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# Automatic Sorting Using Image Processing Improves Post Harvest Blueberries Storage Quality

Prasanta Kumar Sahoo[1]
Aryan Institute of Engineering & Technology, Bhubaneswar, Odisha

Subhadip Goswami[2]

NM Institute of Engineering and Technology, Bhubaneswar, Odisha

Soumya Mishra[3]

Raajdhani Engineering College, Bhubaneswar, Odisha

**ABSTRACT**
South American blueberry organic product creation has been expanding more than 40% the late decade moved for global interest driving for United States of America. Notwithstanding, during capacity and transportation stage, contagious rot might cause genuine harm in group which causes rejects and low costs in objections. In addition, conventional manual strategies to eliminate sick solidarities of blueberry after gather are slow, unconfident and costly. In this work, we propose a basic and non-costly technique to be carried out to eliminate solidarities with contagious harm. It comprises in PC vision calculations to separate and choose data from blueberries and execute the best classifier to isolate naturally solidarities with contagious rot, wilting and mechanical harm from wellbeing solidarities. It was conceivable order effectively more than 96% pictures with parasitic rot and more the 90% of blueberries with worldwide harm (contagious rot, shrinking or repairman harm). The execution of programmed PC vision frameworks to perceive surrenders in blueberries is perplexing because of blueberries morphology, dark tone, little size, wax presence. It results are promissory since will permits increment send out quality when will be carried out underway lines.
*Keywords: blueberry; berry; computer vision; automatic quality control; postharvest disease; physiological disorder.*

## INTRODUCTION

Fresh blueberry (*Vaccinium corymbosum*) needs more than thirty days between harvest in south hemisphere and commercialization in north hemisphere. During this time, serious damages may occur if diseased fruit were not removed immediately after harvest. In spite of manual classifying is done by operators, human sight do not detect all damaged fruit, increasing the risk of lose batch by develop of fungal decay and me chanical damage. A good method for sort blueberries in commercial classes is essential to ensure a desirable quality of exported fruit.

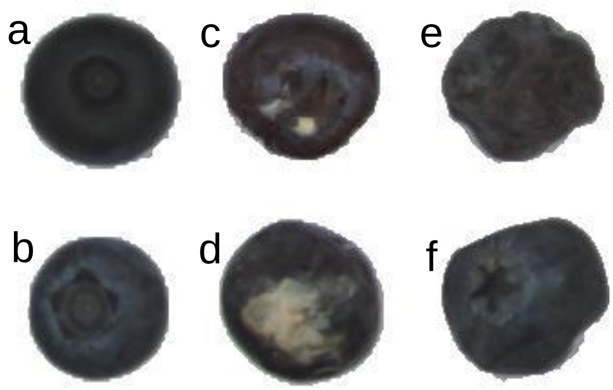


**Figure 1**. Diseased blueberries during postharvest should be segregated. a) and b) health blueberry in pedicel and calyx side; c) and d) decayed berries; e) shriveling blueberry; f) mechanical damage.

Computer vision is a non destructive, low operational cost, confidence, objective and efficient technology based in image processing. A digital image is the interpretation of one or more numerical matrix, where interest object (like blueberry) present numeric affinities that represent colours or gray intensity zones inside image which may be operated with algebraic principles to detect different characteristics of the fruit. In this sense, we have been developing strategies for analyze and design applications of quality control in foods using image processing and pattern recognition techniques which are more confident, safe and quick than human sight [1]. Computer vision stages includes: image pre-processing and pattern recognition. Image processing include all algebraic operations over matrixes to improve signal to noise ratio. Operations include filtering [2] and segmentation to discard non relevant elements and accent important others inside an image [3]. A robust algorithm must be implemented for segment food colour images using threshold and morphological operations. Pattern recognition study how machines may "watch" the environment, to learning pattern of interest and to take decisions over a new object watched that wedge in a category. A pattern is represented for a group of geometric and chromatic features able to define one o more classes. The first step consist in extract with appropriate algorithms the most features from category-known images as possible are [4] after that, features must be selected by its capacity of separate correctly the classes. It step is part of "training" mode allowing at the system to be prepared when a new unknown image enter to be automatically classify in the step of "test" [5]. Classification is done for statistic or clustering algorithms which define what object correspond at one or other class. A complete information about statistical pa ttern recognition might be reviewed in work of Jain [5], Duda [6], Bishop [7], and Holmström and Koistinen [8].

Computer vision in postharvest disease detection allows classify fruit unities in different quality degrees. There are different published information in different kind of fruit like olive [9], apple [10-13] and bayberry [14]. Complete review of non destructive technology in fruit postharvest was done by [15] and [16]. However, computer vision in sorting lines in blueberries is still not published. One of the mean reasons is that common fruit present more visual feasibility to detect defects than blueberry which is smaller, darker and has a white wax film in surface. Knowing the damage patterns that define different kinds of berries as quality levels can be designed automatic classification algorithms to be implemented in the industry, reducing overall batch rejections for damage in transport.

