Comparative Performance Analysis of DWT-SVD Based Color Image Watermarking Technique in YUV, RGB and YIQ Color Spaces

Baisa L. Gunjal and Suresh N. Mali

***Abstract*—In this paper, robust color image watermarking technique based on discrete wavelet transform-singular value decomposition (DWT-SVD) with Arnold scrambling is proposed and tested with YUV, RGB and YIQ color spaces. The PSNR and NC are compared for YUV, RGB and YIQ color spaces and complete analysis is presented. The decomposition is done with 'Haar' which is simple, symmetric and orthogonal wavelet and the direct weighting factor is used in watermark embedding and extraction process. The results are tested with standard database color images of size 512×512 and grey scale watermark of 64×64 sizes. The presented scheme is non blind. The maximum recorded PSNR is 53.1701 for R channel and up to 52.3337 for Y channel and maximum value of NC equal to 0.9997 for U channel and average value remains 0.99 indicating best recovery of watermark for all channels. The proposed scheme is also tested for different attacks like compression, scaling, rotation, cropping noise etc in YUV, RGB and YIQ color spaces and comparative results are presented.**

***Index Terms*—Color spaces, YUV, RGB, YIQ, DWT-SVD, arnold transform.**

I. Introduction

Image watermarking has become one of the widely used means to protect the copyright of digital images. Robustness, Perceptual transparency, capacity and blind watermarking are four essential factors to determine quality of watermarking scheme [1], [2]. In spatial domain, watermark is embedded by directly modifying pixel values of cover image. Least significant bit insertion is example of spatial domain watermarking. These algorithms are simple in implementation. But problems with such algorithms are: Low watermark information hiding capacity, Less PSNR, Less Correlation between original and extracted watermark and less security, hence anybody can detect such algorithms. The Frequency domain the watermarks inserted into transformed coefficients of image giving more information hiding capacity and more robustness against watermarking attacks because information can be spread out to entire image [3]. Digital color image watermarking can be implemented using different color spaces like YUV color space, RGB color space or YIQ color space. The rest of the paper is organized as follows: Section II focuses on survey of existing color image watermarking algorithms. In Section III foundations of proposed methodology i.e. YUV, RGB and YIQ color spaces, discrete wavelet transform (DWT) Domain, singular value decomposition (SVD) domain and Arnold Transforms have been explained. Section IV explorers proposed methodology with embedding and extraction algorithms. Section V shows experimental results after implementation and Testing and the conclusion is drawn in Section VI.

Manuscript received May 25, 2011; revised August 6, 2011.This work was supported by Board of Colleges and University Development (BCUD) under Research Grant Ref. No.-BCUD/OSD/390 Dated 25/10/2010, University of Pune, MS, India.

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II. Survey

Though Fourier transform, short time Fourier transform and continuous wavelet transform are available in transform domain, but all of them are having their own limitations. Discrete wavelet transform provides multi resolution for given image and can efficiently implemented using digital filter, it has become attraction of researchers in image processing area. Here, review of literature survey is done with existing color image watermarking techniques with based on discrete wavelet transform. Following are some existing methods for in color image watermarking. In [4], integer wavelet transform with bit plane complexity segmentation is used with more data hiding capacity. This method used RGB color space for watermark embedding. In [5] DWT based watermarking algorithm of color images is proposed. The RGB color space is converted into YIQ color space and watermark is embedded in Y and Q components. This method gives correlation up to 0.91 in JPEG compression attack. In [6], Watermarking algorithm based on wavelet and cosine transform for color image is proposed. A binary image as watermark is embedded into green or blue component of color image. In [7], Color image watermarking algorithm based on DWT-SVD is proposed in green component of color image. The scrambling watermark is embedded into green component of color image based on DWT-SVD. The scheme is robust and giving PSNR up to 42, 82. In [2], Pyramid wavelet watermarking technique for digital color images is proposed. This algorithm gives better security and better correlation in noise and compression attacks.

III. Foundations of Proposed Methods

A. RGB Color Spaces

Some of researches have used RGB color space for watermark embedding. First R, G, B planes are separated using equations 1, 2, 3 and either one of these planes or combination of two can be used for embedding.

$$R = \ Cover\_Image(:,:,1) \tag{1}$$

$$G \ = \ Cover\_Image(:,:,2) \tag{2}$$

$$B \ = \ Cover\_Image(:,:,3) \tag{3}$$

But, RGB color space is complex in describing the color pattern and has redundant information between each component [5]. Since Pixel values in RGB color space are highly correlated, RGB color space is converted into YUV or YIQ color spaces.

