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Application of Computer Vision System in Food Processing- A Review

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Abstract

Agricultural and food products are present in incredible varieties in terms of shape, size, color and as the market grows more demanding, food products are subdivided in various categories and are destined to different segments. The definition and characterization of different attributes are very important for the business and for the consumer, making it necessary to establish norms of classification and standardization, thus making commercial trading more efficient and allowing for higher awareness on the part of consumers. A computer vision system (CVS) have proven very successful in the analysis of food on the basis of color, size, shape, texture etc. Computer vision is the science that develops the theoretical and algorithmic basis by which useful information about an object or scene can be automatically extracted and analyzed from an observed image, image set or image sequence. An image can be defined as a spatial representation of an object or scene. Image processing is base of computer vision system. Image acquisition, processing, segmentation are basic steps for extracting information of image. CVS system is being used in food industry for the detection of defects in apples, oranges, olives, cherries etc., sorting of potatoes, online monitoring of baking conditions, measurement of browning in chips. It is also being used for checking ripening stages of banana, tomato, cherries etc. Also it can be used to classify different varieties of cereal grains and check their adulteration. It can also be used for checking color of meat and lean yield. Computer vision is an emerging subject in food sector. It is a fast, non-invasive cheap method for evaluating quality of foods. The use of computers allows for increased efficiency with less manpower, reduces dependence on trained experts which is costly and time consuming. Also, we can do modelling of information obtained from image and can be used for future. This paper presents a review of the main publications in the last ten years with respect to new technologies and to the wide application ofsystems

Keywords: *computer vision system, image acquisition, modelling, food sector*

I. Introduction

The great concern with quality control due to new market restrictions in recent years has become so important that it has demanded a technology of process geared toward more reliable tests and new methods of monitoring product quality. Over the past decade, significant advances in techniques of tests have been observed, while extraordinary resources in electronics and informatics were identified as important factors in this development. Automation has motivated the development of testing equipments in production lines, and the evolution of sensor technology has led to the establishment of new techniques of measurement of the products, thus allowing permanent monitoring during the process, with the implementation of visual inspection systems.

In the food industry, some quality evaluation is still performed manually by trained inspectors, which is tedious, laborious, costly and inherently unreliable due to its subjective nature (Francis.,1975).Increased demands for objectivity, consistency and efficiency have necessitated the introduction of computer-based image processing techniques. Recently, computer vision employing image processing techniques has been developed rapidly, which can quantitatively characterize complex size, shape, color and texture properties of foods.

Systems of visual inspection are basically composed of a light source, a device for capturing the image and a computational system for the extraction of characteristics and processing. These systems are normally used in production lines where human activity is repetitive, products are manufactured very rapidly, and fast and accurate measurements are necessary for decision making during the process. Different from the problems present in visual inspection performed by people, these kinds of systems offer accuracy and repeatability in measurements without contact, especially due to the elimination of aspects such as subjectivity, tiredness, slowness and costs associated with human inspection. The use of automatized inspections in agriculture and in food industry has increasingly become an interesting solution for the final analysis of product quality, and the assessed values or characteristics involve not only dimensional aspects, but also characteristics of color, texture and shape (Fernando, A., Mendoza, V., 2005).

Agricultural and food products present an incredible variety of shapes, sizes, colors and flavors, and as the market grows more demanding, food products are subdivided in various categories and are destined to different segments. The definition and the characterization of different attributes are very important for the business and for the consumer, making it necessary to establish norms of classification and standardization, thus making commercial trading more efficient and allowing for higher awareness on the part of consumers. Moreover, with regard to obtaining measurements, even on the basis of images, it is necessary to have metrological rigor, which means having knowledge of the variables involved and of their contribution to error, and also to ensure that the process is replicable and that its results may be repeated, with measurements which are known and controlled within specific ranges. In this light, closer attention is needed to the standardization of measurements, and a higher emphasis on metrology in this sector becomes crucial, aiming to ensure repeatability of the results and the reproduction of the measurements employed, thus improving the reliability of this technique.

Over the past few years, the explosive growth in both computer hardware and software has led to many significant advances in computer vision technology. Computer vision technology provides a high level of flexibility and repeatability at relatively low cost. It also permits fairly high plant throughput without compromising accuracy. Currently, computer vision systems are being developed as an integral part of food processing plants for on-line, real-time quality evaluation and quality control (Gunasekaran. S.,1996.).

