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Machine Vision Techniques Used in Agriculture and Food Industry: A Review

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ABSTRACT

Alternate methods are required to fulfil the demand of the ever-growing population as the natural resources such as land and water available for agriculture are limited. Rapid urbanization has resulted in a huge number of people leaving behind agricultural and thus shortage of workers is encountered during peak seasons. The alternate methods are expected to give higher productivity compared to the traditional cultural practices while retaining the advantages of these traditional practices. A lot of research work has been done on the automation of these cultural operations. Machine vision plays a vital role in the success of a wide range of tasks performed by some of these automated solutions. This paper presents a detailed review on the use of machine vision in agriculture and food industry.

Introduction

Last few decades has seen lot of advancement in the technologies associated with the automation in agriculture and food industry. This includes a wide range of agricultural operations including seedbed preparation, intercultural operations, application of fertilizers and chemicals, harvesting, transportation, and grading. Researchers have developed robots that assist the farmers in getting these operations done and help them overcome the labour shortage problem.

Artificial intelligence has changed the way decisions used to be made in agricultural and other operations and has made automation of many tasks feasible. Machine learning technique is a subtype of artificial intelligence which is used for processing of images of fruits, crop and other objects which can give a wide range of information that may be useful in decision making. With the advancement in GPU and software technology it is possible to process huge amount of data in real time. Further, with the availability of convolutional neural networks such as AlexNet, ResNet, ResNext etc. the feature extraction process is no longer required; which has made processing of these images much easier. Researchers have made use of these advancements to find the solutions for a number of agricultural and industrial operations that required skilled labour and were time consuming. This review presents an application based review of the machine vision technique used in agricultural operations and food industries.

Application of machine vision in agriculture

Detection of target fruits

Detection of fruits is a very critical task that affects the performance of a harvesting robot. Ji *et al.,* (2012) developed a real time fruit detection system to be employed in an apple harvesting robot. A CCD camera was used as the image acquisition device and the images were pre-processed using vector median filter. The segmentation of the fruits from the background was performed using seeded region growing method, colour, and shape feature.

The developed system could able to detect 89% of the fruits. McCool *et al.,* (2016) developed a detection system that could detect sweet pepper. As the fruit and leaves both are green in this crop; the conventional shape feature based segmentation approach would not give appropriate results (Fig. 2.1). Thus, pixel based approach was followed, which gave more weightage to individual pixels with higher probabilities. The developed system could able to detect 69.2% of the sweet peppers. Fu *et al.,* (2018) used deep-CNN technique to detect kiwifruit. ZFNet framework was used to implement faster R-CNN on the images of the fruits acquired from the field environment.

Localization of the target fruits

Localization is a term that refers to the process of obtaining the 3D ordinates of a target object with respect to a fixed point. Just like detection, this process is equally critical and has almost no margin for errors as any error in localization would eventually result in the failure of the robotic system. Plebe *et al.,* (2001)used stereo matching technique to localize oranges, to be employed in an orange harvesting robot. Font *et al.,* (2014) developed a stereovision system consisting of two low cost cameras to obtain the size and 3D-ordinates of the target fruits. The developed system had an error of 4-5% in distance measurements. Bac *et al.,* (2014) used stereovision technique to localize the stems of sweet pepper. Support wires were used as a visual cue to ease the detection process.

Determination of orientation of fruits

Orientation of fruits is a key parameter when the end effecter is expected to grip the fruit from a particular position as any error will result in failure in picking or may damage the fruits mechanically. This is relevant for both, harvesting robots in the field as well as industrial robots that perform sorting and grading by pick-and-place mechanism. Eizentals *et al.,* (2016) proposed an algorithm for detecting the stems of green paper. 3D pose of the fruit was used as the basis of detecting the stem position. Threshold on the R/G ratio and Bayesian linear discriminant analysis based algorithms were used for executing the task. Guo *et al.,* (2016) used convolutional neural network to detect the fruit and to find grasping position on a fruit that is more exposed from a stack of fruits.

