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Abstract

<TODO: 1 page>

# Introduction

**Feedback Dio & Dimi:**

TODO1: Begründung warum kein “einfaches” Color-Filter verwendet; warum keine vorgeschobene Bilderkennung via computer vision => Grund: Zusammenführung von Shape / Size und Farberkennung in einem Model / einer App

TODO2: Farbe-Reifegrad / Zuckergehalt Korrelation darstellen und z.B. Farbabstufungen auf Papier ausdrucken, damit der Leser dies mittels bereitgestellter App auch direct testen kann

TODO3: aus dem aktuellen Reifegrad Empfehlungen ableiten für:

1. die weitere geeignete Verwendung bzw. Verarbeitung (z.B. Verkochen, Drink / Mixer, direkter Verzehr) sowie
2. zur voraussichtlichen weiteren Haltbarkeit (i.S.v. „MHD“)

## Initial Problem

In real-world, detection of ripeness / maturity of banana-fruits in real-time

Target groups:

* industry
* retailer,
* end users,
* persons with disabilities (e.g. red-green deficiency) or sugar intolerances (e.g. diabetes)

## Proposed Solution

BananaCo – Banana colour: Detect objects or rather bananas via image recognition and output result, so that users get a definite statement on the ripeness.

# Bananas

## Introduction

“BANAN” which means finger, from Arabic word the word BANANA originated.

Banana crop is a commercial and economical crop. In the genus Musa there are five main taxonomies. Out of five two consider as edible Bananas. In general, a distinction must be made between plantains and fruit-bananas.  Banana belongs to Musa family. Scientific name for plantains *Musa paradisiaca.* Musa acuminata, is most cultivated banana. The largest herbaceous plant is the banana plant. The two types can be differentiated by its texture and taste. Plantains are starchy and less sweet. They cannot be edible raw rather it has to be cooked before consuming.

In the context of BananaCo project, only the latter is taken into consideration. Although, exact origin of Banana is unknown, some of the research stated that it is originated from Indo-Malaysian region. However, both type of banana originates from tropical regions, predominantly in Africa and South America. They originate from subtropical too. Best suited for warm, costal climate. While fruit-bananas are edible instantaneously, plantains require to be cooked initially to be palatable.

Opposed to fruit-bananas, plantains are rather angular and thicker. In addition, plantains are coloured pale-yellow, grey or cream; once ripe they are characterised by a violet or black peel. Banana peel colour is to be considered as the first quality parameter evaluated by consumers. In fact, the external condition correlates well with its internal, physical and chemical changes during the ripening process. Commercial bananas are plucked and packed when they've grown enough but are still green. These bananas are stored or transported in air tight room or container. These bananas release ethylene gas when they are ripening. This will speed up the production of enzymes that change, texture, colour and flavour of the banana.

Some facts about the ripeness of banana:

* Under ripe bananas have less sugar
* Overripe bananas are good for digestion since it is easier to digest.
* Over ripe brown pigmented banana has antioxidants
* Since starch has broken down into sugar, overripe banana is sweeter than the just ripe bananas.
* Since bananas rich in fiber, it may lead to gas, stomach pain, stomach cramps.
* In some people banana might trigger migraines.

The Banana co application shall support to find out the ripeness. Different category people get benefit according their need. For instance, the people who would like to lose weight could consume under ripe banana which is less sweet in taste. Whereas the people suffering from heart disease might like to have over-ripe banana. To detect the different ripeness level easily the application will support the people.

## Background

Commercial bananas are plucked and packed when they've grown enough but are still green. These bananas are stored or transported in air tight room or container. These bananas release ethylene gas when they are ripening. This will speed up the production of enzymes that change, texture, color and flavor of the banana.

Banana can be easily consumable and have lots of health benefits with its richness in antioxidants, vitamin B6, minerals like potassium. It is good for overall healthy and especially healthy for strengthen your bone, reducing digestion problems, vision improvement etc. It is natural source of potassium to human body.

The maturity stage of fresh banana is important in marketing, for both, industry and dealers as well as end consumers. In early ripening stages, banana fruits synthesize compounds such as alkaloids and tannins, making the fruit taste bitter and astringent. In progressing stages of growth, the fruit incorporates water, sugars, starches, acids and vitamins.

