For our doctors, teacher's assistants, parents

and everyone who help and support us

we are extremely grateful for your patience

encouragement, and guidance.

we are lucky to have such amazing persons in our life.

Thank you so much.

Special thanks

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Hello Product

Graduation Project

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#let_your_product_introduce_himself

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Chapter One

Introduction

1.1 Marketing definition:

In the most generalized form, **"Marketing":** *is the process by which companies create customer interest in products or services.*

"Marketing is used to identify the customer, to keep the customer, and to satisfy the customer."

By absorbing that definition of marketing, we can realize the importance of the communication with the customer and consider it as the atomic process of the whole functionalities of keeping our customer's interest **"Marketing"**, targeting the communication process/tunnel and methodologies between the *customer and the product*, leads to the well-known concepts of *"the offline/online Marketing categorization"*.

As a main goal of marketing: "*Marketing is everything a company does to acquire customers and maintain a relationship with them"*. The ultimate goal of marketing is to match a company's products and services to the people who need and want them, thereby ensuring profitability. The four P's of marketing are product, *place*, price and promotion.

The online marketing has been on top of the list for the past five years however, professional Marketers and Decision Makers recently are publishing about the concept of The "**Dead Digital Marketing**".

1.2 Digital Marketing is dead:

"Digital marketing – advertising brands to consumers through mobile electronic devices such as smartphones and computer tablets – has evolved to the point where the term has become outdated", Procter & Gamble's global brand building officer of P&G.

The divide between online and offline marketing is shrinking every year. Experts now regard the former practice of creating two different strategies for the online and offline world as the old way. The new way to plan your online and offline campaigns is to create a single congruent campaign centered on a central message. Marketing leaders are proclaiming, "Digital marketing is dead", which only means that the term "digital marketing" as a separate and distinct marketing activity should no longer

exist. Digital marketing is a part of the entire campaign just as much as traditional marketing is. The banner ad is a different monster from a banner hanging off the side of a skyscraper, but the message and spirit of the campaign should remain the same.

(Figure 1.1)

1.3 Online & Offline marketing comparison:

And here is an overview of the main characteristics we took in consideration about the communication process between online and offline marketing:

ONLINE & OFFLINE MARKETING Communication

Category	Online	Offline
Focus	**Content**	**Product**
Timing	**Customer need driven**	**Company determined**
Customer Communication	**Email, Chat, Social Media, Mobile**	**In-Person, Direct mail, Staff**
Product Placement	**Third party media, site navigation.**	**Store location, Mass media, catalog placement.**

Benefits	Cost, Immediacy	Reach, Branding
Challenges	Technology, platform, Database	Retail traffic, circulation growth, database

1.4 Customer Relationship Management "CRM":

Customer relationship management (**CRM**) is a term that refers to practices, strategies and technologies that companies use to manage and analyze customer interactions and data throughout the customer lifecycle, with the goal of improving business relationships with customers, assisting in customer retention and driving.

1.5 Offline Marketing" as HELLO PRODUCT's interest:

For many professional services firms, online marketing has become front and center over the last five years, why? It can be easily measured and is often less expensive than traditional marketing. But that doesn't mean there aren't still plenty of offline marketing techniques that can help. In fact, truly effective marketing strategies tend to take advantage of both online and offline initiatives to create a well-rounded, multi-faceted approach.
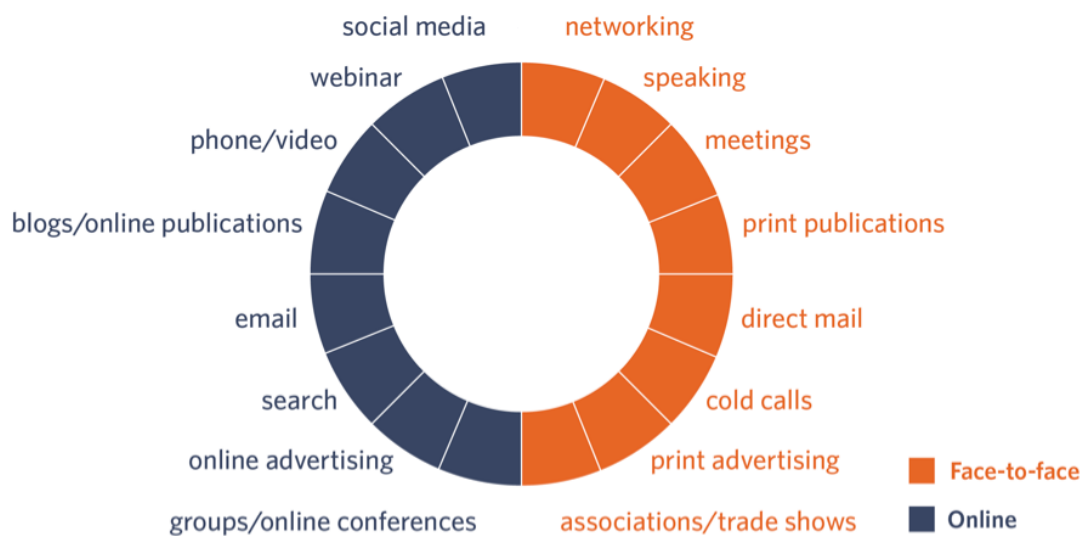
(Figure 1.2)

Offline Marketing: Offline marketing strategies utilize offline media channels to create awareness of a company's products and services. These campaigns can include radio and print advertising – including billboards, signs and pamphlets – telemarketing, and television ads.

Below-the-line advertising: Below-the-line advertising is an advertising strategy in which a product is promoted in mediums other than radio, television, billboards, print and film. Types of below-the-line advertising commonly include direct mail campaigns, trade shows and catalogs, and targeted search engine marketing.

Traditional marketing: refers to any type of promotion, advertising or campaign that has been in use by companies for years, and that has a proven success rate. Methods of traditional marketing can include print advertisements, such as newsletters, billboards, flyers and newspaper print ads.

1.6 Offline Marketing Techniques

1) **Associations and Trade Shows.** *(This will be Hello Product's scope)*

Consider attending trade shows where you can network with other industry leaders and prospective buyers. Trade shows can provide a great opportunity to put the most effective offline marketing strategies in practice. In addition to in-person networking, you can also pass out print materials and perhaps even get the opportunity to be a featured speaker. Luckily, there's no need to choose between offline and online marketing strategies. Offline marketing strategies don't need to take the place of online marketing strategies or vice versa. Instead, offline techniques can be used to supplement online marketing efforts to make your firm's marketing strategy as a whole more robust. The combination of both approaches can bring your marketing full circle by increasing your firm's visibility and bringing more attention to your online brand.

2) **Speaking Engagements**

In-person speaking engagements are a tremendous marketing opportunity for a number of reasons. First and foremost, a speaking engagement puts you in front of a highly targeted and interested audience that is already primed and ready to pay attention to what you have to say.

Speaking engagements are also a great way to build credibility and establish thought leadership within your firm. According to surveyed Visible Experts, speaking engagements are the second most popular way that Visible Experts obtain leads.

However, finding and securing speaking engagement opportunities may be a challenge if you're just starting out in your journey to thought leadership. Try starting small with local associations and don't be afraid to say yes to unpaid opportunities. Chances are, even your earliest experiences will pay off in the long run.

3) Print Publications

While you won't give you the same SEO benefits as an online link back to your website, print publications still have a valuable place in offline marketing. Obtaining relevant placements in industry magazines and journals will help increase your brand visibility and showcase your expertise. Include print opportunities as part of your blogger outreach strategy and keep an eye out for opportunities to appear in both an online and print version of a publication. However, don't seek out print publications just for the sake of it. Just as with your online publications, you need to be selective. Make sure the publications you choose are relevant to your target audience and a reputable source of information.

4) Direct Mail

Even though direct mailers are more costly than online marketing, they can still be an effective lead generating tool. Some members of your target audience may appreciate receiving direct mail because it seems more personalized.

And the practice of sending direct mail for marketing purposes is far from extinct. In fact, some members of your target audience may actually prefer direct mail communication to any other method of online communication.

5) Cold Calls

Similarly, cold calls have that personal touch that often resonates with interested buyers. Phone calls are more personal than emails and demand an instant response – which can be both good and bad. Just make sure you have a concrete reason for why you're reaching out and be mindful of your phone call recipient's time. Cold calls are also a great way to reach out to potential marketing partners about a collaboration opportunity, like hosting a webinar or producing content together.

6) Print Advertising

Along the same lines as publishing an article in a print publication, running print advertisements is another method for getting in front of more potential customers. However, it is significantly more difficult to track the return on investment for print advertising than it is for online ads and they can often be more expensive to run, so consider your options carefully. Print advertisements are best positioned in highly targeted publications where you can guarantee members of your target audience will see your ad. If possible, include a URL or a QR code in the print advertisement to send visitors to the landing page, which will help you track these campaigns better.

7) Networking

Face-to-face connections are still a valuable form of networking and can help drive traffic to your website when your new connections are inspired to learn more about you and your firm.

Being able to put a face to the name can help create a deeper sense of brand loyalty among your buyers, so don't discount the importance of a good, old fashioned handshake. Make your own opportunities for in-person networking by joining local chapters of associations or organizations where your target audience is likely to be found. Over time, this networking can be augmented with attendance at national conferences for those same associations/organizations.

 If area still doesn't have a business group, round up some interested business owners and meet up to start a small network, Creation strategic partnerships with non-competing businesses in the area.

8) Printed marketing material

Quick tips to make business cards stand out:

- Use colored cardboard instead of the usual white
- Change the orientation from landscape to portrait

Another way to get your brand message out to your target market is to give away printed marketing material. Flyer printing may seem like an old tactic, but that doesn't mean it doesn't get results. Go the extra mile and innovate beyond the standard template. There are a lot of creative ways you can get your target market's attention

using flyers and pamphlets, so make sure yours are practical for reading, keeping, and saving.

Quick tips to make flyers and pamphlets worth keeping:

- Print out informative infographics and turn those into flyers
- Add discount coupons at the bottom of your flyers

9) Offer expert advice

Quick tips to be the expert:

- Hold a "free consultation" day.
- Have a section for useful tips on your flyers.

10) Offer group specific discounts

Loyalty Programs. Endorsements: Give a product to prominent local, regional and national individuals for free. If they like it, they will use it, tell other people about it and maybe even endorse it formally.

11) Cross promotions

Cross promotions are popular in retailing but can be used in any type of business. Find companies with related products or services, and then explore ways to promote each other's business. You can do this in respective business locations, through joint advertising and with links to each other's website.

1.7 Ways to Integrate Your Online and Offline Marketing:

1) Mobile Check-In at Physical Locations.

2) Hashtag your Event Wisely (e.g. QR codes).

3) Teaser Advertising.

4) Custom URLs Make Everything Trackable.

Chapter Two
General Idea & Competitors

2.1 Problem statement:

Help companies to market their products with new tool.

2.2 Objective:

In the business world, the level of competition between the companies is increasing, and that made another competition on the techniques of presenting and marketing the products in an advanced and modern way. And our goal is to offer new and powerful way for presenting the product using the technology.

2.3 Abstract:

Using Image Processing, Pattern Recognition and microprocessing and motors from computer science field, "**Hello Product**" add value in marketing field. Product has vision by Hello Product's camera(s) to search for people they are interested in the product, makes the products introduce themselves to customers - new way for attraction - by audio using speakers, bulletin boards (text message is displayed on LCD) or by robot arm giving customers something such as flyers. Hello Product fits all products, in any space. There are some features under research for the representative tool like hologram and augmented reality.

2.4 Target customer:

The owners of shops and shopping malls and exhibition anyone wants to introduce a product in an excellent manner.

2.5 The problems we've solved:

The promotion of a product in a place full of other products such as exhibitions and shopping malls in an innovative way, or the way to promote special product in an excellent manner.

2.6 The solution:

Use the Tool to display products so as to identify the person who follow and look to the product then directing the product to his direction.

2.7 Difficult challenges:

- Capture from two cameras or 360 camera.
- Face detection for all people in 5m-circle.
- Face direction to know who looks to the Product.
- Detect the person place.

2.8 work needed to accomplish project:

There are many aspects of knowledge contribute in this project, that composed of hardware and software parts.

2.8.1 The main hardware components:

- Microcomputer.
- Representative tool.
- Cameras.
- Motor.

All of above needs some electronic skills and there are some tools installed on raspberry to manage the process.

2.8.2 The main software components:

Software part focus on face detection first and then determine its orientation second.

These processes is being implemented using OpenCV libraries with C++ language which was installed on CodeBlocks IDE with the help of CMake tool.

The competition between moving motor using Python or C++ come with development speed and runtime speed trade off, C/C++ are compiled languages, while Python is an interpreted language when it comes to speed, C/C++ faster runtime code, however, runtime speed isn't the only aspect of development to consider — you also have to consider development speed. While Python may be less efficient than C/C++ at runtime, during development it's much more efficient.

2.9 Hello Product is Vision Guided project:

Hello Product is mix between computer vision and embedded system to serve in marketing field in other words Hello product is Embedded Vision project.

"Vision Guided" refers to the practical use of computer vision in machines that understand their environment through visual means.

Vision Guided is a niche application sub-field within embedded systems that requires a good set of skills and knowledge of embedded systems and computer vision. Knowledge of other topics, such as signal and image processing helps, but is not mandatory. Computer vision is the use of digital processing and intelligent algorithms to interpret meaning from images or video. Computer vision has mainly been a field of academic research over the past several decades. Today, however, a major transformation is underway. Due to the emergence of very powerful, low-cost, and energy-efficient processors, it has become possible to incorporate practical computer vision capabilities into embedded systems, mobile devices, PCs, and the cloud. Over the next few years, there will be a rapid proliferation of embedded vision technology into many kinds of systems.

2.10 Hello Product – Black boxes   ?

Hello Product has two black boxes:

- 1st (bottom box): contains motor, electronic shields, e.g. Motor driver, microcontroller, microcomputer and power supply.
- 2nd (upper box): contains Representative tool and cameras.

2.11 Project Plan (Gantt chart):

		Task Mod	Task Name	Duration	Start	Finish
1			A1 - Plan and Search	1 wk	Thu 10/6/16	Wed 10/12/16
2			A2 - Buying hardware	1 wk	Thu 10/13/16	Wed 10/19/16
3			A3 -collecting dataset	1 wk	Thu 10/20/16	Wed 10/26/16
4			B1- Hardware assembling	4 wks	Thu 10/27/16	Wed 11/23/16
5			B2 -binding hardware with algorithm	1 wk	Thu 11/24/16	Wed 11/30/16
6			B3 -Write Initial Documentation	1 wk	Thu 12/1/16	Wed 12/7/16
7			C1 -Set Image Processing Alorithms	4 wks	Thu 12/8/16	Wed 1/4/17
8			OFF for first_semester Final Exams	4 wks	Thu 1/5/17	Wed 2/1/17
9			Completion of C1	8 wks	Tue 1/31/17	Mon 3/27/17
10			D1 -Start Designing	6 wks	Tue 3/28/17	Mon 5/8/17
11			OFF for second_semester Final Exams	4 wks	Tue 5/9/17	Mon 6/5/17
12			D2 -Write Final Documentaion	2 wks	Tue 6/6/17	Mon 6/19/17
13			D3 -Integration Test	2 wks	Mon 6/19/17	Fri 6/30/17
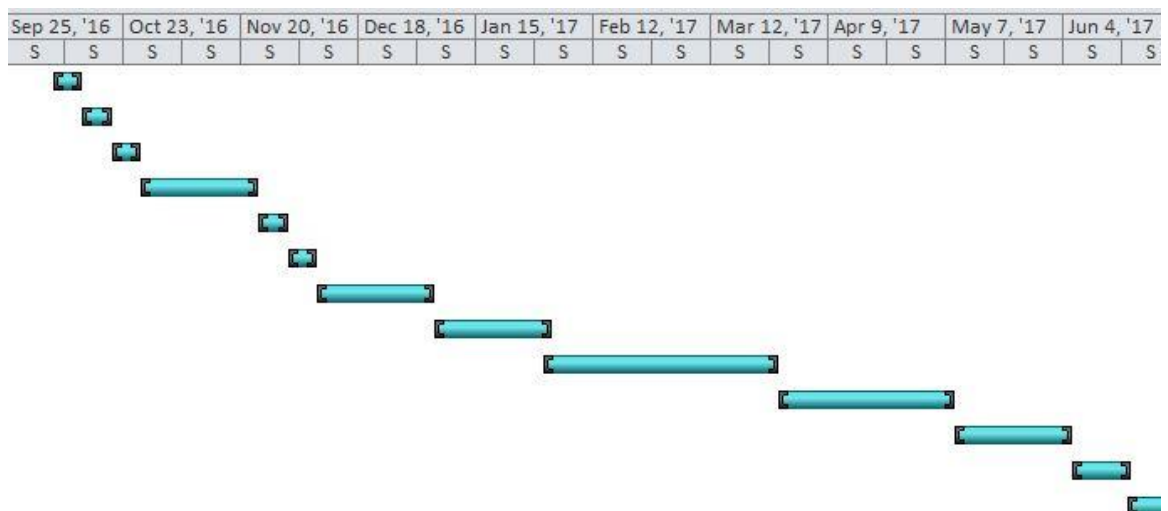
(Figure 2.1)

2.12 How far Hello Product is designed for dynamic usage?

There are two factors the customer can play with:

- Representative tool: which used to make product able to introduce himself. Customer can choose from the following tools:
    - Bulletin boards, once this option is chosen, customer had to prepare and deliver the advertise as a text message to be displayed on LCD screen.
    - Voice message, customer had to prepare sound file either .mp3 or .wav which contains the advertise as a voice message to be played using speakers.
    - Flayers, customer had to prepare flayers to be delivered by robot arm to the clients. This is most expensive techniques.

Customer can follow the marketing advices to write this advertise perfectly. There are some other techniques but still under research phase such as hologram.

