# The Capstone Team Project
# MECT 411

**Name of Project:** *Smart Sorting Machine*

**Group Name:** *TEAM JH*

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# ABSTRACT

The major problem with the currently used sorting machines is that they operate on predefined parameters loaded by the manufacturer. This way doesn't scale well due to the fact that a large amount of different products with different properties are introduced daily. Meaning, in order to classify them it requires to build a giant amount of data representing almost each product properties; this tends to be time and resources consuming process, which is why it seems a natural need to came up with an efficient implementation of a sorting machine that can learn new products through reading their properties in real time and build a model to represent them. Its significance is to reduce the size of data to be predefined as well as the time taken to prepare that data. That leads us to our most important objective that is to pull machine learning concepts into the physical world by using a camera-based-computer-vision-intelligence that will guide the system to detect, identify and classify the goods in a similar way to human beings. On the other side the overall system speed, accuracy and sensitivity would impose performance challenges. However, for the mean time such obstacles could be dealt with by controlling the operating environment to prove our concept and obtain an adaptable sorting machine.

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| | |
|---|---|
| Mog | Mixtture Of Gaussian |
| ML | Machine learning |
| ANN | Artificial Neural Network |
| KNN | K-nearest neighbors |
| X-D | (integer) dimensional |
| K | number of distributions |
| $\omega$ | weight associated with ith gaussian at time t |
| $\mu$ | mean |
| $\sigma$ | standard deviation |
| $\eta$ | Gaussian probability density function |
| $\ominus$ | Morphological erode |
| $\oplus$ | Morphological dilate |

| | |
|---|---|
| $\odot$ | Morphological Open |

# CHAPTER 1 - INTRODUCTION

## 1.1. Detailed definition of the project

The core principle is combining sorting operation, with ML classification algorithms (e.g. KNN …), to adapt a larger variety of goods. Products' properties (color or shape) are collected through image processing: static images at the training stage, while live video stream at the test stage. Subsequent to the extraction of the properties, they are forwarded to the ML algorithm- either to train it or to obtain a prediction of the product category, leading to the gate-response (open/close) to guide the product.

## 1.2 Significance of the project

The proposed project will introduce machine learning to the industry as a replacement of static predefined data, tackling two concerns at the mean time:

- Eliminating the need of large memory capacity to store static data
- Reducing the time taken to prepare the software system by the manufacturer.

## 1.3. Detailed project objectives

The aim is to develop an intelligent sorting machine that will adopt supervised machine learning techniques, and replace the traditional preloaded parameters ones. It will classify products based on visual features, guide them to the required destination and get reconfigured for different sets of products.

## 1.4 Detailed project constraints

Technically, we are limited by a sequential input of products; we can’t pass two or more products at the same time due to the mechanical design as well as the object-detection implemented algorithm. Extracted features are affected by the system sensitivity due to:

- The noise occurring by light and movement of the product
- Similarity of features between different products

These constraints will affect the overall machine decision speed as well as the accuracy.

## 1.5 Report Organization

The 1st chapter is meant to give the reader a general idea about the project. It then proceeds to go further into theoretical detail within the 2nd chapter where backbones-used-technologies are touched. In the 3rd chapter, it will offer an insight on the design and configuration of the sorter system core and also discuss the engineering standards. Chapter 4 describes the manufacturing steps- 5 and 6 discuss the testing and comment on how the results fit our objectives and design. Chapter 7 wraps up with final conclusions.

# CHAPTER 2 - LITERATURE REVIEW

## 2.1 Background information

### 2.1.1 Machine Learning

#### 2.1.1.1 Definition

"Machine learning is a type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed" said Margret [8]. Machine learning is an enormous field, with hundreds of different algorithms for solving myriad different problems. For example, a subclass thereof is the process of classification, whose most common algorithms are K-Nearest Neighbors, Support Vector Machine …etc.

#### 2.1.1.2 K-Nearest Neighbors (KNN)

A simple method that stores all different training cases and predict the numerical value based on a similarity measure. i.e. distance calculation. That value represents a class membership or a property value [4]. Commonly-used distance functions are Euclidean, Manhattan, and Minkowski.

### 2.1.2 Machine Vision

It is computers' ability to acquire digital images and process them to gather information for further usages (e.g. robot control). This technology is adopted by inspection procedures such as counting, gauging, or detecting defects. Replaces relying solely on operator judgment, thus it makes task performance much more time efficient, higher precision and reliable. Machine vision has been deployed in various fields (e.g. medical, security, etc).

#### 2.1.2.1 Vision in industrial automation

Utilizing vision in industry will create a system capable of performing a wide variety of industrial guidance, inspection and identification tasks at a very significant rate. Visual inspection will be applied during any stage of production ranging from raw material to packaging lines. To achieve that, several inspection methods are developed - like OCR/OCV, 1D,2D-code reading, color verification, precision alignment, assembly verification and general defect inspection.

### 2.1.3 Image processing operations

Raw digital-images have no meaning for computers, some translation-operations have to take place, to extract understandable information for future use.

#### 2.1.3.1 Filtering

A software function that changes the appearance of an image or part of it, by altering the shades and colors of the pixels in some manner. Filters add a wide variety of textures, tones and special effects.[10]. Blur filters such as Gaussian blur (figure-X) are used to reduce noise from images[11]

#### 2.1.3.2 Thresholding

In order to segment pixels of interest from the rest, we perform a comparison of each pixel's intensity value I with respect to a threshold value T, and replace each pixel where ( $I < T$ ) with a black one, as shown in the figure-1 below

### 2.1.3.3 Morphological operations

To process images by their shapes. Morophological operations are applied by convolution with a customized kernel matrix.

- Erosion: to extract the foreground ( Figure-2 )
- Dilation: to extract the background ( Figure-3 )
- Open: Erosion followed by dilation to eliminate noise in the scene ( Figure-4 )


Figure [2]. Erode.


Figure [3]. Dilate.