The banana peel green because chlorophyll molecules break down enzymes. The bananas appear golden yellow colour when the green pigment of chlorophyll is destroyed. An amylase enzyme is responsible for breaking down the starch into glucose hence bananas become sweet. The pectinase enzyme breaks the cell walls in the fruit which makes bananas soft. The softness of banana increases as it ripens more and more which leads banana discolouring or blackening. Contusion is caused by polyphenol oxidase enzyme which also increases the oxidation. Generally, it is applicable to peel, but it also effects the flesh of the fruit in case of deep bruising. Present days there are recognized seven ripening stages of banana. All stages are purely based on the colour of the peel. Peel colour of banana is considered as preliminary quality parameter by the buyer.

Since many years, to classify the fruit ripeness, variation in respiration of fruit during the ripening stage was crucial factor. Particularly, the colour development time has changed for many fruits in relation to climacteric peak. It is considered that Ethylene concentration is one of the crucial factor not only for banana but also other fruits for the ripening.

The taste also varies as color changes. Peel color golden yellow to light brown could be considered as best flavor and texture.

Ripening process could be speed up by increasing the ethylene gas concentration. This could be done by covering loosely unripe bananas.

In the meantime, banana fruit turns from green to yellow, then from yellow into yellow with brown spots. Finally, starch and acid contents decrease, while sugar increases; alkaloids and tannins disappear, aromas develop. The calorie content however remains the same, independent of the degree of maturity.

“To ensure the productivity, competitively, quality standards, and reliability of banana fruit products, automatic image processing tools based upon intelligent techniques are paramount over visual features methods.” [Mazen2019]

As per the “ [Jaclyn London, MS, RD, CDN, Good Housekeeping Institute](https://www.goodhousekeeping.com/author/11834/jaclyn-london-ms-rd-cdn/) and Caroline Walder[Sep 25, 2018]” Nutrition content in one ripen banana:

* 105 calories
* 27g carbohydrates
* 1g protein
* <1g total fat
* 0g saturated fat
* 3g fiber
* 14g sugar
* 422mg potassium (12% DV)
* 32mg magnesium (8% DV)
* 10.3mg vitamin C (17% DV)
* 0.433mg vitamin B6 (20% DV)

## Maturity assessment

### General criteria

To detect and classify bananas, certain criteria need to be examined which will be provided subsequently. In theory, one can use several aspects to determine the maturity of fruits in general and bananas in particular, encompassing:

* size / shape,
* peel texture features,
* degree of hardness (e.g. hard or soft),
* starch / sugar proportion,
* smell,
* flavour (e.g. blunt, sweetish, sweet) and, of course the
* peel colour (e.g. green vs. yellow vs. brown).

Hence the ripeness is categorized on the basis of color of ripeness stages, it is difficult to distinguish between one stage ripeness to another. The color does not vary much from third to fourth, fourth to fifth, fifth to sixth stage. Therefore, banana co application uses only three stages of banana rather than seven stages.

Bananas can also be classified by its size. There are different types of banana. Peel thickness also varies as type varies. Fruit-banana breeds vary with the size. \*Some studies provide information about determining the banana size using automatic algorithm derives on computer vision. The banana images are processed in three stages. According to [[Meng-Han Hu](https://www.tandfonline.com/author/Hu%2C+Meng-Han),[Qing-Li Dong](https://www.tandfonline.com/author/Dong%2C+Qing-Li)] the report,

The specific objectives of this work were:

(1) to detect the pedicel location

(2) to test the performance of the Five Points Method which is the key sub-algorithm of the automatic measurement algorithm

(3) to determine the three size indicators of bananas using computer vision and to compare the performance of three different methods.

They concluded, the automatic algorithm was acceptable for banana size determination.

But in Banana co application we would like to implement image processing technique. Collecting the data from internet and processing the image color was the basic idea behind the application. Around three hundred images collected to test the application.

The basic structure of any fruit or vegetable is its texture and color and shape. Using these feature play an important role in visual perception. By extracting the useful spectral property of the image and matching them best with the set of known predefined classification model color classification can be done. An application with combination of both texture and color features is very demanding and helpful in the food industry.

Some of the challenges and limitations that may arise in fruit detection.

* That are recognizing the fruit based on the size. If the fruit shape is completely different then it might not be a problem. But the shape is alike then it might cause some problem. In classification algorithm it is possible to reduce the effect of identical shape problem.
* Color recognition itself might a challenge or a limitation. In the application only fruit-banana is used to train the system. But if the customer would like differentiate between fruit-banana and plantains then the application might not produce the correct result.

### Visual criteria

In literature, a lot of methods developed for ripeness classification involve *colour moments* and *colour histogram*. Also, the variance of RGB (Red Green Blue) or HSV (Hue, Saturation, Value) colour spaces of the banana fruit have been utilised for analysis. According to [Mazen2019], the classification of banana fruits as under-mature, mature and over-mature reached an accuracy of 99.1 %.