The aim of this study was to design a methodology to classify blueberries with fungal decay, shrivelling and mechanical damage using statistical pattern recognition techniques: extracting the most possible features, selecting the best ones, training the best classification algorithm.

## MATERIALS & METHODS

Row material and equipment. "Highbush" blueberries, (*Vaccinium corymbosum* var. Star) were acquired from cultivars in central region of Chile. Before experimentation, blueberries were stored in refrigerated camera at 0° C for 8 weeks to induce different levels of postharvest damages. 30 unities of blueberries were analyzed for each class (a total of 150 unities). Image acquisition was done under standard conditions of scene in a colorimeter DVS-lab colorimeter (Digital Vision Solutions www.divisol.cl). Each fruit was imaged (480 x 640 pixels each color image) in calyx zone and pedicel zone (one image per zone) to study disease localization predominance (Figure 1) . Different quality classes were defined by agronomist specialized in berries diseases, these classes were used to train the algorithms and test the classifier. All data were processed and analyzed using Matlab™ (Mathworks corp.).
Image segmentation: Otsu thresholding and morphologic operations were used to segment each high contrast grayscale image generated from RGB [3]. Four steps of statistical recognition algorithms were used to sort three level-quality of non-classify images of blueberries following [5] recommendations: Geometric and chromatic features extraction: different algorithms extracted 1643 geometric and chromatic features in RGB, HSV, l*, a*, b* and intensity color spaces from each image, the extracted features includes image textures, "Gabor features", "Fourier" [17] and "Discrete Cosine Transformates" [4]. Table 1 present a list of features selected in this study. The features were extracted using "Balu" free use toolbox for recognition patterns (http://dmery.ing.puc.cl/index.php/balu/). Features selection using strategies: The key idea of the feature selection is to select a minor subset of features from total features that leads to the smallest classification error. It was done using 8 combined strategies. The best strategy should optimize a reduce amount of features with the maximal classification hits. The strategies used were "*Sequential forward Selection"* (SFS), with objective functions: "Fisher discriminant", k-nearest neighbour (KNN), "linear and quadratic discriminant analysis" (LDA and QDA); and other feature extractors without objective function: *Forward orthogonal search algorithm by maximizing the overall dependency* (FOSMOD), *Least squares ellipse fitting* (LSEF) and *Rank key features by class separability criteria* RANKFS. A complete description of these algorithms may be read in [5]. Classifiers design: with the selected features, decision lines, planes or hyper planes was implemented using LDA, QDA, minimal distance (MIN. D), Mahalanobis distance (MD), KNN (with 4 to

30 nearest neighbours), Support Vector Machine (SVM) and different Neural Networks techniques (NN). The classifiers statistic validation: was implemented using stratified cross-validation which yields a confidence interval each classification with 95% confidence.

## RESULTS & DISCUSSION

Extracting and selecting better features

Total features were reduced from 1643 to only 7 - 11 using a combined strategy between an extractor of better features and a classifier. SFS - Fisher strategy was better than others like SFS-LDA, SFS-KNN, RANKFS and FOSMOD. These optimal amounts of features involve faster applications in process sorting line shorting computation time in applications used in computer vision like mobile recognition and quantification of wild blueberry for a mobile acquisition system [18] where is important to obtain a real time response. In general, image features presented in Table 1 give information about pixel homogeneity and differences of shape between classes: blueberry fruits with less presence of disease are mores homogenous than fruit with high level of disease, then should exhibit minor values of these features. Differences between shapes of blueberries might be produced for diseases like mechanical damage and should be represented in features like Danielsson algorithm, Hu moments and Fourier descriptors between others.

**Table 1** Selected features to recognize fungal decay in blueberries.

| Generic Feature and nomenclature description | Features found as pattern of blueberry disease | side |
|---|---|---|
| Haralick texture (Tx), "k"esime entropy calculated with "n" pixels, of distance (range or mean) measure in color components H, S, V, R, G or B [14] | Tx2,d1(mean)-H,<br>Tx1,d1(mean)-H,<br>Tx2,d1(mean)-G,<br>Tx8,d1(mean)-R,<br>Tx14,d1(range)-R,<br>Tx5,d1(mean)-S, | Pedicel-calyx<br>Calyx<br>Pedicel<br>Calyx<br>Calyx<br>Calyx |
| Eccentricity (E) is the distance between the eccentric center and its axis [15]. | E | Calyx |
| Euclidian distance measured with Dannielsson algorithm [18]. | EDD | Calyx |
| Hu invariant moment (Hu), -number (N) [16]. | Hu-3 | Pedicel, calyx |
| Hu invariant moment (Hu), number (N), measured in intensity image (int) in saturated image | Hu-3-int | Pedicel |
| Gabor (Ga) - component (n,m), measure in color components (H,S,V,R,G,B or gray) [17]. | Ga(1,3)-gray<br>Gabor(J)-H | Pedicel-calyx<br>Calyx |
| Fourier transform (Fu)-"k"esime descriptor measured in color components (H,S,V,R,G,B, saturation or gray) [13] | Fu-10-gray<br>Fu-3-sat | Pedicel<br>Calyx |
| Average gray intensity of image (G) | G | Calyx |
| Discrete Cosin Transform (DCT) with "n" point measures in color components (H,S,V,R,G,B, saturation or gray) [13] | DCT-4-gray | Pedicel |
| Center of ellipse | CE | Calyx |

