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Comparison of Adapted and Improved Feature Extraction Techniques of Different Potatoes Types using Image Processing

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Abstract— *The characteristics of crack, rotten, sprout, skin peel and good potatoes non destructively with gray level co-occurrence matrix properties (GLCMP), radon, gabor, local binary patterns (LBP) and histogram of oriented gradients (HOG) with default parameters and values i.e. adapted method were compared with improved method. Gabor feature length (16) of improved method was lower compared to adapted method and improved method and it requires less time to plot gabor magnitude and spatial kernels for all potato classes. Radon feature row vector size is same for both adapted and improved methods for all potato classes but differ in column vector size. At theta value of 90° (improved method), the time taken to plot radon transforms is lower compared to adapted method (using theta value 180°). Gray level co-occurrence matrix properties (GLCMP) such as contrast, correlation, energy and homogeneity values were compared to both adapted and improved methods for all potato types. Contrast values found lower in adapted method for all potato classes compared to improved method. But remaining three properties found highest in adapted method for all potato classes compared to improved method. The default values used in adapted method of HOG feature vector length (26140) is higher compared to improved method (1330) for all types of potato images. For crack and rotten potato images, an improved method required higher time to plot visualization than adapted method, while for sprout, good and skin peel images, adapted method has more visualization time. The LBP feature length in improved method was found higher (185) compared to adapted method (59) for all potato classes. The mean time to plot squared errors in adapted and improved methods for crack images were found to be 0.6378 s and 0.6305 s respectively, for rotten images 0.2098 s and 0.2622 s, for sprout images 0.1911 s and 0.2209 s, for skin peel images 0.2197 and 0.2197 s, for good images 0.2672 and 0.2565 s.*

Keywords— ***Local Binary Patterns, Histogram of Oriented gradients, Radon Features, Gabor Features and Grey Level Co-occurrence Matrix Properties***

I. INTRODUCTION

The demand for image processing is increasing day by day by extracting preciuos data from images without touching the objects. An each image contains information and it is extracted either in the form of numerical or in graphical fprm by different feature extraction techniques. Image processing carries excellent verification of agricultural commodities (Unay *et al.,* 2011). One of the most famous cultivations on earth, which is widely consumed as raw or cooked, is potato (*Solanum Tuberosum L.*). Farming of potatoes accounts for almost 80 per cent of countries. Following rice, wheat and maize, it is India's main crop. The need for potatoes for processed products is strong and not for fresh use. This increases the demand on the market for high-quality potatoes (Rani and Prasoon, 2013). In India, 5129.4 million ton potatoes (Anonymous, 2018) are produced for the year 2017-18, and it occupied third position in the world (Anonymous, 2017). In India, potato production has increased substantially over the last six decades. The analysis shows that the potato yield and production increased respectively at the national level at 1.10 and 5.98 million per year during the last decade (Bai *et al.*, 2009). In this paper, gray level co-occurrence matrix (GLCM), local binary patterns (LBP), Histogram of Aloriented gradients (HOG), gabor and radon feature extraction techniques were appiled to crack, rotten, sprout, skin peel and good potato images in adapted and improved techniques, because it is very necessary and important to find best technique interms of feature size and time taken to extract features.

II. REVIEW OF LITERATURE

Local binary patterns and gray level co-occurrence matrix properties are used to estimate the textural features (Matlab, R2018b). Moallem *et al.*, (2013) used three properties of gray level co-occurrence matrix such as contrast; correlation and energy are used for classification using support vector machine and artificial neural network. Alhindi *et al.*, (2018) given that local binary patterns (LBP) for recognizing mammography images, facial recognition and for extracting features of cancerous areas. Ojala *et al.*, (2002) given that LBP features mainly depend on number of neighbors and radius. The general combinations used in LBP are 4, 8, 12, 16 and 24 numbers of neighbors for 1, 1, 1.5, 2.0 and 3.0 radii respectively. Alhindi *et al.*, (2018) stated that output feature has a dimension of 1182 by using radius and number of neighbors as 4 and 14 respectively. In histogram of oriented gradients (HOG), an image is divided into number of cells by using different cell sizes and draw gradients over the image. Features of HOG and LBP are used in facial recognition. An output of 1224 bin dimension HOG vector was formed by using cell size of 18-by-18 and block size of 1-by-1. Gabor features are used for detecting cancerous images from non cancerous images (Alhindi *et al.*, 2018). Radon features uses projections to calculate feature vector (Alhindi *et al.*, 2018).

III. MATERIALS AND METHODS

This section starts with image capturing system development. Five adapted, improved feature extraction techniques used in image analysis were compared and conclusions were drawn.

