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DEFECTS IDENTIFICATION IN APPLES USING MACHINE VISION TECHNIQUES: A REVIEW

P. Vimala Devi1, K.Manjula[2], Dr.V.Kalaichelvi[3]
[1,2]School of CSE, SRC, SASTRA University, Kumbakonam.
[3]School of CSE, SRC, SASTRA University, Kumbakonam.
Email: vimalasarathi@src.sastra.edu

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Abstract:

Background/Objectives: Agro-industry processes the agricultural products after harvest and stores the products for domestic applications. In this, every year million numbers of fruits are processed for many applications. Apple is one among them. The features such as color, shape, size and sugar content determine the quality of the fruit. At the same time defects in a fruit affects the quality of the fruit. This paper reviews about various machine vision techniques used to find the defects in apple fruit. **Methods/Statistical analysis:** The techniques explained in various journal articles are studied.

Findings: Identifying defects by manual is time consuming process. So machine vision techniques are used to find defects automatically.

Applications: The machine vision techniques are also used for sorting and grading of fruits**.**

Keywords: Machine Vision, Agro Industry, Apple, Defects.

1. Introduction

Apple is one of the delicious and popular fruit containing more antioxidants and essential nutrients required for human health. There are three varieties of apples available in markets. Quality of the fruits increases its usage. The quality of the fruits is affected by some defects. The defects which affect the fruits are blue mold, gray mold, speck rot, sphaeropsis rot, mucor rot, bruising, skin color defects etc. These defects are identified using machine vision techniques which include automatic inspection of fruits based on images and analysis of the images. Sorting and grading techniques are used to find the good fruits which increase the quality of the fruit. Manual sorting is one type of the sorting technique using human operators, but it is a time consuming process. So machine vision assisted sorting techniques are used to sort the fruits by identifying defects in the fruits.

2. Apples

In [1]explained the machine vision techniques used to find the quality of the different foods[1]. She reviewed various techniques such as x-ray imaging, MRI, multispectral and hyper spectral imaging techniques for finding defects in oranges, apples, strawberries, cucumber, potatoes, mushrooms, rice, wheat, corn, biscuits and nuts. The various components used in machine vision system are discussed[2]. The computer vision and image analysis based techniques used for sorting and grading of fruits and vegetables are explained[3]. In [4]Sun is explained about the elements used in computer vision and its applications in computer industry[4].The authors also reviewed about computer vision based techniques used for grading some agricultural products such as pizza, cheese and meat[5]. E R Davies reviewed about the machine vision techniques used to analyse the different types of fruits and food[6]. In[7] are reviewed about various techniques used for defect identification in various products[7].

In [8]were also reviewed about the techniques used for identification defect[8]. The techniques such as multispectral imaging and hyperspectral imaging are used to sort the foods. Among this MRI technique is one of the method used to analyze the internal qualities of the agricultural fruits[9]. The techniques used to analyze the internal qualities of food are also reviewed[10]. The components used for automatic detection of internal and external qualities of vegetables and fruits are discussed[11]. Texture analysis is one of the features used for quality inspection. The types of textures, texture analysis methods and their applications are also discussed[12]. The textural features used to sort the apples combined with the techniques known as statistical classifiers and neural networks[13]. The results show that 93.8% of Empire apples and 89.7% of Golden Delicious apples were recognized. Some classifiers are used to categorize vegetables and fruits[14]. In this Classification Trees, Linear Discriminate analysis, Ensembles of trees, Support Vector Machine, and K-Nearest Neighbors were used with fusion classifiers to differentiate different categories fruits and vegetables. The authors achieved 15% of classification rate. The hyper spectral imaging methods are used for fruits and vegetables quality inspection[15]. The machine vision techniques used to find defects in various fruits are also discussed[16].