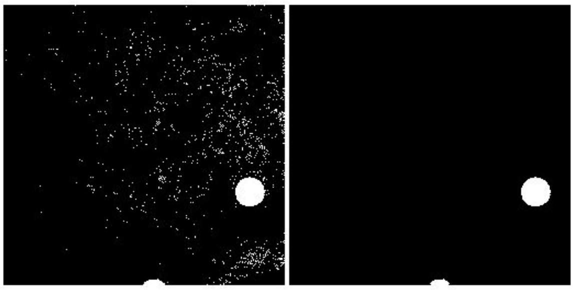


Figure [4]. Open.

### 2.1.3.4 Feature extraction

A feature is a piece of information that carries a specific property (shape, color, size ... etc.). With using specific algorithms to take care of collecting image-features, result is represented in terms of sets of different dimensions.

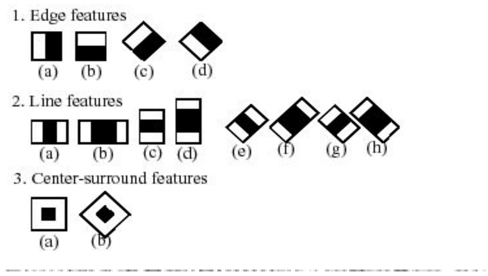
- Edge

  This method takes an image as an input, detects its edges and calculates their length and directions. The result is accumulated into 1-D histogram. The figure-5 below shows an edge-detection result.

Figure [5]. Edge detection.

- Haar-Like

A technique that collects object geometrical-segmentation properties, through considering adjacent rectangular-regions (Figure 6) at a location in the window. Then summing up the pixel intensities in each region and finally calculating the difference between these sums.




### 2.1.3.5 Motion detection

In any scene the moving objects represent the foreground. This foreground is extracted for further processing (e.g. feature extraction). To achieve that, several techniques were developed to detect motion. These techniques are either differentiation-based (e.g. Frame subtraction) or segmentation-based (e.g. Mixture of Gaussian, Figure-7).

Figure [7]. Motion detection via MOG.

## 2.1.4 Sorting Machine

Sorting is any process of arranging items systematically [9]. Yet sorting has two distinct implementations. Ordering or arranging items in a sequence, and categorizing according to predefined specifications such as color, weight, conductivity, etc… Machines were implemented to automate such tasks in pharmaceutical, food and mining industries.

## 2.2 Concurrent solutions

Some of the existing sorting solutions:

- Blizzard optical sorter from TOMRA, used in frozen fruit inspection
- QVision analyzer from TOMRA, used in meat protein and fat analysis

## 2.3 Comparisons of the concurrent solutions

Table [1]. Comparison between the available sorters and the proposed one.

| Machine/Props | *Blizzard* | *QVision* | Current project |
|---|---|---|---|
| **Sensor** | Pulsed led (UV/VIS) | VIS near infrared light | HD web camera |
| **Sensed features type** | Chemical + Physical | Chemical | Physical |
| **Sensed features** | • Color<br>• Shape<br>• Structural differences | • Optical radiation to determine fat, protein | Depends on the scenario, any combination of<br>• Color<br>• Shape<br>• Structural differences |
| **Usage fields** | Food industries-inspection | Food industries-inspection & analysis | Food industries-categorization, Recycling |
| **Product feeding method** | Free fall | Conveyor belt | Rotating table |
| **Rejection mechanism** | Air guns | - | Mechanical gate |

### 2.4 Engineering standards of the concurrent solutions

- ISO 11161:2007: safe integrate ability
- ISO 9001:2015: quality management revision