- Covered range: which used to determine field of view around the product, in other words, the area the product can see around him . It can be 90, 180, 270 or the entire 360 degrees. This range is achieved by using number of cameras respectively to the required range.
- The following represent the relationship between cameras required and covered range:
    - 90 degrees can be achieved by 1 - 2 cameras.
    - 180 degrees can be achieved by 1 - 3 cameras.
    - 270 degrees can be achieved by 1 - 4 cameras.
    - 360 degrees can be achieved by 1 - 5 cameras.

The number of cameras is depending on the type of cameras, if web cameras is used, the number will be increased result why the narrow FOV of this type. Only one 360 cameras can be used to cover the entire areas but the cost will be higher than the use of web cameras. Also security cameras can be used to cover long distances and its FOV is bigger than web.

2.13 Market competitors:

There is no projects quite resemble Hello Product's main idea, but as Vision-Guided system there are many examples use same techniques e.g. "Motion Controls Robotics" company is a leading provider of automation solutions to manufacturing industries, another company called Eyedea provides software routines for object detection and object recognition like ones used in our project with regard to face detection and its orientation.

2.13.1 Marketing and retail organizing groups:

The following are some companies which are competing in the trade-shows and retail design market, providing new and user friendly designs of the retails and calling them smart, but still has no technology, such as **Figure 2.2**:

SMART-TRADE   Orange Smart Store

With all of those fancy designs and amazing colored retails trying to achieve a better CRM, but still applying no technology which makes it smoother.

2.14.2 Robotics and tech groups:

The Following are mostly robotics companies that produce robots which use a high-tech to provide different services in different fields. Softbank Robotics: providing robots operating in customer service.
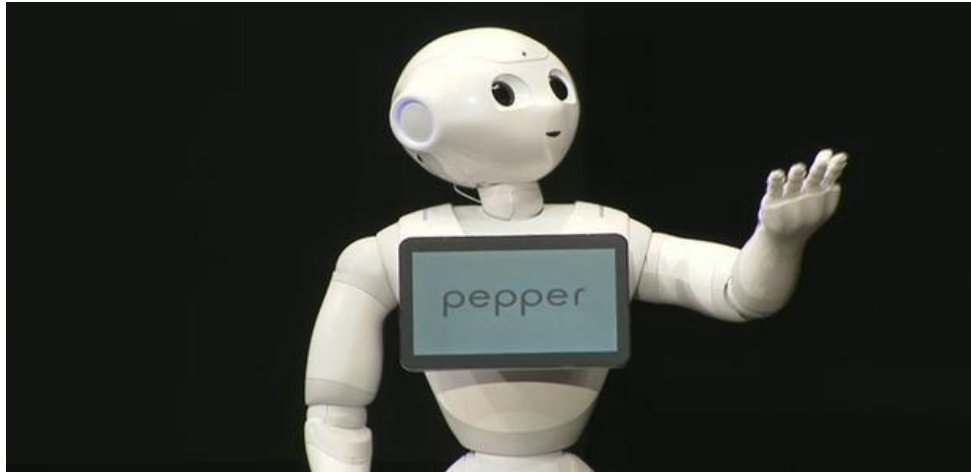
(Figure 2.3)

Future Robot: providing the Furo-D robot for customer service

Robotics products are costly and complicated enough not to be adjustable for different products.

(Figure 2.4)

Chapter three
Design and Analysis

3.1 Computer Vision:

3.1.1 <u>What is Computer Vision?</u>

As humans, we perceive the three-dimensional structure of the world around us with apparent ease. That if someone look at a vehicle, he can tell the shape and type also the color, and even he can distinguish between it and the background, but for computers the image is only a huge matrix filled by different numbers like the following figure.

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

(Figure 3.1)

So Computer Vision has arose as a science field aims to giving computers a visual understanding of the world and especially model, replicate and more importantly exceed human vision using computer software and hardware at different levels.

Vision is difficult that half of primate cerebral cortex is devoted to visual processing which make achieving human-level visual perception is too complicated. However, there is some limitations of human vision that computer vision tends to deal with it:

- Memory can't remember a quickly flashed image.
- Limited to visible spectrum.

a. Computer Vision Hierarchy

- Low level vision: process image for feature extraction (corner, edge, or optical flow).

- Middle level vision: object recognition, motion analysis, and 3D reconstruction using features obtained from the low-level vision.

- High level vision: interpretation of the evolving information provided by the middle level vision as well as directing what middle and low level vision tasks should be performed. Interpretation may include conceptual description of a scene like activity, intention and behavior.

This project focus mainly on middle level by setting algorithm for detecting faces and some low level by equalize the image and convert it to the grey-level one before pass it to the algorithm.

b. Related Fields

Computer vision overlaps significantly with the image processing, and pattern recognition fields.

❖ Computer Vision vs Pattern Recognition

Pattern recognition studies various mathematical techniques such as statistical techniques to classify different patterns. The input data for pattern recognition can be any data.

Pattern recognition techniques are widely used in computer vision.

Many vision problems can be formulated as classification problem.

❖ Computer Vision vs Image Processing

Image processing studies image-to-image transformation. The input and output of image processing are both images. Typical image processing operations include

- image compression
- image restoration
- image enhancement

Most computer vision algorithms usually assumes a significant amount of image processing has taken place to improve image quality.

Image processing and pattern recognition are among many techniques computer vision employs to achieve its goals.

3.1.2 How Computer Vision relate to HELLO PRODUCT?

As a project falls under the Vision Guided systems (VGS) umbrella, the main software part is Computer vision.

Vision Guided system is any system make its decisions according to visual appearance by acquisition digital images and perform some analyzing and processing techniques to extract useful information for making decisions.

And that what HELLO PRODUCT do as the following diagram (**Figure 3.2**):
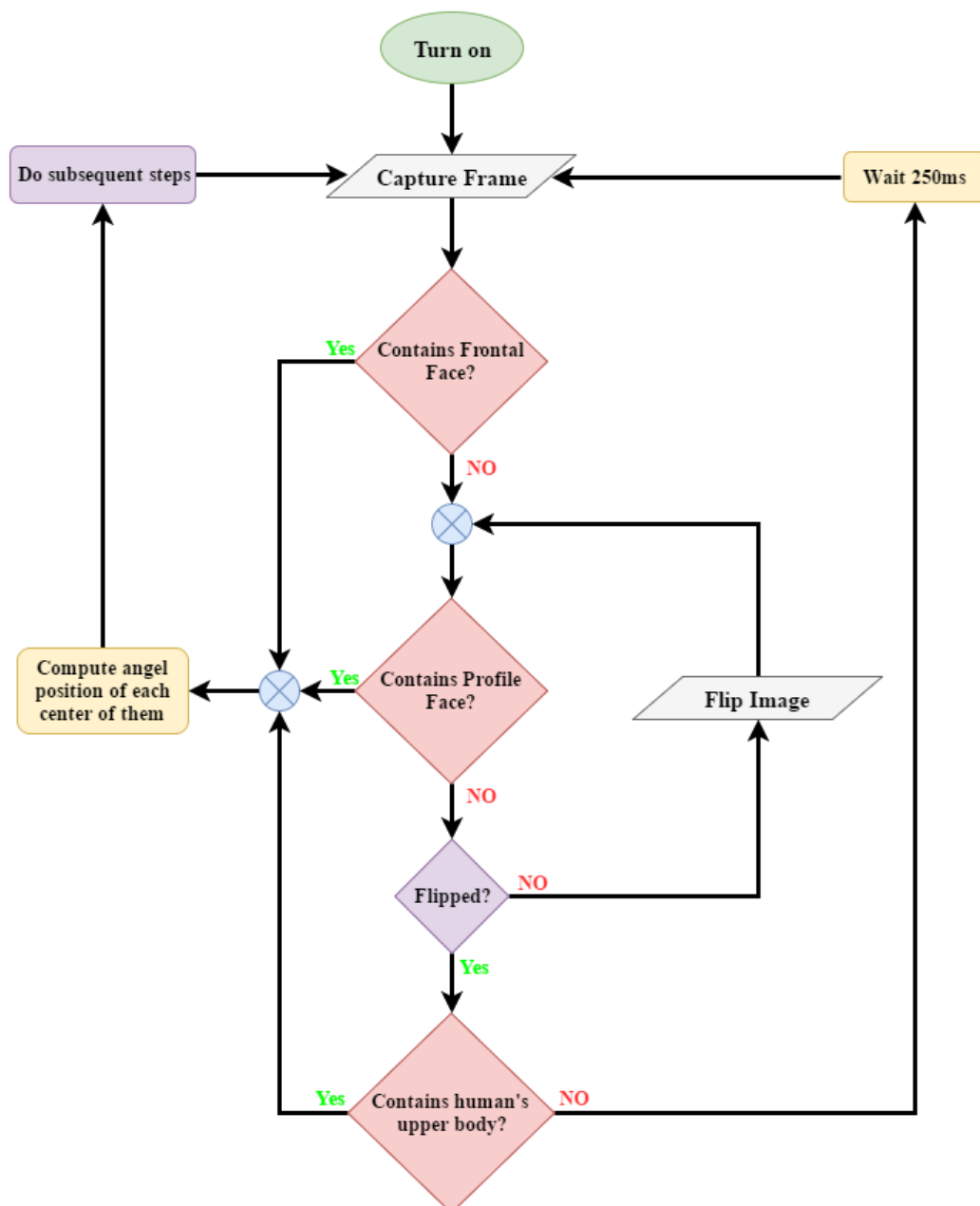
(Figure 3.2)

As flowchart you can notice that there is priority in which must be detected first, so the first priority for whom stand face to face to HELLO PRODUCT that they

must be interested, then whom stand beside device without looking at it that they may not so interested.

Note profile face function called twice because it detect profile faces only rotated to the right, so the image should flipped and repeat calling function to guarantee that all faces in each direction will be detected.

Finally detecting upper bodies is only for make sure that existed person will be detected if Frontal and Profile face failed to detect him.

After detection successfully completed the x center coordinate of each detected face or body will be passed to function that compute the horizontal position of it and return the value as an angle.

For example, if we have camera can cover 45 degree of visual field (Field of view) and produce image with 1280x720 pixels. The first thing must be computed to calculate angle position is "Degree per pixel" which computed by dividing the field of view by the width of produced image, high of image has neglected that angle computed with respect to X axis only because the motor will rotate the loaded product only in horizontal axis.

See the following figure3.3 which represent image contain one person.
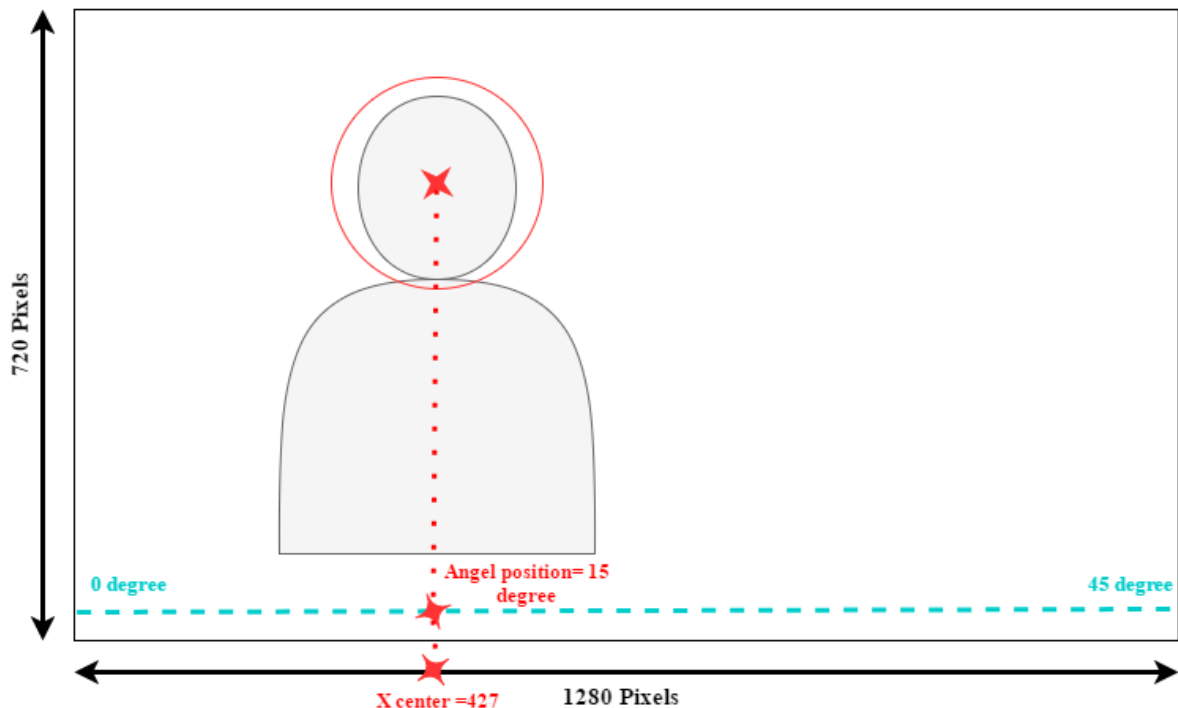
(Figure 3.3)

If the detected face's X center = 427 and Degree per Pixel= 45/1280

➔ ~0.0351

So Angel Position= 427×0.0351 ➔ ~ 15 degrees

After all of the above move to "Do all subsequent steps" which is out of computer vision scope and exist in another code files. This steps include codes for moving motor and playing sound.

b. OpenCV

Abbreviation of Open Source Computer Vision, is a software library of mainly aimed to real time computer vision and machine learning.

Originally developed by Intel, the library is cross-platform and free for use. The library has more than 2500 optimized algorithms and built in function, wherefore OpenCV has chosen to manage the main part of project which is Computer Vision. It has C++, C, Java, Python and MATLAB interfaces. OpenCV is written natively in C++ and has a templated interface that works seamlessly with STL containers, for that reason HELLO PRODUCT has adopted OpenCV C++.

Here are some functions and variables has been used in HELLO PRODUCT respectively:

- mat: matrix variable can handle Image.
- CascadeClassifier: class to detect objects in a video stream, conjunction with load function that load .XML files as classifier.
- VideoCapture: Class for video capturing from camera.
- cvtColor: function converts an image from one color space to another.
- equalizeHist: function that equalizes the histogram of a grayscale images.
- detectMultiScale: function works jointly with CascadeClassifier to implement the loaded XML files.
- flip: function used to flip image.
- Imshow: function that view some image on display, used to see the resulted images after processing.

a. Haar Cascade

There are many different algorithms exist to perform face detection, each of them has its own weaknesses and strengths but most of these algorithms suffer from the same problem; they are computationally expensive.

The image is only a collection of color and light intensity values. Analyzing these pixels for face detection is time consuming and difficult to accomplish because of the wide variations of shape in the human face.

So, approaches based on machine-learning have the advantages of being computationally more efficient in object detecting including face detection and one of them is **HAAR CASCADE CLASSIFIER**. The core basis for Haar classifier object detection is the Haar-like features, developed by **Viola and Jones on the basis of the proposal by Papageorgiou ET. Al in 1998**... These features, rather than using the intensity values of a pixel, use the change in contrast values between adjacent rectangular groups of pixels.

Initially, the algorithm needs a lot of positive images (images of faces) and negative images (images without faces) to train the classifier. Then we need to extract features from it. For this, Haar features shown in **figure 3.4** below are used. They are just like our convolutional kernel. Each feature is a single value obtained by subtracting sum of pixels under white rectangle from sum of pixels under black rectangle. Haar features can easily be scaled by increasing or decreasing the size of the pixel group being examined. This allows features to be used to detect objects of various sizes.
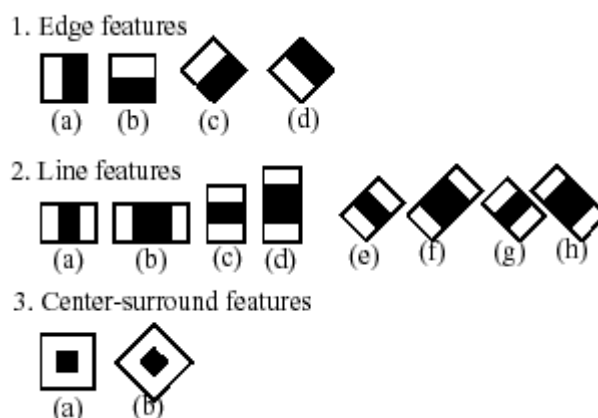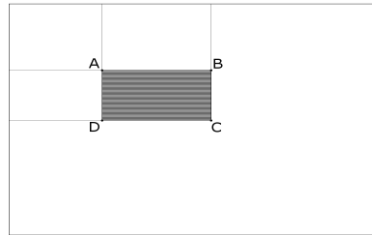
(Figure 3.4)

The algorithm uses an **integral image** in order to process Haar features of a face candidate in constant time.

The **integral image** is an array containing the sums of the pixels' intensity values located directly to the left of a pixel and directly above the pixel at location (x, y) inclusive, as shown in **equation 1** and illustrated in **Figure 3.5**

$$\text{Sum} = I(C) + I(A) - I(B) - L(D) \qquad (1)$$

(Figure 3.5)

But among all these features we calculated, most of them are irrelevant. For example, consider the image below. Top row shows two good features. The first feature selected seems to focus on the property that the region of the eyes is often darker than the region of the nose and cheeks. The second feature selected relies on the property that the eyes are darker than the bridge of the nose. But the same windows applying on cheeks or any other place is irrelevant. So how do we select the best features out of 160000+ features? It is achieved by **Adaboost.**
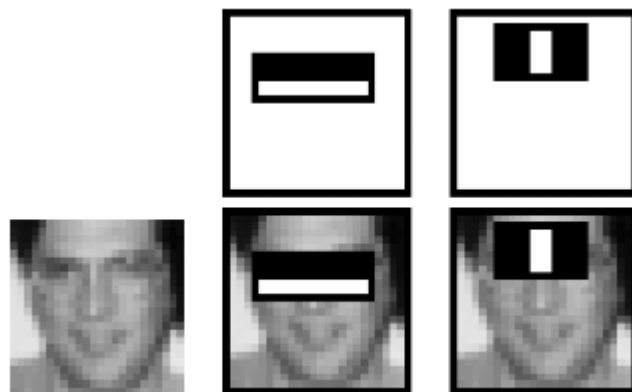
(Figure 3.6)

Adaboost is a machine learning algorithm which help s in finding only the best features among all these 16000+ features. After these features are found a weighted combination of all these features used in evaluating and deciding any given window has a face or not. Each of the selected features are considered okay to be included if they can at least perform better than random guessing (detects more than half the cases).