Quality of the fruits performs main role in food processing industry. The defects in the fruits are identified using machine vision techniques. Multivariate image analysis along with principal component analysis is used to find bruises in apple[17]. A system based on thermal properties is used to find the bruises in apples[18]. These properties cause variations on the fruit surface and these variations were monitored by online design. This system effectively identifies the bruises in apple. The surface defects including bruises were identified using machine vision system[19].The apples were rotated in front of the camera using conveyor belts, and then the images were acquired. The images were

compared with reference image; in this dark area matching both the images is considered as defective area. A method to separate bruises from stem end /calyx in golden delicious apples using hyper spectral imaging technique is explained. The fluorescence and reflectance images are used at different wavelengths. The results show that combination of these images was used to identify stem-end / calyx's and bruises separately [20].

The 3D reconstruction using a shape from shading approach to find stem end and calyxes in golden delicious apples was discussed[21]. The authors achieved a 90.15% of detection rate. Different classifiers are used to find stem and calyxes in jonagold apples[22]. The four classifiers are known as support vector machines, Linear discriminate, fuzzy nearest neighbor and nearest neighbor classifiers. Among these support vector machine classifiers correctly classifies 1005 of calyxes and 995 of stems. The hyperspectral imaging technique is used to find the stem in apple fruits[23]. In this to classify the apples maximum likelihood classification method is used. David W. Penman is also proposed a method to identify stem and calyxes[24]. A method proposed to grade the apples, in this syntactical and statistical classifiers is used to classify the fruits and the authors achieved 93.5% accuracy of recognition rates[25]. Buy[26] explained watershed segmentation method based on multi scale edge detection [26]. This method grades the fruits based on color and shape. This method effectively segments the defected parts of an image.

The Statistical Histogram Based Fuzzy c-means Algorithm was used to find the skin color defects in apples [27]. First the color image is converted into L*a*b color space, then active counter model algorithm is used extract the shape of the apple. Finally the healthy pixels and defected pixels are identified using Statistical Histogram Based Fuzzy c-means algorithm. This algorithm correctly identifies 96% of defected pixels and 91% of healthy pixels. Four segmentation algorithms used to segment the tomato, apple and orange fruit images are compared [28]. The methods are least cost time than extended Otsu method, dynamic threshold segmentation method, adaptive segmentation method based on LVQ network and improved Otsu combined with genetic arithmetic. The results show that dynamic threshold segmentation based on traditional Otsu method has better performance. By[29] is also explained the segmentation techniques in citrus fruits[29]. Segmentaion using contrast stretching provide reasonable results to segment the fruit images. The color segmentation method takes more time to process when compared to other methods. Segmentation by reference image method gives better result to find stem-end rot defects in citrus fruits. Iterative intensity enhancement method also takes more time to process but it works well to find defective parts of the image. In[30] used an algorithm to segment the different color images of food items such as mandarin, pear, wheat, potato chip, green apple, raisin, banana, nectarine, plum, tomato, pepino, orange, red apple and avocado[30]. The

algorithm consists of three steps. First step is used to convert RGB components into grey values. Second is the calculation of global threshold value using statistical approach and third is the morphological operation. Bayesian classifier was used to segment defects in Jonagold apples [31]. This classifier correctly identifies most defects in apples. The three imaging modes known as UV induced fluorescence reflectance and visible light induced fluorescence were combined to acquire the images, and these are classified using neural network classifiers [32]. This technique recognizes the different types of defects in apple. Chilling injury is one of the disease affects the apple fruit due to harmful environmental conditions. The affected fruits were identified using hyper spectral imaging methods[33]. The result shows that method correctly identifies the good and defective apples. The severity of apple blue mould disease was estimated using RGB channels and chemo-biological approach[34]. The result shows that 100% accuracy is detected to estimate apple blue mould disease. The surface defects of apple are identified using computer vision based system [35]. In this the first step was removal of background images, second step segments the defects and finally the stem and calyxes were identified. In[36] is also analyzed surface defects in apples[36]. They used Gabor wavelet transform to extract the textural features and support vector machine classifiers were used to classify the defects. The 85% defected areas were correctly identified by using these techniques. A system used to find external defects, consists of three color cameras to capture the images and multi threshold's method to segment the images and counting is done[37]. The three sensor systems known as machine vision system, near-infrared spectrophotometer and an electronic nose system are used to determine size, color, shape and sugar content [38]. This method provides better result for assessing quality of the fruit. Machine vision and X-ray is used to find the internal qualities such as mould core apples [39]. First lifting wavelet transform was used to collect the images, second the image was enhanced by histogram equalization. In third step the canny operator detects the edge, and then the threshold value is used to classify normal apples and mould core apples.