# CHAPTER 3 -DESIGN and ANALYSIS

## 3.1. System architecture

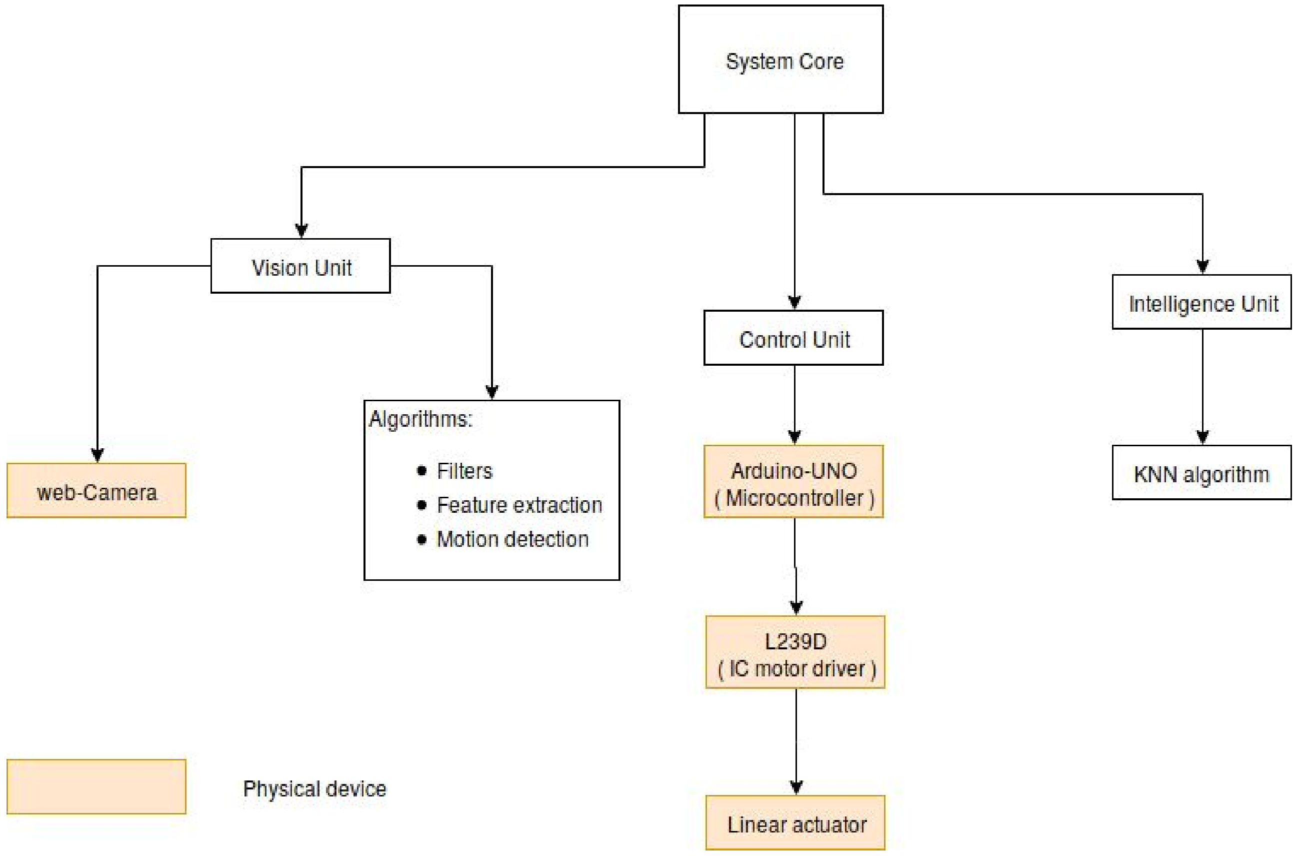



Figure [8]. System architecture.

As shown in figure-8 that the system consists of three independent units:

1. Vision
   Using a web camera (vision sensor), to capture *frames/sec* (a.k.a live-video feed). These frames are forwarded towards filtering, motion-detecting and feature-extraction algorithms.

2. Intelligence
   Utilizing an implementation of KNN algorithm, to build, to rain and then to test a

model representation of products.

3. Control

   A linear actuator (figure 9) is used to guide the products through an opening/closing gate. That actuator is controlled by microcontroller (figure 10) through *L239D* integrated chip (IC). The microcontroller acts as a bridge between the computer system and the physical world, taking a command via serial-port and based on its interpretation it toggles the actuator state. (Schema  tic in APPENDIX-F)

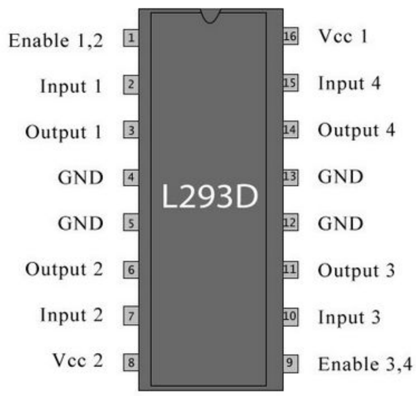
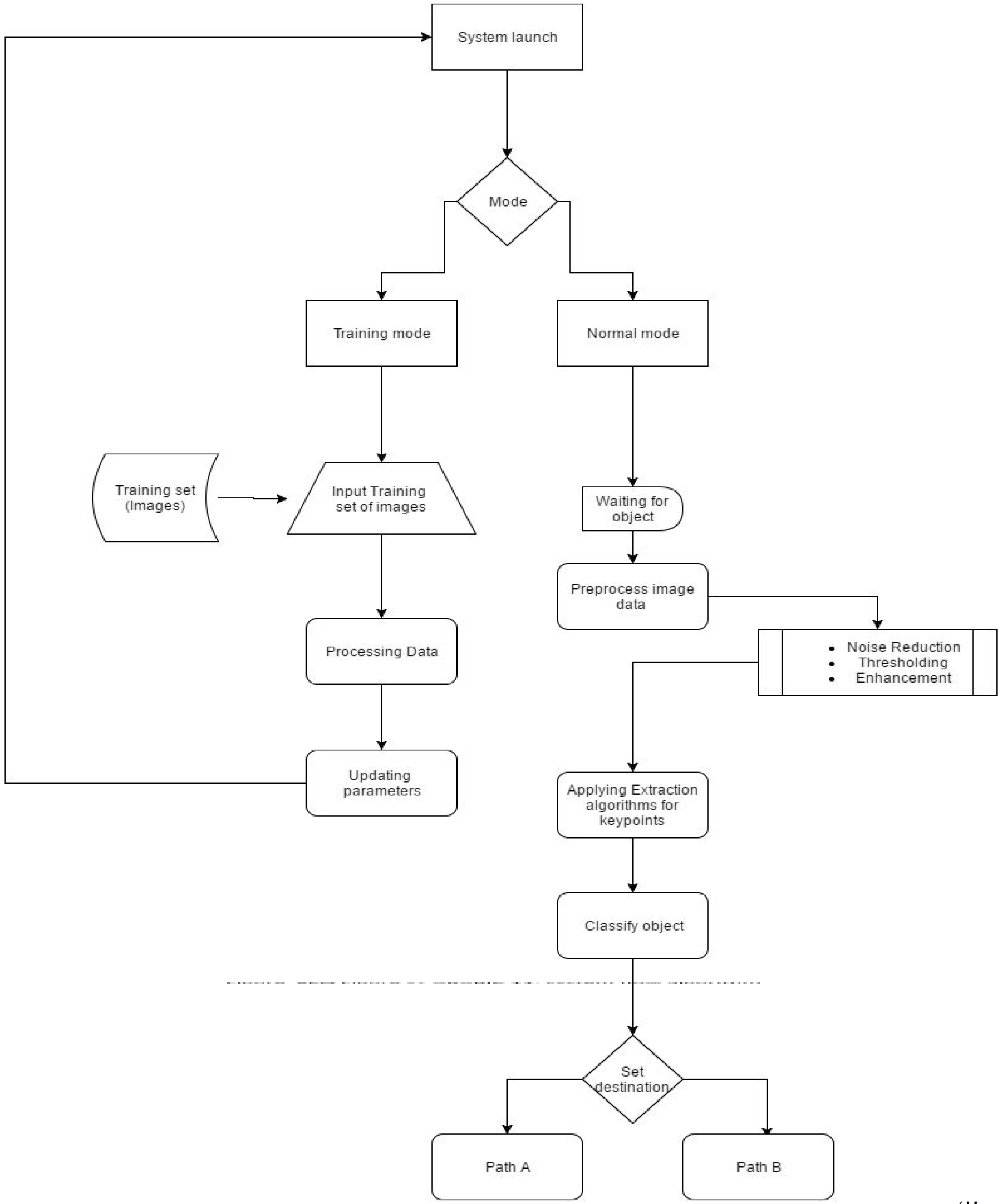



Figure [11]. Motor Shield.

