MedChecker: A Portable Device to Detect Counterfeit Medicine

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DEPARTMENT OF COMPUTER ENGINEERING

APPROVAL SHEET

The proposed design project entitled **"MedChecker: A Portable Device to Detect Counterfeit Medicine"** which was presented on the June 2022 by the proponents:

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is hereby APPROVED by the following members of the committee:

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Head Panel Member

Engr. Rufo I. Marasigan Jr.
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ACCEPTANCE SHEET

The proposed design project entitled **"MedChecker: A Portable Device to Detect Counterfeit Medicine"** has been prepared and submitted by the proponents:

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for approval to the committee for the Design Project.

After a thorough review and evaluation of the proposed design project, the committee has accepted the presented system based on the required criteria.

The acceptance is valid to the information being presented, accepted this June 2022, 2nd semester, 2021-2022 S.Y.

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The Authors

PROJECT ABSTRACT

Title: Med Dev: A Portable Device to Detect Counterfeit Medicine

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Around the world, counterfeit medicines, often known as fake medicines, remain a major concern. These appear similar to the authentic medicine but include incorrect dosages or substances, which can cause a variety of health issues when consumed. Since the vast majority of current solutions include laboratory equipment, which calls for a high level of technical skill and devices that are extremely expensive, the majority of those affected, who live in poor and middle income countries, are completely out of reach. The goal of the project's developers was to build a portable device that uses machine learning algorithms to identify counterfeit medicines. And in order to achieve this, we initially selected local pharmacists and medicine consumers in the Philippines as our project's clientele. After conducting a survey to ascertain their demands, we came up with the following standards: high prediction accuracy, affordability, and portability. We gathered the required dataset, which includes authentic and counterfeit medicines obtained from authorized and unauthorized sources. With the aid of analyses and various computations, the developers of this project compared and contrasted various design options with each respective percentage accuracy, overall cost, weight, and height in order to come up with the best option to offer for the clients that most closely matches their criteria. The final result of this project is a device that can identify counterfeit medicines using the combination of a 13 MP Arducam camera module and Faster RCNN Inception V2 machine learning model.

Keywords: *counterfeit medicines, counterfeit pharmaceuticals, counterfeit detection, counterfeit medicine device, counterfeit portable device, machine learning algorithms, machine learning model*

Engr. Rufo I. Marasigan Jr.	**Engr. Marte D. Nipas**
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Chapter 1
PROJECT BACKGROUND

This chapter contains background information about the project, objectives, potential clients identified by the proponents, scope and limitations, and the entire project development process.

1.1 THE PROJECT

1. Technology Trend

Counterfeit medicines, often known as counterfeit drugs, are pharmaceuticals developed solely to deceive the general public about their origins, effectiveness, and legality. It's mostly made up of substances that aren't inappropriate quantities or aren't of good quality. This can be found in a wide variety of places, including a street pharmacy, an online store, or a legitimate supply chain. In order to avoid this in the past and now, people have become quite accustomed to visually inspecting a medicine to guarantee that it is authentic. However, as we move into the technological age, the strategies of counterfeiters are becoming more advanced, as are the technologies that can effectively counter them. There have been innovations along the medicine's distribution line that have focused on forensic procedures and systems that can transmit unique authenticated data to it. Nirone, for example, enables pharmaceutical companies to efficiently verify their products at any point in their supply chains, from manufacturing to distribution, or in almost any field where product authentication is required. And, down to the market who will receive the distributed medicines there are technologies or devices that are based on a scan-and-send method like RxAll - an AI-hyperspectral platform and a patented molecular sensor device with a database of spectral signatures of medications to carry out non-destructive pill authentication is one of these technologies. Although these technologies have the potential to significantly reduce the distribution of counterfeit drugs, these are frequently prohibitively expensive.

2. Current situation of the target users

The Pharmaceutical Security Institute reported 196 occurrences of pharmaceutical crime in 2002. However, the annual number of such instances has risen dramatically over time, reaching over 5,000 in 2019. Morbidity and mortality are two of the most significant effects on human health. It is well acknowledged that pharmaceutical counterfeiting is on the rise and that there are more ways than ever to obtain medications from unauthorized sources. According to the WHO, counterfeit medications account for between 1% and 10% of all drugs sold worldwide, with up to 50% in some countries. And, counterfeit medicines (including those of poor quality) account for more than 10% of total sales in low and middle-income countries and less than 1% in developed ones. The main public health and economic repercussions of the expanding trade in counterfeit pharmaceuticals are disproportionately harming poor people in developing nations with weak regulatory and enforcement capabilities, as opposed to industrialized countries with more controlled and transparent supply chains. This has obvious public health ramifications, as it increases drug resistance and negates all of the previous efforts in the impoverished world to provide medicines to treat these life-threatening illnesses. Moreover, central laboratories are mostly equipped to analyze counterfeit medicine, and the countries most affected by fake and substandard drugs have restricted access to such laboratories. Some technologies are suitable for use in the field with little training, while others necessitate expensive laboratory equipment and a high level of technical skill.

3. Identified Problems

Medicine counterfeiters focus on reaching low and middle-income countries, where most individuals lack the resources to recognize counterfeit medicine and may have difficulty using existing solutions.

1. Existing technologies are incredibly expensive.
2. Some technologies require laboratory equipment and necessitate a high level of technical skill.
3. The checklist guidelines for visual inspection can be difficult and inconvenient for certain individuals.

4. Proposed Solution

MedDev is a portable device that relies on visual inspection to detect or raise suspicions whether the medicine is counterfeit or not.

1.2 PROJECT OBJECTIVE

The proponents' general objective is to develop a system that will help the affected individuals identify counterfeit medicine.

1. To develop an affordable device for detecting counterfeit medicines.
2. To detect counterfeit medicine without the use of chemical analysis.
3. To develop a device that is handy or compact.
4. To provide an accurate and trustworthy prediction of whether a medicine is counterfeit or not.

1.3 THE CLIENT

This project will help people greatly in detecting counterfeit medicines. The project's potential clients are the following:

Medicine Consumers

For the manufacturing of the drug, the supplier may give altered, expired, low-quality, or other raw materials, which has an indirect impact on the quality of the drug produced and the patient's safety. As a result, to ensure that these consumers do not lose faith in the benefits of drugs and stop taking their medications.

Community Pharmacists

A counterfeit drug factory creates pharmaceuticals that resemble the real drug, but does not have a quality assurance department to ensure that the drugs manufactured are of high quality, and distributes the pills directly to the distributor. This is to assist them by ensuring that their medication supply is legal.

With this, the proponents gathered a total of 10 people who are also medicine consumers to serve as survey respondents in order to thoroughly study the specific needs of the potential clientele listed above.

1.4 REQUIREMENTS AND SPECIFICATIONS

This section will include a list of the requirements specified by the project's clients. Table 1-1 shows the results of the surveys completed by clients in the left column. The right column contains the specifications for each of that requirement. This will be used as a guide for determining factors in the following chapters.

Table 1-1 Client Requirements and Specifications

Client Requirements	Specifications
The device should be reasonably priced.	Overall cost of each device should be priced no more than 13,000 pesos.
The device must accurately detect whether or not the medicines are counterfeit.	The permissible percentage range of accuracy of each device should be 85 percent higher.
The device should be lightweight.	The device should not weigh more than 5.1lbs or 2,313g.
The device should be compact.	The device’s measurements should not exceed 7"x7"x7" or 343 in^3.

1.5 PROJECT SCOPE AND LIMITATIONS

The following is the specific scope of this design project:

1. It can only recognize the physical appearance of a medicine.
2. Only one medicine can be detected at a time.
3. And, only generates results for medicines listed in FDA Advisory No. 2020-1348.

The following are the limitation of MedDev:

1. Other types of drugs, such as liquid, topical, patches, inhalation, injectable, and those with a coated layer packaging, are not detected or scanned.
2. Barcodes in pharmaceutical packaging are not detected or scanned.
3. And, only provides output to medicines that are readily available in the Philippines.

1.6 PROJECT DEVELOPMENT

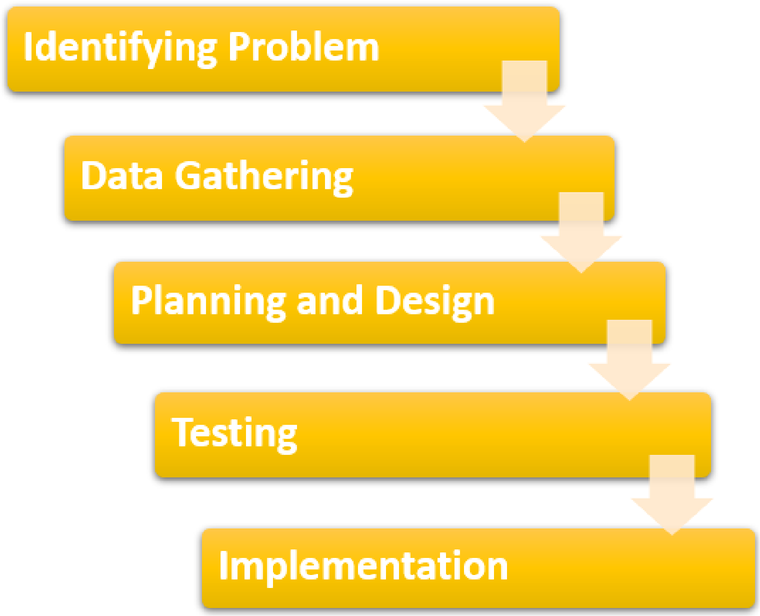


Figure 1.1 Waterfall Model

The initial process in this project's development is to identify the problem. Counterfeit medications have unfortunately continued to rise in demand, affecting practically all countries and posing a severe public health hazard that has taken a silent but devastating toll on society. The persons who do not have access to existing technologies such as laboratory equipment or other devices for detecting counterfeit medicines are the biggest sufferers. Thus, creating a device specifically for them will be quite beneficial.

The proponents gather data from related e-books, journals, articles and news, and other internet sites connected to modern technologies that can be employed on detecting counterfeit medicines from simple to complex tests in the second process of project development.

The third process is planning, to plot the best inputs that the proponents can choose from by taking into consideration creating a visual inspection technology that will allow both consumers and sellers of medicines to easily detect counterfeits without the use of laboratories or chemicals.

The fourth process is designing, in which the proponents will choose which design options are suitable for this project. Client requirements should be used as a starting point for proponents to meet their demands throughout the process.

Testing is the sixth process. Assuming that the project has already been completed with the intended design, it should satisfy the client's needs. As a result, the proponents will be able to improve from any mistakes that have been made.

Implementation is the final process in the project lifecycle. The project must be completed and the constraints met by using various testing and verifying the device's capacity. If the prototype and system work well and match the needs of the clients, the prototype may be ready to go to market.

Chapter 2
DESIGN INPUTS

This chapter describes the client requirements for the project, as well as the design criteria and constraints. It also includes the information obtained for the project that will help it succeed.

2.1 CLIENT REQUIREMENTS

1. The device should be reasonably priced.
2. The device must accurately detect whether or not the medicines are counterfeit.
3. The device should be lightweight.
4. The device should be compact.

2.2 DESIGN CRITERIA/CONSTRAINTS

The proponents developed the project using design criteria based on the client's requirements. However, some constraints may aid in shaping the project to meet the client's exact needs. Both are presented in the table below:

Table 2-1 Design Criteria and Constraints

Design Criteria	Design Constraints
Overall cost of each device should be priced no more than 13,000 pesos.	Cost
The permissible percentage range of accuracy of each device should be 85 percent higher.	Accuracy
The device should not weigh more than 5.1lbs or 2,313g.	Portability
The device's measurements should not exceed 7"x7"x7" or 343 in^3.	

Cost

The materials and components required for this project will be broken down in this estimate. The device's entire cover, camera, display screen, modules, rechargeable battery, microcontroller unit and minor components are all crucial components of the design. Moreover, the overall cost of each device should not exceed 13,000 pesos. This equation should be used by the proponents to compute the total cost of each proposed design and to compare them:

Cost = Σ cost of components (PHP)	(Equation 1: Cost Computation)

Accuracy

This is about the system's prediction output and whether or not it can be accepted by the proponents' clients; according to them, 85 percent or higher is acceptable for this. When curating the system's workflow, must assess both the camera module and the machine learning models separately and jointly by first weighing the best combination of the camera module's dataset and machine learning model by choosing the highest mean average precision per machine learning model.

Moreover, a training data set will be used to train each of the models. And, each will next be applied to a test or validation data set that is separate from the training data to ensure its quality. In this, the mAP is calculated using the prediction outcome of the model on the validation data set.

Following that, the researcher must be able to test each machine learning model with its own paired camera module in order to map its accuracy using the formula below:

Accuracy = $\frac{Number\ of\ correct\ predictions}{Total\ number\ of\ predictions}$	(Equation 2: Accuracy Computation)

Portability

The ability of a device to move from one location to another is referred to as portability. It's also known for its lightness and compactness. Thus, this constraint will be considering two parameters specified by their clients namely the weight and size of each device whereby the weight must not exceed 2,313g or 5.1 pounds and the dimension must not exceed 7”x7”x7” or 343 in^3. And, to determine how light each design option to be considered portable, we must consider the full weight of each device by using the formula below and compare it respectively:

Weight = Σ weight of components (g)	(Equation 3: Weight Computation)

2.3 RELEVANT INFORMATION

This section of the study will present a brief overview of the data the proponents gathered about their topic, such as several ways to identify a medicine and a counterfeit one, as well as its in-depth study to gain more knowledge that will help them curate three design options. With that, we can have a sense of ideas on what we should consider as we design the system.

2.3.1 Counterfeit Medicines

A counterfeit product is defined by the Philippine Republic Act No. 8203, also known as the "Special Law on Counterfeit Drugs," as a medicine with the correct ingredients in the wrong amounts, wrong ingredients, no active ingredients, or a sufficient quantity of active ingredient that reduces the drug's safety, efficacy, quality, strength, or purity. Drug counterfeiting can be classified into six types and sizes, each with its own set of analytical procedures for detection (Degardina et al., 2014) (18).

1. 32.1 percent of products do not contain an active ingredient.
2. Products with an incorrect amount of the active ingredient: 20.2%
3. 21.4 percent of products are made with the incorrect material.
4. 15.6 percent of products contain the correct amount of active ingredients but are packaged incorrectly.
5. 1% of the original copy of the exact product
6. 8.5 percent of products have high levels of pollutants

Moreover, any drug or drug product that is so colored, coated, powdered, or polished that the damage is hidden, or that is made to appear better or of greater therapeutic value than it really is, that is not labeled in the prescribed manner, or that has any statement, design, or device on the label, container, or anything else that comes with the drug that makes a false claim for the drug or that is false or misleading. Any drug or drug product whose container is constructed, shaped, or packed in such a way that it is deceptive. Any drug product that has not been registered with the FDA in conformity with the Food, Drugs, and Related Products Act.

2.3.2 Identifying Medicines

Visual inspection of the product and packaging, mobile applications, analytical methods such as the physical property testing like disintegration, reflectance spectroscopy, and refractive index; chemical tests such as colorimetry and dissolution chromatography; spectroscopic techniques; and mass spectrometry are all examples.

2.3.2.1 Visual Inspection

Pharmaceuticals can be analyzed using a variety of approaches. The first step introduced to individuals to determine if the medicines are counterfeit or not is to visually inspect them. It usually comprises a checklist that the community pharmacist uses with labels to check the packaging and look of the medicine (1). And, as technology progresses, people are being introduced to new technologies that cater to their specific demands.

2.3.2.2 BlockChain Technology

Large pharmaceutical businesses and distributors have been investigating blockchain for several years, but its full potential has yet to be realized. Blockchain technology is a cryptographic ledger that is said to be immutable and fault-tolerant due to repeated sequential hashing and a consensus mechanism and a decentralized, distributed ledger that records the provenance of a digital asset. The capacity of blockchain to retain data integrity makes it particularly beneficial for ensuring the necessary verification at various stages in the supply chain (2).

The system will use the GS1 pedigree standard and will meet the data points in the US FDA's data standardization criteria, with the following 5 nodes: FDA, manufacturer, wholesaler, retailer, and consumers (4). FDA will serve as a supervisory data verification function, with each pedigree type-specific data source serving as a primary data verification position, according to the system's design. The manufacturer will start the supply chain procedure, which will include recursive verification for each transaction. It will allow customers to see the drug delivery history by scanning a code printed on their receipts.

2.3.2.3 Computer Methods/ Applications

PillSafe is a mobile and cloud-based program that uses big data analytics, picture recognition, and mobile and cloud technologies to raise patient awareness of pharmacological adverse events and drug interactions. Using all-spectrum picture recognition and hardware-based real-time ML technologies, detect counterfeit medications on the market to protect public health (5). And, a Veripad is a mobile software that allows anyone to easily check common drugs by "reading" inexpensive chemical test cards. It uses machine learning and Amazon SageMaker to assist improve technology (6).

A computer-implemented pill identification and counterfeit detection method includes the steps of collecting a pill picture with an image frame and detecting contrast shifts within the image frame to locate at least one object with an object outline. An area, a position, a length, a width, an angle, a color, a brightness, a code, a form, a crystal pile size, a crystal geometry, a substance identity, or a character identification is determined for the object(s). The computer generates a result for the user based on the first and second values (7).

2.3.2.4 Analytical Chemistry Methods

Separation, identification, and quantification of matter are all part of this process. It incorporates both classical and modern methodologies, including the use of scientific instruments. Analytical chemistry nowadays usually includes the use of modern, sophisticated instruments.

Recent analytical approaches used to control the quality of medicinal formulations, such as artemisinin derivatives, which are frequently counterfeited pharmaceuticals. Indeed, a wide range of techniques for their analysis have been reported, ranging from in-field methods (colorimetry and thin-layer chromatography) to more advanced laboratory methods (mass spectrometry, nuclear magnetic resonance, and vibrational spectroscopies) through chromatographic methods, which are still the most widely used (7).

2.3.2.4.1 In-field Methods

Colorimetry is a technique used in biological research that involves the quantitative assessment of color frequency (9). When a material binds with color-forming chromogens, it produces color. The color difference is related to the concentration of the substance being measured. The Beer-Lambert law, which provides a direct relationship between absorbance and concentration at a specific wavelength of maximum absorption, is used to determine the concentration of colored chemicals in a solution. And this is a device that measures the absorbance of a specific wavelength of light to determine the concentration of a solution.

This instrument measures 7.8 x 2.7 x 3.9 inches and weighs 500 grams. It costs approximately 107701.47 pesos (10)

Thin layer chromatography (TLC) is a chromatographic technique that uses a thin solid phase supported by an inert backing to separate the components of a mixture (11). It can be used to monitor the progress of a reaction on an analytical scale or to purify small amounts of a compound on a preparative scale. TLC is a popular analytical tool due to its ease of use, low cost, high sensitivity, and rapidity of separation. This costs around 50,085.90 pesos (12).

2.3.4.2.2 Advanced Laboratory Methods

Mass spectrometry (MS) is a commonly used instrumental technique, with the parabola spectrograph being the first of its kind (13). Multiple developments and enhancements in MS have since made MS a mainstay, initially in physics laboratories and now in analytical chemistry and forensic science laboratories. In the gas phase, MS works by ionizing and fragmenting sample molecules. Because each molecule fragments differently, the resulting ion fragmentation pattern can be utilized to determine a molecule's structural information. This item weighs roughly 90 kilograms and costs 1,069,800 pesos.

When an oscillating electromagnetic pulse is supplied to nuclei within a magnetic field, individual nuclei absorb energy and then release it in precise patterns, which is known as nuclear magnetic resonance. The strength of the magnetic field, as well as a few other factors, influence the pattern of energy absorption and release. Physicists can study the quantum mechanical properties of atomic nuclei by looking at these patterns. NMR technology can be used by chemists to investigate the chemical and structural content of samples, and it is also the foundation of a common type of medical imaging equipment (15).

Vibrational spectroscopy is a non-destructive identification method for determining a compound's vibrational energy. The vibrational energy of each chemical bond is different. Even a carbon-carbon bond differs from one chemical to the next depending on the other compounds to which each carbon is attached. Each molecule will have a unique fingerprint, or the output indicating the peak intensities at various vibrations, due to this unique vibrational energy. This fingerprint can be used to identify impurities, determine compound structures, and identify and classify substances. This is accomplished by comparing the fingerprint to those of recognized chemicals (16).

Angle dispersive x-ray diffraction is used to investigate or analyze materials using wave or particle radiation, for example, to detect counterfeit pharmaceuticals in blister packs. X-rays or neutrons by diffraction of the radiation by the materials, for example, to investigate crystal structure; by scattering of the radiation by the materials, for example, to investigate non-crystalline materials; by reflection of the radiation by the materials, for example, to investigate non-crystalline materials (17). The starting price is 2,407,905 pesos (18).

2.3.2.5 Artificial Intelligence for Image Processing

Machines may be taught to understand visuals in the same manner that our brains do, and to evaluate them considerably more deeply. Face recognition and authentication can be powered by image processing with artificial intelligence for assuring security in public spaces, identifying and recognizing objects and patterns in photos and videos, and so on. And, deep learning networks can be successfully applied to big data for information exploration, knowledge deployment, and knowledge-based prediction. It also entails employing neural networks with numerous convolutional nodes of artificial neurons to learn patterns in data structures. An artificial neuron is a type of cell that takes several inputs, does a calculation, and then returns the output, much like a biological neuron (20). Multiple layers of artificial neurons make up convolutional neural networks. Artificial neurons are mathematical functions that calculate the weighted sum of various inputs and output an activation value, similar to their biological counterparts (21). Each layer creates many activation functions that are passed onto the next layer when you input an image into a ConvNet.Face recognition, picture search and editing, augmented reality, and other computer vision applications all employ CNNs today.

Image processing is the process of modifying an image to improve it or extract information from it. Analog and digital image processing are the two options. The input is an image in both cases. The result of analog image processing is always an image. However, the result of digital image processing can be a picture or information about that image, such as data on features, attributes, bounding boxes, or masks (22). Neural networks and deep learning are the most effective machine learning models for image processing. Deep learning uses neural networks to tackle complicated problems in the same way that the human brain does. From simple binary classification (whether an image meets or does not meet a set of criteria) to instance segmentation, neural networks can be used to solve a variety of image processing tasks. In order to create an efficient AI-based image processing system, choosing the correct type and design of a neural network is critical.

2.3.2.6 Image Processing Basics

The ability to capture objects on a two-dimensional plane is referred to as image processing. As a result, image processing is now commonly employed as a substitute to visual inspections in automated inspections. This section covers CCD (pixel) sensors, which are the core of image processing, as well as image processing fundamentals. A digital camera has a structure that is nearly identical to that of a traditional (analog) camera, with the exception that a digital camera incorporates a CCD image sensor. A Charge Coupled Device, or CCD, is a semiconductor element that turns pictures into digital signals. It is approximately 1 cm in height and breadth and is made up of tiny pixels aligned in a grid. The light reflected from the target is transferred through the lens and forms an image on the CCD when a photograph is taken using a camera. When light strikes a pixel on the CCD, an electric charge equal to the light intensity is generated. The light intensity (concentration value) received by each pixel is calculated by converting the electric charge into an electric signal. This means that each pixel (photo diode) is a light-detecting sensor, and a 2 million-pixel CCD is a collection of 2 million photodiodes. A photoelectric sensor can detect the presence or absence of a specific size target in a specific location. A single sensor, on the other hand, is ineffective for more complex applications like identifying targets in different positions, detecting and measuring targets of different forms, or making overall position and dimension measurements (23).

Chapter 3
PROJECT DESIGN

This chapter covers the design options as well as each of the hardware and software functions. It will be evaluated here based on the design constraints imposed by the proponents. This is a critical phase in determining the best or final design.

3.1 INTRODUCTION

There will be a basis or criteria to follow in analyzing and assessing each design option for this chapter, and that is the specifications derived from the clients' requirements. The information in Table 3-1 should be checked and adhere to the design options offered in this chapter.

Table 3-1 Specific requirements to be adhered to in generating possible solutions

Specific Information	Specifications
The device should be reasonably priced.	Overall cost of each device should be priced no more than 13,000 pesos.
The device must accurately detect whether or not the medicines are counterfeit.	The permissible percentage range of accuracy of each device's prediction output should be 85 percent higher.
The device should be lightweight.	The device should not weigh more than 5.1lbs or 2,313g.
The device should be compact.	The device's measurements should not exceed 7"x7"x7" or 343 in^3.

3.2 SYSTEM ARCHITECTURE

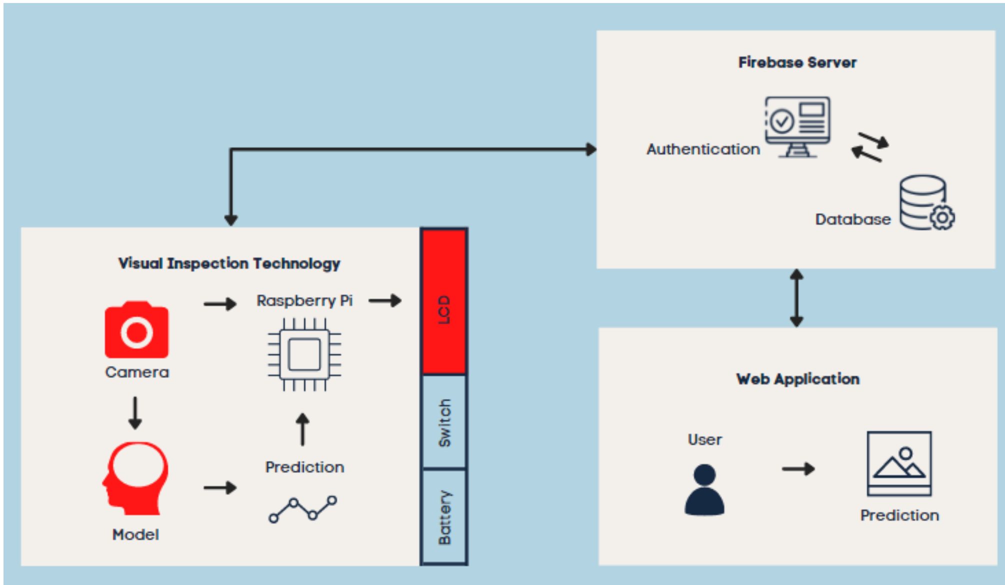


Figure 3.1 Med Dev's System Architecture

Figure 3.1 displays the Med Dev system architecture, which is made up of three functional blocks: visual inspection technology, firebase server, and web application, as well as how functional blocks are connected. The hardware components of visual inspection technology are the camera module, CPU, LCD, battery, and switch. A machine learning model is also included, which will transform the input into a prediction output that will be displayed on the LCD that will be delivered to the firebase server, where the database is stored, so that the web application's authenticated user may access it.

3.3 STORYBOARD

The Med Dev is a portable device that can be used to determine whether or not a medicine is counterfeit. It should be simple and hassle-free for the user; once the medicine has been put, the user must wait for a while for the prediction output without doing much with the medicine. The device will then capture the medicine, process it, and feed it to a machine learning model, which will predict an output for the user and display it on the device's screen or LCD.

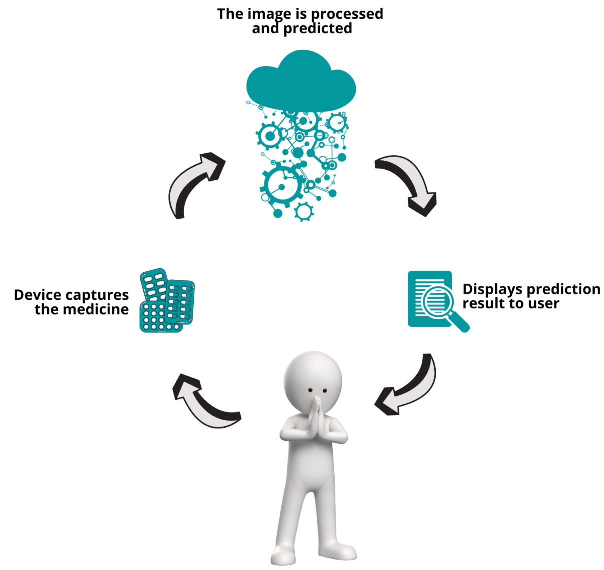


Figure 3.2 Med Dev's Storyboard

3.4 DESIGN BREAKDOWN

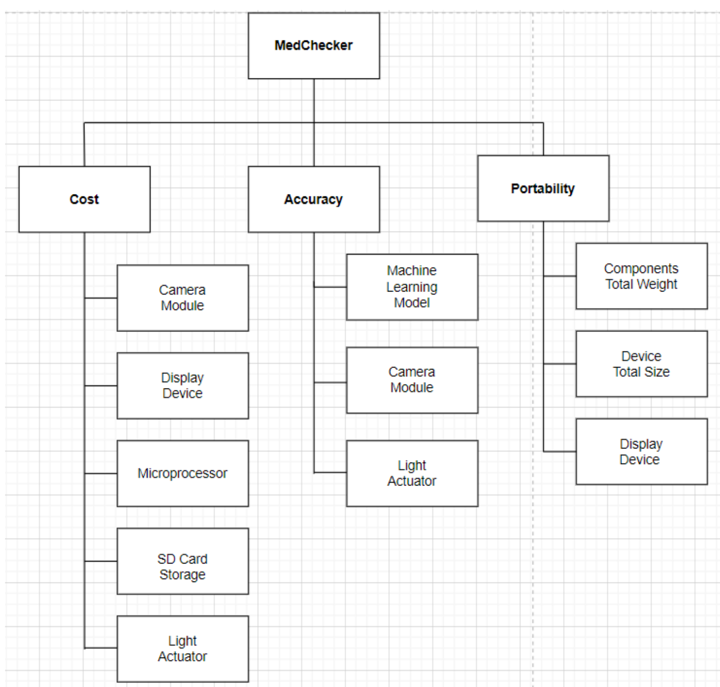


Figure 3.3 Design Breakdown

The proponents grouped each of the aspects affecting each of the design constraints, namely cost, accuracy, and portability, as shown in the diagram above. When building out a design option, the proponents might gather possibilities in any factor this manner.

3.5 DATA GATHERING

Before getting into the design options, the proponents first identified the best combination of capturing devices and machine learning models to choose from. The following is the approach proponents used:

I. Selection of Capturing Devices

The proponents should have the capturing devices ready before curating the best design possibilities. The proponents chose the available phone camera models for this project to match the same specifications as the camera module that may be deployed to construct the device.

Table 3-2 Phone Camera Model and Specifications

Camera Module	Equivalent Phone Model	Resolution	Sensor Pixel Size	Megapixel
13mp Arducam IMX135 MIPI	Redmi 9C	1080	1.12μm	13mp
8mp Raspberry Pi V2	IPhone 6 Plus	1080	1.5μm	8mp
5mp Arducam OV564	IPhone 4	1080	1.4μm	5mp

The phone models listed in table 3-2 will be used to test the machine learning models that will temporarily act as the camera module, with the same specifications as those chosen in the next sections of this discussion.

II. Data Gathering

Since the capturing devices have already been selected, the next step is to collect the necessary medicines, such as those that are listed in the FDA advisory the proponents are basing from. We then went to Mercury Drug and bought authentic drugs and counterfeit medicines on the streets of Tondo. We also sought confirmation from a local pharmacist in the area to verify if what we purchased was authentic and counterfeit, which she confirmed later, as seen in the image below.

Figure 3.4 Confirmation from a Local Pharmacist

We've also gathered five medicines, each with one counterfeit version, to represent the total of the ten medicines to train. The medicines in question include Alaxan FR, Paracetamol Biogesic, Bioflu, Medicol Advance, and Neozep Forte, with specifics on each listed below.

Table 3-3 Specific Details of Medicines

Medicine Name	Medicine Type	Source	Price per Piece
Alaxan FR	Authentic	Mercury Drug	₱ 12.00
Paracetamol Biogesic	Authentic	Mercury Drug	₱ 7.00
Bioflu	Authentic	Mercury Drug	₱ 12.00
Medicol Advance	Authentic	Mercury Drug	₱ 14.00
Neozep Forte	Authentic	Mercury Drug	₱ 9.00
Alaxan FR	Counterfeit	Tondo, Manila	₱ 10.00
Paracetamol Biogesic	Counterfeit	Tondo, Manila	₱ 6.00
Bioflu	Counterfeit	Tondo, Manila	₱ 12.00
Medicol Advance	Counterfeit	Tondo, Manila	₱ 12.00

Neozep Forte	Counterfeit	Tondo, Manila	₱ 8.00

We can determine the difference between a counterfeit and a real medicine with the medicines we have acquired. Some blister packing has a diamond pattern, while others have a dotted pattern. Please see the images below for an example of an authentic and a counterfeit paracetamol biogesic.

Figure 3.5 Authentic Version of Paracetamol Biogesic

Figure 3.6 Counterfeit Version of Paracetamol Biogesic

We must then shoot each medicine from four angles, both front and back, using the medicines we already have and have categorized. We then built up a controlled environment to generate more reliable data to feed into the model of choice.

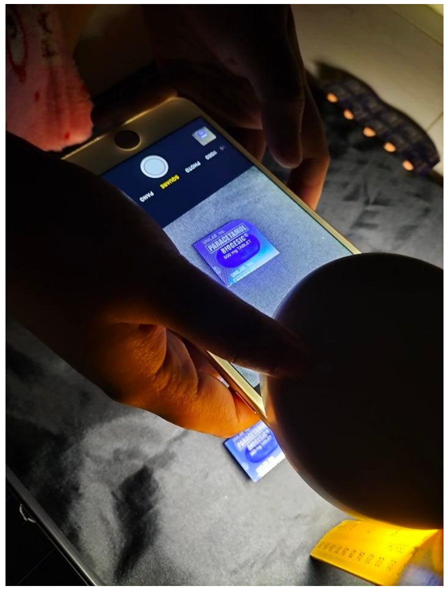


Figure 3.7 Controlled Environment Set Up

Setting up a controlled environment in which to train a dataset is key for producing reliable images after training to the chosen model. The camera was set 4 inches above the medicine with a led light, and all of the captures were done using a black cloth as a background to ensure a clean and focused image.

Figure 3.8 Sample of Data Gathered

Figure 3.9 Sample of Data Gathered

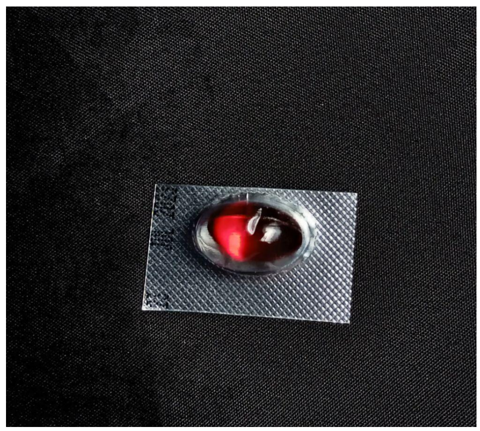


Figure 3.10 Sample of Data Gathered

Figure 3.11 Sample of Data Gathered

Furthermore, we have gathered raw captures of 80 photos of medicines for both counterfeit and authentic purposes, as seen in the figures above. We must go through data annotation with these 80 images, labeling each with its name and whether it is counterfeit or not. Then comes data augmentation, which exposes it to a wider range of training data and allows it to construct different versions of comparable data. We decided to add random brightness, random blur, random rotation, flip vertical, and horizontal to it. As a result of the data augmentation process, our original 80 photographs grew to a total of 12,000 images.