3.1 Setup for Image Capturing

The image processing units were consisting of acquisition devices, followed by image analysis unit like computer with image storage unit as shown in Figure 1. Image capturing requires an artificial light, image sensor and image storage unit as shown in Figure 1.

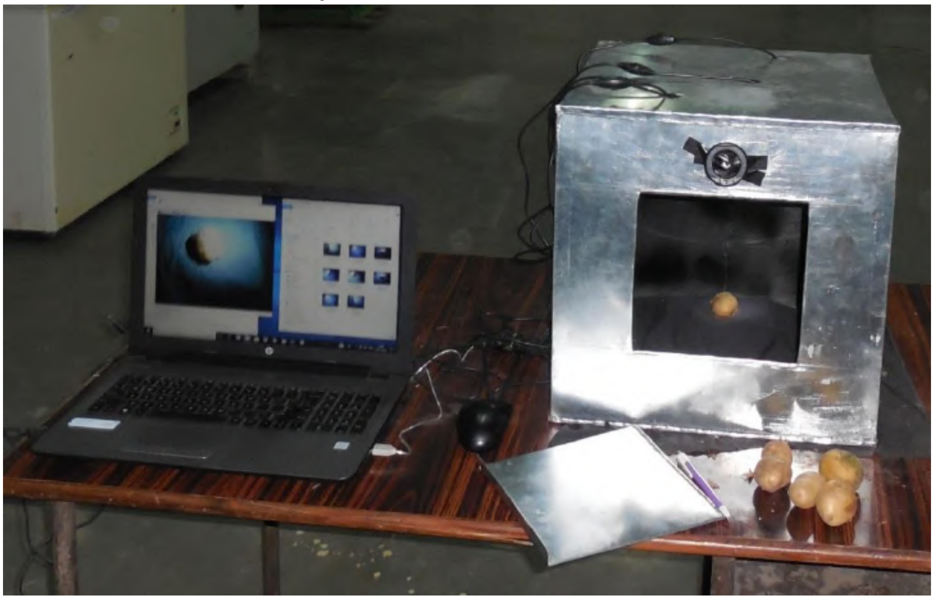

Fig.1 Image processing setup developed for potatoes

A setup was developed with the help of a 40×40×40 cm box using a 20-gauge galvanized iron sheet. Four still web cameras (Model no. QHM495LM) equipped with inbuilt six LED lights and potentiometers were installed on the inner four side walls of the box focussing in the centre of the box (Figure 1). The four ends of cameras were connected to laptop through USB (Zebronics, ZEB-04HB) Hub. While capturing care must be taken by allowing light to settle on potatoes. Potentiometers were used for adjusting the light intensity. Walls of the box were painted with black color to eliminate reflections. A door was provided at the front to place and remove potatoes. After developing setup, next step is image capturing. Crack, rotten, sprout, skin peel and good potato images each of twenty having different image sizes are taken for adapted and improved feature extraction. Feature extraction is the step before classification.

3.2 ADAPTED FEATURE EXTRACTION TECHNIQUES

Feature extraction techniques like gray level co-occurrence matrix properties, local binary patterns, histogram of oriented gradients, gabor and radon transforms were applied to five types of potato images by some default values and adapting changes according to their properties (Matlab, R2018b). Features from images are extracted to maximise the object identification and information available in images. To calculate time taken to plot for all techniques except GLCMP, *tic* function at starting of the algorithm and *toc* function at the end of the algorithm is applied (Matlab, R2018b).

3.2.1 Adapted Gray Level Co-occurrence Matrix Properties (GLCMP)

In adaptive method, an offset of [0 1] is applied to find the contrast, correlation, energy and homogeneity values (Haralick *et al.*, 1973). Following algorithm was developed for extracting the properties of GLCM.

Algorithm 1 : Finding properties of GLCM

Input: Color potato picture

Output: Values of gray level co-occurrence matrix i.e. variance, correlation, uniformity and homogeneity

Step 1: Read color potato image to a variable using imread function.

Step 2: Convert the color potato image to gray image.

Step 3: Specify number of gray levels and offsets to observe GLCM size using *graycomatrix*.

Step 4: Find GLCM properties using *graycoprops* at given number of offsets.

Step 5: Find the mean of above set of values to calculate single value of variance, correlation, uniformity and homogeneity.

3.2.2 Adapted Local Binary Patterns

In adapted method, the default values of 1 and 8 are taken as the radius and number of neighbors respectively (Ojala *et al.*, 2002). For calculating the plot time between squared error and histogram bins, images are rotated to 30°. For calculating feature vector rotation invariant property (Upright) is set to 'true' and incase of calculating plot, time rotation invariant property is set to 'false'. The following algorithm was developed for local binary patterns.

