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Real-World Smartphone Sensing

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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

The word *banana* originates from “BANAN”, the Arabic word for “finger”. Banana crop is a commercially and economically used crop. In the genus *Musa*, there are five main taxonomies. Out of five, two are considered as edible bananas.

In general, a distinction must be made between plantains and fruit-bananas. Plantain banana belongs to the Musa family, having the scientific name *Musa paradisiaca.* *Musa acuminate* is the most cultivated banana. The largest herbaceous plant is the banana plant. The two types can be differentiated by their texture and taste. Plantains are starchy and less sweet. They are not edible in raw form but rather must be cooked before consuming.

In the context of BananaCo project, only the latter is taken into consideration. Although the exact origin of Banana is unknown, some of the research stated that it originates from the Indo-Malaysian region. However, both types of banana originate from tropical regions, predominantly Africa and South America, also from the subtropics and are 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 have grown enough but are still green. These bananas are stored or transported in air tight room or container and 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:

* underripe bananas contain less sugar;
* overripe bananas are good for nutrition, since they are easier to digest;
* overripe brown pigmented bananas have antioxidants;
* overripe bananas are sweeter than just ripe bananas, because starch transformed into sugar;
* due to bananas being rich in fibre, it may lead to flatulence, stomach pain and cramps;
* in some cases, banana consumption may trigger migraine.

The BananaCo 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

Bananas may be consumed easily and have lots of health benefits with their richness in antioxidants, vitamin B6 and minerals such as potassium. The consumption of bananas is good for the overall health. It is especially healthy regarding the strengthening of bone structure, reduction of digestion problems, improving vision, and so on. Also, it is a natural source of potassium supplier to the human body.

The maturity stage of fresh banana is important in marketing, for both, industry and dealers on the one hand as well as end consumers on the other hand. 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 is green due to the internal process of chlorophyll molecules breaking down enzymes. Bananas appear in a yellow, golden 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, leading to banana discolouring or blackening. Contusion is caused by the polyphenol oxidase enzyme which also increases the oxidation. In general, it is applicable to the peel, but it also affects the flesh of the fruit in case of deep bruising. At present days, seven ripening stages of bananas are recognized. All stages are purely based on the colour of the peel, which is considered as preliminary quality parameter by the buyers as well.

Variation in respiration of fruit during the ripening stage was a crucial factor since many years in classifying the fruit ripeness. Particularly, the colour development time changes for many fruits in relation to their climacteric peak. It is considered that ethylene concentration is one of the crucial factors for ripening, not only for bananas but also other fruits as well.

The taste also varies as colour changes. A banana fruit with a peel colour of golden yellow to light brown could be considered having the best flavour and texture. The ripening process itself can be speed up by increasing the ethylene gas concentration in the storage room. This can be achieved by covering loosely, unripe bananas.

In the meantime, the 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]

According to *London and Walder*[[1]](#footnote-1), the nutrition content of a ripe banana comprises:

* 105 calories,
* 27g carbohydrates,
* 1g protein,
* < 1g total fat,
* 0g saturated fat,
* 3g fibre,
* 14g sugar,
* 422mg potassium (12 % DV [daily vitamins]),
* 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 based on the colour of ripeness stages. It is difficult to distinguish between one stage ripeness and another. The colour does not vary much from the third to fourth, fourth to fifth and fifth to sixth stage. Therefore, BananaCo application uses only three stages of banana ripeness rather than seven stages.

Bananas can also be classified by their size. There are different types of banana. Peel thickness also varies with banana types. Fruit-banana breeds vary with the size as well. Some studies provide information about determining the banana size using automatic algorithm derived from computer vision. Banana images are processed in three stages.

The specific objectives of [Meng-Han2015]’s work was:

(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.

The report concluded that automatic algorithm for banana size determination was acceptable. But in the BananaCo application, an image processing technique is aimed to be implemented. The basic idea behind the application was to collect data from the Internet and process the image colours. Around three hundred images were collected to train and test the application.

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

Some of the challenges and limitations that may arise in fruit detection are recognizing the fruit based on the size. If the fruit shape is completely unique, it might not be a problem. But if the shape is alike others, then it might cause some problems. Using classification algorithms, it is possible to reduce the effect of identical shape problem.

Colour recognition itself might be a challenge or a limitation. In the application only fruit-bananas are used to train the system. In case the customer would like to differentiate between fruit-banana and plantains, then the application might not produce the correct, i.e. expected result.

### Visual criteria

In literature, a lot of methods that have been 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 produce representative results.

BananaCo on the contrary focuses onto automated visual, i.e. image recognition utilising cameras integrated into smartphones. Also, computer aided analysis techniques are used, 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 BananaCo application can be used for different purposes, some possible use cases are described in detail below:

* To detect defected fruits in the food industries. In food industry, it is difficult to identify damaged fruits from the lot. This process needs lots of human resources and is quite time consuming. To automate the defect detecting process, the application at hand can be used.
* To classify the fruits, the application can be used. Till recent year, food grading is also one of the most time consuming and manually carried out processes. Whether it may be farmers, food industries or supermarkets grading the food for different application, a lot of manual work is involved.

By using the application, one could easily differentiate the food according to its grading. It can be installed on smartphones and it then used without the need of any additional components. To capture the image of the fruit, the embedded smartphone camera shall be used.

* The consumer could use it to check the fruit quality. Bananas colour ranges from green to yellow, pigmented yellow and brown. According to their needs, people could use the app to detect the ripeness stage of the banana fruit. Elderly people face difficulties because of the poor vision. The application could assist them in recognising the best fruits.
* Furthermore, the application could be used to assist and educate people suffering from disabilities such as Down syndrome, blindness or some other specially impaired and / or challenged people.

For example, people suffering from the Down syndrome, often have trouble understanding certain patterns. The results produced by the app could be used to train them in pattern recognition.

* Finally, in the retail sector, the application could be used to label banana fruits (e.g. in supermarkets).

## 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[[2]](#footnote-2) 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, min. 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

Possible content / ideas:

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

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Appendix

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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 |
| DV | Daily vitamins |
| HSV | Hue Saturation Value colour model |
| RGB | Red Green Blue colour model |

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2. 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-2)