Selecting the best strategy with the appropriate number of features

Using a brief amount of features with the two best classifiers: "LDA" and "NN" was possible classify correctly over than 96% images with fungal decay (Figure 2). Using "SVM", "LDA" and "QDA" was possible design classifiers to segregate more the 90% of blueberries with global damage (fungal decay plus shriveling plus mechanic damage compared with healthy unities).

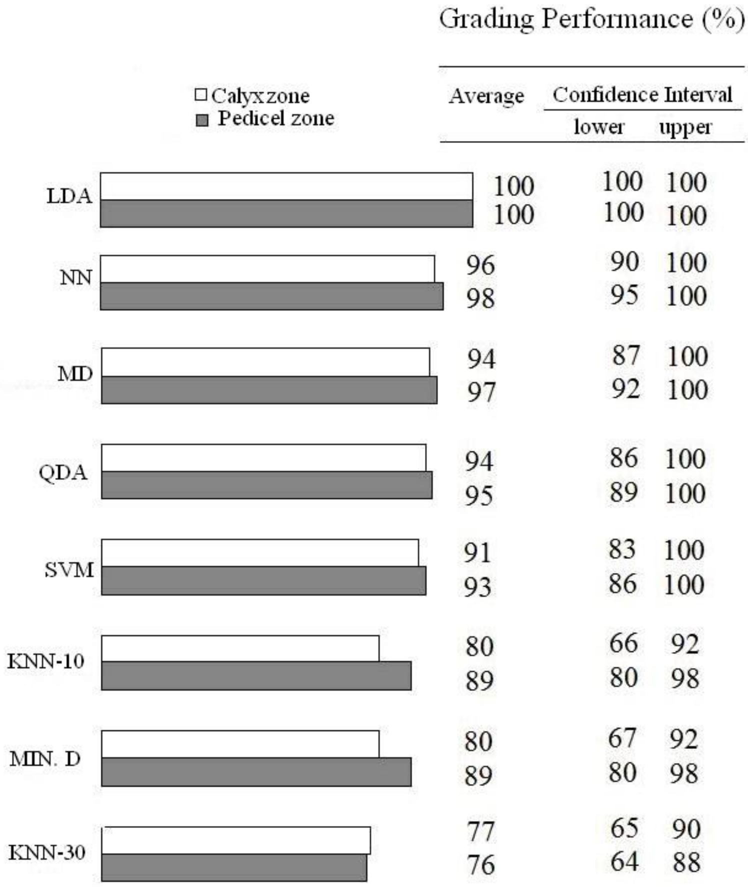


**Figure 2.** Grading performance with different classifiers of fungal decay

Actually, operators remove diseases as fungal decay, mechanical damage and shriveling. However, this process is slow and expensive. Blueberry fruits have several characteristic that make difficult the quality inspection through computer vision techniques: is smaller than common fruit as apple or pears; high variability of shapes, weighs, colors; dark color and wax presence that block an appropriate vision of defects. In this sense, the work presented has the goal to be the first approach to develop a system able to be implemented in an automatic process line, or to be a tool that complements actual systems to control manual labors. Further work should include evaluate other visual damages and others non visual as softening. The best technology might be implemented with spectral imaging and image processing with similar algorithms that this approach.

The proposed methodology to find the better few features, the best clas sifiers might be slow in a first. However, once known the selected algorithms, the selection is done in real time. Is interesting to notice that better classifier was LDA, the simplest algorithm. Other good results were done with other algorithms as a neuronal network or support vector machine, both slower in calculus time.

## CONCLUSION

Using these eight features with the two best classifiers: "LDA" and "NN" was possible classify correctly over than 96% images with fungal decay. Using "SVM", "LDA" and "QDA " was possible design classifiers to segregate more the 90% of blueberries with global damage (fungal decay, shrivelling or mechanic damage). This methodology was capable to classify between 90 and 100% of damaged blueberries using computer vision, in spite of blueberries is a difficult fruit to detect postharvest diseases, ten percent more than common manually sorting. The present study is the first approach to diminishing operations cost and rejections of blueberries batches in destine using computer vis ion techniques.

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