Quality of the fruit is not only based on finding defects in fruits. It also depends on size and shape of the fruit. The shape, size, and surface spottiness for single fruit are determined using digital parameterization method[40]. Statistical and analytical methods are also used to determine the size of the apples[41]. The grading techniques are used to determine the shape, color and identifying surface defects [42]. A model described using computer vision is used to determine number of fruits and diameter of the fruit by analysing color, shape and texture properties of the fruit [43]. The guava and lemon fruits are classified based on curve let transform and texture of the fruit surface [44].The features entropy, standard deviation, mean and energy were calculated and the classifiers such as Probabilistic Neural

Networks and support vector machines were used to classify the defected fruits and healthy fruits. The fruits such as oranges, apples, carrots, mangoes and bananas are also classified using neural networks and digital image processing[45]. An algorithm known as a new semi-supervised affinity propagation algorithm combined with partial least square regression is proposed to find soluble solid content and firmness of the apple[46]. In[47] is also measured firmness of the apples[47]. The images were collected at different wavelength using visible/near infrared spectroscopy and the Lorentz and distribution function, multi-linear regression model were used to find the firmness of the fruit. The nutritional and physical properties of two varieties of apples are explained[48]. The physical properties were geometric, arithmetic and equivalent mean diameters, average fruit length, surface area, width and thickness, sphere city index, projected area, aspect ratio, bulk and fruit densities, fruit mass, coefficient of static friction and volume and the nutritional properties were total soluble solids, PH, titratable and acidity. The analysis shows that both varieties were differ at 1% and 5% levels in their properties. The authors also examined the mass value of two Iranian apples using physical properties[49]. The volume of apples was estimated using image processing[50]. In this the images are categorized into spherical, paraboloid, and ellipsoid shapes, and then analyzed using analytical methods. The starch index of apples is estimated using multivariate analysis[51].

In this Partial least-square discriminant analysis (PLSDA) technique was used to identify the individual pixels that determine the maturity level of the apples. A method was proposed to evaluate apple maturity state using watershed algorithm[52]. The maturity spots from the fruit images were acquired by laser. Along with watershed algorithm, multi resolution method is also used to determine the maturity state. The fruit based on the features such as color, edge of the input, intensity and orientation are identified[53]. The algorithm based on these features was used to locate the fruits in the tree.

The spatial-temporal speckle correlation technique is used to find the shelf life of the fruits such as guava, apple and pear [54]. The results show that the small changes in cross correlation coefficients affect the shelf life. Artificial neural network methods are used to classify the fruits from the bulk fruit images based on texture and color features[55]. From the images of orange, apple, mango, sweet lime and chickoo, the color and texture features were extracted and the neural network classifier was used to classify these fruit images.

3. Conclusion

Postharvest process includes cooling, cleaning, sorting, grading and packing of fruits. In this sorting and grading of fruits determines the quality. Defects in fruit is also affects the quality. The techniques partial least square

discriminate analysis, multispectral imaging-ray vision, wavelet transform etc. are used to find defects in fruits and also used determine the features such as color, shape, size, maturity state etc. This review summarizes various techniques used for defects detection in apple fruit. Also this review discusses the techniques used to find internal and external features of apple fruit.