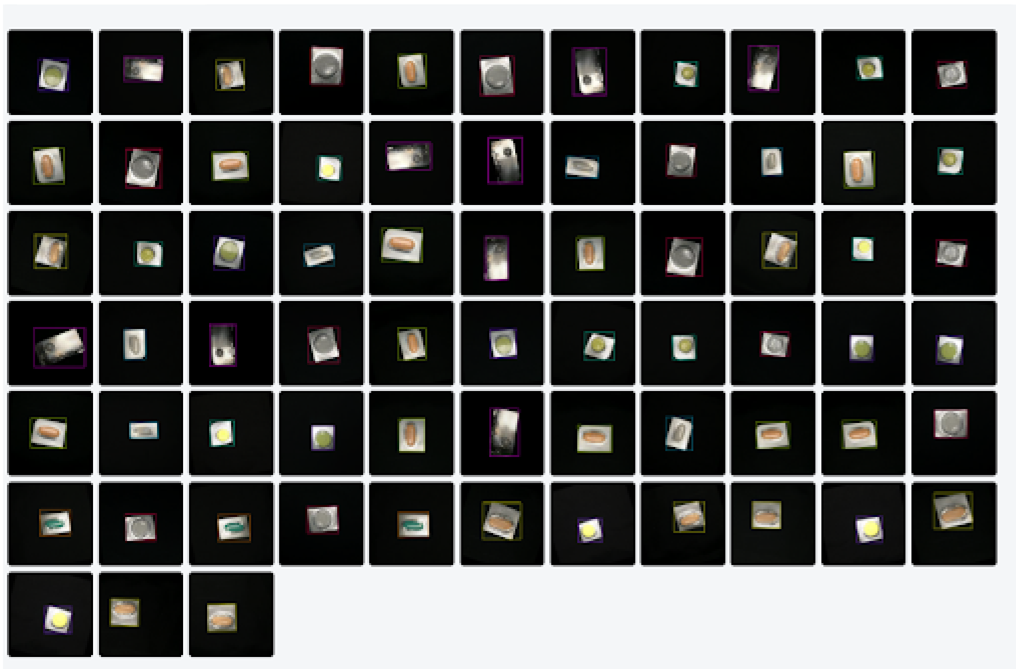


Figure 3.12 Data Annotation

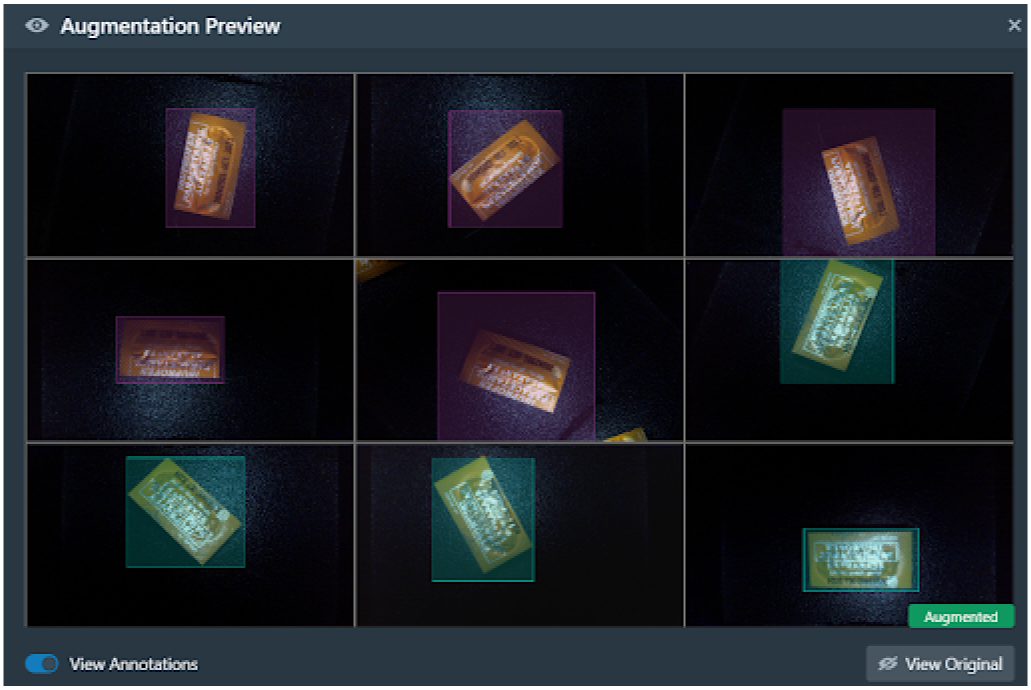


Figure 3.13 Data Augmentation

We now have a dataset containing 12,000 images of our ten medicines on which to train models.

III. Selection of Machine Learning Models

Following the creation of the dataset, the next step is to choose the best technique to train it with a machine learning model. A convolutional network, also known as a CNN, is a deep learning neural network that is used to handle structured arrays of data, such as images. It is widely used in computer vision and has become the state-of-the-art for many visual applications such as image classification. It is particularly adept in detecting patterns in the input image, such as lines, gradients, circles, or even eyes and faces. According to Yalcin (2020), the table below shows the models ranking that were evaluated on ImageNet, based on their accuracy (23).

Model	Size	Top-1 Accuracy	Top-5 Accuracy	Parameters
Xception	88 MB	0.79	0.945	22,910,480
VGG16	528 MB	0.713	0.901	138,357,544
VGG19	549 MB	0.713	0.9	143,667,240
ResNet50	98 MB	0.749	0.921	25,636,712
ResNet101	171 MB	0.764	0.928	44,707,176
ResNet152	232 MB	0.766	0.931	60,419,944
ResNet50V2	98 MB	0.76	0.93	25,613,800
ResNet101V2	171 MB	0.772	0.938	44,675,560
ResNet152V2	232 MB	0.78	0.942	60,380,648
InceptionV2	92 MB	0.779	0.937	23,851,784
InceptionResNetV2	215 MB	0.803	0.953	55,873,736
MobileNet	16 MB	0.704	0.895	4,253,864
MobileNetV2	14 MB	0.713	0.901	3,538,984
DenseNet121	33 MB	0.75	0.923	8,062,504
DenseNet169	57 MB	0.762	0.932	14,307,880
DenseNet201	80 MB	0.773	0.936	20,242,984
NASNetMobile	23 MB	0.744	0.919	5,326,716
NASNetLarge	343 MB	0.825	0.96	88,949,818
EfficientNetB0	29 MB	0.771	0.933	5,330,571
EfficientNetB1	31 MB	0.791	0.944	7,856,239
EfficientNetB2	36 MB	0.801	0.949	9,177,569
EfficientNetB3	48 MB	0.816	0.957	12,320,535
EfficientNetB4	75 MB	0.829	0.964	19,466,823
EfficientNetB5	118 MB	0.836	0.967	30,562,527
EfficientNetB6	166 MB	0.84	0.968	43,265,143
EfficientNetB7	256 MB	0.843	0.97	66,658,687

Figure 3.14 Convolutional Neural Network Models

The CNN architecture is made up of numerous layers that turn the input volume into an output volume using a differentiable function. Deep learning is essentially a reincarnation of the artificial neural network, which stacks artificial neurons. Converting kernels into layers with outputs from preceding layers creates network features in CNN. The kernels in the first invisible layer perform convolutions on the input images. Although early hidden layers capture forms, curves, and edges, later hidden layers catch more abstract and complicated information (24).

Figure 3.9 shows the accuracy of each CNN model wherein the developers chose from which are the ResNet 152, InceptionV2, and MobileNetV2 to train with the dataset obtained from the previous discussions. Each of the chosen machine learning models was trained and proceeded to base on the highest mAP (mean average precision) per machine learning model and capturing device deployed. The following is the outcome of the training:

Table 3-4 FasterRCNN ResNet152 Training Result

Camera Module Used	mAP@.50IOU (Mean Average Precision)
8mp Raspberry Pi V2	61%
13mp Arducam IMX135 MIPI	70%
5mp Arducam OV564	83%

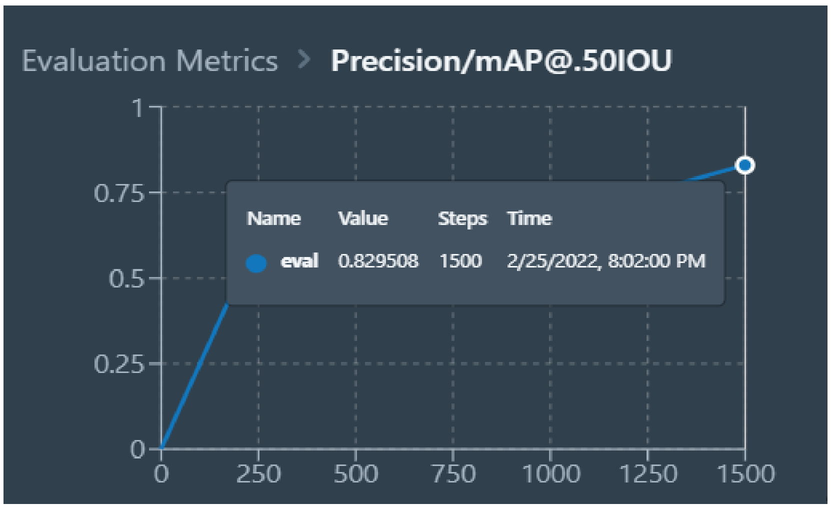


Figure 3.15 ResNet152 Training Result

The results of training the FasterRCNN ResNet512 to three datasets from three capturing devices are shown in Table 3-3. The 5mp Arducam OV564 has the highest mAP@.50IOU at 83 percent, followed by the 13mp Arducam IMX135 MIPI at 70 percent, and the 8mp Raspberry Pi V2 with 61%, as shown in Figure 3.7.

Table 3-5 FasterRCNN InceptionV2 Training Result

Camera Module Used	mAP@.50IOU (Mean Average Precision)
8mp Raspberry Pi V2	63%
13mp Arducam IMX135 MIPI	99%

5mp Arducam OV564	54%

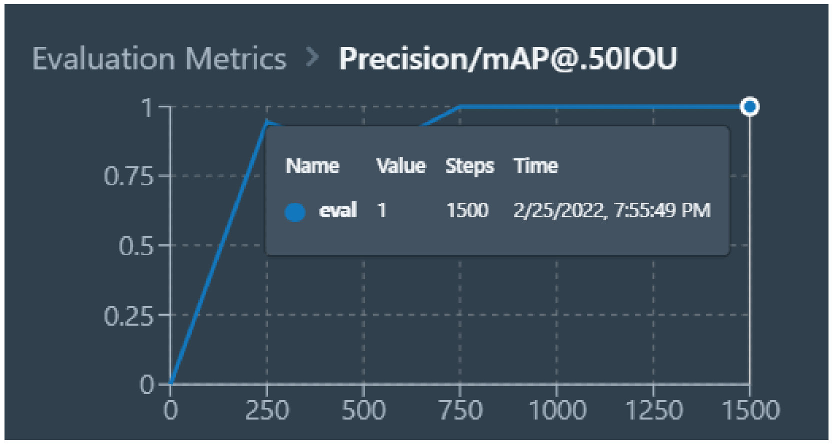


Figure 3.16 InceptionV2 Training Result

The results of training the FasterRCNN InceptionV2 to three datasets from three capturing devices are shown in Table 3.3. The 13mp Arducam IMX135 MIPI has the highest mAP@.50IOU at 99 percent, followed by the 8mp Raspberry Pi V2 at 63 percent, and the 5mp Arducam OV564 with 54%, as shown in Figure 3.11.

Table 3-6 Retina MobileNetV2 Training Result

Camera Module Used	mAP@.50IOU (Mean Average Precision)
8mp Raspberry Pi V2	72%
13mp Arducam IMX135 MIPI	68%
5mp Arducam OV564	71%

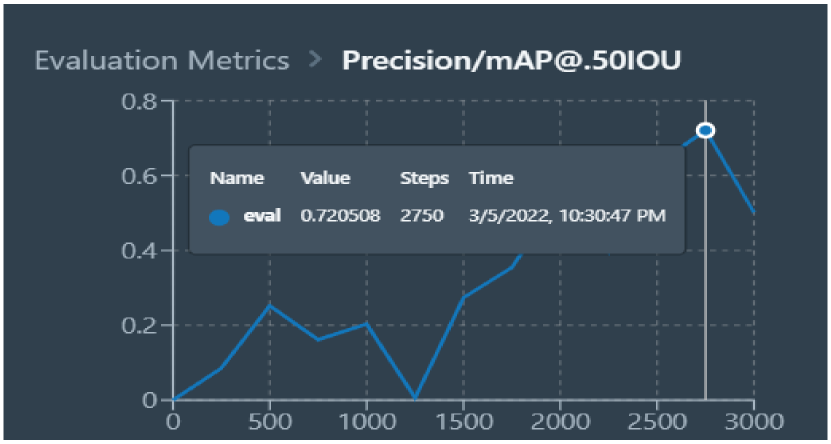


Figure 3.17 Retina MobileNetV2 Training Result

The results of training the Retina MobileNetV2 to three datasets from three capturing devices are shown in Table 3.4. The 8mp Raspberry Pi V2 has the highest mAP@.50IOU at 72 percent, followed by the 5mp Arducam OV564 at 71 percent, and the 13mp Arducam IMX135 MIPI with 68%, as shown in Figure 3.12.

The proponents went through a series of steps to identify the best combination of capturing device and machine learning model, ultimately settling on ResNet152 and 5mp Arducam OV564, InceptionV2 and 13mp Arducam IMX135 MIPI, and MobileNetV2 and 8mp Raspberry Pi V2.

IV. Hardware Components

Moving on to hardware components, the proponents compiled a list of the most important hardware components in general form that will feature in each design option. The names of the components, as well as their functions, are listed in table below:

Table 3-7 Hardware Components and Functionality

Hardware Components	Functionality
Case	To house the components as a whole
Microprocessor	To serve as the device’s processor
Power Supply for Microprocessor	To source the power of the microprocessor
Camera Module	To capture the images that is needed
LED	To improve the quality of images being captured

Display Screen	To display an output
Switch	To operate the device
SD Card	To stand as the initial storage for OS and files

3.6 SUMMARY OF DESIGN OPTIONS

Table 3-8 Summary of Design Options

	Design Option 1	**Design Option 2**	**Design Option 3**
Camera Module	5mp Arducam OV564	13mp Arducam IMX135 MIPI	8MP RaspberryPi V2
LCD Display	PiTFT 2.4" HAT Mini Kit - 320x240 TFT Touchscreen Adafruit	Adafruit Pi TFT 3.5”	HDMI 5 inch 800x480
SD Card Storage	16gb	16gb	32gb
Microprocessor	Raspberry Pi 4B	Raspberry Pi 4B	Raspberry Pi 4B
Machine Learning Model	FasterRCNN ResNet152	FasterRCNN InceptionV2	Retina MobileNet V2
Overall Size	126 in^3	165 in^3	216 in^3
Overall Weight	828.47 g	823.36 g	1086.01 g

Table 3-8 summarizes the comparison of each of the design options that will be discussed and evaluated in this chapter. Following the design constraints that were mentioned in the preceding chapters, this was designated as to. The cost should be calculated using the total cost of all the components. When it comes to accuracy, the camera module and the machine learning model that will be used are the most important factors. Finally, we have the size in dimension or in cubic inches and the weight in grams or in pounds for portability. The proponents may readily map out the considerations in determining the best design option for this project with this information.

3.7 DESIGN OPTION 1: AR5

3.7.1 System Architecture

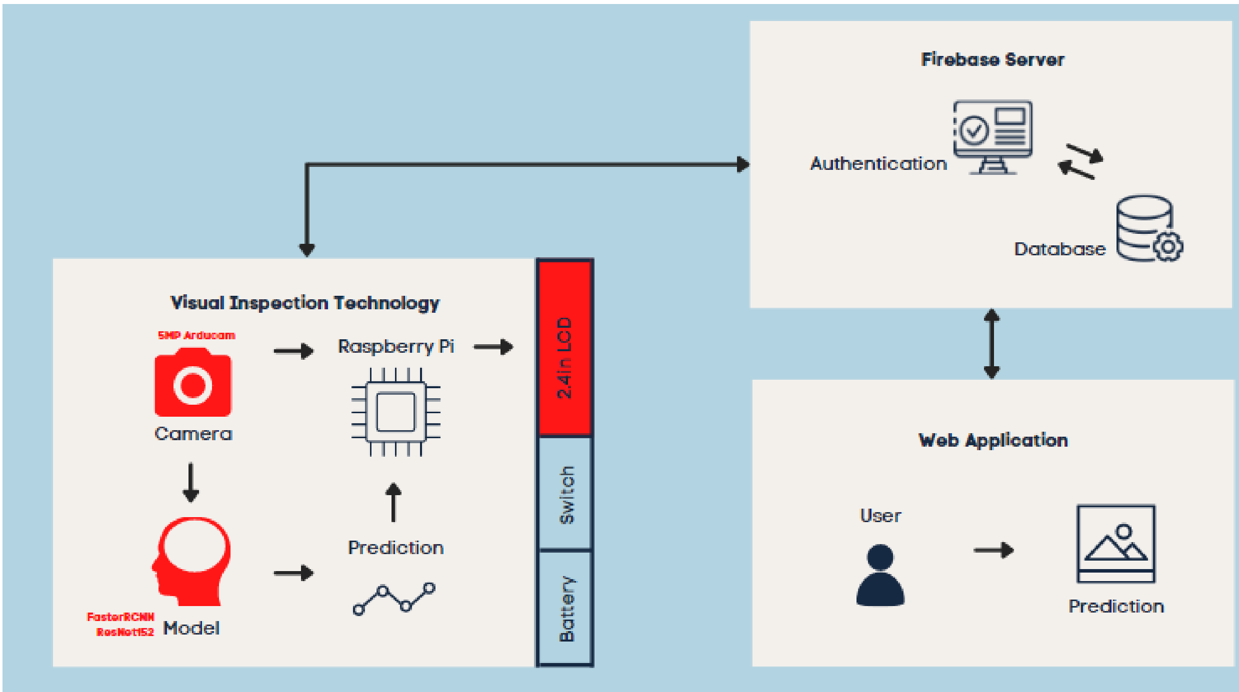


Figure 3.18 Design Option 1 System Architecture

The entire system architecture of design option one is shown in Figure 3.13. The proponents chose to employ the 5mp Arducam OV564 camera module in conjunction with FasterRCNN ResNet152 as its machine learning model, which both plays an important part in producing a reliable prediction output. In addition, proponents chose a PiTFT 2.4" HAT Mini Kit - 320x240 TFT Touchscreen Adafruit. Above and beyond, there is the firebase server to allow the web application and visual inspection technology device to connect with one another while also adding a layer of protection for the users and data.

3.7.2 System Layout/Drawings

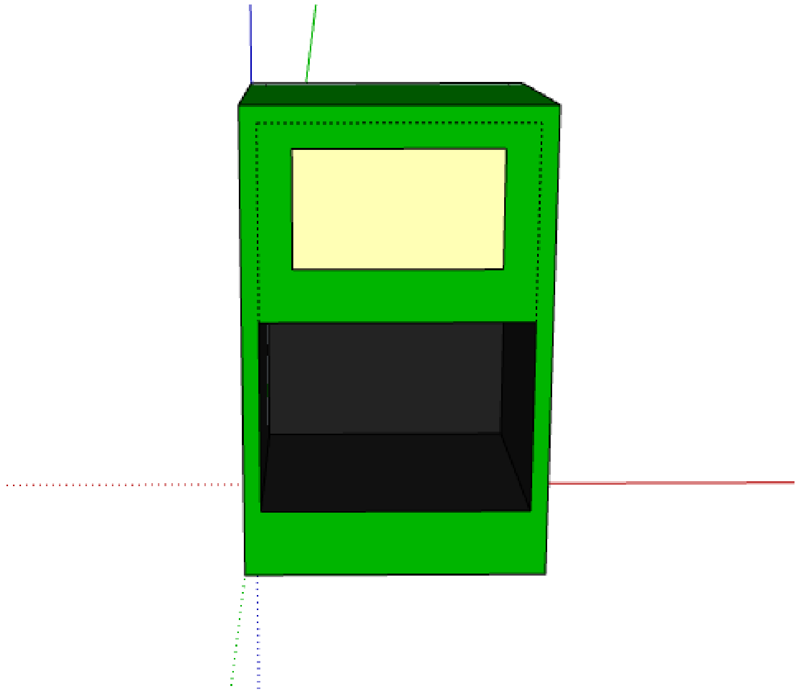


Figure 3.19 Dimensions of the Prototype

The prototype is shown above with labeled dimensions in inches. It has a height of 7 inches, a width of 4 inches, and a length of 4.5 inches.

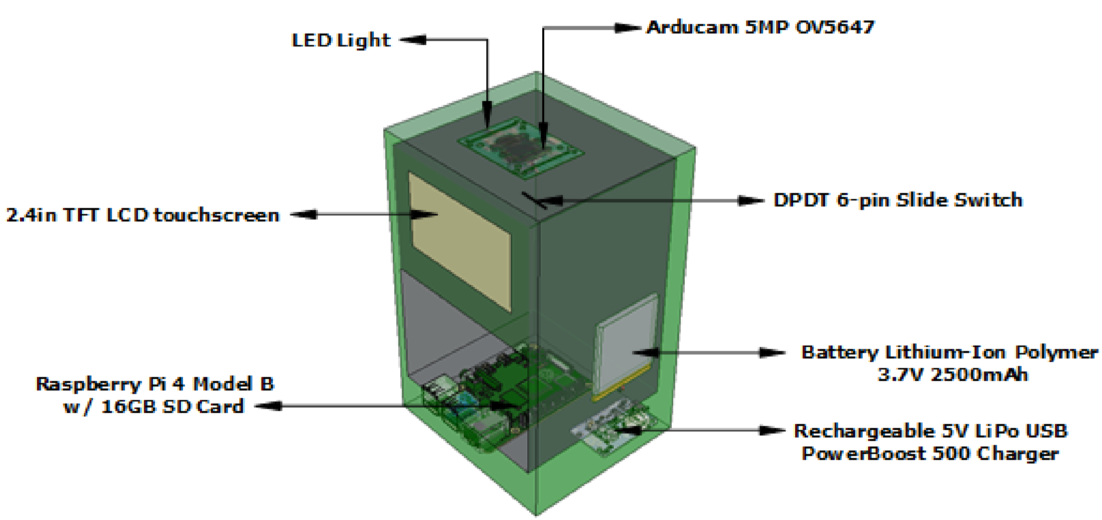


Figure 3.20 Labeled Components

The labeled components of the prototype for this design option are shown in the figure above. The 5mp Arducam OV564 camera module, as well as the LED 3V, are positioned on the prototype's top, presumably to capture images of the medicine on the black platform below. The device also has a sliding cover for easy opening when the user is using it, as well as a switch for control. There will also be a PiTFT 2.4" HAT Mini Kit - 320x240 TFT Touchscreen Adafruit LCD display where the output will be displayed.

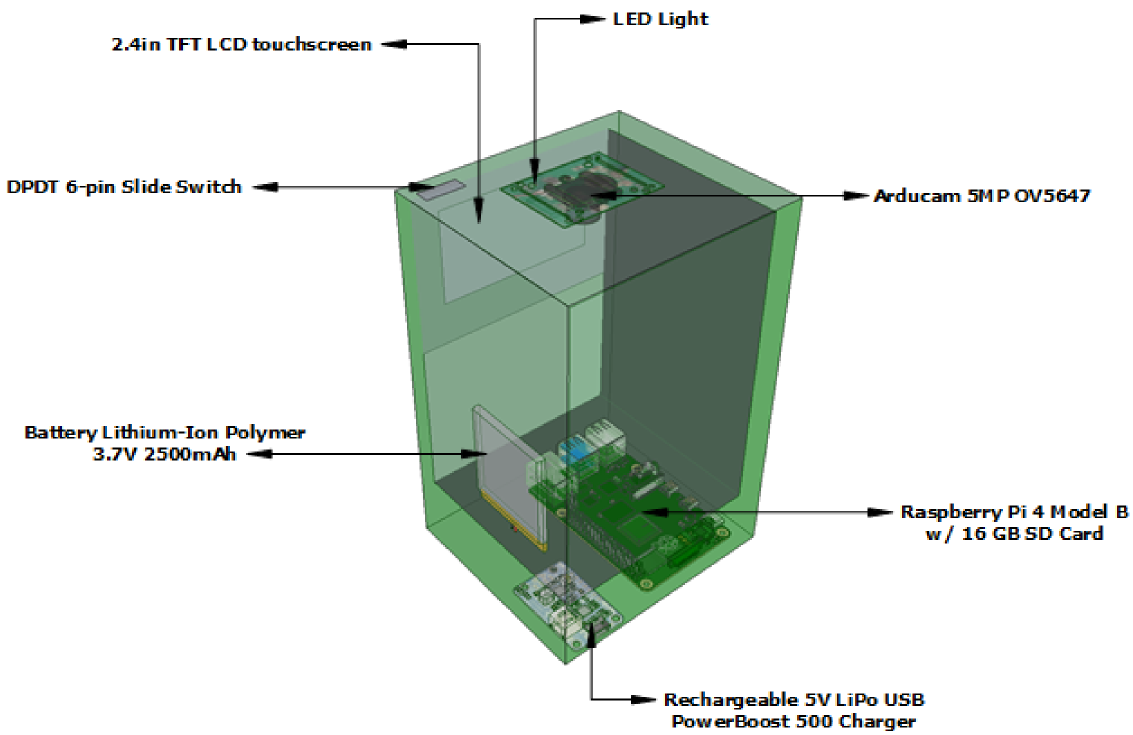


Figure 3.21 Labeled Components

To add, Raspberry Pi 4b and a 2,500 mAh battery, as well as a 16GB SD card, are also included in the prototype. The charging port will also be located at the back of this prototype. It's also protected by an ABS casing.

3.7.3 Hardware Design

The system layout comes before this part. And, the components that built it electrically and mechanically will be reviewed and illustrated in this section. It should also take into account the design constraints in order to meet the client's requirements.

3.7.3.1 Functional Specifications

Figure 3.22 Raspberry Pi 4B

Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers. It offers groundbreaking increases in processor speed, multimedia performance, memory, and connectivity compared to the prior-generation Raspberry Pi 3 Model B+, while retaining backwards compatibility and similar power consumption. For the end user, Raspberry Pi 4 Model B provides desktop performance comparable to entry-level x86 PC systems. This product's key features include a high-performance 64-bit quad-core processor, dual-display support at resolutions up to 4K via a pair of micro-HDMI ports, hardware video decode at up to 4Kp60, up to 8GB of RAM, dual band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability (via a separate PoE HAT add-on). The dual-band wireless LAN and Bluetooth have modular compliance certification, allowing the board to be designed into end products with significantly reduced compliance testing, improving both cost and time to market.

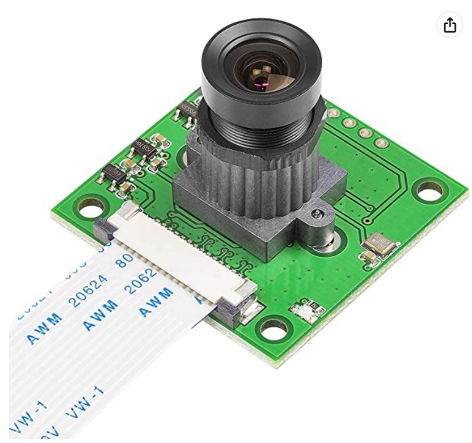


Figure 3.23 Arducam 5MP OV5647

The V1 camera family of 5MP OV5647 cameras is widely utilized in Raspberry Pi camera applications. The 5MP OV5647 cameras, unlike the V2 cameras, which are encrypted on the camera board using a chip, can be easily modified and altered by third-party manufacturers, resulting in a wide range of variations.

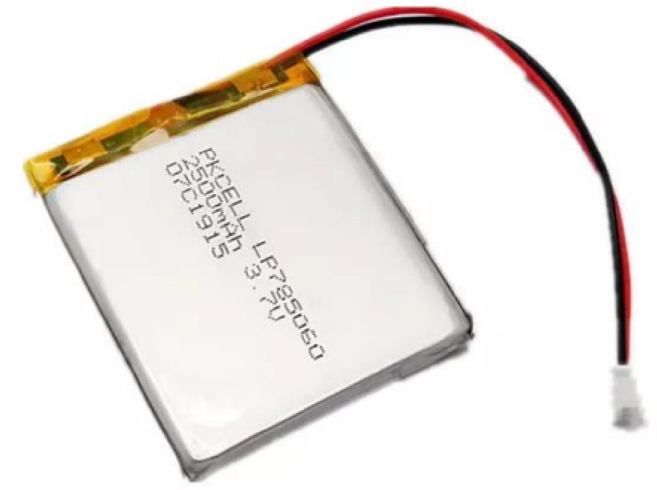


Figure 3.24 Battery Lithium-Ion Polymer 3.7V 2500mAh

Lithium-ion polymer (also known as 'lipo' or 'lipoly') batteries are thin, light, and powerful. The output ranges from 4.2V when completely charged to 3.7V. This battery has a capacity of 2500mAh for a total of about 10 Wh with a genuine JST connector. The batteries come pre-attached with a genuine 2-pin JST-PH connector as shown and include the necessary protection circuitry. The included protection circuitry keeps the battery voltage from going too high (over-charging) or low (over-use) which means that the battery will cut out when completely dead at 3.0V. It will also protect against output shorts. However, even with this protection, it is very important that you only use a LiIon/LiPoly constant-voltage/constant-current charger to recharge them at a rate of 1200mA or less.

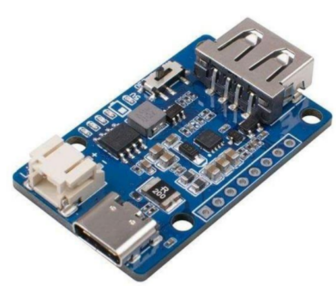


Figure 3.25 Rechargeable 5V LiPo USB PowerBoost 500 Charger

PowerBoost 500C is the perfect power supply with a built-in battery charger circuit, it will be able to keep running even while recharging the battery. The DC/DC boost converter module can be powered by any 3.7V LiIon/LiPoly battery and convert the battery output to 5.2V DC for running 5V projects. The charger circuitry is powered from a micro-USB jack and will recharge any 3.7V/4.2V LiIon or LiPoly battery at 500mA max rate. It can charge and boost at the same time with no problem, without any interruption of the output.

Figure 3.26 Warm White LED Light

Warm White has a bit of a yellow tint to it and is similar to standard incandescent light bulbs. It has proven to be the best balance of warmth and utility. Temperatures below 3000K begin to appear more yellow than white, the result being a sacrifice to rendering ability as well as pure function and aesthetics.

Figure 3.27 2.4in TFT LCD touchscreen 240x320

It's a 2.4" SPI TFT LCD Screen Module with a 10pins interface, and the LCD drive ic is ILI9341. It's a 240 * 320 (resolution), 2.4 inch TFT LCD screen with a wide viewing angle and good contrast. The display interface is serial, and it only requires 5 wires (CS, RS, SCL, SDA, RST) for operation.

Figure 3.28 DPDT 6-pin Slide Switch

A 6 Pin Push Switch also known as Mini DPDT Push Switch, is a combination of two push switches placed together inside one package. Unlike momentary switches which connect the wires of the switch only for a second, this switch retains its ON-OFF state till pushed later. For example, if push it once so that it's turned on, it will remain in the ON state till it's pushed again. That's why this switch is useful in controlling power connections most of the time. It will easily interpret that this switch has two common pins which are simultaneously switched ON and OFF. When the trigger is pushed and moves down a notch, the connections between Pin 1 to Pin 2 and Pin 5 to Pin 6 are made. This is the ON state of the switch.

Figure 3.29 16GB SD Card

An SD card, or Secure Digital card, is a removable memory card that can be used in a variety of mobile phones, cameras, smart devices, and other devices to read and write large amounts of data.

Figure 3.30 ABS Case

ABS or Acrylonitrile butadiene styrene is a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which the material is machined by plastic manufacturers.

3.7.3.2 Block Diagram

The visual depiction of design option 1 is shown in the diagram below, which depicts the general arrangement of the pieces or components of a major system or process, such as an electronic circuit. This is only to demonstrate the connections between the components stated previously.

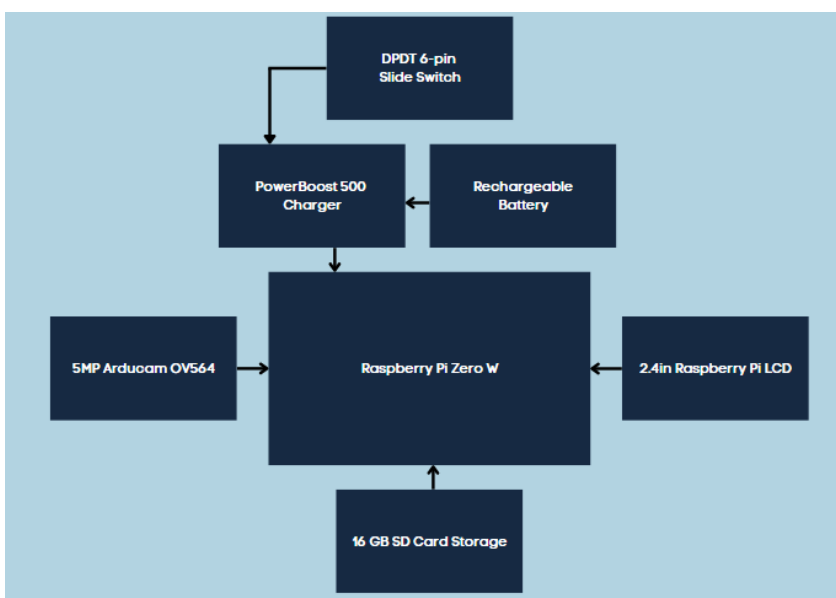


Figure 3.31 Block Diagram

3.7.3.3 Schematic Diagram

In this part will be visualized how each of the components connected to one another, looking at it abstractly as a wiring or circuit diagram wherein the lines are represented as wires.

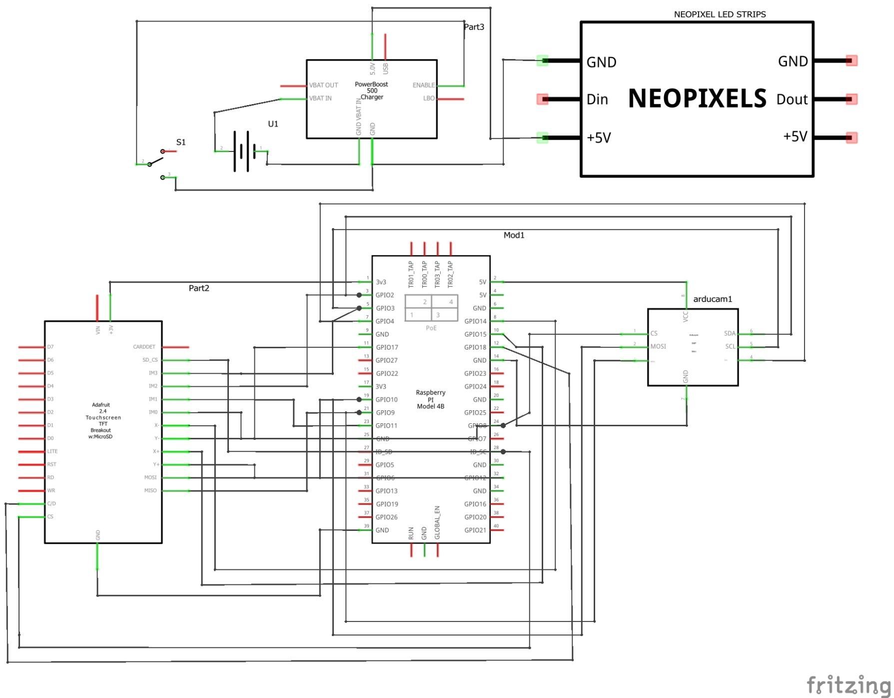


Figure 3.32 Schematic Diagram

3.7.4 Software Design

The functions that flow inside the system when it is running will be explored and depicted using diagrams from input to output in this section. It also explains which functions should be implemented in the system and what role each component plays.

3.7.4.1 System Flowchart

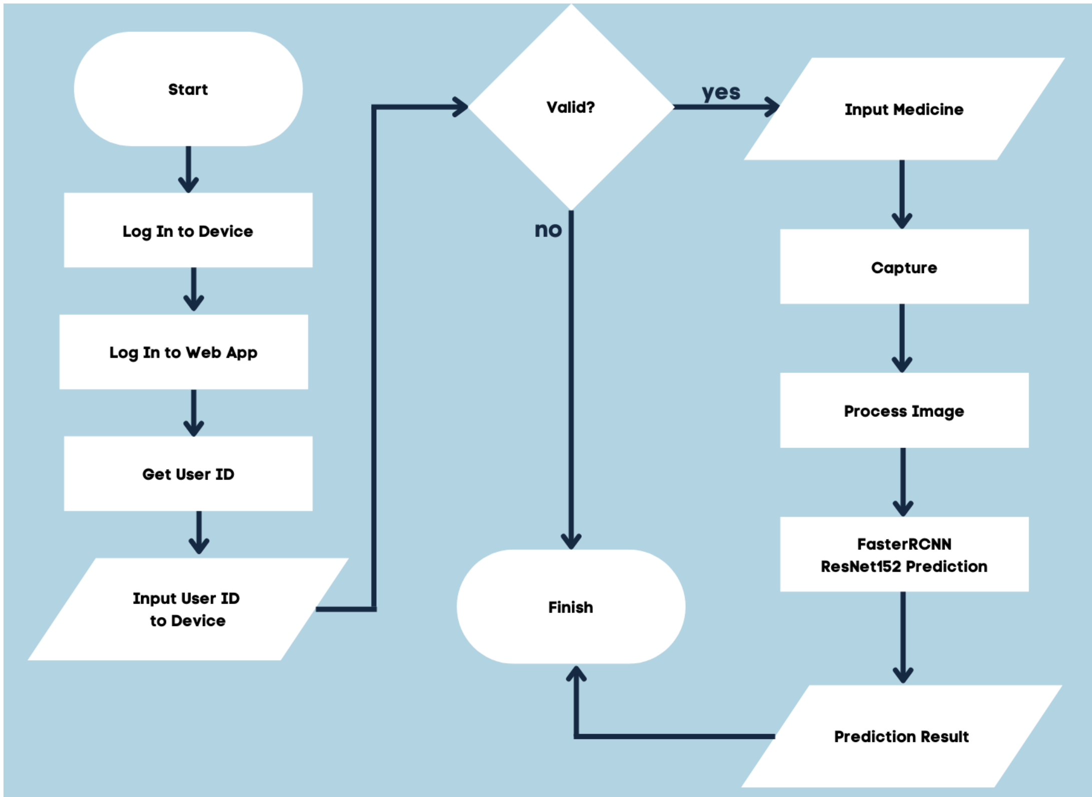


Figure 3.33 System Flowchart

Figure 3.33 shows a representation of how the system's process flow will be carried out. As seen in the diagram above, the user must enter a code in order to proceed with the device's scanning, which can be obtained via the web application. Following the user's validation, the system will capture and process the image in order to feed it to the algorithm, which will then provide a prediction output, which is the final step in the process.

