Half toning with Unique Block Identification for Image Data Compression

Dr. H. B. Kekre, Dr. Tanuja Sarode, Sanjay Sange, Charmy Shah, Ritika Rao, Disha Parekh

Abstract—Available frequency spectrum is the natural resource. Optimization of spectrum bandwidth is the major objective of this paper. In this paper, the image data is compressed in two folds. First Half tone technique is applied on input image to convert 8-bit pixel into 1-bit pixel representation hence gives 12.5% Compression Ratio. For further compression of this data Unique Block Identification (UID) technique is proposed. Experimental results are compared with standard Floyd-Steinberg and Jarvis half tone operators with proposed Small and South-East operators. Using 4 by 4 distinct block size on half tone image proposed UID technique is implemented. Results are compared in terms of Compression Ratio (CR), Structure Similarity Index (SSIM) and Root Mean Square Error (RMSE). Proposed algorithm achieves the higher CR that ensures optimum utilization of network resources and storage and it can be used for Video-Conferencing application.

Index Terms— Half tone, Block Truncation Coding(BTC), Compression Ratio(CR), Unique block Identification(UID)

1 INTRODUCTION

HALF TONE process reduces visual reproductions to an image that is printed with only one color of ink, in the form of dot. These tiny half tone dots are blended into smooth tones by the human eye, this term is referred to as optical illusion or in other words, human being integrates entire image and do not read image pixel by pixel. In this way half tone process converts 8-bit into 1-bit pixel information. This is the great advantage of half toning those results into 8:1 CR in a single iteration. Color printing is made possible by repeating the half tone process for each subtractive color, most commonly using what is called the CMYK color model. BTC has major deficiencies of blocking and false contouring and these can be improved by Error- Diffused BTC (EDBTC), it require extremely small bias factor to increase watermark capacity without damaging image quality [1]. Other techniques also reduce blocking effect such as Ordered BTC (OBTC) [2] and Dot-Diffused BTC (DDBTC) [3]. Performance of Absolute Moment Block Truncation Coding (AMBTC) is compared with BTC whereas block redundancy is reduced and it provides BPP 1.25 and CR 85%. Proposed technique is faster, better quality, increases mean, reduces mean of block and increases CR [4]. BTC has major deficiencies of blocking and false contouring and these can be improved by Error- Diffused BTC (EDBTC), it require extremely small bias factor to increase watermark capacity without damaging image quality [1]. Other techniques also reduce blocking effect such as Ordered BTC (OBTC) [2] and Dot-Diffused BTC (DDBTC) [3]. Performance of Absolute Moment Block Truncation Coding (AMBTC) is compared with BTC whereas block redundancy is reduced and it provides BPP 1.25 and CR 85%. Proposed technique is faster, better quality, increases mean, reduces mean of block and increases CR [4]. Interpolative BTC and Modified Interpolative BTC are compared with BTC where sub-sampling technique is used and it gives 2 bits/pixel and CR 75% [5]. Modified scheme of BTC provides significant reduction in bit-rate. From the pattern book the optimum bit pattern is to be selected, hence instead of entire block only its index can transmitted. The experimental results are compared with the proposed scheme with VQ-CIBTC and Adaptive D/I in terms of BPP and PSNR [6]. Basic BTC and various improvements in BTC approaches with advantages of simplicity, fault tolerance, relatively high CR and good image quality of the decoded image are explained in detail as a survey on BTC as in [7].

Half tone itself is lossy technique on which other lossy and lossless techniques are used for further compression of image data. On half tone image Kekre's Fast Codebook Generation (KFCG) lossy vector quantization technique is used by Kekre et al as in [8]. Lossy half tone with lossless Huffman coding technique is presented as in [9]. Lossy half tone with lossless Run-Length-Encoding technique is presented as in [10]. Wavelet Transform loses some information is applied on lossy half tone image [11]. At the receiving side, corresponding decoder results into half tone image and to reconstruct image back using inverse half-toning algorithm is represented as in [12].

Section II explains about the Methodology and issues in the half tone process, few operators and proposed UID algorithm. Section III explains the experimental results and discussion in terms of measuring parameters. Conclusion and future scope of the paper are discussed in section IV.