References

1. Vijayarekha K. Machine Vision Application for Food Quality: A Review. Research Journal of Applied Sciences, Engineering and Technology. 2012 Dec, 4(24), pp. 5453-5458.
2. Chen Y R, Chao K, Kim M S. Machine vision technology for agricultural applications. Computers and Electronics in Agriculture. 2002 Nov, 36(2-3), pp.173-191.
3. Mahendran R, Jayashree G C, Alagusundaram K. Application of Computer Vision Technique on Sorting and Grading of Fruits and Vegetables. Food Processing & Technology. 2012 Aug, pp.1-7.
4. Brosnan T, Sun D W. Improving quality inspection of food products by computer vision—a review. Journal of Food Engineering. 2004 Jan, 61(1), pp.3-16.
5. Brosnan T, Sun D W. Inspection and grading of agricultural and food products by computer vision systems-a review. Computers and Electronics in Agriculture. 2002 Nov, 36(2-3), pp.193- 213.
6. Davies E R. The application of machine vision to food and agriculture: a review. The Imaging Science Journal. 2009, 57(4), pp.197-217.
7. Mishra R, Shukla D.A Survey on Various Defect Detection, International Journal of Engineering Trends and Technology.2014, 10(13), pp.642-648.
8. Khandelwal P, Gautam P. A Review on Various Defect Detection Techniques. International Journal of Current Engineering and Technology. 2013 Dec, 3(5).pp.1-3.
9. Patel K K, Khan M L, Kar A. Recent developments in applications of MRI techniques for foods and agricultural produce—an overview. Journal of Food Science and Technology.2015 Jan, 52(1), pp.1-26.
10. Butz P, Hofmann C, Tauscher B. Recent Developments in Noninvasive Techniques for Fresh Fruit and Vegetable Internal Quality Analysis. Journal of Food Science. 2005 Nov, 70(9), pp.131-141.
11. Cubero S, Aleixos N, Moltó E, Sanchis J G, Blasco J. Advances in Machine Vision Applications for Automatic Inspection and Quality Evaluation of Fruits and Vegetables. Food Bioprocess Technology. 2011 May, 4(4), pp.487–504.

12. Zheng C, Sun D W, Zheng L. Recent applications of image texture for evaluation of food qualities—a review. Trends in Food Science & Technology. 2006 Mar,17(3), pp. 113–28.
13. Kavdır I, Guyer D E. Comparison of Artificial Neural Networks and Statistical Classifiers in Apple Sorting using Textural Features. Biosystems Engineering.2004 Nov, 89 (3), pp.331–344.
14. Rocha A, Hauagge D C, Wainer J, Goldenstein S. Automatic fruit and vegetable classification from images. Computers and Electronics in Agriculture. 2010 Jan, 70(1), pp. 96–104.
15. Lorente D, Aleixos N , Sanchis J G, Cubero S, Navarrete O L G , Blasco J. Recent Advances and Applications of Hyperspectral Imaging for Fruit and Vegetable Quality Assessment. Food Bioprocess Technology. 2012 May, 5(4), pp.1121–1142.
16. Devi PV, Vijayarekha K. Machine Vision Applications to Locate Fruits, Detect Defects and Remove Noise: A Review. Rasayan Journal of chemistry. 2014 Jan- Mar, 7(1), pp.104-113.
17. Vijayarekha K. Multivariate image analysis for defect identification of apple fruit images. Industrial Electronics, 2008. IECON 2008. 34th Annual Conference of IEEE. 2008 Nov, pp.1499-1503.
18. Jianmin Z, Qixian Z, Juanjuan L, Dongdong X. Design of on-line detection system for apple early bruise based on thermal properties analysis. Intelligent Computation Technology and Automation (ICICTA), 2010 International Conference on, 2010 May, pp. 47-50.
19. Bennedsen B S, Peterson D L, Tabb A. Identifying defects in images of rotating apples. Computers and Electronics in Agriculture. 2005 Aug, 48(2), pp.92–102.
20. Xing J, Karoui R, Baerdemaeker J D. Combining multispectral reflectance and fluorescence imaging for identifying bruises and stem-end/calyx regions on Golden Delicious apples. Sensors & Instrument, Food Quality. 2007 Jun, 1, pp.105–112.
21. Jiang L, Zhu B, Cheng X, Luo Y, Tao Y.3D Surface Reconstruction and Analysis in Automated Apple Stemend/calyx Identification, American Society of Agricultural and Biological Engineers. 2009 Aug, 52(5), pp.1775-1784.
22. Unay D, Gosselin B. Stem and calyx recognition on 'Jonagold' apples by pattern recognition. Journal of Food Engineering. 2007 Jan, 78(2), pp.597-605.
23. ElMasry G, Radwan S M, El-Amir M S, Wang N. Detection of Apple Stem Using Hyperspectral Imaging. New Trends in Agricultural Engineering, 2006 Nov, pp. 838 – 857.

