Design and Development of Low-Cost Coffee Bean Sorting Machine Through Machine Learning

A Design Project

Presented to the

Department of Computer Engineering
College of Engineering
University of the East
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In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

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Abstract

This design project presents the design and development of a low-cost coffee bean sorting machine that utilizes machine learning techniques. The project addresses the need for affordable sorting solutions in the coffee industry while improving efficiency and accuracy.

The proposed machine incorporates an RPi camera and machine learning algorithms such as Convolutional Neural Networks and Support Vector Machine to distinguish the coffee beans' grades. There are four classifications of coffee beans, which are from grades 1 to 4, where grade 1 is the recommended coffee beans suggested for making coffee grounds, grade 2 for the coffee beans which were dampened during the drying process, which results in its darken color, grade 3 for coffee beans that are not whole, and grade 4 are rejected coffee beans. The machine could correctly sort the coffee beans into their respective grading with 83.33% up to 90% accuracy. With this result, the machine was proven helpful but not efficient as it takes longer time for the machine to sort the coffee beans than manual sorting.

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APPROVAL SHEET

The ***undergraduate design project***

DESIGN AND DEVELOPMENT OF LOW-COST COFFEE BEAN SORTING MACHINE THROUGH MACHINE LEARNING

which was presented before a Panel of Examiners of Department of Computer Engineering, College of Engineering, University of the East - Manila Campus, Philippines, on May 31, 2023 by

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is hereby **APPROVED** and **ACCEPTED** in partial fulfillment of the degree **Bachelor of Science in Computer Engineering (BS CpE)** with the overall rating of **EXCELLENT**.

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CERTIFICATE OF ORIGINALITY

We, the undersigned design project proponents hereby declare that this manuscript is our own work and that, to the best of our knowledge and belief, it contains no material previously published or written by another person or organization, except where the due acknowledgement is made in the text.

We have duly acknowledged all the sources from which the ideas and extracts have been taken. The manuscript is free from any form of plagiarism act and has not been submitted elsewhere for any publication.

Design Project Title:

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CERTIFICATE OF PLAGIARISM CHECK

This is to certify that the manuscript of the design project entitled

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Chapter 1
Background of the Design Project

A. Introduction

Agriculture is the general term for the art and science of managing land for growing crops and livestock. Farming involves planting seeds, growing plants, and raising livestock and poultry for their meat, eggs, milk, fur, leather, and wool. It is also imperative to human lives, especially to the economic gain of a country, by producing raw materials to contribute to the global supply chain and economic development.

The Philippines formerly ranked as one of the world's fourth top exporters of coffee beans. However, the coffee industry never recovered its former status due to coffee rust, a disease caused by a fungus. Although the country vanished from the top exporter, that does not mean that the coffee industry is not thriving in the Philippines as more and more entrepreneurs gradually venture into this field.

According to an article by (Caretti, 2016), the process of Coffee bean farming is not quite complicated; the planting process in which the farmer will plant unprocessed coffee seeds in the soil to let the seeds germinate and grow sprouts. Newly planted coffee bushes take about three to four years to produce fruit. There are two methods of harvesting coffee bean fruit: strip picking and selective picking. Strip picking is usually done by stripping all coffee bean fruit from the branches using machines or by hand picking. Selective picking is an intensive method of harvesting the fruit; Only ripe coffee fruit is harvested by hand during selective harvesting. For the later harvest, unripe coffee is left on the tree. Overripe coffee can either be harvested and kept apart from the ripe fruit on the tree or left on the branch. The farmer will return a few weeks later and collect only ripe fruit this time. This procedure is repeated until the producer decides it is no longer worthwhile to harvest. After harvesting, it will be laid on a large surface under the sun for 15 to 20 days to dry. They are regularly raked to prevent fermentation and to ensure that the beans are dried evenly. To remove the skin of the coffee beans, the farmers use different methods, one of which is the wet method. They use water to move and remove the skin of the coffee cherries. Later, the coffee bean will be manually sorted and entered into the coffee milling process.

The coffee plant can be subjected to diseases and pests. Coffee can have diseases caused mainly by pathogenic microfungi. However, some are caused by viruses and bacteria. According to an article by (Wisniowski, 2022), one of the most commonly found in a coffee bean tree is coffee leaf rust (Hemileia vastatrix), an orange rust-like dust fungus found on the underside of the coffee leaves. In addition, the coffee plant can be subjected to pests. Due to pests like coffee berry borer, the yields are reduced because young affected beans fall prematurely, and all harvested beans have lower weight and density, which could degrade the quality and affect the commercial value of the coffee bean.

The agricultural revolution is one of human history's most significant milestones, initiating a series of changes that would ripple gradually for more than a thousand years. The idea of agriculture began to originate thousands of years ago.

However, the techniques developed in that period continued to evolve from shifting agriculture, one of the most ancient ways of farming, to the utilization of advanced technology for farming. With technological advancements such as in agricultural sensors like soil moisture, and air temperature and humidity, farming is more productive, safe for farmers, and more environmentally friendly (*Agriculture Technology*, n.d.). The innovation of farming and technology usage has become more critical now than ever. These modern farms use technology to plant or provide nutrients or fertilizer for their crop. Also, through technology, modern farmers can provide suitable environments for crops to help them grow.

Machine learning is a subfield of artificial intelligence used to imitate human behavior and adapt without following explicit instructions using algorithms and statistical models to analyze the data. At the same time, an embedded system combines hardware and software designed for specific functions.

With the use of machine learning and embedded systems combined, farming can become more efficient and make the process faster with the help of technology to harvest and produce more products by providing what the farmer needs making their work faster and more efficient.

Farming requires many steps to ensure that the quality of the coffee beans is up to standards. As such, it is also prone to human error, such as misidentifying its health and quality. Aside from that, the number of farmers and their farmland is out of proportion leading to overwork nowadays as most of the farmers choose to dwell in urban cities due to higher income rates.

Having a machine capable of identifying the grades of coffee beans would be beneficial for the farmers as it would make their workload lighter and more efficient.

B. Statement of the Objectives

The design project aims to design and develop a low-cost coffee bean sorting machine and specifically:

- **Design and develop** a device that is capable of identifying the quality of the coffee bean and sort pest-infested beans from the healthy ones.
- **Integrate** machine learning to identify the quality of the coffee beans based on its physical characteristics such as color, whether the coffee bean is whole or not and also if it has a hole.
- **Evaluate** the accuracy of machine learning algorithms, specifically Convolutional Neural Network and Support Vector Machine, capable of classifying which coffee bean is infected with coffee bean borer.
- **Evaluate** the accuracy, reliability and effectiveness of the system by comparison of human and device sorting process.

C. Conceptual Framework

This design project focused on designing and developing a machine capable of sorting dried coffee beans according to physical characteristics.

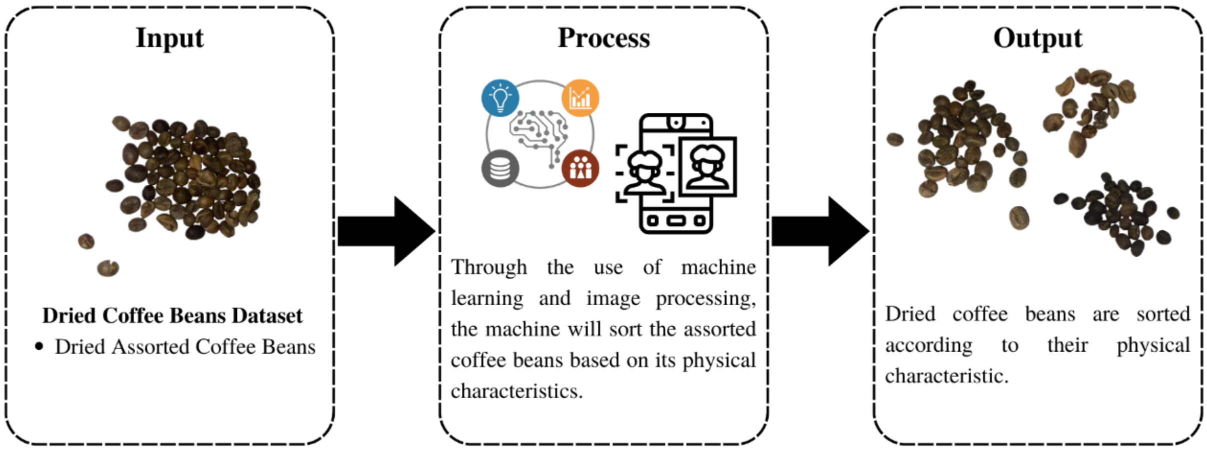


Figure 1. Conceptual Framework for the Sorting of the Dried Coffee Beans

Figure 1 shows the conceptual framework of the design project for the machine. The first box contained the machine's input, the dried coffee beans dataset. The machine would be integrated with machine learning, particularly image processing, which will be used to identify which is which from the coffee beans. Finally, the expected output from the machine is sorted coffee beans according to their physical characteristics.

D. Scope and Delimitations

This project aims to design and develop a low-cost coffee bean sorting machine integrated with machine learning to identify the quality of the coffee beans according to their grades. The classification of these coffee beans was based on four (4) grading; Grade 1 for the great quality dried coffee beans which are recommended for making coffee, Grade 2 for usable dried coffee beans, which is the coffee beans that have been damp during the drying process, Grade 3 for coffee beans that are used in other coffee products and Grade 4 for rejected coffee beans.

The design project's scope is the following;

[1] The dried coffee beans would be classified through machine learning with the use of Python programming language and a Raspberry Pi Camera for the machine to see the dried coffee beans,

[2] The machine learning algorithms that were tested are Convolutional Neural Networks and Support Vector Machines,

[3] A prototype machine that can sort Robusta coffee beans according to their grades and that works the way the user (farmer) expects it to,

[4] Assessing the sorting machine's performance in terms of accuracy, throughput, and efficiency.

The design project's prototype, low-cost sorting machine, is limited to only sorting dried coffee beans, specifically Robusta, and not other types of beans. Furthermore, the machine could only handle 0.9 kg of coffee beans of each grade as it was the limit of the load cell that the proponents used. It was also to ensure that the coffee beans were not crowded in the rotating disc of the machine. It is also preferred that the machine will only be used indoors as it is not waterproof, and its power comes from an external plug-in outlet to maximize the efficiency and functionality of the sorting machine. That said, the machine will not be able to work without electricity.

E. Significance of the Study

The design project would be beneficial for the following:

Rodil's Coffee Farm and Mr. Francisco "Borg" Año. As the primary beneficiary of this design project. The prototype of this design project could financially aid them by having a sorting machine to sort dried coffee beans by their classifications instead of hiring personnel to sort them manually. Also, the proposed prototype sorting machine is cheaper than the industrial-grade sorting machines.

Coffee Bean Farmers. This design project can financially aid coffee bean farmers by providing information and statistical data about a low-cost dried coffee bean sorting machine.

Allied Agriculture Professionals. This design project can provide them with enough information about low-cost machines to aid small farm farmers.

Future Researchers and Future Studies. This design project may serve as a guide and reference for their future selected studies that are in line with the proponents' design project.

F. Operational Definition of Term

For better clarification and understanding of the terms related to this design project, the following terms are defined conceptually and operationally.