2 METHODOLOGY

2.1 Issues of Half toning

a) Coarse Quantization Contouring:

Coarse Quantization (block size) problem arises as a result of the constraints applied in using a half toning algorithm. In general the digital half toning algorithms which are used in image reproduction separate the image into small n-by-n pixel blocks. This approach allows only a limited number 2n of bit

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- *Dr. H. B. Kekre, Sr. Professor, Computer Engineering Department MPSTME, NMIMS University, Mumbai, India, E-mail: hbkekre@yahoo.com*
- *Dr. Tanuja K. Sarode, Associat Professor in Computer EngineeringTSEC Mumbai University, Mumbai, India, E-mail: tanuja0123@yahoo.com*
- *Mr.Sanjay Sange is currently pursuing Ph. D in Computer engineering in NMIMS University, Mumbai, India, E-mail: sanjay.sange@rediffmail.com*

combinations. Under these circumstances false image contours can be generated due to coarse quantization. So it is required to ensure that the number n is not large enough to adequately represent the tonal range of the image. Block size should be n-by-n and exact divisible to image size N-by-N.

b) Space, Time considerations:

When the algorithm is applied on larger images, the time required for computation will increase greatly, as computations have to be done on 3 distinct image planes. This can be greatly reduced by applying the algorithm simultaneously on the three planes, using MATLAB's parallel computing toolbox.

2.2. Half toning

Half toning is a process that creates the visual illusion of gray scale using a dot pattern that has only two levels of gray. A half tone image is made up of a series of dots rather than a continuous tone. Half toning basically takes advantage of the limited visual perception of the human eye. A normal printing process is binary in nature that is it can only either print ink on a spot or leave it blank.

Color pictures can also be printed using half toning. In this, the picture is divided into three primary color bands (R-G-B) and each band is half toned.

In this paper, we have used four Half toning operators for the implementation. They include the standard Floyd-Steinberg, Jarvis and proposed Small and South-East (SE) half tone operator as shown in figure 1a to 1d respectively. In all operators, X represents the central pixel, on which neighborhood processing is carried out. After neighborhood processing, X will be replaced by the resultant value.

0	0	0
0	X	7
3	5	1

Figure 1. a) Floyd

0	0	0	0	0
0	0	0	0	0
0	0	X	7	5
3	5	7	5	3
1	3	5	3	1

Figure 1. b) Jarvis

0	0	0
0	X	1
0	1	3

Figure 1. c) Small

0	0	0	0	0
0	0	0	0	0
0	0	X	1	9
23	7	5	3	11
21	19	17	15	13

Figure 1. d) South-East (SE)

Next step is to apply Quantization process so as to obtain binary image e.g. only either in 1 or in 0 form. Quantization process itself leads to loss of image information by converting eight numbers of gray levels in plane into only two levels i.e. white (0) and black (1).

2.3. Proposed Unique Block Identification (UID) Algorithm:

Step 1: Resize the input image to fixed 256 X 256. Separate the image into its constituent R-G-B planes. This is shown in figure 2 where a colour 24-bit image is divided into 8-bit R-G-B planes.

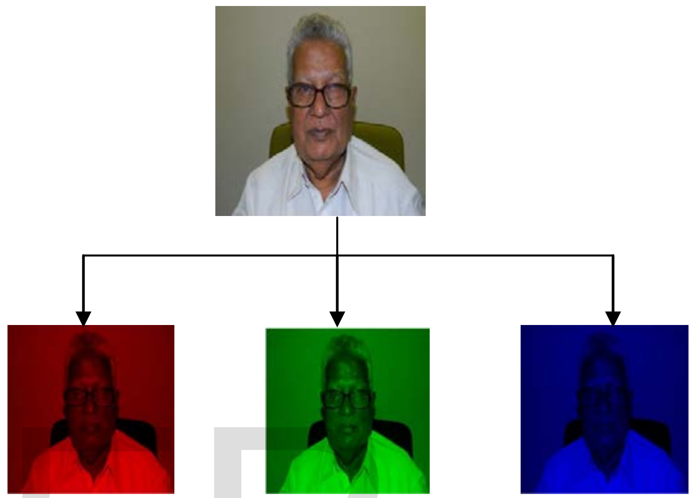

Figure 2. Color 24-bit image divided into R-G-B Planes

Step 2: Apply a half toning operators shown in figure 1a to figure 1d, each plane is to convert it into 256 X 256 binary planes separately. Figure 2 shows the half toned result (0's and 1's) of a given image.

```
1010101011110101000000
1010101010101010111110
1010101111111111111111
0100000000000000101010
1010101010100000000000
0001010110101010111111
1111101001011111111111
1111101010010101010101
0010111010100100010101
0100101010010101010101
0010010101010100101010
```