24. Penman D W. Determination of stem and calyx location on apples using automatic visual inspection. Computers and Electronics in Agriculture. 2001 Dec, 33(1), pp.7-18.
25. Unay D, Gosselin B, Kleynen O, LeemansV, Destain M F, Debeir O. Automatic grading of Bi-colored apples by multispectral machine vision. Computers and Electronics in Agriculture. 2011 Jan, 75(1), pp.204-212.
26. Deepa P, Geethalakshmi S N. Improved watershed segmentation for Apple fruit grading. Process Automation, Control and Computing (PACC), 2011 International Conference on. 2011 Jul, pp.1-5.
27. Moradi G, Shamsi M, Sedaaghi M H, Moradi S. Apple defect detection using statistical histogram based Fuzzy C-means algorithm. 2011 7th Iranian Conference on Machine Vision and Image Processing. 2011 Nov, pp.1-5.
28. Yin J, Hanping, Mao, Xie Y. Segmentation Methods of Fruit Image and Comparative Experiments. Computer Science and Software Engineering, 2008 International Conference on. 2008 Dec, 1, pp.1098-1102.
29. Vijayarekha K. Segmentation Techniques Applied to Citrus Fruit Images for External Defect Identification. Research Journal of Applied Sciences, Engineering and Technology. 2012 Dec, 4(24), pp.5313-5319.
30. Mery D, Pedreschi F. Segmentation of colour food images using a robust algorithm. Journal of Food Engineering. 2005 Feb, 66(3), pp.353–360.
31. Leemans V, Magein H, Destain M F. Defect segmentation on 'Jonagold' apples using colour vision and a Bayesian classification method. Computers and Electronics in Agriculture. 1999 Jun, 23(1), pp.43–53.
32. Ariana D, Guyer D E, Shrestha B. Integrating multispectral reflectance and fluorescence imaging for defect detection on apples. Computers and Electronics in Agriculture. 2006, 50, pp.148–161.
33. ElMasry G, Wang N, Vigneault C. Detecting chilling injury in Red Delicious apple using hyperspectral imaging and neural networks. Postharvest Biology and Technology. 2009, 52, pp.1–8.
34. Farahani L, Etebarian H R, Takallou H M, Sahebani N. Computer-based recognition of severity of apple blue mould using RGB components. International Research Journal of Applied and Basic Sciences. 2012, 3 (1), pp.39-45.
35. Li Q, Wang M, Gu W. Computer vision based system for apple surface defect detection. Computers and Electronics in Agriculture. 2002 Nov, 36, pp.215-223.
36. Huang W, Zhang C, Zhang B. Identifying Apple Surface Defects Based on Gabor Features and SVM Using Machine Vision. IFIP International Federation for Information Processing. 2011 Oct, pp. 343–350.