II. Computer Vision System

Computer vision is the science that develops the theoretical and algorithmic basis by which useful information about an object or scene can be automatically extracted and analyzed from an observed image, image set or image sequence (Haralick, R.M.,1992). An image is thus the core of computer vision system and it can be defined as a spatial representation of an object or scene. Computer vision systems are being used increasingly in the food industry for quality assurance purposes. Essentially, such systems replace human inspectors for the evaluation of a variety of quality attributes of raw and prepared foods.

CVS has found many applications in academic research and the food industries, ranging from a simple quality evaluation of foods to a complicated robot guidance application. In the last decade, this technique has been successfully used in color measurement analysis and quality inspection of a great variety of foods, including product classification or grading based on surface feature detection and defect finding. Alternatively ,computer vision system (CVS), a non destructive method, offering objective measures for color and other physical factors.

For a typical application of computer vision in the food industry, the key or core elements are the visual meanings or descriptions of food products in images (Ballard, D. A.,1982) which are known as image features that are extracted from images as indicators of food qualities. Images of food products captured in a computer system are stored, processed, and displayed in the form of matrices (the elements are called pixels for image processing purpose) in which information stored can be obtained as image features.

III. Image Processing

An image is an array, or a matrix, of square pixels (picture elements) arranged in columns and rows. Pixels are basic components of images. Two kinds of information are contained in each pixel, i.e. brightness value and locations in the coordinates that are assigned to the images. The former is the color feature while features extracted from the latter are known as size or shape features. Image processing systems play a more and more important role in the food quality evaluation by maintaining accuracy and consistency while eliminating the subjectivity of manual inspections. They offer flexibility in application and can be reasonable substitutes for the human visual decision-making process. In order to develop an automated system for food quality evaluation, image processing techniques are often combined with mechanical and instrumental devices to replace human manipulative effort in the performance of a given process. In such a system, the image processing system is the centre, which controls the operation of the machinery (Li, Q. Z., 2002).

IV. Matlab Toolbox

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems. In 2004, MATLAB had around one million users across industry and academia (Richard G., 2002) MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprise.

V. Artificial Neural Network

Artificial neural networks (ANNs) are biologically inspired computer programs designed to simulate the way in which the human brain processes information. ANNs gather their knowledge by detecting the patterns and relationships in data and learn (or are trained) through experience, not from programming. An ANN is formed from hundreds of single units, artificial neurons or processing elements (PE), connected with coefficients (weights), which constitute the neural structure and are organised in layers. The power of neural computations comes from connecting neurons in a network. Each PE has weighted inputs, transfer function and one output. The behaviour of a neural network is determined by the transfer functions of its neurons, by the learning rule, and by the architecture itself. The weights are the adjustable parameters and, in that sense, a neural network is a parameterized system. The weighed sum of the inputs constitutes the activation of the neuron. The activation signal is passed through transfer function to produce a single output of the neuron. Transfer function introduces non-linearity to the network. During training, the inter-unit connections are optimized until the error in predictions is minimized and the network reaches the specified level of accuracy. Once the network is trained and tested it can be given new input information to get output. A typical ANN consists of input layer, hidden layer and output layer. Input layer consists of your input values, hidden layer consists of calculation parts with involves multiplication of weights and addition of bais, and output layer consist of the required ouput for the given inputs.

Developing a neural network requires three phases:

- the training or learning phase,
- the recall phase (validation) and
- the generalization phase (testing).

The training phase is the first phase where a network is given various inputs and output, to train the network in the form of a text file, so that network will learn the inputs and their outputs. In the second stage network is made to recall all the process and to check its accuracy. If it showed 99% accuracy, then no need of further training and if not then go back to training phase again until 99% accuracy is achieved. The last step is the testing setup in which we test the pre-trained neural network (Traeger M, et al., 2003).

VI. Computer Vision Setup

Computer vision system consists of following main parts:

- Lighting system
- Digital camera and image acquisition
- Image processing

(i) Lighting system: Sample whose image is to be taken should be illuminated using two parallel lamps (with two fluorescents tubes by lamp, TL-D Deluxe, Natural Daylight, 18W/965, Philips, USA) with a color temperature of 6500 K (*D65*, standard light source commonly used in food research) and a color-rendering index (Ra) close to 95%. Both lamps (60 cm long) were situated 35 cm above the sample and at an angle of 45º with the sample. Additionally, light diffusers covering each lamp and electronic ballast assured a uniform illumination system.