B. YUV Color Spaces

Here, RGB color space is converted into YUV Color space and then Watermark is embedded. Initially color image is read and R, G, B components of original Cover Image are separated. Then they are converted into YUV color Space using following equations.

$$Y \ = \ 0.299 \times R \ + \ 0.587 \times G \ + \ 0.114 \times B; \tag{4}$$

$$U \ = -0.147 \times R \ - \ 0.289 \times G \ + \ 0.436 \times B \tag{5}$$

$$V \ = \ 0.615 \times R \ - \ 0.515 \times G \ - \ 0.100 \times B \tag{6}$$

After embedding the watermark using DWT, YUV color space is converted back into RGB color space using following equations.

$$R = \ Y \ + \ 1.140 \times V \tag{7}$$

$$G \ = \ Y \ - \ 0.395 \times U \ - \ 0.581 \times V \tag{8}$$

$$B \ = \ Y \ + \ 2.032 \times U \tag{9}$$

C. YIQ Color Spaces

In YIQ color space. Y’ is similar to perceived luminance; ‘I and Q’ carry color information and some luminance information. Here, color image is read and R, G, B components of original Cover Image are separated. Then they are converted into YIQ color Space using following equations [5]. After conversion of RGB color spaces into YIQ color spaces, Watermark is embedded.

$$Y \ = 0.299 \times R \ + \ 0.587 \times G \ + \ 0.114 \times B \tag{10}$$

$$I \ = \ 0.596 \times R \ - \ 0.274 \times G \ - \ 0.322 \times B \tag{11}$$

$$Q = \ 0.211 \times R \ - \ 0.522 \times G \ + \ 0.311 \times B \tag{12}$$

After embedding the watermark using DWT, YIQ color space is converted back into RGB color space using following equations.

$$R = \ Y \ + \ 0.956 \times I \ + \ 0.621 \times Q \tag{13}$$

$$G \ = \ Y \ - \ 0.272 \times I \ - \ 0.647 \times Q \tag{14}$$

$$B \ = \ Y \ - \ 1.106 \times I \ + \ 1.702 \times Q \tag{15}$$

D. Discrete Wavelet Transform (DWT)

ISO has developed and generalized still image compression standard JPEG2000 which substitutes DWT for DCT. DWT offers mutiresolution representation of image and DWT gives perfect reconstruction of decomposed image. Discrete wavelet can be represented as

$$\psi_{j,k}(t) = a_0^{-j/2} \psi \ (a_0^{-j} t - k b_0) \tag{16}$$

For dyadic wavelets a_0=2 and b_0=1, Hence we have,

$$\psi_{j,k}(t) = 2^{-j/2} \psi \ (2^{-j} t - k \ ) \text{j, k} \in Z \tag{17}$$

When image is passed through series of low pass and high pass filters, DWT decomposes the image into sub bands of different resolutions [3]. Decompositions can be done at different DWT levels.