## 3.2 System workflow

A workflow was developed to build a scenario for the sorting system as shown in figure 12 below.

As described in figure 12, there exist 2 modes for the



system, explained in the following pseudo-code:

if ***mode*** is *training*:

images = Get images, tagged by category ( operator selects a folder containing them)

filtered_images = *filter* ( images )

features = *extract_features* ( filtered_images )

ml = *train_algorithm_on_features* ( features )

else ***mode*** is *testing*:

images = *get_video_feed_from_camera*()

if detect_motio_in_images ( images ):

filtered_images = *filter* (images)

features = *extract_features* ( filtered_images )

**classification** = *predict_category* ( features )

if **classification** is <u>first type</u>:

open gate, let go to path 1

else if **classification** is <u>second type</u>:

close gate, let go to path 2

## 3.3 Design calculations and parameters

### 3.3.1 Mechanical

- Design parameters matrix

Table [2]. Design parameters matrix

| | Requirement | Solution |
|---|---|---|
| Material | Prototype requires:<br>• Light-weight<br>• Cost-effective<br>• Easy to work into new shapes | Aluminum |
| Goods infeed mechanism | • Easy to implement<br>• Consume small area<br>• Light weight | Wood, rotating table<br>$\phi = 300\ mm$<br>THK = 4mm |
| Distinguishing mechanism | • Integrability with infeed mechanism<br>• Requirements available ( locally ) | Gate mechanism<br>Open/Close → 2 paths |

- Linear actuator position adjustment

Using a basic geometry calculation to obtain the distance $x$ between shaft and an actuator with $stroke\ length\ =\ 20\ mm$, that will open the gate at ( 45 ~ 55 degree)::

$$x = \frac{20}{tan(45 \leftrightarrow 55)} = 14 \leftrightarrow 20\ mm$$

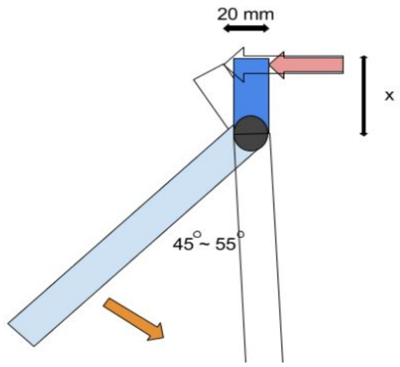



Figure [13]. Position adjustment

### 3.3.2 Electronics

Table [3]. Electronics requirements.

| | Requirements | Solution |
|---|---|---|
| Motor ( for rotating table ) | ● DC<br>● Low speed<br>● High torque | 5V geared DC motor |
| Motor driver | ● IC<br>● Arduino compatible,<br>● Contains H-Bridge ( for dual directions ) | L239D |
| Microcontroller | ● Easy to setup<br>● c++ program lang<br>● cost effective | Arduino-UNO |
| Power supply | ● Volt: 5V<br>● Current ≥ 1 Amp<br>● Safe to use | ASUS AC adaptor AD835M1 |

The chosen devices in table-X above are implemented in the electronic circuit of the project ( Details in schematic APPENDIX-F)

### 3.3.3 Image processing

- Mixture Of Gaussian (MOG)

Each pixel is characterized - by its intensity in RGB color space- in order to detect motion. Then the probability of observing the current pixel value is given by the following formula:

$$P(X_t) = \sum_{i=1}^{K} \omega_{(i,t)} . \eta(X_t, \mu_{(i,t)}, \sigma_{(i,t)}) \qquad (1)$$

where $\eta$ is given by:

$$\eta(X_t, \mu, \sigma) = \frac{1}{(2\pi)^{\pi/2} |\sigma|^{1/2}} e^{-0.5(X_t - \mu)\,\sigma^{-1}(X_t - \mu)} \qquad (2)$$

Each pixel is characterized by a mixture of K Gaussians. Once the background model is defined the MOG parameters are initialized. The first foreground detection is made and then the parameters are updated. Supposing that a background pixel corresponds to a high weight with a weak variance due to the fact that the background is more present than moving objects and that its value is practically constant. As video scene proceeds the process is repeated and the parameters are updated to detect motion ( foreground-view). [11]

- Gaussian blur

In order to apply any filter on the image, a structural element is required.

$$O(i,j) = \sum_{m,n} F(i+m, j+n)\, h(m,n) \qquad (3)$$

Gaussian kernel prioritise its center-member, and the standard deviation $\sigma$ between its elements affect the strength of the blurring process. The calculations is an example of gaussian smoothing with kernel $h$ of size (3,3) and image $A$ of size (5,4).

| | | |
|---|---|---|
| 1 | 2 | 1 |
| 2 | 4 | 2 |
| 1 | 2 | 1 |

| | | | |
|---|---|---|---|
| 50 | 50 | 100 | 100 |
| 50 | 50 | 100 | 100 |
| 50 | 50 | 100 | 100 |
| 50 | 50 | 100 | 100 |
| 50 | 50 | 100 | 100 |

Ex. Calculating for pixel at position (2,2), the result is:

$$O(2,2) = \frac{1*50+2*50+1*100+2*50+4*50+2*100+1*50+2*50+1*100}{16} = \frac{1000}{16} = 62.5$$

- ## Morphological open

Previously, it's declared that its an erosion followed by dilation process

$$A \odot B = ( A \ominus B ) \oplus B \qquad (4)$$

Where $A$ is - binary or grayscale- image and $B$ is the structural element

( $mxm$ matrix; $m$ *is odd* ).