These features are also called as weak classifiers. Adabost constructs a strong classifier as linear combination of these weak classifiers.

$$F(x) = \alpha1f1(x) + \alpha2f2(x) + \alpha2f3(x) + \cdots$$

Strong classifier   **Weak classifier**

Final classifier is a weighted sum of these weak classifiers. It is called weak because it alone can't classify the image, but together with others forms a strong classifier, even 200 features provide detection with 95% accuracy. Their final setup had around 6000 features, from 160000+ features to 6000 features that is a big gain.

In an image, most of the image region is non-face region. So, it is a better idea to have a simple method to check if a window is not a face region. If it is not, discard it in a single shot, don't process it again. Instead focus on region where there can be a face. This way, we can find more time to check a possible face region.

For this they introduced the concept of **Cascade of Classifiers**. Instead of applying all the 6000 features on a window, group the features into different stages of classifiers and apply one-by-one. (Normally first few stages will contain very less number of features).

The system detects objects in question by moving a window over the image. Each stage of the classifier labels the specific region defined by the current location of the window as either positive or negative – positive meaning that an object was found or negative means that the specified object was not found in the image. If the labelling yields a negative result, then the classification of

this specific region is hereby complete and the location of the window is moved to the next location.

If the labelling gives a positive result, then the region moves of to the next stage of classification. The classifier yields a final verdict of positive, when all the stages, including the last one, yield a result, saying that the object is found in the image.
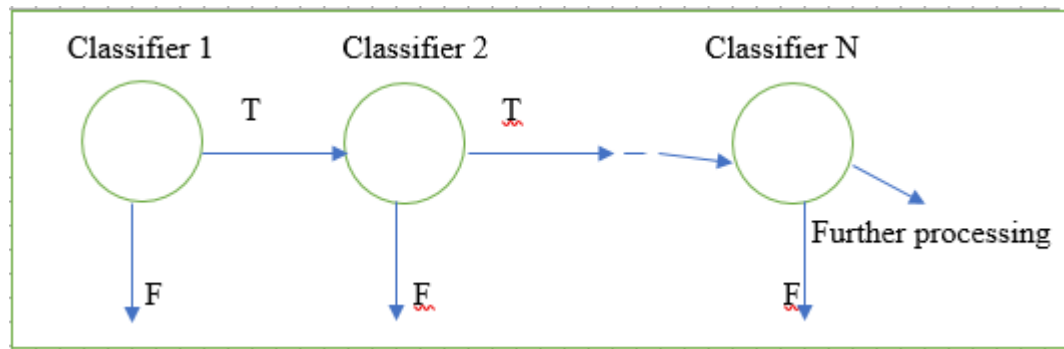
(Figure 3.7)

Cascaded of stages. Must pass all the stages to detect Face.

3.1.3 <u>Additional related consideration</u>

a. Camera types (suggested to be used in Hello Product):

There is too many different type of cameras but few of it can be used in our project, that each of it has its cons and pros

1. <u>IP Camera</u> (Not adopted):

The main purpose of using this cameras is for surveillance and for security goals.

IP is abbreviation of Internet Protocol that it send and receive data via Internet by device called DVR(digital video recorder) attached with using Ethernet cable(CAT5 UTP), which make it difficult to use in our project, in addition it require voltage power larger than provided by all USB ports.

Advantages	Disadvantages
Acceptable price	Difficult to configure without DVR
Large field of view	Need external power supply (12V

	Adapter)
Built in software features(face detection, Motion tracking…etc.	Its size mostly large
Provide night vision	RJ-45 jack rather than USB
Almost provide high resolution	Produce barrel image if it has fish-eye lens

2. <u>Camera on Chip</u> (Not adopted):

Similar to internal cameras associated with any chip bored like mobile camera, laptop camera and raspberry pi camera that we focus on.

Advantages	Disadvantages
Low price	Attached to board socket
Acceptable field of view	Raspberry can't handle more than one camera
Easy to configure with raspberry pi	Does not have cover case
Light driver	

3. <u>Web Cams</u> (Adopted):

Usually used in personal video calls

| Advantages	Disadvantages
Easy to configure	Usually provide narrow field of view
Has USB plug	High price for accepted resolution ones
Small size and light weight	Sometimes consume voltage more than provided by the Raspberry
Raspberry can handle until four camera(because has 4 USB ports)	Heavy driver may slow down the Raspberry especially when using more than one

Adopted because most of disadvantages can be resolved completely or partially and the urgent need of using more than one camera to extend field of view as possible.

b. Failed of view

It is the visual field that camera can cover, it measured by degree
There is three field of view of image plane produced by the camera

- Diagonal FOV
- Vertical FOV
- Horizontal FOV (which HELLO PRODUCT interested in)
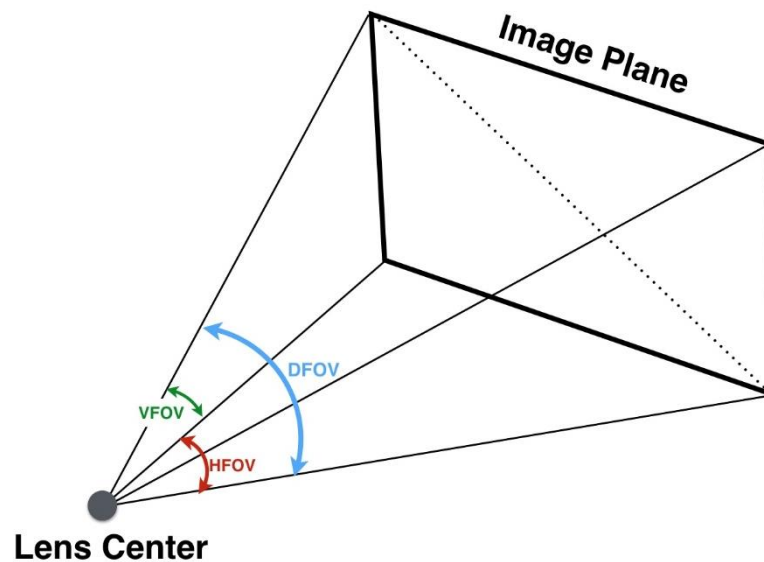
(Figure 3.8)

 FOV is so important to this project that determine how many degree can motor spin loaded product, because it can't move to those who doesn't included in the camera image plan, for this reason as well as the use of webcams that have narrow FOV, HELLO PRODUCT has attached with two webcams (Microsoft HD-3000) each of them has nearly 60 degrees FOV, that mean both of them cover 120 degrees, still narrow wherefore it has extended by replacing its original glass lens cover with external lenses which used alongside frontal camera of mobile phones to get wider selfie photos. See the figure 3.9 of the lens.

(Figure 3.9)

It extend the FOV nearly (36 ~ 40) % to become nearly (80 ~ 84) degrees of each one, both 2× (80 ~ 84) = (160 ~ 168) degrees

The resulted image are not barrel one but it is a bit blurry, in which it doesn't affect the algorithm of detection.

There is a method was invented to calculate the FOV because usually it doesn't specified by the manufacturers, that take photo to some known dimensions plan (e.g. paper) from defined distance, note that the photo must include only the plan without any excrescences, then draw lines that represent the plan and distance between it and camera, as follow figure 3.10 with some number for simplicity:

(Figure 3.10)
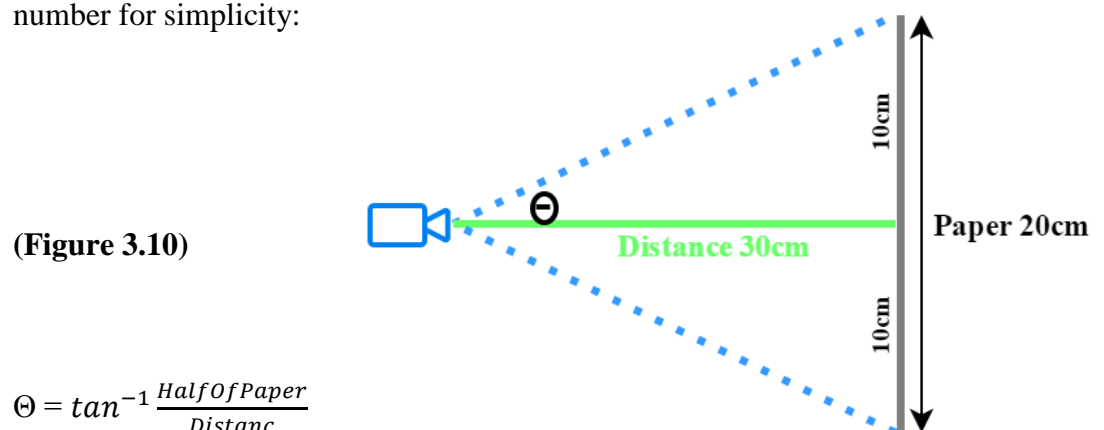
$$\Theta = tan^{-1} \frac{Half\,Of\,Paper}{Distanc}$$

➔ $= tan^{-1} \frac{10}{30}$ ➔ ~ 18.43

FOV = 2×θ ➔ = 2×18.43

➔ FOV ~ 36.9 degrees

3.2 Embedded System:

3.2.1 <u>What is been used?</u>

It is embedded system project contains computer vision points.

An embedded system is a dedicated computer system designed for one or two specific functions. This system is embedded as a part of a complete device system that includes hardware, such as electrical and mechanical components. The embedded system is unlike the general-purpose computer, which is engineered to manage a wide range of processing tasks.

Required components to build Hello Product:

- Microcontroller (i.e. Arduino Uno (optional))
- Microcomputer (i.e. Raspberry Pi 3 Model B)
- Motor driver (i.e. Tb6560)
- Camera(s) (i.e. Webcams)
- Motor (i.e. Stepper motor Nema 23 (9 kg/cm 4 leads))
- Power Supply
- Representative tool (i.e. Speakers)

In details, Appendix 1 talks about microcontroller Microcomputer Raspberry Pi. Appendix 2 talks about motor driver Tb6560 and stepper motor Nema 23.

<u>How did components play together?</u>

From power source to microcomputer and power supply. Power supply to motor driver, from motor driver to motor. From microcomputer to microcontroller (if exist). From microcomputer to representative tool and cameras.

Microcontroller gets the power from microcomputer, sends the control signals to motor driver. Microcomputer feeds microcontroller with power and control signals via serial communication. Microcontroller has code responsible for moving product. Microcomputer contains Python scripts and C++ files.

Software Snapshots to see example for Python scripts and C++ files can be used to build Hello Product.

3.2.2 <u>Major components in details:</u>

- **Motor:** Responsible for the motion of the product to introduce himself to interested people. Can be stepper or servo motor. The type of motor depends on: the size and weight of product, cost of Hello Product totally. To know what is best for specific product read the following comparison between servo and stepper.

Stepper Motor
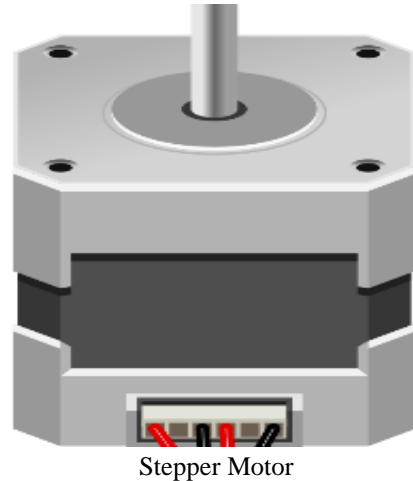
Characteristics	Servo	Stepper
Cost	The cost for a servo motor and servo motor system is higher than that of a stepper motor system with equal power rating.	This feature would have to go to stepper motors. Steppers are generally cheaper than servo motors that have the same power rating.
Efficiency	Servo motors are very efficient. Yielding 80-90% efficiency given light loads.	Stepper motors consume a lot of power given their output, much of which is converted to heat. Stepper motors are usually about 70% efficient but this has some to do with the stepper driver.
Flexibility in motor resolution	Since the encoder on a servo motor determines the motor resolution servos have a wide range of	Stepper motors usually have 1.8 or 0.9-degree resolution. However, thanks to micro-stepping steppers can obtain higher resolutions. This is

	resolutions available.	up to the driver and not the motor.
Noise	Servo motors produce very little noise.	Stepper motors produce a slight hum due to the control process. However, a high-quality driver will decrease the noise level.
Power Range	Because servo motors are available in DC and AC servo motors have a very wide power availability range.	The power availability range for stepper motors is not that of servo motors.
Direct Drive Capability	Servo motors usually require more gearing ratios due to their high RPM. It is very rare to see a direct drive servo motor setup.	Stepper motors will work fine in direct drive mode. Many people simple use a motor couple and attach the motor shaft directly to the leadscrew or ballscrew.
Motor Simplicity	Servo motors are more mechanically complex due to their internal parts and the external encoders.	Stepper motors are very simple in design with no designed consumable parts.
Versatility	Servo motors are very versatile in their use for automation and CNC applications.	Stepper motors are also very versatile in their use for automation and CNC applications. Because of their simplicity stepper motors may be found on anything from printers to clocks.
Reliability	This is a toss-up because it depends on the environment and how well the motor is protected.	The stepper takes this category only because it does not require an encoder which may fail.

Frame Sizes	Servo motors are available in a wide variety of frame sizes, from small to large motors capable of running huge machines. Many of the motors come in NEMA standard sized.	Stepper motors do not have as many size selections as servo motors in the large sizes. However, stepper motors may still be found in a variety of NEMA frame sizes.
Setup Complexity	Servo motors require tuning of the (PID) closed loop variable circuit to obtain correct motor function.	Stepper motors are almost plug-and-play. They require only the motor wires to be wired to the stepper motor driver.
Repeatability	Servo motors can have very good repeatability if setup correctly. The encoder quality can also play into repeatability.	Because of the way stepper motors are constructed and operate they have very good repeatability with little or no tuning required.

- **Motor Driver:**

A motor driver IC is an integrated circuit chip which is usually used to control motors in autonomous robots. Motor driver ICs act as an interface between microprocessors in robots and the motors in the robot.
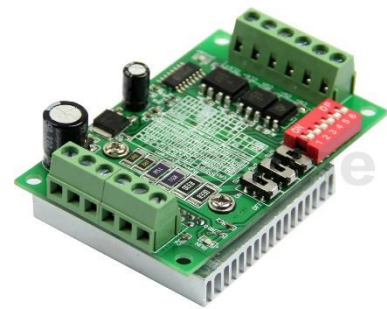
Why we need Motor Driver IC?

Most microprocessors operate at low voltages and require a small amount of current to operate while the motors require a relatively higher voltage and current. Thus, current cannot be supplied to the motors from the microprocessor. This is the primary need for the motor driver IC.

How Motor Driver operates?

Receives signals from the microprocessor and transmits the relative signal to the motors. Switching output signal according to the input received from the microprocessor.

For Example: If the microprocessor sends a 1(digital high) to the Input Pin of L293D, then the L293D transmits a 1(digital high) to the motor from its Output Pin. An important thing to note is that the L293D simply transmits the signal it receives. It does not change the signal in any case.

Note if stepper motor is the chosen, most of L298N support max current 2 amp and most steppers needs min current 3 amp. Tb6560 is recommended for steppers, it supports 3 amps.

- **Power supply:**

Is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another. As a result, power supplies are sometimes referred to as electric power converters.

Why we need power supply?

The primary need for the power supply is providing the required power to motor driver from the main power source.

- **Microcomputer**

A microcomputer is a complete computer on a smaller scale and is generally a synonym for the more common term, personal computer or PC, a computer designed for an individual. A microcomputer contains a microprocessor (a central processing unit on a microchip), memory in the form of read-only memory and random-access memory, I/O ports and a bus or system of interconnecting wires, housed in a unit that is usually called a motherboard.
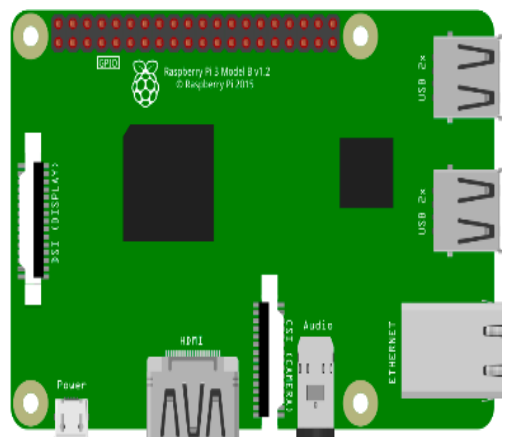
Why we need microcomputer?