- **Artificial Intelligence -** is a branch of computer science that will be used to train the machine to interpret and identify the classification of different coffee beans.
- **Coffee bean** - the fruit that the proponents choose as the design projects focus**.**
- **Coffee Bean Borer** - A pest that affects the coffee bean which makes the coffee tree to reduce the amount of its yield and its quality
- **Computer Vision -** is a field of Artificial Intelligence that will be used in the machine to understand and help visualize the actual coffee beans.
- **Embedded System -** a combination of hardware and software systems used in making the machine.
- **Internet of Things** - will be used to show the data gathered by the machine.
- **Machine Learning** - use to identify the characteristics of the coffee bean.
- **Quality** - refers to the state of the coffee beans.
- **Sorting Machine -** the proposed machine that can sort dried coffee beans.

- **Grade 1 Quality Coffee Beans-** Dried coffee beans that are whole, have no defects and the color is light to medium brown.
- **Grade 2 Quality Coffee Beans** - Dried coffee beans that are whole, have no defects and the color is dark brown.
- **Grade 3 Quality Coffee Beans -** Dried coffee beans that are broken and the color is light to medium brown.
- **Grade 4 Quality Coffee Beans** - Dried coffee beans that have defects (pest-infected coffee beans).

Chapter 2
Review of Related Literature and Studies

A. Agriculture in the Philippines

According to a study by (Madayag & Estanislao, 2021) , the Philippines was one of the top agricultural countries in the world in the 1960s, with a gross domestic product (GDP) of 31%; it hindered the effects of the Great Chinese Famine on the country. However, the Philippines began to struggle in the agricultural sector when the GDP gradually decreased from 31% to 10% by 2017 as the country continues to experience declining production, efficiency, and competitiveness from our local farmers. The reason for the drop rate in the GDP in the Philippines' agriculture is the lack of support/prioritization from the government and the failure to use emerging agricultural technologies.

According to recent data by (*Agriculture in the Philippines - Statistics & Facts | Statista*, 2021), the Philippines' agricultural sector includes farming, fisheries, livestock, and forestry. Farming and fisheries are the main sub-sectors in the Philippines because of the country's climate and ecosystem. In connection, a study by (Cosrojas & Eguia, 2021) determined the main agriculture sub-sectors in 16 regions in the Philippines and what produces the regional industry concentrates. Using data from 2009–2012, statistical methods: Location quotient to identify the critical industries in each region in the Philippines, and correlation analysis to identify and determine the relationship between the industry concentration and GVA in each region. In this study's beneficiary region is located in the CALABARZON region, and poultry (fowl) farming is the key agricultural sub-sector; mainly, game fowl or cockfight chickens are raised in the region. Their study concludes that regions with high rates of LQ do not always associate with a high GVA in the agricultural sector.

The coffee industry in the Philippines began when Spanish Franciscan Monk brought and planted the first coffee tree in Lipa, Batangas, in the 1970s, which later became the coffee capital of the Philippines (MacDonell, n.d.). The Philippines is part of the equatorial zone called "the bean belt"; it is where 44 countries can grow and produce coffee beans. According to an article by (Milton, 2021), the countries within the bean belt have the best climate and environmental conditions for growing excellent-quality coffee.

As stated in a study by (Habaradas & Mia, 2021), Filipinos made coffee their staple go-to beverage. By 2025, every Filipino is expected to consume 3.78 kilograms of coffee annually, up from an estimated 3.05 kilograms per capita in 2021. Although the demand for coffee is still increasing, coffee production continues to decline due to production issues that include the land, coffee farmers, farming practices, and low income for coffee farmers. In connection, a study by (Sta. Barbara, 2022), stated that the Philippines produces four varieties of coffees; Robusta, Arabica, Excelsa, and Liberica. The variety of coffee with the highest number of production is Robusta because it is popularly used in espresso and instant coffee.

According to the SCAA standard for specialty-grade coffee, there are two categories of defects in coffee beans. Category 1 includes full black, full sour, Dried cherry pod, fungus damage, foreign matter, and severe insect damage. Category 2 defects include partial black, partial sour, parchment or pergamino, floater, immature, withered, shell, broken or chipped, hull or husk, and slight insect damage.

Full black and partial black both result from over-fermented pigment associated with microorganisms, while full sour and partial sour is from microbial contamination during the harvesting and processing of the coffee beans. Fungus damage can come from different fungi from Aspergillus, Penicillium, and Fusarium genera, infecting coffee beans from any point from harvesting to storage. Foreign matter is any debris that accumulates from any part of the processing of the coffee beans. Dried cherry/pods came from a poor pulping process and failure to remove the dry coffee cherry; it can also result from improper hulling and sorting of coffee beans. Severe and slight insect damage results from coffee bean borer infesting the coffee beans. Broken and Chipped coffee beans commonly occur during the pulping or dry milling process, where the pressure from the machine exerts its force and damages the coffee beans. Immature coffee beans are unripe coffee beans harvested, while a lack of water mainly causes withered beans during the growth of the coffee bean. Shell is a genetic phenomenon, while hull or husk is from a natural process by poor calibration of de-pulping machines. Floaters are caused by improper storage or drying; parchment is a defect resulting from improper calibration of the hulling machine.

B. Diseases in Coffee Beans

Coffee bean diseases can reduce the amount of producing consumable coffee beans. As stated in the study of (Waller, 1985), coffee diseases are pathogenic microfungi and occasionally bacteria and some viruses cause; they affect different plant organs resulting in weakening, deformity, and sometimes the death of the whole plant.

With it said, a leaf disease can also cause a problem in the production of the coffee bean due to the reduction of the photosynthetic capacity of a coffee tree. When the photosynthetic capacity of the coffee tree is severely reduced, the growth and ripening of the coffee berry will be affected, and it may even fall, inducing quantitative losses (Ribeyre & Avelina, 2012).

According to the study of (Abu-Naser et al., 2019) a root disease such as the Brown root is a type of infection caused by Cercospora infection that penetrates the seed causing the pulp to stick to the parchment during the process, causing damage to the product where infected plants show gradual yellowing of leaves and defoliation followed by the death of the entire plant while the brown fungal crust gives the name brown root disease. The disease's favorable condition is the exposure of the developing berries to the sun in the absence of adequate overhead shade and hot, humid conditions.

Another fungus called coffee rust is also caused by the fungus *Hemileia vastatrix* and is recognized by the orange powdery spots on the undersides of coffee leaves. With it said, diseased leaves are shed prematurely, reducing the amount of vegetative growth and, consequently, the following seasons' yield (Waller, 1985). As stated in the study of (Lu et al., 2022), the fungus mentioned has spread to all coffee cultivation areas worldwide. Meanwhile, the life cycle of the disease, called *urediniospores*, as its most important source of inoculum, can cause infection and develop into lesions, producing more urediniospores.

Another disease, stated by (Lu et al., 2022), is Coffee Wilt Disease. This disease was first detected in 1927 in Oubangui-Chari (now the Central African Republic) and was initially thought to be caused by root rot. The mentioned disease cycle has an incubation period from first symptoms to death of the tree varies, although most affected trees die 2–3 months after initial symptoms were observed. It usually kills infected mature trees within just six months after the first external symptoms appear, resulting in a decline in total yield. According to the description in the study of (Rutherford & Phiri, 2006), the yellowing, folding and inward curling of the leaves are among the first signs of Coffee Wilt Disease. The leaves feel limp to the touch, then dry up, become brown, and eventually drop off, leaving affected trees completely leafless.

In conclusion, various diseases in coffee beans can affect the whole process of coffee bean production. Those diseases could reduce the total amount of beans that can be consumed, and they can also diminish the business of coffee bean farming. For instance, brown root causes damage to the plant, such as yellowing of leaves and defoliation, followed by the death of the plant, while *Hemilea vastatrix*, also known as coffee rust, can be recognized by the orange spots on the underside of the coffee leaves that can reduce the amount of vegetative growth. With it said, leaf diseases can cause problems in the production of coffee beans due to the problem with the photosynthetic capacity of a coffee, also resulting in weakening, deformity, and sometimes death of the plant.

C. Pest Infestation in Coffee Beans

Pest infestation is one of the challenges coffee farmers face worldwide. As stated by (Johnson et al., 2020), Coffee Berry Borer, with its scientific name, Hypothenemus hampei (Ferrari) (Coleoptera: Curculionidae: Scolytinae), or CBB, is the most dreadful and destructive insect pest to coffee in the world. CBB degrades the quality of coffee products and decreases farmers' coffee yield, resulting in annual losses of more than US$500 million. Its infestation happens when the adult female CBB creates a hole in the bean and buries itself inside, where it produces its offspring. Then the larval will feed the bean's endosperm. With its rapid invasive characteristic and no countermeasures taken, almost all berries can disintegrate in no time.

Large-scale coffee plantations include intensive sanitation practices in their CBB control plans. Large coffee farms have no problem executing it because they have the resources to implement this method. Unfortunately, small-scale coffee farms often cannot afford these procedures due to labor costs. Good pre-season and early-season sanitation practices, such as pruning and strip-picking, are common techniques to maintain infestation levels low until the end of the growing season. If infestation levels are high at the start of the season, administering B. bassiana will do small to invert crop damage. B. bassiana is used as a biological insecticide for CBB infestation.

Pruning can also rejuvenate coffee trees and improve production but can have varying results on CBB infestation and distribution depending on the method applied. As stated by (Aristizábal et al., 2017), pruning can also potentially eliminate CBB habitat, such as bark chinks, thus supplying an additional cultural look for the tree. In some parts of the world, occasionally pruning entire blocks of the coffee tree is a technique that significantly diminishes the number of CBB in that location.

As stated in a study by (Ruiz-Diaz & Rodrigues, 2021), vertical trapping for CBB with a mixture of Methanol and Ethanol is one of the practical implementations of biological pest management tools. These chemicals were combined in a bottle and hung in the tree to capture CBB. In this method, the chemicals were not directly applied to the bean or tree, ensuring it cannot harm human health, and the taste quality of the coffee stays the same. Also, proper height adjustment has a high impact on capturing CBB. Placement of traps at a lower height always delivered the highest capture of CBB. These traps are for keeping track of their flight and pest management.

According to the study by (Dantas et al., 2021), another well-known coffee pest to farmers is the Coffee Leaf Miner (Leucoptera coffeella), or CLM. This moth made its name infamous by causing severe damage to coffee plantations. The moth's larvae feed on the coffee leaves' palisade parenchyma. Therefore, weakening the tree's ability for berry production. The CLM harm both bean quality and quantity, which has a detrimental effect on the coffee supply chain. Scientists are working on developing integrated pest management (IPM) methods because downsides of chemical control using pesticides, namely the harm they do to the environment and human health. Therefore, developing innovative resistant cultivars, biological control, nano-biopesticides, and other methods are crucial for effective long-term CLM control management.

D. Relationship Between Agriculture and Technology

Agriculture is an essential part of human life. It provides food, which is one of the human necessities, and with a growing population, the demand for food rises. Thinking and creating a way to innovate traditional farming to satisfy the demands without sacrificing the quality of the products is where technology will present itself.