The operation works as follows:

- let $a \in A$
- let translation $Ba$: $B$ origin at $a$

1. Dilation:
   The dilation of $A$ by $B$ is simply the set of all points $a$ such that the intersection of $Ba$ with $A$ is non-empty.

   $\forall a \in A;\ Ba \cap A \neq \phi$

2. Erosion:
   Then the erosion of $A$ by $B$ is simply the set of all points $a$ such that $Ba$ is a subset of $A$.

   $\forall a \in A;\ Ba \subseteq A$

3. The result is an image with removed imperfections ( figure - up up )

## ● EDGE EXTRACTION

In order to extract and subsequently represent the edges, two steps to be taken:

1. Detect edges using *Canny edge detector*:
   a. Noise Reduction: Using Gaussian blur
   b. Intensity gradient of the image
      Convolving with sobel operator ( kernel ) in both x and y directions:

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

      Obtaining the gradient strength & direction:

$$Edge\_Gradient\ (G) = \sqrt{G_x^2 + G_y^2}$$
$$Angle\ (\theta) = \tan^{-1}\left(\frac{G_y}{G_x}\right) \qquad (5)$$

   c. Non-maximum suppression: delete pixels that are not part of edges
   d. Thresholding:
      Applies 2 level thresholding, and consider the output:

      - $If\ G(X) \geq Upper\ threshold \Rightarrow X \in Edge$
      - $If\ Upper\ threshold \geq G(X) \geq Lower\ threshold :$
        $If\ X\ is\ connected\ to\ Y;\ G(Y) \geq Upper\ threshold\ :$

        $X \in Edge$

      - $If\ G(X) < Lower\ threshold \Rightarrow Reject$

2. Describe edges ( lines ) by applying *Hough transform*:
   Canny obtains the edges pixels. However, it is not enough to represent

edge-features of an image. Based upon that, Hough transform is used to describe each edge-point as $(\rho, \theta)$ combination. Then a histogram be built out of Hough results.

$$y = mx + b \text{ ( cartesian coordinate )} \quad (6)$$

$$\rho = x\,cos(\Theta) + y\,sin(\Theta) \text{ ( polar coordinate )} \quad (7)$$

- Using the *polar coordinate*
- let $(x_0, y_0)$ be represented by $(\rho_0, \theta_0)$
- Retrieve & plot all lines that pass through that point
- Repeat the preceding step for all points
- If 2 lines related to 2 different points intersects → They are related to the same line
- Accumulate the resulted points into a histogram

- ## HAAR-LIKE EXTRACTION

To collect haar-like features from an image, the sum of each rectangular subsection is calculated, via the equation-8. Then these sums are accumulated into a histogram to create a feature-set.:

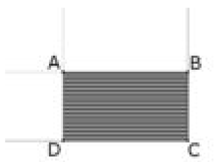



Figure [14]. Rectangular Section.

$$sum = I(C) + I(A) - I(B) - I(D) \quad (8)$$

Where $I$ is obtained by calculating the *integral-image* at each point *A,B,C,D*:

$$I_{\sum}(x,y) = \sum_{x' \leq x,\, y' \leq y} img(x', y') \qquad (9)$$

### 3.3.4 Machine learning

- **KNN**

This algorithm is considered a simple, and easy to implement. After preparing the training data set, prediction process will take the following steps:

1. Determine $K$ ( number of nearest neighbors )
2. Calculate the distance between the queried instance features and all the training samples. Distance is calculated using Euclidean formula:

$$\begin{aligned} \mathrm{d}(\mathbf{p},\mathbf{q}) = \mathrm{d}(\mathbf{q},\mathbf{p}) &= \sqrt{(q_1-p_1)^2 + (q_2-p_2)^2 + \cdots + (q_n-p_n)^2} \\ &= \sqrt{\sum_{i=1}^{n}(q_i-p_i)^2}. \end{aligned} \qquad (11)$$

3. Sort the distances & create a set $S$ -based on k-th rank- of the nearest neighbors
4. Gather category set $Y$ of the $S$ elements
5. Return the majority category of $Y$ as the prediction of the query

- **Scores**

It is recommended to have precision, accuracy, recall and F1 scores calculated for each training session, to judge the usability of the trained model. To do so, let D be the set of classes A and B, T.P and T.N denote correct classification results of A and B respectively.

While F.P and F.N  denote incorrect ones:

accuracy  determines how much close the results are to true values.

$$accuracy = \frac{T.P + T.N}{D} \quad (12)$$

And the precision is the ability of the classifier to get True judgement for class A

$$precision = \frac{T.P}{T.P + F.P} \quad (13)$$

Recall  (a.k.a sensitivity) score denotes the ratio of  obtained True judgements of A

$$recall = \frac{T.P}{D} \quad (14)$$

F1 weighted harmonic mean of the precision and recall [10]

$$F1 = \frac{2 * precision * recall}{precision + recall} \quad (15)$$

## 3.4 Engineering standards

Standards to be followed are (descriptions are in APPENDIX ):

- Mechanical:
  - ASME Y14.5M-1994: Followed in structure design
- Electrical:

- BS-1363: Followed in the motor driver circuit
- ISO/IEC JTC 1/SC 24/WG 7 : Followed in images codecs

- Industrial:
  - ISO 11161:2007: Followed in the concept of system integrability with other systems

## 3.5 Cost analysis

Table [4]. BOM.

| Item | PART NO | PART NAME | QUANTITY | PRICE ($) | SHIPPING COST ($) | DESCRIPTION | SOURCE |
|---|---|---|---|---|---|---|---|