Algorithm 2: Extracting local binary pattern (LBP) features

Input: Color potato image

Output: Local binary feature vector and plot between squared error and LBP histogram bins

Step 1: Read an image to a variable using imread function

Step 2: Convert the color image into gray image using rgb2gray function

Step 3: Rotate gray image to an angle of 30°

Step 4: Calculate local binary feature vector of gray image and rotate gray image using extractLBPFeatures function

Step 5: Square the difference of local binary feature vectors of gray image and rotate gray image

Step 6: Draw bar chart between squared error and LBP histogram bins

3.2.3 Adapted Histogram of Oriented Gradients

In adaptive method all default values are used to calculate HOG feature vector i.e. Cell size 8-by-8, block size 2-by-2, block over lap 1-by-1, number of bins 9 and Used signed orientation is set to false (Dalal and Triggs, 2005). Algorithm for determining of histogram of oriented gradients is given below:

Algorithm 3: Feature vector of histogram of oriented gradients

Input: Gray Image

Output: Visualization of Gradients and feature vector

Step 1: Read an image using *imread* function
Step 2: Selecting the size of cell
Step 3: Extract HOG Feature vector using *extractHOGFeatures* function.
Step 4: Plot distribution of gradients
Step 5: Displaying result.

3.2.4 Adapted Gabor Feature

A wavelength of 2 (Matlab, R2018b) to 10 with equal interval of 2 and orientation of 0 to 180 with an interval of 22.5 degrees was taken for extracting adapted gabor feature vector. Five wavelength values and eight orientation values are suggested by (Bai *et al.*, 2009 and Zhu *et al.*, 2007). Algorithm for extracting gabor feature is given below:

Algorithm 4: Extracting gabor features

Input image: Color image

Output image: Gabor filtered image and visualization of wavelength and orientation

Step1: Read the color image using imread function

Step2: Resize the image by using a fraction of 0.1 using imresize function

Step3: Convert resized color image into gray scale image using rgb2gray function

Step4: Assign the wavelength and orientation values

Step5: Form gabor array

Step6: Apply gabor filter to gray scale image using imgaborfilt function

Step7: Display gabor filtered images

Step 8: Give wavelength and orientation ranges to visualize the wavelength and orientation of spatial kernels.

3.2.5 Adapted Radon Feature

In adaptive radon transform the default values of theta ranges from 0 to 180° are taken (Matlab, R2018b). Algorithm for extracting radon features was given below:

Algorithm 5 : Calculating radon features of a color potato image

Input: Potato color (RGB) image

Output: Radon features of an image

Step 1: Read a color image to a variable using imread function

Step 2: Converting RGB image into gray scale image using rgb2gray function

Step 3: Set projection angle theta (θ) between 0 to 179°.

Step 4: Find the sizes of radon and radial coordinates feature vectors

Step 5: Plotting graph between projection angle (theta) and vector coordinates of radon using plot function

3.3 IMPROVED FEATURE EXTRACTION TECHNIQUES

Adapted feature extraction techniques were limited to their standard type of algorithm but improved feature extraction techniques are will give better and convenient results than adapted techniques. Contrast, correlation, energy and homogeneity values were computed by changing offset in improved GLCMP (Gray Level Co-occurrence Matrix Properties) technique. Cell size and block size are selected to find improved HOG technique. Wavelength and orientation values are selected to find improved gabor features. Half of the projection angle used in adapted technique used to find radon features respectively. Parameters like improved radon are selected based on preliminary studies. Except for GLCMP, time taken to execute plot was applied.

3.3.1 Improved Gray Level Co-occurrence Matrix Properties (GLCMP)

In improved gray level co-occurrence matrix size an offset of [4 0] was applied to find the feature vector containing contrast, correlation, energy and homogeneity values. Offset parameter [4 0] taken because of good coverage of neighboring pixels in calculating contrast, correlation, energy and homogeneity.

3.3.2 Improved Local Binary Patterns (LBP)

In improved method of LBP the radius and number of neighbors taken as 4 and 14 respectively (Alhindi *et al.*, 2018) and the remaining steps are same as shown in Algorithm 2.

3.3.3 Improved Histogram of Oriented Gradients (HOG)

In improved histogram of oriented gradients a cell size of 18-by-18 and block size of 2-by-2 was used (Alhindi *et al.*, 2018) instead of 8 by 8 in adapted HOG, while remaining steps were same.