37. Xu1 Q, Zou X, Zhao J. On-Line Detection of Defects on Fruit by Machine Vision Systems Based on Three-Color-Cameras Systems. Computer and Computing Technologies in Agriculture II. 2008 Oct,3, pp.2231–2238.
38. Xiaobo Z, Jiewen Z. Apple quality assessment by fusion three sensors. IEEE Sensors. 2005 Oct –Nov.
39. Yang F， Yang L, Yang Q, Kang L. Nondestructive Detection of the Internal Quality of Apple Using X-Ray and Machine Vision. Computer and Computing Technologies in Agriculture II. 2008 Oct, 3, pp.1699–1706.
40. Radojević R L, Petrović D V, Pavlović V B, Nikolić Z M, Urošević M P. Digital parameterization of apple fruit size, shape and surface spottiness. African Journal of Agricultural Research. 2011, 6(13), pp. 3131-42.
41. Rao P S, Renganathan S. New Approaches for Size Determination of Apple Fruits for Automatic Sorting and Grading. Iranian Journal of Electrical and Computer Engineering. 2002, 1(2), pp.90-97.
42. 42.Gao H, Cai J, Liu X. Automatic Grading of the Post-Harvest Fruit: A Review. IFIP International Federation for Information Processing. 2010, pp.141–146.
43. Stajnko D, Rakun J, Blanke M. Modelling Apple Fruit Yield Using Image Analysis for Fruit Colour, Shape and Texture. European Journal of Horticultural Science. 2009, 74 (6), pp. 260–267.
44. Khoje S A, Bodhe S K, Adsul A. Automated Skin Defect Identification System for Fruit Grading Based on Discrete Curvelet Transform. International Journal of Engineering and Technology. 2013 Aug, 5(4), pp.3251-3256.
45. Nur Badariah Ahmad Mustafa, Kumutha Arumugam, Syed Khaleel Ahmed, Zainul Abidin Md Sharrif. Classification of Fruits using Probabilistic Neural Networks - Improvement using Color Features. TENCON 2011 - 2011 IEEE Region 10 Conference. 2011 Nov, pp. 264 – 269.
46. Zhu Q, Huang M, Zhao X, Wang S. Wavelength Selection of Hyperspectral Scattering Image Using New Semi-supervised Affinity Propagation for Prediction of Firmness and Soluble Solid Content in Apples. Food Analysis and Methods. 2013 Feb, 6(1), pp.334-342.
47. Lu R, Peng Y. Comparison of Multispectral Scattering and Visible/NIR Spectroscopy for Predicting Apple Fruit Firmness. Information and Technology for Sustainable Fruit and Vegetable Production. 2005 Sep, pp.493-501.
48. Chakespari A G, Rajabipour A, Mobli H. Post Harvest Physical and Nutritional Properties of Two Apple Varieties. Journal of Agricultural Science. 2010, 2(3), pp.61-68.
49. Chakespari A G, Rajabipour A, Mobli H. Mass modeling of two apple varieties by geometrical attributes. Australian Journal of Agricultural engineering. 2010, 1(3), pp.112-118.

50. Iqbal S, Gopal A, Sarma A S V. Volume Estimation of Apple Fruits using Image Processing. Image Information Processing (ICIIP), 2011 International Conference on. 2011 Nov, pp.1 – 6.
51. Menesatti P, Zanella A, D'Andrea S, Costa C, Paglia G, Pallottino F. Supervised Multivariate Analysis of Hyper-spectral NIR Images to Evaluate the Starch Index of Apples. Food Bioprocess Technology. 2009 Sep, 2(9), pp.308–314.
52. Laemmer E, Deruvver A, Sowinska M. Watershed and Adaptive Pyramid for Determining the Apple's Maturity State. Image Processing 2002, Proceedings. 2002 International Conference on .2002, 1, pp. I-789 - I-792.
53. Patel H N, Jain R K, Joshi M V. Fruit Detection using Improved Multiple Features based Algorithm. International Journal of Computer Application. 2011, 13(2), pp.1-5.
54. Ansari M Z, Minz P D, Nirala A K. Fruit Quality Evaluation Using Biospeckle Techniques. Recent Advances in Information Technology (RAIT), 2012 1st International Conference on. 2012 Mar, pp. 873 - 876.
55. Savakar D. Identification and Classification of Bulk Fruits Images using Artificial Neural Networks. International Journal of Engineering and Innovative Technology.2012 Mar, 1(3), pp.36-40.