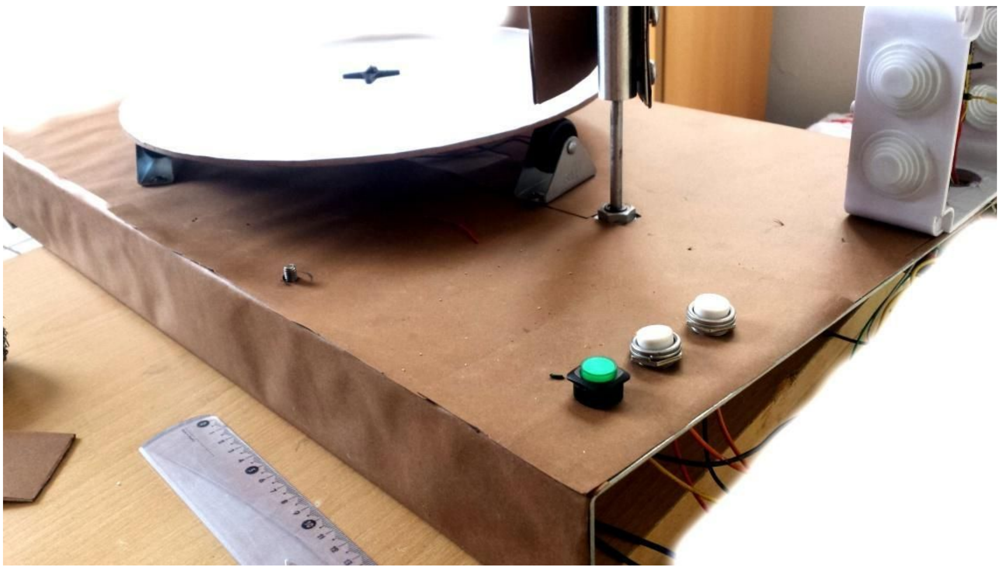
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1** | | Arduino | 1 | 6 | - | Microcontroller | Ebay.com |
| **2** | | L293D | 1 | 2 | - | H-bridge Motor Driver | Ebay.com |
| **3** | | Linear Actuator | 1 | - | - | | Dep. Mechanical Eng. |
| **4** | | Wires, sockets | | 5 | - | | Sertelektronik-magusa |
| **5** | | screws | 8 | 10 | - | | Ebay.com |
| **6** | | Stabilization wheels | 3 | 3 | - | - | Magusa, industrial area . |
| **7** | | SWITCH-SPDT | 1 | 5 | - | Slideswitch A switch that allows you to close or open a circuit permanently. | Ebay.com |
| **8** | | HD webcam | 1 | 10 | - | | Ebay.com |
| **9** | | TACTILE-PTH | 2 | 5 | | Pushbutton Momentary switches that close a circuit when pressed. | Ebay.com |
| **10** | | Motor Connector | 1 | 11 | | DC Motor Converts electrical energy into a mechanical energy, which makes the shaft rotate on it's axis. | Ebay.com |

# CHAPTER 4 - MANUFACTURING

## 4.1. Manufacturing process selection

For the manufacturing of this project, majority of the work done was by means of assembly.
Component or end item comprising of a number of parts or subassemblies put together to perform a specific function, and capable of disassembly without destruction. What may be an assembly at one point, may be however a subassembly of another.[1] In the selected design for the sorting machine, the work revolved around adjusting three main components in such a way that would run the project smoothly and assist in achieving its objective.

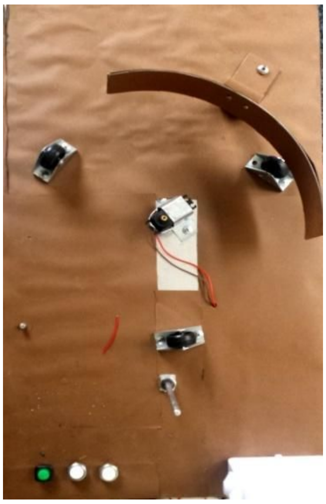
Starting off with the base component, the aluminum plate was store bought with the necessary dimensions. The remaining parts were assembled upon this plate by using generic fasteners including screws, nuts, bolts, etc. This includes the fitting of the rotating wooden table which was custom made by a local carpenter in order to satisfy the design requirements. Last but not least, the gate composed of aluminum parts that is responsible for product passage based on the received classification commands, shall be attached to the motor to gain enough power for opening and closing.



## 4.2. Detailed manufacturing process

### 4.2.1 Base

The base plate was initially a slate shaped flat aluminum plate of dimensions (600*340 mm) In order to compile the other various parts onto it, the plate we began working with had to be bent at its opposing edges by a factor of about (60 mm) with the help of a hydraulic bending machine we happened to find in a workshop abroad.



### 4.2.2 Rotating Table

For creating the round rotating table, we purchased a wooden block of length (300 mm) and breadth (4 mm) and then carried this block over to a handy woodcraft man to cut it into a circular shape using the (electric saw machine).

Figure [17]. Rotating plate.

### 4.2.3 Gate

At the very bottom and beneath the aluminum plate lays a motor from which a shaft extends. This shaft reaches up to the cylindrical rod of the arm which was formerly drilled vertically to accommodate for the shaft length inserted. The rod is also drilled such that the other flag shaped aluminum plate acting as the pathway gate which has two pin holes on its side can be screwed to it.

Figure [18]. Gate.

# CHAPTER 5 - PRODUCT TESTING

## 5.1 Verification of Project Objectives

To check whether the machine is going to fulfill the objective, the operator shall follow the protocol assigned below stepwise,

### 5.1.1 Resource Preparation

Firstly, the operator will either use an images that he/she captured or a suitable picture of the product taken from online sources such as **IMAGENET.**


Figure [19]. Image resources

### 5.1.2 Train the machine against the images

To begin with, noise filters were applied such as (erosion, Gaussian blur ...etc.).

Features are extracted using either one of the following extractors or a combination of them:

- Raw pixel
- Shape
- Haar like features
- Edge histogram features

- Hue histogram features
- Hog features

  and a vector V = [F1 F2 F3 …] was created out of the extracted features which represents the image being entered.