Hello Product needs RAM to load frames from cameras till finish the required processes (need powerful CPU) on the frames and absorb information, I/O ports for attaching cameras or introducing tool such as speakers.
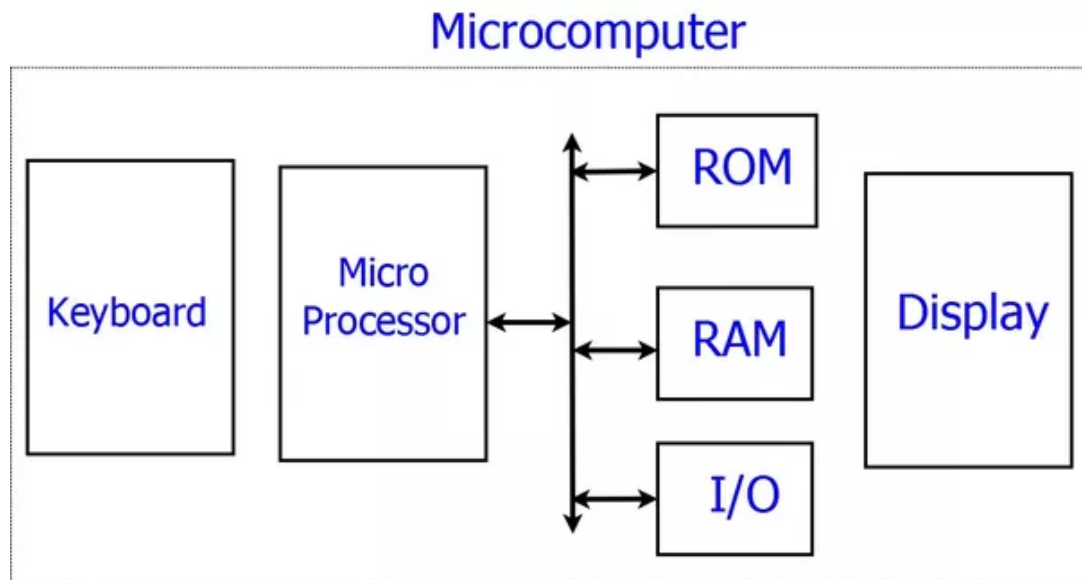
(Figure 3.11)

- **Microcontroller**

is a small and low-cost computer built for the purpose of dealing with specific tasks, such as displaying information in a microwave LED or receiving information from a television's remote control. Microcontrollers are mainly used in products that require a degree of control to be exerted by the user.
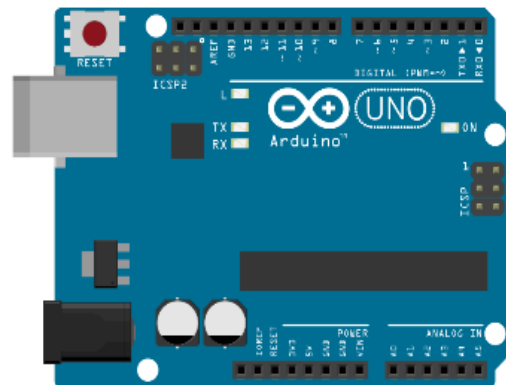
Why we need microcomputer?

Hello Product needs microcontroller to control the motion of product specifically if the load is high, so for safety concept "Don't attach motors directly to microcomputers", use microcontroller. Also for decrease processing load from the microcomputer, making microcomputer specified for computer vision tasks only.
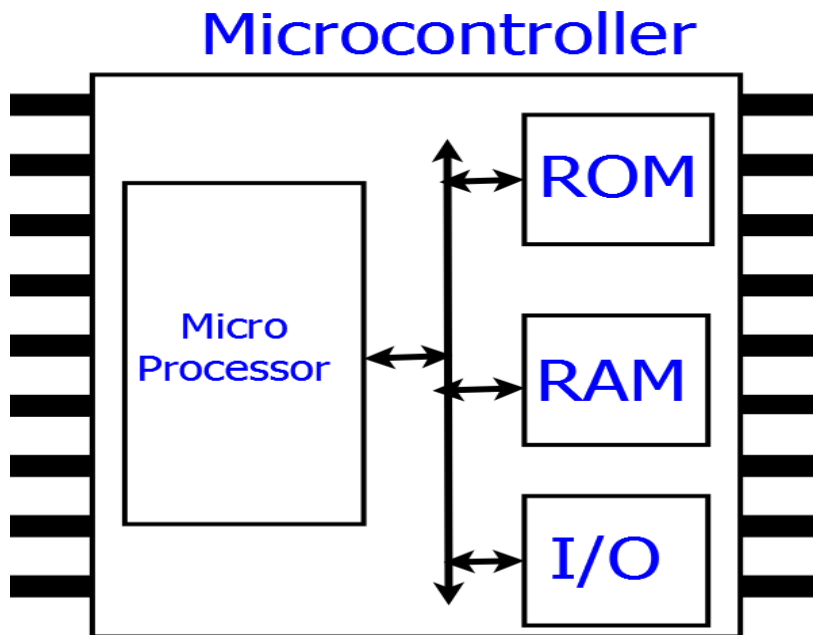
(Figure 3.12)

3.2.3 Components could not be used in this project:

- Only microcontroller and save cost of microcomputer:

This project requires powerful processor because it depends on a lot of image processing and computer vision so no chance for depending on microcontroller's CPU. The vice versa (use only microcomputer) can be achieved in case of use very safe circuits in connections between motor and microcomputer.

This project requires storage and main memory for buffering captured frames by cameras.

Hello Product could be built in the most inexpensive, hard way if the creator built the custom microcomputer (something like raspberry pi but without the additional features like Ethernet cable) also building custom cameras for the specific field of view will save much power, memory and processing. The other components depend on the product e.g. there is no way to use small servo motor to hold car.

- Step-up volt circuits instead of power supply and save space to make better case:

Motor needs 3 amp, 12 voltages. If step-up volt circuits are used with input 5 volt coming from raspberry pi trying to get the required voltage (12 v) it will reduce the current as the following law: $P = IV$ P: power, I: current, V: voltage.

And the current from pi is already small so it will damage the pi because it will hurt the ROM not causing breaking SD card, so take care. and the motor will not power because the minimum requirements not achieved. Sometimes this circuits is better to achieve better design and save the space when using power supply but technically isn't good way.

3.2.4 <u>Components could be used in this project:</u>

- <u>The Compute Module IO Board V3:</u>

This chip is very costly if you haven't problems with cost , it's recommended .

The Compute Module IO Board V3 is a development kit for those who wish to make use of the Raspberry Pi in a more flexible form factor, intended for industrial applications. The IO Board V3 is made for developing with CM3, CM3L, and CM1.

*The Compute Module contains the guts of a Raspberry Pi 3 (the BCM2837 processor and 1GB RAM). The accompanying IO Board is a simple, **open-source** breakout board that you can plug a Compute Module into. The board hosts 120 GPIO pins, an HDMI port, a USB port, **two camera ports**, and two display ports. Designing the Module into a custom system should be relatively straightforward as we've put all the tricky bits onto the Module itself, and you have the freedom to add extra components and place parts exactly where your product needs them.*

The CM1, CM3, and CM3L are available for purchase in single units, or in batches of hundreds or thousands. Since field of view RPI camera is about 45 degrees, the total field of view if using the above monster and two RPI cameras will be 90 degrees without any lenses.
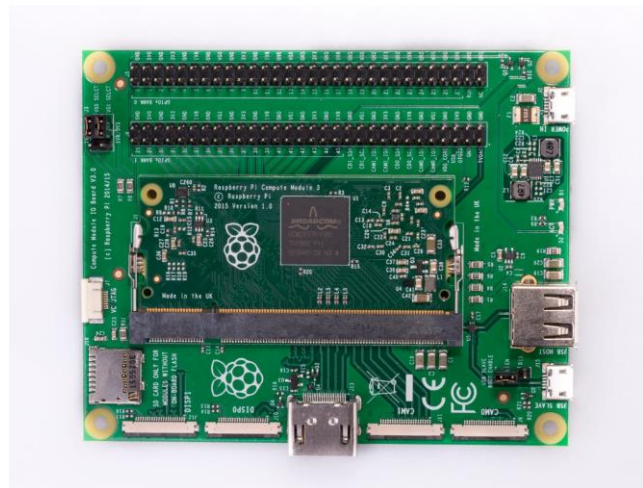
- Servo Motor:

This motor weight is small if you haven't problems with loads, it's recommended.
Servo motor has special function, it knows where the 0 degree, 45 degrees...is etc.
 So you won't calculate the position and have to manually change direction of the motor. But you will have to deal with load as described below:

It will be 10kg if you put load 1cm from your servo axis.
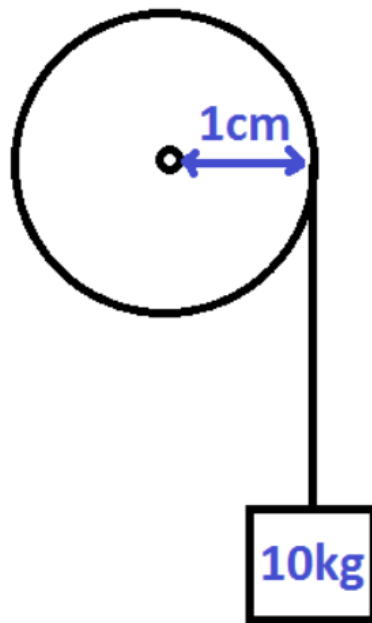
If you put it at 10cm from axis - it will be able to pull 10 times less (1kg). You can use Law of lever to calculate this.
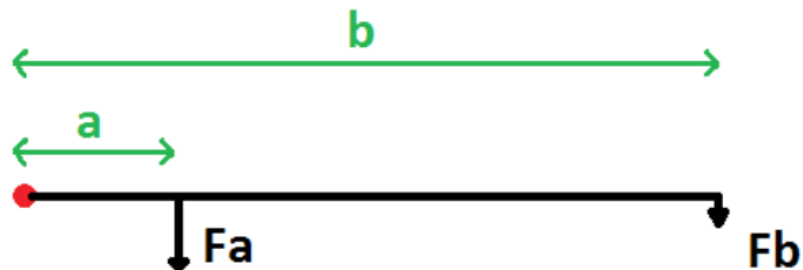
(Figure 3.13)

Fb/Fa = a/b

3.2.5 <u>Tips:</u>

- Be careful when wiring the on/off button to microcomputer.
- Prefer using microcontroller and don't attach motors directly to microcomputer.
- Use motor driver can support the required current for motor, e.g., don't use L298N motor driver to run stepper motor Nema 23 as the max support of the referred motor driver is 2 amps and Nema 23 requires 3 amps so it can cause damage of your entire circuit. Can use Tb6560 for stepper motor Nema 23.
- Put reasonable wait time between catching frames from cameras to decrease the processing load from microcomputer. Also, don't make it long time, to be able to catch people and not to be slow system.

3.3 Project Body Design:

To design the project body two important term should be clear first.

The first one is **Centre of gravity**, in physics, an imaginary point in a body where the total weight of the body may be thought to be concentrated. The concept is sometimes useful in designing static structures (e.g., buildings and \bridges).

In a uniform gravitational field, the center of gravity is identical to the center of mass, A term preferred by physicists. The location of a body's center of gravity may coincide with the geometric center of the body, especially in a symmetrically shaped object composed of homogeneous material. An asymmetrical object composed of a variety of materials with different masses, however, is likely to have a center of gravity located at some distance from its geometric center.
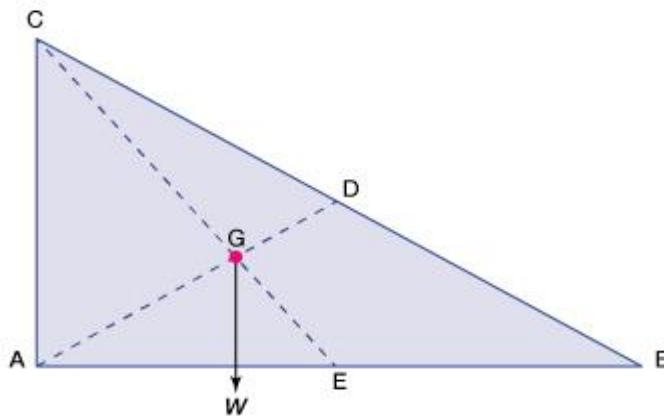
(Figure 3.14) Centre of gravity. The red dot is the center of gravity G.

The center of gravity of anybody can also be determined by a simple physical procedure. For example, for the plate in the figure, the point **G** can be located by suspending the plate by a cord attached at point A and then by a cord attached at **C**. When the plate is suspended from **A**, the line **AD** is vertical; when it is suspended from **C**, the line **CE** is vertical.

The center of gravity is at the intersection of **AD** and **CE**. When an object is suspended from any single point, its center of gravity lies directly beneath that point.

Another important term in object balance is the **Equilibrium Rule.** Equilibrium of

a body is defined as the state when all the forces and actions acting on the body nullify each other resulting in a stable, balanced and unchanging position. It is the stage when the body is either in a state of rest or moving with a constant velocity. Suppose the force acts on left side, the equal force would be acting on the right to balance it. Similar effect would be on up and down that balances each other's forces

Types of Equilibrium

There are mainly three types of equilibrium:

a. **Stable equilibrium** – when forces or disturbing moment is applied on a body such that on removal of that force or moment the body returns to its original position, it is called as Stable equilibrium. In such equilibrium, the center of gravity of the body lies below the point from which it is suspended or supported. For example, a table on the floor.

b. **Unstable equilibrium** – when forces or disturbing moment is applied on a body such that on removal of that force or moment the original position is never restored but rather continually moves to new positions is called unstable equilibrium. In such equilibrium, the center of gravity of the body lies above the point from which it is suspended or supported. For example, a pen standing on its point.

c. **Neutral equilibrium** - when forces or disturbing moment is applied on a body such that on removal of that force or moment the body doesn't retain its original position but attains a new position is called neutral equilibrium.
In such equilibrium, the center of gravity of the body coincides with the point of support or suspension. For example, a dice rolling on the game board.

The **equilibrium equation** can be written in the scalar form as:

∑FX=0, ∑FY=0

∑F = ∑FX + ∑FY

Sum of the force components in the x and y directions are both zero.

Force analysis using trigonometry function:
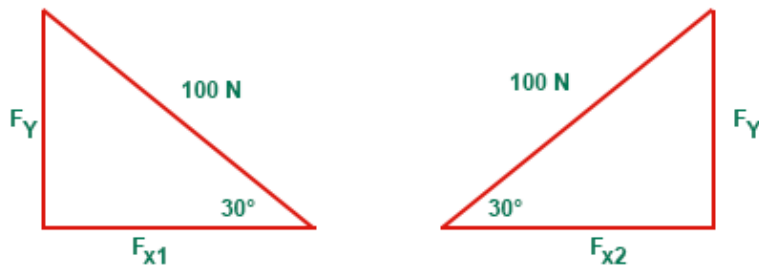
$F_Y = 100 Sin30$
$$= 100 \times \frac{1}{2}$$
$$= 50N$$

$F_{X1} = 100 Cos30$
$$= 100 \times \frac{\sqrt{3}}{2}$$
$$= 50\sqrt{3N}$$

$F_{X2} = 100 Cos30$
$$= 100 \times \frac{\sqrt{3}}{2}$$
$$= 50\sqrt{3N}$$

The leftward force **FX1** is balanced by the rightward force **FX2** and the upward force is balanced by the weight of the wall. Therefore, we can say that is static equilibrium the resultant force acting on the body is **zero** and all the forces or moment acting on the body balances each other.

Now with using these two conditions designing and the components distribution will be more easily according to its weights and center of mass to make the project body as a cube balanced on one of its corner.

The hardware components we have:

- **Stepper Motor:**

  Weight:670g , Dimension:45*45*65mm(L*W*H)

- **Power Supply:**

  Weight:800g , Dimension:220*120*50mm(L*W*H)

- **Motor Driver:**

  Weight:70g , Dimension:80*40*30mm(L*W*H)

- **Raspberry Pi 3:**

  Weight:60g , Dimension:130*70*30mm(L*W*H)

- **Arduino UNO:**

  Weight:40g , Dimension:100*40*20mm(L*W*H)

- **Microsoft HD Webcam:**

  Weight:40g X2, Dimension:40*30*20mm(L*W*H)

- **Speaker:**
- **Weight:90g, Dimension:50*50*65mm(L*W*H)**

The most Weighted components
are Stepper Motor and
Power Supply:
$670 + 800 = 1470g$.