3.3.4 Improved Gabor Features

In improved gabor feature extraction four wavelength values and four orientation values are taken. Wavelengths of 32, 26, 18 and 16 pixels/cycle and orientation values of 0, 45, 90 and 135 degrees are taken (Fogel and Sage, 1989) and remaining values is similar to Algorithm 4.

3.3.5 Improved Radon Features

In improved radon feature extraction the radon transforms are calculated by using theta value ranging from 0 to 90° and remaining values similar to Algorithm 5.

IV. RESULTS AND DISCUSSION

The developed image capturing setup has a resolution of 0.22 mm/pixel which was in acceptance with strawberry grading system with 0.17 mm/pixel resolution (Xu and Zhao, 2010). The results of five feature extraction methods in terms of adapted and improved techniques were compared and analysed. The size of GLCM in adapted and improved techniques is same i.e. 8-by-8, because all input images were 8-bit images.

4.1 Comparison of adapted and improved gray level co-occurrence matrix properties

Similar patterns are observed for properties of GLCM among all potato classes for adapted and improved feature extraction techniques. Contrast values are lower in adapted method for all potato classes compared to improved method. A difference of contrast values in adapted and improved method was observed in the range of 0.2-0.3. Correlation values are higher in adapted method for all potato classes compared to improved method. A difference of correlation values between adapted and improved method of crack potatoes is 0.04, while for rotten potatoes it is 0.04, for sprout potatoes it is 0.035, skin peel potatoes it is 0.04 and for good potatoes it is 0.025. Energy values are 0.2 times higher in adapted method for all potato classes compared to improved method. Homogeneity values are higher in adapted method for all potato classes compared to improved method (Figure 2).

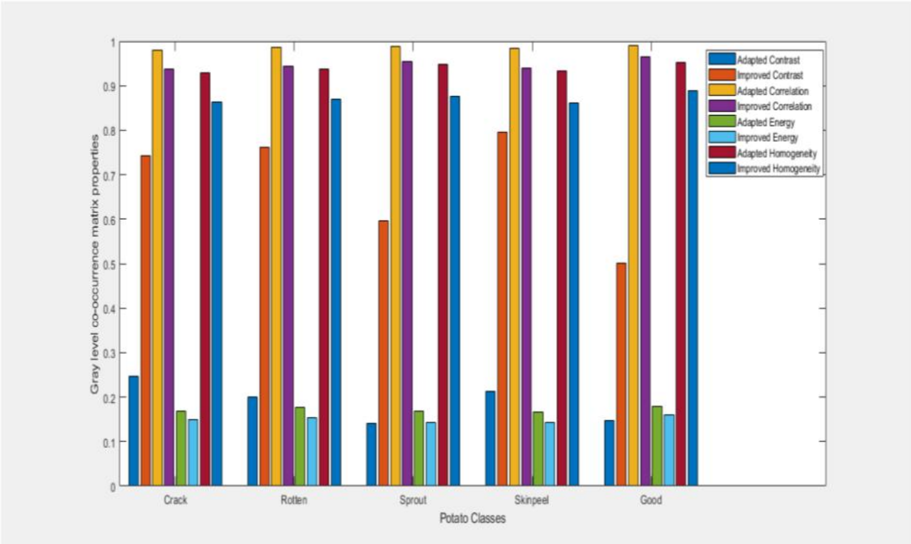

Fig.2 Comparison of adapted and improved GLCMP in relation to potato classes

Homogeneity value of 0.06 was observed for crack potato as difference value of adaptive and improved methods. Similarly, a difference of 0.069 was observed for rotten, 0.07 for sprout, 0.0728 for skin peel and 0.063 for good potatoes were observed.

4.2 Comparison of Adapted and Improved Gabor Features

Adapted gabor feature vector length (40) was same for all types of potato images. The size of gabor feature length depend upon the number of elements in the wavelength and orientation vectors. The size of gabor feature array is the product of number of elements in the wavelength and orientation vectors. Gabor features in adapted and improved techniques were compared using feature vector lengths and time taken to plot magnitude and spatial kernels in seconds. An improved gabor method has lower gabor feature length compared to adapted gabor method (Figure 3).