- ## Training session example

  - Configure settings.py ( figure 20)
    - EXTRACTORS list to use Edge & Haar-like features, this combination will give a judgement based on the object structure
    - CLASSIFIER_CORE to use KNN algorithm
    - PRE_OPERATIONS to be empty list ( no filters to preprocess )

```
CLASSIFIER_CORE = 'configs.classifiers.KNN'

EXTRACTORS = [
'configs.features.EHFE',
'configs.features.HLFE',
]

PRE_OPERATIONS = [

]
```

Figure [20]. Config file

  - Select the training datasets, with respect to their tag through the GUI ( figure - 21)

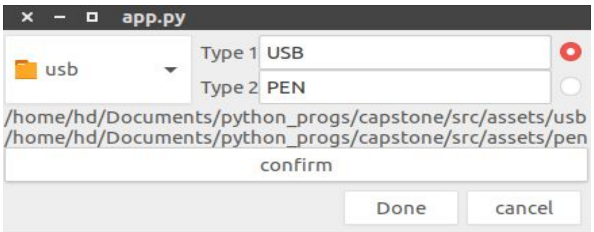



Figure [21]. Training data set selection

  - Press *Done*, then press *Train model*
  - The training process will start. At its end, a report describing the performance scores will be shown ( as in figure - 22)

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| PEN | 0.75 | 1.00 | 0.86 | 3 |
| USB | 1.00 | 0.95 | 0.97 | 19 |
| avg / total | 0.97 | 0.95 | 0.96 | 22 |

Figure [22]. Scoring report.

### 5.1.3 Test against new samples and run on spot

Once the machine is run, an object movement -on the rotating table- must be detected in the scene by applying MOG. Hence, the filtering and features extraction procedures are repeated on the exact frame where object was detected. Finally, the trained model will then predict the category suitable for that object and send the process command to the gate for opening or closing the object's path.

## 5.2 Verification of Engineering Standards

- Mechanical: APPENDX-F contains the engineering drawings, that follows the standard ( ASME Y14.5M-1994 )
- Electrical: The use of insulated wires to connect between electronic components ( BS-1363 ), as shown in the figure below
- Industrial: The overall design concept, implements the standard through the ease and safe of integrality with other systems ( ISO 1161:2007 )

# CHAPTER 6 - RESULTS and DISCUSSIONS

## 6.1. The results

In the previous section of this report discussing the project's testing operations and functionality, we mentioned using an assorted sample of products. This sample included (3 different product categories: coins, pens, USB disks). using Haar + edge as features It was noted that 3 out of 7 trails were correct output, and that result with confidence of prediction going from (60 → 85 %).However, we can make adjustments to minimize this kind of shortcomings by working on the background subtraction and noise elimination as well as estimating the best time to capture the scene.

## 6.2. The constraints

Perfection is a concept that is very difficult to achieve. Hence, the barriers to reach the utmost performance for this project are discussed as enlisted below;

### 6.2.1 Accuracy of Classification:

When selecting a sample of products, it is preferred to select rather different objects so as not to confuse the working algorithm i.e. products with relative resemblance in their features increase the chance of error as a result of false positive output.

### 6.2.2 Speed of Decision Making:

This characteristic depends on processor, algorithm, signal transmitting, controller, as well as gate motion motor speed. The rate of each of the stated speeds is expected to impact the system as a whole and have a negative impact on the decision process speed.

### 6.2.3 Complexity of Product:

Often times, the products we run on the sorting machine can have seemingly complex features. This may be in the form of texture, shape, color, etc. or any other trait that might not be very common on readable by the extraction algorithm. There by becoming one of the constraints.

### 6.2.4 Environment:

In general, the atmosphere surrounding the sorting machine, more specifically the region of interest which in this case happens to be the camera focus zone, must be in constant control by the operator so as to ensure lighting, external noise, background, etc. have little to no effect on the classification process.

### 6.2.5 Sequential Product Input

No more than one object can be read and interpreted by the machine at a time. This is due to the system gate operation design and the algorithm detection property making it a limiting sorting process.

All of the above mentioned points contribute to the constrictions for productivity. Reducing their occurrence on the other hand whenever possible would lead to a more efficient classification.

# CHAPTER 7 - CONCLUSIONS and FUTURE WORKS

## 7.1 Conclusions

Introducing ML to industrial machines is an interesting topic. Our project confirms the ability to implement ML in sorting process up to some level, and shows that challenges for obtaining good judgments. However, for now the project focuses on *proof of concept*, which reduces the importance of limitations at this stage.

## 7.2 The future works

Process reliability is the main work that would be done, that could be achieved through improving both mechanical structure and the algorithms, to accept parallel products input, the overall sorting - from software judgement to hardware response - speed. While noise elimination and supporting much more distinguishing-features shall be took into consideration.

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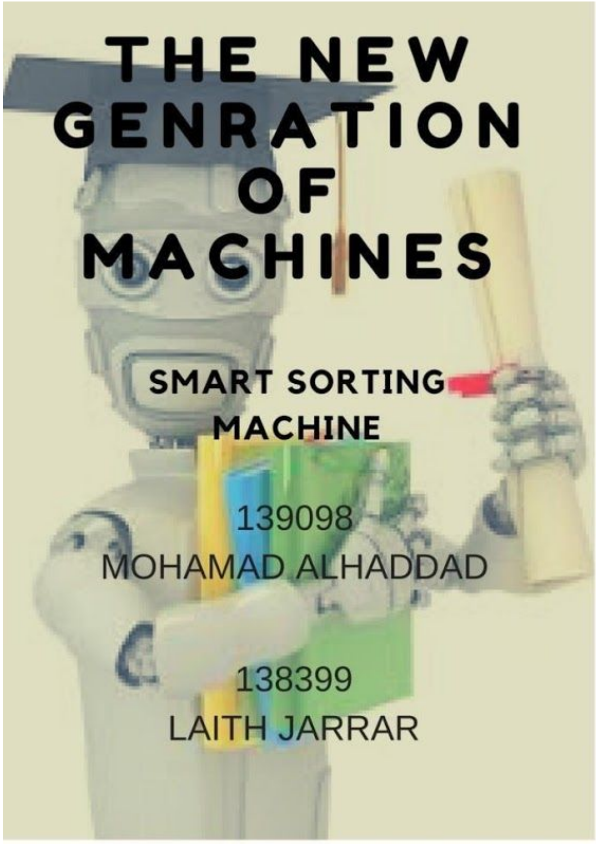
## APPENDIX A: Electronic Media