3.7.4.2 Data Pre-processing

The process of changing raw data into a usable, intelligible format is known as data preprocessing. Real-world or raw data is prone to inconsistencies in formatting, human errors, and incompleteness. Data preprocessing solves these problems by making datasets more complete and efficient to analyze. It's an important step that can make or break data mining and machine learning projects. It speeds up knowledge extraction from datasets and may have an impact on machine learning model performance (25).

```python
def load_label_map(label_map_path):
    label_map = {}

    with open(label_map_path, "r") as label_file:
        for line in label_file:
            if "id" in line:
                label_index = int(line.split(":")[-1])
                label_name = next(label_file).split(":")[-1].strip().strip("'")
                label_map[label_index] = {"id": label_index, "name": label_name}

    return label_map

def load_image_into_numpy_array(path, height, width):

    image = Image.open(path).convert("RGB")
    image_shape = np.asarray(image).shape

    image_resized = image.resize((height, width))
    return np.array(image_resized), (image_shape[0], image_shape[1])

def args_parser():
    parser = argparse.ArgumentParser(
        description="Datature Open Source Prediction Script"
    )
    parser.add_argument(
        "--input", help="Path to folder that contains input images", default="./input"
    )
    parser.add_argument(
        "--output", help="Path to folder to store predicted images", default="./output"
    )
    parser.add_argument(
        "--size", help="Size of image to load into model", default="320x320"
    )
    parser.add_argument(
        "--threshold", help="Prediction confidence threshold", default=0.7
    )
    parser.add_argument(
```

Figure 3.34 Model Prediction

After the image has been preprocessed, the model prediction codes are shown in the diagram above. The program will first load the label map, which contains the annotations for each image in the dataset, before moving on to the prediction.

```python
## Load model
print("Loading model...")
start_time = time.time()
trained_model = tf.saved_model.load(args.model)
print("Model loaded, took {} seconds...".format(time.time() - start_time))

## Run prediction on each image
for each_image in glob.glob(os.path.join(args.input, "*")):
    print("Predicting for {}...".format(each_image))

    height, width = args.size.split("x")

    ## Returned original_shape is in the format of width, height
    image_resized, origi_shape = load_image_into_numpy_array(
        each_image, int(height), int(width)
    )

    ## The input needs to be a tensor, convert it using `tf.convert_to_tensor`.
    input_tensor = tf.convert_to_tensor(image_resized)

    ## The model expects a batch of images, so add an axis with `tf.newaxis`.
    input_tensor = input_tensor[tf.newaxis, ...]

    ## Feed image into model
    detections_output = trained_model(input_tensor)

    num_detections = int(detections_output.pop("num_detections"))
    detections = {
        key: value[0, :num_detections].numpy()
        for key, value in detections_output.items()
    }
    detections["num_detections"] = num_detections

    ## Filter out predictions below threshold
    indexes = np.where(detections["detection_scores"] > float(args.threshold))
```

Figure 3.35 Model Prediction

The trained model will be loaded here in order to generate a prediction output for the image input. The detection scores will be the acting percentage accuracy of the prediction output, which can be viewed beside the class name once the output image has been generated.

3.7.4.3 Model

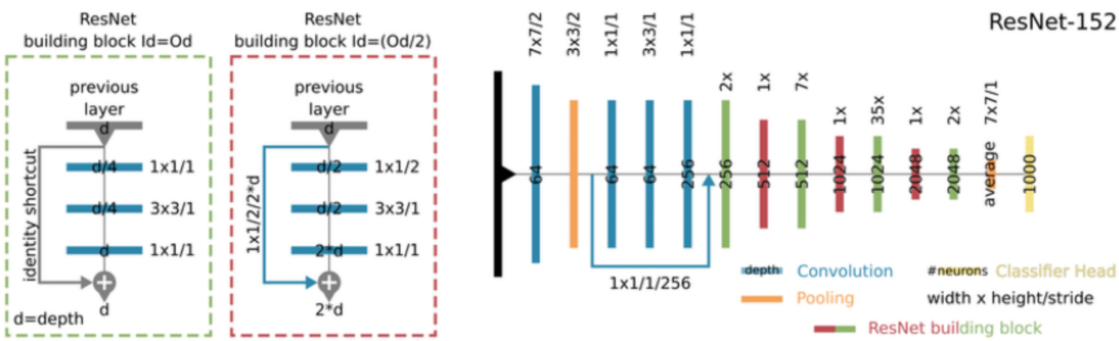


Figure 3.36 FasterRCNN ResNet 152 Network Architecture

The two ResNet building blocks show the convolutional operations in the main trunk, extracting features, and the residual connections surrounding these operations to enable a more efficient transport of gradients during training. (Left) The ResNet building blocks show the convolutional operations in the main trunk, extracting features, and the residual connections surrounding these operations to enable a more efficient transport of gradients during training. The distinction between the two forms is that the first transmits the block's input value without modifying it (identity shortcut), but the second employs stride 2 convolution to match the main trunk's output resolution and depth. (Right) ResNet-152's overall design has 152 layers due to stacked ResNet building components (26).

3.7.4.4 Data Flow Diagram

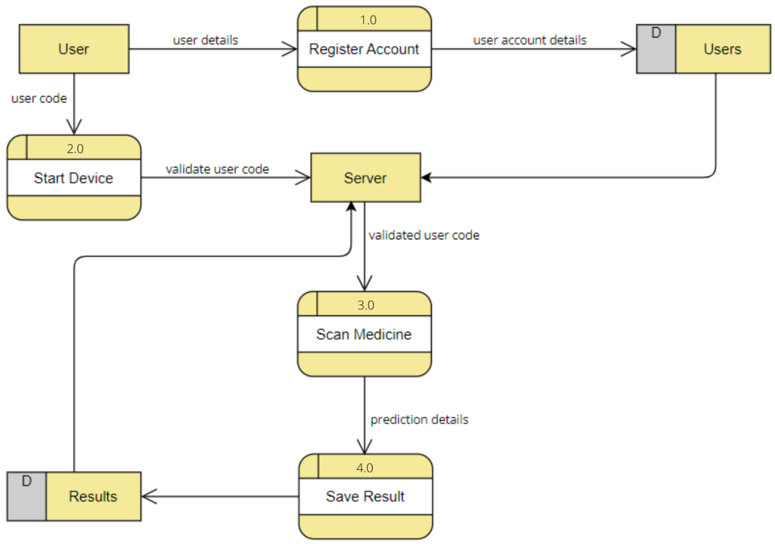


Figure 3.37 DFD Level 1

The data flow diagram, which depicts how data moves from input to storage in the system, is shown in the diagram above. The figure depicts four main processes, beginning with the creation of an account, which will require some user details or information to be placed in the users' data storage. And, as a second process, the user can start the device and enter the code, which will be confirmed by the server, and if valid, the process will proceed to scan the medicine. When the medicine is scanned, the prediction details are saved to the user's account's results data storage, which users may access via history or reports as part of the online application's added features.

3.7.5 Constraints Computations

3.7.5.1 Cost

Table 3-9 Overall Cost Computation for Design Option 1

Quantity	Components	Weight	Source	Amount
1	Raspberry Pi 4b	45.36 grams	Circuit Rocks	4,810.00 PHP
1	Rechargeable 5V LiPo USB Powerboost	9 grams	Circuit Rocks	985.00 PHP

	500 Charger			
1	Battery Lithium-Ion Polymer 3.7V 2500mAh	52 grams	Circuit Rocks	985.00 PHP
1	5mp Arducam OV564	40.11 grams	Amazon	1559.48 PHP
1	1W Warm White LED Light	2 grams	Circuit Rocks	34.00 PHP
1	PiTFT 2.4" HAT Mini Kit - 320x240 TFT Touchscreen Adafruit	70 grams	Circuit Rocks	2,049.00 PHP
1	DPDT 6-pin Slide Switch	6 grams	Circuit Rocks	45.00 PHP
1	ABS Case	595 grams	The Garage Manila International	950.00 PHP
1	16GB SD Card	9 grams	Circuit Rocks	250.00 PHP
			Total Cost	**11,667.48 PHP**

The overall cost computation for this design option sums up to 11,667.48 pesos, composed of nine components.

3.7.5.2 Accuracy

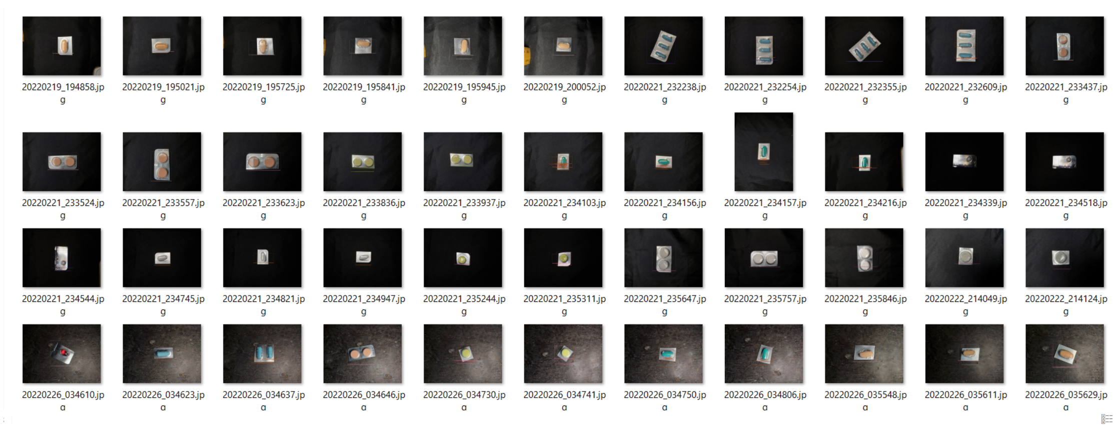


Figure 3.38 FasterRCNN ResNet152 Testing Result

Figure 3.39 FasterRCNN ResNet152 Sample Result

Table 3-10 Accuracy Computation for Design Option 1

Camera Used	Total No. of Test	True	False	% Accuracy
5mp Arducam OV564	60	40	20	**66.67%**

The developers tested an actual image made up of random images in both an uncontrolled and a controlled environment. Following that, we manually listed the true and false predictions per image output and computed them using the accuracy formula, resulting in an accuracy of 66.67% for this design option.

3.7.5.3 Portability

The developers are evaluating two factors for this design constraint: the device's overall size and weight. Thus, the overall size of this design option is 126 in^3 and has a total weight of 828.47 g.

3.7.6 Design Option 1 Summary

In conclusion, Design Option 1 looks to be a tiny and tall device that uses a 5MP Arducam and a FasterRCNN ResNet152 model. The three design constraints that the proponents must adhere to were used to assess this. The total cost of this prototype, including administrative expenditures, was around 11,667.48 pesos. In terms of accuracy, the camera module and model combined yielded an accuracy of 66.67%. With a total weight of 828.47 grams and dimensions of 4.5"x4"x7"or 126 in^3.

3.8 DESIGN OPTION 2: MedCheck

3.8.1 System Architecture

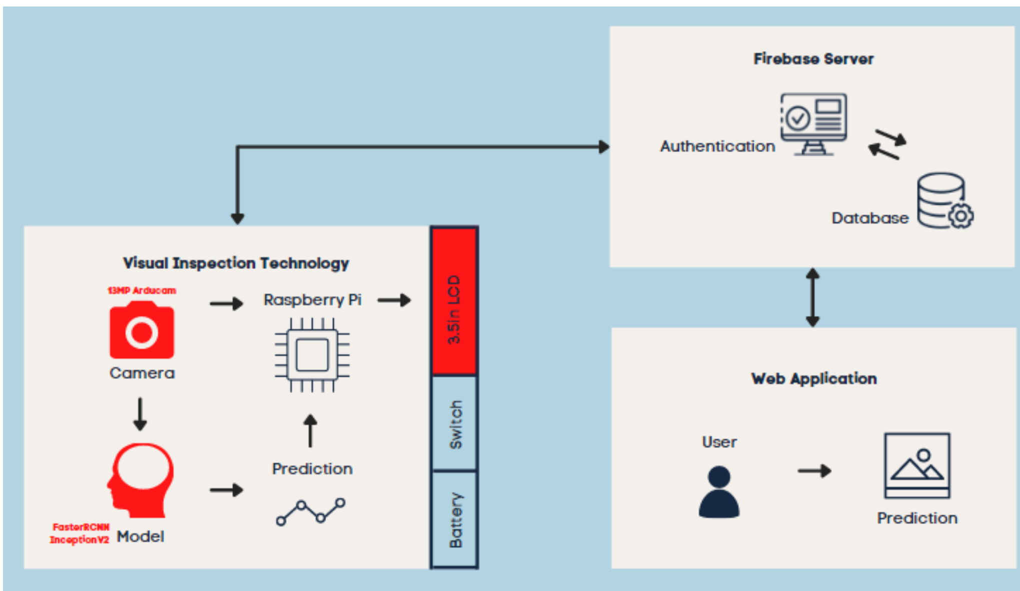


Figure 3.40 Design Option 2 System Architecture

The entire system architecture of design option one is shown in Figure 3.40. The proponents chose to employ the13MP Arducam camera module in conjunction with FasterRCNN InceptionV2 as its machine learning model, which both plays an important part in producing a reliable prediction output. In addition, we chose a 3.5inch LCD. Above and beyond, there is the firebase server to allow the web application and visual inspection technology device to connect with one another while also adding a layer of protection for the users and data.

3.8.2 System Layout/Drawings

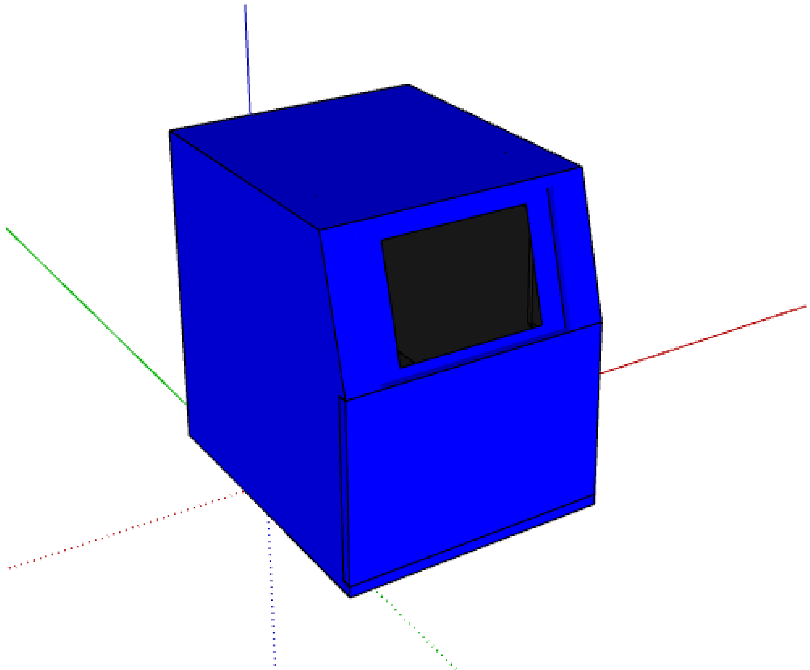


Figure 3.41 Dimensions of the Prototype

The prototype is shown above with labeled dimensions in inches. It has a height of 6 inches, a width of 5 inches, and a length of 5.5 inches.

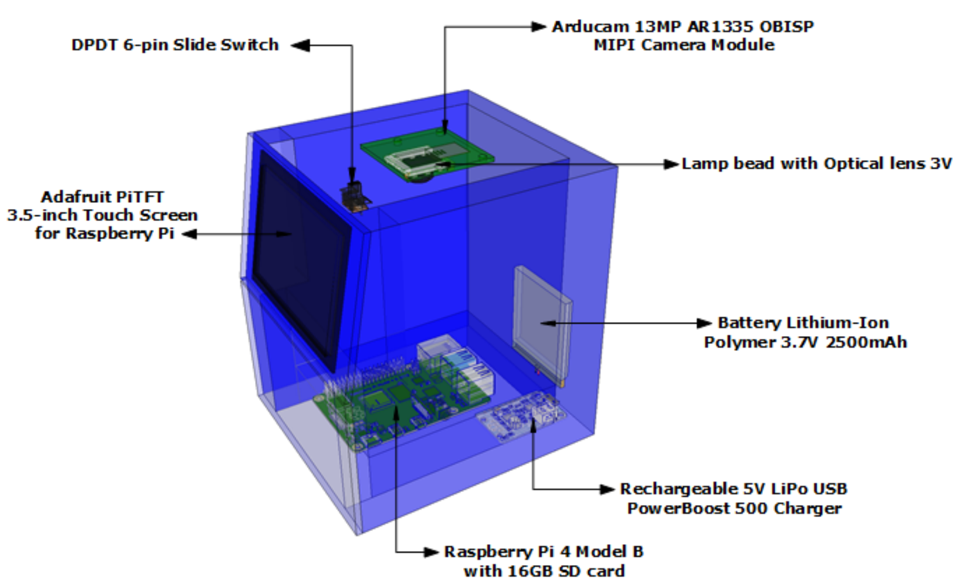


Figure 3.42 Labeled Components

The labeled components of the prototype for this design option are shown in the figure above. The 13mp Arducam IMX135 MIPI camera module, as well as the LED strip light with 1W, are positioned on the prototype's top, presumably to capture images of the medicine on the black platform below. As well as a DPDT 6-pin slide switch for control. There will also be a TFT 3.5” screen where the output will be displayed.

3.8.3 Hardware Design

The system layout, or the 2D and 3D of this design option, comes before this part. And, the components that built it electrically and mechanically will be reviewed and illustrated in this section. It should also take into account the design constraints in order to meet the client's requirements.

3.8.3.1 Functional Specifications

Figure 3.43 Raspberry Pi 4 Model B

Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers. It offers groundbreaking increases in processor speed, multimedia performance, memory, and connectivity compared to the prior-generation Raspberry Pi 3 Model B+, while retaining backwards compatibility and similar power consumption. For the end user, Raspberry Pi 4 Model B provides desktop performance comparable to entry-level x86 PC systems. This product’s key features include a high-performance 64-bit quad-core processor, dual-display support at resolutions up to 4K via a pair of micro-HDMI ports, hardware video decode at up to 4Kp60, up to 8GB of RAM, dual band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability (via a separate PoE HAT add-on). The dual-band wireless LAN and Bluetooth have modular compliance certification, allowing the board to be designed into end products with significantly reduced compliance testing, improving both cost and time to market.

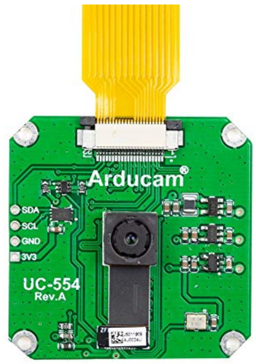


Figure 3.44 13mp Arducam IMX135 MIPI

The Arducam 13MP MIPI camera module is designed specifically for Raspberry Pi boards, and it can be connected directly to the RPi's CSI-2 camera interface without any additional hardware.

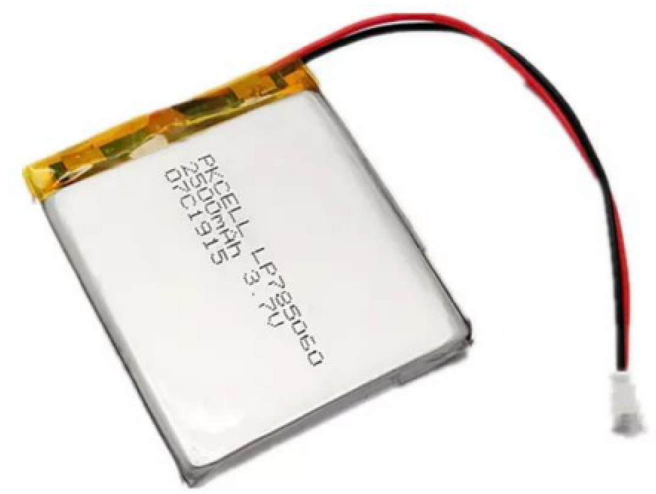


Figure 3.45 Battery Lithium-Ion Polymer 3.7V 2500mAh

Lithium-ion polymer (also known as 'lipo' or 'lipoly') batteries are thin, light, and powerful. The output ranges from 4.2V when completely charged to 3.7V. This battery has a capacity of 2500mAh for a total of about 10 Wh with a genuine JST connector. The batteries come pre-attached with a genuine 2-pin JST-PH connector as shown and include the necessary protection circuitry. The included protection circuitry keeps the battery voltage from going too high (over-charging) or low (over-use) which means that the battery will cut out when completely dead at 3.0V. It will also protect against output shorts. However, even with this protection, it is very important that you only use a LiIon/LiPoly constant-voltage/constant-current charger to recharge them at a rate of 1200mA or less.

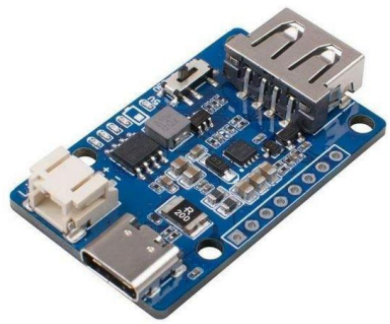


Figure 3.46 Rechargeable 5V LiPo USB PowerBoost 500 Charger

PowerBoost 500C is the perfect power supply with a built-in battery charger circuit, it will be able to keep running even while recharging the battery. The DC/DC boost converter module can be powered by any 3.7V LiIon/LiPoly battery and convert the battery output to 5.2V DC for running 5V projects. The charger circuitry is powered from a micro-USB jack and will recharge any 3.7V/4.2V LiIon or LiPoly battery at 500mA max rate. It can charge and boost at the same time with no problem, without any interruption of the output.

Figure 3.47 1W Warm White LED Light

Warm White has a bit of a yellow tint to it and is similar to standard incandescent light bulbs. It has proven to be the best balance of warmth and utility. Temperatures below 3000K begin to appear more yellow than white, the result being a sacrifice to rendering ability as well as pure function and aesthetics.

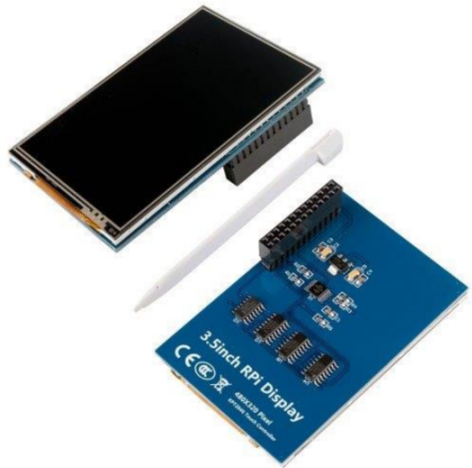


Figure 3.48 Adafruit Pi TFT 3.5”

A 3.5" display with 480x320 16-bit color pixels and a resistive touch overlay but it’s only slightly larger than the popular original. The plate uses the high-speed SPI interface on the Pi and can use the mini display as a console, X window port, displaying images or video. It's designed to fit nicely onto the Pi Model A or B but also works perfectly fine with the Model B+. The hardware used SPI pins (SCK, MOSI, MISO, CE0, CE1) as well as GPIO #25 and #24. GPIO #18 can be used to PWM dim the backlight. All other GPIO are unused. There's a 2x13 header on the bottom, it can connect a standard Pi GPIO cable to it to use any of the other pins.

Figure 3.49 DPDT 6-pin Slide Switch

A 6 Pin Push Switch also known as Mini DPDT Push Switch, is a combination of two push switches placed together inside one package. Unlike momentary switches which connect the wires of the switch only for a second, this switch retains its ON-OFF state till pushed later. For example, if push it once so that it's turned on, it will remain in the ON state till it's pushed again. That's why this switch is useful in controlling power connections most of the time. It will easily interpret that this switch has two common pins which are simultaneously switched ON and OFF. When the trigger is pushed and moves down a notch, the connections between Pin 1 to Pin 2 and Pin 5 to Pin 6 are made. This is the ON state of the switch.

Figure 3.50 16GB SD Card

An SD card, or Secure Digital card, is a removable memory card that can be used in a variety of mobile phones, cameras, smart devices, and other devices to read and write large amounts of data.

Figure 3.51 ABS Case

ABS or Acrylonitrile butadiene styrene is a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which the material is machined by plastic manufacturers.

3.8.3.2 Block Diagram

The visual depiction of design option 2 is shown in the diagram below, which depicts the general arrangement of the pieces or components of a major system or process, such as an electronic circuit. This is only to demonstrate the connections between the components stated previously.

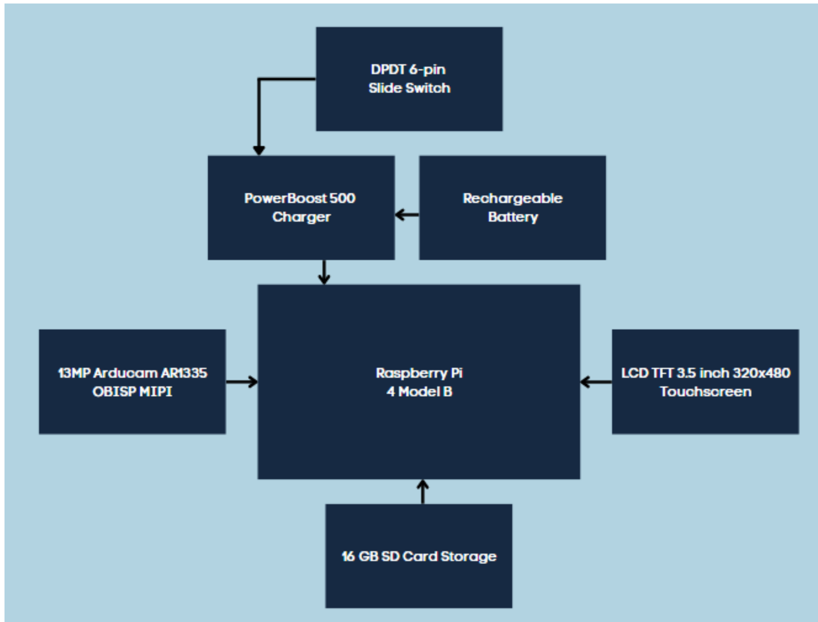


Figure 3.52 Block Diagram

3.8.3.3 Schematic Diagram

In this part will be visualized how each of the components connected to one another, looking at it abstractly as a wiring or circuit diagram wherein the lines are represented as wires.

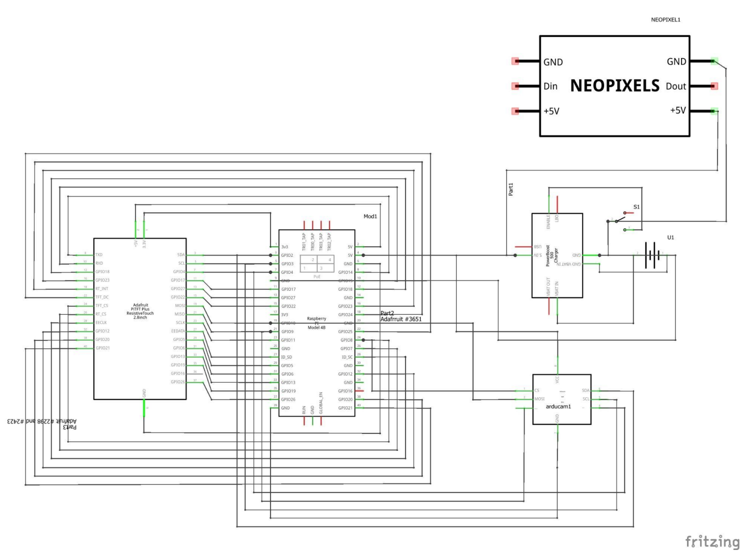


Figure 3.53 Schematic Diagram

3.8.4 Software Design

The functions that flow inside the system when it is running will be explored and depicted using diagrams from input to output in this section. It also explains which functions should be implemented in the system and what role each component plays.

3.8.4.1 System Flowchart

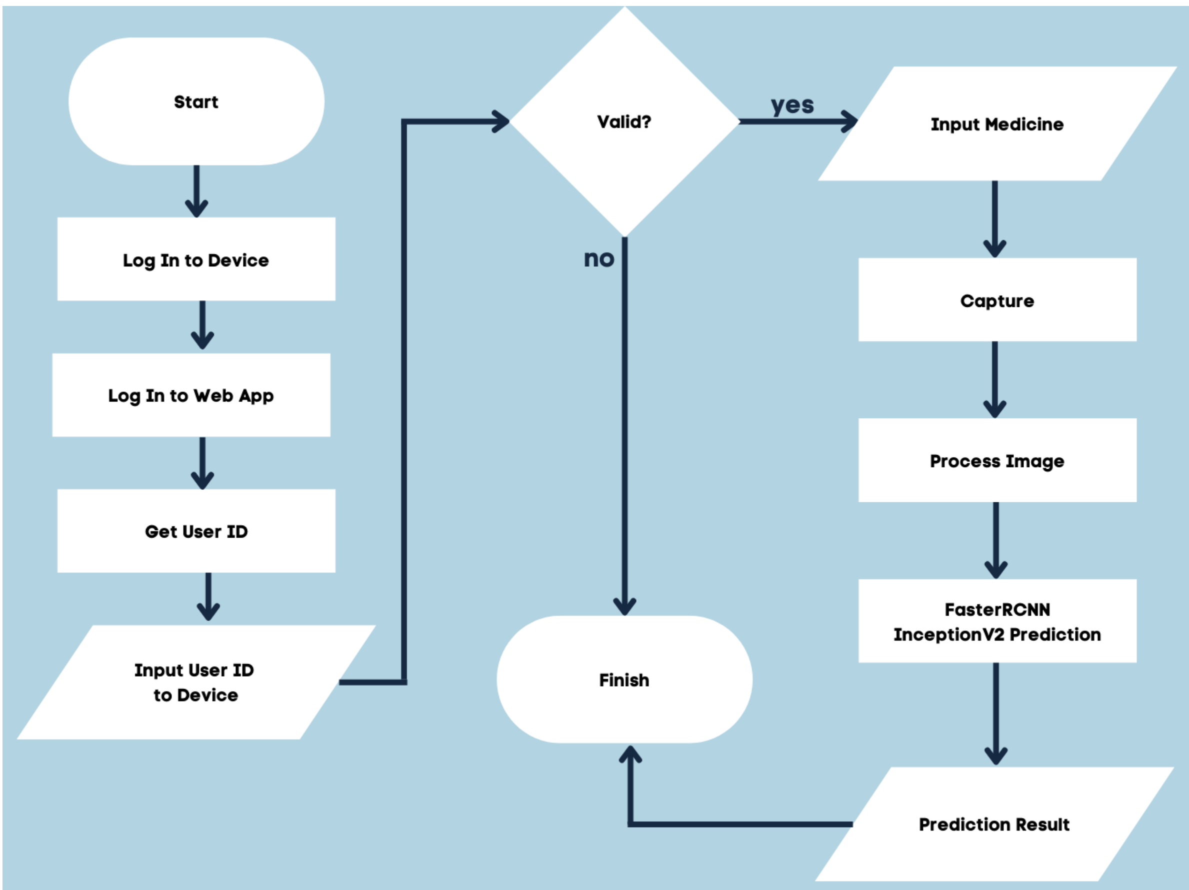


Figure 3.54 Med Dev's System Flowchart

Figure 3.54 shows a representation of how the system's process flow will be carried out. As seen in the diagram above, the user must enter a code in order to proceed with the device's scanning, which can be obtained via the web application. Following the user's validation, the system will capture and process the image in order to feed it to the algorithm, which will then provide a prediction output, which is the final step in the process.

3.8.4.2 Data Pre-processing

The process of changing raw data into a usable, intelligible format is known as data preprocessing. Real-world or raw data is prone to inconsistencies in formatting, human errors, and incompleteness. Data preprocessing solves these problems by making datasets more complete and efficient to analyze. It's an important step that can make or break data mining and machine learning projects. It speeds up knowledge extraction from datasets and may have an impact on machine learning model performance (25).

```python
def load_label_map(label_map_path):
    label_map = {}

    with open(label_map_path, "r") as label_file:
        for line in label_file:
            if "id" in line:
                label_index = int(line.split(":")[-1])
                label_name = next(label_file).split(":")[-1].strip().strip("'")
                label_map[label_index] = {"id": label_index, "name": label_name}

    return label_map

def load_image_into_numpy_array(path, height, width):

    image = Image.open(path).convert("RGB")
    image_shape = np.asarray(image).shape

    image_resized = image.resize((height, width))
    return np.array(image_resized), (image_shape[0], image_shape[1])

def args_parser():
    parser = argparse.ArgumentParser(
        description="Datature Open Source Prediction Script"
    )
    parser.add_argument(
        "--input", help="Path to folder that contains input images", default="./input"
    )
    parser.add_argument(
        "--output", help="Path to folder to store predicted images", default="./output"
    )
    parser.add_argument(
        "--size", help="Size of image to load into model", default="320x320"
    )
    parser.add_argument(
        "--threshold", help="Prediction confidence threshold", default=0.7
    )
    parser.add_argument(
```

Figure 3.55 Model Prediction

After the image has been preprocessed, the model prediction codes are shown in the diagram above. The program will first load the label map, which contains the annotations for each image in the dataset, before moving on to the prediction.

```python
## Load model
print("Loading model...")
start_time = time.time()
trained_model = tf.saved_model.load(args.model)
print("Model loaded, took {} seconds...".format(time.time() - start_time))

## Run prediction on each image
for each_image in glob.glob(os.path.join(args.input, "*")):
    print("Predicting for {}...".format(each_image))

    height, width = args.size.split("x")

    ## Returned original_shape is in the format of width, height
    image_resized, origi_shape = load_image_into_numpy_array(
        each_image, int(height), int(width)
    )

    ## The input needs to be a tensor, convert it using `tf.convert_to_tensor`.
    input_tensor = tf.convert_to_tensor(image_resized)

    ## The model expects a batch of images, so add an axis with `tf.newaxis`.
    input_tensor = input_tensor[tf.newaxis, ...]

    ## Feed image into model
    detections_output = trained_model(input_tensor)

    num_detections = int(detections_output.pop("num_detections"))
    detections = {
        key: value[0, :num_detections].numpy()
        for key, value in detections_output.items()
    }
    detections["num_detections"] = num_detections

    ## Filter out predictions below threshold
    indexes = np.where(detections["detection_scores"] > float(args.threshold))
```

Figure 3.56 Model Prediction

The trained model will be loaded here in order to generate a prediction output for the image input. The detection scores will be the acting percentage accuracy of the prediction output, which can be viewed beside the class name once the output image has been generated.

3.8.4.3 Model

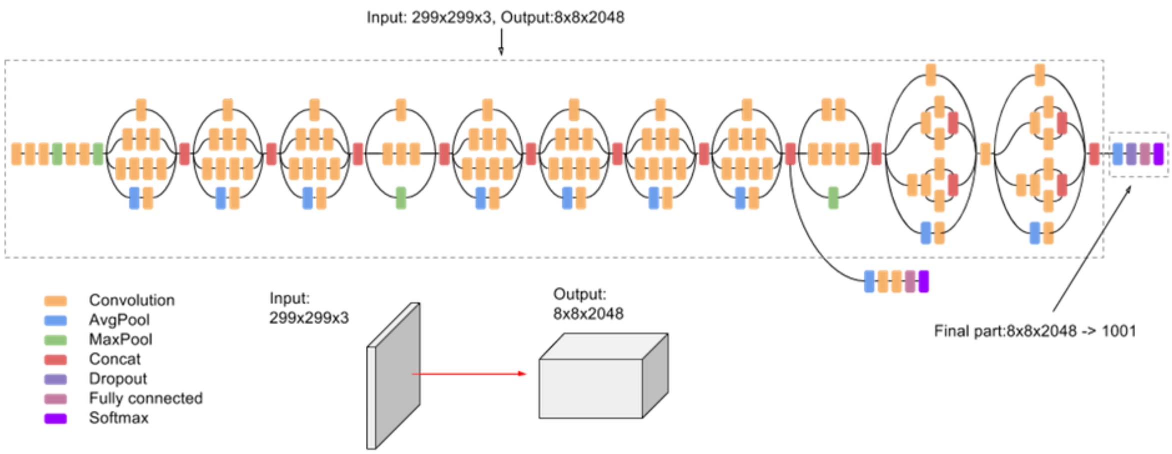


Figure 3.57 FasterRCNN InceptionV2 Network Architecture

The Inception V2 architecture is used since it is one of the most accurate Convolutional Neural Network architectures (27). To improve, the Faster R-CNN model's optimal learning rate and epoch parameters are improved. We have two Inception modules at the coarsest 8 x 8 level, as shown in figure 6, with a concatenated output filter bank size of 2048 for each tile.