Technology affects human life in every way possible. Its effect can also be discerned in agriculture, specifically in farming. (Rose & Chilvers, 2018) state that "smart farming can provide enormous benefits to sustainable agriculture. Increasing the efficiency and productivity of food production as well as potentially providing environmental and social benefits". Using technology, researchers have already developed many things to increase the volumes and enhance the shelf life of the produce. Some of them are fertilizers that replace the essential nutrients for the plant to grow and pesticides that omit anything threatening the plant's growth. Although technology allows farmers to increase their efficiency in farming, it is also evident that most farmers are unable to implement the newest technology in their farming practice due to a lack of knowledge of it, and it is not cost-friendly. Another reason is that most farmers still depend on the season for irrigation.

Undeniably, technology during this time is an essential part of human life. Thus, making humans accustomed to seeing technology in different sectors of society. Naturally, it is also evident in agriculture. The findings in the research by (Takahashi et al., 2019), recommended that “the adoption of integrated farm management systems may increase crop yields and sustain yield gains. However, it is not widely used for its complexity, and it is needed to train certain farmers in integrating technology with their current way of farming, for not all are capable of understanding the new and complicated technologies.” Using technology in farming is convenient and efficient. However, it is not plausible during this state.

E. Internet of Things (IoT) in Agriculture

The Internet of Things (IoT) becomes a network of communication between the physical device (sensors) and the internet network. In a study by (Billa et al., 2021) in India, the soil and climate conditions were quite unpredictable, causing a decline in the economy. In their study, they proposed a system that can monitor the soil's moisture and the humidity and temperature of the environment; the gathered readings are shown on an app like VNC viewer. They concluded that their proposed system is beneficial to the farmers to monitor the water content in the soil and the humidity and temperature of the environment without exerting any labor or workforce.

The study by (Idoje et al., 2021) stated that the Internet of Things (IoT) can significantly impact today's agriculture. Smart farming can reduce the ecological footprint by sending robots, UAVs, or smart machines to minimize the ecological footprint by only applying fertilizers and pesticides on a particular part of the land. In connection, a study by (Walter et al., 2017) stated that smart farming might be more financially rewarding for farmers because it can reduce their labor and maintenance resources. After all, smart technologies can provide specific data for the farmers to do work, like weather forecasts and monitoring of diseases and disasters.

In conclusion, a study by (Elijah et al., 2018), stated the several benefits of IoT in agriculture. These benefits are; IoT in agriculture can ensure the safety of the farmers and lessen the negative economical impacts of farming, and with the help of IoT devices in agriculture, it can reduce the time and money used in farming large areas and can promote more operational efficiency in farming and decision making with the data gathered agricultural monitoring. Other benefits of IoT in agriculture are; IoT enables farmers to produce higher-quality goods, which can mean an increase in product demand. However, with all of the benefits of IoT in agriculture, there are still challenges and issues with the application of IoT in agriculture. IoT devices can be expensive for small rural farms; requires IoT platform and devices. Furthermore, even with the government's aid in the application of IoT in small farms, the concept of IoT still needs to be introduced to small rural farmers. Another is the technical issues; the farm needs to consider the interference of the chosen communication network to reduce the loss of data and to ensure the reliability of the IoT devices. Other issues in IoT are the security of the IoT devices and the privacy of the data.

F. Machine Learning in Agriculture

Farmers benefits from the innovation of technology in agriculture, specifically through the help of machine learning. As stated in the study by (Liakos et al., 2018), Machine learning enhanced digital agriculture, especially crop management, with its application on yield prediction that helped farmers enhance productivity. The study mentioned examples of ML applications in agriculture, one of those in the study of (Ramos et al., 2017), "an efficient, low-cost, non-destructive method that automatically counted coffee fruits on a branch using computer vision." The proponents mentioned above constructed a fruit-counting machine vision system. As a first step in estimating coffee production, this method substitutes for harmful counting resulting in counterproductivity of the tree. The technique identifies and divides coffee fruits into three categories. First, if it is harvestable; second, if it is not harvestable; and lastly, as fruits with disregarded maturation stage. The technique also determined the weight and maturation percentage of the coffee beans. The knowledge provided by this work can assist coffee farmers in organizing their agricultural activities and boosting economic benefits.

With relevance to the studies showcasing the effectiveness of algorithms used by machine learning in agriculture, as shown in a study by (Lewis & Espineli, 2020), Convolutional Neural Networks (CNN) notably provides the highest accuracy score in classifying and detecting nutritional deficiencies in coffee plants. The numbers proved that Convolutional Neural Network (CNN) is the most appropriate algorithm for recognizing and identifying images, above other deep learning neural networks. Various computer vision tasks also use CNN, mainly for image classification and object detection. The study was an opportunity to showcase deep learning, which solves challenging classification and detection problems that traditional computer vision algorithms cannot handle. Deep learning functions with artificial neural networks, developed to mimic how humans process information, while machine learning uses simple methods.

Another known algorithm for image recognition and classification is the Support Vector Machine (SVM). SVM is a supervised learning algorithm applied when working with regression and classification. According to the study by (Wang et al., 2020), which uses both CNN and SVM as an algorithm for image recognition, although SVM produced an excellent accuracy score, CNN still accumulated a higher accuracy score.

G. Synthesis

Food is one of the necessities of human life, and one way to create food is through agriculture. The amount of food produced globally is inversely proportional from the population growth leading to famine in some parts of the world, overworking farmers, and an uneven state of the economy.

The coffee industry has been thriving in the Philippines since the 1980s. Unfortunately, it shattered due to coffee leaf rust, a disease caused by a fungus that destroys the coffee bean tree. The industry never regained its former glory. Nevertheless, many farmers are still investing in it since Filipinos love coffee.

Farming is challenging, especially in the Philippines, where the government neglects farmers' rights. Many leave farming to go to a rural city to make more money and have sufficient income. Moreover, it takes many steps to produce something edible for human consumption. It is time-consuming, and in some cases, consumers are not satisfied with the quality and price of the product.

Although the agricultural sector in the Philippines is behind in terms of innovation and technological advances, some farmers who have the financial capability to upgrade their equipment still need to do so. Through the use of technology, human intervention is reduced. One example is the use of a machine to sort the coffee beans based on their sizes as well as their color. Furthermore, through technology, farmers reduced the cost of producing crops since they did not need to hire other farmers to do their work.

The above studies help the proponents deepen their knowledge and provide better insights about how the design project should be implemented, as well as present which machine learning algorithm can be used to integrate into the machine to acquire better results. Furthermore, it provided context about how the design project could help the beneficiary prepare coffee beans for human consumption.

Chapter 3
Design Methodology

A. Methodology

The design that the proponents used in this design project is experimental research design. Experimental research uses two or more variables to determine the cause-and-effect relationship between the variables (Tanner, 2002). The proponents used experimental research design on the design project because this design allows the proponents to identify whether the machine meets the objectives of the design project and benefits the beneficiary by comparing the performance of sorting dried coffee beans on the proposed sorting machine over the manually sorted coffee beans.

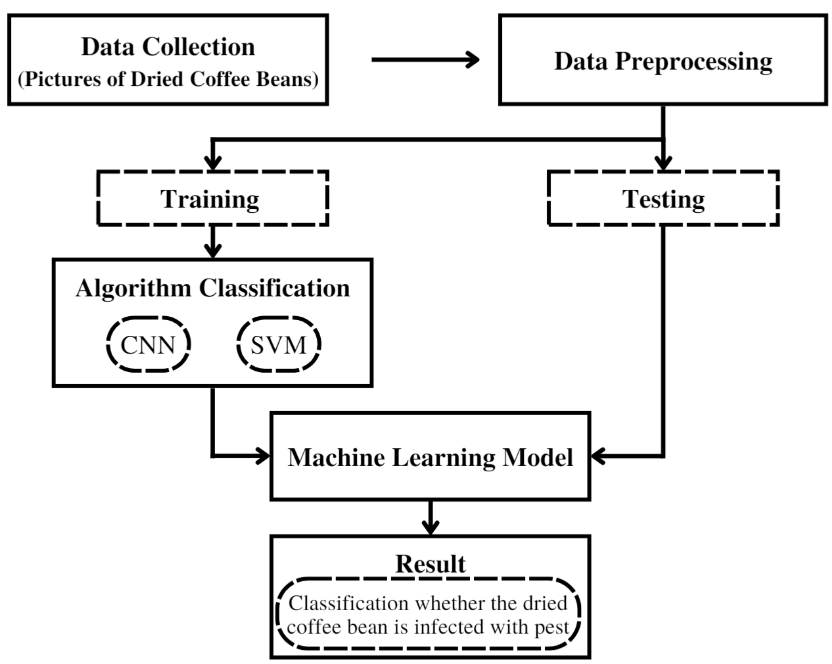


Figure 2. Design Project Methodology

Figure 2 above depicts the design project methodology used to obtain the expected output. The picture of the dried coffee beans will be used as input. It will go through data cleaning and organizing to omit unnecessary data that will confuse the machine using Python programming. Afterward, it will be split into training and testing data sets and through model training and predictions. After going through the steps, the machine will identify which dried coffee bean is infected with pests and which is not.

B. Respondents/Beneficiary of the Design Project

In this design project, the beneficiary is located in Purok 1, Pangil, Amadeo, Cavite, as shown in Figure 4. The farm is named "Rodil's Coffee Farm," with 1.4 hectares of coffee bean trees planted and managed by the head operator Mr. Francisco "Borg" Año, the son-in-law of the owner of the said farm. The coffee farm production is commercially called "Montanskopi." Furthermore, besides the farm, there is a small eatery called "Food Fiesta Pangil Amadeo Cavite" that also sells coffee products and goods produced by the farm.

Figure 3. Google Maps Screenshot of the Beneficiary's Location

Figure 4. The proponents with the beneficiary. Mr. Francisco "Borg" Año.

Figure 3 above shows the Google map screenshot of the farm's location. Now, in figure 4, is shown the first visitation of the proponents to the coffee farm; Mr. Francisco "Borg" Año guides and teaches the proponents the processes of their coffee farming procedure. Moreover, he showed and told the proponents about the other fruits and vegetables available on their farm. He stated some problems he encountered, which resulted in some of their coffee tree dying. Some of the issues he describes are the other tree, such as the pomelo tree, which overshadows the coffee bean tree, leading to low sunlight for the latter. Furthermore, some other plants absorbed the nutrients from the soil, making the coffee bean tree lacking in nutrients. After further discussion, he stated that the biggest problem he encountered was sorting the beans because he still hires some people to do the sorting, and the process takes too much time.

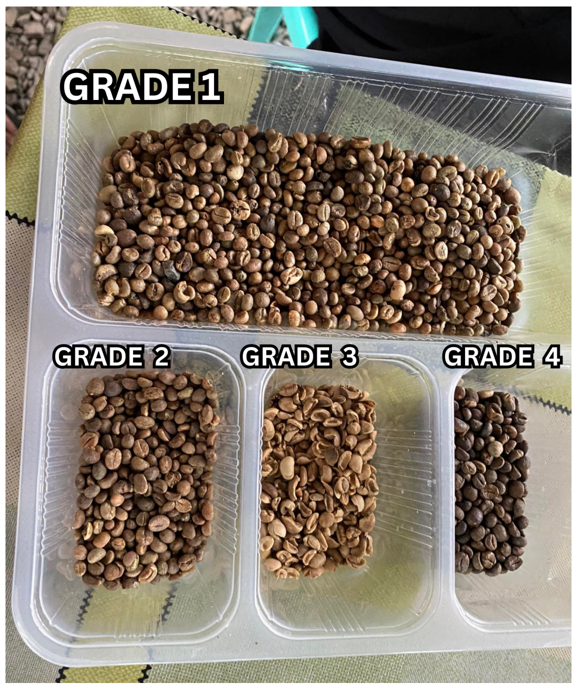


Figure 5. Sample Sorted Dried Coffee Beans.