So, to balance the cube motor should
be close to the cube center of mass
and the power supply in the back
And the angle between the ground
and the cube should be **50** degrees
from the back.
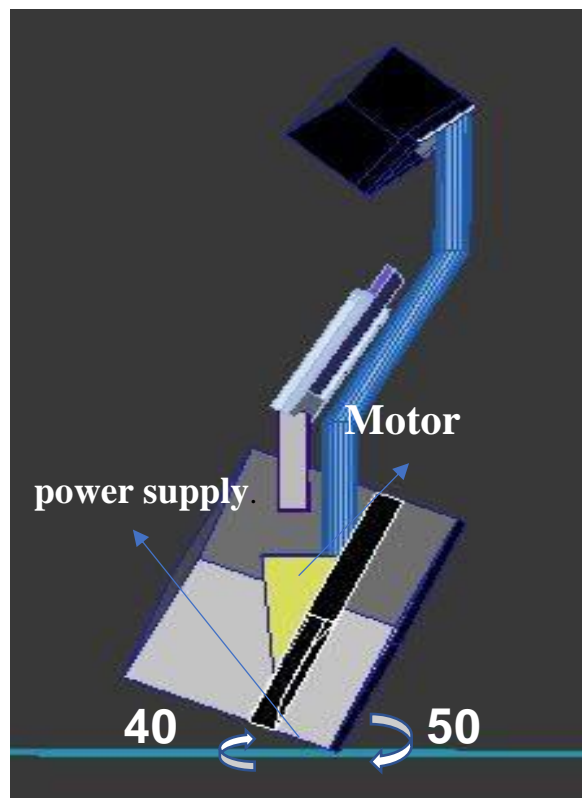
(Figure 3.15)
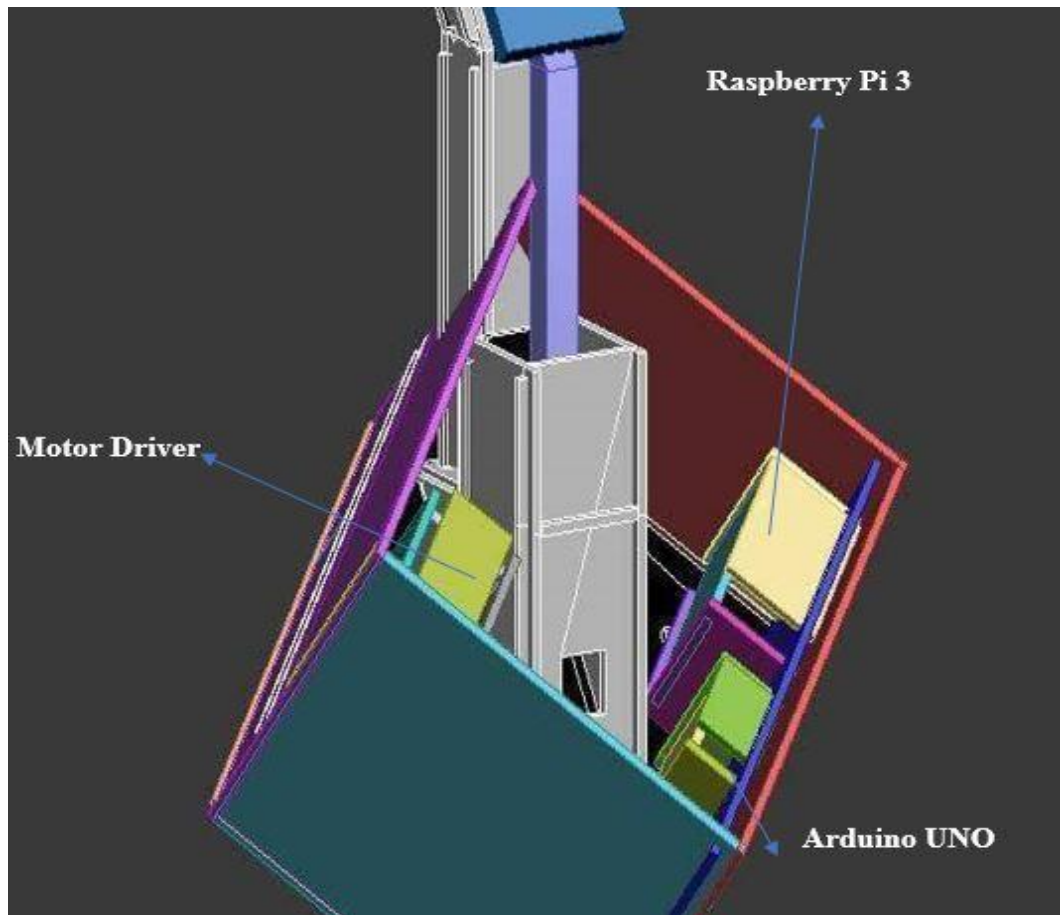
(Figure 3.16)

Figure 3.15 and **Figure 3.16** show the distribution for hardware in the bottom Cube (**250x250 mm**) and the angle between the ground and the cube.
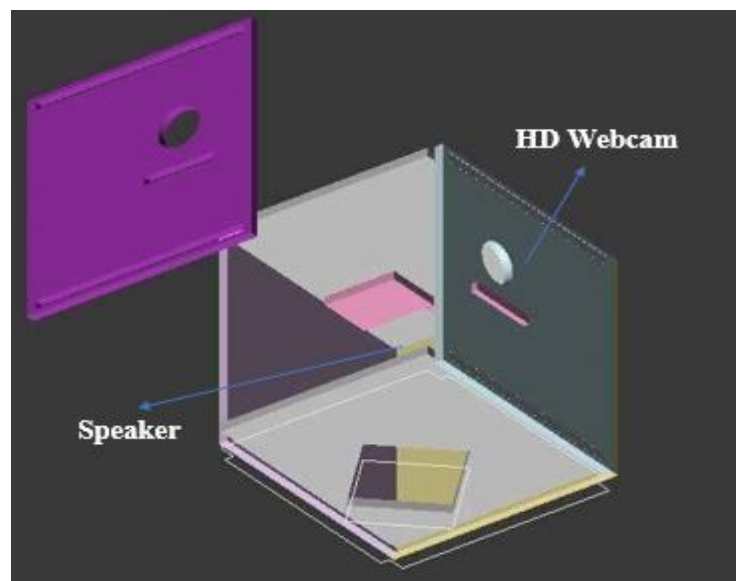
(Figure 3.17)

Figure 3.17 show the upper cube (130 x 130 mm) and hardware distribution in it.
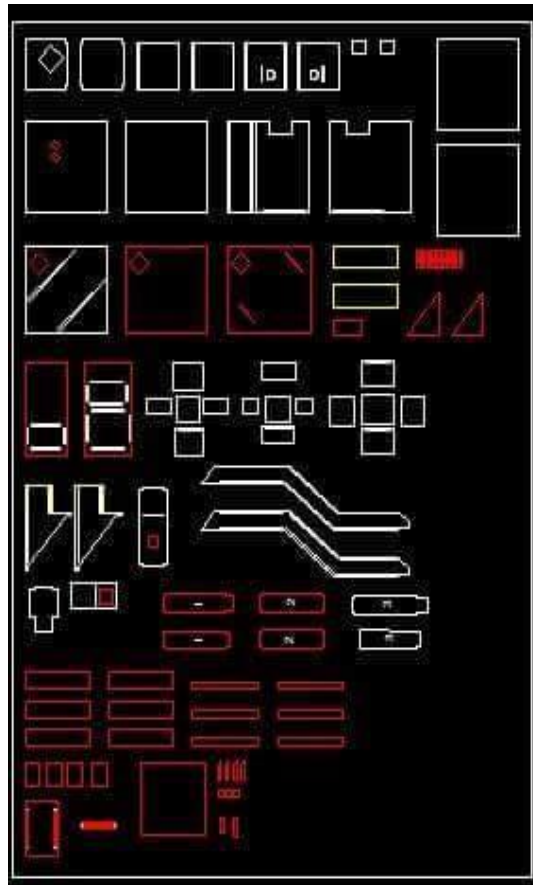
(Figure 3.18)
Figure 3.18 show all design component foe the bottom cube and for the upper cube.

3.4 Software Design:

Recommended Design Patterns:

Chain of Responsibility Pattern is the recommended design pattern to make all software parts able to communicate with each other's. As the name suggests, the chain of responsibility pattern creates a chain of receiver objects for a request. This pattern decouples sender and receiver of a request based on type of request. This pattern comes under behavioral patterns.

Singleton pattern is one of the simplest design patterns in Java. This type of design pattern comes under creational pattern as this pattern provides one of the best ways to create an object. This pattern involves a single class which is responsible to create an object while making sure that only single object gets created. This class provides a way to access its only object which can be accessed directly without need to instantiate the object of the class.
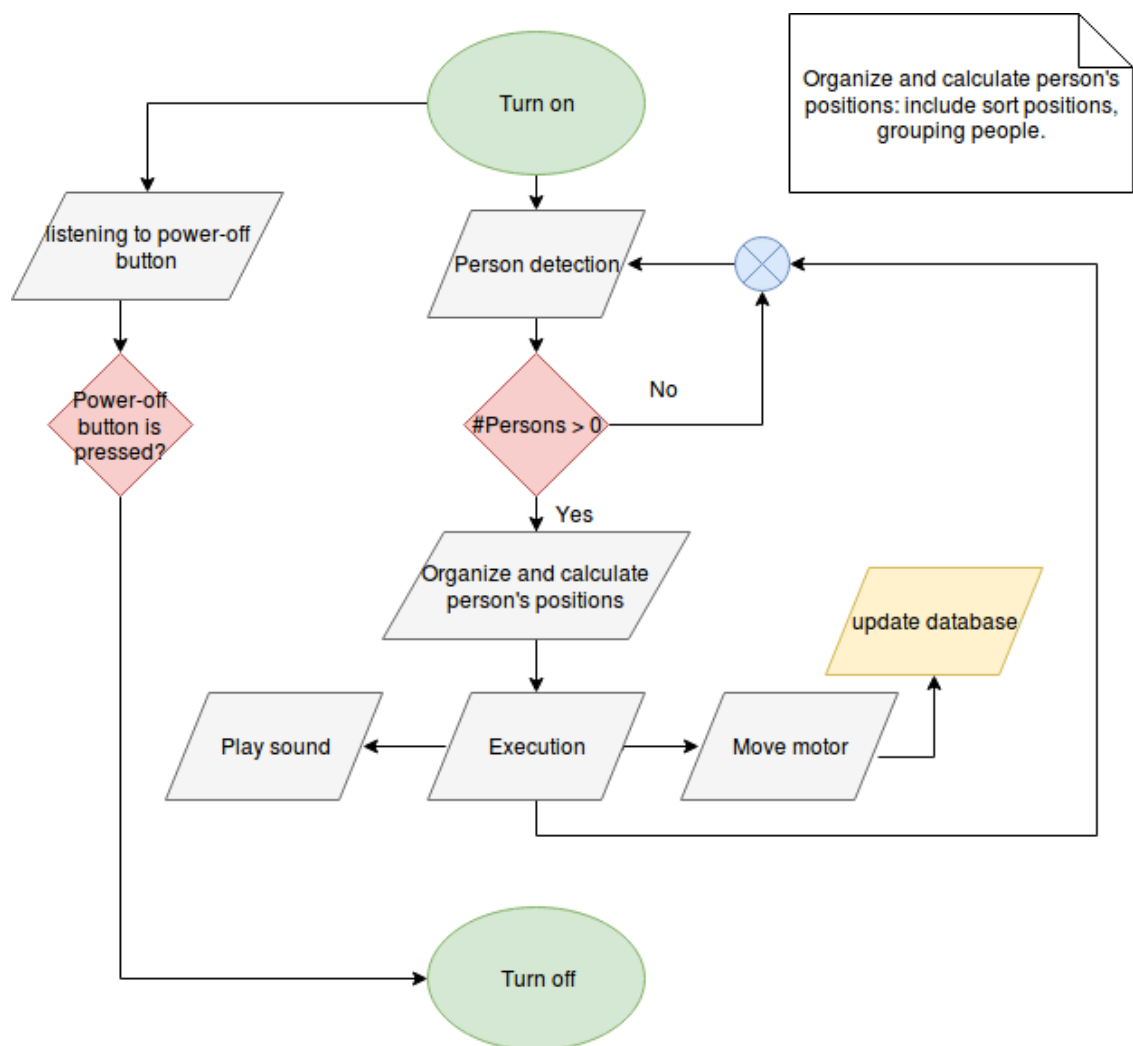
(Figure 3.19)

Flowchart:

Person detection is infinite loop. Person detection output is major reason for system to do some primary tasks. Once persons are exist, Hello Product works on identifying the positions and make groups of people who stands together, then sort them to be ready for execution function which calls two function in parallel (play sound, move motor). After each motor movement, Hello Product saves the current position of the product on storage to be available if system crashed or restarted.

Hello Product keeps listening to Power-off button as if it is pressed, orders to shutdown will be given.

How can achieve much efficient code?

- Train model to extract feature for detection of left profile face instead of flipping the frame to be able to detect as the available Haar cascade profile face only support the right profile.
- Build safety circuit for attaching motor directly to raspberry pi. For building safety circuit, relays, opto isolator or 4066 microchip.
- Reduce the frame size by determining the excited areas (areas usually contain faces) in frame. It can be achieved for reduce the pyramid (type of multi-scale signal representation).
- Once motor attached to raspberry pi, it can reduce the number of used technologies such as Arduino programming language, python scripts by replace all of them into C++.
- Use only one camera is always the best solution to avoid wasting areas, binding frames and a lot of required codes related to image processing.
- Use raspberry compute model for much powerful processing, two ports specially built for cameras (able to use raspberry pi camera).

Chapter Four
Snapshots

4.1 Software snapshots:
4.1.1 Raspberry PI Power-off:
The following is python script, used to power off raspberry pi (microcomputer).

1. GPIO.setup(17, GPIO.IN,pull_up_down=GPIO.PUD_UP)
because of read input attached to wire of feeding ,
GPIO.PUD_UP (pull up) mode is chosen.
2. while True:
3.   state = GPIO.input(17)
4.   if state == False:
so once button pressed next will be executed.
5.   os.system("sudo shutdown -h now")
"-h now" meaning "halt now" , used to force power off and avoid any scheduling might be happened.
6.   prev_state = state
7. time.sleep(0.10)
just small delay to let the raspberry pi has the chance to response.
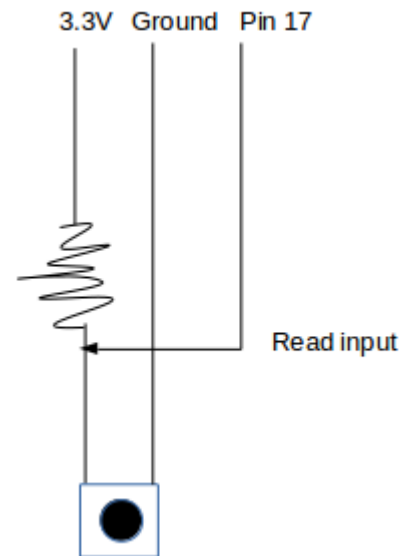
This code is used to read input from button. This button works as off only.

Figure 4.1

4.1.2 Play Audio Advertise:
The following python script to output voice message from raspberry pi via 3.5 jack.
1. os.system('omxplayer -o local /home/pi/Documents/REPO/GP/huawei.mp3')
omxplayer is installed program on raspberry pi, able to play .mp3 / .wav files with different modes too . The chosen mode – local – as need to play the audio files by speakers attached to the raspberry pi via 3.5 jack. As shown in the above code, played audio advertise is loaded into raspberry pi storage and its paths fed to the code in static way.

Omxplayer has three modes:
- *local: analog output (3.5 jack)*
- *hdmi: hdmi output*
- *both: both outputs*

4.1.3 From Pi to Arduino:

Transfer angle to Arduino & check if the product is arrived to the desired position.

1. ser=serial.Serial("/dev/ttyUSB0",9600)

because pi is connected to arduino via serial communication and 9600 serial is chosen for sharing the information between pi and arduino.

2. while not connected:

3.   serin = ser.read()

4.   connected =True

every time the connection is closed after sharing information so the above loop to assure that the connection is open and available to exchange operation.

5. desiredPosition=""+ sys.argv[1]

this script code is slave for the master code which booted at first as startup application. Master code make a system call to run this script and send the desired position as a parameter.

6. ser.write(desiredPosition)

sending the desired via serial communication.

7. time.sleep(5)

just small delay to let the raspberry pi has the chance to response.

8. while not arrived:

9.   serin = ser.read()

10.   if serin == "$":

11.   file = open("/home/pi/Documents/REPO/GP/reached","w")

12.   file.write("1")

13.   file.close()

14.   arrived =True

The above loop assure that the product is arrived to the desired position. After master code sent the desired position, it would keep reading reached file and once it found the written one by this script in line 12, it continues its work. After the product arrived, the running code on Arduino would send "$" via serial communication to assure that the product is arrived.

15. ser.close

closing the serial communication.

4.1.4 Arduino Code:

The following Arduino code is responsible for moving motor and assure that to raspberry pi.

```
1. int stp =8,dir=9;
```
the two lead wires which is connected to motor driver, the other two leads is connected to the ground.

For more information about motors and leads wires, see appendix 2.

```
2. void setup(){
3.   ..
4.   Serial.begin(9600);
5.   Serial.write("1");}
```
open serial communication and send message to raspberry
```
6. void run(int angle){
7.   double steps =(double) angle /1.8;
8.   double a=0;
9.   while(a<steps){
10.    a=a+1.8;
11.    digitalWrite(stp, HIGH);
12.    delay(20);
13.    digitalWrite(stp, LOW);
14.    delay(20);
15.   }
16. }
```
The major function of this code. The above function translate the angle into steps as the applied case of this project uses stepper motor. If servo motor was used, there is no need for this function. Dividing the desired position on 1.8 because the used motor speed is 1.8 angle per step. Delay (20) to choose reasonable speed for the motor.
```
17. void changeDirection(){
18.   digitalWrite(dir, HIGH);
19. }
20. void changeDirection2(){
21.   digitalWrite(dir, LOW);}
```
The above two functions is needed to change the direction of motor instead of wasting time to complete his cycle and back to desired position which is in the opposite movement direction.

```
23. void loop()
24. {
25.   if(Serial.available() > 0)
26.   {
```

execute the following only if the serial communication is open .

```
27.    String str = Serial.readStringUntil('\n');
28.    int desiredPosition = str.toInt();
```

read the desired position which is sent by raspberry pi to Arduino code via serial.

```
29.    if(desiredPosition<0){
30.      changeDirection();
31.      val=val*-1;
32.      run(val);
33.      changeDirection2();
34.        Serial.write("$");
35.    }
36.    else{
37.      run(val);
38.        Serial.write("$");
39.    }
```

The above "if and else "do the following in order:

check where does the desired position which is in the opposite movement direction.
 So there is need to change direction or not, and it is determined by the desired position value if positive so no need to change the direction otherwise there is need.

Call the major function with the absorbed (the value after removing sign if exist) value from desired position as a parameter

assure that the product has reached the desired position by sending dollar sign delimiter "$" via serial, which returned by Python script from Arduino to C++ function in Raspberry, to assure that master code has notified that "the motor has just arrived".

This code is loaded into Arduino and is running all the time once it start up

4.1.5 Master Code:

The following C++ code is startup app and responsible for assigning tasks to other codes and functions, we will see some snapshots from master code with headlines refer to important parts inside master code.

Constant and global variables:

The following separated C++ lines are variables which are defined globally in master code.

1. static const int ORG_SOUNDFILE_LENGTH = 8*1000000; // in microseconds

the length of the sound message which is set in static way in micro computer storage.

2. static const int ANGLE_THRESHOL=10;

If the distance between two persons is less than or equal 10 degrees, Hello Product will treat them as a group.

3. int width=1280;

because of two cameras each width = 640 , so totally 1280.

4. double FOV=160,dpp=FOV/((double)width);

after calculation of Field-of-View , found = 160 ~ 168

5. Mat frame1,frame2;

to catch from two cameras

6. bool stopFaceDetection = false;

to stop or re-play face detection loop

7. std::vector<double> AnglesVector;

to store angles from face detection function

8. VideoCapture capture;

to open cameras and capture frames.

General notes:

Each part of code is wrapped by "try and catch" closing to avoid program crashing to avoid restarting of Hello Product to back to work.

Each major function is wrapped by thread turned on/off by condition variables works to make the program logic is correct.