Weed, pest and disease detection

It is important to detect the weeds, pest and disease in the field so that appropriate measures can be taken to control them. Tellaeche *et al.,* (2011) developed a vision system for detecting avenasterilis, a variety of weeds using support vector machines. Srivastava *et al.,* (2015) developed a disease detection system for soybean plant foliar. Padol *et al.,* (2016) used SVM classification technique to detect disease in grape leaf. K-means clustering technique was used for segmentation after pre-processing the image. Fuentes *et al.,* (2017) developed a real time disease and pest detection system for tomato crops using deep learning technique. The developed system was robust to variation in the illuminating conditions, size difference and variations in the background. Faster R-CNN, R-FCN and SSD meta-structures were used. Habib *et al.,* (2018)used K-means clustering and support vector machine algorithm to detect disease in papaya fruit.

Maturity stage assessment

Mohammadi *et al.,* (2015) developed a classification system to classify persimmon fruits into three maturity stage based on image processing technique. The classification of the fruits was based upon the external colour as there was no significant difference in the size, sphericity and other external physical parameters. Pereira *et al.,* (2018) developed a computer vision system to identify the ripening stage of the papaya fruit (Fig. 2.2). Image analysis was performed on the images of the papaya fruits which were classified into three maturity stages. The hand-crafted colour features obtained from this analysis was evaluated upon two datasets containing cross validation and prediction sets.

Crop yield assessment

You *et al.,* (2017) developed a real time yield forecasting system for soybean using CNN and LSTM. Cheng *et al.,* (2017) used image analysis for predicting the yield of apple fruits using fruit and canopy feature. Colour based segmentation method was used for estimating the number of fruits.

Navigation and control of autonomous robots

Hague *et al.,* (1996) developed anavigation and control system which located crop rows in real time. The machine vision system utilized an algorithm based on Kalman filter. The developed vehicle could able to follow the expected path at a speed of 1.5 m/s with an accuracy of ±20 mm.

Pesticide residue detection on fruits

Now-a-days people are more conscious about the food they consume. Presence of pesticide on fruits is a common problem that is encountered in daily life. Jiang *et al.,* (2017)used NIR hyper-spectral imaging technique to detect the pesticide residues on mulberry leaves. Jiang *et al.,* (2019) developed a pesticide residues detection system for apple, making use of machine learning and deep learning technique in combination. Otsu segmentation algorithm along with roundness analysis was used to obtain the region of interest (ROI) in the binary images of the fruits. Convolutional neural network (CNN) was used for further classification making use of the existing AlexNet architecture.

Detection of defects and mechanical damage on the fruits

Any defects on the fruits affect its shelf life and its market value. Traditionally this task was performed manually. Liu *et al.,* (2006) used hyper-spectral imaging technique to detect chilling injuries on cucumber fruits. Reflectance was used as the parameter to detect the chilling injury on the skin of the cucumbers.

Fig.1 *Left*: Probability map; *Right*: Actual image. The circles indicate the regions with maximum probability (Source: McCool *et al.,* 2016)

Fig.2 Papaya fruit maturity stage assessment system (Source: Pereira *et al.*, 2018)