(ii) Digital camera and image acquisition: The stage of image acquisition consists of capturing a real image and transforming it into a digital image using devices such as cameras, scanners, videos, etc. A digital image is a numerical representation of an image that can be computationally processed. A Color Digital Camera (CDC), model used should be located vertically over the background at a distance of 30 cm. The angle between the camera lens and the lighting source axis was approximately 45º, since the diffuse reflections responsible for the color occurs to this angle from the incident light (Francis and Clydesdale, 1975). Also, considering that ambient illumination is very critical for reproducible imaging (Shahin and Symons 2001), sample illuminators and the CDC were covered with a black cloth to avoid the external light and reflections. As standard capture conditions, images were taken on a matte black background and using the following camera settings: manual mode with the lens aperture and speed, no zoom, no flash, intermediate resolution of the CDC pixels, and storage in JPEG format. The capture pictures should be then transferred to PC with is loaded with the image processing software.

(iii) Image processing: All the algorithms for preprocessing of full images, segmentation from the background, and color analysis were written in MATLAB 6.5 (The MathWorks, Inc., USA). Pre-processing is the stage preceding the extraction of characteristics, which aims at improving the acquired image and highlighting the features or regions of interest, thus removing distortions and noise while not adding further information to its content. Pre-processing involves techniques to highlight regions and details and to remove any noise which may interfere in the analysis of objects and/or regions of interest. In this context, there is a great variety of techniques from which we can highlight the gray scale and color transformation, as well as thresholding and filtering (Koschan A., 2008). This is an important stage in an automatic inspection system.

The segmentation process can be based on the similarity of the color of each pixel and its neighbouring pixels. Sometimes similar pixels, in terms of color, are not part of the same object or feature. The extraction of parameters enables the association between regions of the image and objects in the scene (Gonzalez RC., 2009). After these stages, the image should be ready for the extraction of important characteristics. The final stage—processing—aims to recognize and interpret the images, seeking to make sense of the set of objects of the image, with the goal of improving human visualization and the automatic perception of data in a computer.

VII. Calibration of the CVS

The standard *RGB* involves two parts: (i) the viewing environment parameters, which are recommended for viewing photographic images on monitors, and (ii) the definitions and transformations standard device space colorimetric which provide the necessary transforms to convert between the *RGB* color space and the *L*a*b** color space (Stokes et al., 1996). The camera zoom, resolution have to be calibrated and this can be achieved by using some standard reference chart or color chart (Fig 1.1) whose RGB and *L*a*b** values are know. The camera calibration can be done by taking picture of the color card in the image processing chamber and extracting it RGB or *L*a*b** values and matching of values with the given values of color card. The conditions were the values obtained from camera come close to the value of color card, means the camera and conditions are calibrated and these settings should be recorded and used for further use.

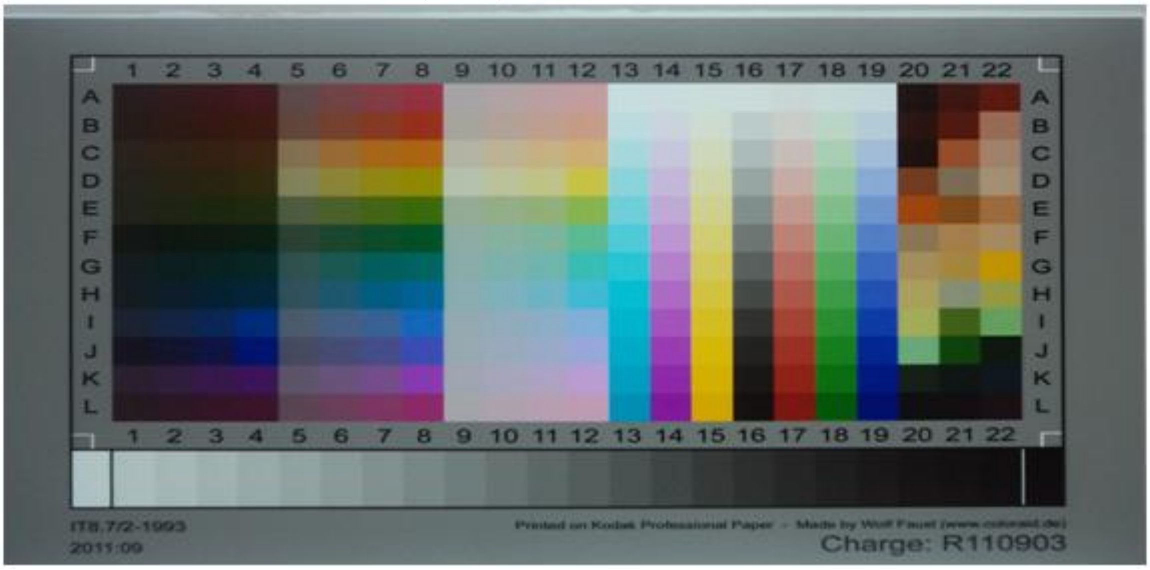

Fig 1.1: Color card for calibration of CVS system.