In Figure 5, Mr. Año showed the proponents some sorted dried coffee beans to help the proponents identify the different classifications/gradings of coffee beans. Grade 1 is the light brown dried coffee beans that are best to roast and consume.

Grade 2 is the dark brown dried coffee beans; Mr. Año stated that these grading of coffee beans got wet during the drying process. Grade 3 is the light brown dried coffee beans that have damaged or imperfect dried coffee beans. Lastly, grade 4 is the dried coffee beans that had been pest-infected by the coffee bean borer and other things gathered during the harvesting and drying process, like small rocks or unpeeled coffee beans.

C. System Architecture

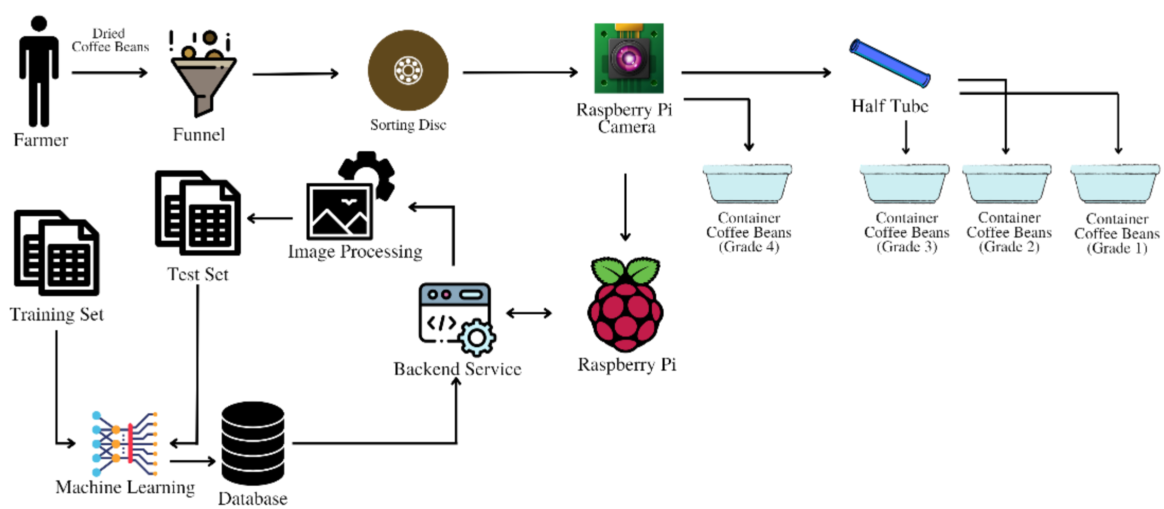


Figure 6. System Architecture

Figure 6 portrays the system architecture of the design project. The farmer/operator would place 500 grams of the assorted dried coffee beans into the funnel, which goes straight into a tube to the rotating disc. The RPi Camera would serve as the machine eye to identify the grades of the coffee beans. The machine would then sort the coffee beans into their containers.

D. System Block Diagram

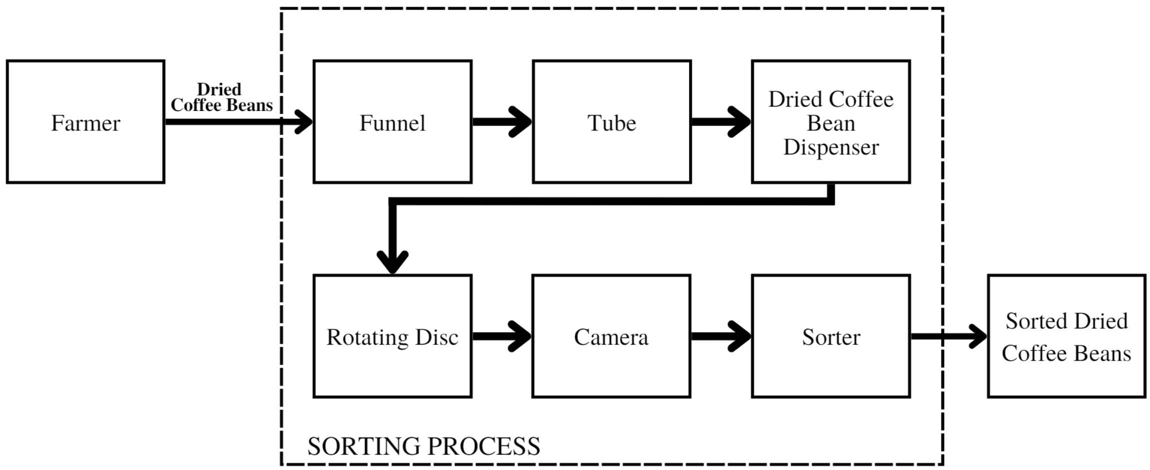


Figure 7. System Block Diagram of the Sorting Machine

Figure 7 exhibits the system block diagram of the low-cost coffee bean sorting machine. The operator/farmer would put a certain amount of assorted dried coffee beans into the funnel, leading the beans into the tube and to the rotating disc. After, the rotating disc would send the coffee beans into another tube where the RPi camera would help the machine identify its grade. Subsequently, the machine would sort the coffee beans into their corresponding container.

E. System Flowchart

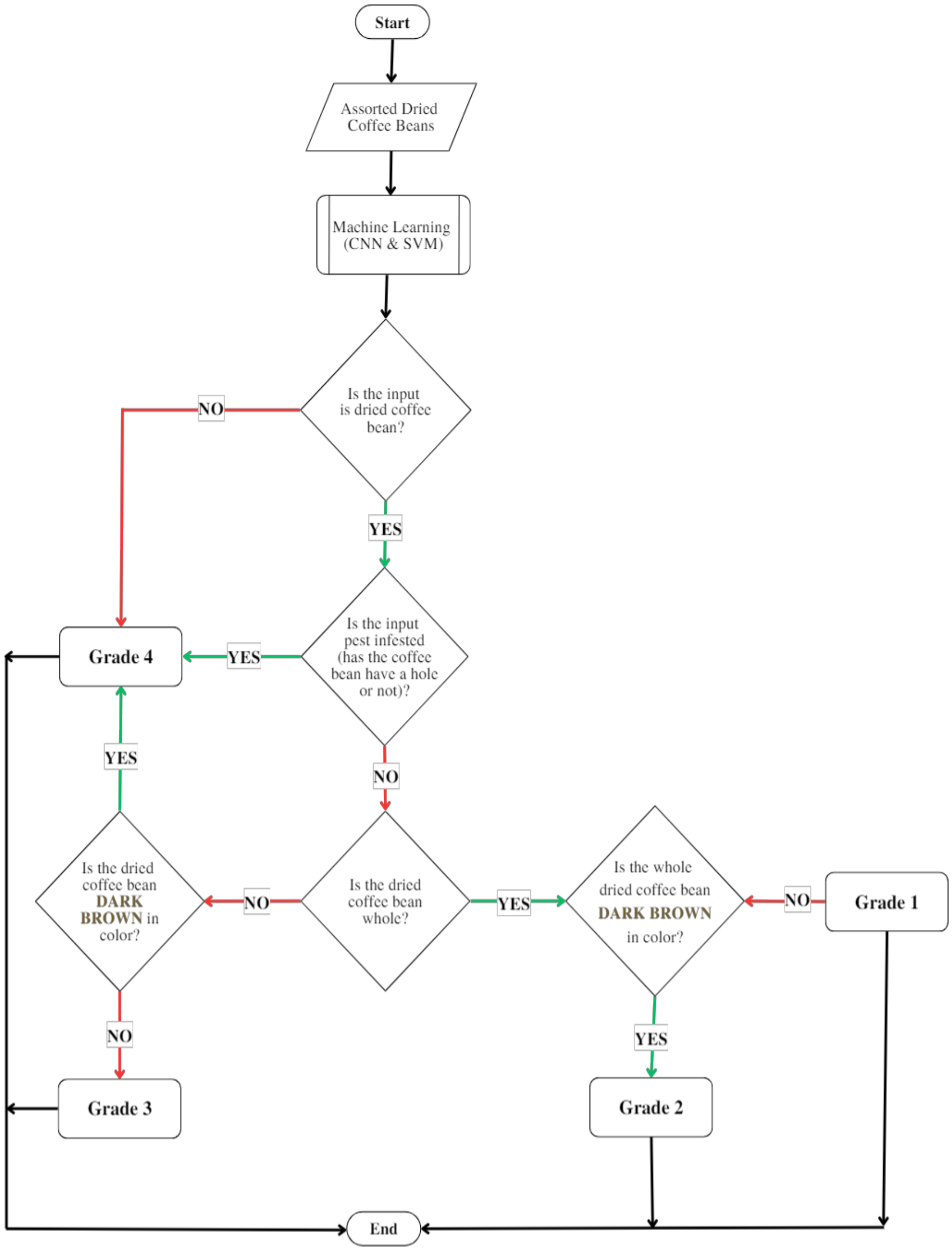


Figure 8. System Flowchart of the Sorting Machine

Figure 8 above indicates the system flowchart of the low-cost coffee bean sorting machine. After the assorted dried coffee beans enter the machine, it will then be identified whether it has a hole or not. The hole serves as the indicator of whether the coffee beans are infected with the coffee bean borer. If the coffee beans do not have a hole, the machine will then identify if the coffee bean is of great or good quality.

F. Hardware Requirements

The proponents used the following hardware components in creating the prototype of this design project.

Raspberry Pi 4 - Raspberry Pi 4 with 8GB ram is a microcomputer that the proponents used as the prototype's brain. This is where the main program of the prototype is located.

Figure 9. Raspberry Pi 4

Image Solid State Drive (SSD)- The researchers used Solid-State Drive (SSD) as a storage device for the Raspberry Pi operating system to maximize the computing speed and performance of the prototype..

Figure 10. Solid State Drive (SSD)

Power Supply (AC Adapter) – The AC Adapter was used to supply the necessary power for the prototype/

Figure 11. Power Supply (AC Adapter)

Servo Motor – An actuator that guides the coffee beans to their respective containers depending on the signal sent by the system.

Figure 12. Servo Motor

Geared DC Motor - A gear motor is an all-in-one combination of a motor and gearbox. This component rotates the disc so that the coffee beans would fall into the tube where the RPi Camera lies at the end.

Figure 13. Geared DC Motor

Arduino Mega - The Arduino Mega is a microcontroller board based on the ATmega2560. It is used as a slave in a master-slave communication, the Arduino Mega receives commands and data from the master device, processes them, and sends back responses or performs actions accordingly.