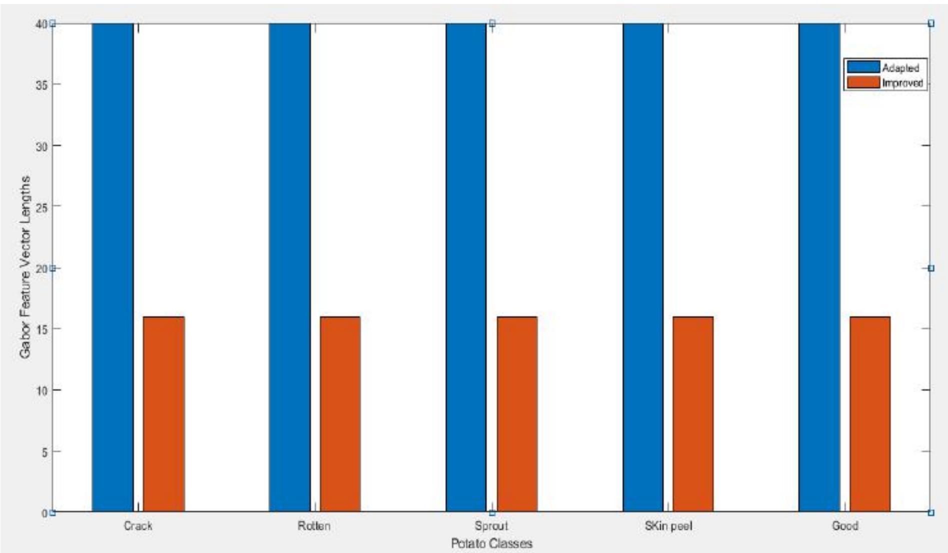

Fig.3 Comparison of adapted and improved gabor feature vector lengths in relation to potato classes

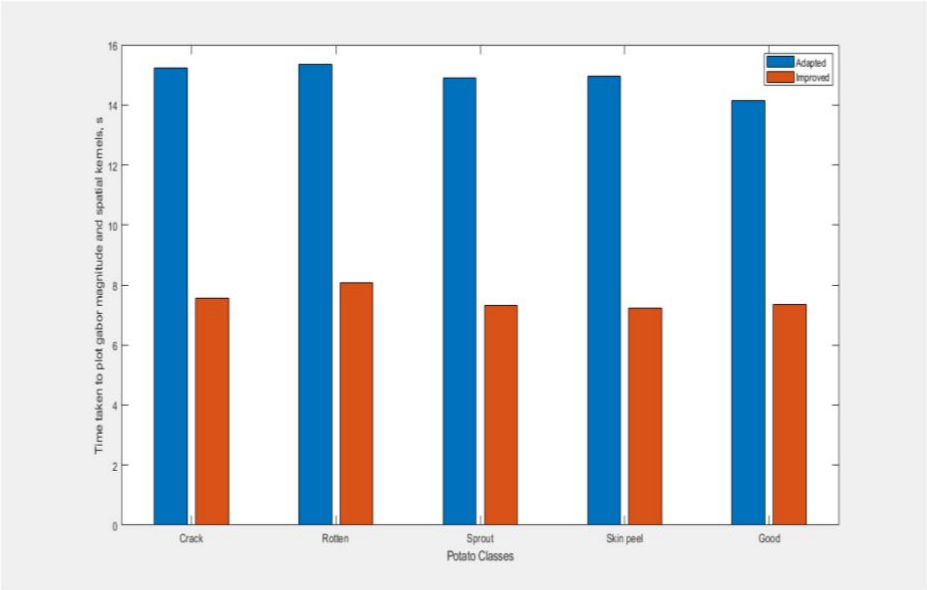

Fig.4 Comparison of adapted and improved plot timings of gabor magnitude and spatial kernels in relation to potato classes

Improved gabor method requires less time to plot gabor magnitude and spatial kernels for all potato classes (Figure 4).

The time taken to plot magnitude and real spatial parts of all types of potato images in adapted radon method is twice to the time taken in improved radon method.

4.3 Comparison of Adapted and Improved HOG Features

The HOG feature vector lengths in adapted HOG method had highest compared to the improved HOG method proposed by (Alhindi *et al.*, 2018) (Figure 5).