VIII. Feature extraction from images

According to the diverse information stored in pixels, image features obtained can be categorized into four types - color, size, shape, and texture (Du & Sun, 2004a).

(i)Color: Color is the intensity of pixels, while size reflects the number of pixels and shape describes the boundary of food products.

(ii)Size and Shape: Size reflects the number of pixels and shape describes the boundary of food products. Size features are usually obtained using measurements of area, perimeter, length, and width. Shape is characterized mostly in two ways, i.e., size dependent measurements such as compactness and elongation, and size independent measurements such as spatial moment and Fourier descriptor (boundary shape).

(iii)Texture: Texture is normally the dependency between pixels and their neighbouring pixels or the variation of intensity of pixel. Texture is normally the dependency between pixels and their neighbouring pixels or the variation of intensity of pixels.

IX. Application of CVS in Fruits and Vegetables

Potato inspection on the basis of shape, size and color, analysis of defects have been successful achieved using CVS system. In 2010, Barnes et al., developed a new method of detecting defects in potatoes using computational vision. In order to reduce shadow effects and changing conditions of illumination during image acquisition, the potatoes have been placed inside a white cylinder, with daylight lamps placed around the top of it, on a total of 4 lamps. After the segmentation of the potato on the bottom, a pixel classifier was trained to detect spots using extraction of characteristics of the image. Some parameters were used based on statistical information extracted from color and texture of the region surrounding the pixel, and then, an algorithm was used to automatically sort spots and not spots. The result showed that the method was able to classify and optimize the performance of classification with low computational cost, presenting levels of accuracy for white and red potatoes of 89, 6 and 89, 5 %, respectively. Noordam,et. al., 2009 and Cabrer, et. al., 2008 .analysed potatoes as a whole, and, to this end, a camera with mirrors has been used in order to obtain a global image**.**

CVS consists of an image acquisition set up, digital image analysis and special sensory color chart to classify objectively potato chips according to their color in different categories. For this purpose, sensory measurements of color in 100 potato chips were correlated with the corresponding objective

Potato chips with and without ruffles of different brands were used for training and validation experiments. Sensory evaluations done with a special color chart classified potato chips in seven color categories. Simultaneously, the color of the same potato chips classified by the sensory panel, was determined objectively by a computer vision system in L*, a*, b* units. Color measured by the sensory assessors was highly correlated with the color determined objective in *L**, *a**, *b** units by a CV system (Franco, P., 2009).

Apples are very susceptible to damage and the presence of bruises on the apple skin affects not only the appearance of the apple, which is an important indicator of quality, but also accelerates its deterioration. Therefore, an effective system of removing damaged apples allows the maintenance of the quality of the other products in a tray, and it is one of the essential stages in the processing of apples. However, certain types of apples show a bicolored characteristic, that is, they exhibit two colors on their appearance, which makes their sorting in processing very hard to meet European requirements with regard to classification. According to Madieta , it is necessary to know the interval in the color variation of the apple skin in order to decide the best manner of measuring it. Based on the type of color distribution on the skin, the apple may be classified as homogenous, heterogeneous or bicolored. In this way, many studies are carried out with the goal of reaching better performance of visual systems with a view to meeting these requirements, seeking improvements in the localization of defects (Madieta, E.,2003 and Unay D., 2006)

measurements obtained by computer vision system.

Image processing and MATLAB TOOLBOX were used to detect and calculate external appearance of an olive's skin which is considered to the most decisive factor in determining its quality as a fruit. Seven commercial categories of olives, established by product experts, were used: undamaged olives, mussel-scale or 'serpeta', hail-damaged or 'granizo', mill or 'rehu´ s', wrinkled olive or 'agostado', purple olive and undefined-damage or 'molestado'. The original images were processed using segmentation, color parameters and morphological features of the defects and the whole fruits. The application of three consecutive discriminant analyses resulted in the correct classification of 97% and 75% of olives during calibration and validation, respectively. However the correct classification percentages vary greatly depending on the categories, ranging 80–100% during calibration and 38–100% during validation (Riquelme, M T.,2008).

