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Exotic Fruit Ripening Based on Optical Characterisation

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Abstract Re-sellers and customers in super markets expect perfect quality fruit in terms of ripeness, sweetness, taste and a lack of inner and outer defects. Especially exotic fruits provide many challenges due to long transport routes and the logistics of ripening processes. Optical characterisation of the fruits could help ensure the required quality. A combination of visual and infrared light evaluation techniques allows the measurement of quality parameters that support the control system of the reseller's store and the delivery logistics to the super market. For the inspection of chemical fruit characteristics (e.g. dry matter, sugar content), a hyperspectral near-infrared sensor is used. Additionally, an RGB camera is responsible for the visual defect analysis. Based on this measurement principle, a ripening control machine was developed and tested in daily business, successfully.

Keywords Exotic fruits ripening, hyperspectral imaging, Sherlock Food Analyzer

1 Introduction

During the last years the demand of ripened mangos and avocados rose significantly because shops offered more and more „Ready to eat“ products. In former times the consumers found mostly unripened fruit and tried to achieve ripeness by simple methods at home. In most cases the result was unsatisfactory, keeping the consumption demand on lower levels. In order to improve the situation, some fruit traders started their own ripening processes. The result was an explosion of sale quantities. The company Frutura GmbH [1] has long-time experience in ripening of bananas, leading to the idea of following the ripening trend. After these ripening processes, the result was often an uneven product with several defects and sorting had to be done manually. The market did not yet provide proper sorting equipment for these types of fruit. The Austrian company Insort [2] was selected as project partner, developer and producer of a new kind of sorting machine.

Characterisation of Exotic Fruits In order to deliver perfect exotic fruits, in the appropriate ripening stage, a few requirements have to be met. For mangos, size and weight have to meet a defined range and should be sorted in respective quality classes. The right water content (moisture, dry matter value) and sugar concentration (Brix value) have to be met to ensure a tasty and sweet fruit. The visual appearance of the fruit should have a ripe color and lack damages caused by rot or diseases. The peel should be free of cosmetic defects or bruises. In case of avocados, the oil content given by the dry matter value is the essential quality parameter. These parameters are typically measured on single fruit samples offline in a lab using e.g. destructive sample preparations and high measurement times in the range of a few minutes per fruit. In this project, a nondestructive inline measurement method was required reaching measurement speeds of 5000 mangos per hour on a conveyor belt with a velocity of 1 m/s.

2 Ripeness Sorting Using the Sherlock Food Analyzer

The basic instrumentation idea for the development of a ripeness analyser/sorter was the use of an optical system as an inline measurement device, the Sherlock Food Analyzer (see left image in 2.1). Additionally, in order to bring the fruits to the line of inspection, mechanical infeed machinery is required. Due to the necessity of double sided analysis for proper fruit quality inspection, a turning station was introduced in combination with a second Sherlock Food Analyzer. After analyzing the fruits on the conveyor belt, the Sherlock Food Analyzer acts as a control device capable of piloting appropriate eject mechanisms for quality class sorting.

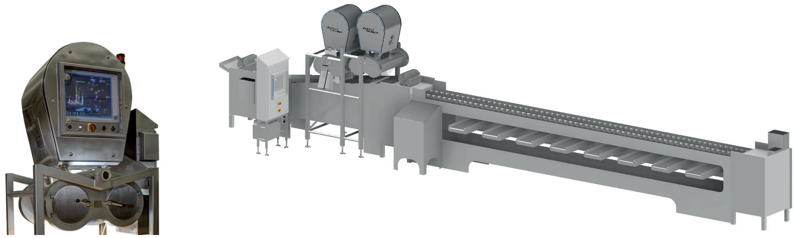

Figure 2.1: Ripening sorter using Sherlock Food Analyzer and eight ejection units.

2.1 Components of the Sherlock Food Analyzer

In order to understand the measurement concept and the idea of the instrumentation, a short introduction to the capabilities and key elements of the Sherlock Food Analyzer will be given in the following paragraphs.