Visual inspection by humans may underlie subjection and is tedious as well as time-consuming and labour-intensive. Utilising instruments such as colorimeters provide the advantage of accurate and reproducible measurements but require quite unique surface colours. Additionally, several sample locations are required to product representative results.

BananaCo on the contrary focuses onto automated visual, i.e. image recognition using smartphone cameras. Also, computer aided analysis techniques are utilised, offering objective measurement and mitigating deficiencies of manual visual and instrumental techniques. Suitable aspects for visual detection include:

* size / shape,
* peel colour,
* development / mottle of brown spots and
* analysis of peel texture features.

The Banana Co application can be used for different purposes. Some of them are explained below:

* To detect the defect fruits in the food industries. In food industry it is difficult to find the defect fruits from the lot. This process needs lots of human resource and time consuming. To automate the defect detecting process this application can be used.
* To classify the fruits, the application can be used. Till recent year, food grading is also one of the time consuming and manual process. Whether it may be farmers, food industries or supermarkets grading the food for different application involves lots of manual work. By using the application, one could easily differentiate the food according to its grading. It can be installed in the smartphones and it could be used without any additional components. To capture the image of the fruit phone cameras which is embedded in the phone shall be used.
* The consumer could use it to check the fruit quality. Bananas color from green to yellow, to pigmented yellow, to brown. According to their need, people could use the app to detect the stage of banana. Elderly people face difficulties because of the poor vision. The application could assist them to recognize and buy the right choice.
* The application could be used to educate down syndrome people/children, blind people or some other special challenged people. Often down syndrome people could only understand particular pattern. This app result could be used to train them in pattern recognition.
* In supermarket this application could be used to label the fruit.

## Classification and Feature Selection

* Regarding literature, one encounters most approaches in classifying the maturity level of fruit-bananas to be based on at least five, more frequent seven[[1]](#footnote-1) or even 15 stages. In the scope of BananaCo project, the smartphone camera is used to scan fruits and determine their maturity based on visuals. To limit the complexity within the boundaries of the project, the granularity is initially limited to subsequent three ripening stages with according feature aspects (table 1):

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| * Class | * Peel colour | * Maturity stage | * Feature Aspects | | |
|  |  |  | * Stern | * Fruiting body | * Tip |
| * 1 | * green | * unripe | * green | * green | * green |
| * 2 | * yellow | * ripe | * yellow | * yellow | * brown |
| * 3 | * brown | * overripe | * brown | * brown, at least 50 % of peel surface | * brown |

Table 1: Maturity categories

## Methodology

The criteria listed before is used later to manually categorise banana images acquired from the internet into three maturity stages (unripe, ripe, overripe, cf. figure 2), thus creating data sets. These images will then be labelled and fed into the computer vision / neural network, serving as training data.



unripe ripe overripe

Figure 2: Banana ripe stages as used for BananaCo classification

# Neural Network

## Introduction

My text…

## Methodology

My text…

## Operating Principle

My text…

# Graphical User Interface

## Mock-up

My text…

## BananaCo App UI

My text…

.

# Operating Principle

## Introduction

My text…

## Flowchart

My text…

# Conclusion

* Expected results vs. actual
* Prediction accuracy
* Chosen methodology
* Computer vision vs. manual / instrumental
* Possible extensions / improvements
* outlook

Appendix

List of abbreviations

|  |  |
| --- | --- |
| **Abbreviation** | **Explanation** |
| BananaCo | “Banana colour”, the title of the project related to the undertaking of recognising the ripeness of fruit-bananas with the help of computer vision … |
| HSV | Hue Saturation Value colour model |
| RGB | Red Green Blue colour model |
|  |  |

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Template:

* template: \_ws5\_listing
* Listing
* Figure

Number

1. template: \_ws5\_number
2. number a
3. number b[[2]](#footnote-2)
4. number c[[3]](#footnote-3)

Template of figure: \_ws5\_figure

Figure 1: Sample Figure

1. According to [Mendoza2005], seven stages are recognised in the context of trading: stage 1: green; stage 2: green, traces of yellow; stage 3: more green than yellow; stage 4: more yellow than green; stage 5: green tip and yellow; stage 6: all yellow and stage 7: yellow, flecked with brown. [↑](#footnote-ref-1)
2. [footnote 1] [↑](#footnote-ref-2)
3. [footnote 2] [↑](#footnote-ref-3)