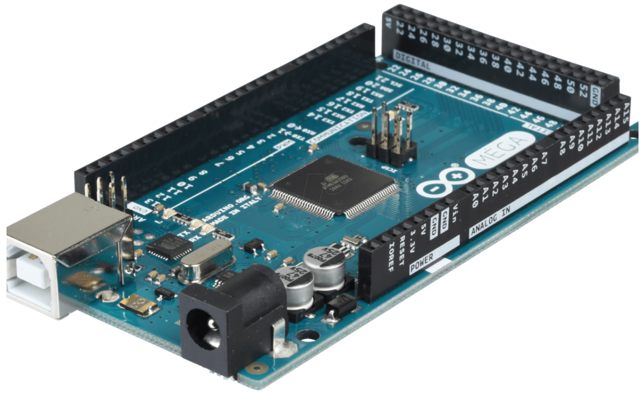


Figure 14. *Arduino Mega*

RPi Camera – This component was used to distinguish the grade of the coffee beans. The image that it captures were processed by the RPi4 which leads to the sorting of the coffee beans.

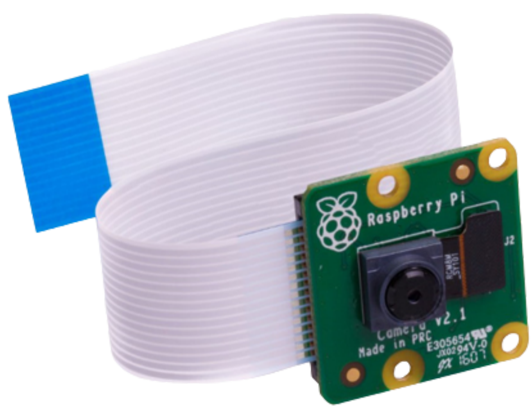


Figure 15. R*Pi Camera*

G. Software Requirements

The proponents used these software tools, programming languages and algorithms for the prototype to work.

Jupyter Notebook. A software that is used as IDE for the development of programs and for machine learning.

MySQL. A database management system where the data was stored.

Python. The Python programming language was used for machine learning. With the use of this programming language, the system was able to function, identify the quality of the beans and send the command to the actuators. Furthermore, the programming language was also used for MySQL queries.

SQLite. This application was used to store data in the database as commanded by the Python program.

RealVCN. A software used as a remote controller for the RPi. The software can also be used as a monitor for the RPi.

Convolutional Neural Network (CNN). Machine learning algorithm that will be tested.

Support Vector Machine (SVM). Machine learning algorithm that will be tested.

H. Data Gathering Procedures

The proponents used the data they gathered to create the dataset needed for the design project. The proponents visited the farm location in November 2022 to investigate and acquire knowledge about the coffee beans that the farm grows and how it was processed and become coffee grounds that are commercialized and sold. From there, the proponents bought 1.25 kg of assorted dried coffee beans. The proponents sorted the coffee beans and took pictures of them to use as data for the machine-learning part of the project. The proponents used 14000 total dataset which were separated into 80% training set and 20% testing set.

I. Testing Procedures

The proponents tested the accuracy and reliability of the low-cost coffee bean sorting machine by getting the accuracy and precision of the machine learning algorithms. Also, comparing the mean and t-test scores of the time it takes for the machine and human to sort the dried coffee beans served as a test for the effectiveness of the machine. Afterward, the proponents interpreted the results. The machine were also tested by comparing the time it takes for the prototype and human to sort a total of 100 dried coffee beans.

J. Design Project Validators

The proposed machine will be validated by Mr. Francisco “Borg” Año, the son-in-law of the farm owner and the head farm manager. Mr. Año will validate the proposed sorting machine to determine if it meets the desired objectives and benefits the farm. Mr. Año is a Bachelor of Science in Information Technology graduate from Ateneo de Naga University in 2008. He has been a lead developer at Accenture, Inc. since 2015. Also, Mr. Año previously worked in ABS-CBN Interactive and Digital Media Division as a web developer and application developer from 2011 to 2015. The proponents believe that Mr. Año can validate the machine through his knowledge and experience in the IT industry and farming.

K. **Design Project Evaluation Instrument**

The proponents compared the time it takes for the machine to sort the dried coffee beans and the time it takes for the human to sort the same amount of dried coffee beans. The comparison method helps answer how efficient and effective the machine is for the beneficiary and how it helps the coffee bean production process. Furthermore, the method provides context on where the machine is lacking and which part needs improvement.

A confusion matrix was implemented to appraise the model that the proponents used. The confusion matrix was used to calculate the value of the precision and accuracy of the model. Through this, the proponents could distinguish which algorithm to use in order for the machine to identify the coffee beans' quality correctly.

L. Statistical Treatment of Data

A statistical treatment is a method to turn meaningless numbers into meaningful output. The design project requires a statistical treatment to interpret the data gathered.

According to (Hayes, 2022), the mean is the average value of a group of numbers. The mean is computed by adding all values and then dividing the sum by the total number of values to get the average or central tendency of the data. The researchers will compute the mean to find out the average value of the data.

Formula for Mean:

$$A = \frac{1}{n}\sum_{i=1}^{n} a_i$$

The proponents will use a T-test to indicate the two sets of measurements to compare the values acquired from sorting the beans by human and by machine.

T-test is used to find and compare the significant difference in means between two samples or between a population and a sample (Bevans, 2020). The proponents will determine what type of t-test to use on the design project.

There are three types of T-test:

1. **One Sample T-test.** Used to compare the mean of a group against the set average (or mean).

2. **Two Sample T-test.** The commonly used (and misused) form of the t-test. It tests for significant differences in the means of two distinct populations.

3. **Paired T-test.** It is used to determine if there is a difference between the averages (means) of the two measurements.

Formula for T-Test:

$$t = \frac{m - \mu}{\frac{s}{\sqrt{n}}}$$

t = T-test

m = Mean

μ = Theoretical Value

s = Standard Value

n = Variable Set Size

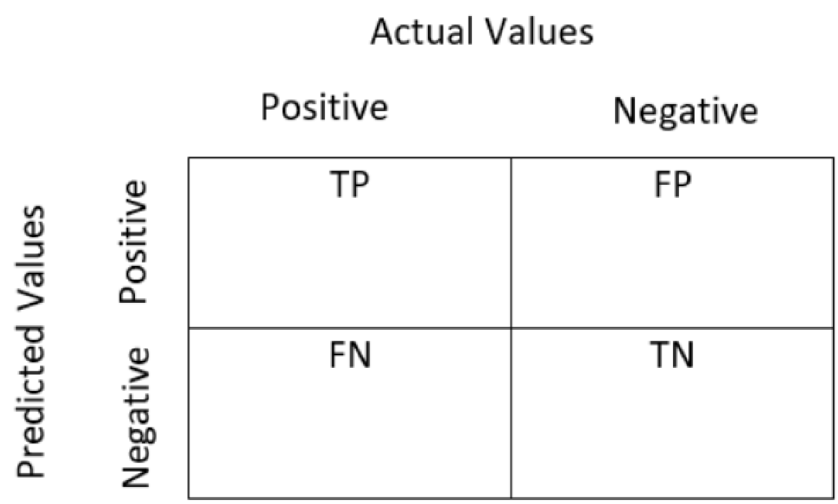
A confusion matrix is a table that is commonly used to describe the performance of a model. The matrix shows four classification outcomes, namely:

1. **True positive.** Which describes the number of predicted outcomes as actually positive,

2. **True negative.** Which depicts the number of predicted outcomes as really negative,

3. **False-positive.** Which describes the number of predicted outcomes identified as positive; however, it is a negative, lastly,

4. **False-negative.** which depicts the number of predicted outcomes identified as negative; however, it is positive.



Accuracy is the ratio of correct predictions to total predictions made. Based on the formula, it is calculated by dividing the summation of the total of true positive and true negative divided by the total of true positive, false positive, false negative, and true negative.

$$Accuracy = \frac{\Sigma\, TP + TN}{\Sigma\, TP + FP + FN + TN}$$

On the other hand, precision quantifies the number of correct positive predictions that belong to the positive class. Shown below is the formula for the precision in which it is calculated as the summation of true positive divided by the summation of the total of true positive and false positive.

$$Precision = \frac{\Sigma\, TP}{\Sigma\, TP+FN}$$

Mean square error (MSE) assesses the average squared difference between the observed and the predicted value. It measures the amount of measure in a statistical model, meaning if the MSE is zero, then the model that the proponents acquires has no error.

$$MSE = \frac{\sum(y_i - \hat{y}_i)^2}{n}$$

The above formula is the formula to acquire mean squared error where in:

y_i is the i^{th} observed value ;

$\hat{Y}i$ is the predicted value;and

n is the number of observations

Chapter 4

Presentation, Analysis, and Interpretation of Data

A. Project Description

Figure 19.1 Front View of the Whole Prototype

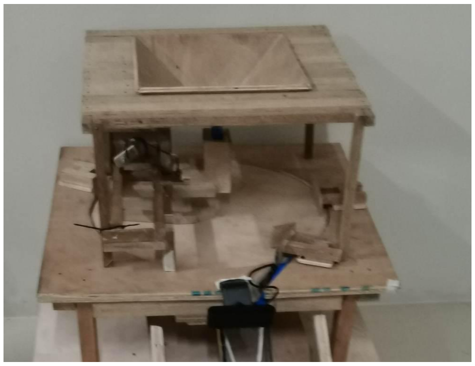


Figure 19.2 Dried Coffee Beans Alignment Part of the Prototype

Figure 19.3 Sorting Part of the Prototype

The prototype of the design project works by first gradually releasing the coffee beans into the dispenser through the funnel. The coffee beans will then be guided to form a line in order to go the tube. The tube serves as the bridge between the disk and the sorting station of the prototype. The web camera and RPi camera will then detect whether there is a bean aligned to its lens. If there is no coffee bean present within the lens of the cameras, the prototype will wait. If there is a coffee bean, then the machine will identify its grade. The servo motors would then direct the coffee into its respective containers.

B. Data Results

The main objective of the study was to design and develop a low-cost coffee bean sorting machine capable of identifying the grades of Robusta coffee beans cultivated from the beneficiary farm. In this regard, the proponents present the results of different tests which was done in order to determine whether the machine was effective and reliable.

Figure 19. Image of Grade 1

Dried Coffee Beans

Figure 20. Image of Grade 2

Dried Coffee Beans

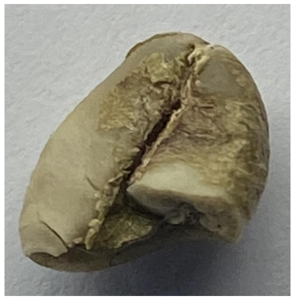


Figure 21. Image of Grade 3

Dried Coffee Beans

Figure 22. Image of Grade 3

Dried Coffee Beans

Pictures shown in Figures 19-20 are the Robusta coffee beans grown from the beneficiary's farm that was used as data to feed the machine learning algorithm of the coffee bean sorting machine. Grade 1 coffee beans are coffee beans that are used to produce ground coffee beans which are then commercialized to the public. Grade 2 coffee beans are coffee beans that were dampened during the drying process which results in their dark color. Grade 3 coffee beans are coffee beans that are not whole, while Grade 4 coffee beans are the accumulation of coffee beans that are pest infested, too dark colored, and those debris that were included unintentionally such as small rocks.

Characteristics	Grades			
	1	2	3	4
Colors				
Light Brown	0	0	30	0
Brown	30	0	0	0
Dark Brown	0	30	0	0
Black	0	0	0	15
Composition				
Whole	30	30	0	0
Not Whole	0	0	30	0
With Hole	0	0	0	15
Withouzt Hole	0	0	0	0

Table 1. Physical Characteristics of the Coffee Beans

Table number 1 shows the physical characteristics of the coffee beans that was tested by the proponents. There were 30 whole and color brown for grade 1, 30 whole and dark brown for grade 2, 30 not whole and colored light brown, while there were 15 color black and 15 with hole, which indicates that it was pest infested, grade 4 coffee beans.