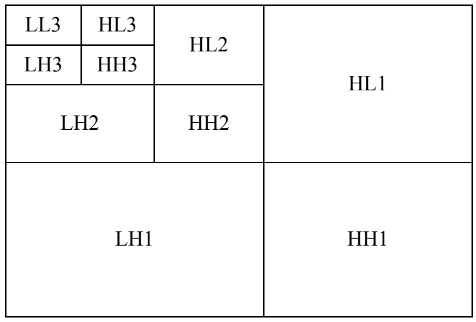


Fig. 1. Three level image decomposition

At level 1, DWT decomposes image into four nonover lapping multiresolution sub bands: LL1 (Approximate sub band), HL1 (Horizontal sub band), LH1 (Vertical sub band) and HH1 (Diagonal Sub band). Here, LL1 is low frequency component whereas HL1, LH1 and HH1 are high frequency (detail) components [8], [9], [10].To obtain next coarser scale of wavelet coefficients after level 1, the sub band LL1 is further decomposed. Three level image decomposition is shown in Figure:1. Embedding watermark in low frequency coefficients can increase robustness significantly but maximum energy of most of the natural images is concentrated in approximate (LL3) sub band. Hence modification in this low frequency sub band will cause severe and unacceptable image degradation. Hence watermark is not embedded in LL3 sub band. The good areas for watermark embedding are high frequency sub bands (HL3, LH3 and HH3), because human naked eyes are not sensitive to these sub bands. They yield effective watermarking without being perceived by human eyes. But HH3 sub band includes edges and textures of the image. Hence HH3 is also excluded. Most of the watermarking algorithms have been failed to achieve perceptual transparency and robustness simultaneously because these two requirements are conflicting to each other. The rest options are HL3 and LH3. But Human Visual System is less sensitive in horizontal than vertical. Hence Watermarking done in HL3 region.

E. Singular Value Decomposition (SVD)

Singular Values of the image gives very good stability. When a small value is added, it does not result too much variation. Hence Singular Value decomposition in linear algebra is used to solve many mathematical problems. Every real matrix A can be decomposed into product of three matrices $A=U\sum V^T$, where U and V are orthogonal matrices such that, $UU^T = I$ and $VV^T = I$and $\sum$ is summation of diagonal entries $\lambda_1, \lambda_2 \cdots$ gives the singular vectors of A. These diagonal entries are called as Singular Values of A and the decomposition is called as ‘Singular Value Decomposition’. Thus we have,

$$A = \lambda_1 U_1 V_1^T + \lambda_2 U_2 V_2^T + \cdots .. + \lambda_r U_r V_r^T \tag{18}$$

where r is rank of matrix A. Singular Values specifies the luminance of an image layer while corresponding pair of singular vectors specifies the geometry of the image layer. The SVD can be used as convenient tool for watermarking in DWT domain [7].

F. Arnold Transform

Watermark Scrambling can be carried out through many steps to improve security levels. Different methods can be used for image scrambling such as Fass Curve, Gray Code, Arnold Transform, Magic square etc. Arnold Transform has special property of Arnold Transform is that image comes to it's original state after certain number of iterations. These 'number of iterations' is called 'Arnold Period' or 'Periodicity of Arnold Transform'. Arnold Transform of image is

$$\binom{x_n}{y_n} = \begin{bmatrix}1 & 1\\1 & 2\end{bmatrix}\binom{x}{y}(modN) \quad (19)$$

where, (x, y) = {0, 1 ...N} are pixel coordinates from original image. (x_n, y_n) are corresponding results after Arnold Transform. The periodicity of Arnold Transform (P) is dependent on size of given image. From equation: 3 we have,

$$x_n = x+y \quad (20)$$

$$y_n = x+2\times y \quad (21)$$

If *(mod (x_n, N) ==1 andand mod (y_n, N) ==1)*then *P=N* (22)

IV. Proposed Methodology

The idea of proposed algorithm is extended from methods given in [7] and [5]. In [7], watermark is embedded in green component in RGB color space, while in [5], watermark is embedded in Y and Q components of YIQ color space. The proposed technique is implemented in all YUV, RGB and YIQ color spaces by implementing new strongly robust algorithm giving exact correlation between original watermark and extracted watermark in all color spaces. Following embedding algorithm used Q component of YIQ color space. Same procedure is applied for *R, G, B, Y, U, V* and I components one by one according to given color spaces.

A. Watermark Embedding Algorithm

Step 1: Read Color cover Image and convert it into YIQ color space to separate *Y, I* and *Q* components using equations 10,11 and 12

Step 2: Apply 3 levels DWT to *Q* component to get *'Q_HL3_Component'* as shown in figure: 1.

Step 3: Apply SVD to '*Q_HL3_Component'* as follows:

$$[U, S, V] = SVD(Q\_HL3\_Component) \quad (23)$$

Step 4: Read Watermark say *'W'*.

Step 5. Apply 'Arnold Transform to given watermark *'W'* to give scrambled watermark say '*W1*' using equations 20 and 21 and 22.