3.8.4.4 Data Flow Diagram

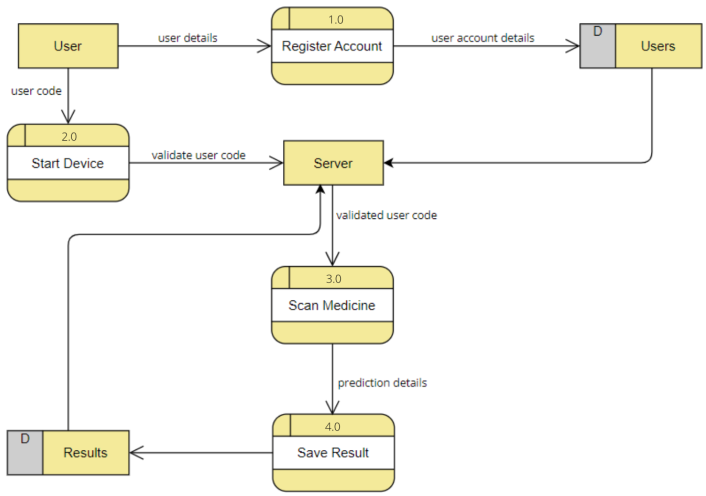


Figure 3.58 DFD Level 1

The data flow diagram, which depicts how data moves from input to storage in the system, is shown in the diagram above. The figure depicts four main processes, beginning with the creation of an account, which will require some user details or information to be placed in the users' data storage. And, as a second process, the user can start the device and enter the code, which will be confirmed by the server, and if valid, the process will proceed to scan the medicine. When the medicine is scanned, the prediction details are saved to the user's account's results data storage, which users may access via history or reports as part of the online application's added features.

3.8.5 Constraints Computations

3.8.5.1 Cost

Table 3-11 Overall Cost Computation for Design Option 2

Quantity	Components	Weight	Source	Amount
1	Raspberry Pi 4 Model B	45.36 grams	Circuit Rocks	4,810.00 PHP
1	Rechargeable 5V LiPo USB Powerboost 500 Charger	9 grams	Circuit Rocks	985.00 PHP

1	Battery Lithium-Ion Polymer 3.7V 2500mAh	52 grams	Circuit Rocks	985.00 PHP
1	13mp Arducam IMX135 MIPI	4 grams	Amazon	2,199.52 PHP
1	1W Warm White LED Light	2 grams	Circuit Rocks	34.00 PHP
1	3.5” TFT Display	46 grams	Circuit Rocks	1,150.00 PHP
1	DPDT 6-pin Slide Switch	6 grams	Circuit Rocks	8.00 PHP
1	ABS Case	650 grams	The Garage Manila International	1140.00 PHP
1	16GB SD Card	9 grams	Circuit Rocks	200.00 PHP
			Total Cost	**11,511.52 PHP**

The overall cost computation for this design option sums up to 11,511.52 pesos, composed of nine components that are mostly purchased from Circuit Rocks, one item from Amazon, and one from The Garage Manila International.

3.8.5.2 Accuracy

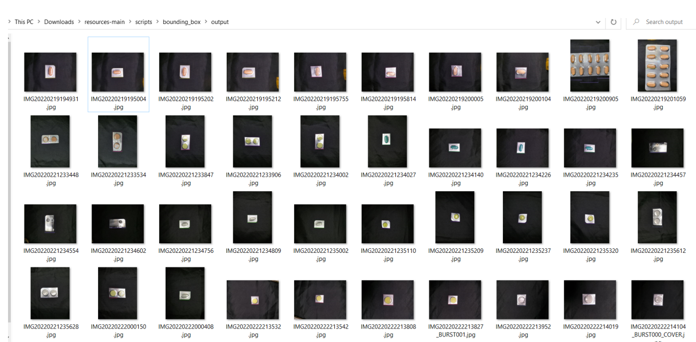


Figure 3.59 FasterRCNN InceptionV2 Testing Result

Figure 3.60 FasterRCNN InceptionV2 Sample Result

Table 3-12 Accuracy

Camera Used	Total No. of Test	True	False	% Accuracy
13mp Arducam IMX 135 MIPI	60	55	5	**91.67%**

The developers tested an actual image made up of random images in both an uncontrolled and a controlled environment. Following that, we manually listed the true and false predictions per image output which resulted in 55 true and 5 false predictions and computed them using the accuracy formula, resulting in an accuracy of 91.67% for this design option.

3.8.5.3 Portability

The proponents are evaluating two factors for this design constraint: the device's overall size and weight. Thus, the overall size of this design option is 165 in^3 and it has a total weight of 823.36 grams.

3.8.6 Design Option 2 Summary

In conclusion, Design Option 2 is a device that uses a 13MP Arducam and a FasterRCNN InceptionV2 model. The three design constraints that the proponents must adhere to were used to assess this. The total cost of this prototype, including administrative expenditures, was around 11,511.52 pesos. In terms of accuracy, the camera module and model combined yielded an accuracy of 91.67%. With a total weight of 823.36g and with dimensions of 5.5”x5”x6” or 165 in^3.

3.9 DESIGN OPTION 3: MRPi

3.9.1 System Architecture

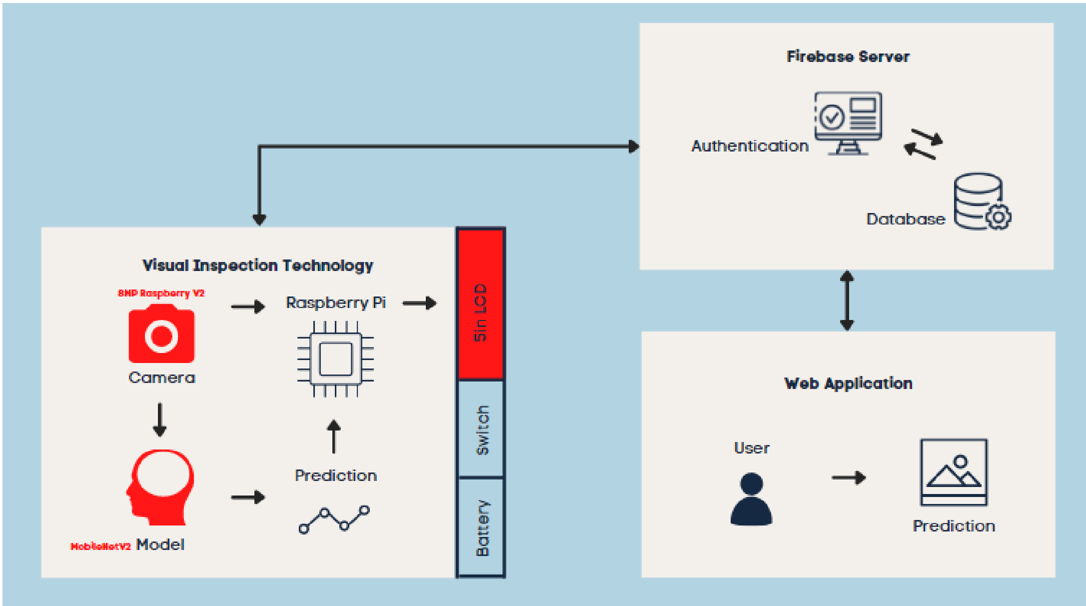


Figure 3.61 Design Option 3 System Architecture

The entire system architecture of design option one is shown in Figure 3.54. The proponents chose to employ the 8MP Raspberry Pi V2 camera module in conjunction with Retina MobileNnet V2 as its machine learning model, which both plays an important part in producing a reliable prediction output. In addition, we chose a 5 inch LCD. Above and beyond, there is the firebase server to allow the web application and visual inspection technology device to connect with one another while also adding a layer of protection for the users and data.

3.9.2 System Layout/Drawings

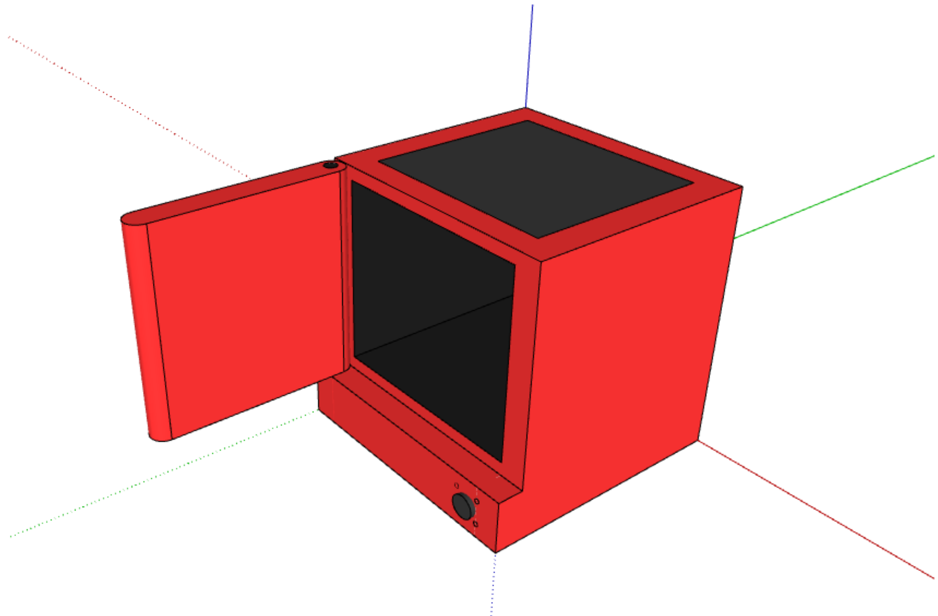


Figure 3.62 Dimensions of the Prototype

The prototype is shown above with labeled dimensions in inches. It has a height of 6 inches, a width of 6 inches, and a length of 6 inches.

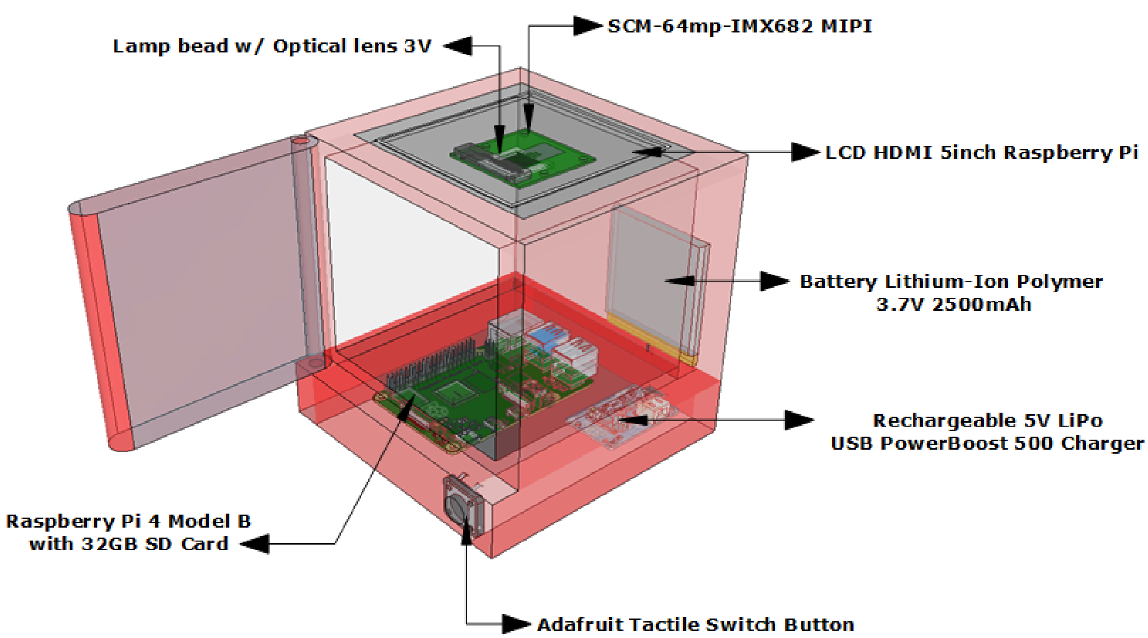


Figure 3.63 Labeled Components

The labeled components of the prototype for this design option are shown in the figure above. The 8mp Raspberry Pi V2 camera module, as well as the LED strip light with 1W, are positioned on the prototype's top, presumably to capture images of the medicine on the black platform below. The device also has an opening cover for when the user is using it, as well as a tactile switch for control. There will also be a LCD HDMI 5 inch 800x480 Raspberry Pi where the output will be displayed.

3.9.3 Hardware Design

The system layout, or the 2D and 3D of this design option, comes before this part. And, the components that built it electrically and mechanically will be reviewed and illustrated in this section. It should also take into account the design constraints in order to meet the client's requirements.

3.9.3.1 Functional Specifications

Figure 3.64 Raspberry Pi 4 Model B

Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers. It offers groundbreaking increases in processor speed, multimedia performance, memory, and connectivity compared to the prior-generation Raspberry Pi 3 Model B+, while retaining backwards compatibility and similar power consumption. For the end user, Raspberry Pi 4 Model B provides desktop performance comparable to entry-level x86 PC systems. This product’s key features include a high-performance 64-bit quad-core processor, dual-display support at resolutions up to 4K via a pair of micro-HDMI ports, hardware video decode at up to 4Kp60, up to 8GB of RAM, dual band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability (via a separate PoE HAT add-on). The dual-band wireless LAN and Bluetooth have modular compliance certification, allowing the board to be designed into end products with significantly reduced compliance testing, improving both cost and time to market.

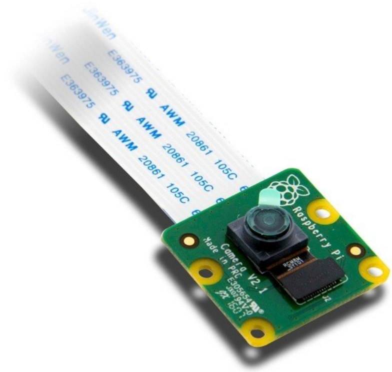


Figure 3.65 8mp Raspberry Pi V2

The Raspberry Pi Camera Module v2 is a custom-built Raspberry Pi add-on board containing an 8-megapixel Sony IMX219 image sensor and a fixed focus lens. Static photos up to 3280 x 2464 pixels are supported, as well as video up to 1080p30, 720p60, and 640x480p60/90.

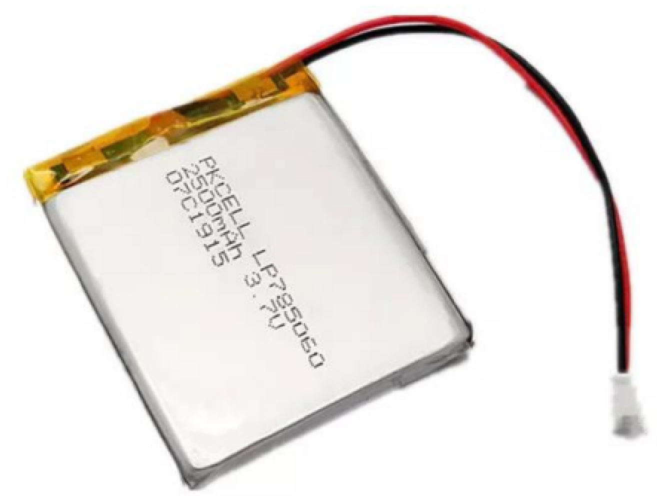


Figure 3.66 Battery Lithium-Ion Polymer 3.7V 2500mAh

Lithium-ion polymer (also known as 'lipo' or 'lipoly') batteries are thin, light, and powerful. The output ranges from 4.2V when completely charged to 3.7V. This battery has a capacity of 2500mAh for a total of about 10 Wh with a genuine JST connector. The batteries come pre-attached with a genuine 2-pin JST-PH connector as shown and include the necessary protection circuitry. The included protection circuitry keeps the battery voltage from going too high (over-charging) or low (over-use) which means that the battery will cut out when completely dead at 3.0V. It will also protect against output shorts. However, even with this protection, it is very important that you only use a LiIon/LiPoly constant-voltage/constant-current charger to recharge them at a rate of 1200mA or less.

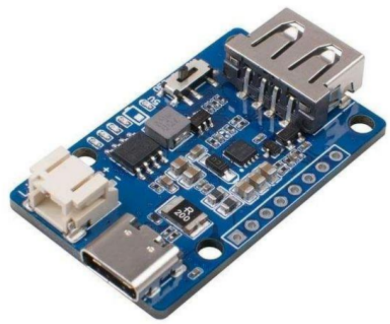


Figure 3.67 Rechargeable 5V LiPo USB PowerBoost 500 Charger

PowerBoost 500C is the perfect power supply with a built-in battery charger circuit, it will be able to keep running even while recharging the battery. The DC/DC boost converter module can be powered by any 3.7V LiIon/LiPoly battery and convert the battery output to 5.2V DC for running 5V projects. The charger circuitry is powered from a micro-USB jack and will recharge any 3.7V/4.2V LiIon or LiPoly battery at 500mA max rate. It can charge and boost at the same time with no problem, without any interruption of the output.

Figure 3.68 1W Warm White LED Light

Warm White has a bit of a yellow tint to it and is similar to standard incandescent light bulbs. It has proven to be the best balance of warmth and utility. Temperatures below 3000K begin to appear more yellow than white, the result being a sacrifice to rendering ability as well as pure function and aesthetics.

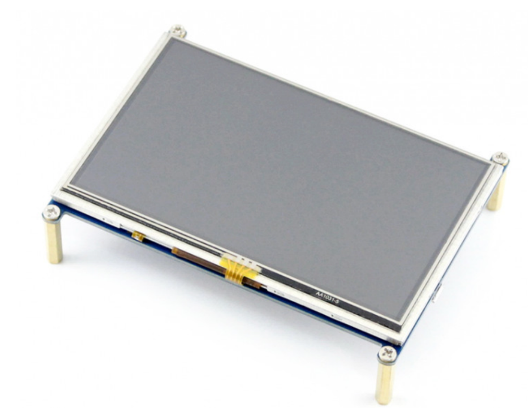


Figure 3.69 LCD HDMI 5 inch 800x480 Raspberry Pi

800×480 high resolution, touch control, Compatible and Direct-connect with any revision of Raspberry Pi. It has Drivers provided HDMI interface for displaying, no I/Os required. The backlight can be turned off to lower power consumption and High quality immersion gold surface plating.

Figure 3.70 DPDT 6-pin Slide Switch

A 6 Pin Push Switch also known as Mini DPDT Push Switch, is a combination of two push switches placed together inside one package. Unlike momentary switches which connect the wires of the switch only for a second, this switch retains its ON-OFF state till pushed later. For example, if you push it once so that it's turned on, it will remain in the ON state till it's pushed again. That's why this switch is useful in controlling power connections most of the time. It will easily interpret that this switch has two common pins which are simultaneously switched ON and OFF. When the trigger is pushed and moves down a notch, the connections between Pin 1 to Pin 2 and Pin 5 to Pin 6 are made. This is the ON state of the switch.

Figure 3.71 32GB SD Card

An SD card, or Secure Digital card, is a removable memory card that can be used in a variety of mobile phones, cameras, smart devices, and other devices to read and write large amounts of data.

Figure 3.72 ABS Case

ABS or Acrylonitrile butadiene styrene is a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which the material is machined by plastic manufacturers.

3.9.3.2 Block Diagram

The visual depiction of design option 1 is shown in the diagram below, which depicts the general arrangement of the pieces or components of a major system or process, such as an electronic circuit. This is only to demonstrate the connections between the components stated previously.

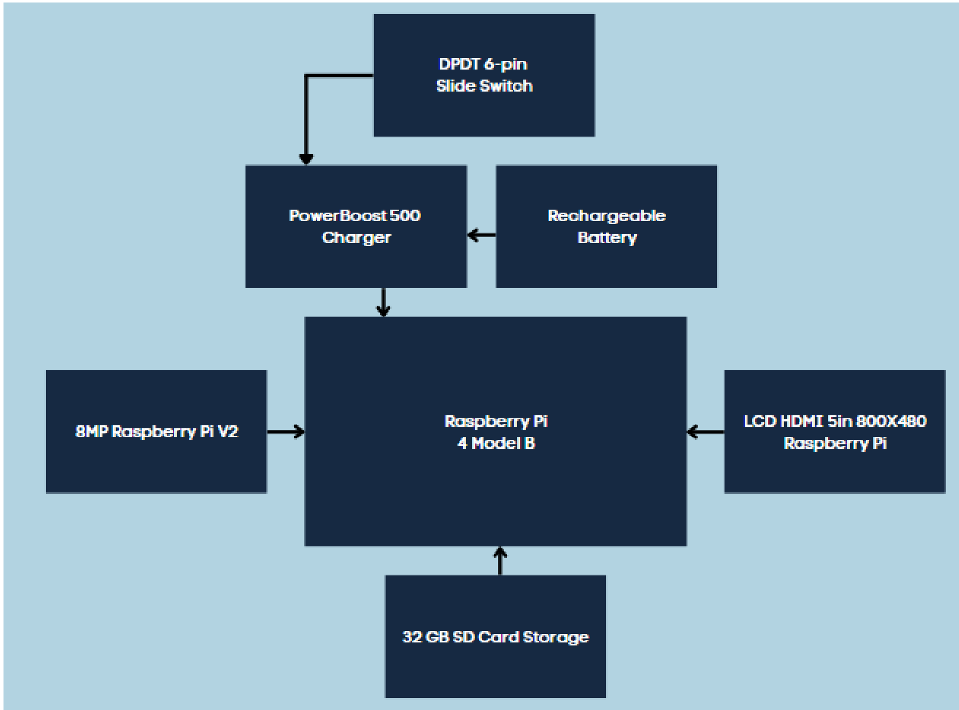


Figure 3.73 Block Diagram

3.9.3.3 Schematic Diagram

In this part will be visualized how each of the components connected to one another, looking at it abstractly as a wiring or circuit diagram wherein the lines are represented as wires.

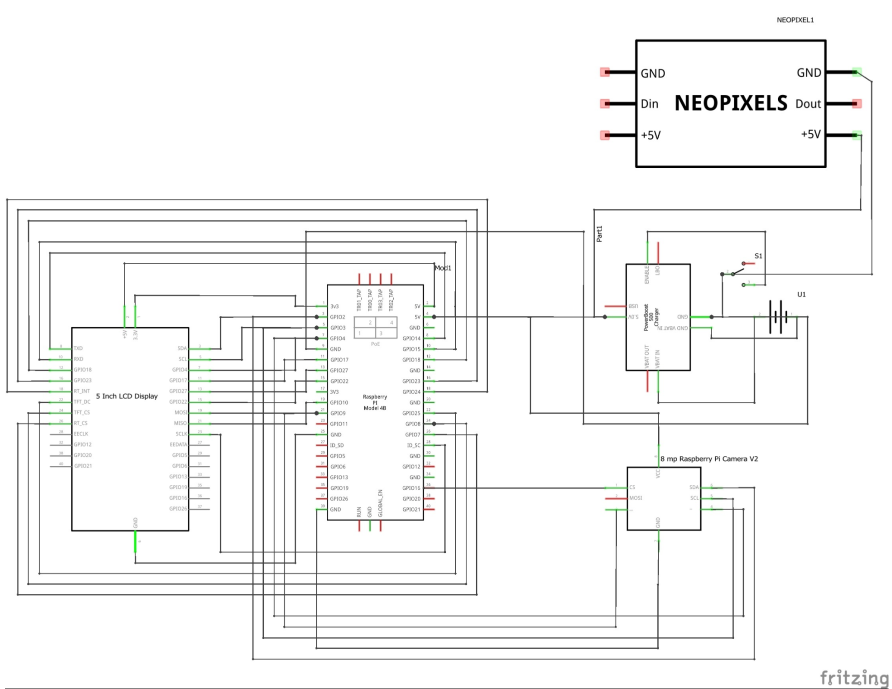


Figure 3.74 Schematic Diagram

3.9.4 Software Design

The functions that flow inside the system when it is running will be explored and depicted using diagrams from input to output in this section. It also explains which functions should be implemented in the system and what role each component plays.

3.9.4.1 System Flowchart

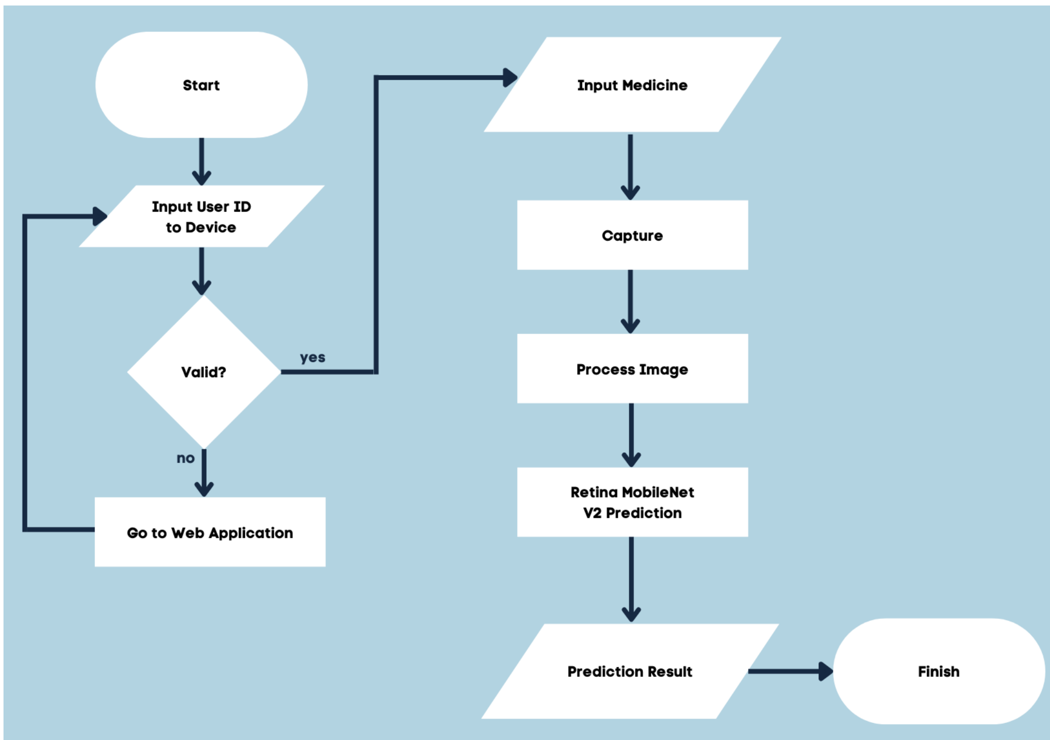


Figure 3.75 System Flowchart

Figure 3.68 shows a representation of how the system's process flow will be carried out. As seen in the diagram above, the user must enter a code in order to proceed with the device's scanning, which can be obtained via the application. Following the user's validation, the system will capture and process the image in order to feed it to the algorithm, which will then provide a prediction output, which is the final step in the process.

3.9.4.2 Data Pre-processing

The process of changing raw data into a usable, intelligible format is known as data preprocessing. Real-world or raw data is prone to inconsistencies in formatting, human errors, and incompleteness. Data preprocessing solves these problems by making datasets more complete and efficient to analyze. It's an important step that can make or break data mining and machine learning projects. It speeds up knowledge extraction from datasets and may have an impact on machine learning model performance (25).

```python
def load_label_map(label_map_path):
    label_map = {}

    with open(label_map_path, "r") as label_file:
        for line in label_file:
            if "id" in line:
                label_index = int(line.split(":")[-1])
                label_name = next(label_file).split(":")[-1].strip().strip("'")
                label_map[label_index] = {"id": label_index, "name": label_name}

    return label_map

def load_image_into_numpy_array(path, height, width):

    image = Image.open(path).convert("RGB")
    image_shape = np.asarray(image).shape

    image_resized = image.resize((height, width))
    return np.array(image_resized), (image_shape[0], image_shape[1])

def args_parser():
    parser = argparse.ArgumentParser(
        description="Datature Open Source Prediction Script"
    )
    parser.add_argument(
        "--input", help="Path to folder that contains input images", default="./input"
    )
    parser.add_argument(
        "--output", help="Path to folder to store predicted images", default="./output"
    )
    parser.add_argument(
        "--size", help="Size of image to load into model", default="320x320"
    )
    parser.add_argument(
        "--threshold", help="Prediction confidence threshold", default=0.7
    )
    parser.add_argument(
```

Figure 3.76 Model Prediction

After the image has been preprocessed, the model prediction codes are shown in the diagram above. The program will first load the label map, which contains the annotations for each image in the dataset, before moving on to the prediction.

```python
## Load model
print("Loading model...")
start_time = time.time()
trained_model = tf.saved_model.load(args.model)
print("Model loaded, took {} seconds...".format(time.time() - start_time))

## Run prediction on each image
for each_image in glob.glob(os.path.join(args.input, "*")):
    print("Predicting for {}...".format(each_image))

    height, width = args.size.split("x")

    ## Returned original_shape is in the format of width, height
    image_resized, origi_shape = load_image_into_numpy_array(
        each_image, int(height), int(width)
    )

    ## The input needs to be a tensor, convert it using `tf.convert_to_tensor`.
    input_tensor = tf.convert_to_tensor(image_resized)

    ## The model expects a batch of images, so add an axis with `tf.newaxis`.
    input_tensor = input_tensor[tf.newaxis, ...]

    ## Feed image into model
    detections_output = trained_model(input_tensor)

    num_detections = int(detections_output.pop("num_detections"))
    detections = {
        key: value[0, :num_detections].numpy()
        for key, value in detections_output.items()
    }
    detections["num_detections"] = num_detections

    ## Filter out predictions below threshold
    indexes = np.where(detections["detection_scores"] > float(args.threshold))
```

Figure 3.77 Model Prediction

The trained model will be loaded here in order to generate a prediction output for the image input. The detection scores will be the acting percentage accuracy of the prediction output, which can be viewed beside the class name once the output image has been generated.

3.9.4.3 Model

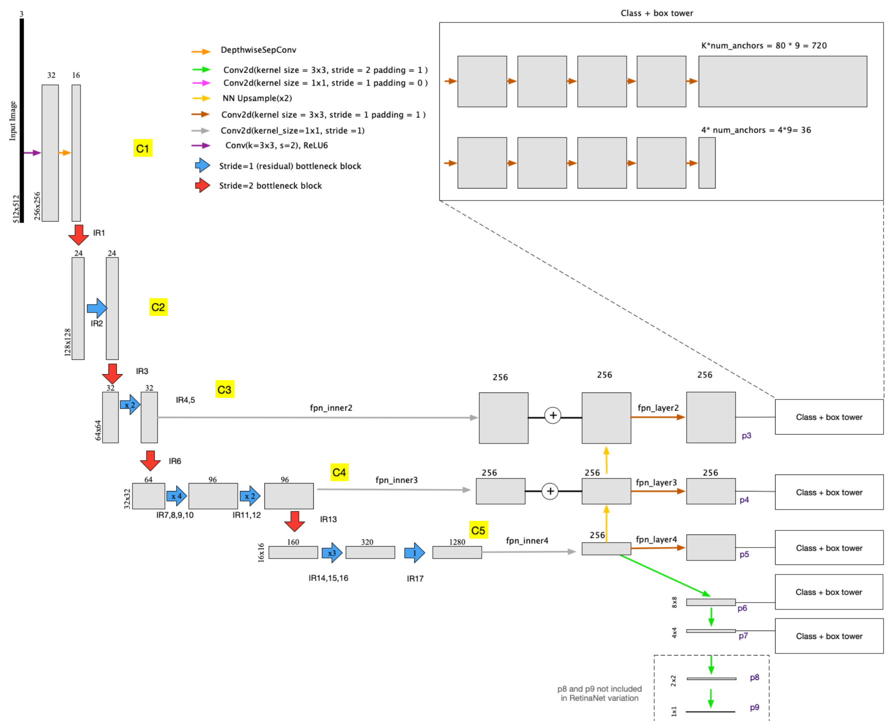


Figure 3.78 Retina MobileNetV2 Network Architecture

RetinaNet is a one-stage object detection model that achieves good COCO performance by employing a targeted loss function. For embedded use-cases, the network is currently too large to implement. By replacing the backbone with MobileNetV2 and reducing the FPN channels to 96, we can get a much reduced parameter count while still attaining a competitive AP (28). The number of feature planes is represented by the width of the rectangles in figure 3., while the resolution is represented by their height.

3.9.4.4 Data Flow Diagram

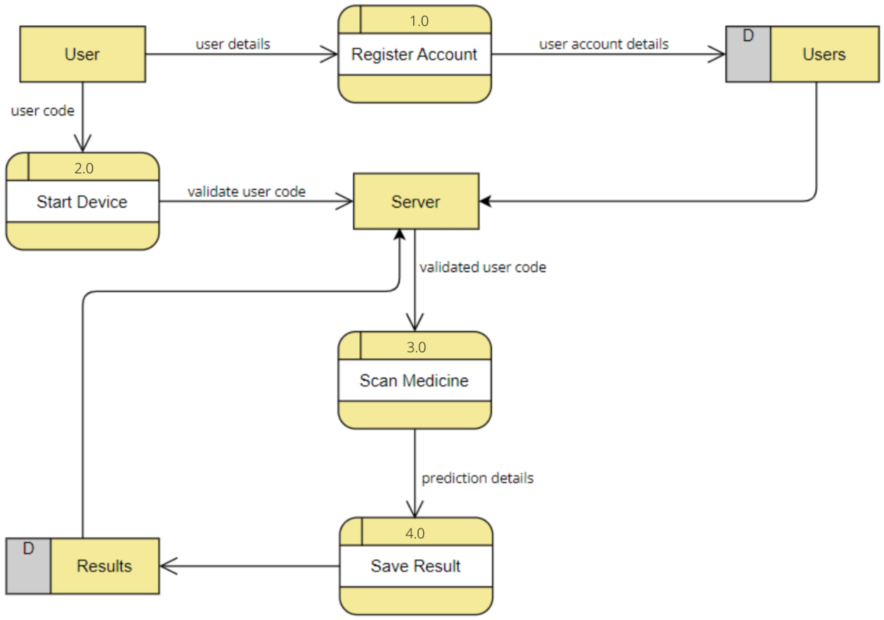


Figure 3.79 DFD Level 1

The data flow diagram, which depicts how data moves from input to storage in the system, is shown in the diagram above. The figure depicts four main processes, beginning with the creation of an account, which will require some user details or information to be placed in the users' data storage. And, as a second process, the user can start the device and enter the code, which will be confirmed by the server, and if valid, the process will proceed to scan the medicine. When the medicine is scanned, the prediction details are saved to the user's account's results data storage, which users may access via history or reports as part of the online application's added features.

3.9.5 Constraints Computations

3.9.5.1 Cost

Table 3-13 Overall Cost Computation for Design Option 3

Quantity	Components	Weight	Source	Prices
1	Raspberry Pi 4 Model B	45.36 grams	Circuit Rocks	4,810.00 PHP

1	Rechargeable 5V LiPo USB Powerboost 500 Charger	9 grams	Circuit Rocks	985.00 PHP
1	Battery Lithium-Ion Polymer 3.7V 2500mAh	52 grams	Circuit Rocks	985.00 PHP
1	8MP Raspberry Pi V2	3 grams	Circuit Rocks	2,347.40 PHP
1	LCD HDMI 5 inch 800x480 Raspberry Pi	125 grams	Circuit Rocks	2,450.00 PHP
1	1W Warm White LED Light	2 grams	Circuit Rocks	34.00 PHP
1	DPDT 6-pin Slide Switch	6 grams	Circuit Rocks	8.00 PHP
1	ABS Case	839 grams	The Garage Manila International	1900.00 PHP
1	32GB SD Card	9 grams	Circuit Rocks	500.00 PHP
			Total Cost	**13,321.4 PHP**

The overall cost computation for this design option sums up to 13,321.4 pesos, composed of nine components that are all purchased from Circuit Rocks.

3.9.5.2 Accuracy

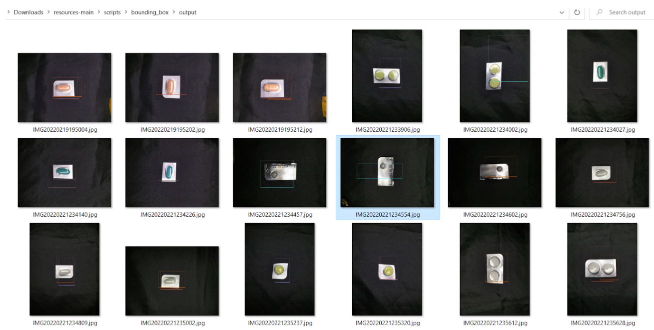


Figure 3.80 Retina MobileNetV2 Testing Result

Figure 3.81 Retina MobileNetV2 Sample Result

Table 3-14 Accuracy

Camera Used	Total No. of Test	True	False	% Accuracy
8mp Raspberry PI V2 Camera Module	60	48	12	**80%**

The developers tested an actual image made up of random images in both an uncontrolled and a controlled environment. Following that, we manually listed the true and false predictions per image output and computed them using the accuracy formula, resulting in an accuracy of 80 % for this design option.

3.9.5.3 Portability

We are evaluating two factors for this design constraint: the device's size and weight. Furthermore, the overall size of this design option is 216 in^3 and it has a total weight of 1086.01 g.

3.9.6 Design Option 3 Summary

In conclusion, Design Option 3 is a device that uses a 8MP Raspberry PiV2 and a Retina MobileNetV2 model. The three design constraints that the proponents must adhere to were used to assess this. The total cost of this prototype, including administrative expenditures, was around 12,321.4 pesos. In terms of accuracy, the camera module and model combined yielded an accuracy of 80%. With a total weight of 1086.01 grams and dimensions of 6”x6”x6” or 216 in^3.