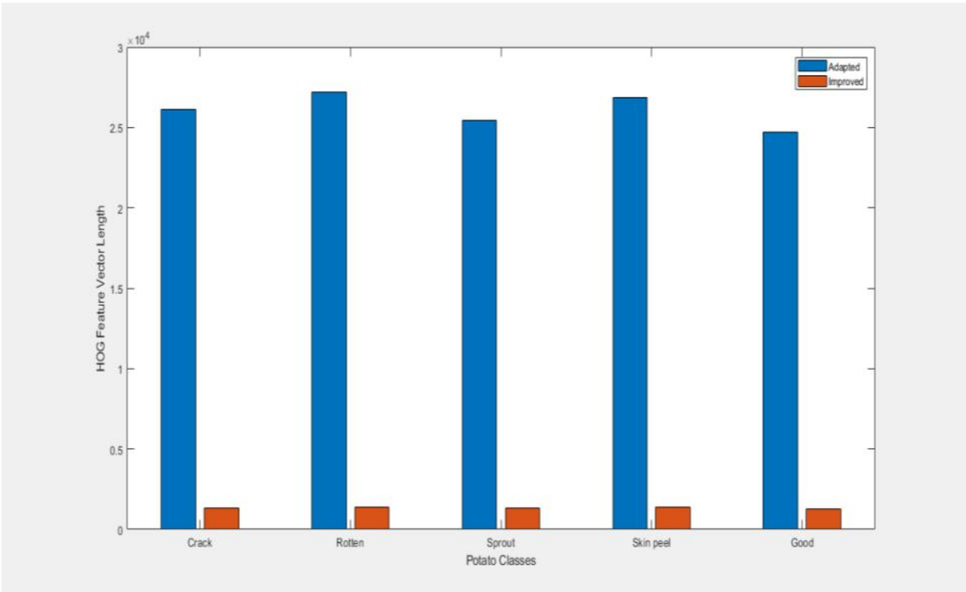

Fig.5 Comparison of HOG feature vector lengths in adapted and improved techniques in relation to potato classes

For crack and rotten images, an improved HOG method proposed by Alhindi *et al.*, (2018) has required higher time to plot visualization than adapted HOG method. While for sprout, good and skin peel images, adapted HOG method has more HOG visualization time because of cell size 8- by-8 compared to improved HOG cell size of 18-by-18 (Figure 6).

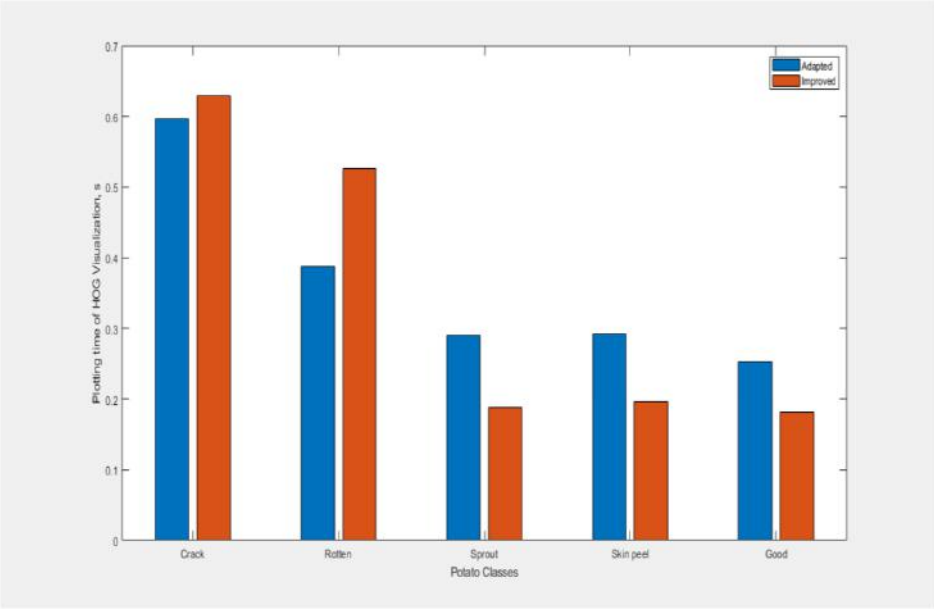

Fig.6 Comparison of adapted and improved HOG visualization times in relation to potato classes