Step 6. Apply following formulae for Watermark formulation and embedding:

$$S1 = S \times K1 \times W1 \quad (24)$$

where *K1* is flexing factor

Step 7: Apply SVD for above *S1* component

$$[U1, SS, V1] = SVD(S1) \quad (25)$$

Step8: Apply inverse SVD to get *'New_HL3_Component'*.

$$New\_HL3\_Componet = U \times SS \times 'V' \quad (26)$$

Step 9: Apply Inverse DWT at Level 3, Level 2 and Level 1 step by step to get '*Q_Watermarked_Component'*.

Step 10: Convert '*Q_Watermarked_Component' Y* and Icomponents to get final '*Watermarked Image'* in RGB color space using equations 13,1 4, and 15.

B. Watermark Extraction Algorithm

Step 1: Convert '*Watermarked_Image'* from RGB color space into *Y, I, Q* color space. Here we get *'Q_New_Component'* using equations 10, 11 and 12.

Step 2: Decompose '*Q_New_Component'* using 3 level DWT to get '*Q_New_HL3_Component'* shown in figure: 1.

Step 3: Apply SVD to '*Q_New_HL3_Component'*.

$$[UU, S2, VV] = SVD(Q\_New\_HL3\_Component) \quad (27)$$

Step 4: Apply following final extraction formulae to get 'Extracted_Watermark'.

$$S\_New = U1 \times S2 \times 'V1' \quad (28)$$

$$Extracted\_Watermark = (S\_New - S)/K \quad (29)$$

Step 5: Perform 'Image Scrambling' using 'Arnold Transform' with' *KEY'* that we had used in embedding process to recover Watermark using equations 20 , 21 and 22.

V. Experimental Results

This scheme is implemented in Mat lab. Results are tested, analyzed for all channels in YUV, RGB and YIQ color spaces. Here, two performance parameters are applied to measure the performance of watermarking scheme: 'Perceptual Transparency' and 'Robustness'.'Perceptual Transparency' is measured in terms of 'Peak Signal to Noise Ratio'. Bigger is PSNR, better is quality of image. PSNR for image with size M x N is given by:

$$PSNR(db) = 10log_{10}\frac{(Max_I)^2}{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j)-f'(i,j)]^2} \quad (30)$$

where,*f (i, j)* is pixel of original image. *f '(i, j)* is pixel values of watermarked image. Maxis the maximum pixel value of image. Robustness is measured in terms of Normalized Correlation *(NC)*.The correlation factor (Normalized Correlation) measures the similarity and difference between original 'watermark and extracted watermark. It's values is ideally 1, but the value more than 0.75 is highly accepted. Normalized Correlation *(NC)* is given by:

$$NC = \frac{\sum_{i=1}^{N} w_i w_i'}{\sqrt{\sum_{i=1}^{N} w_i}\sqrt{\sum_{i=1}^{N} w_i'}} \quad (31)$$

where, *N* is number of pixels in watermark, *wi* is original watermark, *wi'* is extracted watermark. The standard color Lena image of 512X512 sizes and grey scale watermark of 64x64 is used for testing. The flexing factor is varied for 10 different values. The *PSNR* and *NC* are recorded for YUV, RGB and YIQ color spaces as shown in Table 2 and Table 3. In Figure:5, Comparative results of Flexing factor versus PSNR and factor versus *NC* for YUV, RGB and YIQ color spaces are given. The maximum recorded *PSNR* is 53.1701 for R channel and up to 52.3337 for Y channel and maximum value of *NC* equal to 0.9997 for U channel and average value remains 0.99 indicating best recovery of watermark for all YUV, RGB and YIQ color spaces. It is clear that *PSNR* and *NC* are two contrast requirements. If we try to achieve more *PSNR, NC* is degraded and vice versa. The proposed scheme is tested for different attacks like compression, scaling, rotation, cropping noise etc. It's observed that embedding watermark in RGB is less robust than YUV and YIQ color spaces.

Fig. 2. Original color lena image with 5212 × 512 size, Y,U,V components and watermarked image.

Fig. 3. Original color lena image with 5212 × 512 size, R,G,B components and watermarked image.