Grades	Test Data			
	True Positive	True Negative	False Positive	False Negative
1	25	0	0	5
2	27	0	0	3
3	26	0	0	4
4	27	0	0	3

Table 2.Test Data for the Machine

The table above indicates the test data used in order to test the machines reliability and effectiveness in classifying different grades of the coffee beans. The machine were able to identify twenty-five out of thirty grade 1, twenty-seven out of thirty grade 2 and grade 4, twenty-six out of thirty grade 3. Based on the data on the table, the machine demonstrate a relatively high level of accuracy in recognizing grades 1, 2, 3, and 4 coffee beans. The result suggests that the machine shows that it is reliable and effective in sorting dried coffee beans.

Predicted \ Actual	Positive	Negative
Positive	25	0
Negative	5	0

Figure 23. Confusion Matrix for Grade 1 Coffee Beans

Figure 23 shows the confusion matrix for Grade 1 coffee beans. The proponents tested thirty (30) actual Grade 1 coffee beans where in the machine was able to correctly identify twenty-five (25) actual grade 1 coffee beans while it also recognizes five (5) grade 1 coffee beans as different grade. The confusion matrix indicates that as the machine success rate in identifying grade 1 coffee beans is 83.33% which implies that the machine demonstrated high accuracy in predicting grade 1 coffee beans.

Predicted \ Actual	Positive	Negative
Positive	27	0
Negative	3	0

Figure 24. Confusion Matrix for Grade 2 Coffee Beans

Figure 24 indicates the confusion matrix for Grade 1 coffee beans. The proponents tested thirty (30) actual Grade 2 coffee beans where in the machine was able to correctly identify twenty-seven (27) actual grade 2 coffee beans while it also recognizes three (3) grade 2 coffee beans as different grade. Based on the confusion matrix above, it can be denoted that the machine was proven accurate in identifying the grade 2 coffee beans.

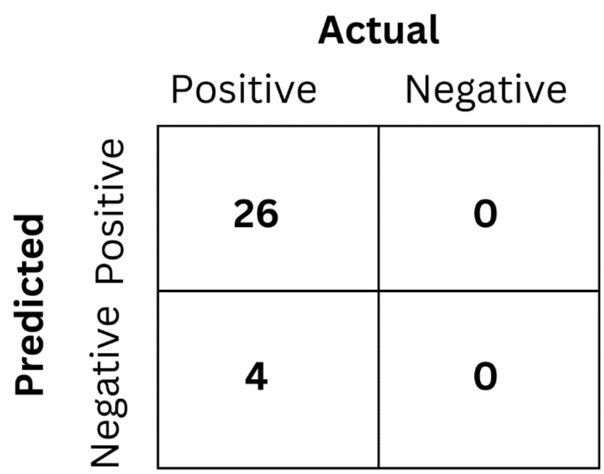


Figure 25. Confusion Matrix for Grade 3 Coffee Beans

Figure 25 displays the confusion matrix for Grade 3 coffee beans. The machine that was created by the proponents was able to correctly identify twenty-six (26) actual grade 3 coffee beans and distinguish four (4) grade 3 beans as different grade. The above confusion matrix indicates that the machine was accurate in identifying grade 3 coffee beans.

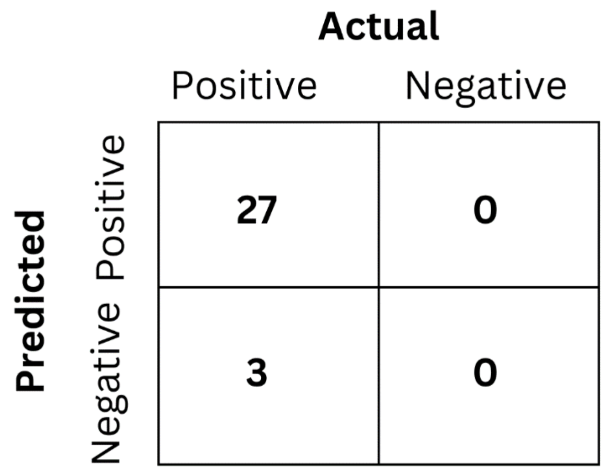


Figure 26. Confusion Matrix for Grade 4 Coffee Beans

Figure 26 exhibits the confusion matrix for grade 4 coffee beans. The machine was able to correctly identify twenty-seven coffee beans as grade 4 whilst three (3) were misidentified as another grade. The result above indicates that the machine were accurate in identifying the grade 4 coffee beans.

Coffee Bean Grades

	Grade 1	Grade 2	Grade 3	Grade 4
Accuracy	83.33%	90%	86.67%	90%
Precision	100%	100%	100%	100%

Table 3. Accuracy and Precision of the Machine

Table number 3 shows the accuracy and precision score of the machine that was created by the proponents wherein the precision score of all grades where 100% while accuracy differs from each grade such as 83.33% for grade 1, 90% for grades 2 and 4, and 86.67% for grade 3.

The proponents created two machine learning models which utilize Convolutional Neural Networks and Support Vector Machine to make the prototype work. A total of 14000 datasets were used in which it is separated into 80% training set and 20% testing set. The training was iterated 20 times in order to make sure that the models were able to identify the characteristics of a good quality coffee bean.

	Algorithms	
	Convolutional Neural Network	Support Vector Machine
Accuracy	98.89%	20.39%
Precision	98.97%	4.08%
MSE	0.33%	16.07%

Table 4. Accuracy, Precision, MSE for CNN and SVM

Table number 4 shows the accuracy and precision score of the machine learning models that the proponents created. The table indicates that the CNN model was more accurate, precise and has a low mean score error than the SVM. Wherein CNN model figures were 98.89%, 98.97% and 0.33% respectively. While SVM acquires 20.39%, 4.08% and 16.07%, respectively. The above table highlights the performance of the CNN model over the SVM model.. The accuracy score indicates that CNN model has a higher rate in correctly predicting the quality of the coffee beans compared to the SVM model. Identically, the precision score of the CNN suggests that it was able to make fewer false positive predictions compared to the SVM model. Additionally, the mean squared error indicates that the CNN model has a low error rate than the SVM model which acquires 16.07% indicating a greater average discrepancy between the predicted and actual value of the coffee beans. The above table indicates that the CNN model outperformed SVM model in terms of accuracy, precision and mean squared error.

The efficiency of the coffee bean sorting machine has been tested by comparing the time it takes for the sorting machine to sort a specific weight of the dried coffee bean and for the human to sort about the same amount of weight of the dried coffee beans.

	Duration of Trials	
Number of Beans	Prototype	Human
100	685 secs	391 secs
100	627 secs	406 secs
100	675 secs	384 secs

Table 5. Time comparison between the coffee bean sorting machine and manual sorting

The table above shows the time comparison between humans and the low-cost coffee bean sorting machine. The proponents tested the ability of the prototype to sort the coffee beans by sorting approximately 100 pieces of coffee beans. The prototype took twice the time it takes for human to sort the coffee bean.

	Mean	**T-test**
Prototype	662.33	11.27
Human	393.67	

Table 6. Mean and T-test Results

Table 6 Indicates the value of the mean between the result of the time comparison of the time it takes for humans and the machine to sort the coffee beans. Moreover, the table shows that the mean average time for the human to sort the machine is lower than that of the prototype. The proponents used a paired t-test to determine the difference between the means, whereas the result indicates a significant value of the difference between the two.

Item	Response	Interpretation
1	5	Strongly Agree
2	3	Neutral
3	3	Neutral
4	5	Strongly Agree
5	4	Agree
6	5	Strongly Agree
7	4	Agree
8	4	Agree
9	5	Strongly Agree
10	4	Agree

Table 7. Usability Scale Result

The table above indicates the response of the beneficiary to the post-prototype usability questionnaire that was given after the testing. Items number 1, 4, 6 and 9 received a score of 5 points from the beneficiary, these items revolves around the machines accuracy and effectiveness in sorting the coffee beans. While items number 5,7,8 and 10 revolve around the machines reliability, these items received a 4 points from the beneficiary.

Chapter 5
Conclusion and Recommendations

I. Conclusion

The proponents created a low-cost coffee bean sorting machine capable of sorting pest-infested Robusta coffee beans and identifying their grade based on their physical characteristics, such as whether it is whole or not and their color. The machine could identify the grades of the coffee bean with 83.33% - 90% accuracy and 100% precision for each grade. Moreover, the proponents created a machine learning model with two different machine learning algorithms: Support Vector Machine and Convolutional Neural Network. However, the proponents used CNN for their prototype as it garnered higher accuracy and precision, 98.89% and 98.97%, respectively, compared to SVM, which accumulates accuracy and precision of 20.39% and 4.08%, respectively. The mean time it took for the prototype of the design project was 662.33, while the mean time for humans to sort the coffee beans was 393.67, which means that the prototype was much slower than the human.

The prototype of the design project poses great potential for commercial use of the targeted market. Moreover, the prototype does well in sorting the coffee beans based on its quality.

II. Recommendation

The design project aims to create a low-cost coffee bean sorting machine. Creating a sorting machine with limited time and money makes the proponents more flexible in thinking of alternative materials and ways to make the sorting machine efficient and valuable. For future researchers aiming to create a low-cost coffee bean sorting machine, the proponents highly recommend the following:

- Create an IoT system so the farmer/operator can access it anywhere.
- Add additional raspberry pi cameras. The proponents used one RPi Camera and a webcam as the machine's eye for sorting. Having another RPi Camera provides vivid images making the machine more reliable in sorting the coffee beans.
- Use other low-cost materials as an alternative for the component's main parts that affect the machine's performance and a better and firm foundation for the machine's build.
- Use better and clearer cameras to distinguish the coffee beans better and increase machine performance.
- Reduce the epoch when training the model that will be used in order to reduce the precision. Too much precision leads to the machine looking at every detail in the data being fed, resulting in misidentification of the quality of the coffee beans.
- Design a more efficient mechanism for the alignment and sorting of the dried coffee bean

By addressing these recommendations, the low-cost sorting machine can continue to evolve and offer improved functionality, cost-effectiveness, and usability, empowering coffee farmers and processors while contributing to the sustainable growth of the coffee industry.

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Appendices

Appendix A

Design Project Validator Curriculum Vitae

FRANCISCO LINO U. AÑO
1037 Pangil Rd, Pangil, Amade Cavite
+63917.808.1428
francisclin@gmail.com

CAREER OBJECTIVE

To apply my knowledge and skills to the existing and new technological developments related to Information Technology and develop the necessary professional expertise needed to enhance efficiency of the technical and business operations of the Company.

TECHNICAL SKILLS AND CAPABILITIES

- Develop websites using Sitecore, PHP, MySQL, C#, MsSQL, Oracle, HTML/HTML5, Wordpress. Use MVC architecture to websites developed; Knowledgeable on software such as Visual Studio 2012, Git Software, Azure Storage Explorer software, Adobe Photoshop, Adobe Flash, and Adobe Dreamweaver; and computer software/hardware troubleshooting.
- Accustomed to work in a team
- Proficient in MS Office Applications (Word, Excel, PowerPoint, Access, Visio, Project)
- Decent oral and written communication
- Can work without close supervision.

