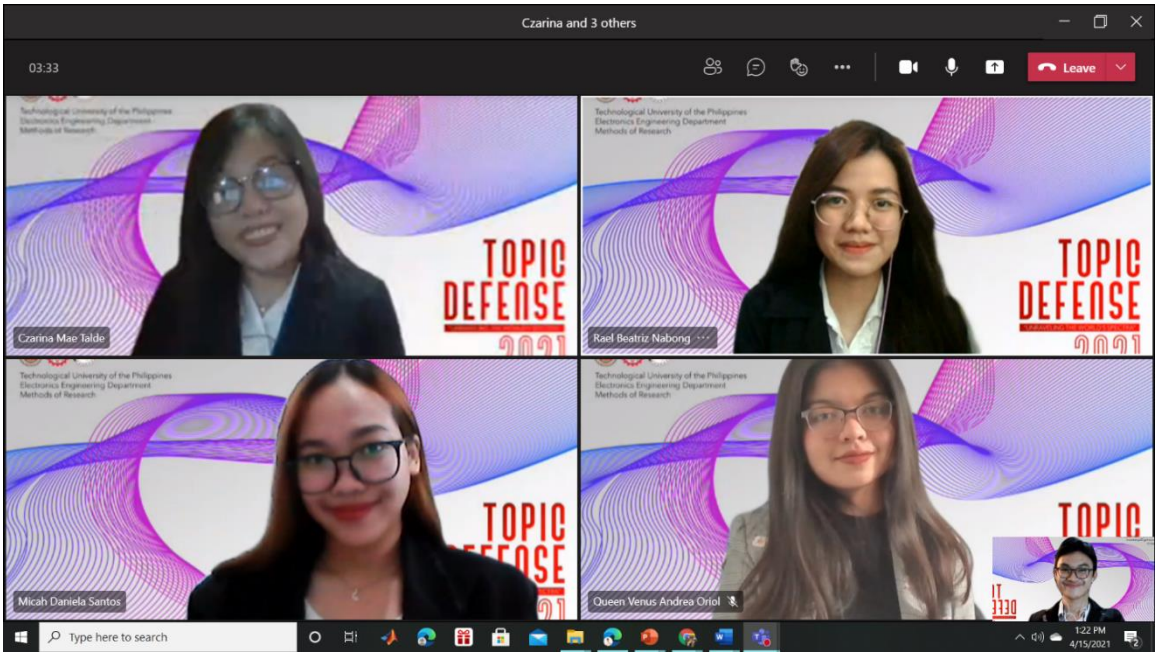
Technological University of the Philippines - Manila
Ayala Blvd, Ermita, Manila, 1000 Metro Manila

College of Engineering
Electronics Engineering Department
Email: pentatronics.polyseg@gmail.com • Contact No.: 0926 032 873