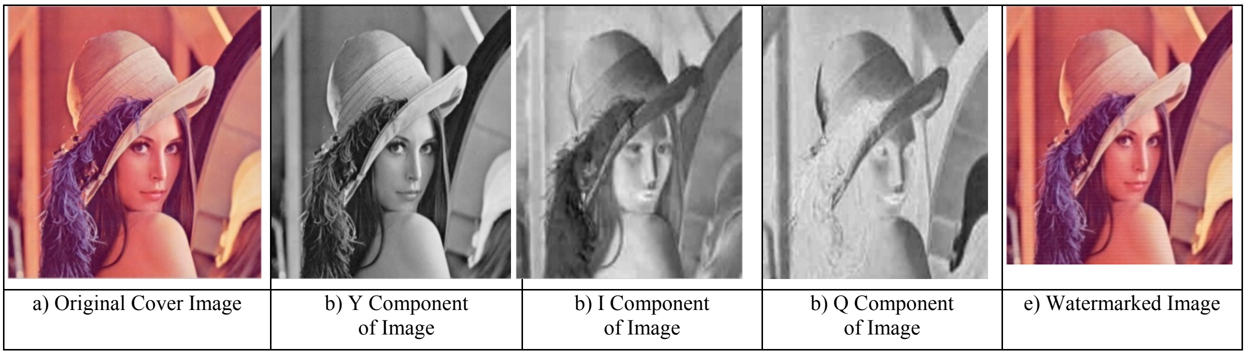


Fig. 4. Original color lena image with 5212 × 512 size, Y, I, Q components and watermarked image.

Color Space	YUV Color space			RGB Color Space			YIQ Color Space		
Channel	Y	U	V	R	G	B	Y	I	Q
Original Watermark	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE
Extracted Watermark	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE	AVCOE

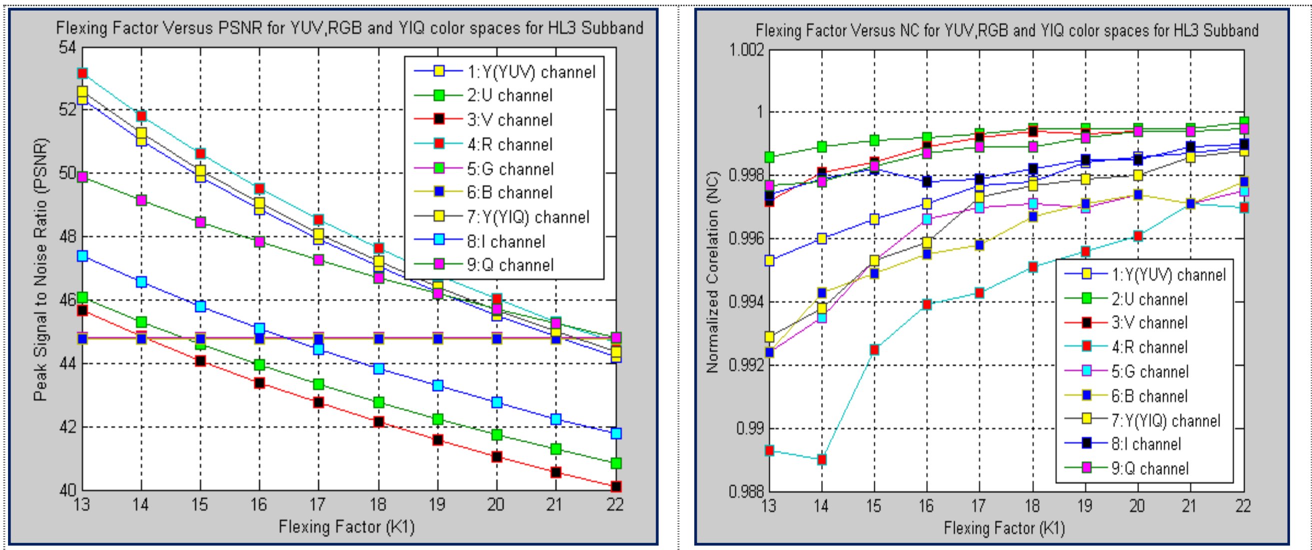
TABLE I: SAMPLE ORIGINAL AND EXTRACTED WATERMARKS FOR ALL CHANNELS FOR FLEXING FACTOR K1=22