Grouping:

Int ThresholdingGroupPeople(std::vector<double> &v , std::vector<double> &InCurrent);

Thresholding group of people function works on grouping persons who stand by each other's with small distance between them. It will be so silly if two persons came together and Hello Product treat them each one alone and introduce himself for each one alone, and it will make other people waits too. This is the first function called after face detection process.

This function do the following:

1.if there is someone stands in position (by tolerance way) in same position of product, this will be the first priority for product to introduce himself for, this priority not count in sortAngles function and executed first of all. Those people in the current position is stored in InCurrent vector which is passed by reference.

2. Repeat the first thing but for each group of interested people who stands together to make product can introduce himself in easy, not boring and fast way. And return the number of groups are exist.

Sort:

std::vector<double> SortAngles(std::vector<double> AnglesVector);

Second call for a primary function from main function after face detection process. This function sorts angles (Interested people positions) for execution function (ExeAngles), to be easy for product to move to every interested person. Sort to minimize the waited time which the interested person has to wait to see the product introducing himself. There are three cases this function faces:

1. All of the the persons in one direction: the farther and the nearest person to the current position of product are on direction. Product goes on one of the following options:

  1. Go to left only.
  2. Go to right only.

And pass by each person on his way. The choice is depending on where the persons are, according to the following situations:

  A. All people on left.
  B. All people on right.

If A then 1,
If B then 2.

Figure 4.2

2. Persons are exist in both directions and nearest person is chosen firstly: in this case, people are on both directions, product assumed there are ***n*** person(s) on each direction. Product compares between the nearest and the farther one in each direction, Product goes on one of the following options:

1. Go left then right.
2. Go right then left.

And pass by each person on his way.

The choice is depending on where the persons are, according to the following situations:

A. Nearest person is only one in the right direction.
B. Nearest person is only one in left direction.
C. The distance between **farther** person on the **right** direction and current position of the product is less than the distance between **farther** person on the **left** direction and current position of the product.
D. The distance between **farther** person on the **left** direction and current position of the product is less than the distance between **farther** person on the **right** direction and current position of the product.
E. The distance between **nearest** person on the **right** direction and current position of the product is less than the distance between nearest person on the left direction and current position of the product.
F. The distance between **nearest** person on the **left** direction and current position of the product is less than The distance between **nearest** person on the **right**

If A & C then 1
If B & D then 2
If C & E then 1
If D & F then 2
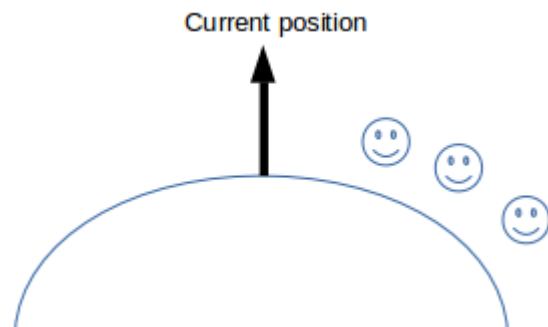

The product goes to empty faces then into solid.
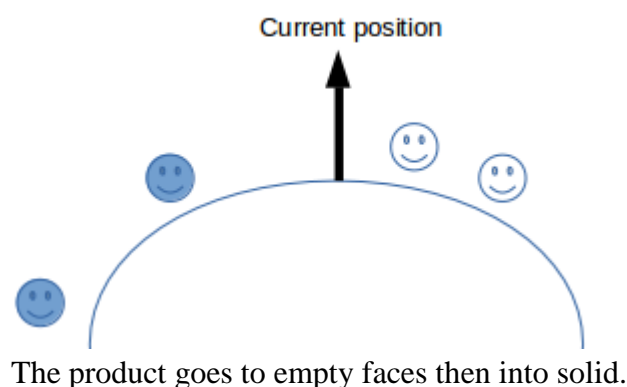
Figure 4.3

3. Persons are exist in both directions and nearest person is **not** chosen firstly: in this case, people are on both directions, product assumed there are **n** person(s) on each direction. Product compares between the nearest and the farther one in each direction, Product goes on one of the following options:

1. Go left then right.
2. Go right then left.

And pass by each person on his way.

The choice is depending on where the persons are, according to the following situations:

- A. Nearest person is only one in the right direction.
- B. Nearest person is only one in left direction.
- C. The distance between **farther** person on the **right** direction and current position of the product is less than the distance between **farther** person on the **left** direction and current position of the product.
- D. The distance between **farther** person on the **left** direction and current position of the product is less than the distance between **farther** person on the **right** direction and current position of the product.
- E. The distance between **nearest** person on the **right** direction and current position of the product is less than the distance between nearest person on the left direction and current position of the product.
- F. The distance between **nearest** person on the **left** direction and current position of the product is less than The distance between **nearest** person on the **right**

If C & F then 2
If D & E then 1
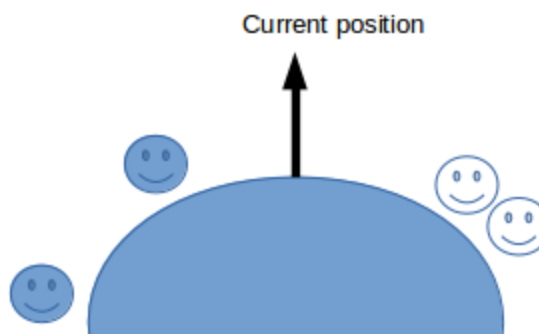
**Figure 4.4** the product goes to empty faces then into solid.

Execution:

void ExeAngles(std::vector<double> InCurrent , std::vector<double> others);

Second call for a primary function from main function. Calling MoveMotor and PlaySound from internal function which is called from here. First of all, Product introduces himself to whom in InCurrent group. The product introduce himself for each group only one time and turning his head to group members while introducing himself.

Others is sorted angles vector for positions product should be there to introduce himself. This function do the grouping process again (like ThresholdingGroupPeople), then call internal function (not major, serve only for this function) which called ExeAnglesForInternalGroup till Product finishes introducing himself for the all.

The following functions serve this function:
- ExeAnglesForInternalGroup: responsible for play the introducing message only one, moving the product to each member of the group while the introducing message is playing.
- MoveMotor: do system call with angle as a parameter for python script which responsible for sending this angle to arduino.
- PlaySound: do system call for python script which responsible for playing the introducing message.
- CheckNextTripIsExist: responsible for not wasting time in turning around for interested people don't interest anymore and gone while the introducing message was playing for someone else (other interested people) .

Face Detection:

The following functions are triggers in face detection process:

- Mat RunFaceDetection()

This function is responsible about opening cameras and getting good frames.

1. capture.set(CV_CAP_PROP_FRAME_WIDTH, 1280);
2. capture.set(CV_CAP_PROP_FRAME_HEIGHT, 720);

if camera opened , mode would be 1280*720 pixels. This will make the frame dimensions 16:9 instead of 3:4 of 640*480 pixel. To get bigger FOV.

3. capture.open(0);
4. capture.read(frame1);
5. capture.release();

Opening first attached camera, get frame and store it as a matrix inside frame variable (cv::Mat) and release the camera to save power and open the other camera and keep read frames.

6. int rows = max(frame1.rows, frame2.rows);
7. int cols = frame1.cols + frame2.cols;
8. Mat3b frame(rows, cols, Vec3b(0,0,0));
9. frame1.copyTo(frame(Rect(0, 0, frame1.cols, frame1.rows)));
10. frame2.copyTo(frame(Rect(frame1.cols, 0, frame2.cols, frame2.rows)));

To save processing time, cameras are set in positions to make frames after read operations ready to be bound instead of making stitching.

11. Size size(1280,720)
12. resize(frame,frame,size);

Also for save processing time, decrease the size of two frames to 50%.

- std::vector<double> DetectFacesInFrame(Mat frame)

This function is responsible for getting persons from frames.
It looks for frontal faces of persons first then profile faces (as the used haarcascade.xml for detection is only detect right faces it looks for profile left face in the flipped frames) and the last priority for the bodies which is detected.
The returned vector is vector of angles for the people's positions they are detected.

frontalFace_cascade.detectMultiScale(frame_gray, faces, 1.2, 3,0|CASCADE_SCALE_IMAGE, Size(30, 30));

Frame_gray is the gray frame which is read and should be used to detect faces
frontalFace_cascade is CascadeClassifier for detect frontal faces after loading haarcascade_frontalface_alt.xml into the classifier. In the same way profileFace_cascade and body_cascade are used too.
The following functions serve this function:

- double angle(double x,bool flipped): it returns the position angle after calculation using FOV , flipped or not. The x value is the position of the detected person in frame.

- int ConfigFaceDetection(void);

This function is used to load haarcascades into classifiers.if successfully loaded it returns 0, and -1 otherwise.

4.1.6 Dbrw:

Dbrw (Database - read – write) is class responsible for any required write or read operation on files stored in microcomputer. This class contains some static functions:

WriteAngle: save the current position on file on microcomputer storage. As the current position of product is needed if the entire program is restarted or the power is turned off.

ReadAngle: read the current position of the product.

ReadReached: this file contains only one value = 1 which is written by python script to assure that the product is reached to the desired position which is sent to, read by c++ code written inside this function (ReadReached).

ClearReached: clear file for not causing any conflicts with the written value by the python script.

4.2 Hello Product snapshots:
4.2.1 Hello Product -frontal view:
The following snapshot for Hello Product before painting.

Figure 4.5

4.2.1 Hello Product - Upper box:
This box contains speakers and cameras.

Figure 4.6

4.2.1 Hello Product - Bottom box:

That's how Hello Product balanced at one angle.

Figure 4.7

4.3 Testing snapshots:
4.3.1 Face detection testing:

1. Comment: difficulty of person who bowed his head.

Figure 4.8

2. Comment: good drawn faces are detected.
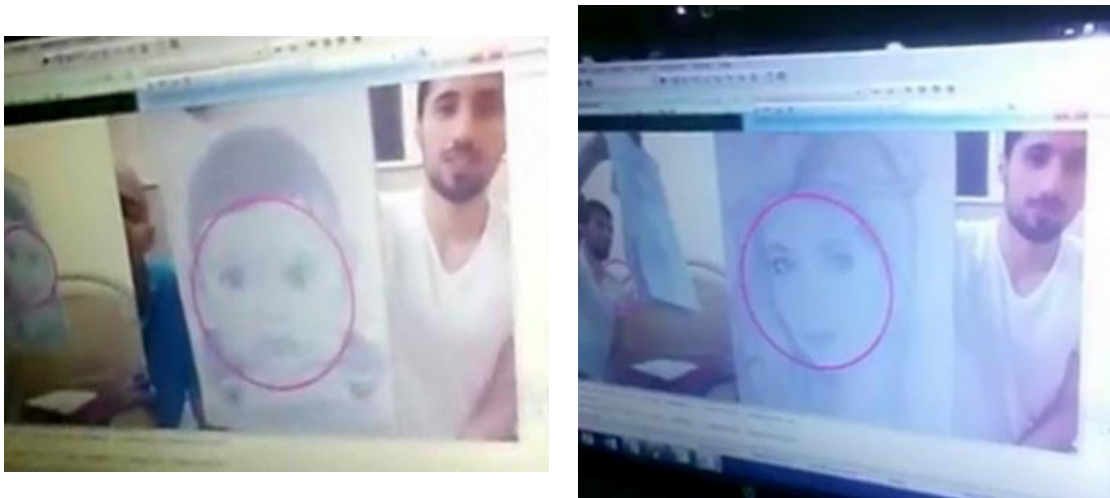
Figure 4.9
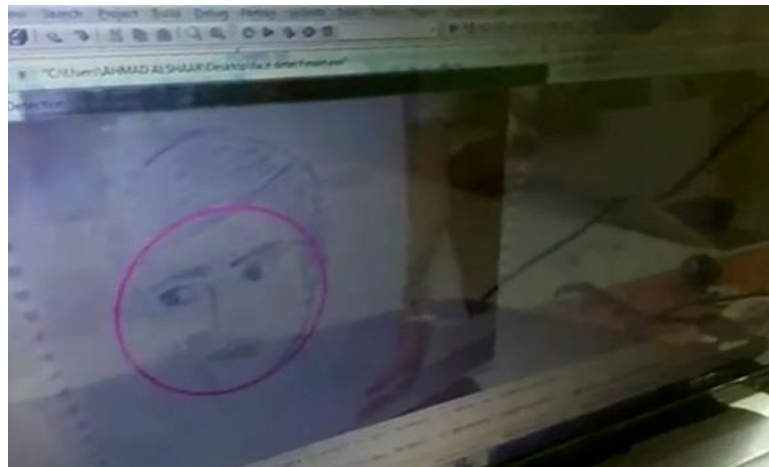
4.4 Website snapshots:
4.4.1 Screenshot from Hello Product's website - Home Page:
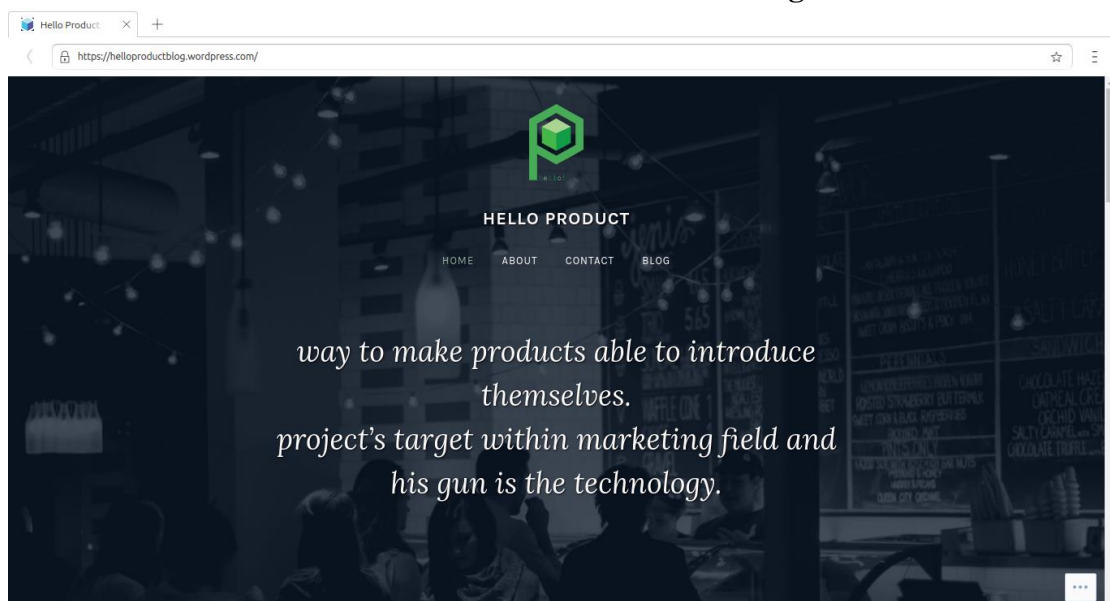
Figure 4.10

Chapter Five
Conclusion & Statistics

As stated previously, this project is covered hardware and software technology aspects that contains functionality is now common in the field of vision guided. It is a fast-growing rapidly evolving technology proving to be economically advantageous in countries with high manufacturing overheads and skilled labor costs by reducing manual intervention.

5.1 SWOT:

SWOT analysis (alternatively SWOT matrix) is an acronym for *strengths*, *weaknesses*, *opportunities*, and *threats* and is a structured planning method that evaluates those four elements of an organization, project or business venture.

S:	W:
- New tool in marketing field. - Less cost and much powerful in compare with competitors. - Dynamic usage for all products, fit in any space and different ways for representation.	Accuracy is decreased as long as the light is decreased.
O:	T:
- Augmented reality to show additional info / offers for people who downloaded Hello Product application into their phones. Collect data and make statistics about who follows-up the product and the number of times they interest. - Interactive machine using AI (Artificial Intelligence). - Product hologram	- Software bugs might appears after release which may make marketing field refuse more interactions by technologies. - Another way appears in marketing field and get the field.

5.2 General Comparison between Hello Product and other Competitors:

	Market Competitors	Technology Competitors	Hello Product
Cost	Varies Medium-high	Very high cost	low
Flexibility	Flexible to different products	Needs high maintenance to be flexible	Can be applied with any product
Technology	No high-tech is used.	Very high-tech is used.	Using available technologies to provide best service.
Maintenance	Not required	Should be maintained periodically	Easy maintained

5.3 Customer experience in statistics:

- By 2016, 89% of companies plan to compete on the basis of customer experience.
- 89% of consumers began doing business with a competitor following a poor customer experience.
- U.S. brands are losing approximately $41 billion each year due to poor customer service.
- 65% of consumers have cut ties with a brand over a single poor customer service experience.
- 40% of global consumers said they prefer self-service over human contact for their future interactions with companies.
- 64% of people think that customer experience is more important than price in their choice of a brand.