Visual features of raisins such as wrinkle edge density, angularity, elongation for the purpose of grading were analysed by computer vision (Okamura, Dewiche, & Thompson, 1993). The developed system accuracy was comparable to industrial standard air stream sorter but poorer than sight grading results.
Sorting of strawberries based on shape and size was performed using computer vision with accuracy of 98% reported for the developed system (Nagata, Cao, Bato, Shrestha, & Kinoshita., 1997). Also CVS system is used to detect the various defects in citrus fruits (Fig 1.2).

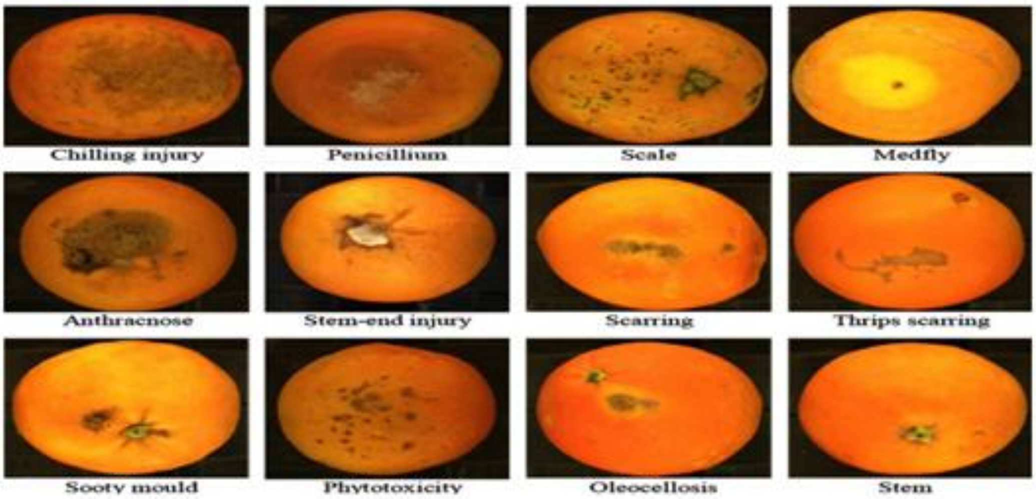

Fig 1.2: Defects in citrus (Blasco, J., et al. 2007)

X. Application of CVS in Cereals

Image processing was used to determine the utility of morphological features for classifying individual kernels of five varieties of barley. It was found, that the method using morphological features may be successfully employed in image analysis for a preliminary varietal identification of barley kernels. It was also shown that the data reduction considerably improved the results of the classification of barley kernels. Furthermore, linear discriminant analysis (LDA) was found to be the method which best separated different varieties of objects (Piotr, Z.,2008).

Digital image analysis was used to monitor baking process, in order to check and control quality of baked goods. Industrial baking is a temperature and time controlled process, which considers neither the actual quality of the raw materials nor the process parameters like humidity, pastry temperature and actual pastry status. Furthermore the baking process is irreversible. Digital image processing can be used to make digital images of the baking goods from inside the oven in a continuous form. The goal was the development of algorithms for distinction of baking goods and characterization of color saturation and shape, altogether resulting in an optical online process monitoring system (Paquet, D.O.,2011).

Combination of digital image from digital camera, computer and vision builder have good potential to be used for color measurement and this technique can provide color information such as for parboiled rice compared to a color measuring instrument (Bin Lv, et al., 2009). It has provided a less expensive and more versatile technique to determine the surface color of parboiled rice compared to instrumental color measurement.