Measurement Principles for Analyzing The device is based on the optical characterisation of food products by means of light spectroscopy over a broad range of wavelengths. On one hand the hyperspectral imaging camera measures light information in the near infrared range, therefore gathering data results on the chemical structure of the product. On the other hand, an RGB camera uses the range of visible light and evaluates visual appearance of the products. In both wavelength ranges line scan cameras are implemented as push broom applications. Regarding the data acquisition, a false color coding method (Insort branding: *CIT*, Chemical Imaging Technology) is used. This means that after a manual modelling step, by means of software, the spectra of the NIR camera are classified and color coded according to class characteristics. In order to have a common software interface, false color coding is also used for the RGB camera images, highlighting visual characteristics of the fruit.In case of the RGB camera, a qualitative approach is used. Product defects are coded in desired colors based on categories: Good product (e.g. green) or product defects (e.g. red, violet). This coding is then used within the operating software in order to evaluate type, count and area of defects on each fruit. The hyperspectral camera has two modes available for analyzing spectral information. The already mentioned qualitative approach distinguishes between the spectra of the good product in contrast to product defects, which typically differ in chemical composition. Based on this model a false color picture is generated and evaluated by software inline and in real-time. An additional and very important method provided by the hyperspectral camera is the so-called quantitative approach. Based on the reflected light intensity in the selected wave length range (region of interest, ROI), a regression model is established which brings the reflected light intensity in correlation with the laboratory analysis of the chemical components' concentration (e.g. moisture, dry matter). Hence both camera types transfer false color pictures inline and in real-time to the evaluation software.

Optical and Mechanical Sensors The key element in this optical characterisation project is the hyperspectral camera. The near infrared camera *EVK Helios G2* [3] provides 320 pixel spatial resolution and 240 wavelengths per pixel in the range from 900-1700 nm. The line scan camera works in a push broom application and transfers the classified spectra, coded as false color RGB pictures, by means of Ethernet: GigE protocol. The camera needs a model upload upon initialization, together with basic parametrizations (e.g. frame rate). The modelling software *SQALAR* [4] enables the user to generate the model for the fruits and to update the camera.
The used RGB camera [5] provides 2048 pixel and also works in line scan mode. Utilizing a qualitative model, this camera determines fruit size and color defects. The qualitative classification is additionally optimized for black or dark spot area measurement and visible bruise detection. By means of the software *Falco* [6], a false color model is generated and executed on the analysis computer during runtime .
A weight measurement cell [7] is implemented as part of the mechanical infeed system. The load cell is placed after the optical inspection section and before the ejection system. The fruits, placed in cups,

are transported over the load cell and the derived online measurement value is transferred to the analyzing software. The load cell provides an analogue current interface evaluated by a PLC [8]. After calculation and filtering, the fruit weight reading is transferred to the PC by means of an Ethernet connection. The challenge of the weight measurement is the fact, that the fruits in the cup are moving over the weight cell without stopping. In order to get a correct reading (+/- 2 gram), an adaptive filtering algorithm is necessary to flatten the measurement peak occurring in the moment the cup touches the weight cell with a velocity of 1 m/s.
Another important sensor in the system is the rotary encoder placed on the conveyor chain. Based on this sensor and the appropriate parametrization, the distance between the line of inspection, the weight measurement and the ejectors is determined. The interface from this central position encoder is connected to the PLC. Based on the PLC-PC Ethernet communication the detection of objects (fruits) in the line of inspection and the control of weight measurement and ejector actuating is synchronized.

Illumination Regarding the two types of optical cameras used, two different kinds of illumination are necessary.

On one hand, there is the need of broad band illumination for the hyperspectral camera implemented by means of halogen lamps and a reflector encased into an air cooled steel housing. This illumination is focused onto the line of inspection in order to provide sufficient light for optical evaluation. The fruits reflect this light to the hyperspectral camera enabling spectroscopic evaluations.