Chapter 4
CONSTRAINTS, TRADE-OFFS, AND STANDARDS

The constraints of this project design will be thoroughly examined in this chapter, including data acquired from different testings undertaken by the proponents. Following that, a ranking as well as a sensitivity analysis will be performed in order to select the best design option from the previous chapters.

4.1 DESIGN CONSTRAINTS

Each constraint's ranking will be tabulated below for each design option. This will depict the data based on the constraint and the design option being computed, such as determining which option received the least and most value in terms of any of the constraints measured. The proponents' clients prioritized accuracy as the most critical requirement for this project, followed by cost efficiency and portability.

Table 4-1 Considerations of Constraints and Possible Solutions

CONSTRAINTS	CRITERION OF IMPORTANCE
Accuracy	0.5
Cost	0.3
Portability	0.2

Accuracy

Detecting counterfeit medicine using a visual inspection checklist guide, as in this project design, requires a reliable output or prediction, as even a minor error can result in a higher danger. As a result, the proponents' clients decided that this constraint was the most important of all giving at .5.

Economic Cost

When it came to the proponents' clients, this constraint was in the middle with .3. It should be at least reasonably priced, as one of the challenges the clients are now facing is the high cost of counterfeit medicine detection devices, not to mention the technicalities and laboratories required.

Portability

One of the client's requirements is that the device be light in weight or small in size, so that it can be carried easily and doesn't take up a lot of space. Moreover, proponents' clients prioritized this as the least important criterion, as putting accuracy and cost first may be sufficient for the majority of them.

4.2 TRADE-OFFS

A trade-off analysis is a compromise that achieves a balance between many desirable but incompatible features. Technically, we can view the ranking we've established for each constraint and the value for each of their design options in this project design based on the criterion of importance. The possible ranking score ranges from zero to five, with zero (0) being the lowest and five (5) as the highest possible score by using the formula shown below:

$$\boldsymbol{Ranking} = \left(\mathbf{1} - \frac{\boldsymbol{MV} - \boldsymbol{RV}}{\boldsymbol{RV}}\right) \times \mathbf{5}$$	(Equation 4: Ranking Score)

where:

MV is the value to be ranked and RV denotes the reference value, which can be either the highest or lowest in the value group.

4.2.1 ACCURACY

As for this accuracy constraint, the proponents are referring to the highest value to be the reference value for the formula. So, the formula is tweaked to provide a positive number from 0 to 5. This is done by getting the absolute value of the original formula subtracted by 10. This is expressed using the formula below:

$$\boldsymbol{Ranking} = \left|\left(\mathbf{1} - \frac{\boldsymbol{MV} - \boldsymbol{RV}}{\boldsymbol{RV}}\right) \times \mathbf{5} - \mathbf{10}\right|$$	(Equation 5: Accuracy Ranking Score)

Table 4-2-1 Accuracy constraint trade-off analysis

DESIGN OPTION	VALUE	RANKING SCORE
1	66.67 %	3.64
2	91.67 %	5
3	80%	4.36

Table 4-2-1 shows the accuracy constraint trade-off analysis. When the accuracy constraint ranking score is determined using the aforementioned formula with design option 2 as the reference value at 91.67% because it has the highest accuracy value, design option 2 receives the highest ranking score of 5, followed by design option 3 at 4.36, and design option 1 at 3.64.

4.2.2 COST

Table 4-2-2 Cost constraint trade-off analysis

DESIGN OPTION	VALUE	RANKING SCORE
1	11,667.48 PHP	4.93
2	11,511.52 PHP	5
3	13,321.4 PHP	4.21

Table 4-2-2 depicts the economic cost constraint trade-off analysis. The reference value for computing this constraint was set to the lowest value, which is design option 2 at 11,511.52 PHP. As a result, design option 2 obtained the highest score of 5, followed by 4.93 for design option 1 and 4.21 for design option 3.

4.2.3 PORTABILITY

For portability constraint, the proponents should consider both the device's overall size and weight as its two parameters. As the proponents' clients opted for a portable device that is small in size and be the lightest as possible.

Table 4-2-3-1 Ranking score for the weight of each design option

DESIGN OPTION	VALUE	RANKING SCORE
1	828.47 g	4.97
2	823.36 g	5
3	1086.01 g	3.41

The ranking score of each design option's overall weight is shown in the table above. We used the formula and selected design option 2 as the reference value because it is the lightest. As a result, design option 2 obtained the highest score of 5, followed by 4.97 for design option 1 and 3.41 for design option 3.

Table 4-2-3-2 Ranking score for the size of each design option

DESIGN OPTION	VALUE	RANKING SCORE
1	126 in^3	5

2	165 in^3	3.45
3	216 in^3	1.43

The size ranking score for each design option is presented above as a figure of numbers in cubic inches. We used the formula to compute with the design option 1 as the reference value because it is the smallest in terms of size. As a result, design option 1 has the highest ranking score at 5, followed by design option 2 with 3.45, and design option 3 at last with 1.43.

Table 4-2-3-3 Portability constraint trade-off analysis

DESIGN OPTION	WEIGHT	SIZE	RANKING SCORE
1	4.97	5	4.99
2	5	3.45	4.23
3	3.41	1.43	2.42

Table 4-2-3-3 depicts the portability constraint trade-off analysis. The size and weight of each design option were combined in the process of computing this constraint, with the average serving as the final ranking score. As a result, design option 1 received the highest score of 4.99 points, followed by design option 2 with 4.23 points, and design option 3 with 2.42 points.

4.3 OVERALL RANKING

Table 4-3 Overall Ranking

CONSTRAINTS	CRITERION'S IMPORTANCE	DESIGN 1 RANKING	DESIGN 2 RANKING	DESIGN 3 RANKING
Economic Cost	0.3	4.93	5	4.21
Accuracy	0.5	3.64	5	4.36
Portability	0.2	4.99	4.23	2.42
OVERALL = ∑(i*Ranking)		4.30	4.85	3.93

In terms of overall ranking, design option 2 came out on top with a score of 4.85, followed by design option 1 with a score of 4.30, and design option 3 with a score of 3.93. Specifically, design option 2 is the least and has the most accuracy in predicting an output, with an exact 5 score. And, design option 1 receives a 4.99 ranking score for portability constraint.

4.4 SENSITIVITY ANALYSIS

Table 4-4 Sensitivity analysis for Design Option 1

	Criterion Importance			Design Option 1			Total
				Cons1 (4.93)	**Cons2 (3.64)**	**Cons3 (4.99)**	
Base Value	0.3	0.5	0.2	1.48	1.82	1	4.30
SA1	0.5	0.2	0.3	2.47	0.73	1.50	4.70
SA2	0.2	0.3	0.5	0.99	1.09	2.50	4.58
SA3	0.33	0.33	0.33	1.63	1.20	1.65	4.48

Table 4-4 shows the result after applying sensitivity analysis for the Design Option 1. It shows that if the cost constraint was changed to 0.5, accuracy constraint to 0.2, and portability constraint to 0.3, it would yield a score of 4.70. If the cost constraint was changed to 0.2, accuracy constraint to 0.3, and portability constraint to 0.5, it would yield a score of 4.58. Lastly, if all the constraints were given the same value of 0.33, it would yield a score of 4.48.

Table 4-5 Sensitivity analysis for Design Option 2

	Criterion Importance			Design Option 2			Total
				Cons1 (5)	**Cons2 (5)**	**Cons3 (4.23)**	
Base Value	0.3	0.5	0.2	1.5	2.5	0.85	4.85
SA1	0.5	0.2	0.3	2.5	1	1.27	4.77
SA2	0.2	0.3	0.5	1	1.5	2.12	4.62
SA3	0.33	0.33	0.33	1.65	1.65	1.40	4.70

Table 4-5 shows the result after applying sensitivity analysis for the Design Option 2. It shows that if the cost constraint was changed to 0.5, accuracy constraint to 0.2, and portability constraint to 0.3, it would yield a score of 4.77. If the cost constraint was changed to 0.2, accuracy constraint to 0.3, and portability constraint to 0.5, it would yield a score of 4.62. Lastly, if all the constraints were given the same value of 0.33, it would yield a score of 4.70.

Table 4-6 Sensitivity analysis for Design Option 3

	Criterion Importance			Design Option 3			Total
				Cons1 (4.21)	Cons2 (4.36)	Cons3 (2.42)	
Base Value	0.3	0.5	0.2	1.26	2.18	0.48	3.92
SA1	0.5	0.2	0.3	2.11	0.87	0.73	3.71
SA2	0.2	0.3	0.5	0.84	1.31	1.21	3.36
SA3	0.33	0.33	0.33	1.39	1.44	0.80	3.63

Table 4-6 shows the result after applying sensitivity analysis for the Design Option 3. It shows that if the cost constraint was changed to 0.5, accuracy constraint to 0.2, and portability constraint to 0.3, it would yield a score of 3.71. If the cost constraint was changed to 0.2, accuracy constraint to 0.3, and portability constraint to 0.5, it would yield a score of 3.36. Lastly, if all the constraints were given the same value of 0.33, it would yield a score of 3.63.

Furthermore, the design option 2 won all of the analyses conducted in this chapter, including the trade-offs and sensitivity assessments. As a result, the proponents decided to use this design option as the project's final design.

Chapter 5

FINAL DESIGN

The chosen design option from the previous chapter will be examined and evaluated in detail in terms of architecture, parameters, and layout in this chapter. Furthermore, it will be put through testing to check if the objectives were reached. Then, close up this chapter with a conclusion and recommendations.

5.1 ARCHITECTURAL DESIGN

5.1.1 Components

Figure 5.1 Raspberry Pi 4 Model B

This compact, low-cost device has revolutionized how individuals learn about computers and do daily chores. The power of computing is in your hands with this little green circuit board with embedded electronic components. It's an excellent way for beginners in computer science to learn about programming, coding, and computing. It's also a low-cost approach to add computer-level intelligence to any project. The Raspberry Pi OS (formerly known as Raspbian) is a Linux-based operating system. It's a Linux-based operating system that runs on a variety of devices, including laptops, desktops, and servers. Raspberry Pi may be used to learn programming languages like Scratch and Python, as well as how computers work, but it has far more applications.

The Raspberry Pi 4 Model B is the most recent addition to the popular Raspberry Pi computer line. It improves on the previous-generation Raspberry Pi 3 Model B+ in terms of CPU speed, multimedia performance, memory, and connection while maintaining backwards compatibility and power efficiency. In terms of desktop performance, the Raspberry Pi 4 Model B is equivalent to entry-level x86 PC computers. A high-performance 64-bit quad-core processor, dual-display support at resolutions up to 4K via a pair of micro-HDMI ports, hardware video decode at up to 4Kp60, up to 4GB of RAM, dual-band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability are among the key features of this product (via a separate PoE HAT add-on).

Processor & Memory Raspberry Pi 4 Specifications:

CPU: Quad Core Cortex-A72 ARM (v8) 64-bit SoC
Speed: 1.5GHz
Operating Temperature: 0–50 Degrees Celsius, 32-122 Fahrenheit Ambient
Ram: LPDDR4-3200 2GB, 4GB or 8GB available depending on Model

Storage:

Onboard: Micro-SD Card Slot used for Loading Operating System & Data Storage.

Networking:

1 IEEE 802.11ac Wireless Connection at 2.4 GHz and 5.0 GHz
1 Bluetooth 5.0, and BLE Wireless Connection
1 Gigabit Ethernet Port for Wired Connection

Input & Output Raspberry Pi 4 Specifications:

USB 2.0: – 2 Ports
USB 3.0: – 2 Ports
GPIO: 40 pin Standard Raspberry Pi GPIO Header (Backward Compatible with Previous Boards)

Audio Video:

Camera Port: 1 MIPI CSI camera port (2-Lane)
HDMI: 2 HDMI (Up to 4kp60) Ports for Dual Monitor Support (Run 2 Monitors at the same time)
Displayport: 1 MIPI DSI display port (2-Lane) (Used primarily for 7inch Touch)
Composite Audio Video: 4-pole Stereo Audio and Composite Video Port
Audio Video Encoding Decoding: H.265 (4kp60 decode), H264 (1080p60 decode, 1080p30 encode)

Power Requirements for Raspberry Pi 4 Specifications:

Input via USB-C Connector Port: 5V DC (minimum 3A)
Input via GPIO Header: 5V DC (minimum 3A)
Input PoE: Power over Ethernet Enabled (Requires separate PoE HAT)

Power Recommendations:

If downstream USB peripherals consume less than 500mA in total a good quality 2.5 amp power supply can be used, otherwise it is recommended to use a 3.0 amp power supply.

Other Raspberry Pi 4 Specifications:

Graphics: OpenGL ES 3.0 Graphics
Release Date: June 24th, 2019
Obsolescence Statement: Raspberry Pi 4 Model B will remain in production until at least January 2026.

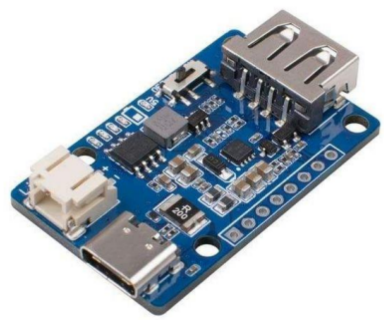


Figure 5.2 Rechargeable 5V LiPo USB PowerBoost 500 Charger

The PowerBoost 500C power supply is an ideal portable project. This little DC/DC boost converter module may be powered by any 3.7V LiIon/LiPoly battery and converts the output to 5.2V DC for use in 5V projects. The TPS61090 boost converter from TI is at the heart of the PowerBoost 500C. Low battery detection, a 2A internal switch, synchronous conversion, exceptional efficiency, and 700KHz high-frequency operation are all features of this boost converter chip.

Specifications:

1. Synchronous operation means you can disconnect the output completely by connecting the ENable pin to ground. This will completely turn off the output
2. 2A internal switch (~2.5A peak limiting) means you can get 500mA+ from a 3.7V LiPoly/LiIon battery. We had no problem drawing 1000mA, just make sure your battery can handle it!
3. Low battery indicator LED lights up red when the voltage dips below 3.2V, optimized for LiPo/LiIon battery usage
4. Onboard 500mA charge-rate 'iOS' data resistors.
5. Full breakout for battery in, control pins and power out
6. 90%+ operating efficiency in most cases (see datasheet for efficiency graphs), and low quiescent current: 5mA when enabled and power LED is on, 20uA when disabled (power and low batt LED are off)

Technical Details:
1. Dimensions: 22mm x 37mm x 2mm / 0.9" x 1.5" x 0.08"
2. Height w/ JST: 7mm / 0.3"

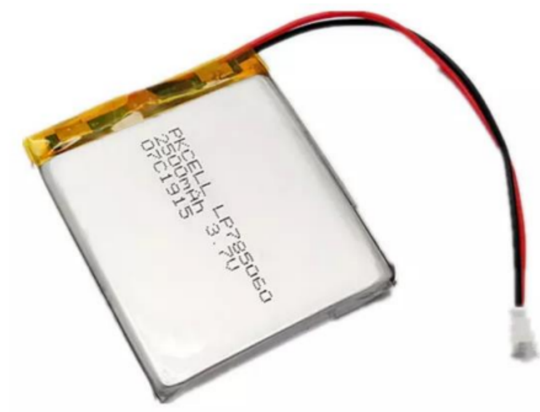


Figure 5.3 Battery Lithium-Ion Polymer 3.7V 2500mAh

The term "LiPo" refers to the type of electrolyte used in LiPo batteries, which is lithium polymer. Despite the fact that LiPo batteries have been around since the 1970s, it only recently became popular in mainstream applications. LiPo batteries have become a feasible alternative to fuel for unmanned aerial aircraft due to their compact and lightweight design. By using a lithium polymer as an electrolyte, LiPo batteries improve on the design of standard batteries. The lithium polymer is a gel-like substance that may be formed into an extremely thin and long semi-porous layer instead of a liquid. The lithium salt electrolyte is suspended in most LiPo batteries using one of four polymer types: polyethylene oxide, polyacrylonitrile, polymethyl methacrylate, or polyvinylidene fluoride.

Lipo Rechargeable Battery 3.7V 2500mAH (Lithium Polymer), often known as Lipo or Lipoly batteries, are thin, light, and powerful. The capacity of this battery is 2500mAH. GPS, DVD, iPod, Tablet PC, MP4 Player, Power Bank, Mobile Backup Power Supply, Bluetooth Speaker, IOT, and other DIY and Industrial applications all use these batteries.

Specifications:
- Voltage: 3.7V
- Capacity: 2500mAH
- Approx Size: 92mm x 32mm x 3.7mm

Figure 5.4 16GB SD Card

The SD card is a simple means of transferring and storing data. The good thing about it is that, like other storage devices, it's a non-volatile option that doesn't require a power source to store the data. Furthermore, it is extremely portable and mobile, and a standard micro SD card will work with a wide range of mobile devices that accept SD cards. The SD card is – next to the power supply – a critical additional component of the Raspberry Pi.

To use your Raspberry Pi, you'll need to insert your SD card and install the operating system. You can do this from your computer or laptop, or you can buy an SD card preloaded with the Raspberry Pi operating system. As long as you have enough storage space and can insert the SD card into your Raspberry Pi, either method will work. The SD card will store any files you save and any applications you run on your Raspberry Pi that are not included in the operating system, in addition to running your operating system.

SanDisk and Toshiba have a joint venture for flash manufacturing. However, in 2009, SanDisk transferred the rights to the fabs to Toshiba to become a fabless flash memory manufacturer. Memory development is still done together. SanDisk and Toshiba, along with Matshushita, are the founders of the SD standard, introduced in 1999. The microSD standard was also created by SanDisk.

Figure 5.5 Arducam 13MP AR1335 OBISP MIPI Camera Module

The Arducam 13MP OBISP MIPI camera has an onboard ISP (Image Signal Processor), and it uses the standard Raspberry Pi 15 pin MIPI CSI-2 interface. It works with the Raspberry Pi, Jetson Nano, and other platforms that support the MIPI CSI-2 interface protocol. To function, this camera requires kernel drivers - one kernel version, one camera driver. A kernel bump occurs when you upgrade or downgrade your operating system, and you'll need to reinstall the appropriate driver.

Features:

- Resolution: High Resolution
- Shutter Type: Rolling Shutter
- Color Type: Color
- IR Sensitivity: 650nm IR filter, visible light only.
- Output Interface: 2-Lane MIPI CSI-2
- Output Format: YUV422, RGB888
- ISP Features: AWB, AE, Flip, Mirror, DeNoise, Gamma, Sharpness, Saturation, Contrast Digital Zoom, Digital Pan/Tilt, Special Effects etc
- Platform Support: Raspberry Pi, Jetson Nano or platform with MIPI CSI-2 interface

Specifications:

- Sensor Type: 13MP AR1335
- Pixel Size: 1.1um x 1.1um
- Resolution: 4160×3120
- Optical Size: 1/3"
- Lens Spec: M12 Low distortion lens, EFL: 4.73mm, FoV(H): 50°, F/NO: 2.2
- Max Data Rate: 1.2Gbps/laneFrame Rate: 7fps@4160×3120, 11fps@3264×2448/3840×2160, 24fps@2560×1440, 30fps@1600×1200/1920×1080/640×480/320×240
- Responsivity: 4.7k e/lux-sec
- SNR(Max): 37dB
- Dynamic Range: 69dB
- Power Consumption: 270mW
- Temperature Range: -10 ~ 70 degrees
- Camera Driver: V4L2 Compliant driver for Raspberry Pi and Jetson Nano
- Board Size: 38mm x 38mm
- Powerline Frequency: 50Hz, fixed

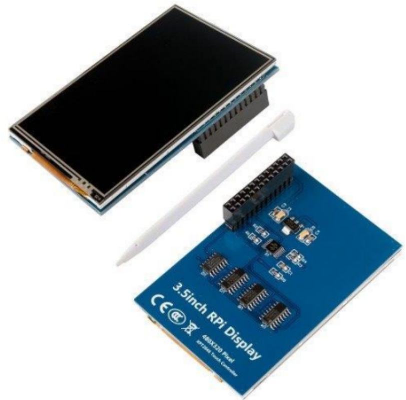


Figure 5.6 Adafruit PiTFT 3.5-inch Touch Screen

It has a 3.5" display with 480x320 16-bit color pixels and a resistive touch overlay, and it uses the Pi's high-speed SPI interface to use the mini display as a console, X window port, displaying images or video, and so on. It's designed to fit nicely onto the Pi Model A or B, but it also works fine with the Model B+ if you don't mind the PCB overhanging the USB ports by 5mm.

Figure 5.7 DPDT 6-pin Slide Switch

The circuit is turned on or off by turning the slide switch's actuator (switch handle). It is widely used in electrical appliances, machinery, communications, digital audio and video, building automation, and electronic devices, and has the features of flexible slider action, stable and reliable performance.

Figure 5.8 ABS Case

ABS enclosures are an excellent choice for almost any plastic project box. ABS cases are made of high-quality, flame-resistant ABS plastic and come in a variety of sizes and shapes to meet your ABS box needs. ABS (acrylonitrile butadiene styrene) is a thermoplastic polymer that is commonly used in injection molding. This engineering plastic is popular because of its low manufacturing cost and the simplicity with which plastic makers can machine it. Better yet, the ABS material's inherent advantages of affordability and machinability do not interfere with the required properties:

- Impact Resistance
- Structural Strength and Stiffness
- Chemical Resistance
- Excellent High and Low Temperature Performance
- Great Electrical Insulation Properties
- Easy to Paint and Glue

During the manufacturing process, ABS plastic gains these physical characteristics. Chemical chains' ' attract one another and link together to make ABS stronger by polymerizing styrene and acrylonitrile in the presence of polybutadiene. ABS has better hardness, gloss, toughness, and resistance qualities than pure polystyrene because of this combination of components and plastics.

5.1.2 Block Diagram

When it's vital to visualize information or control flows – or when processes are involved - block diagrams are commonly employed. We may depict sophisticated algorithms, information flows, and communication among various components inside a huge system.

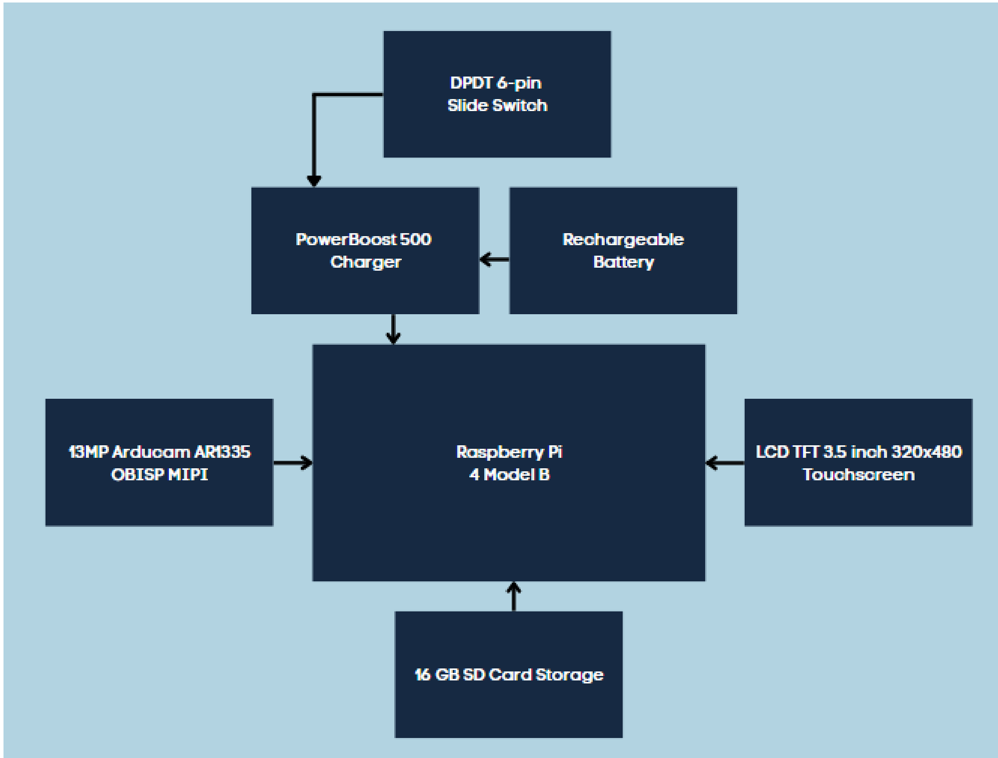


Figure 5.9 Block Diagram of Med Dev

The connection that is happening in the device, namely between the hardware components, as depicted in the figure above. All input from other components such as the power source, camera module, memory, and display screen is received by the Raspberry Pi 4 Model B. And it processes any data it receives.

5.1.3 System Architecture

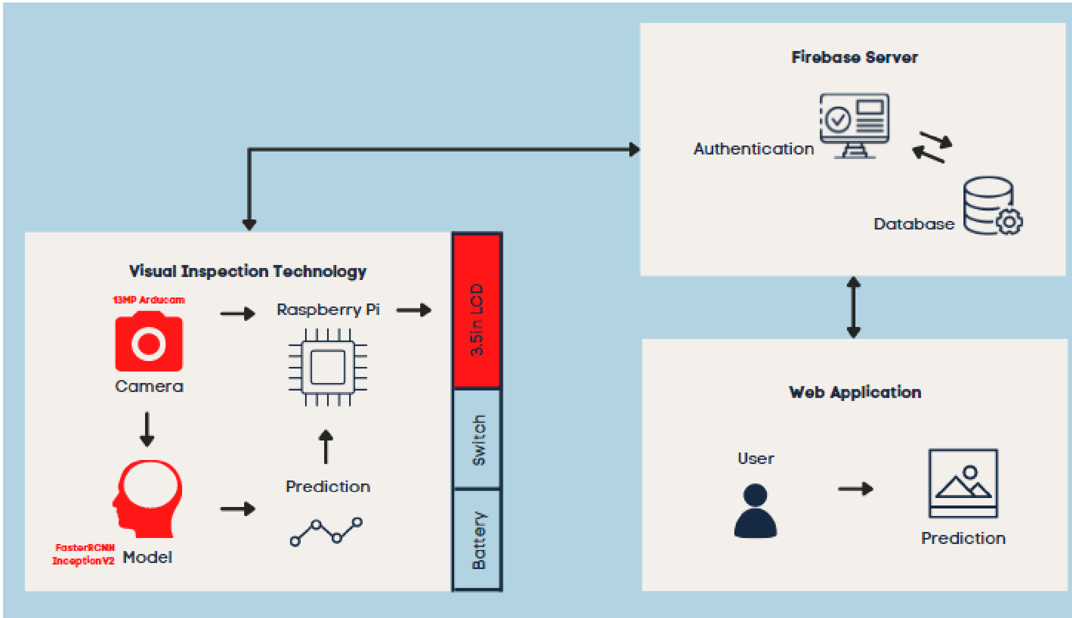


Figure 5.10 System Architecture of Med Dev

This entire system design demonstrates how each sector connects and works together to create the Med Dev. The visual inspection technology, the web application, and the firebase server where the data can communicate with each other are shown in the diagram above. Processes in each section will be explained in more detail below:

5.1.4 Flow Charts

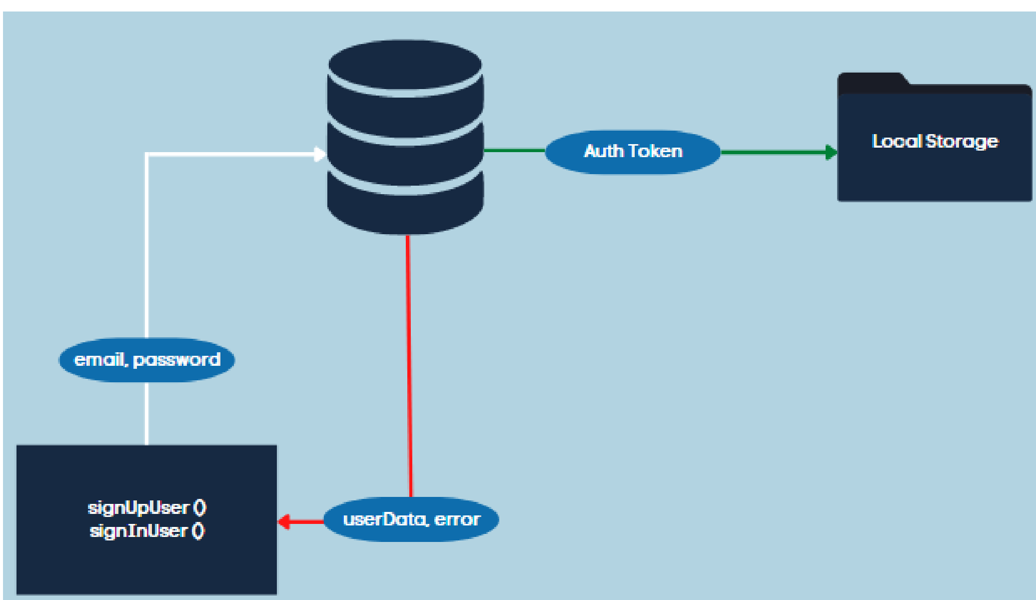


Figure 5.11 Firebase Authentication Flowchart

When implementing an online system, it is critical to maintain track of whether the individual using the platform is the person who is authorized to use it. Using a method that checks that individual is one of the finest methods to check this. Authentication is the term for this process. It can be done in a variety of ways, with SMS, phone, or email verification being the most prevalent. The associated account or contact can use this authentication method to verify and confirm that no unregistered users are accessing the platform.

Firebase authentication is a user authentication capability that Firebase provides as part of its backend services. This is a token-based authentication system that integrates easily with the majority of systems. The finest feature is that it is a role-based system, which means that different roles may be assigned to different users. And, this is primarily the user's first step into both the device and the web application by registering or signing in their account (29).

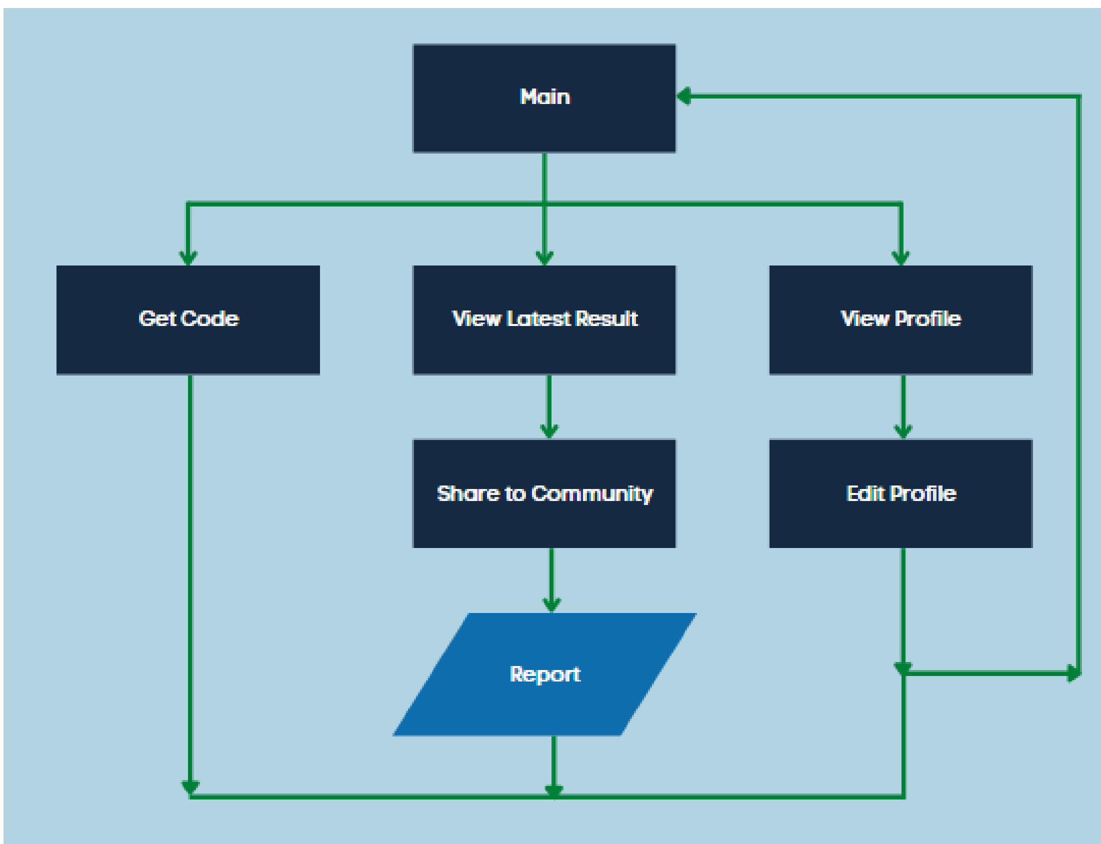


Figure 5.12 Web Application Flowchart

When a user is authorized and logged in to the web application, it will use some of the website's features. This is where the users will find the code that will allow the device to start. And, where users may access their device's scan results, report some of the counterfeit medicines the device has detected, and help the community by raising awareness about the issue.

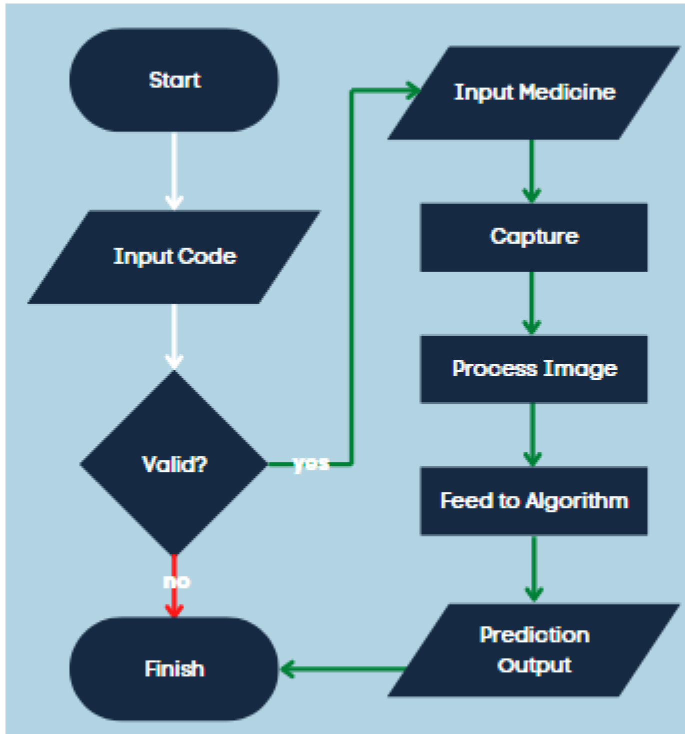


Figure 5.13 Visual Inspection Device's Flowchart

The user can now enter the code that was received from the web application into the device and scan their medicine. However, the device must first initialize and validate the input data, and with that, it can already be seen on the device and application communicating over Firebase. Furthermore, if the code is valid, it will follow the system's steps, capturing and processing the image before feeding it into the algorithm and model to get a prediction result. This output will then be saved to the user's logged-in database, where the users will be able to retrieve it at a later time.

5.1.5 Algorithm

Machine learning algorithm systems have advanced rapidly in recent years, particularly in reinforcement learning, natural language processing, computer and robot vision, image processing, voice, and emotional processing and comprehension. The current volume presents a few innovative research works and their applications in the real world, such as stock trading, medical and healthcare systems, and software automation, in response to the growing importance and relevance of machine learning models, algorithms, and applications, as well as the emergence of more innovative uses cases of deep learning and artificial intelligence.

The higher performance of convolutional neural networks with picture, speech, or audio signal inputs sets them apart from conventional neural networks. It has three different types of layers: Convolutional Layer, Pooling Layer, and Fully–connected Layer (30).

Convolutional Layer
A convolutional network's first layer is the convolutional layer. While further convolutional layers or pooling layers can be added after convolutional layers, the fully-connected layer is the last layer. The CNN becomes more complicated with each layer, detecting larger areas of the image. Earlier layers concentrate on basic elements like colors and borders. As the visual data passes through the CNN's layers, it begins to recognize larger elements or shapes of the object, eventually identifying the desired object.

The convolutional layer is the foundation of a CNN and is where the majority of the computation takes place. It requires input data, a filter, and a feature map, among other things. Assume the input is a color image composed of a 3D matrix of pixels. This means the input will have three dimensions, which correspond to RGB in a picture. A feature detector, also known as a kernel or a filter, will traverse over the image's receptive fields, checking for the presence of the feature. Convolution is the term for this procedure.

Pooling Layer
Downsampling, also known as pooling layers, is a dimensionality reduction technique that reduces the number of factors in the input. The pooling process sweeps a filter across the entire input, similar to the convolutional layer, however this filter does not have any weights. Instead, the kernel uses an aggregation function to populate the output array from the values in the receptive field. Pooling can be divided into two categories:

Max pooling: The filter selects the pixel with the highest value to send to the output array as it advances across the input. In comparison to average pooling, this strategy is employed more frequently.
Average pooling: As the filter advances over the input, the average value within the receptive field is calculated and sent to the output array.

Fully-connected Layer
In partially linked layers, the pixel values of the input image are not directly connected to the output layer, as previously stated. Each node in the output layer, on the other hand, connects directly to a node in the previous layer in the fully-connected layer.