Quality characteristics of corn have also been investigated by the use of computer vision. The classification of germplasms (ear of corn) was performed by use of an algorithm developed to discriminate round-shaped samples (Panigrahia, Misrab, &Willsonc, 1998). A discrimination was done between cylindrical and noncylindrical germplasms with an overall accuracy of 82.5% for this classification (Fig 1.3)

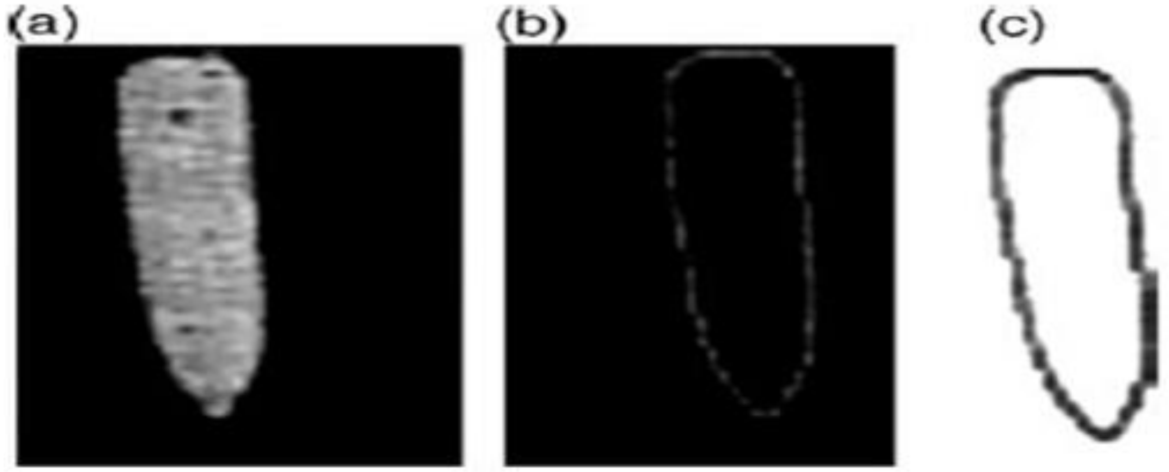

Fig 1.3: Image processing of corn: (a) the digitised image of a corn germplasm, (b) the background removed image and (c) the extracted boundary of the image.

XI. Application in Animal Products

Visual inspection is used extensively for the quality assessment of meat products applied to processes from the initial grading through to consumer purchases. (McDonald and Chen.,1990) investigated the possibility of using image-based beef grading in some of the earliest studies in this area. They discriminated between fat and lean in longissimus dorsi muscle based on reflectance characteristics, however poor results were reported. Recently greater accuracy was found in a study by (Gerrard et al.,1996) where R^2 (correlation coefficient) values of 0.86 and 0.84 for predicted lean color and marbling were recorded, respectively, for 60 steaks using image analysis. (Li et al.,1997) measured image texture as a means of predicting beef tenderness. Color, marbling and textural features were extracted from beef images and analysed using statistical regression and neural networks. Their findings indicated that textural features were a good indicator of tenderness. Image analysis was also used for the classification of muscle type, breed and age of bovine meat (Basset, Buquet, Abouelkaram, Delachartre, & Culioli., 2000).

A technique for the spectral image characterisation of poultry carcasses for separating tumourous, bruised and skin torn carcasses from normal carcasses was investigated by Park, Chen, Nguyen, and Hwang (1996). Carcasses were scanned by an intensified multi-spectral camera with various wavelength filters (542–847 nm) with the results indicating that the optical wavelengths of 542 and 700 nm were the most useful for the desired classification. For separating tumourous carcasses from normal ones, the neural network performed with 91% accuracy.

Storbeck and Daan (2001) measured a number of features of different fish species using an image processing algorithm based on moment-invariants coupled with geometrical considerations for discrimination between images of fish as they passed on a conveyor belt at a speed of 0.21 m/s perpendicular to the camera as shown in Fig. 1.4.