Flexing Factor	K1=13	K1=14	K1=15	K1=16	K1=17	K1=18	K1=19	K1=20	K1=21	K1=22
Y of(YUV) Channel	52.3337	51.0430	49.8893	48.8500	47.9068	47.0449	46.2525	45.5200	44.8396	44.2048
U Channel	46.0759	45.3006	44.5911	43.9461	43.3467	42.7688	42.2489	41.7465	41.3000	40.8557
V Channel	45.6565	44.8344	44.0823	43.3892	42.7466	42.1475	41.5863	41.0592	40.5624	40.0922
R Channel	53.1701	51.8211	50.6081	49.5138	48.5213	47.6160	46.7857	46.0200	45.3105	44.6500
G Channel	44.8049	44.8049	44.8049	44.8049	44.8049	44.8049	44.8049	44.8049	44.8049	44.8049
B Channel	44.7643	44.7643	44.7643	44.7643	44.7643	44.7643	44.7643	44.7643	44.7643	44.7643
Y of(YIQ) Channel	52.5824	51.2753	50.1064	49.0538	48.0992	47.2275	46.4268	45.6872	45.0005	44.3603
I Channel	47.3928	46.5614	45.8011	45.1009	44.4519	43.8473	43.2813	42.7495	42.2479	41.7732
Q Channel	49.8753	49.1447	48.4701	47.8435	47.2585	46.7101	46.1938	45.7061	45.2439	44.8049

TABLE II: PSNR FOR YUV, RGB AND YIQ COLOR SPACES FOR FLEXING FACTORS K1=13 TO K1=22

Flexing Factor	K1=13	K1=14	K1=15	K1=16	K1=17	K1=18	K1=19	K1=20	K1=21	K1=22
Y of(YUV)	0.9953	0.9960	0.9966	0.9971	0.9977	0.9978	0.9984	0.9986	0.9987	0.9989
U Channel	0.9986	0.9989	0.9991	0.9992	0.9993	0.9995	0.9995	0.9995	0.9995	0.9997
V Channel	0.9972	0.9981	0.9984	0.9989	0.9992	0.9994	0.9993	0.9994	0.9994	0.9995
R Channel	0.9893	0.9890	0.9925	0.9939	0.9943	0.9951	0.9956	0.9961	0.9971	0.9970
G Channel	0.9924	0.9935	0.9953	0.9966	0.9970	0.9971	0.9970	0.9974	0.9971	0.9975
B Channel	0.9924	0.9943	0.9949	0.9955	0.9958	0.9967	0.9971	0.9974	0.9971	0.9978
Y of(YIQ)	0.9929	0.9938	0.9953	0.9959	0.9973	0.9977	0.9979	0.9980	0.9986	0.9988
I Channel	0.9974	0.9979	0.9982	0.9978	0.9979	0.9982	0.9985	0.9985	0.9989	0.9990
Q Channel	0.9977	0.9978	0.9983	0.9987	0.9989	0.9989	0.9992	0.9994	0.9994	0.9995

TABLE III: NC FOR YUV, RGB AND YIQ COLOR SPACES FOR FLEXING FACTORS K1=13 TO K1=22



A) Flexing factor versus PSNR for YUV, RGB and YIQ Color Spaces in HL3 Sub band

B)Flexing factor versus NC for YUV, RGB and YIQ color spaces in LH3 Sub band

Fig. 5. Flexing factor versus PSNR and flexing factor versus NC for YUV, RGB and YIQ color spaces

VI. CONCLUSION

In this paper we have demonstrated comparative performance analysis by DWT-SVD based robust color image watermarking technique in YUV, RGB and YIQ color spaces. We have got *PSNR* up to 53.1701 for R channel and up to 52.3337 for Y channel and maximum value of *NC* equal to 0.9997 for U channel, average value remains 0.99 indicating best recovery of watermark for all YUV, RGB and YIQ color spaces. It's observed that watermark embedding in YUV and YIQ color spaces is more robust than embedding in RGB color spaces in different attacks like compression, scaling, rotation, cropping, Noise addition etc. This work can be extended for Video watermarking effectively.

ACKNOWLEDGMENT

Thanks to Board of Colleges and University Development (BCUD), University of Pune, Maharashtra, India, for providing 'Research Grant' for the research project "Robust Digital Image Watermarking using Discrete Wavelet

Transform" for period 2010-2012. Also thanks to Amrutvahini College of Engineering, Sangamner, Ahmednagar, and Imperial College of Engineering and Research, Wagholi, Maharashtra, India for providing Technical Support during this research work.

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