This layer performs classification tasks based on the features retrieved by the previous layers and their various filters. While convolutional and pooling layers typically utilize ReLu functions to categorize inputs, FC layers typically use a softmax activation function to produce a probability from 0 to 1.

Faster R-CNN is an object identification model that improves on Fast R-CNN by combining the CNN model with a region proposal network (RPN). The RPN and the detection network exchange full-image convolutional features, allowing for almost cost-free region proposals. It's a fully convolutional network that predicts object limits and objectness scores for each position at the same time. The RPN is trained from start to finish to create high-quality region proposals that Fast R-CNN uses for detection. By sharing their convolutional features, RPN and Fast R-CNN are integrated into a single network: the RPN component informs the united network where to look.

Data Processing Using FasterRCNN InceptionV2 Model

```python

import os
import time
import glob
import argparse
import numpy as np
import tensorflow as tf
import cv2

from PIL import Image

## Comment out next line to use GPU
os.environ["CUDA_VISIBLE_DEVICES"] = "-1"
## Comment out to set verbose to true
os.environ["TF_CPP_MIN_LOG_LEVEL"] = "3"


def load_label_map(label_map_path):
    """
    Reads label map in the format of .pbtxt and parse into dictionary
    Args:
      label_map_path: the file path to the label_map
    Returns:
      dictionary with the format of {label_index: {'id': label_index, 'name': label_name}}
    """
    label_map = {}

    with open(label_map_path, "r") as label_file:
        for line in label_file:
            if "id" in line:
                label_index = int(line.split(":")[-1])
                label_name = next(label_file).split(":")[-1].strip().strip("'")
                label_map[label_index] = {"id": label_index, "name": label_name}

```

Figure 5.14 Code of Data Processing

```python
prediction.py ●
prediction.py > ...

def load_image_into_numpy_array(path, height, width):
    """
    Load an image from file into a numpy array.
    Args:
      path: the file path to the image
      height: height of image
      width: width of image
    Returns:
      uint8 numpy array with shape (img_height, img_width, 3), (original_height, original_width)
    """
    image = Image.open(path).convert("RGB")
    image_shape = np.asarray(image).shape

    image_resized = image.resize((width, height))
    return np.array(image_resized), (image_shape[0], image_shape[1])


def args_parser():
    parser = argparse.ArgumentParser(
        description="Datature Open Source Prediction Script"
    )
    parser.add_argument(
        "--input", help="Path to folder that contains input images", required=True
    )
    parser.add_argument(
        "--output", help="Path to folder to store predicted images", required=True
    )
    parser.add_argument(
        "--size", help="Size of image to load into model", default="320x320"
    )
    parser.add_argument(
        "--threshold", help="Prediction confidence threshold", default=0.7
    )
    parser.add_argument(
        "--model", help="Path to tensorflow pb model", default="./saved_model"
    )
```

Figure 5.15 Code of Data Processing

```python
prediction.py
prediction.py > main
    )
    parser.add_argument(
        "--label", help="Path to tensorflow label map", default="./label_map.pbtxt"
    )
    return parser.parse_args()


def main():
    ## Load argument variables
    args = args_parser()

    if os.path.exists(args.input) is False:
        raise Exception("Input Folder Path Do Not Exists")

    if os.path.exists(args.output) is False:
        raise Exception("Output Folder Path Do Not Exists")

    if os.path.exists(args.model) is False:
        raise Exception("Model Folder Do Not Exists")

    category_index = load_label_map(args.label)

    ## Load color map
    color_map = {}
    for each_class in range(len(category_index)):
        color_map[each_class] = [int(i) for i in np.random.choice(range(256), size=3)]

    ## Load model
    print("Loading model...")
    start_time = time.time()
    trained_model = tf.saved_model.load(args.model)
    print("Model loaded, took {} seconds...".format(time.time() - start_time))

    ## Run prediction on each image
    for each_image in glob.glob(os.path.join(args.input, "*")):
        print("Predicting for {}...".format(each_image))
```

Figure 5.16 Code of Data Processing

```python
prediction.py
prediction.py > main
        height, width = args.size.split("x")

        ## Returned original_shape is in the format of width, height
        image_resized, origi_shape = load_image_into_numpy_array(
            each_image, int(height), int(width)
        )

        ## The input needs to be a tensor, convert it using `tf.convert_to_tensor`.
        input_tensor = tf.convert_to_tensor(image_resized)

        ## The model expects a batch of images, so add an axis with `tf.newaxis`.
        input_tensor = input_tensor[tf.newaxis, ...]

        ## Feed image into model
        detections_output = trained_model(input_tensor)

        num_detections = int(detections_output.pop("num_detections"))
        detections = {
            key: value[0, :num_detections].numpy()
            for key, value in detections_output.items()
        }
        detections["num_detections"] = num_detections

        ## Filter out predictions below threshold
        indexes = np.where(detections["detection_scores"] > float(args.threshold))

        ## Extract predictions
        bboxes = detections["detection_boxes"][indexes]
        classes = detections["detection_classes"][indexes].astype(np.int64)
        scores = detections["detection_scores"][indexes]

        ## Draw Predictions
        image_origi = Image.fromarray(image_resized).resize(
            (origi_shape[1], origi_shape[0])
        )
        image_origi = np.array(image_origi)

        if len(bboxes) != 0:
```

Figure 5.17 Code of Data Processing

prediction.py ●

prediction.py > main

```python
        if len(bboxes) != 0:
            for idx, each_bbox in enumerate(bboxes):
                color = color_map.get(classes[idx] - 1)

                ## Draw bounding box
                cv2.rectangle(
                    image_origi,
                    (
                        int(each_bbox[1] * origi_shape[1]),
                        int(each_bbox[0] * origi_shape[0]),
                    ),
                    (
                        int(each_bbox[3] * origi_shape[1]),
                        int(each_bbox[2] * origi_shape[0]),
                    ),
                    color,
                    2,
                )

                ## Draw label background
                cv2.rectangle(
                    image_origi,
                    (
                        int(each_bbox[1] * origi_shape[1]),
                        int(each_bbox[2] * origi_shape[0]),
                    ),
                    (
                        int(each_bbox[3] * origi_shape[1]),
                        int(each_bbox[2] * origi_shape[0] + 15),
                    ),
                    color,
                    -1,
                )

                ## Insert label class & score
                cv2.putText(
                    image_origi,
```

Figure 5.18 Code of Data Processing

prediction.py ●

prediction.py > main

```python

                ## Insert label class & score
                cv2.putText(
                    image_origi,
                    "Class: {}, Score: {}".format(
                        str(category_index[classes[idx]]["name"]),
                        str(round(scores[idx], 2)),
                    ),
                    (
                        int(each_bbox[1] * origi_shape[1]),
                        int(each_bbox[2] * origi_shape[0] + 10),
                    ),
                    cv2.FONT_HERSHEY_SIMPLEX,
                    0.3,
                    (0, 0, 0),
                    1,
                    cv2.LINE_AA,
                )

            ## Save predicted image
            filename = os.path.basename(each_image)
            image_predict = Image.fromarray(image_origi)
            image_predict.save(os.path.join(args.output, filename))

            print(
                "Saving predicted images to {}...".format(
                    os.path.join(args.output, filename)
                )
            )


if __name__ == "__main__":
    main()
```

Figure 5.19 Code of Data Processing

Shown by the figures above is the whole system of a python code on how we preprocess the dataset we gathered and create the prediction on the later part. We first imported the important environment variables such as os, time, glob, argparse, numpy, tensorflow and cv2. On a system-wide level, environment variables are defined. The variables can be used in your website's code, but it can also be used in a shell script that you write to import data into your database.

Following the previous step, the primary focus will be on gathering data, processing it, and producing an output. After loading the model, the software will specify the path to the input and output folders, where it can simply toss the data it analyzed. And, before the model generates an output, it will use the label map we provided, which contains the image annotations from our obtained dataset.

5.1.6 Data Flow Diagram

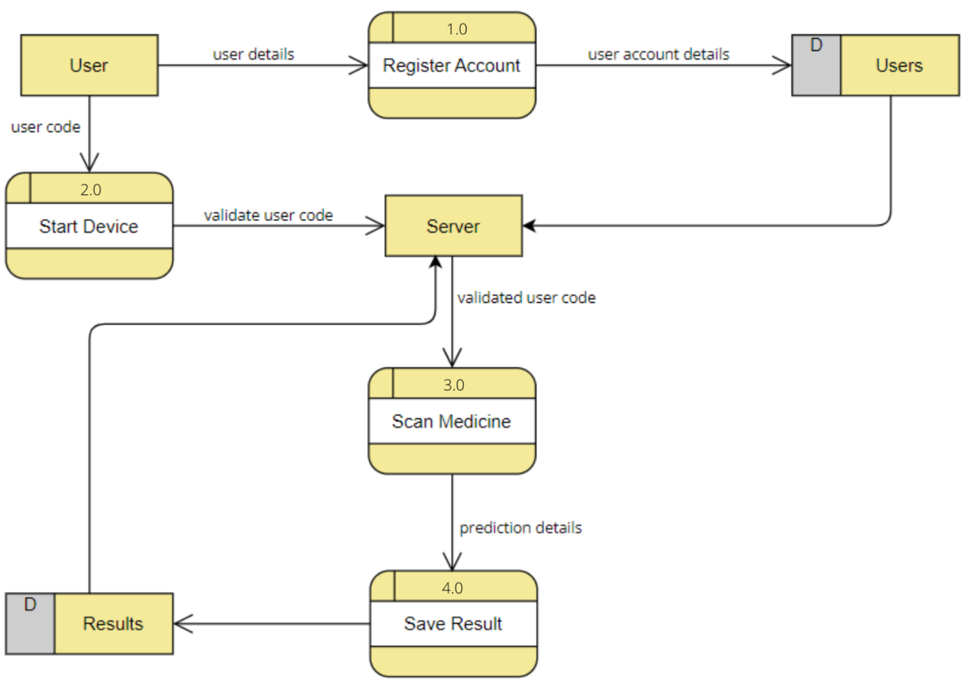


Figure 5.20 DFD Level 1

The data flow diagram, which depicts how data moves from input to storage in the system, is shown in the diagram above. The figure depicts four main processes, beginning with the creation of an account, which will require some user details or information to be placed in the users' data storage. And, as a second process, the user can start the device and enter the code, which will be confirmed by the server, and if valid, the process will proceed to scan the medicine. When the medicine is scanned, the prediction details are saved to the user's account's results data storage, which the user may access via history or reports as part of the online application's added features.

5.2 PARAMETRIC DESIGN

Table 5-1 Bill of Materials for MedDev

Quantity	Component Name	Source	Amount
1	Raspberry Pi 4 Model B	Circuit Rocks	4,810.00 PHP
1	Rechargeable 5V LiPo USB Powerboost 500 Charger	Circuit Rocks	985.00 PHP
1	Battery Lithium-Ion Polymer 3.7V 2500mAh	Circuit Rocks	985.00 PHP
1	13mp Arducam IMX135 MIPI	Amazon	2,199.52 PHP
1	1W Warm White LED Light	Circuit Rocks	34.00 PHP
1	3.5” TFT Display	Circuit Rocks	1,150.00 PHP
1	DPDT 6-pin Slide Switch	Circuit Rocks	8.00 PHP
1	ABS Case	The Garage Manila International	1140.00 PHP
1	16GB SD Card	Circuit Rocks	200.00 PHP
		TOTAL	**11,511.52 PHP**

The bill of materials used in developing the Med Dev can be seen above the table. It is made up of exactly ten parts, totaling 11,511.52 pesos. Most of these were purchased from Circuit Rocks Philippines, with the exception of the camera module, which was purchased from Amazon because it was unavailable in the Philippines at the time and the ABS Case which was purchased from The Garage Manila International.

Table 5-2 Weight of Each Component of MedDev

Quantity	Component Name	Net Weight
1	Raspberry Pi 4 Model B	45.36 grams
1	Rechargeable 5V LiPo USB Powerboost 500 Charger	9 grams
1	Battery Lithium-Ion Polymer 3.7V 2500mAh	52 grams
1	13mp Arducam IMX135 MIPI	4 grams
1	1W Warm White LED Light	2 grams
1	3.5” TFT Display	46 grams
1	DPDT 6-pin Slide Switch	6 grams
1	ABS Case	650 grams
1	16GB SD Card	9 grams
	TOTAL	823.36g

And here's the table with the weights of each component listed. The total weight of the nine components was around 823.36 grams.

5.3 DETAILED DESIGN

5.3.1 Schematic Diagram

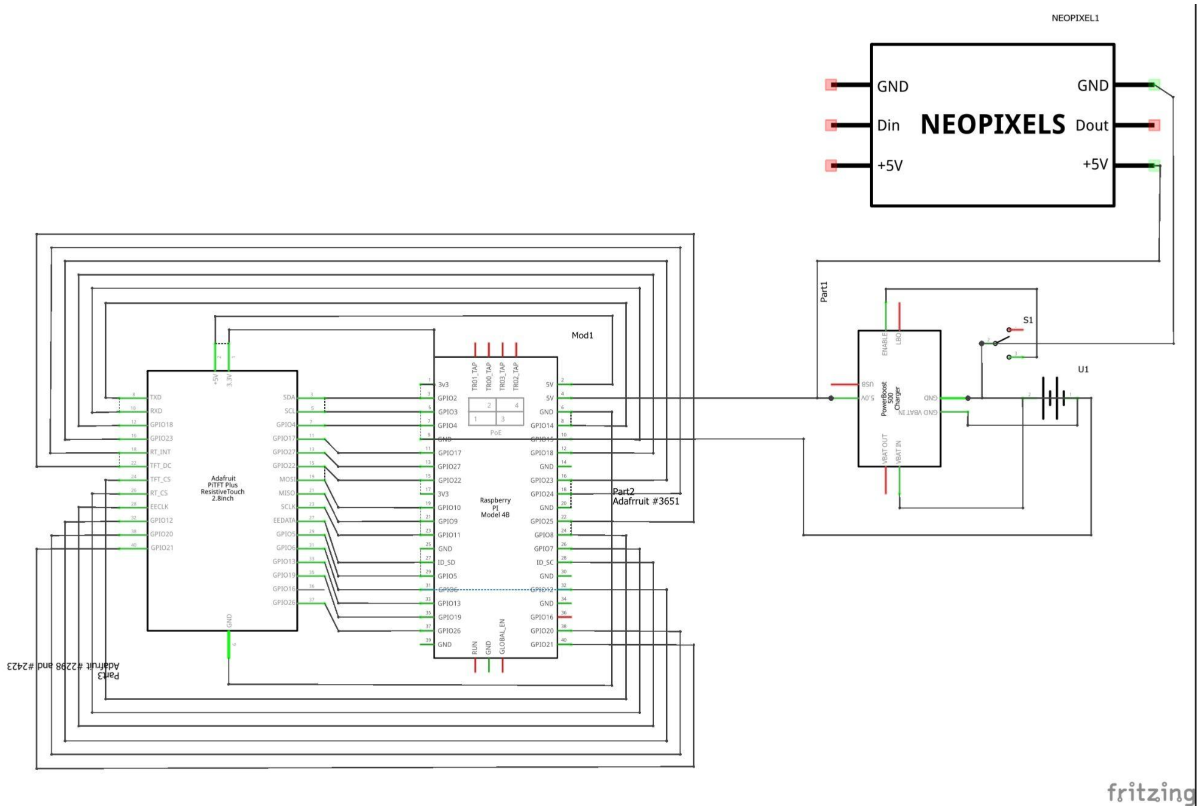


Figure 5.21 Schematic Diagram of Med Dev

In this part will be visualized how each of the components connected to one another, looking at it abstractly as a wiring or circuit diagram wherein the lines are represented as wires.

5.3.2 User Interface

5.3.2.1 Web Application

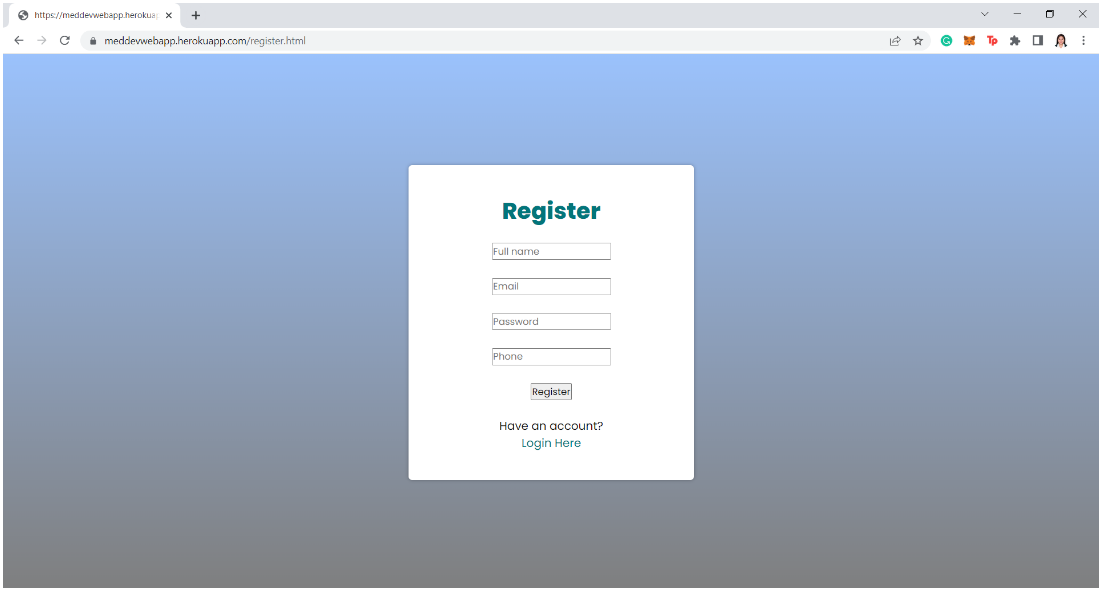


Figure 5.22 Sign Up Page of Web Application

The registration of users will take place here. We will need certain information from them in order to create an account with us, specifically their name, email address, and phone number. Because we're simply using email and password for firebase authentication, this is fairly short.

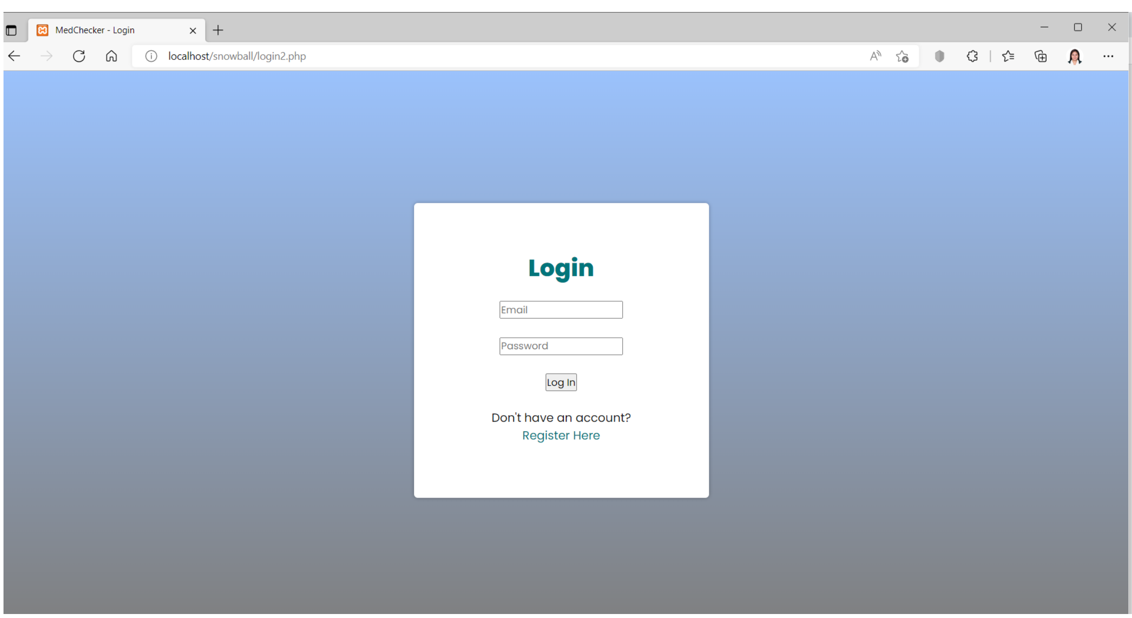


Figure 5.23 Sign In Page of Web Application

The user can immediately log in and enjoy their experience with us after creating an account. This is the point where the data backend checks, authenticates, and authorizes the data that was requested in order to proceed to the main page.

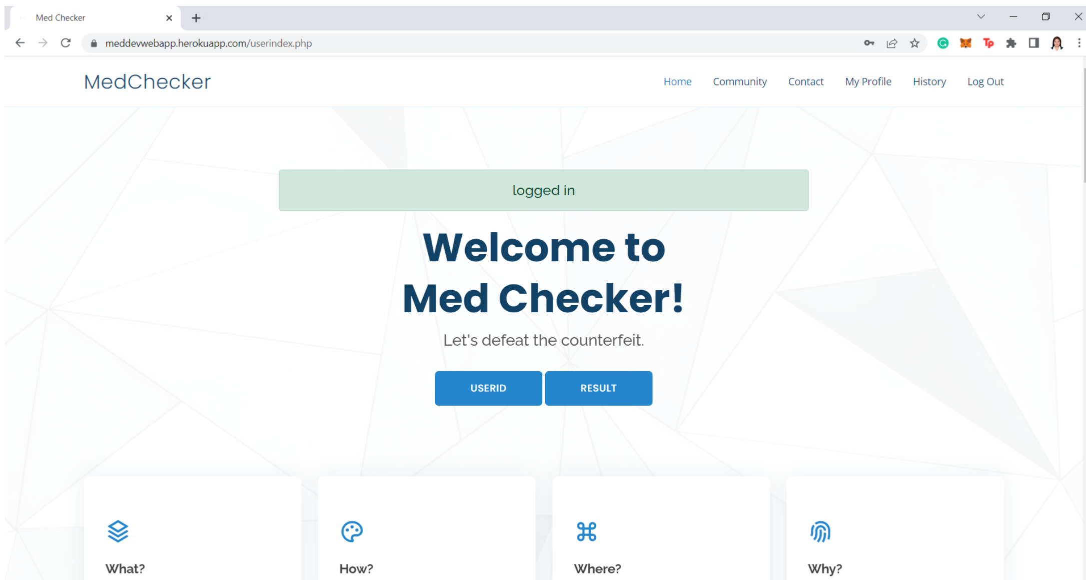


Figure 5.24 User Home Page of Web Application

This is the main page that a logged in user can see and access. Aside from the essential functions of the website, such as the profile, the user id and result button that is presented right in front of them is the most important aspect for them. The user id button displays the device's code, while the result button displays the device's most recent scan.

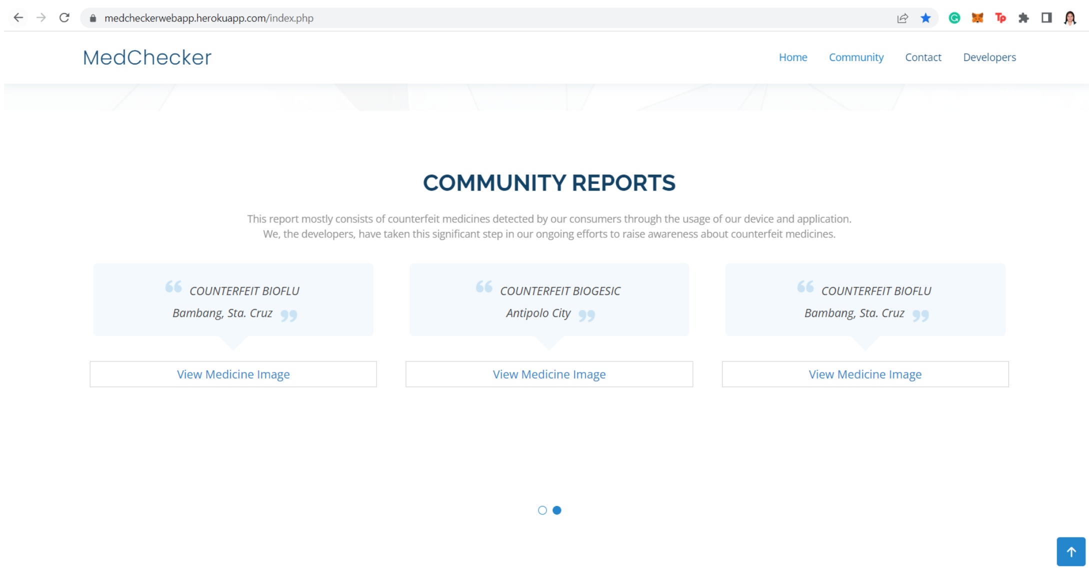


Figure 5.25 Community Reports of Web Application

The user can see reports of counterfeit medicines in the lower portion of the Med Dev's home page.

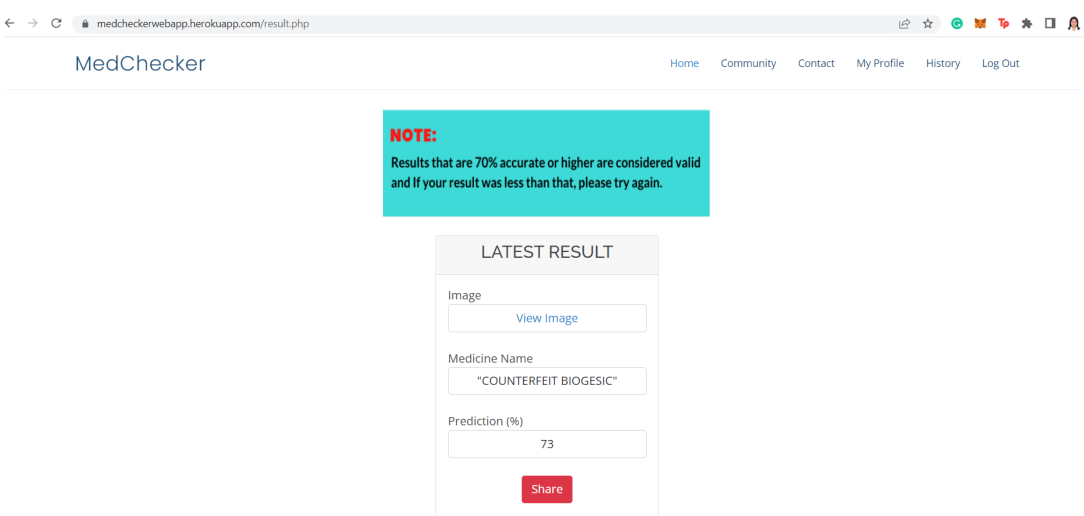
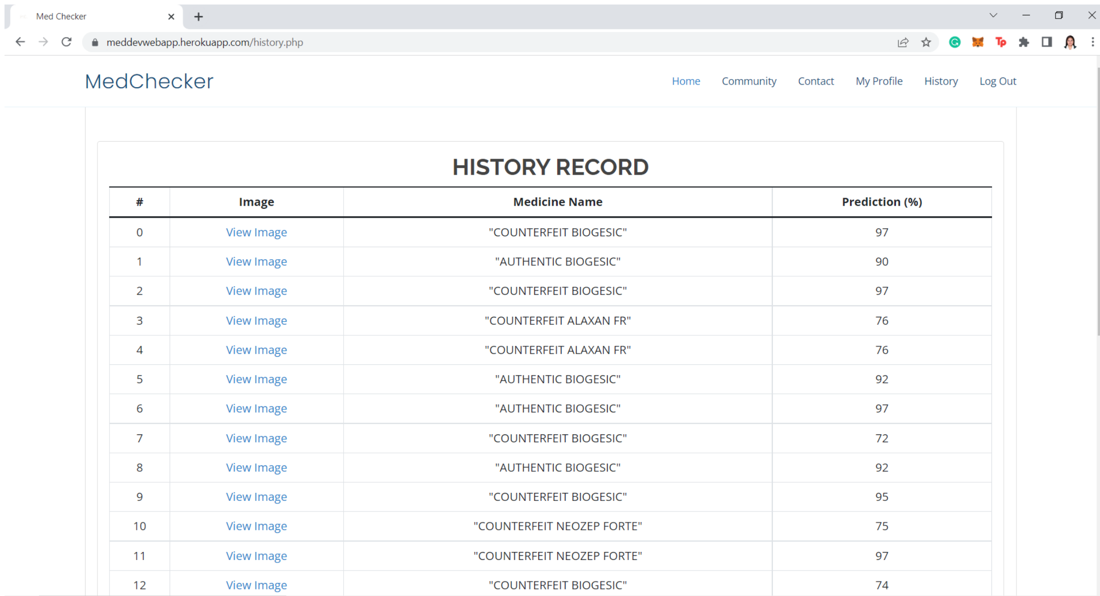


Figure 5.26 Latest Scan Result

This is the most recent result that a logged in user can access, where the user can check the results of their most recent scan.



#	Image	Medicine Name	Prediction (%)
0	View Image	"COUNTERFEIT BIOGESIC"	97
1	View Image	"AUTHENTIC BIOGESIC"	90
2	View Image	"COUNTERFEIT BIOGESIC"	97
3	View Image	"COUNTERFEIT ALAXAN FR"	76
4	View Image	"COUNTERFEIT ALAXAN FR"	76
5	View Image	"AUTHENTIC BIOGESIC"	92
6	View Image	"AUTHENTIC BIOGESIC"	97
7	View Image	"COUNTERFEIT BIOGESIC"	72
8	View Image	"AUTHENTIC BIOGESIC"	92
9	View Image	"COUNTERFEIT BIOGESIC"	95
10	View Image	"COUNTERFEIT NEOZEP FORTE"	75
11	View Image	"COUNTERFEIT NEOZEP FORTE"	97
12	View Image	"COUNTERFEIT BIOGESIC"	74

Figure 5.27 History Page of Web Application

Aside from the result button, there is a history button that shows all of the scans that the user has done. The graphic represents the prediction result, as well as the name of the medicine being scanned and the percentage of it.

5.3.2.2 Visual Inspection Device

Figure 5.28 Opening GUI of Med Dev

When the user opens the device, this is the first thing that appears. A simple logo for our team that will let people see or grasp who we are and what we do.

Figure 5.29 Welcome Screen of Med Dev

The next screen will open, and it will essentially welcome the user and provide them with some instructions as well as a button to begin scanning or using the device. To operate the device, the user must first register for the web application using the link provided above.

Figure 5.30 Enter Button of Med Dev

This is the screen that the user will view after hitting the next button. This UserID is used in the web application and is specific to each individual user. We can employ this to construct a connection and authentication for each registered user, allowing us to request and receive data from the Firebase server in a more secure manner.

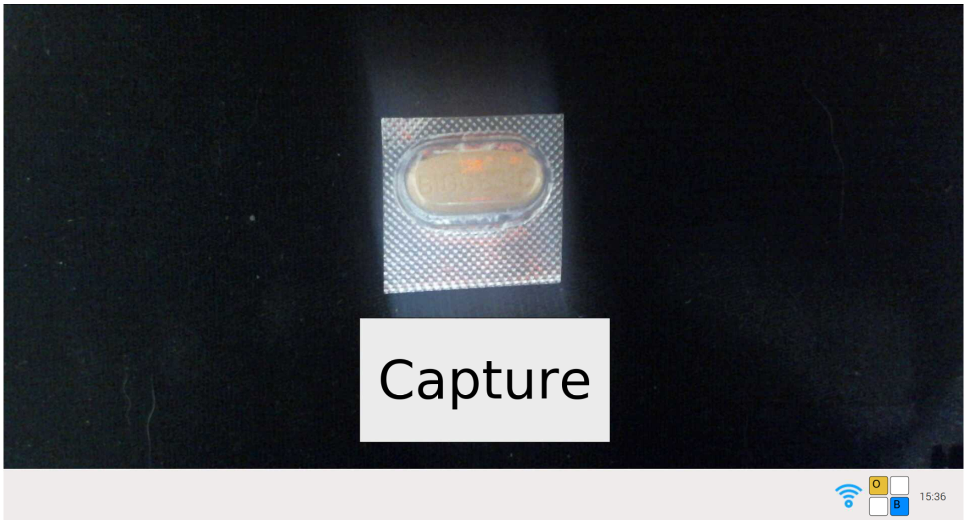


Figure 5.31 Capture Button of Med Dev

This will be the page that appears after the user's code has been authenticated. The user can keep capturing the medicine on the device's platform, which has its own controlled environment, so the algorithm can rely on more reliable images.

Figure 5.32 Result Page of Med Dev

This is the final stage in the process, which will display the output image along with a prediction result, as seen in the figure above. It will eventually be able to access this on the web application via the result and history buttons. Then, depending on their needs, users might try again or exit the process.

5.4 TESTING OF MED DEV

This testing is only to see if the device works and functions properly with the web application that was created exclusively for this purpose. The assessment section of this chapter will be subjected to additional testing. The example outputs from device run testing are shown in the figures below.

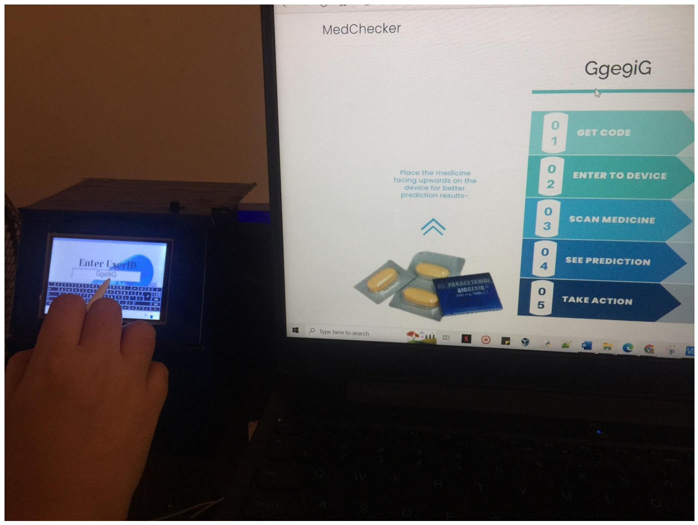


Figure 5.33 Accessing the Device with Web Application

The web application is displayed in the right part of the image, as shown in the diagram above. The user is already logged in, and it displays the UID to enter on the device, which is typed on the device on the image's left half.

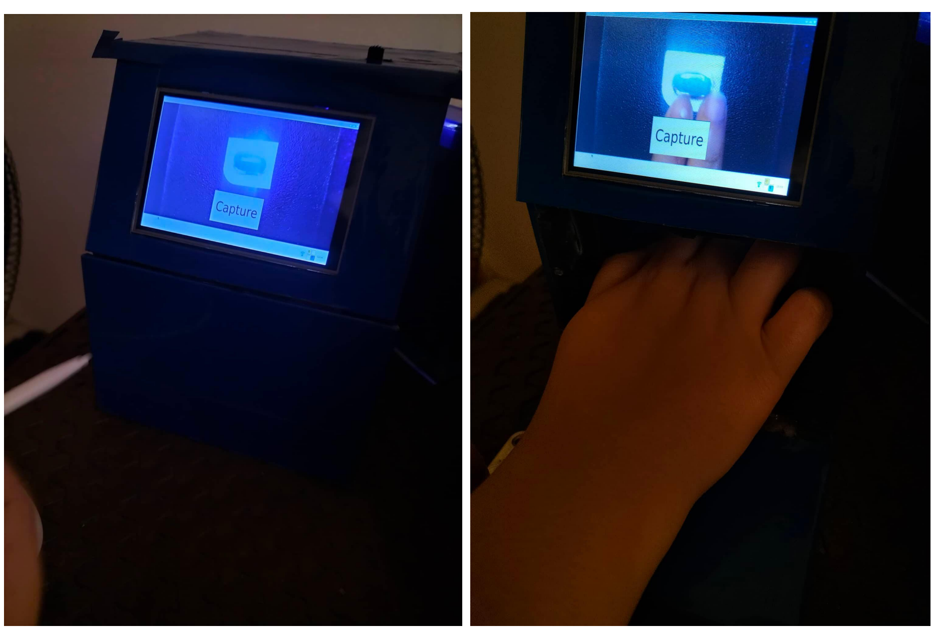


Figure 5.34 Input Testing of the Med Dev

After the code and the user have been authenticated, the medicine will be captured on the device's platform. All that is required of the user is to press the capture button and wait for the image to be processed.

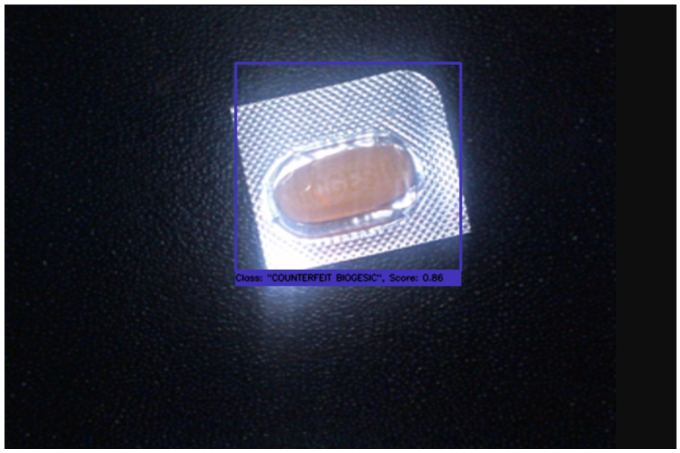


Figure 5.35 Sample Correct Output from Testing

Figure 5.36 Sample Correct Output from Testing

Figure 5.37 Sample Correct Output from Testing

Figure 5.38 Sample Wrong Output from Testing in Low Light

5.5 SUMMARY OF FINDINGS

In this section, we'll evaluate the final design we've chosen in light of our project's goals. To do so, the procedure must be able to test various medicine inputs in order to validate the system's accuracy as well as the whole device itself. Begin by registering as a user on Med Dev's web application, which contains the necessary code for the Med Dev's device to scan a medicine. After that, a registered user must be able to receive an output in the medicines that have been placed on the platform for the device to detect. Finally, users can use the web application, where the user can check the history of their scans as well as community reports of counterfeit medicines from other Med Dev users.