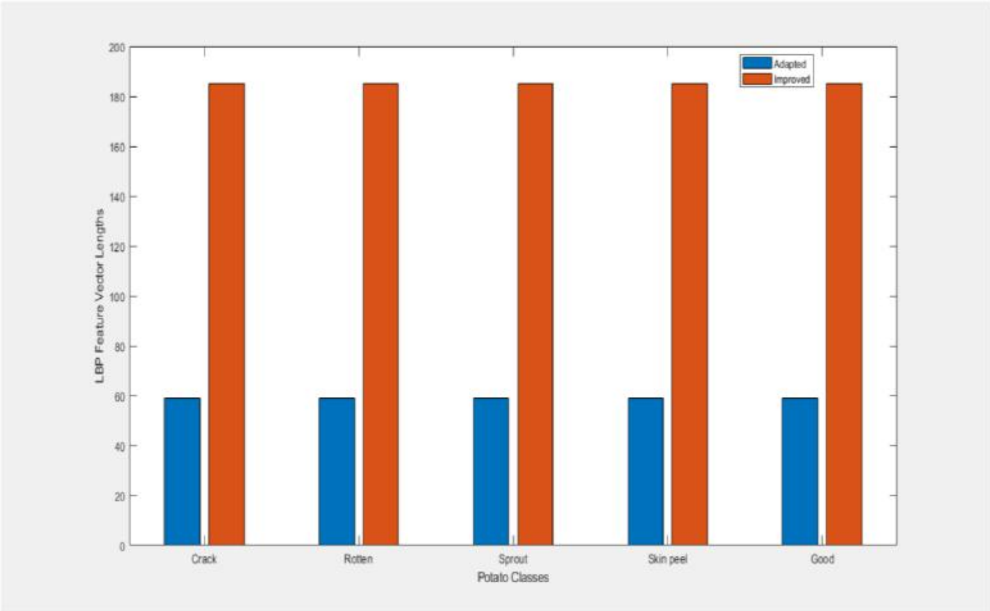

Fig.7 Comparison of adapted and improved techniques in relation to potato classes using LBP feature vector lengths

4.4 Comparison of Adapted and Improved LBP Features

The feature vector lengths of an improved method proposed by Alhindi *et al.*, (2018) were higher (185) compared to adapted method (59) (Figure 7).

The mean time to plot squared errors in adapted and improved methods for crack images were found to be 0.6378 s and 0.6305 s respectively, for rotten images 0.2098 s and 0.2622 s, for sprout images 0.1911 s and 0.2209 s, for skin peel images 0.2197 s in both methods, for good potato images 0.2672 s and 0.2565 s (Figure 8).

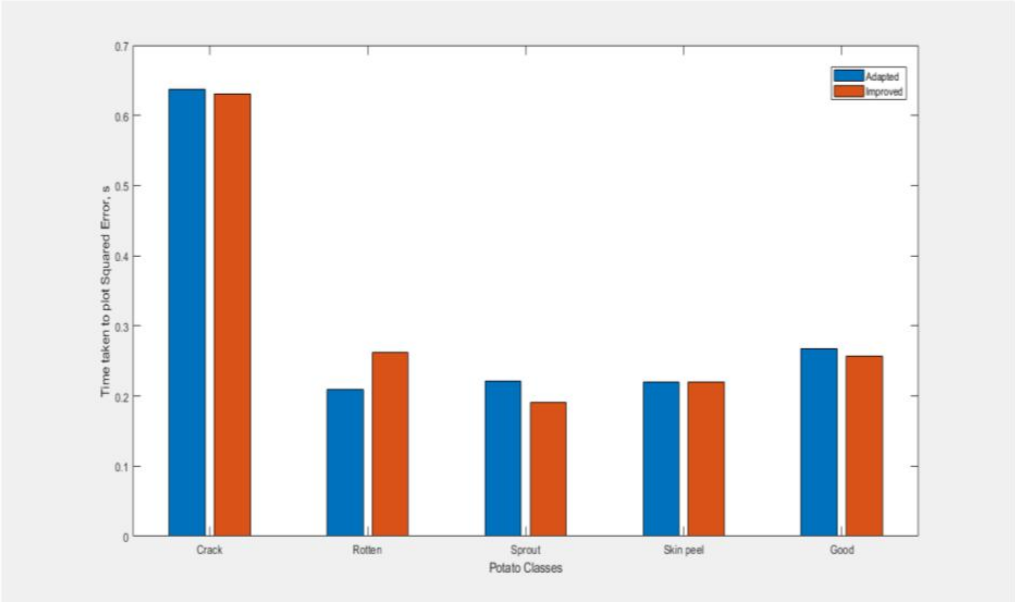

Fig.8 Comparison of adapted and improved techniques in relation to potato classes using squarred errors in LBP

4.5 Comparison of Adapted and Improved Radon Features

Radon feature sizes of adapted (Matlab, R2018b) and improved methods were same but differ in radon transform plotting time. From radon feature sizes of adapted and improved methods, it is inferred that the theta value effect the size of the radon feature (Figure 9).