Meetings/Consultations with our Adviser

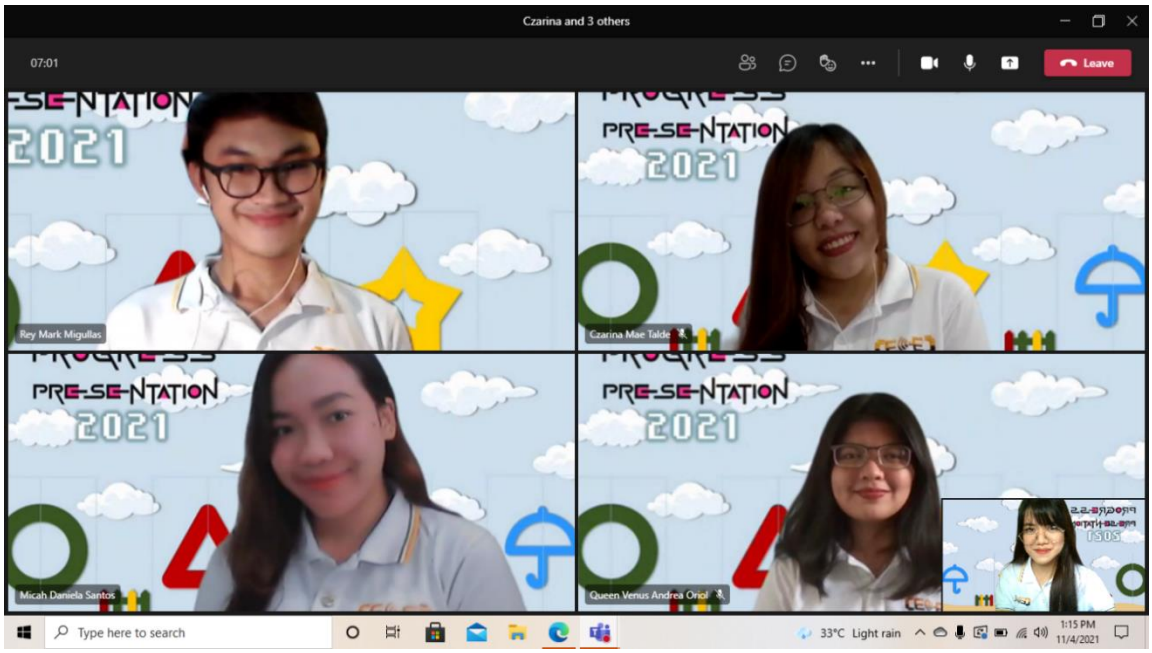


TOPIC DEFENSE



TITLE DEFENSE

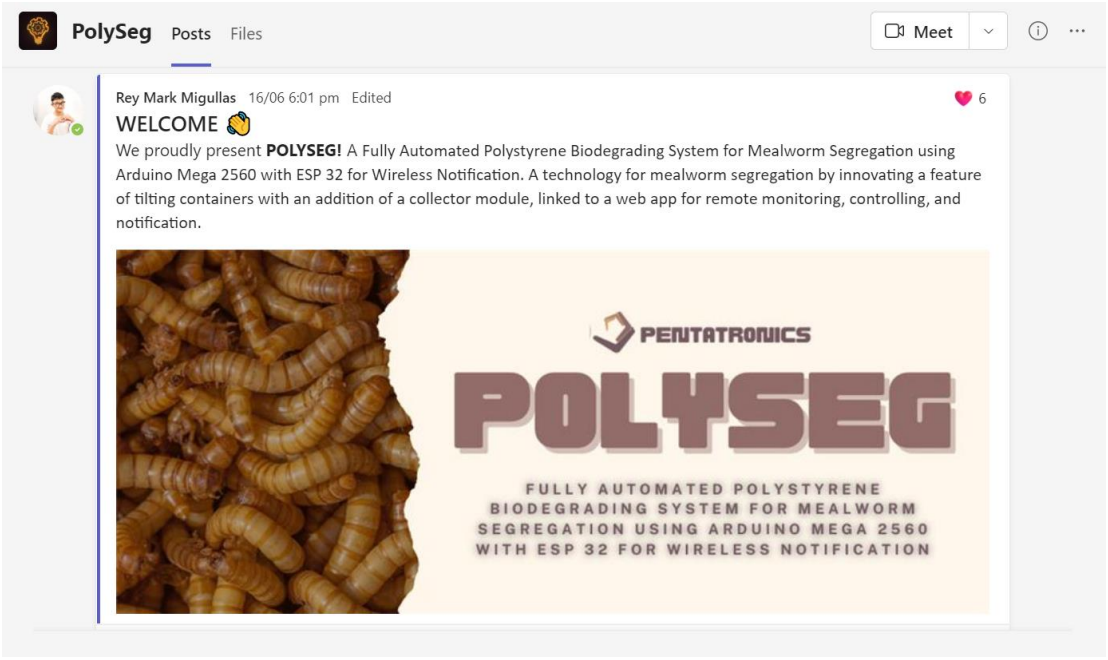
PROGRESS DEFENSE



PRE-FINAL DEFENSE

FINAL DEFENSE

APPRECIATE on MS Teams



APPENDIX F

Researcher's Profile

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Date of Birth:

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Place of Birth:

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Age:

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Gender:

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EDUCATION

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Technological University of the Philippines - Manila
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2018 - 2022

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Muntinlupa Science High School
999 Buendia St., Tunasan, Muntinlupa City
Science, Technology, Engineering, and Mathematics (STEM)
2016 - 2018

Muntinlupa National High School – NBP Annex
Phase 3, Southville III, Brgy. Poblacion, Muntinlupa City
2012 - 2016

PRIMARY

Itaas Elementary School – NBP Annex
Phase 1, Southville III, Brgy. Poblacion, Muntinlupa City
2006 - 2012

CO-CURRICULAR ACTIVITIES

2018 – 2022

Member, DOST Scholars' Club

Technological University of the Philippines – Manila

2020 – 2021

Senior Vice-President, Organization of
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Technological University of the Philippines – Manila

NABONG, Rael Beatriz G.

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Gender:

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Member, Google Developer Student Clubs TUP Manila
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Gender:

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Member, IECEP Manila Student Chapter

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2018 – 2019

Member, Organization of Electronics Engineering Students

Technological University of the Philippines – Manila

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Place of Birth:

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Age:

23 years old

Gender:

Female

EDUCATION

TERTIARY

Technological University of the Philippines - Manila
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2018 - 2022

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Technological University of the Philippines - Taguig
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31st cor 51st Sts. Pamayanang Diego Silang, Taguig City
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CO-CURRICULAR ACTIVITIES

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Technological University of the Philippines – Manila

2020 – 2021

Vice President for Academic Affairs, Organization of Electronics Engineering Students
Technological University of the Philippines – Manila

TALDE, Czarina Mae M.

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Home Address:

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Poblacion Sur, Maddela,
Quirino

Date of Birth:

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Place of Birth:

Santiago City, Isabela

Age:

22 years old

Gender:

Female

EDUCATION

TERTIARY

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Bachelor of Science in Electronics Engineering
2018 - 2022

SECONDARY

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Saint Vincent School
Poblacion Sur, Maddela, Quirino
2012 - 2016

PRIMARY

Saint Vincent School
Poblacion Sur, Maddela, Quirino
2006 - 2012

CO-CURRICULAR ACTIVITIES

2018 – 2021

Member, IECEP Manila Student Chapter

Technological University of the Philippines – Manila

2020 – 2021

Secretary-General, Organization of
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