### ABSTRACT

- Sorting is a technique for organizing matter in a symmetric manner
- Sorting processes are commonly used in industrial & manufacturing fields
- Legacy sorting machines operate based on pre-specified properties to apply classifcation

### OBJECTIVES

- To Implement a cutting edge technology; Machine learning in Industrial environment
- To Improve the machine-user interface and to create a friendly platform to interact with
- To expose the importance of Computer Vision in the industry field

### FUTURE WORKS

- Enhancing sustainability in different environments
- Increasing the decision accuracy and diminishing the false classifications
- Improving the overall mechanical structure
- Supporting more complex objects. (for tenses to be coherent as in the preceding points.)

## APPENDIX B: Constraints

| | YES | NO |
|---|---|---|
| Economic | X | |
| Environmental | X | |
| Sustainability | X | |
| Manufacturability | X | |
| Ethical | | X |
| Health and Safety | | X |
| Social | | X |
| Political | | X |
| (Other (Availability | | X |

# APPENDIX C: Standards

| TS-EN Drawing Standard | Technical Drawing Standard |
|---|---|
| BS-1363 | Requires that all power pins, are partially insulated. However, earth pins must be solid brass, or, in the case of plugs intended solely for use with non-earthed devices |
| ISO/IEC JTC 1/SC 24/WG **7** | Image processing and interchange |
| ISO 11161:2007 | Integrated manufacturing systems, it deals with safety of interconnection between machines and components |

# APPENDIX D: Logbook

| | |
|---|---|
| 11/10/2016 | Meeting with the supervisor to talk about the selected capstone project |
| 13/10/2016 | Group members meeting to gather information about capstone project |
| 13/11/2016 | Preparing the abstract of the project |
| 18/11/2016 | Meeting with supervisors to discuss the project purpose |
| 18/11/2016 | Group members meeting to select an appropriate name for the project |
| 20/11/2016 | Preparing chapter 1, the introduction of the project |
| 25/11/2016 | Meeting with supervisors to discuss the introduction and literature review |
| 2/11/2016 | Getting started with Computer vision and openCV library |
| 7/12/2016 | Learning simple environment enhancement through image processing |
| 11/12/2016 | Learning simple feature extraction and key-points localization |
| 12/12/2016 | Learning key-points matching between similar images |
| 13/12/2016 | Meeting with supervisors to show project progress |
| 15/12/2016 | Designing simple mechanical structure to for the system |
| 22/12/2016 | Meeting with expert, to get feedback about the mechanical design |
| 15/01/2017 | Designing system algorithm |
| 20/01/2017 | Contacting an expert, to get feedback about the software design |

| | |
|---|---|
| 21/02/2017 | Implementing system code using python programming language |
| 25/03/2017 | Refactoring code and testing against static images |
| 05/04/2017 | Mechanical structure manufacturing |
| 07/04/2017 | Meeting with supervisors to show project progress |
| 28/04/2017 | Mechanical structure manufacturing |
| 15/05/2017 | Electrical circuit designed |
| 18/05/2017 | Electrical circuit implementation |
| 19/05/2017 | Testing on real product scenario |
| 14/05/2017 | Learning about classification optimization |
| 20/05/2017 | Finalizing report |
| 21/05/2017 | Finalizing report |

## APPENDIX E: Project Timeline

| Task | Duration ( Days ) | Start | Finish | Assigned to |
|---|---|---|---|---|
| Project selection | 7 | 10/11/2016 | 17/11/2016 | Mohamad & Laith |
| State the objectives | 3 | 20/11/2016 | 23/11/2016 | Mohamad & Laith |
| Supervisor discussion | 20 meetings | 25/11/2016 | 15/05/2017 | Laith & Mohamad |
| Computer Vision Research | 90 | 5/12/2016 | 4/03/2017 | Mohamad & Laith |
| Automation Research | 3 | 7/12/2016 | 10/12/2016 | Laith |
| Sorting methods research | 90 | 10/12/2016 | 9/03/2017 | Mohamad & Laith |
| Machine learning research | 90 | 7/12/2016 | 26/03/2017 | Mohamad & Laith |
| Environment choose | 7 | 01/04/2017 | 08/04/2017 | Mohamad & Laith |
| First work-flow draft design | 3 | 20/11/2016 | 23/11/2016 | Mohamad & Laith |
| System architecture design | 1 | 24/11/2016 | 25/11/2016 | Mohamad & Laith |
| Second work-flow draft design | 3 | 12/04/2017 | 15/04/2017 | Mohamad & Laith |
| Mechanical design first draft | 1 | 20/11/2016 | 21/11/2016 | Mohamad |
| Mechanical manufacturing | 15 | 01/05/2017 | 20/05/2017 | Mohamad |
| Electronics ordering | 45 | 11/11/2016 | 27/12/2016 | Laith |
| Software modules selection | 60 | 7/12/2016 | 07/02/2017 | Mohamad |
| System algorithm implementation | 90 | 7/12/2016 | 11/04/2017 | Mohamad |
| Overall optimization | 50 | 10/04/2017 | 20/05/2017 | Mohamad |
| Circuit design | 3 | 15/05/2017 | 18/05/2017 | Laith |
| Circuit prototype | 1 | 18/05/2017 | 19/05/2017 | Laith |
| Circuit manufacturing | 2 | 19/05/2015 | 20/05/2017 | Laith |
| Testing | 80 | 01/02/2017 | 25/05/2017 | Mohamad & Laith |

# APPENDIX F: Engineering Drawings

Circuit schematic