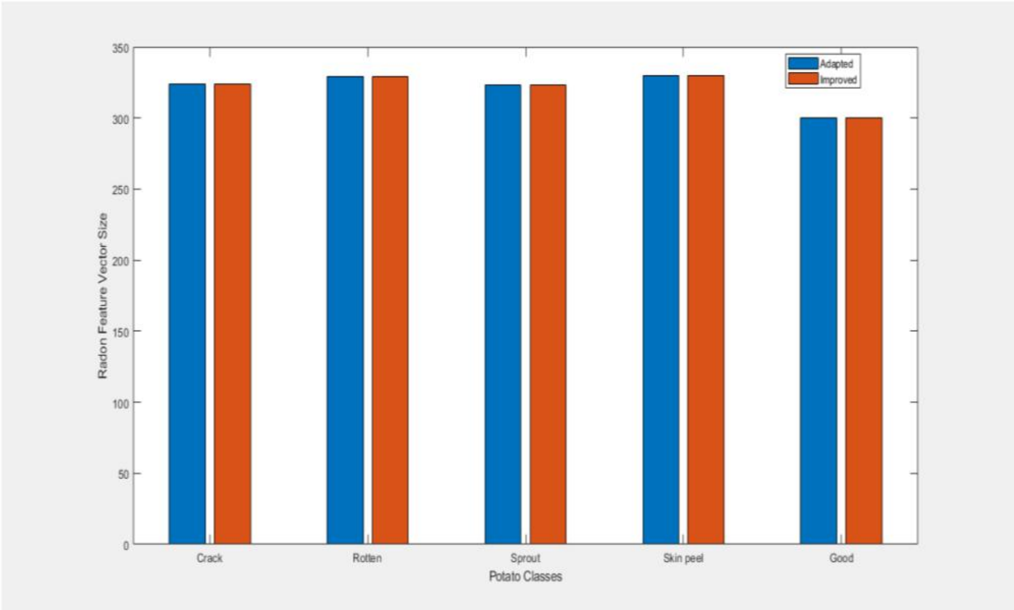

Fig.9 Comparison of radon feature vector lengths of adapted and improved techniques in relation to potato classes

At half of the theta value (90°) in improved method, the time taken to plot radon transforms is lower compared to adapted method (at theta value 180°) (Figure 10).

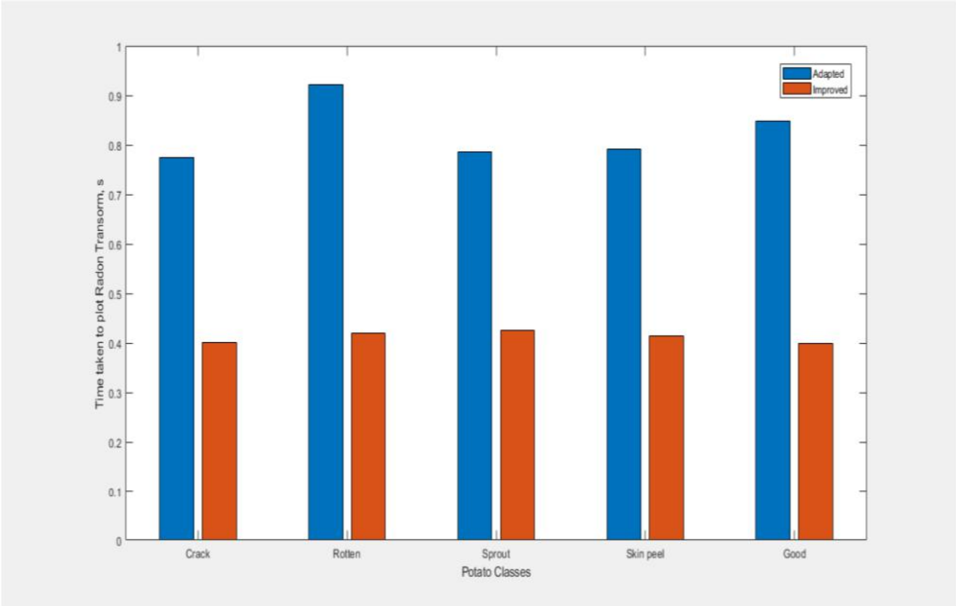

Fig.10 Comparison of time taken to plot radon transforms of adapted and improved techniques in relation to potato classes

V. CONCLUSIONS

The adapted feature vector lengths in HOG were found highest compared to the improved HOG method for all potato classes. For crack and rotten potato images, HOG visualization time in improved method was higher compared to adapted method but for remaining potato image classes adapted method has more HOG visualization time compared to improved method. The LBP feature vector lengths in improved method were higher compared to adapted method for five potato classes. In improved LBP method, the squared error's for all potato classes were same. The gabor feature vector length was highest in adapted method compared to improved method for all potato classes. An Improved Gabor method required less time to plot gabor magnitude and spatial kernels for all potato classes compared to adapted method. For all potato classes radon feature vector sizes were same in both adapted and improved methods but differ in plotting times of radon transformation. Theta value affected the radon feature vector size in all potato classes. In improved radon method, less time had taken for plotting radon transforms for five classes of potato compared to adapted method. In improved GLCMP method, contrast values were highest compared to adapted method for all five potato classes. In adapted GLCMP method, correlation values were greater than adapted method for all potato classes. In adapted GLCMP method, energy values were greater for all potato classes compared to improved method. Also, in adapted GLCMP method, homogeneity values were greater for all five potato classes compared to improved GLCMP method.

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