5.5.1 Assessment of the attainment of the project objectives

Project Objective 1:
To develop an affordable device for detecting counterfeit medicines.

Table 5-3 Overall Cost Computation of Med Dev

Components	Prices
Raspberry Pi 4 Model B	4,810.00 PHP
Rechargeable 5V LiPo USB Powerboost 500 Charger	985.00 PHP
Battery Lithium-Ion Polymer 3.7V 2500mAh	985.00 PHP
13mp Arducam IMX135 MIPI	2,199.52 PHP
1W Warm White LED Light	34.00 PHP
3.5” TFT Display	1,150.00 PHP
DPDT 6-pin Slide Switch	8.00 PHP
ABS Case	1140.00 PHP
16GB SD Card	200.00 PHP
Aluminum Metal Heatsink	689.00 PHP
Jumper Wires Male-Female 10cm 20pcs	59.00 PHP
USB Type A to Type C Cable - 6” long	79.00 PHP
Total Cost	**12,338.52 PHP**

The first objective of the proponents is to develop a device that is reasonably priced, as per their survey with their clients. Then, the clients specified a range of no more than 13,000 pesos. With that, the first objective has been attained because it only costs 12,338.52 pesos.

Project Objective 2:
To detect counterfeit medicine without the use of chemical analysis.

For this project, the proponents employed the machine learning algorithm of CNN or Convolutional Neural Network. A convolutional neural network (CNN) is a sort of artificial neural network that analyzes data using perceptrons. Image processing, natural language processing, and other cognitive tasks can all benefit from CNNs.

Convolutional neural networks are utilized in image and audio processing and are based on the anatomy of the human visual cortex. It is made up of three layers: convolution, pooling, and completely connected. To observe the image individually for the first time, convolutional neural networks divide it into smaller sections. It has a built-in convolutional layer that decreases image dimensionality without sacrificing information. This is why CNNs are well-suited to this application. When using a fully-connected neural network for image processing, we rapidly learn that it does not scale well.

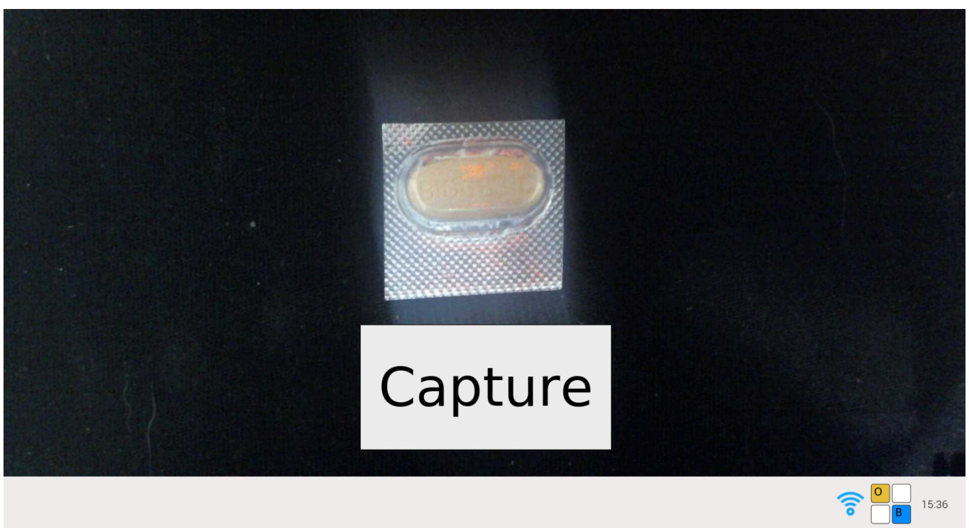


Figure 5.39 Sample Input for Image Processing

A medicine, specifically a counterfeit paracetamol biogesic, was placed on the device's platform and began capturing it in this image. After pressing the capture button, the device will process the image and feed it to the algorithm.

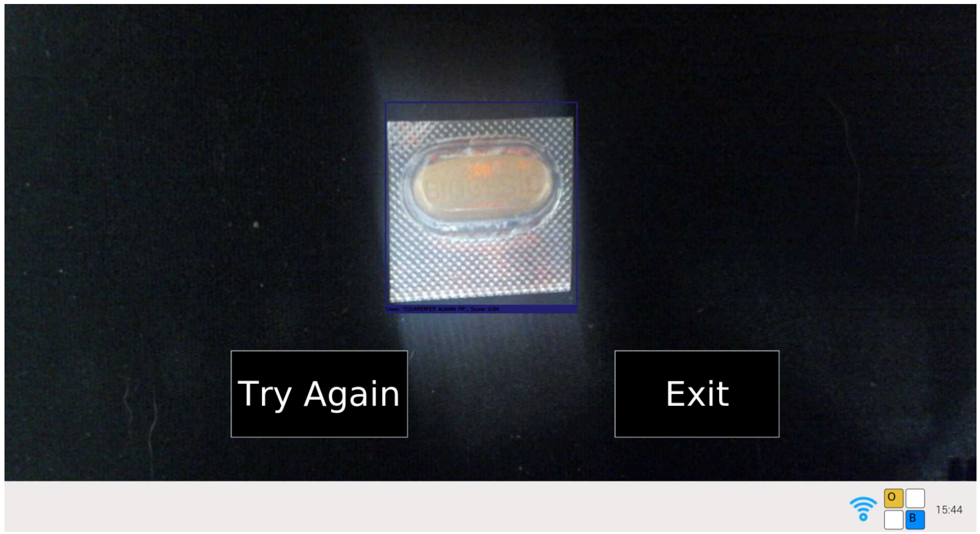


Figure 5.40 Sample Output with Prediction

After a few moments, the same image from the input was displayed as an output, but with a bounding box and a percentage prediction of whether or not the medicine was counterfeit.

Med Dev solely relied on image processing in conjunction with hardware components, the most important of which are the camera module, microprocessor, power supply, and screen display. It was developed in conjunction with the FasterRCNN InceptionV2 machine learning model to recognize a medicine by analyzing the image acquired by the camera. And, it excludes any chemical analysis that is often used with medicine or drug identification devices.

Project Objective 3:
To develop a device that is handy or compact.

Figure 5.41 Front View of Med Dev

Figure 5.42 Side View of Med Dev

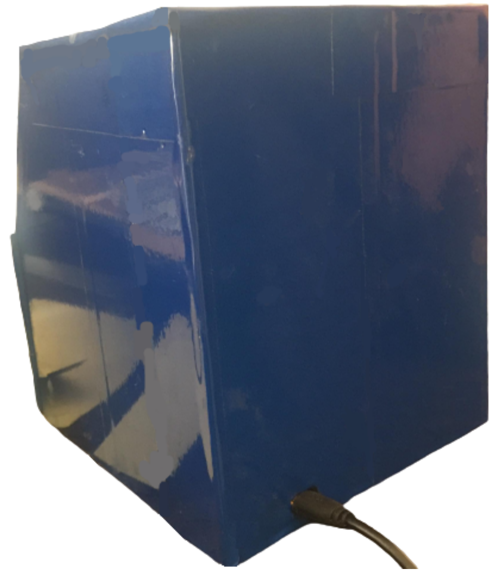


Figure 5.43 Back View of Med Dev

The third goal of the proponents is to design a device that is handy or small in terms of both overall size and weight, as determined by the proponents' client survey. The device's weight and dimensions shall not exceed 2,313g and 343 in^3 in terms of criteria or requirements.

Med Dev weighs 823.36 grams and measures 165 in^3 which clearly meets the provided requirements, thus it meets the project's design standards and can be regarded as a portable device.

Project Objective 4:
To provide an accurate and trustworthy prediction of whether a medicine is counterfeit or not.

We put the device to the test using sixty (60) runs with medicine inputs that are not from the dataset developed in the previous chapters to see how accurate it is. This allows us to observe exactly how the device detects different inputs and determine the likelihood of something happening.

We plot the results of the generated output with the use of a confusion matrix. A confusion matrix is a machine learning classification performance evaluation technique. It's a type of table that lets you see how well a classification model performs on a set of test data for which the true values are known.

Truth data

Classifier results		Class 1	Class 2	Classification overall	User's accuracy (Precision)
	Class 1	42	3	45	93.333%
	Class 2	4	11	15	73.333%
	Truth overall	46	14	60	
	Producer's accuracy (Recall)	91.304%	78.571%		

Overall accuracy (OA):	88.333%
Kappa[1]:	0.682

Figure 5.44 Confusion Matrix for Accuracy Testing

Returning to the design requirements the clients established, a permissible or acceptable prediction output that the clients can rely on must be at least 85%, indicating that Med Dev has exceeded the client's least expected percentage with 88.33 percent.

To prove the system's accuracy, proponents request a face-to-face brief interview with one of the 10 clients and ask to use both the device and the web application.

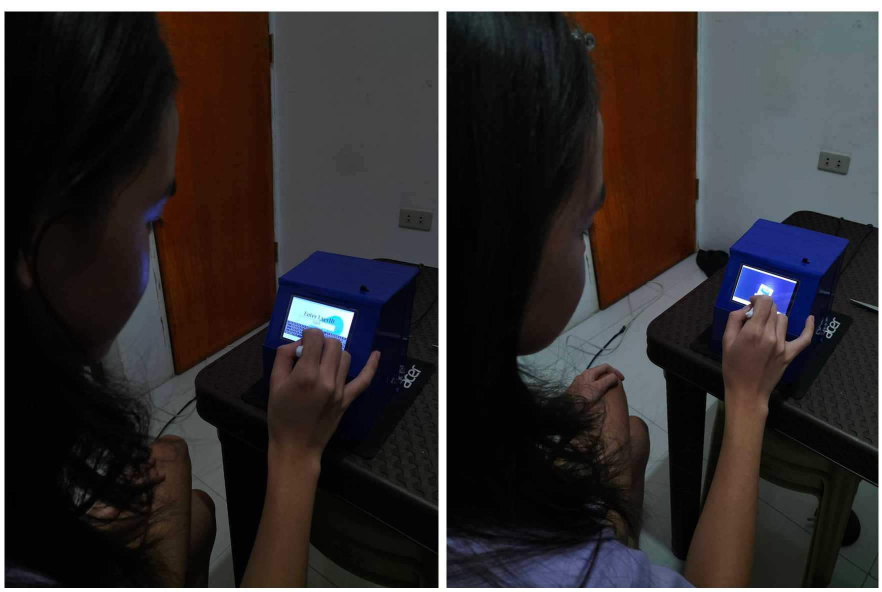


Figure 5.45 Device Testing Performed by a Client

The client was entering the User ID, which can be generated from the online application once a registered user, as indicated in Figure 5.41 on the left side of the image, to begin capturing the medicine on the right side of the image.

Figure 5.46 Device Testing Performed by a Client

The client verified and agreed on the accuracy of the prediction output generated by the device and also added “Akala ko ito yung authentic na meron ako, yung fake pala! Hindi ko napansin agad. Ang galing!” as her statement. The proponents also recommended that the client log into her account via the web application and view their results or history, as indicated in the picture above. When asked about her experience with the device, the client said, “Ayos din pala na may access ako online at pwedeng makashare. Mas pwede kong maishare ng madali!”.

In addition, as shown in the figure below, the local pharmacist with whom we spoke in the previous chapter has agreed to test the device and validate the results it would produce. She tried one of the medicines she confirmed were genuine and counterfeit for the device to scan, the Alaxan FR authentic, which produced a correct prediction. She then also added “Minsan kasi hindi na makita nang maayos kung ano ang pinagkaiba, tulad nito authentic pala. Kung titignan sa malayo halos walang pinagkaiba eh.”

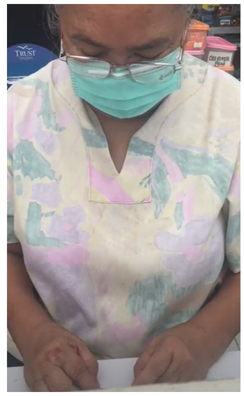


Figure 5.47 Validating with Local Pharmacist

5.6 CONCLUSION

The proponents of this paper aimed to develop and design a portable device that employs artificial intelligence to detect counterfeit medicine that is mostly targeted at the counterfeiters' most vulnerable victims being their clients. We are able to obtain critical data to act as a basis for constructing this device through the engineering design process, such as design criteria contributed by their client, which eventually lead to three constraints: cost, accuracy, and portability. Furthermore, we gave three design options and choose the best design among them based on the importance factors specified by their client. We next put that best design through a system test and evaluation to check if the project's goals were met under all constraints.

Truth data

Classifier results

	Class 1	Class 2	Classification overall	User's accuracy (Precision)
Class 1	42	3	45	93.333%
Class 2	4	11	15	73.333%
Truth overall	46	14	60	
Producer's accuracy (Recall)	91.304%	78.571%		

Overall accuracy (OA): 88.333%

Kappa[1]: 0.682

Figure 5.48 Med Dev's Confusion Matrix

We discovered that per result output takes five to seven minutes after testing the system, which is due to the device's low memory storage and the machine learning model's loading. In terms of the system's overall accuracy, it comes in at 88.33 percent, as indicated in the confusion matrix in the picture above. It contains data from 60 tests conducted with various medicine inputs, which differs from the dataset used to train the system's model. Over and above, the Med Dev, is a portable device weighing 823.36 pounds and measuring 165 in^3. It is also fairly priced, with an overall cost of 12,338.52 PHP, and it delivers an accurate prediction output on whether the medicine is counterfeit or not, according to its 88.33 percent accuracy. With the specifications listed above, everything met or exceeded the client's expectations, indicating that it is the best design to go with while also considering the project's goals and objectives.

5.7 RECOMMENDATIONS

The proponents make the following recommendations for future works based on the findings from the approaches taken prior to this section:

1. To increase the accuracy of detecting a counterfeit medicine using the most effective machine learning model and camera module combination.
2. To include an offline connectivity option in detection.
3. To gather more fake and authentic medicines for the dataset.
4. And, to create a more sturdy hardware and smaller design

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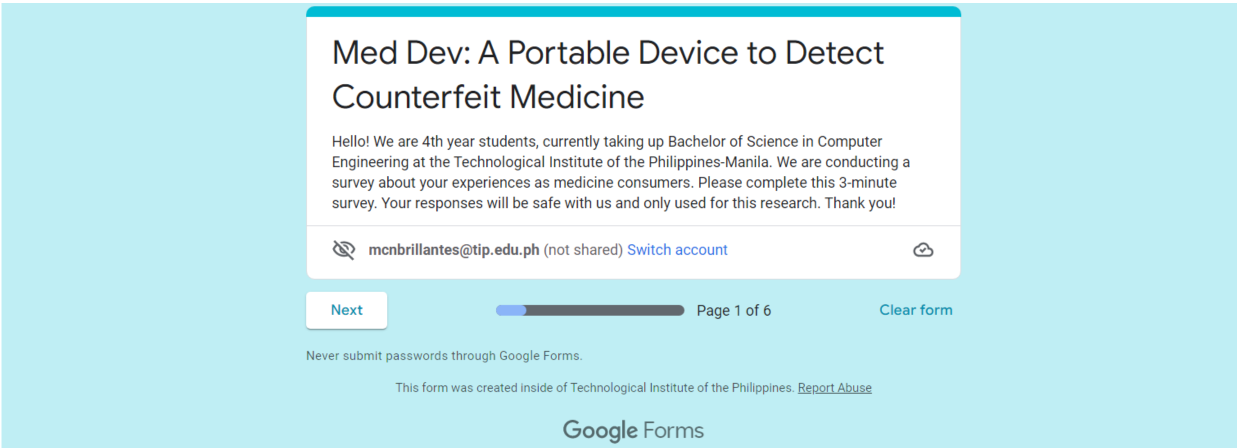
APPENDICES

APPENDIX A: SURVEY QUESTIONNAIRE



Med Dev: A Portable Device to Detect Counterfeit Medicine

Hello! We are 4th year students, currently taking up Bachelor of Science in Computer Engineering at the Technological Institute of the Philippines-Manila. We are conducting a survey about your experiences as medicine consumers. Please complete this 3-minute survey. Your responses will be safe with us and only used for this research. Thank you!

mcnbrillantes@tip.edu.ph (not shared) Switch account

Next Page 1 of 6 Clear form

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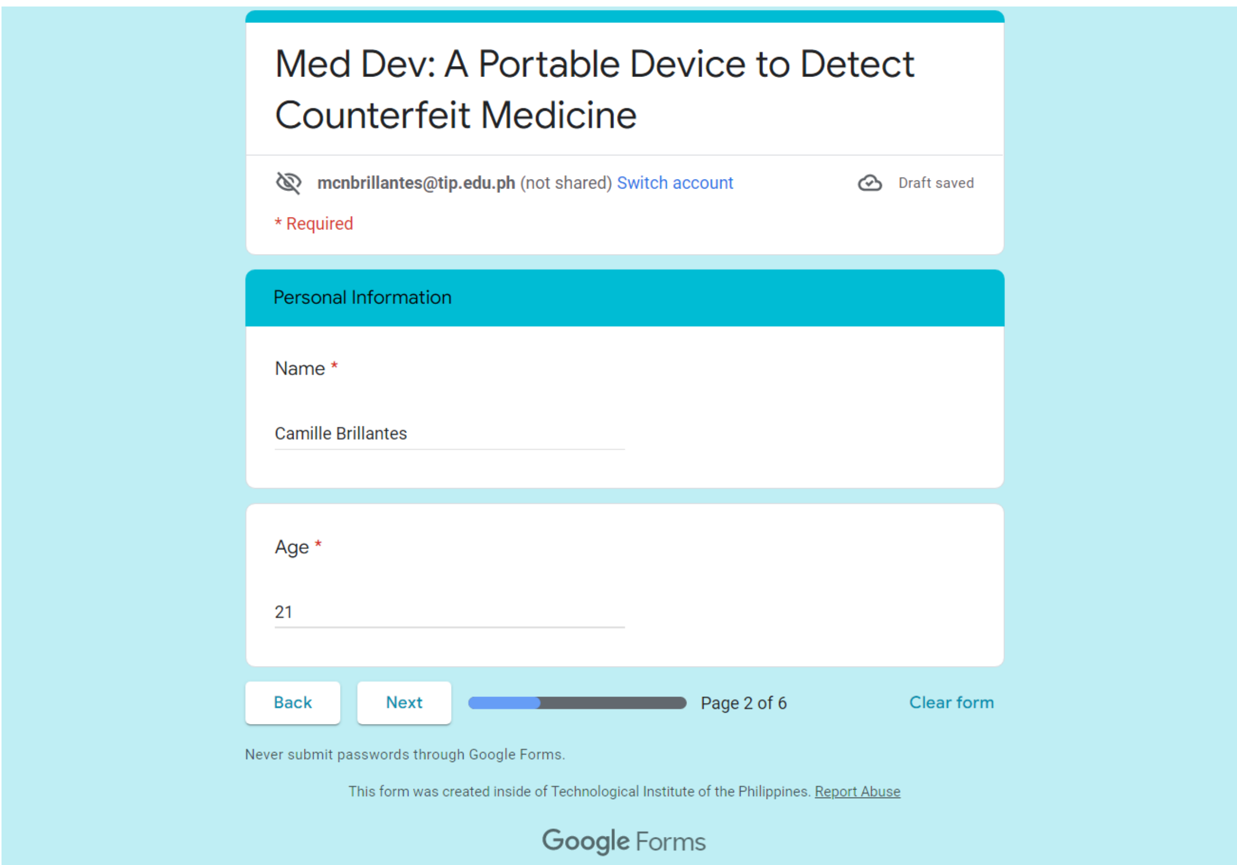

Med Dev: A Portable Device to Detect Counterfeit Medicine

mcnbrillantes@tip.edu.ph (not shared) Switch account Draft saved

* Required

Personal Information

Name *

Camille Brillantes

Age *

21

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Untitled Section

What type of medicines do you buy often? *

- ◯ Over-the-counter Medicines
- ◯ Prescription Medicines
- ◯ Both

Where do you usually buy your medicines? *

- ◯ Local/Community Pharmacy
- ◯ Online Store/Delivery
- ◯ Both
- ◯ Other: ____________

Have you ever encountered or taken a counterfeit or fake medicine? *

- ◯ Yes
- ◯ No
- ◯ I am not sure

If yes, what actions did you take to confirm it was a fake one?

- ☐ Visual Inspection
- ☐ Laboratory Testing
- ☐ Software Applications
- ☐ None
- ☐ Other: ____________

Do you think that developing a device to detect fake or counterfeit medicine is helpful? *

- ◯ Yes
- ◯ No
- ◯ Maybe

Back Next Page 3 of 6 Clear form

Untitled Section

What features would you desire in a device if you were to buy one? Check everything that applies. *

- [ ] Reasonably priced
- [ ] Portable
- [ ] Dependable/Reliable Detection
- [ ] Ease of Operation
- [ ] Durability

At what price range are you willing to pay for the device? (Please answer if you've chosen Reasonably priced)

- ○ 10,000 - 13,000 PHP
- ○ 13,000 - 16,000 PHP
- ○ 16,000 - 19,000 PHP

What size do you consider portable? (Please answer if you've chosen Portable)

- ○ 7"x7"x7"
- ○ 8"x8"x8"
- ○ 9"x9"x9"
- ○ Other:

What weight do you consider portable? (Please answer if you've chosen Portable)

- ○ 2000g / 2kg
- ○ 2500g / 2.5kg
- ○ 3000g / 3kg
- ○ Other:

With what minimum and realistic percentage of accuracy can you tell that a prediction is reliable? Based on research, the range of realistic accuracy is between 70 to 90 percent. (Please answer if you've chosen Dependable/Reliable Detection)

- ○ 75 %
- ○ 85 %
- ○ 95 %

What is your expected life span of the product? (Please answer if you've chosen Durability)

- ○ 5 years
- ○ 8 years
- ○ 10 years
- ○ Other: ______

Untitled Section

From your chosen 3 features, rate them from most to least priority, with 3 being the most.

Reasonably Priced

1	2	3
○	○	○

Portable

1	2	3
○	○	○

Dependable/Reliable Detection

1	2	3
○	○	○

Ease of Operation

1	2	3
○	○	○

Durability

1	2	3
○	○	○

Back Next Page 5 of 6 Clear form

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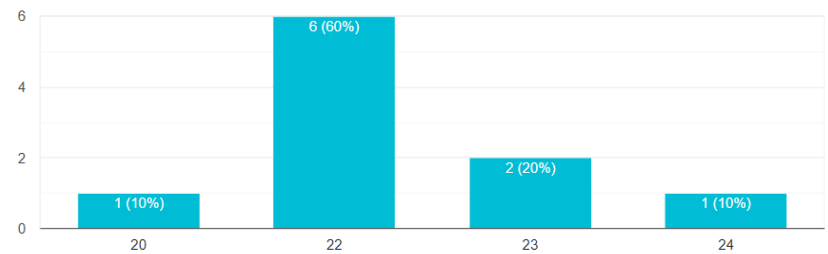
APPENDIX B: SURVEY RESULTS

Age

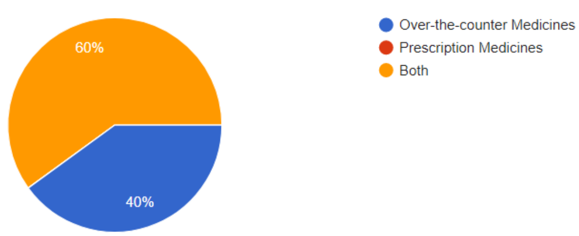
10 responses



Untitled Section

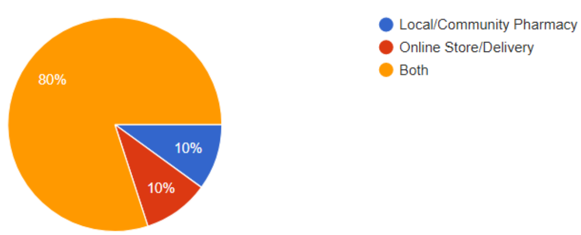
What type of medicines do you buy often?

10 responses



Where do you usually buy your medicines?

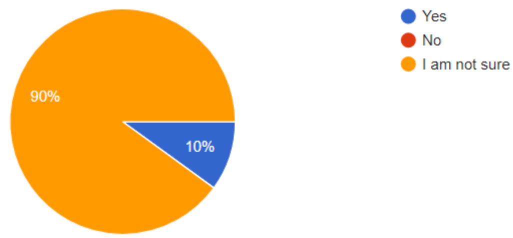
10 responses



Have you ever encountered or taken a counterfeit or fake medicine?

Copy

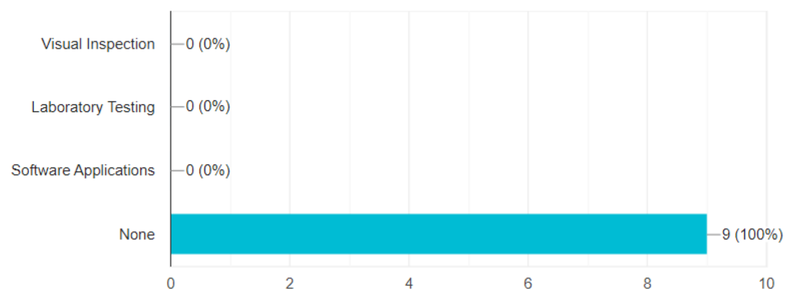
10 responses



If yes, what actions did you take to confirm it was a fake one?

Copy

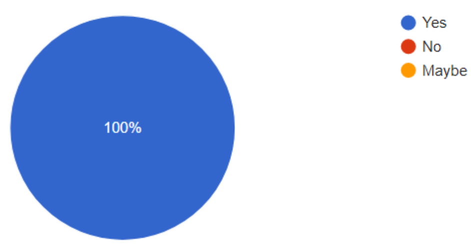
9 responses



Do you think that developing a device to detect fake or counterfeit medicine is helpful?

Copy

10 responses

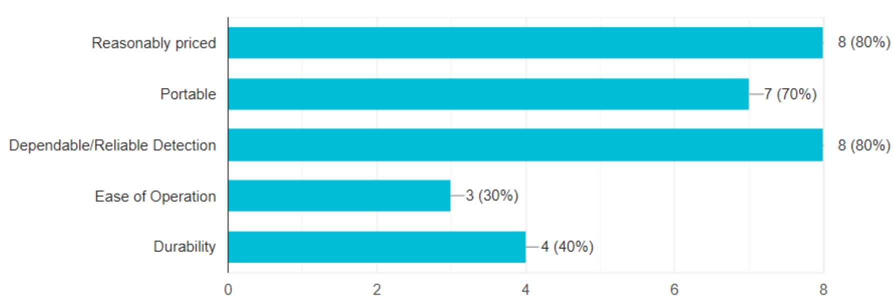


Untitled Section

What features would you desire in a device if you were to buy one? Check everything that applies.

Copy

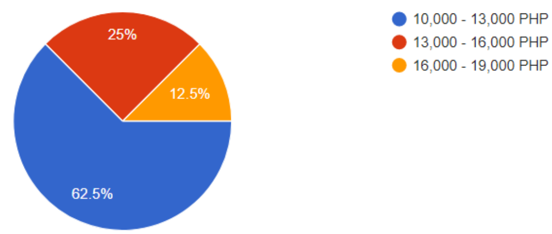
10 responses



At what price range are you willing to pay for the device? (Please answer if you've chosen Reasonably priced)

Copy

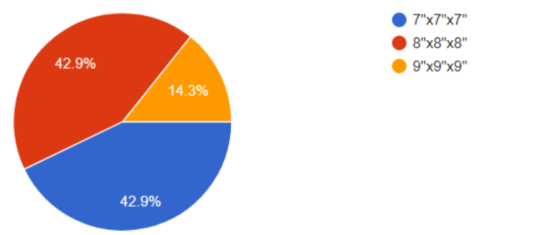
8 responses



What size do you consider portable? (Please answer if you've chosen Portable)

Copy

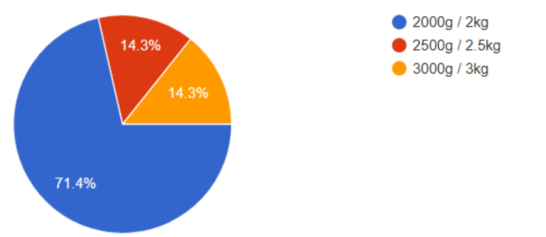
7 responses



What weight do you consider portable? (Please answer if you've chosen Portable)

Copy

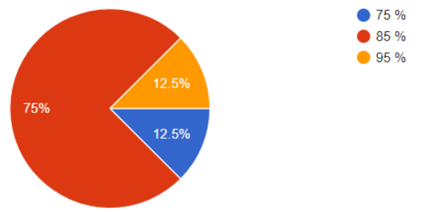
7 responses



With what minimum percentage of accuracy can you tell that a prediction is reliable? (Please answer if you've chosen Dependable/Reliable Detection)

Copy

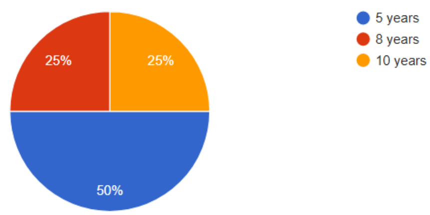
8 responses



What is your expected life span of the product? (Please answer if you've chosen Durability)

Copy

4 responses



Untitled Section

Reasonably Priced

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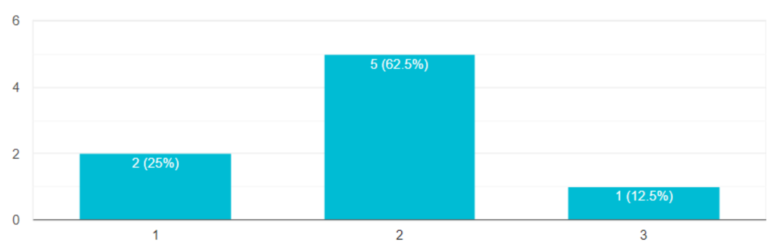
8 responses



Portable

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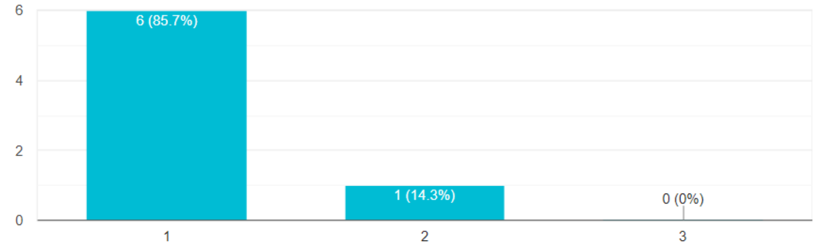
7 responses



Dependable/Reliable Detection

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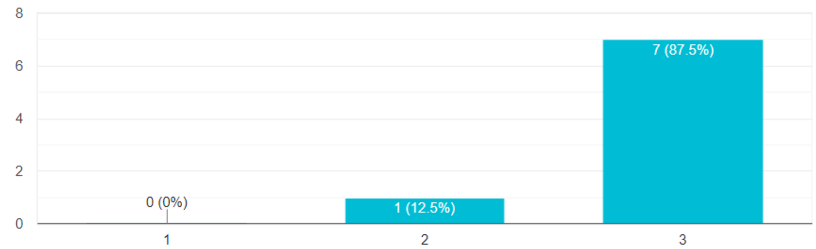
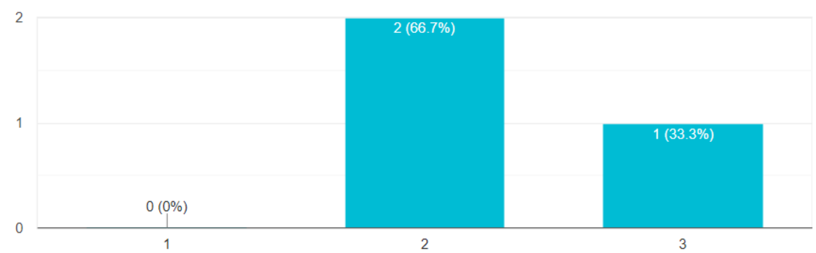
8 responses



Ease of Operation

Copy

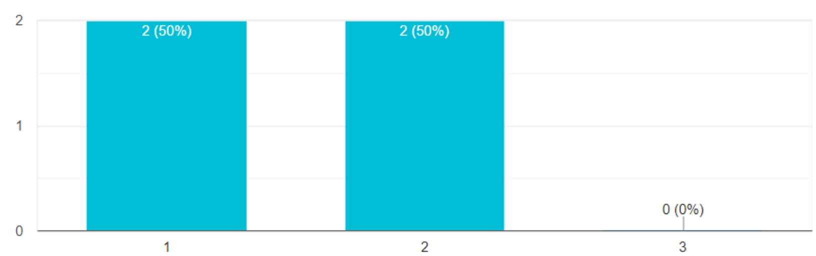
3 responses



Durability

Copy

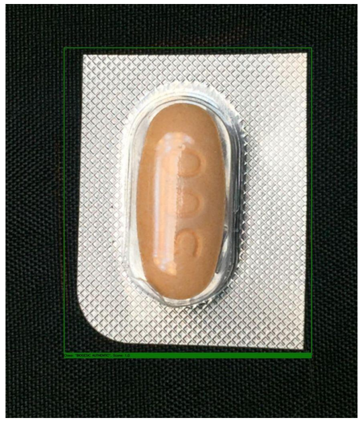
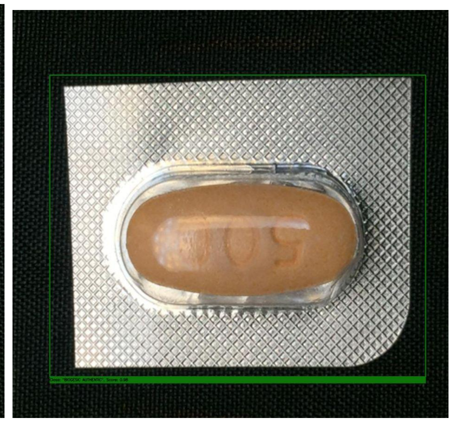
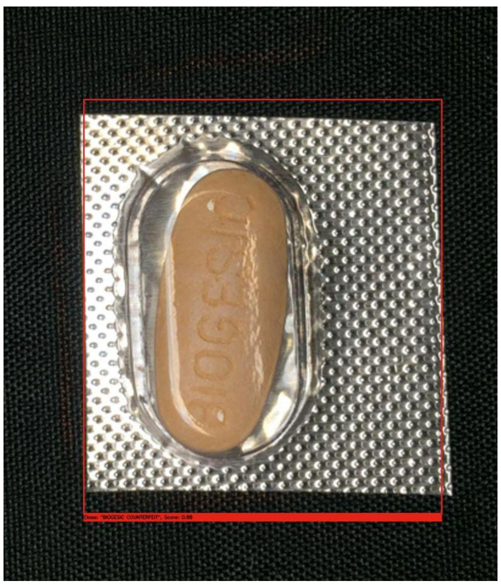
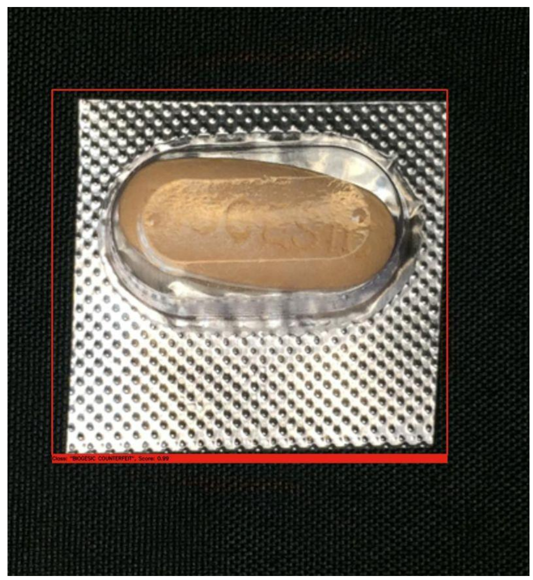
4 responses

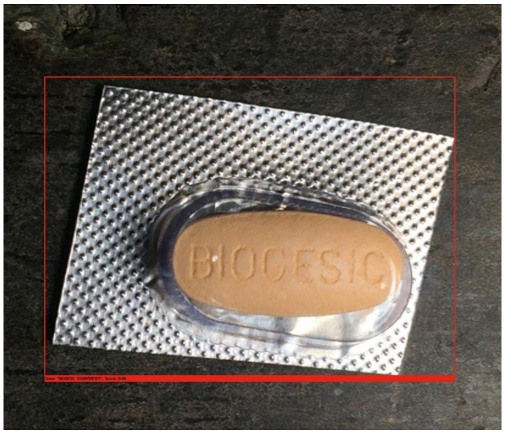


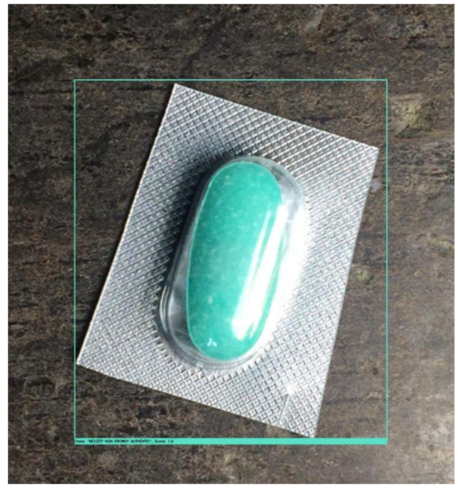
Thank you for your response!