EDUCATIONAL BACKGROUND

COLLEGE	Ateneo de Naga University Ateneo Avenue, Naga City B.S. Major in Information Technology	2002 - 2008
HIGH SCHOOL	Ateneo de Naga University Ateneo Avenue, Naga City	1998 to 2002
ELEMENTARY	Naga Parochial School Ateneo Avenue, Naga City	1992 to 1998

WORKING EXPERIENCE

2015 Accenture Inc (September 2015-Present)
- Lead Developer

2014 ABS-CBN Digital Media Division (September 2013-15)
- Web Developer

2011 ABS-CBN Interactive (August 2011 – September 2013)
- Application Developer

- http://mmk.abs-cbn.com (PHP-MySQL)
- http://pamaskongbati.abs-cbn.com (PHP-MySQL)
- http://nickschoolpromo.abs-cbn.com (PHP-MySQL)

SEMINAR ATTENDED

January 21 – 25 2013	Sitecore CMS Training 9th flr ELJCC Building, Diliman Quezon City
November 2012	Agile/Scrum Training 13th flr ELJCC Building, Diliman Quezon City
November 18, 2006	CONVERGENCE (Regional IT Congress 2006) Avenue Square Magsaysay Avenue, Naga City
February 17, 2007	CONVERGENCE (Regional IT Congress 2007) Naga Regent Hotels Ellias Angeles st, Naga City

PERSONAL DATA

Age: 29	Civil Status: Single	Gender: Male
Birthday: August 12, 1984	Nationality: Filipino	Religion: Roman Catholic

PERSONAL REFERENCES

Miguel C. Katigbak
Technical Head, ABS-CBN Interactive

Eugene C. Paden
Managing Director, ABS-CBN Global

Ronald B. Rodil
Solutions Architect, ABS-CBN Digital Media Division

Appendix B

Post-Prototype Usability Questionnaire

UNIVERSITY OF THE EAST
COLLEGE OF ENGINEERING
COMPUTER ENGINEERING DEPARTMENT

Post-Prototype Usability Questionnaire
Reglos, N.R., Nares, A.J., Rolda, M.A., Tio, R.R.

Good day!

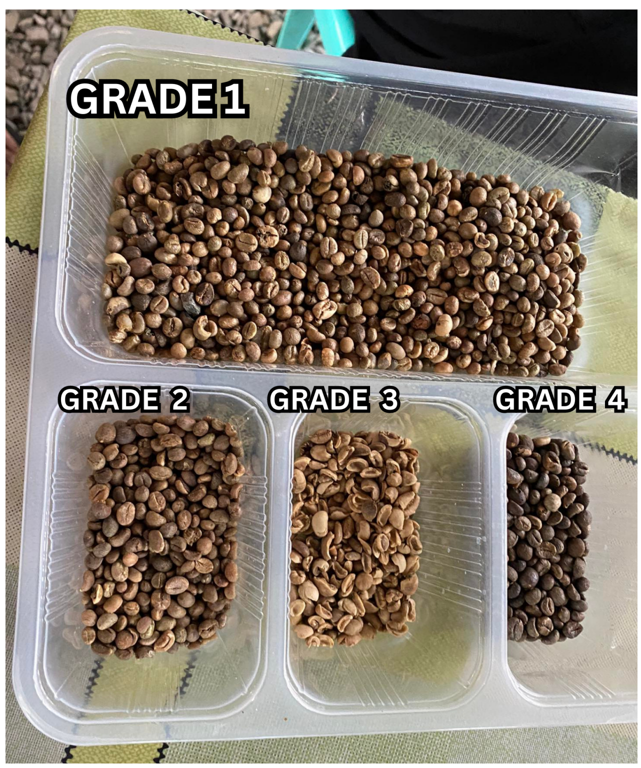
I hope you're doing great! I just wanted to ask if you could spare a few minutes to fill out our Post-Prototype Usability Questionnaire about our study titled "**DESIGN AND DEVELOPMENT OF A LOW-COST COFFEE BEAN SORTING MACHINE THROUGH MACHINE LEARNING**". Your feedback will be incredibly valuable.

Thank you in advance for your time and input. Feel free to reach out if you have any questions or need any assistance.

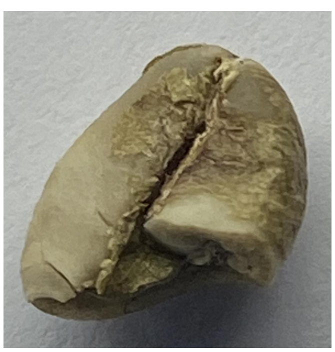
Post-Prototype Usability Questionnaire	Strongly Agree				Strongly Disagree
Questions	5	4	3	2	1
The prototype works as it's intended to.					
I was able to complete the sorting process quickly using the prototype.					
I felt comfortable using the prototype.					
The prototype helps coffee farmers manage their time efficiently while using the prototype					
I believe I could become productive using this prototype.					
The prototype finds it easy to distinguish the pest-infested coffee beans.					
The prototype's coffee bean grading is consistent					
The prototype was able to sort the coffee beans according to their grades effectively					
The prototype helps produce good-quality coffee beans.					
Overall, I find the prototype very easy to use.					