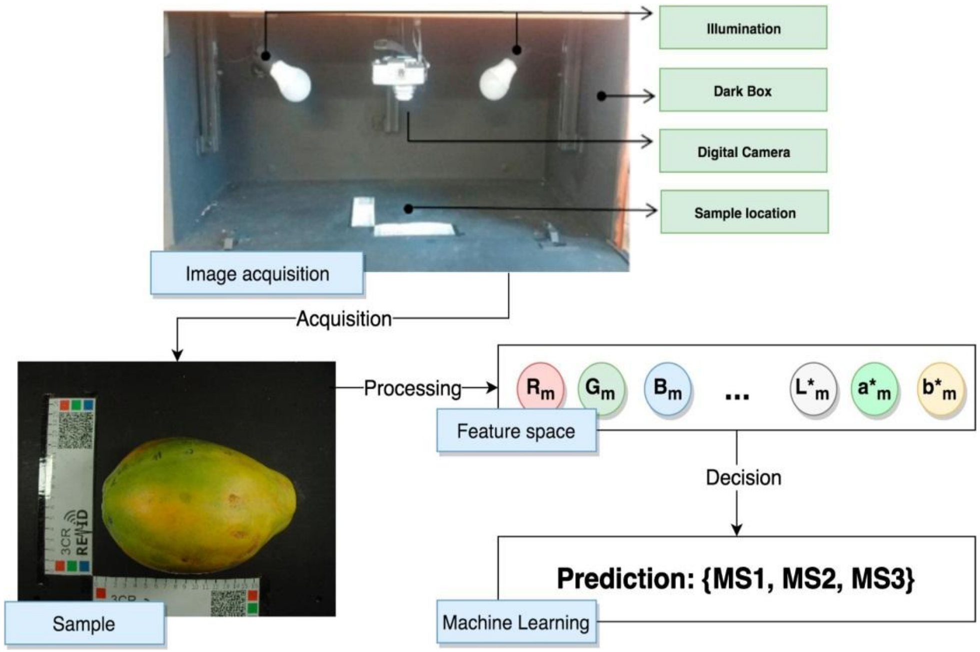
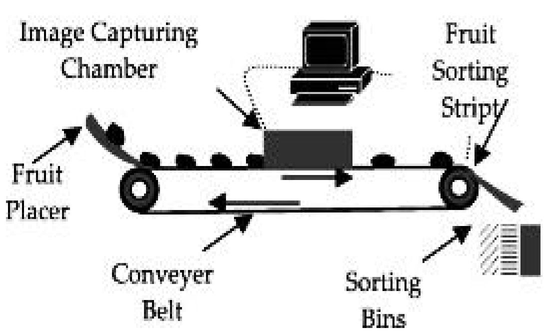


Fig.3 Date fruit sorting and grading system (Source: Al Ohali, 2011)



Vijayarekha (2008) used multivariate image analysis to detect visible defects on apple. Zhao *et al.*, (2010) developed a bruise detection system for pear fruit using hyperspectral imaging sensor. Mahalanobis distance classification (MDC) and spectral angle mapper (SAM) algorithms were found suitable for executing this task. Zhang *et al.*, (2014) developed a bruise detection system for apples using hyper-spectral imaging and MNF transform. Lee *et al.*, (2015) developed a defect detection system for fruits. The image segmentation was performed using LAB colour space in k-means algorithm and was found to be better than Otsu algorithm. Mechanically damaged fruits are prone to pathogen infections; thereby possess the risk of affecting the shelf life of the other fruits if not separated. Wang*et al.*, (2018)developed a mechanical damage detection system for blueberry fruits. Two deep CNN architectures ResNet and ResNeXT were used for the detection of the mechanical damage on the hyper-spectral transmittance data.

Sorting and grading of high value fruits

Traditionally sorting of high value fruits were performed manually both by the farmers and at industrial level. However, many machines have been developed to automize this process for a wide range of products. Xiaobo *et al.*, (2008) used Fourier expansion and genetic program algorithm to grade apple fruit based upon shape feature. Blasco *et al.*, (2009)developed an automatic sorting machine for pomegranate arils using difference in colour as the distinguishing parameter. Apart from sorting the arils the machine was also able to detect other unwanted materials such as defected arils and inner membrane. Al Ohali (2011) developed a sorting system for sorting and grading of dates into three categories based upon external appearance of the fruits (Fig. 2.3). Back propagation neural network classifier was employed upon the RGB images of the fruits. Nandi *et al.,* (2016) developed a grading system for mango fruit based upon maturity, size, shape and visible defects. Support vector regression and fuzzy incremental learning algorithm were used for decision making.

In conclusion, computer vision is an established technology in many agricultural and industrial applications. It can perform a wide range of tasks that makes decisions based upon any visual differences viz. colour, shape, texture, reflectance, size, roundness etc. Machine vision is a prominent technique for the agricultural robots as it is used for detecting, localizing and many other operations that help in decision making in the agricultural operations and estimating the yield. It is also used in detecting the presence of weed, pest and disease in the crops. Once the crop is harvested, it can be used to detect the immature and defected fruits. In the food industry it is used to perform tasks like sorting, grading, quality assessment, presence of unwanted materials in the product.

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