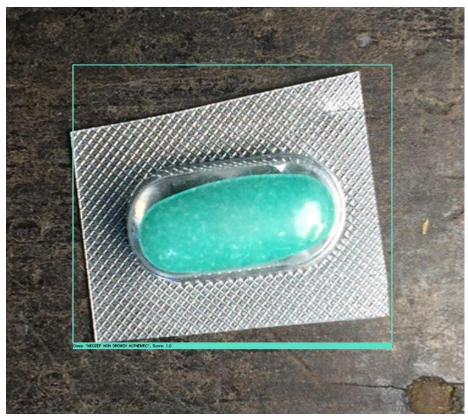
APPENDIX C: SYSTEM TESTING

IPHONE 6S: FASTER RCNN INCEPTION V2

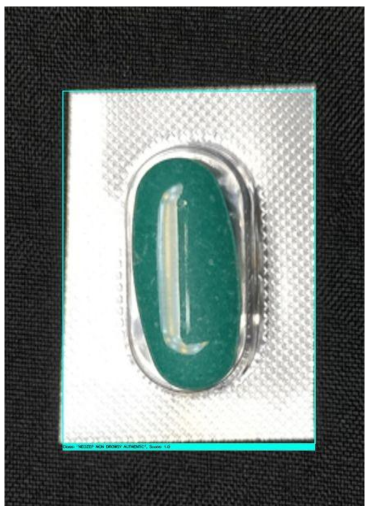






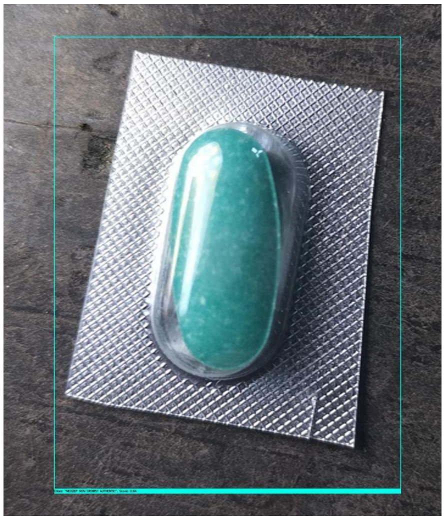

BIOGESIC
Class: "BIOGESIC COUNTERFEIT", Score: 0.99


Class: "NEOZEP NON DROWSY AUTHENTIC", Score: 1.0

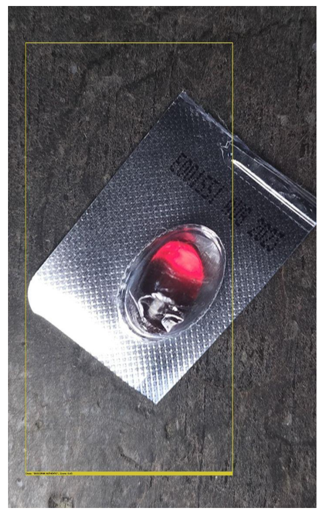

Class: "NEOZEP NON DROWSY AUTHENTIC", Score: 1.0

REDMI 9C: FASTER RCNN INCEPTION V2

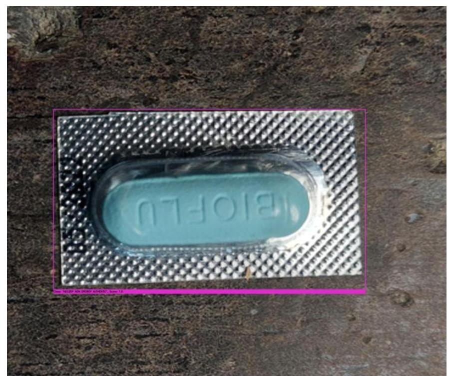





BIOFLU
BIOFLU

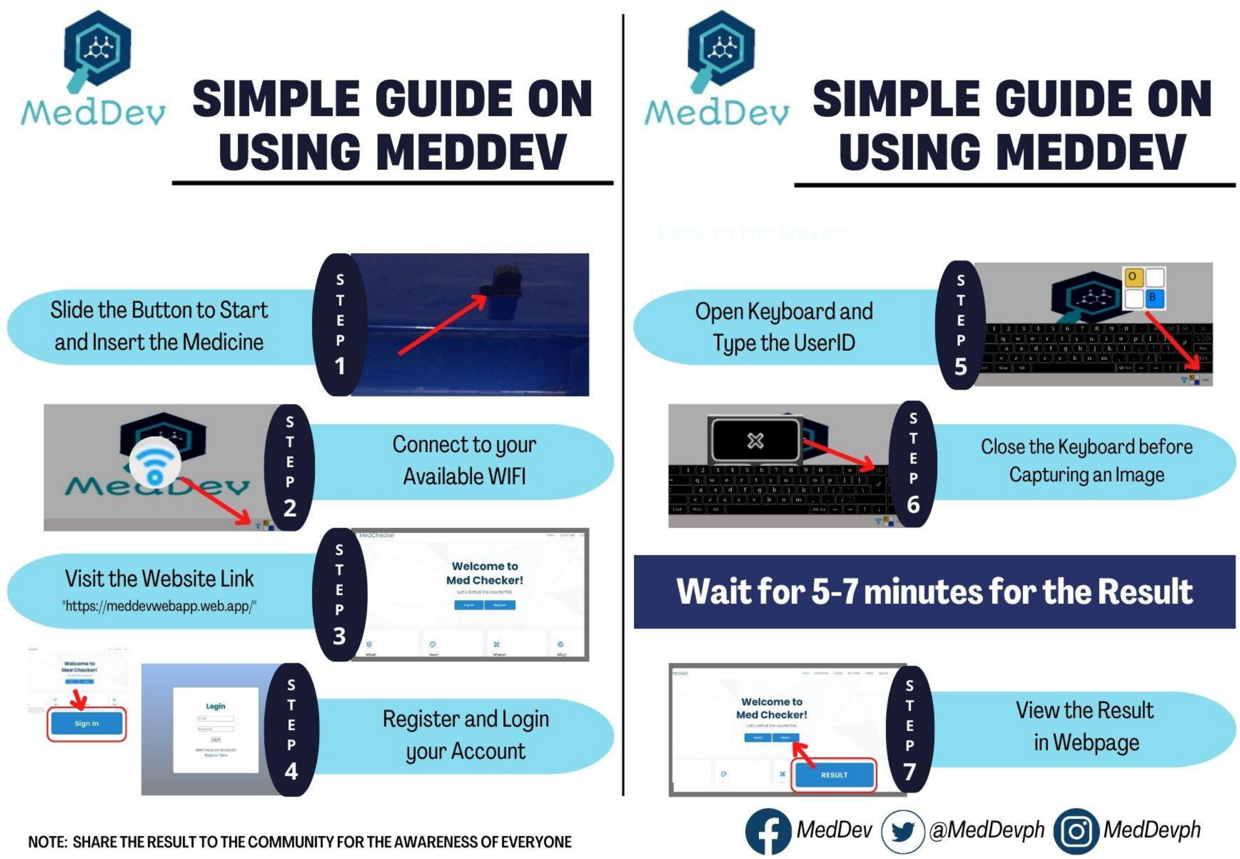


iPHONE 4: FASTER RCNN INCEPTION V2




BIOGESIC

APPENDIX D: USER'S MANUAL



APPENDIX E: CURRICULUM VITAE

CAMILLE BRILLANTES

San Mateo City
09634295553
mcnbrillantes@tip.edu.ph

PERSONAL INFORMATION

Birthday: June 30, 2000
Birthplace: Quezon City
Age: 22
Nationality: Filipino
Civil Status: Single

EDUCATIONAL BACKGROUND

TERTIARY
Technological Institute of the Philippines - Manila
2018-present

SECONDARY
Technological Institute of the Philippines - Manila
2016-2018

JESSALYN A. GARCIANO

Manila City
09501455712
mjagarciano@tip.edu.ph

PERSONAL INFORMATION

Birthday: May 12, 2000
Birthplace: Manila City
Age: 21
Nationality: Filipino
Civil Status: Single

EDUCATIONAL BACKGROUND

TERTIARY
Technological Institute of the Philippines - Manila
2018-present

SECONDARY
Arellano University - Manila
2016-2018

ANGEL C. LEBIOS

Taguig City
09264739204
maclebios@tip.edu.ph

PERSONAL INFORMATION

Birthday: December 8, 1999
Birthplace: Manila City
Age: 22
Nationality: Filipino
Civil Status: Single

EDUCATIONAL BACKGROUND

TERTIARY
Technological Institute of the Philippines - Manila
2018-present

SECONDARY
Philippine Christian University - Manila
2016-2018

ALLIAH B. KANACAN

Manila City
09222581942
mabkanacan@tip.edu.ph

PERSONAL INFORMATION

Birthday: December 4, 1999
Birthplace: Manila City
Age: 21
Nationality: Filipino
Civil Status: Single

EDUCATIONAL BACKGROUND

TERTIARY
Technological Institute of the Philippines - Manila
2018-present

SECONDARY
STI College - Manila
2016-2018

Category	Topic	Authors	Source	Relevant Findings / Information
1.	Special Law on Counterfeit Drugs	Quintin L. Kintanar	Kintanar, Q. (1996). *Special Law on Counterfeit Drugs*. retrieved from https://www.fda.gov.ph/wp-content/uploads/2021/03/RA-8203-Counterfeit.pdf	Counterfeit medicine is a medicine with the correct ingredients in the wrong amounts, wrong ingredients, no active ingredients, or a sufficient quantity of active ingredient that reduces the drug's safety, efficacy, quality, strength, or purity.
2.	Cigarettes, medicine top counterfeit goods entering the Philippines	Maya M. Padillo	Padillo, M. (2019). *Cigarettes, medicine top counterfeit goods entering the Philippines*. Davao City - BusinessWorld Publishing retrieved from https://www.bworldonline.com/cigarettes-medicine-top-counterfeit-goods-entering-the-philippines/	Cigarettes and alcohol remain the top counterfeit goods being smuggled into the Philippines, followed closely by fake medicines and personal care products.
3.	Stopping counterfeit drugs in their tracks in the Philippines	Anviksha Patel	Patel, A. (2018). *Stopping counterfeit drugs in their tracks in*	The counterfeit pharmaceutical industry in the Philippines is clearly lucrative, while the importation of fake drugs

			the Philippines. World Finance: The voice of the market retrieved from https://www.worldfinance.com/markets/stopping-counterfeit-drugs-in-their-tracks-in-the-philippines	through various channels is an added burden for authorities. Counterfeit drug makers and suppliers will continue to distribute and manufacture as long as affordable medications are needed.
4.	Probe sought on PH having 'highest incidence' of fake drugs	Gov.ph	Gov.ph (2019). *Probe sought on PH having 'highest incidence' of fake drugs*. Manila - Philippines News Agency retrieved from https://www.pna.gov.ph/articles/1077600	If the reports are true that fake medicines are being sold for lower prices at sari-sari stores then proceed to victimizing the poor who often have to borrow money to buy medicines or cost-cut by buying doses lower than what the doctor has prescribed.
5.	Fake, unregistered drugs seized in 2015 double in value – FDA	Jocelyn R. Uy	Uy, J. (2015). *Fake, unregistered drugs seized in 2015 double in value – FDA*. Manila - Inquirer.net retrieved from https://newsinfo.inquirer.net/741787/fake-unregistered-drugs-seized-in-2015-double-in-value-fd	Counterfeit medicines could worsen an existing disease, cause adverse reactions with other medications and could lead to permanent disability and even death. Most of the cases of counterfeit drugs detected from January to October this year were from Metro Manila, Cavite, Pampanga, Isabela, Cebu, Bohol, Leyte, Davao and Zamboanga.

			a	
6.	3 Pakistanis nabbed for fake drugs	Rey Galupo	Galupo, R. (2017). 3 Pakistanis nabbed for fake drugs. Manila - The Philippine Star retrieved from https://www.philstar.com/metro/2017/08/11/1728055/3-pakistanis-nabbed-fake-drugs	3 Pakistanis were arrested after being handed three boxes of counterfeit brands of naproxen sodium, paracetamol and a mix of dextromethorphan, phenylephrine and paracetamol to an undercover police officer. A concerned citizen told them the Pakistanis were trying to offer branded medicine for a much lower price.
7.	Fake medicine distributor nabbed in Cavite	Gov.ph	Gov.ph (2018). Fake medicine distributor nabbed in Cavite. General Trias Cavite - Philippine News Agency retrieved from https://www.pna.gov.ph/articles/1032568	The fake or counterfeit medicines consisted of multivitamins, cough tablets, and paracetamol among others that are normally sold over the counter in retail stores. Investigators said the suspect sold the fake medicines for only PHP2 per tablet and the sari-sari store owner in turn sold the fake medicines to customers for PHP10 per tablet.
8.	Combating Fake Drugs With Technology	Martins Ikhilae	Ikhilae, M. (2013). Combating Fake Drugs With Technology. AllAfrica Global Media GALE - A335554099	The programme involves the packaging of drugs with a scratch card placed on drug packs from the point of manufacture. When scratched, the hidden codes revealed on the packs could be sent free of charge via SMS to 38353 on the MTN, Zain and Globalcom networks. Shortly afterwards, the sender will receive a

				reply confirming whether the product is genuine or not.
9.	Counterfeit Drugs			Counterfeit drugs not only take income from consumers, by having them pay for products that have little or no medical value, but it can also lead to unresolved health problems, and even death. Drug manufacturers are using custom packaging and better authentication techniques to better protect their products from counterfeit practices but illicit drug manufacturers are working with specialists who can replicate both custom packaging and authentication efforts.
10.	Counterfeit drugs and medical devices in developing countries	Beverley D. Glass	Glass, B. (2014). *Counterfeit drugs and medical devices in developing countries. Research and Reports in Tropical Medicine; Macclesfield Vol.5 11-22. DOI:10.2147/RRTM.S39354*	The World Health Organization has reported that counterfeit medicines potentially make up more than 50% of the global drug market, with a significant proportion of these fake products being encountered in developing countries.
11.	A Comprehensive Drug Management System by Segregating Spurious and Substandard Drugs Using Blockchain Technology	Sourav Raxit, Jobair Hossain Gourob, Homayun Kabir	Raxit, S., Gourob, J.H., Kabir, H. (2021). *A Comprehensive Drug Management System*	One of every ten medicines are either fake otherwise don’t follow standard of drugs in developing countries and making the situation worse there. It is very tough

			by Segregating Spurious and Substandard Drugs Using Blockchain Technology. International Conference on Automation, Control and Mechatronics for Industry – IIEE DOI:10.1109/ACMI53878.2021.9528238	to standardize safety regulation of medicines because of the rise of internet pharmacies. Counterfeited drug passes through various distributed complex networks. So, it is hard to detect the counterfeited medicines. For distributed complex networks, the fake drugs get chance to get into the genuine drug supply chain.
12.	Drug Governance: IoT-based Blockchain Implementation in the Pharmaceutical Supply Chain	Victoria Ahmadi, Sophia Benjelloun, Michel El Kik, Tanvi Sharma, Huihui Chi, Wei Zhou	Ahmadi, V., Benjelloun, S., El Kik, M., Sharma, T., Chi, H., & Zhou, W. (2020). Drug Governance: IoT-based Blockchain Implementation in the Pharmaceutical Supply Chain. 2020 Sixth International Conference on Mobile And Secure Services (MobiSecServ). doi:10.1109/mobisecserv48690.2020.9042950	Internet of Things (IoT) based blockchain is a type of distributed ledger (DLT) that maintains an immutable record of all transaction information that is incapable of being falsified and is visible to all participants.

13.	Identifying and combating counterfeit drugs	Albert I Wertheimer	Wertheimer, A. (2008). Identifying and combating counterfeit drugs. Expert Reviews Ltd. Expert Review of Clinical Pharmacology(Vol. 1, Issue 3) DOI:http://dx.doi.org/10.1586/17512433.1.3.333	It appears that most counterfeits are produced in Asia and brought into patient homes from purchases made while abroad and from internet pharmacies.
14.	The Real Impact of Counterfeit Medications	LaKeisha Williams, Ellen McKnight	13. McKnight, E., Williams, L. (2014). The Real Impact of Counterfeit Medications. U.S Pharmacist – Affordable Medicines retrieved from https://www.uspharmacist.com/article/counterfeit-meds?utm_source=TrendMD&utm_medium=cpc&utm_campaign=US_Pharmacist_TrendMD_1	Counterfeit medications may be detrimental to a patient's health status. The use of substandard drugs may result in adverse side effects, treatment failure, resistance, toxicity, and even death.

15.	Rise in online pharmacies sees counterfeit drugs go global	Fiona Clark	Clark, F. (2015). Rise in online pharmacies sees counterfeit drugs go global. The Lancet, 386(10001), 1327–1328. doi:10.1016/s0140-6736(15)00394-3 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)00394-3/fulltext?rss%3Dyes=	Counterfeit drugs have been found in 124 countries across all continents and between 2011–14 more than 55 million doses were seized by authorities
16.	Risk of medicines: Counterfeit drugs	Akunyili Dora Nkem, Nnani Ijeoma	Akunyili, D.N., Nnani, I. (2004) Risk of medicines: Counterfeit drugs. International Journal of Risk and Safety in Medicine, vol. 16, no. 3, pp. 181-190, 2004 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)00394-3/fulltext?rss%3Dy	Counterfeit medicines constitute a risk to the pharmaceutical industry, healthcare providers, the healthcare system as a whole and ultimately to the patient. The risks to the patient include, lack of effect, toxicity, adverse drug reactions (ADRs), loss of economic and other resources and ultimately death.

			es=	
17.	Faking it - II: Countering and preventing counterfeiting of drugs	Swaminath, G	Swaminath, G. (2019). Faking it - II: Countering and preventing counterfeiting of drugs. Indian Journal of Psychiatry; Mysore Vol. 51, Iss.1: 9-11. DOI:10.4103/0019-5545.44899 https://www.proquest.com/docview/862878963/C465164298ED44B6PQ/36?accountid=36184	Counterfeit drugs are a major cause of morbidity, mortality, and loss of public confidence in medicines and health structures.
18.	Epidemic of Fake Medicines Plagues Asia	SICPA	SICPA - Epidemic of Fake Medicines Plagues Asia https://brandprotection.sicpa.com/epidemic-of-fake-medicines-plagues-asia/	Impacts in health are adverse effects (for example toxicity or lack of efficacy) from incorrect active ingredients, Failure to cure or prevent future disease, increasing mortality, morbidity, and the prevalence of disease, progression of antimicrobial resistance, and drug-resistant infections
19.	The Deadly World of Drugs	Rodriguez, E., Chowdhury, D., Magunia R., Lounatmaa, K.	Rodriguez, E., Chowdhury, D., Magunia R.,	life-threatening fake pharmacology, manufacturing drugs used to treat cancer, HIV/Aids, and serious heart conditions

			Lounatmaa, K. (2008). THE DEADLY WORLD OF FAKE DRUGS. retrieved from https://www.aei.org/wp-content/uploads/2011/10/20081023_FakeDrugs_168.pdf	
20.	WHO launches taskforce to fight counterfeit drugs	William Burns	20. Burns, W., (2006). WHO launches a task force to fight counterfeit drugs. Bulletin of the World Health Organization. vol.84 (9), 689-690 https://www.scielosp.org/article/bwho/2006.v84n9/689-690/	impact that counterfeit drugs can have on patients' health, as well as the way these undermine health systems
21.	BC woman killed by fake drugs bought online	Sam Solomon	21. Solomon, S. (2007). BC woman killed by fake drugs bought online. National Review of Medicine Vol.4 no.13 https://safemeds.typepad.com/Fact_Pack_Archi	angerous metals during production in Southeast Asia and sold by a website

			ve/22%20-%20NRM_%20BC%20woman%20killed%20by%20fake%20drugs%20bought%20online.pdf	
22.	The global counterfeit drug trade: Patient safety and public health risks	Tim K.Mackey, Bryan A.Liang	Mackey, T. K., & Liang, B. A. (2011). *The global counterfeit drug trade: Patient safety and public health risks*. Journal of Pharmaceutical Sciences, 100(11), 4571–4579. doi:10.1002/jps.22679 https://www.sciencedirect.com/science/article/abs/pii/S002235491531858X	WHO estimates that between 1% and 10% of drugs sold around the world are counterfeits, and as many as 50% in some countries.
23.	The Hunt Counterfeit Medicine	Rajendrani Mukhopadhyay	Mukhopadhyay, R. (2007). The Hunt for Counterfeit Medicine. Analytical Chemistry, 79(7), 2622–2627. doi:10.1021/ac071892p https://pubs.acs.org/doi/	Fake drugs were not only killing people but the drugs were also killing businesses. Millions of lives have been saved. Industries have been revived, referring to the damage counterfeiting does to public trust in companies and their products.

			pdf/10.1021/ac071892p	
24.	The Global Threat of Counterfeit Drugs: Why Industry and Governments Must Communicate the Dangers.	Cockburn R, Newton PN, Agyarko EK, Akunyili D, White NJ	Cockburn, R., Newton, P., Agyarko, E.K., Akunyili, D., White, N. (2005). The Global Threat of Counterfeit Drugs: Why Industry and Governments Must Communicate the Dangers. PLoS Medicine; San Francisco Vol. 2, Iss. 4: e100. DOI:10.1371/journal.pmed.0020100 https://www.proquest.com/docview/1288070444/C465164298ED44B6PQ/1?accountid=36184	mandatory reporting to governmental authorities, which should also have a legal duty to investigate
25.	5 Strategies To Combat Counterfeit Drugs And Other Pharma Supply Chain Threats	Michael Esposito	Esposito, M. (2018). 5 Strategies To Combat Counterfeit Drugs And Other Pharma Supply Chain Threats. Pharmaceutical Online retrieved from	1. The design of the system will place FDA in a supervisory data verification role, with each pedigree type-specific data source serving a primary data verification role.

			https://www.pharmaceuticalonline.com/doc/strategies-to-combat-counterfeit-drugs-and-other-pharma-supply-chain-threats-0001	
26.	Blockchain Technology for Detecting Falsified and Substandard Drugs in Distribution: Pharmaceutical Supply Chain Intervention	Patrick Sylim, Fang Liu, Alvin Marcelo, Paul Fontelo	Sylim, P., Liu, F., Marcelo, A., Fontelo P. (2018). Blockchain Technology for Detecting Falsified and Substandard Drugs in Distribution: Pharmaceutical Supply Chain Intervention. JMIR Publication Vol.7, No.9 doi:10.2196/10163 https://www.researchprotocols.org/2018/9/e10163/	Drug counterfeiting is a global problem with significant risks to consumers and the general public.
27.	Applied Artificial Intelligence for Better Health Solutions	Ben Duan, Xin Liu, Ellen Crayton	Duan, B., Liu, X., Crayton, E. (2019). Applied Artificial Intelligence for Better Health Solutions. Precise Software	PillSafe Application

			Innovation Team retrieved from https://static1.squarespace.com/static/5f609241230ea4160f9d55ad/t/5fad373f54d7bd32baa78757/1605187429976/Applied+AI+for+Better+Health+Solutions.pdf	
28.	Veripad: Identifying fake medications with machine learning	Slalom	Slalom ,Veripad: Identifying fake medications with machine learning https://www.slalom.com/case-studies/veripad-machine-learning	Veripad's founders created a mobile app that "reads" inexpensive chemical test cards, enabling anyone to quickly verify common medicines. We helped them improve the technology with machine learning and Amazon SageMaker.
29.	Counterfeit drugs: analytical techniques for their identification	R. Martino, M. Malet-Martino, V. Gilard, S. Balayssac	Martino, R., Malet-Martino, M., Gilard, V., & Balayssac, S. (2010). Counterfeit drugs: analytical techniques for their identification. Analytical and Bioanalytical Chemistry, 398(1), 77–92.	The lack of robust information on the prevalence of fake drugs is an obstacle in the fight against drug counterfeiting

			doi:10.1007/s00216-010-3748-y https://link.springer.com/article/10.1007/s00216-010-3748-y	
30.	UV Visible Spectrometer (UV VIS Spectrometer)	Labcompare	Labcompare. UV Visible Spectrometer (UV VIS Spectrometer). Retrieve from https://www.labcompare.com/Spectroscopy/408-UV-Visible-Spectrometer-UV-VIS-Spectrometer/	UV Visible (UV VIS) Spectrometers perform absorption and reflectance spectroscopy using light in the visible and adjacent ranges. When purchasing a UV Visible spectrometer, it is important to consider the instrument's wavelength range, the lamp's lifetime, the image capture system and software, the resolution, and the amount of sample that is needed for input.
31.	Identification of counterfeit drugs using near-infrared spectroscopy	S.H. Scafi, C. Pasquini	Scafi, S. H. F., & Pasquini, C. (2001). Identification of counterfeit drugs using near-infrared spectroscopy. The Analyst, 126(12), 2218–2224. doi:10.1039/b106744n https://pubmed.ncbi.nlm.nih.gov/11814205/	The identification is based on the comparison of the NIR spectrum of a sample with typical spectra of the authentic drug using multivariate modelling and classification algorithms (PCA/SIMCA).

32.	How to spot a counterfeit medicine	Australian Government Department Of Health Therapeutic Goods Administration	Australian Government Department Of Health Therapeutic Goods Administration (2020) - How to spot a counterfeit medicine https://www.tga.gov.au/blogs/tga-topics/how-spot-counterfeit-medicine	Counterfeit medicines can be hard to identify. Lower your risk by buying your medicine from a registered pharmacy.
33.	RxAll is a deep learning-hyperspectral IoT Platform for Authenticating Drugs.	RxAl Inc.l	RxAll Inc. (2020)-RxAll is a deep learning-hyperspectral IoT Platform for Authenticating Drugs. https://www.rxall.net/about-us	RxAll
34.	This startup built a device to figure out if prescription drugs are fake	Eillie Anzilotti	Anzilotti, E. (2019). This Startup built a device to figure out if prescription drugs are fake. World Changing Ideas. Fast Company retrieved from https://www.fastcompany.com/90323372/this-startup-built-a-device-to-fi	RxAll first launched in Africa, its solution to the counterfeit drug crisis is by no means limited to that continent.

			gure-out-if-prescription-drugs-are-fake	
35.	Using Raman spectroscopy to combat the threat of counterfeit drugs during the COVID-19 pandemic	Dr Saurabh Kumar Banerjee	Banjeree, S.K. (2020). Using Raman spectroscopy to combat the threat of counterfeit drugs during the COVID-19 pandemic. European Pharmaceutical Review retrieved from https://www.europeanpharmaceuticalreview.com/article/121730/using-raman-spectroscopy-to-combat-the-threat-of-counterfeit-drugs-during-the-covid-19-pandemic/	The correct identification and retrieval of relevant information about individuals is extremely important during passenger transition through airports.
36.	Technologies for Detecting Falsified and Substandard Drugs in Low and Middle-Income Countries	Stephanie Kovacs, Stephen E. Hawes, Stephen N. Maley, Emily Mosites, Ling Wong, Andy Stergachis	Kovacs, S., Hawes, S. E., Maley, S. N., Mosites, E., Wong, L., & Stergachis, A. (2014). Technologies for Detecting Falsified and Substandard Drugs in Low and Middle-Income Countries. PLoS ONE,	Mass Spectrometer is a device that produces a mass spectrum read-out by measuring the individual mass spectra in a sample.

			9(3), e90601. doi:10.1371/journal.pone.0090601 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0090601	
37.	Drug Anomaly Detection	Liu Xin, Ba Ruomin, Wang James, Duan Bin, Yang Xu, Wang Hang	Liu, X., Ba, R., Wang, J., Duan, B., Yang, X., Wang, H. (2021) DRUG ANOMALY DETECTION. Precise Software Solutions, Inc. Rockville MD – US 20210035288 https://uspto.report/patent/app/20210035288?__cf_chl_jschl_tk__=PwEMqtkYzvn.heiKBwOocg6I6pW8yYa2OypBPfGL1Ao-1635448075-0-gaNycGzNCWU#D00000	A portable anomaly drug detection device The device includes at least one light source, a detector to scan or process the subject drug, and a control circuit having a controller. At least one light source, the camera, and the control circuit are disposed of within an enclosure.
38.	Hand-Held Near-Infrared Spectroscopy for Authentication of Fengdous and	Hui Yan, Yi-Chao Xu, Heinz W. Siesler, Bang-Xing Han, Guo-Zheng	Yan, H., Xu, Y.-C., Siesler, H. W., Han,	Hand-held Near-Infrared Spectroscopy

	Quantitative Analysis of Mulberry Fruits	Zhang	B.-X., & Zhang, G.-Z. (2019). Hand-Held Near-Infrared Spectroscopy for Authentication of Fengdous and Quantitative Analysis of Mulberry Fruits. Frontiers in Plant Science, 10. doi:10.3389/fpls.2019.01548 https://www.frontiersin.org/articles/10.3389/fpls.2019.01548/full	
39.	Technologies for Detecting Falsified and Substandard Drugs in Low and Middle-Income Countries	Kovacs Stephanie, Hawes Stephen E, Maley Stephen N, Mosites Emily, Wong Ling et al.	Kovacs, S., Hawes, S.E., Maley, S.N., Mosites, E., Wong, L., et al. (2014). Technologies for Detecting Falsified and Substandard Drugs in Low and Middle-Income Countries. PLoS One; San Francisco Vol. 9, Iss. 3: e90601. DOI:10.1371/journal.po	he workflow starts with the inspection of packaging, followed by quantitative High-Performance Liquid Chromatography (HPLC), Raman and Near-Infrared spectroscopy (NIR), and colorimetric tests for the correct API; dissolution testing is used to ensure the correct amount of the API is present.

			ne.0090601 https://www.proquest.com/docview/1510500271/C465164298ED44B6PQ/30	
40.	Universal HPLC Analysis for Counterfeit Medication: A Partnership of Pur tnership of Purdue Univ due University and the Kilimanjar ersity and the Kilimanjaro School of o School of Pharmacy	Jordyn McCord, Michael Mavity, Shanygne Ashley Damayo, David Wintczak	McCord, J., Mavity, M., Damayo, S. A., & Wintczak, D.(2015). Universal HPLC analysis for counterfeit medication: A partnership of Purdue University and the Kilimanjaro School of Pharmacy. Purdue Journal of Service-Learning and Engagement, 2, 23–26. http://dx.doi.org/10.5703/1288284315692	universal HPLC Analysis for Counterfeit Medication
41.	COUNTERFEIT PRODUCTS	Organization for Economic Co-operation and Development	Organization for Economic Co-operation and Development (2007)- Counterfeit Products https://www.unodc.org/d	Product counterfeiting is a form of consumer fraud: a product is sold, purported to be something that it is not.

			ocuments/data-and-analysis/tocta/8.Counterfeit_products.pdf	
42.	Combating a global pandemic of weak, adulterated, and fake drugs	Menghis Bairu	Bairu, M. (2015). Combating a global pandemic of weak, adulterated, and fake drugs. thinkBiotech LLC. Journal of Commercial Biotechnology Vol. 21, Issue 3. DOI: http://dx.doi.org/10.5912/jcb712	It's difficult to quantify the problem because falsified drugs often go undetected due to weak or absent regulatory systems in some parts. In Africa, the lack of access to innovative drugs makes the population vulnerable to counterfeits and inefficacious copies of medicines that are much needed.
43.	How am I able to protect myself from Counterfeit Drugs	Singh N, Dhyani A., Nainwal P., Lall S., Vijay Kumar	Singh, N., Dhyani, A., Nainwal, P., Lall, S., Vijay, K. (2019). How am I able to protect myself from Counterfeit Drugs. International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-8 Issue-6S4	The use of more advanced technology for inspection and regulation of pharmaceutical supply may be helpful to overcome the problems of spurious drugs.

44.	WHO launches task force to fight counterfeit drugs	William Burns	Burns, W. (2006) WHO launches a task force to fight counterfeit drugs. SCIELOSP. Retreived from https://www.scielosp.org/article/bwho/2006.v84n9/689-690/	According to WHO, drugs commonly counterfeited include antibiotics, antimalarials, hormones and steroids. Increasingly, anticancer and antiviral drugs are also faked.
45.	WHO Global Surveillance and Monitoring System for Substandard and Falsified Medical Products.	Dr Elizabeth Pisan	Pisani, E. (2017). WHO Global Surveillance and Monitoring System for Substandard and Falsified Medical Products. License: CC BY-NC-SA 3.0 IGO. Switzerland ISBN 978-92-4-151342-5. Retrieved from https://www.who.int/medicines/regulation/ssffc/publications/GSMSreport_EN.pdf?ua=1	Pharmacopeia evaluates existing and emerging drug screening technologies that can be used at ports and in health care settings other than high-specification laboratories.
46.	Countering the Problem of Falsified and Substandard Drugs	National Academy of Sciences	National Academy of Sciences (2013). Countering the Problem	There are technologies commonly used to detect substandard and falsified drugs, ranging from inexpensive field assays to

			of Falsified and Substandard Drugs. NAP. Retrieved from https://www.nap.edu/read/18272/chapter/8	highly sophisticated laboratory methods. One of the technologies used with imaging techniques, near-infrared, can yield information about a tablet's composition and compare images of a pain relief tablet, one captured using near-infrared imaging and the other not. Portable, battery-powered near-infrared spectrometers are a more accessible alternative to traditional spectrometers.
47.	Regional Workshop on improving Medicines Surveillance and Regulatory Functions	WORLD HEALTH ORGANIZATION REGIONAL OFFICE FOR THE WESTERN PACIFIC	WORLD HEALTH ORGANIZATION REGIONAL OFFICE FOR THE WESTERN PACIFIC (2007). Regional Workshop on improving Medicines Surveillance and Regulatory Functions. Manila, Philippines - iris.wpro.who, Retrieved from https://iris.wpro.who.int/bitstream/handle/10665.1/6252/RS_2007_GE_51_PHL_eng.pdf	For combating counterfeit medicines, medicines surveillance should target high risk products in high-risk areas, such as remote places, borders area and unlicensed establishments, where counterfeiting will have a deadly health impact. Sophisticated technology age, direct involvement of the consumer can be very important and useful. The existing system needs to be extended to encourage consumer reporting, especially with the increasing use of self medication products.
48.	Public Awareness and Identification of	Linus Mhando, Mary B. Jande,	Mhando, L., Jande,	The result of this research reported that counterfeit

	Counterfeit Drugs in Tanzania: A View on Antimalarial Drugs	Anthony Liwa, Stanley Mwita, Karol J Marwa,	MB., Liwa, A., Mwita, S., Marwa KJ. (2016). Public Awareness and Identification of Counterfeit Drugs in Tanzania: A View on Antimalarial Drugs. Researchgate. Retrieved from https://www.researchgate.net/publication/303872734_Public_Awareness_and_Identification_of_Counterfeit_Drugs_in_Tanzania_A_View_on_Antimalarial_Drugs.	drugs will be successfully reduced through sen-sitizing people's awareness against counterfeit drugs..
49.	FIGHTING COUNTERFEIT AND SUBSTANDARD DRUGS AT PERIPHERY: THE UTILITY OF BASIC QUALITY CONTROL TESTS	Patil, Deepak D; Pandit, Viraj S; Pore, Shraddha M; Chavan, Chandrashekhar S.	Patil, DD., Pandit, VS., Pore, SM., Chavan CS. (2012). FIGHTING COUNTERFEIT AND SUBSTANDARD DRUGS AT PERIPHERY: THE UTILITY OF BASIC QUALITY CONTROL TESTS. Proquest. Retrieved from https://www.proquest.com/docview/1016299346	Disintegration tests and color reactions are easy to perform and should be adopted by tertiary care government hospitals which serve a large population. Consistently performing such tests not only helps to identify the counterfeit drugs but also to create a data file with which the quality of future products can be compared and reliable suppliers can be identified.

			/C465164298ED44B6PQ/23	
50.	5 Tips on How to Identify Fake Drugs	Pharmapproach	Pharmapproach (2021). 5 Tips on How to Identify Fake Drugs. Pharmapproach. retrieved from https://www.pharmapproach.com/how-to-identify-fake-drugs/	Visual inspection still remains the first step in identifying potential fake drugs. These are needed to check when buying medicine, the seal of the package breaks or tears in the sealing tape and seals, unusual fonts, font sizes, print colour, and spelling errors. Also batch number if it's readable or not, differences in the physical appearance (colour uniformity, size, shape, consistency etc.) of the drug.