Appendix C

Design Project Beneficiary Visitation Pictures

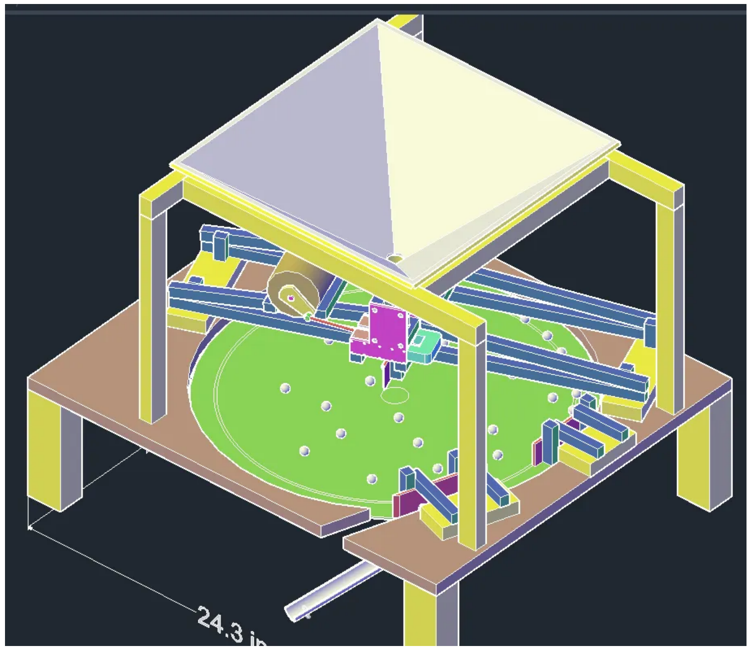


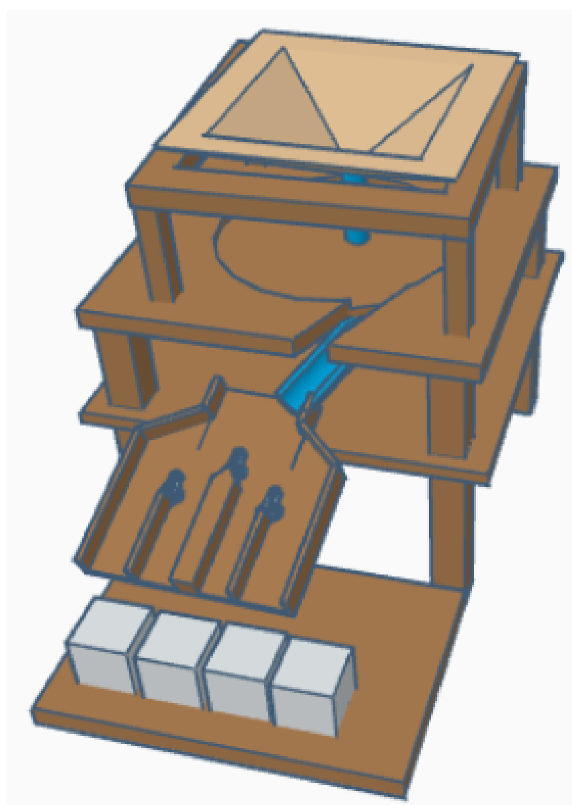

Pangil Rd
Rodil's Coffee Farm
- TiyoMontansKopi
Food Fiesta Pangil
Pangil Rd

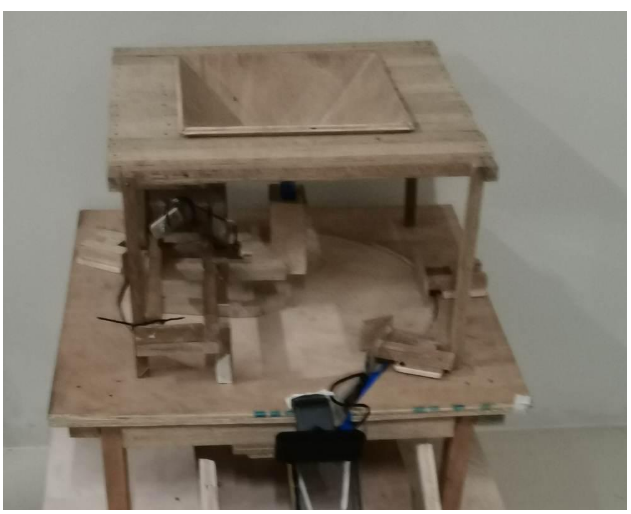


Appendix D

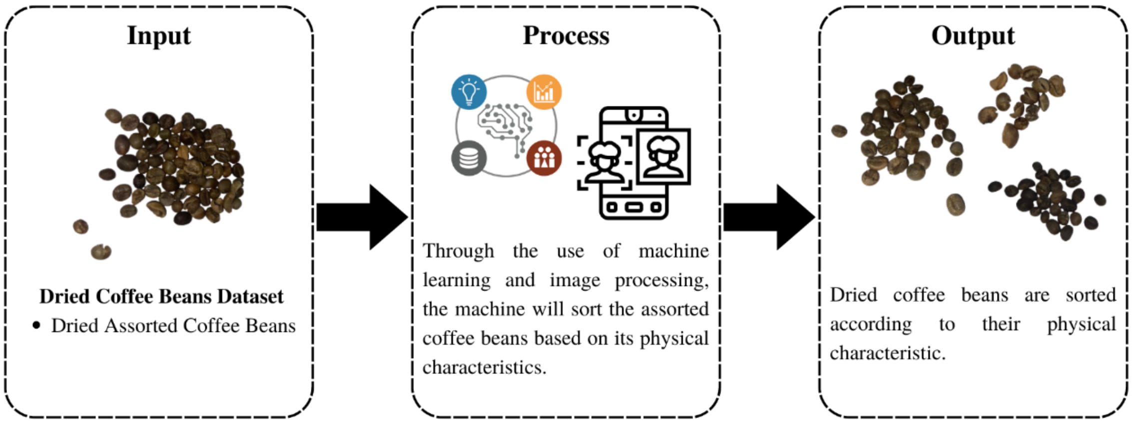
Design Project Prototype Outcome

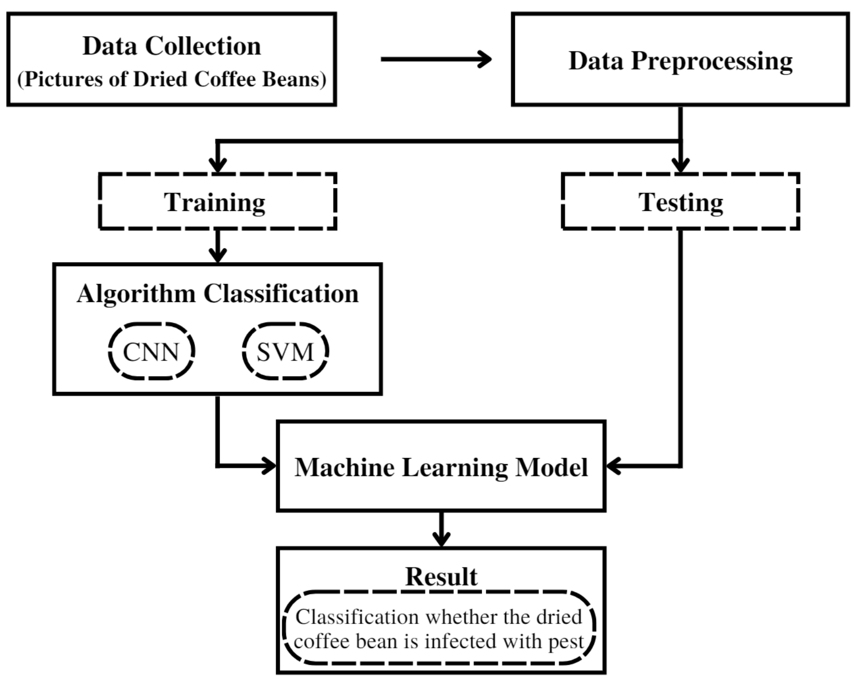


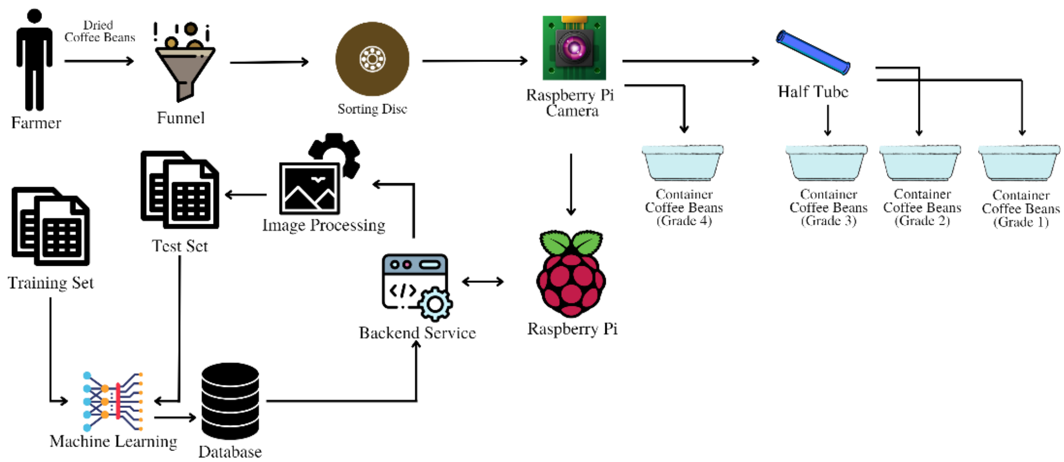


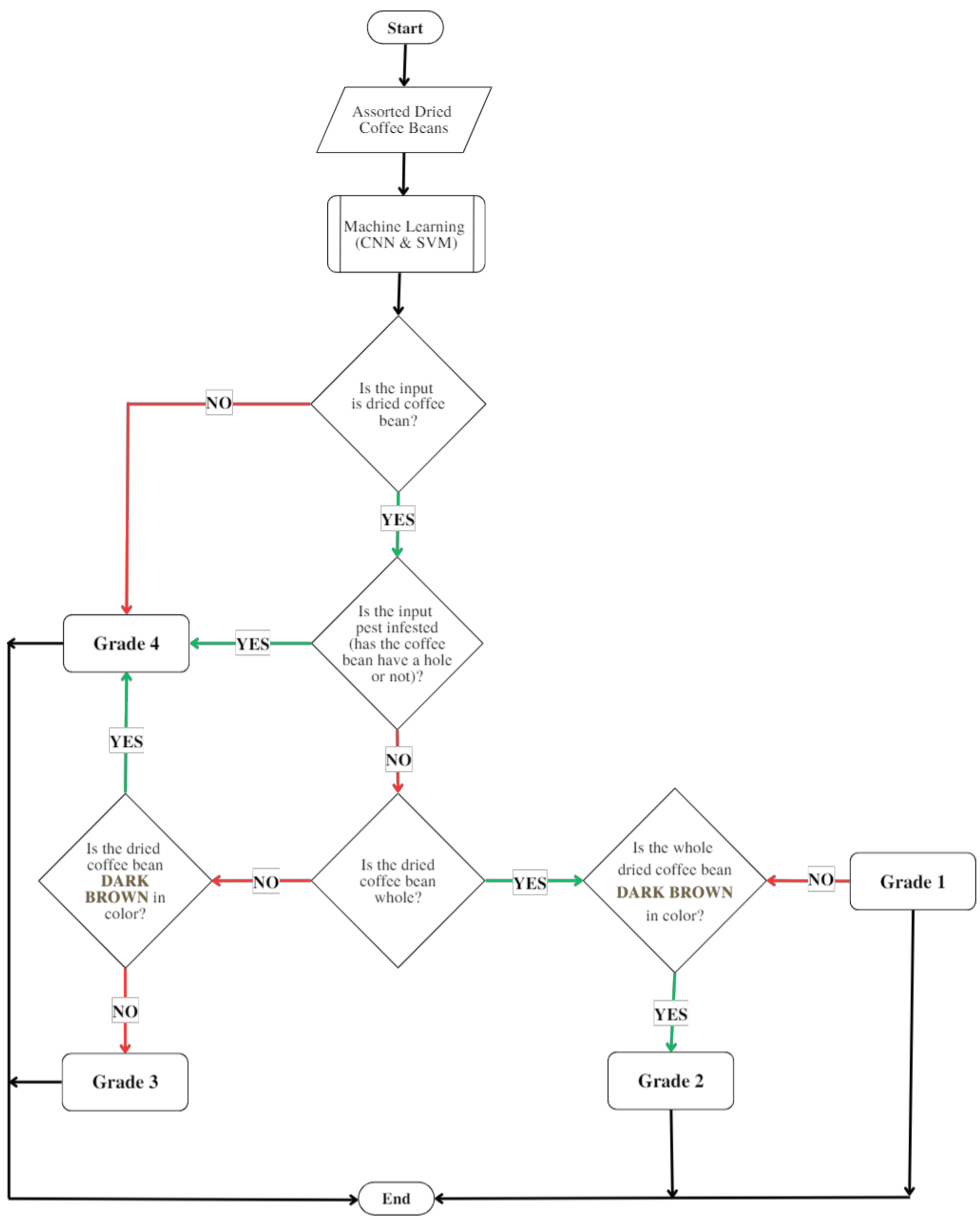


Appendix E
Design Project Figures






Farmer
Dried Coffee Beans
Funnel
Sorting Disc
Raspberry Pi Camera
Half Tube
Container Coffee Beans (Grade 4)
Container Coffee Beans (Grade 3)
Container Coffee Beans (Grade 2)
Container Coffee Beans (Grade 1)
Training Set
Test Set
Image Processing
Backend Service
Raspberry Pi
Machine Learning
Database


Start
Assorted Dried Coffee Beans
Machine Learning (CNN & SVM)
Is the input is dried coffee bean?
NO
YES
Is the input pest infested (has the coffee bean have a hole or not)?
YES
NO
Grade 4
Is the dried coffee bean whole?
NO
YES
Is the dried coffee bean DARK BROWN in color?
YES
NO
Grade 3
Is the whole dried coffee bean DARK BROWN in color?
YES
NO
Grade 2
Grade 1
End

Appendix F

Design Project Tables

		Actual Positive	Actual Negative
Predicted	Positive	**25**	**0**
Predicted	Negative	**5**	**0**

		Actual Positive	Actual Negative
Predicted	Positive	**27**	**0**
Predicted	Negative	**3**	**0**

		Actual Positive	Actual Negative
Predicted	Positive	**26**	**0**
Predicted	Negative	**4**	**0**

		Actual Positive	Actual Negative
Predicted	Positive	**27**	**0**
Predicted	Negative	**3**	**0**

Characteristics	Grades			
	1	2	3	4
Colors				
Light Brown	0	0	30	0
Brown	30	0	0	0
Dark Brown	0	30	0	0
Black	0	0	0	15
Composition				
Whole	30	30	0	0
Not Whole	0	0	30	0
With Hole	0	0	0	15
Withouzt Hole	0	0	0	0

	Test Data			
	True Positive	True Negative	False Positive	False Negative
Grades				
1	25	0	0	5
2	27	0	0	3
3	26	0	0	4
4	27	0	0	3

Coffee Bean Grades

	Grade 1	Grade 2	Grade 3	Grade 4
Accuracy	83.33%	90%	86.67%	90%
Precision	100%	100%	100%	100%

Algorithms

	Convolutional Neural Network	Support Vector Machine
Accuracy	98.89%	20.39%
Precision	98.97%	4.08%
MSE	0.33%	16.07%

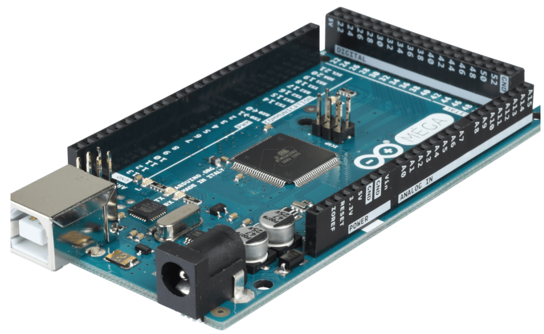
Duration of Trials

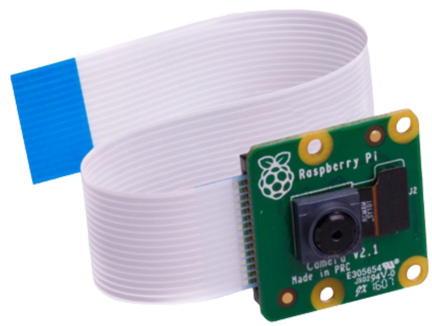
Number of Beans	Prototype	Human
100	685 secs	391 secs
100	627 secs	406 secs
100	675 secs	384 secs

	Mean	T-test
Prototype	662.33	11.27
Human	393.67	

Item	Response	Interpretation
1	5	Strongly Agree
2	3	Neutral
3	3	Neutral
4	5	Strongly Agree
5	4	Agree
6	5	Strongly Agree
7	4	Agree
8	4	Agree
9	5	Strongly Agree
10	4	Agree

Appendix G
Design Project Hardware Requirements Figures




Raspberry Pi