Figure 3. 1-bit Half tone image

Step 3: Divide the binary plane into distinct equal sized blocks, e.g. 4 X 4 blocks. The block size must be a factor of the image size to ensure that the blocks fit exactly. Assign a block number to each block based on its position within the image. Store these block numbers in an array, as an index to the blocks. Figure 3 shows the block numbers stored in an array that is the binary plane is divided into blocks.

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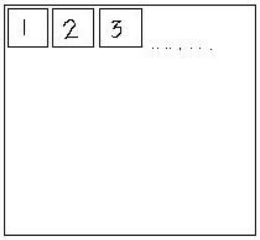

Figure 4. Binary Plane divided into blocks

Step 4: Store the block number of the first block into an array as the Unique Identifier (UID) for the elements of that array as shown in equation 1

U1 = {1} (1)

Compare the data of the next block with the data of the UID of the array U1.
If it is an exact match, store the block number as the next element of the array as shown in equation 2.

U1 = {1, 2 ...} (2)

If it is not a match then store the block number in a new array as the UID of that array as shown by equations 3 and 4.

U1 = {1…} (3)
U2 = {2…} (4)

Compare the remaining blocks of the image against the UID's given in the arrays. If a match is made, add that block number as the next element to the corresponding array. Else, create a new array with the block number as the unique identifier UID. Figure 5 shows the comparison taking place between the remaining blocks bit-by-bit.

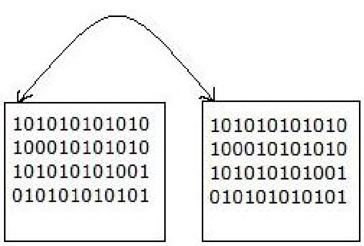

Figure 5. Comparing the remaining blocks

Step 5: Once all the image blocks have been assigned to an array, create a table containing the array information. Figure 6 shows the table in which the information is contained.

Uid	Block Data	Blocks
u1	111000	3,6..
u2	10011.	4,7...

Figure 6: Table created for array information

The first is the UID column contains the UID of each array; each UID is a block number. The second is Block Data column consists of the data of the block number that the UID represents. The third is Blocks column contains the remaining elements in each array (block numbers) that are identical to the block represented by the corresponding UID. This is highly compressed and in encoded form data. As shown in figure 6, Table of image data is then transmitted across the transmission channel, as opposed to the actual image itself.
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Step 6: At the receiver end, the table of information is decoded. The block number information is used to determine the position of a block within the image. The UID block data is used to obtain the actual data of the block.
Using the block number and UID block data, the correct data block is placed at the right location within the image as shown in figure 7 below. Pasting of block at its appropriate position leads to create half tone image.

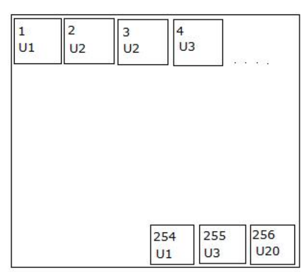

Figure 7: UID data block placed at right location

Step 7: Image reconstruction happens by applying inverse half-toning algorithm; in which separable FIR filter is used [11].The image is reconstructed by combining the R, G and B planes, to give the original image back.

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3 RESULTS AND DISCUSSION

The algorithm discussed in previous section is implemented on different 10 different test images. Root Mean Square Error (RMSE), Structural Similarity Index (SSIM) and Compression Ratio (CR) are the performance measuring parameters.

3.1. Compression Ratio (CR):

Calculation of CR is represented by equation 5 below:

CR = (size (AR) +size (AG) +size (AB)) / (3* BlkNum) (5)

Where, BlkNum is the total number of blocks in the image plane. AR, AG and AB are the arrays containing the total number of unique blocks for each of the R, G and B planes. Thus, the CR is calculated by comparing the number of unique blocks and arrays of block numbers that follows corresponding UID to the total number of blocks in the original image. The SSIM, CR and RMSE are calculated as the average of the values for the three planes.