On the other hand, additional light in the visible range is needed for the high resolution RGB cameras. A white LED is therefore used to enhance the amount of light in the line of inspection. In order to support the applied machine vision algorithm for the detection of fruits (background segmentation), the conveyor rollers are kept in a unique color (blue). By means of blue light LED illumination, the background of the rollers is filled up homogeneously (see 2.2).

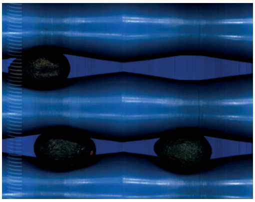

Figure 2.2: Blue conveyor rollers and the active blue LED background.

2.2 Mechanical Infeed for Optical Inspection and Ejector Units

The way of a fruit from the store to one of the eight quality category outputs is controlled by a complex conveyor system. At the entrance the fruit boxes are unloaded and the fruits are transported to an elevating conveyor in order to reach the height of the inspection line. Next, a short conveyor is used to separate the fruits in order to only carry two fruits at once onto the following rollers of the conveyor. The rollers section is used to transport the fruits to the line of inspection of the first Sherlock Food Analyzer. The fruits are detected by the camera system and their path is tracked and calculated in order to synchronize the following steps of the infeed process. The next step is the rotating part of the conveyor where the rollers are used to turn the fruits for the inspection of the rear side at the position of the second Sherlock Food Analyzer. After this inspection step, the fruits are transported to cups. By means of the rotary encoder, the position of the cups is calculated and the weight is measured on the fly in the moment the cup touches the integrated load cell.

Now the analysis PC has to evaluate the sensors and derive the necessary criteria for ejecting the fruit in one of the eight quality outputs based on the implemented rule engine. Again, the position of the electro-mechanical ejectors is derived from the rotary encoder and the rule engine's results. Boxes at all outputs are prepared for receiving the analyzed fruits.

Figure 2.3: Infeed to the Sherlock Food Analyzer with Conveyor System and Ejection Unit.

2.3 Object Analysis and Measurement Quantities

The analysis of fruit is conducted in the context of a so-called sorting program. A sorting program stores all parameters necessary for optical characterisation of the dedicated fruit. Not only different fruits are selectable but, in case of different optical characteristics, selections for different varieties of the fruit are available. In addition to that, the sorting criteria of the implemented rule engine are part of this program.

In terms of optical characterisation there is a distinction between the evaluation on the hyperspectral camera and the RGB image analysis. Nevertheless the results of both will be combined by software and treated as an abstract data structure called: object. The attributes of this object are the physical quantities measured. In the moment an object is generated, the position of the fruit is determined by the position of the rotary encoder. The offset due to calculation time is corrected and the values are then used to determine the position of the fruit on the conveyor. Regarding the measurement of damages and diseases, the amount of pixels and the size of areas in a certain false color coding combined with mechanical parameters (distance, conveyor speed) lead to classification into a certain category.

The false color coding for the RGB pictures is related to the visual optical appearance. Characteristics to be analyzed are: Several diseases, rot, scars, outer bruises, dark spots, color class, size. In a manual parametrization step, classes are generated from the RGB recordings for these categories and coded in different colors using the offline software (Falco). In contrast to this, classification of chemical character-

istics is conducted with the hyperspectral camera images. Quantities to be measured are: Sugar content mango (BRIX, precision <1° Brix), dry matter (%, precision +/- 1%) an inner bruises (mm^2).
In order to reach the demanded quantitative measurement quality, a calibration process followed by a validation step is necessary to generate a linear regression curve. In a first step, a selection of fruits is analyzed in the line of inspection to derive their spectral information. Then, samples are taken from these fruits at distinct surface positions. After packaging and identifications, these samples are sent to the food lab to be analyzed in terms of sugar concentration and moisture. By means of the parametrization software, the concentration values of the fruits are correlated to the magnitude of the reflected spectra in the region of interest.