5.4 Difficulties (technical):

- **Overheating in raspberry pi and motor.**
- **We can't do stitching rather than binding for camera's images, because stitching is so difficult in real time and need so much of raspberry pi resources.**
- **Binding generate overlapping between the images in 10% of the FOV.**
- **Can't detect the back upper body for the persons.**
- **If the customer want to power off the Hello Product by unplug the cable to change its place he should wait time more than usual due to raspberry pi processes shutdown scheduling.**

5.5 Cost:

5.5.1 CPU (Processing):

The following **Figure 5.1** shows comparison between raspberry pi 3 and Intel core i3, frames-per-second is an important factor which affects the CPU usage. In the prototype, Hello Product's frames-per-second is 4 fps.
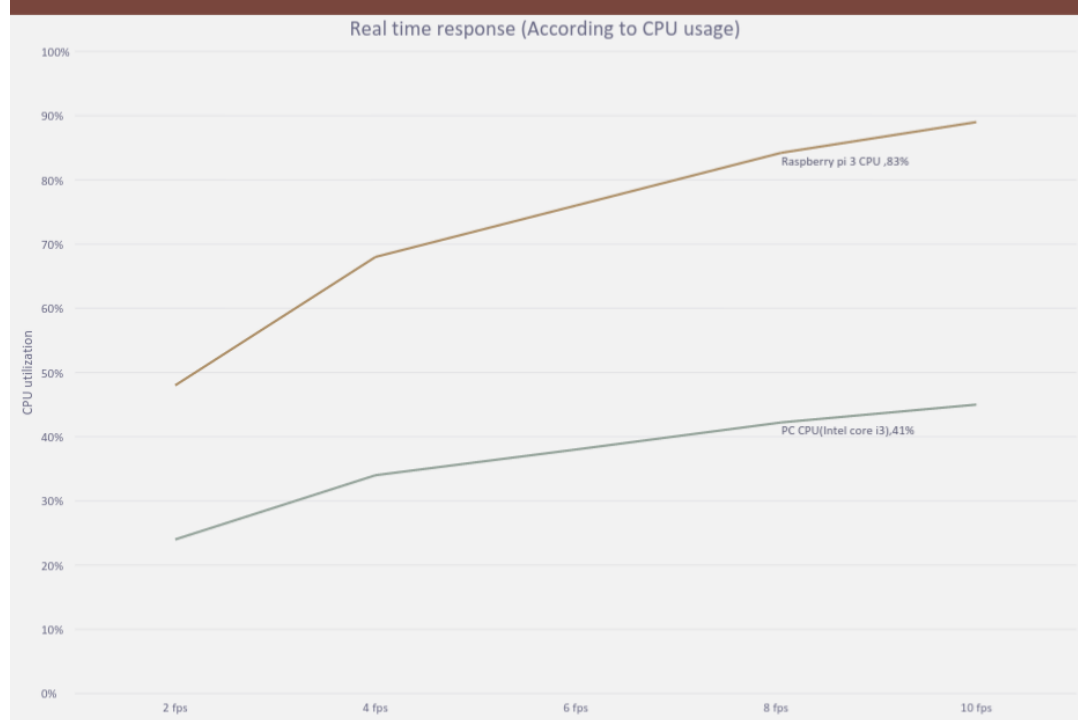
5.5.2 Memory usage:

Nearly 50 MB is needed to load frames and objects of the entire project into RAM and running perfectly.

5.5.3 Storage:

Max needed storage is 6MB is needed to make the Hello Product according to the following components:

- codes (C++, Python and Arduino)
- auto generated files (Cmake, makefile and executable)
- Static files (media, database, Haar Cascade)

Total lines of codes:

File	#lines of code
Master	~636 - 640
btn_off.py	~10
playsound.py	~10
MoveMotor/MoveMotor.ino	~55 - 60
Total	**~ 720**

Hello Product is built using control version GitHub, easily can get the details of the files using the following command: git ls-files | xargs wc -l

Almost 21 KB is the size of codes. Size of auto generated files is about 680 KB.
Static files:
- **Database:** Hello Product consumes two .txt files for storing single double value in each of them. So each file's size will be ~ 3 bytes which concludes **6 bytes**.
- **Media:** Hello Product needs at least one sound file to be played as advertise, the size of voice message will determine the size of media. In prototype of Hello Product, **47 KB is** used to store 8sec voice message.
- **Haar Cascades**: Hello Product need Haar cascades to build classifiers, **3.6 MB** is required to store profile, frontal face and upper body Haar cascades.

5.6 Future plans:
- Support new representative techniques like the following:
  - Interactive machine using AI (Artificial Intelligence).
  - Product hologram
  - Motion detection to avoid detection of not interested person who passed by the covered area.
  - Augmented reality to show additional info / offers for people who downloaded Hello Product application into their phones.
  - Supporting virtual reality
  - Collecting big data and statistics to improve Hello Product.
- Build teams to build Hello Product perfectly, e.g. sales to negotiate with customers, marketing to market the project, finance to determine the perfect profit and the price of the project…etc.
- Support multiple designs :
  - Design #1 :

    4 fixed camera, very

    initial, No motor.
  - Design #2 :

    2 camera, motor.
  - Design # 3:

    1 camera, 1 motor.
  - Design #4 :

    2 fixed camera, No motor.
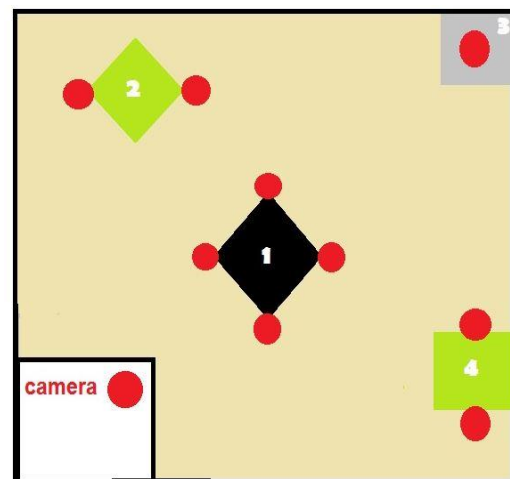
Figure 5.2

5.7 Links for Hello Product:
Website: https://helloproductblog.wordpress.com/
GitHub: https://github.com/SeifMostafa/GP
Google Drive:
https://drive.google.com/drive/u/0/folders/0B2Iyvxa0a1sTWmg1Yk5rRlJfdkU

Appendices

Appendix 1: Raspberry Pi

Table of Contents:

Introduction:

What is a Raspberry PI?

The Raspberry Pi is a credit-card-sized computer that plugs into your TV and a keyboard. It is a capable little computer which can be used in electronics projects, and for many of the things that your desktop PC does, like spreadsheets, word processing, browsing the internet, and playing games. It also plays high-definition video.

Raspberry Pi Models and cost:

Raspberry Pi Models	Cost
Raspberry Pi Model A+	$20
Raspberry Pi Model B+	$25
Raspberry Pi 2 Model B	$35
Raspberry Pi 3 Model B	$35
Raspberry Pi Zero	$5
Raspberry Pi Zero W	$10

The Differences between models:

Product	SoC	Speed	RAM	USB ports	Ether net	Wireless / Bluetooth
Raspberry Pi Model A+	BCM2835	700Mhz	512 MB	1	No	No
Raspberry Pi Model B+	BCM2835	700Mhz	512 MB	4	Yes	No
Raspberry Pi 2 Model B	BCM2836 or BCM2837	900Mhz	1GB	4	Yes	No
Raspberry Pi 3 Model B	BCM2837	1200Mhz	1GB	4	Yes	Yes
Raspberry Pi Zero	BCM2835	1000Mhz	512 MB	1	No	No
Raspberry Pi Zero W	BCM2835	1200Mhz	512 MB	1	No	No

General:

ON/OFF switch:

There is no on/off switch! To switch on, just plug it in. To switch off, if you are in the graphical environment, you can either log out from the main menu, exit to the Bash prompt, or open the terminal. From the Bash prompt or terminal you can shut down the Raspberry Pi by entering "sudo halt -h" (without the quotation marks). Wait until all the LEDs except the power LED are off, then wait an additional second to make sure the SD card can finish its wear-levelling tasks and write actions. You can now safely unplug the Raspberry Pi. Failure to shut the Raspberry Pi down properly may corrupt your SD card, which would mean you would have to re-image it.

Dimensions:

The Raspberry Pi Model B versions measure 85.60mm x 56mm x 21mm (or roughly 3.37″ x 2.21″ x 0.83″), with a little overlap for the SD card and connectors which project over the edges. They weighs 45g. The Pi Zero and Pi Zero W measure 65mm x 30mm x 5.4mm (or roughly 2.56″ x 1.18″ x 0.20″) and weighs 9g.

SoC:

System on a Chip (SoC) is a method of placing all necessary electronics for running a computer on a single chip. Instead of having an individual chip for the CPU, GPU, USB controller, RAM, Northbridge, Southbridge, and so on, everything is compressed down into one tidy package.

All models of Raspberry Pi use Broadcom SoC's, containing a Videocore 4 GPU, but with various ARM CPU cores.
The original Raspberry Pi used a Broadcom BCM2835. This contains a single core ARM1176JZFS with floating point, running at 700Mhz, and a Videocore 4 GPU. The GPU is capable of Bluray-quality playback, using H.264 at 40 MBits/s. It has a fast 3D core, accessed using the supplied OpenGL ES 2.0 and OpenVG libraries.
The Pi 2 Model B originally used the Broadcom BCM2836. This contains a quad-core ARM Cortex-a7 processor with floating point and NEON, running at 900MHz, and the same Videocore 4 GPU that is in the earlier models of Raspberry Pi.
The Pi 3 Model B uses the Broadcom BCM2837, containing a quad-core ARM Cortex-A53 running at 1.2GHz. Its GPU capabilities are equivalent to the Pi 2.

SD Card:

Whether you want to use the NOOBS installer or a standalone distro image, the minimum size SD card we recommend using is 8GB. This will give you the free space you need to install additional packages or make programs of your own. We have tried cards up to 128GB, and most cards seem to work OK. You can also attach a USB stick or USB hard drive to provide extra storage.

Software:

Operating System:

There are several official distributions (distros) available on raspberry pi downloads page. New users will probably find the NOOBS installer the easiest to work with, as it walks you through the download and installation of a specific distro. The recommended distro is Raspbian, which is specifically designed for the Raspberry Pi and which our engineers are constantly optimizing. It is, however, a straightforward process to replace the root partition on the SD card with another ARM Linux distro, so we encourage you to try out several distros to see which one you like the most. The OS is stored on the SD card.

Linux distros runs on the PI, e.g. Raspbian (based on Debian), Arch Linux run on the Raspberry Pi 1, 2, and 3. Ubuntu MATE and Ubuntu Snappy Core run on Pi 2 and 3 only. There are also other community-developed distributions available.

The default username for Raspbian OS is "pi" (without any quotation marks) and the default password is "raspberry" (again, do not include the quotation marks).

Official programming language:

The Raspberry Pi Foundation recommends Python as a language for learners. We also recommend Scratch for younger children. Any language which will compile for ARMv6 (Pi 1) or ARMv7 (Pi 2) can be used with the Raspberry Pi, though, so you are not limited to using Python. C, C++, Java, Scratch, and Ruby all come installed by default on the Raspberry Pi.

How powerful is it?

The GPU provides OpenGL ES 2.0, hardware-accelerated OpenVG, and 1080p30 H.264 high-profile encode and decode. The GPU is capable of 1 Gpixel/s, 1.5Gtexel/s or 24 GFLOPs of general purpose compute and features a bunch of texture filtering and DMA infrastructure. This means that graphics capabilities are roughly equivalent to the original Xbox's level of performance. Overall real-world performance for models A, A+, B, B+, CM, Zero and Zero W is something like a 300MHz Pentium 2, only with much better graphics. The Pi 2 Model B is approximately equivalent to an Athlon Thunderbird running at 1.1GHz: again, it has the much higher-quality graphics that come from using the same GPU as in previous models. The Pi 3 Model B is around twice as fast as the Pi 2 Model B, depending on the benchmarks chosen.

Hardware:

Hardware interfaces does it have:
      Depending on the model, the Raspberry Pi has either 40 or 26 dedicated GPIO (General Port Input Output) pins. In all cases, these include a UART, an I2C bus, a SPI bus with two chip selects, I2S audio, 3V3, 5V, and ground. The maximum number of GPIOs can theoretically be indefinitely expanded by making use of the I2C or SPI bus.
      There is also a dedicated CSI-2 camera port for the Raspberry Pi camera, and a DSI display port for the Raspberry Pi LCD touch screen display.

Extra memory?
      No. The RAM on the model A, A+, B, B+, and Zero is a Package on Package (POP) on top of the SoC, so it is not removable or swappable. The RAM on the Pi 2 and 3 Model B versions is on a separate chip on the bottom of the PCB, but 1GB is the maximum RAM that the SoC used by the Pi 2 and 3 Model B versions can support.

Camera, Display, Audio and Control Remotely:

Camera module:
      The Camera Module is a small PCB that connects to the CSI-2 camera port on the Raspberry Pi using a short ribbon cable. It provides connectivity for a camera capable of capturing still images or video recordings. The camera connects to the Image System Pipeline (ISP) in the Raspberry Pi's SoC, where the incoming camera data is processed and eventually converted to an image or video on the SD card (or other storage).
      The Camera Module V2 is a Sony IMX219, while the original Camera Module is an Omni vision OV5647. They are comparable to cameras used in mobile phones. The Camera Module V2 is capable of taking photos up to 8 megapixels (8MP). It supports 1080p30, 720p60 and VGA90 video modes, as well as still capture. The original Camera Module is capable of taking photos up to 5 megapixels and can record video at resolutions up to 1080p30.
      The Raspberry Pi Camera Modules supports raw capturing (Bayer data direct from the sensor) or encoding as JPEG, PNG, GIF and BMP, uncompressed YUV, and uncompressed RGB photos. They can record video as H.264, baseline, main, and high-profile formats

Display can be used:
      There is composite and HDMI out on the board, so you can hook it up to an old analogue TV through the composite or through a composite to scart connector, to a digital TV or to a DVI monitor (using a cheap, passive HDMI to DVI cable for the

DVI). For the Model B+, Pi 2, and Pi 3, the RCA composite jack has been replaced with a 3.5mm jack that combines audio and video in one. You'll need a 3.5mm to 3RCA adapter cable to connect it to an older TV. There are many different types of this cable out there, but you want to purchase one that is compatible with the iPod Video (the iPod will have the left and right audio channels reversed, but the version of Raspbian included with NOOBS can swap this for you). The Pi Zero uses a mini-HDMI port.

There is no VGA support, but active adapters are available. Passive HDMI to VGA cables will not work with the Raspberry Pi. When purchasing an active VGA adapter, make sure it comes with an external power supply. HDMI to VGA adapters without an external power supply often fail to work

Standard audio in and out:

There is a standard 3.5mm jack for audio out to an amplifier. You can add any supported USB microphone for audio in or, using the I2S interface, you can add a codec for additional audio I/O. Sound over HDMI is supported.

VNC (Virtual Network Computing):

VNC is a graphical desktop sharing system that allows you to remotely control the desktop interface of one computer (running VNC Server) from another computer or mobile device (running VNC Viewer). VNC Viewer transmits the keyboard and either mouse or touch events to VNC Server, and receives updates to the screen in return.

You will see the desktop of the Raspberry Pi inside a window on your computer or mobile device. You'll be able to control it as though you were working on the Raspberry Pi itself.

Power:

Power requirements:

The device is powered by 5V micro-USB. Exactly how much current (mA) the Raspberry Pi requires is dependent on which model you are using, and what you hook up to it. We recommend a 2.5A (2500mA) power supply, from a reputable retailer, that will provide you with enough power to run your Raspberry Pi for most applications, including use of the 4 USB ports. Very high-demand USB devices may however require the use of a powered hub. The table below outlines the specific power requirements of each model.

Product	Recommended PSU current capacity	Maximum total USB peripheral current draw	Typical bare-board active current consumption
Raspberry Pi Model A+	700mA	500mA	180mA
Raspberry Pi Model B+	1.8A	600mA/1.2A (switchable)	330mA
Raspberry Pi 2 Model B	1.8A	600mA/1.2A (switchable)	350mA
Raspberry Pi 3 Model B	2.5A	1.2A	400mA
Raspberry Pi Zero	1.2A	Limited by PSU, board, and connector ratings only.	100mA

The specific current requirements of each model are dependent on the use case: the PSU recommendations are based on "typical maximum" current consumption, the typical current consumption is for each board in a "desktop computer" configuration. The Raspberry Pi Model A, A+, and B can supply a maximum of 500mA to downstream USB peripherals. If you wish to connect a high-power USB device, it is recommended that you connect a powered USB hub to the Pi and connect your peripherals to the USB hub. The Raspberry Pi B+ and 2 Model B can supply 600mA/1.2A to downstream USB peripherals, switchable by a firmware setting. This allows the vast majority of USB devices to be connected directly to these models, assuming the upstream power supply has sufficient available current. Very high-current devices or devices which can draw a surge current such as certain modems and USB hard disks will still require an external powered USB hub. The power requirements of the Raspberry Pi increase as you make use of the various interfaces on the Raspberry Pi. The GPIO pins can draw 50mA safely (note that that means 50mA distributed across all the pins: an individual GPIO pin can only safely draw 16mA), the HDMI port uses 50mA, the Camera Module requires 250mA, and keyboards and mice can take as little as 100mA or as much as 1000mA! Check the power rating of the devices you plan to connect to the Pi and purchase a power supply accordingly. If you're not sure, we would advise you to buy a powered hub.
Here is a table comparing the amount of power drawn in a (amps) under different situations:

		Pi1 (B+)	Pi2 B	Zero	Pi3 B
Boot	max	0.26	0.40	0.20	0.75
	avg	0.22	0.22	0.15	0.35
idle	avg	0.20	0.22	0.10	0.30
Video playback (H.264)	max	0.30	0.36	0.23	0.55
	avg	0.22	0.28	0.16	0.33
Stress	max	0.35	0.82	0.35	1.34
	avg	0.32	0.75	0.23	0.85

Power Raspberry PI from USB hub:

It depends on the hub. Some hubs comply with the USB 2.0 Standard and only provide 500mA per port, which may not be enough to power your Raspberry Pi. Other hubs view the USB standards more like guidelines, and will provide as much power as you want from each port. Please also be aware that some hubs have been known to "backfeed" the Raspberry Pi. This means that the hubs will power the Raspberry Pi through its USB input cable, without the need for a separate micro-USB power cable, and bypass the voltage protection. If you are using a hub that "backfeeds" to the Raspberry Pi and the hub experiences a power surge, your Raspberry Pi could potentially be damaged.

Power Raspberry PI from Batteries:

Running the Raspberry Pi directly from batteries requires special care and can result in damaging or destroying your Raspberry Pi. If you consider yourself an advanced user, though, you could have a go. For example, four AA rechargeable batteries would provide 4.8V on a full charge. 4.8V would technically be just within the range of tolerance for the Raspberry Pi, but the system would quickly become unstable as the batteries lost their full charge. Conversely, using four AA Alkaline (non-rechargeable) batteries will result in 6V. 6V is outside the acceptable tolerance range and would potentially damage or, in the worst-case scenario, destroy your Raspberry Pi. It is possible to provide a steady 5V from batteries by using a buck and/or boost circuit, or by using a charger pack which is specifically designed to output a steady 5V from a couple of batteries; these devices are typically marketed as mobile phone emergency battery chargers.