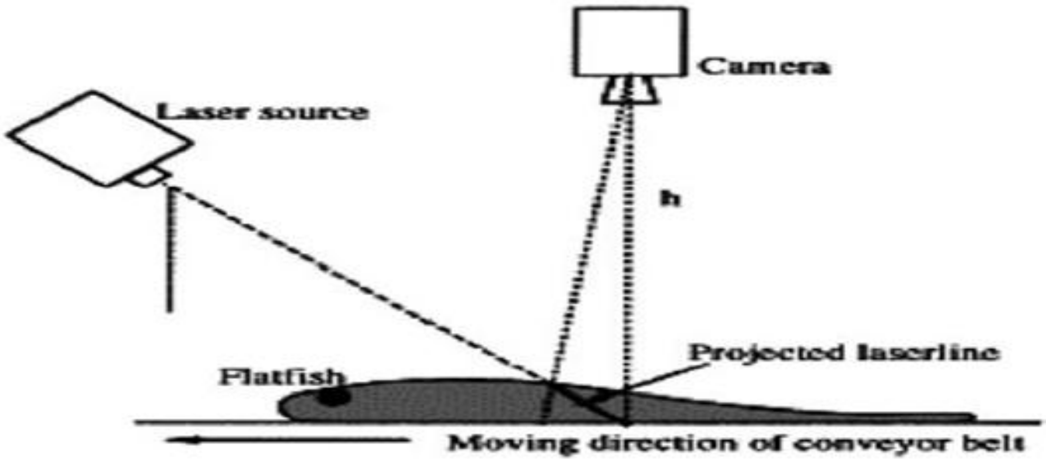

Fig 1.4: Schematic of computer vision system for evaluating the volume of fish on a conveyor belt.

XII. Other Applications

The tea quality depends upon a number of physical attributes such as color, particle shape, particle size and texture**.** Computer vision methods have been found to be very helpful in quality evaluation of tea. Using computer vision it has been observed that the tea images contain some definite patterns or texture due to different surface features of tea granules. Image processing applications such as classification, detection and segmentation of images could be applied optimally to determine these parameters. The color development of tea during fermentation can be determined using CVS system (Gill, G. S., 2011).

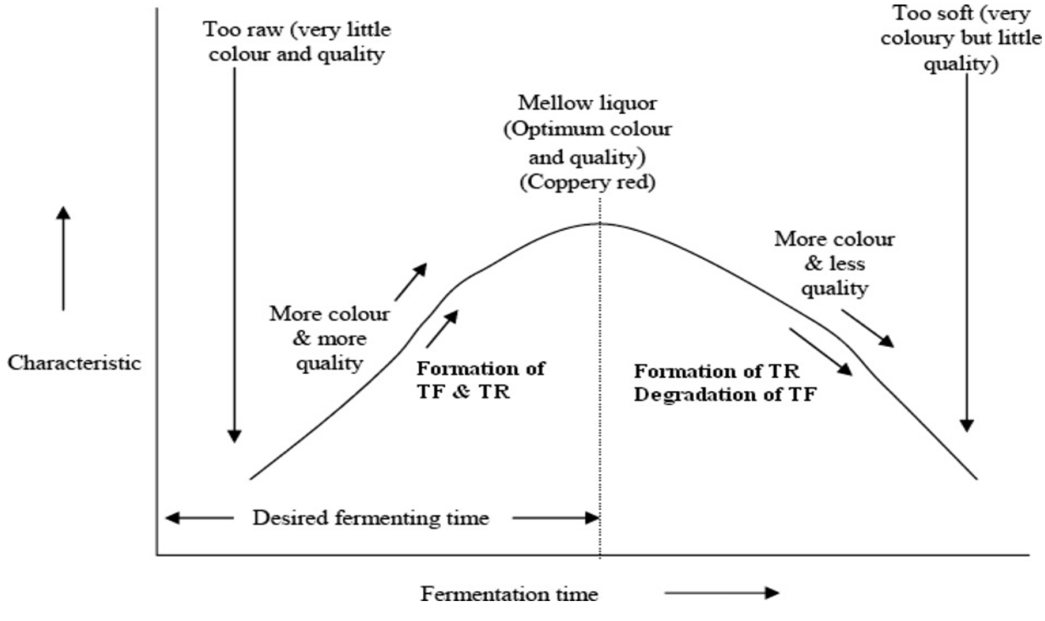

Fig. 1.5: Development of color and quality during fermentation.

Computer vision can be successfully used for the assessment of pizza topping quality. Three different indexes were used to quantify the quality of the toppings examined i.e whole pizza, mushroom and ham toppings. New styles of pizza are being produced in this highly competitive market all the time. Among them, topping percentage and distribution are the key parameters of pizza quality and CVS has proved to be reliable method for determining Pizza quality.

A comparison was made with the CVS read L* a* b* values and huntercolorlab. An excellent correlation was found between a* values from the CVS and from the Hunterlab (R^2= 0.97). But L* and b* values, the correlation coefficients were smaller (R^2= 0.80).This difference between both color systems may be largely due to the fact that measurements with the colorimeter do not extend over the whole surface.

XIII. Conclusion

- A fast, non-invasive cheap method for quality evaluation of food.
- Computer Vision is an emerging subject in food sector.
- The use of computers allows for increased efficiency with less manpower.
- Reduces dependence on trained experts which is costly and time consuming.
- The information obtained can be stored and used for future prediction.

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