Hence, a linear regression model is established, ready to be sent to the hyperspectral camera for the following validation step. New fruits are analyzed with the generated model in order to check the quality of the model in terms of accuracy.
For geometrical measurement calibration (e.g. length, area) an object with known dimensions is analyzed at the line of inspection to adjust the size parameters. Typically, the width of the infeed is given by the conveyor dimensions, but the adjustable product speed has an big influence on the image of a line scan camera. Hence, geometric corrections have to be prepared for the particular sorting program.

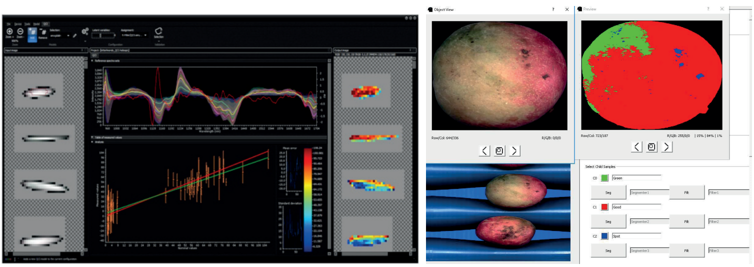

Figure 2.4: Software Tools: Hyperspectral modelling - Sqalar (EVK) and RGB color classification with Falco (KestrelEye).

2.4 Analysis Software

The used software has to fulfill several tasks to enable ripeness sorting. It starts with the data acquisition from two hyperspectral and two RGB cameras located in the Sherlock Food Analyzer. This is done via Ethernet connection and the GigE protocol. The false color pictures are transferred from the network card to the computer's memory. With the availability of the accessed pictures, the next data processing step takes place: background segmentation. Upon successful segmentation, the objects (fruits) are extracted from the conveyor background. As soon as an object is generated, the synchronisation with the conveyor for positioning is started. Now the geometrical and color-based attributes are calculated in order to obtain false color images. This process is repeated on the second Sherlock Food Analyzer after rotating the fruit. Additionally, special algorithms called classifiers are used for the detection of further object attributes (e.g. black spots). Last but not least, the weight of each fruit is derived from the load cell and added to the fruit attributes.
Now all the needed measurement values are available to make the quality decision. The decision making parameters and thresholds are configured by means of the graphical interface of the implemented rule engine. The operator is in charge of selecting the appropriate ejection position based on a defined set of rules. The applied rule can logically combine sugar concentration, moisture, bruises, weight and black spot areas. Based on the selected sorting program, the rule engine is configured to the corresponding parameters and rule settings. The measurements and the rule decisions of every fruit are stored on the machine in a file that is available to be sent to host computers in the plant.

3 Conclusions

The company Insort mastered the challenge and built a unique new sorting machine using their Sherlock Food Analyzer as the key element. Hyperspectral imaging technology in combination with the RGB cameras is able to sort out chemical parameters as well as color differences. The sorting is conducted with a higher precision and velocity than manually before. After the realization of this project, the customer is able to successfully sort the fruits into different quality categories based on important parameters and supply high quality fresh fruit to the fast growing market.Implementation of the optical characterisation system was done for mango and avocado sorting. Ideas for the sorting of other fruits are being considered.

4 Acknowledgment

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References

1. "Frutura, wir sind obst und gemüse." [Online]. Available: www.frutura.com
2. "insort, intelligent selection." [Online]. Available: www.insort.at
3. "Evk helios nir g2 320 class." [Online]. Available: https://www.evk.biz/de/produkte/hyperspectral-imaging/evk-helios-nir-g2-320-class/
4. "Evk sqalar, qualitative and quantitative software tool." [Online]. Available: https://www.evk.biz/de/produkte/analysis-software-tool/evk-sqalar/
5. "Teledyne dalsa linea." [Online]. Available: https://www.teledynedalsa.com/en/products/imaging/cameras/linea/
6. "Kestrel eye, falco." [Online]. Available: http://kestrel-eye.com/products/
7. "Hbm an hbk company." [Online]. Available: https://www.hbm.com/de/
8. "Siemens sps s7 1200." [Online]. Available: https://new.siemens.com/global/de/produkte/automatisierung/systeme/industrie/sps/s7-1200.html