Glossary:

BGA: Ball grid array. A type of surface mount packaging for electronics.

Distro: A specific package ("flavour") of Linux and associated software.

GPIO: General Purpose Input/Output. A pin that can be programmed to perform a wide range of tasks.

GPU: Graphics processing unit. The hardware that handles the graphics.

PoE: Power over Ethernet. Powering a device via an Ethernet cable.

PXE: Reboot execution environment. A way to get a device to boot via the network.

SoC: System on a Chip. A computer on a single chip.

Appendix 2: Motor

**Table of Contents:**

Motors:
Motor Driver:

Motors:

Motor definition:

An **electric motor** is an electrical machine that converts electrical energy into mechanical energy. The reverse of this is the conversion of mechanical energy into electrical energy and is done by an electric generator, and generators and motors have much in common.

Motor types:

The following is motor types in general picture.
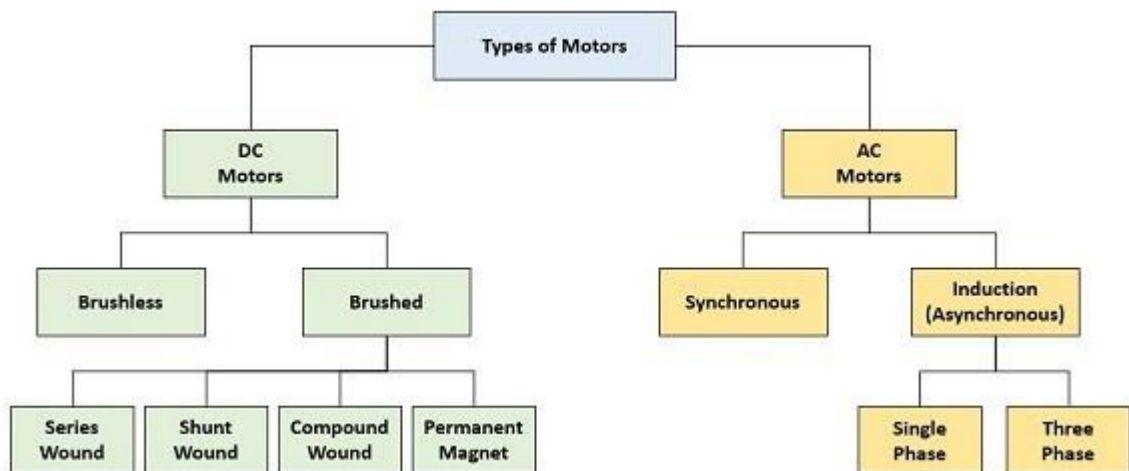
Servo motor:

A servomotor is a motor, very often sold as a complete module, which is used within a position-control or speed-control feedback control system mainly control valves, such as motor-operated control valves. Servomotors are used in applications such as machine tools, pen plotters, and other process systems. Motors intended for use in a servomechanism must have well-documented characteristics for speed, torque, and power. The speed vs. torque curve is quite important and is high ratio for a servo motor. Dynamic response characteristics such as winding inductance and rotor inertia are also important; these factors limit the overall performance of the servomechanism loop. Large, powerful, but slow-responding servo loops may use conventional AC or DC motors and drive systems with position or speed feedback on the motor. As dynamic response requirements increase, more specialized motor designs such as coreless motors are used. AC motors' superior power density and acceleration characteristics compared to that of DC motors tends to favor PM synchronous, BLDC, induction, and SRM drive applications

Stepper motor:

Stepper motors are a type of motor frequently used when precise rotations are required. In a stepper motor an internal rotor containing PMs or a magnetically soft

rotor with salient poles is controlled by a set of external magnets that are switched electronically. A stepper motor may also be thought of as a cross between a DC electric motor and a rotary solenoid. As each coil is energized in turn, the rotor aligns itself with the magnetic field produced by the energized field winding. Unlike a synchronous motor, in its application, the stepper motor may not rotate continuously; instead, it "steps"—starts and then quickly stops again—from one position to the next as field windings are energized and de-energized in sequence. Depending on the sequence, the rotor may turn forwards or backwards, and it may change direction, stop, speed up or slow down arbitrarily at any time.

Simple stepper motor drivers entirely energize or entirely de-energize the field windings, leading the rotor to "cog" to a limited number of positions; more sophisticated drivers can proportionally control the power to the field windings, allowing the rotors to position between the cog points and thereby rotate extremely smoothly. This mode of operation is often called microstepping. Computer controlled stepper motors are one of the most versatile forms of positioning systems, particularly when part of a digital servo-controlled system.

Motor driver:

Motor driver definition:

A motor driver is a little current amplifier; the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.

Motor driver types:

The following is screenshot from http://www.electrodragon.com/w/index.php?title=Category:Driver_Board Shows good comparison between motor drivers and their aspects.

Type	Drive	Use
BTS7960		
DRV8825	2x H full-bridge	stepper
DRV8833	2x H full-bridge	brushed DC or bipolar stepper motors
TB6612	2x H full-bridge	
TB6560	2x H full-bridge	CNC router drive
TB6600	2x H full-bridge	CNC router drive
DSP MA860H	2x H full-bridge	CNC router drive
LV8729	2x H full-bridge	CNC router drive
VNH2SP30-E	1x H full-bridge	"Arduino monster shield"
L9110	1x H full-bridge	
L293 L293D	Quadruple half-H bridge	
L298 N/P	2x H full-bridge	
A3967	2x H full-bridge	Microstepping Driver with Translator
A4988	2x H full-bridge	DMOS Microstepping Driver with Translator And Overcurrent Protection
ULN2003	7 x Darlinton array	

Current Peak Iout	Current RMS	Votlage
43A		45V
2.5A @24V	1.75A @24V	8.2-45V
	1.5A RMS @5V	2.7 to 10.8 V
3.2A	1.2A	4.5-13.5V
TB6560AHQ: 3.5 A		40V
5 A		50V
7.2 A		AC18V-60V, DC24V-80V
1.8 A		9-32V, 12V
30A		41V
0.8A		2.5V-12V
0.6A		36V
4A total		46V
850mA	750mA	35V
2A		35V

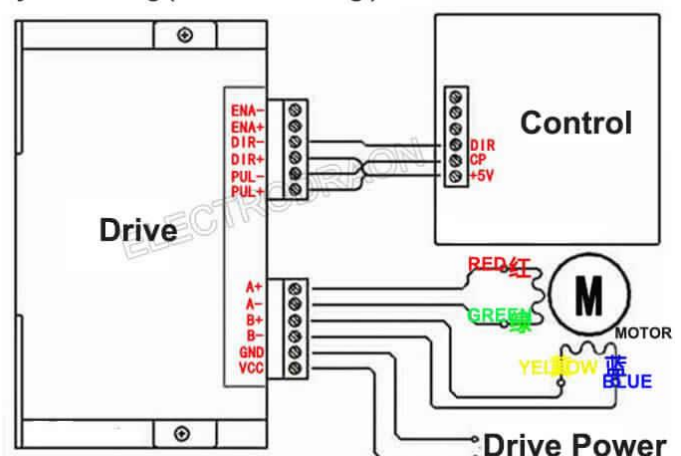**Motor driver TB6600, 6560:**

● **Note:**

Double check the wiring before to use, otherwise the module could be burnt.

Do not use more than 3A motor?

● **Wiring:**

Simple wiring between drive, control, motor, and drive power.

System wiring (COM-ANODE e.g.)

- **Pin Definition**

Name	Name2	Description	Mode
+24V, GND		Motor power	
A+/-, B+/-		Motor phase A/B	
CLK +/-	PUL +/-	Pulse	
CW +/-	DIR +/-	Direction	Clockwise on H-TTL, vice serse
EN+ EN-	ENA, ENB	Enable	Standby/lock mode on H-TTL, vice serse

CLK, CW and EN can be configured to work as high TTL or Low TTL

Default TTL signal is 5V, If use 12V signal, serial connect a 1K resistor, if use 24V signal, serial connect a 2.4K resistor

- **Configuration TB6560**

TB6600 Step Configuration: the following screenshot shows the mapping of switched and current.

Current(A)	PK Current	S4	S5	S6
0.5	0.7	ON	ON	ON
1.0	1.2	ON	OFF	ON
1.5	1.7	ON	ON	OFF
2.0	2.2	ON	OFF	OFF
2.5	2.7	OFF	ON	ON
2.8	2.9	OFF	OFF	ON
3.0	3.2	OFF	ON	OFF
3.5	4.0	OFF	OFF	OFF

Resources

1. Computer Vision: Algorithms and Applications - Richard Szeliski - 2010.
2. OpenCV 2 Computer Vision Application Programming Cookbook - Robert Laganière - 2011.
3. Learning Image Processing with OpenCV - 2015.
4. Camera–based 3D Object Tracking and Following Mobile Robot - Nazim Mir-Nasiri ,School of Engineering -Swinburne University of Technology -Sarawak Campus, Malaysia - nnasiri@swinburne.edu.my.
5. J. Denzler, D.W.R Paulus, "Active Motion detection and object tracking", Proceedings of the IEEE International Conference on Image Processing, (ICIP-94), 1994, Vol. 3, pp. 635 – 639.
6. J.N. Carter, P. Lappas, R.I. Damper,"Acoustics Evidence-based object tracking via global energy maximization", Proceedings of the 2003 IEEE International Conference on Speech, and Signal (ICASSP '03), 2003, Vol.:3, pp. 501- 4.
7. Xiao-Jing Shen, Jun-Min Pan, "A simple adaptive control for visual servoing", Proceedings of the 2003 International Conference on Machine Learning and Cybernetics, 2003, Vol. 2, pp. 976 – 979.
8. Yi Ma,J. Koˇseckˊa, S. S. Sastry, "Vision Guided Navigation for a Nonholonomic Mobile Robot", IEEE Transactions on Robotics and Automation Vol. 15, No. 3, June 1999, pp. 521.
9. W. E. Dixon, D. M. Dawson, E. Zergeroglu, A. Behal, "Adaptive Tracking Control of a Wheeled Mobile Robot via an Uncalibrated Camera System", IEEE Transactions on Systems, Man, and Cybernetics—Part B: Cybernetics, Vol. 31, No. 3, June 2001, pp. 341.
10. C. Balkenius, L. Kopp. "Visual tracking and target selection for mobile Robots," 1st Euromicro Workshop on Advanced Mobile Robots (EUROBOT), 1996, p. 166.
11. https://goo.gl/Xt33HO
12. http://abyz.co.uk/rpi/pigpio/index.html
13. http://docs.opencv.org/2.4/doc/tutorials/introduction/linux_install/linux_install.html#linux-installation
14. http://codeandlife.com/2012/07/03/benchmarking-raspberry-pi-gpio-speed/
15. http://www.hertaville.com/rpiservo.html
16. https://www.youtube.com/watch?v=h3w0lw8NYNg
17. http://raspberrypi.stackexchange.com/
18. https://www.raspberrypi.org/documentation/
19. http://www.learnopencv.com/facial-landmark-detection/
20. https://facedetection.com/algorithms/
21. https://en.wikipedia.org/wiki/Kanade–Lucas–Tomasi_feature_tracker

22. http://free-d.org/3d-head-tracking-in-video/
23. https://en.wikipedia.org/wiki/Perspective-n-Point
24. http://www.morethantechnical.com/2011/11/13/just-a-simple-laplacian-pyramid-blender-using-opencv-wcode/
25. http://blog.blackhc.net/2010/07/panorama-stitching/
26. http://stackoverflow.com/questions/20801015/recommended-values-for-opencv-detectmultiscale-parameters
27. http://www.chucklohr.com/808/AOV/
28. http://stackoverflow.com/questions/17499409/opencv-calculate-angle-between-camera-and-pixel
29. http://vrguy.blogspot.com.eg/2013/04/converting-diagonal-field-of-view-and.html
30. link .cpp and .ino
31. http://docs.opencv.org/2.4/modules/imgproc/doc/geometric_transformations.html#resize
32. https://stackoverflow.com/questions/11420748/setting-camera-parameters-in-opencv-python
33. https://en.wikipedia.org/wiki/Haar-like_features
34. http://www.businessdictionary.com/definition/marketing.html
35. https://qemu.weilnetz.de/doc/qemu-doc.html
36. http://download.qemu.org/qemu-doc.html
37. https://blogs.msdn.microsoft.com/iliast/2016/11/10/how-to-emulate-raspberry-pi/
38. https://jeffskinnerbox.wordpress.com/2012/11/15/getting-audio-out-working-on-the-raspberry-pi/
39. http://elinux.org/Omxplayer
40. http://www.pyimagesearch.com/2016/04/18/install-guide-raspberry-pi-3-raspbian-jessie-opencv-3/
41. https://oscarliang.com/connect-raspberry-pi-and-arduino-usb-cable/
42. http://conoroneill.net/connecting-an-arduino-to-raspberry-pi-for-the-best-of-both-worlds/
43. https://computing.llnl.gov/tutorials/pthreads/#Abstract
44. http://www.cs.wm.edu/wmpthreads.html
45. https://www.tutorialspoint.com/cplusplus/cpp_multithreading.htm
46. http://www.electrodragon.com/w/index.php?title=Category:Driver_Board&redirect=no
47. https://www.rs-online.com/designspark/different-types-of-motors-and-their-use
48. https://en.wikipedia.org/wiki/Electric_motor
49. https://stackoverflow.com/questions/37737860/running-c-file-with-raspberry-pi
50. http://www.hertaville.com/rpiservo.html
51. http://codeandlife.com/2012/07/03/benchmarking-raspberry-pi-gpio-speed/

52. https://raspberrypi.stackexchange.com/questions/31739/how-to-run-2-servos-with-wiringpi2-on-raspberry-pi-2

53. https://www.youtube.com/watch?v=h3w0lw8NYNg

54. http://www.cplusplus.com/forum/beginner/32470/

55. https://www.raspberrypi.org/documentation/usage/gpio-plus-and-raspi2/

56. https://www.raspberrypi.org/forums/viewtopic.php?f=29&t=80341

57. https://raspberrypi.stackexchange.com/questions/45844/launching-applications-from-gpio-button-presses-via-a-python-script

58. https://raspberrypi.stackexchange.com/questions/38644/pigpio-cant-lock-var-run-pigpio-pid

59. https://pinout.xyz/pinout/pin12_gpio18#

60. https://github.com/bazyle/FaceRecognitionLibrary

61. http://abyz.co.uk/rpi/pigpio/examples.html#C++%20code

62. http://www.ladyada.net/library/picvsavr.html

63. http://wiringpi.com/

64. http://www.instructables.com/id/Pan-Tilt-face-tracking-with-the-raspberry-pi/

65. http://mitchtech.net/raspberry-pi-servo-face-tracker/

66. http://answers.opencv.org/question/84695/using-a-raspberry-pi-and-opencv-to-control-a-servo-motor/

67. https://www.chiefdelphi.com/forums/archive/index.php/t-135892.html

68. https://raspberrypi.stackexchange.com/questions/3343/accessing-gpio-pins-using-c-program-in-raspberry-pi

69. https://learn.pimoroni.com/tutorial/bash/getting-started-with-bash

70. https://cmake.org/examples/

71. https://www.sparkfun.com/tutorials/400

72. http://www.anaheimautomation.com/manuals/forms/stepper-motor-guide.php#sthash.mSKJxNOY.nJQPaxzw.dpbs

73. http://www.instructables.com/id/ARDUINO-UNO-TB6560-Stepper-motor-driver/

74. http://bioeng.nus.edu.sg/mm/wp-content/uploads/2012/07/MotorControl-1japwem.pdf

75. https://www.arduino.cc/en/Tutorial/SimpleAudioPlayer

76. http://www.pyimagesearch.com/2015/11/16/hog-detectmultiscale-parameters-explained

77. https://stackoverflow.com/questions/20801015/recommended-values-for-opencv-detectmultiscale-parameters

78. http://opencvexamples.blogspot.com/2013/10/face-detection-using-haar-cascade.html

79. http://physics.tutorvista.com/motion/equilibrium-rule.html

80. https://www.merriam-webster.com/dictionary/center%20of%20gravity

81. https://en.wikipedia.org/wiki/Center_of_mass#Center_of_gravity

82. http://study.com/academy/lesson/what-is-center-of-gravity-definition-equation-examples.html

83. http://ap.isr.uc.pt/archive/153.pdf
84. http://www.cs.utexas.edu/~grauman/courses/spring2008/slides/Faces_demo.pdf
85. http://ds.cs.ut.ee/Members/artjom85/2014dss-course-media/Object%20detection%20using%20Haar-final.pdf
86. http://www.diva-portal.org/smash/get/diva2:601707/fulltext01.pdf
87. https://stackoverflow.com/questions/4363943/what-are-haar-pyramids
88. https://www.embedded-vision.com/what-is-embedded-vision
89. https://www.raspberrypi.org/documentation/remote-access/vnc/README.md
90. http://www.qr-code-generator.com/
91. https://www.raspberrypi.org/documentation/linux/usage/rc-local.md
92. http://ryanstutorials.net/bash-scripting-tutorial/bash-script.php
93. https://raspberrypi.stackexchange.com/questions/8734/execute-script-on-start-up
94. https://raspberrypi.stackexchange.com/questions/8734/execute-script-on-start-up
95. https://raspberrypi.stackexchange.com/questions/19554/is-it-safe-to-use-the-gpio-p6
96. https://www.digikey.co.uk/en/resources/conversion-calculators/conversion-calculator-resistor-color-code-4-band
97. https://raspberrypi.stackexchange.com/questions/27263/change-the-gpio-pull-up-down-gpio-pud-up-to-gpio-pud-down
98. https://acapela-box.com/AcaBox/index.php
99. http://www.wikihow.com/Execute-a-Script-at-Startup-on-the-Raspberry-Pi
100. http://www.raspberry-projects.com/pi/pi-operating-systems/raspbian/auto-running-programs-gui