The experimental results are shown in terms of CR, SSIM and RMSE for the test images and the four half toning operators, using 4X4 block size are presented in the following tables. The information presented in the tables is visually summarized in the form of graphs for comparison.

Table 1shows the CR between the encoded data with the size of input image. Overall average CR varies from 45% to 66% for prescribed all four half tone operators on set of images. The UID technique gives average CR in the range of 45% to 66% on half tone data whereas half tone process results 12.5% CR irrespective of the image. It is observed that the Jarvis operator has an average CR of 44.62%, which is the least among all the half-toning operators.

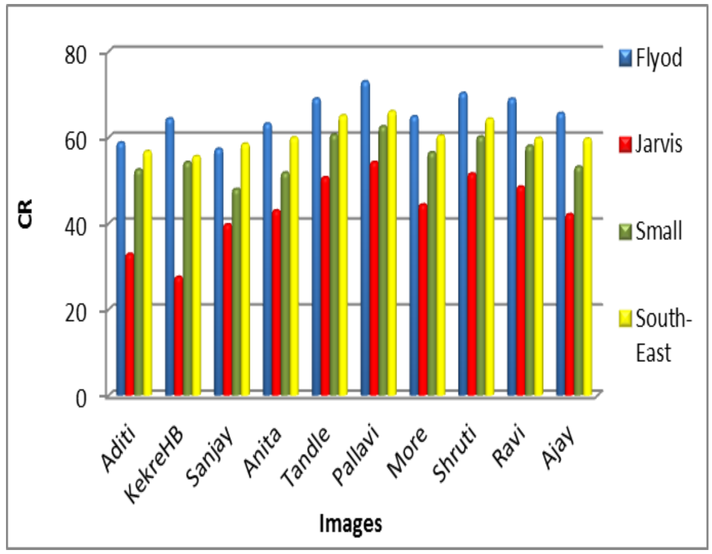

Figure 8: CR for Block size 4x4

Among the proposed operators the Small operator has an average CR of 55.72% is comparatively less, while the South-East (SE) operator has a CR of 60.6% which is close to the standard Floyd operator. The Floyd operator provides the highest compression of 65.52% as well as very good image quality.

3.2. Structure Similarity Index (SSIM):

Table 2 shows the results for the SSIM and detail about SSIM explained as in [10]. All the operators show good results for SSIM that ranges from 0.95 to 0.99. The highest and most consistent SSIM values are obtained using the South East operator.

TABLE 1.
COMPRESSION RATIO (CR) FOR 4 BY 4 BLOCK SIZE

S.N.	Image	Floyd	Jarvis	Small	SE
1	Aditi	58.7484	32.8532	52.474	56.7383
2	KekreHB	64.3473	27.4902	54.1911	55.5745
3	Sanjay	57.2998	39.7135	47.9329	58.4798
4	Anita	63.1755	42.9525	51.7578	59.9447
5	Tandle	68.986	50.6836	60.6038	65.0716
6	Pallavi	72.9818	54.2318	62.5244	66.04
7	More	64.8519	44.3441	56.4616	60.3597
8	Shruti	70.2881	51.5544	60.14	64.2985
9	Ravi	68.9697	48.5107	57.9834	59.8389
10	Ajay	65.6006	42.0736	53.1494	59.6598
CR	**Average**	**65.5249**	**44.6172**	**55.7218**	**60.6006**

TABLE 2.
STRUCTURE SIMILARITY INDEX (SSIM) FOR 4 BY 4 BLOCK SIZE

S.N.	Image	Floyd	Jarvis	Small	SE
1	Aditi	0.9922	0.9918	0.9921	0.9926
2	KekreHB	0.949	0.9585	0.9549	0.981
3	Sanjay	0.971	0.9906	0.9837	0.9977
4	Anita	0.9717	0.9745	0.9733	0.9952
5	Tandle	0.9617	0.9853	0.9777	0.9857
6	Pallavi	0.9676	0.9904	0.9753	0.9998
7	More	0.9675	0.9896	0.9777	0.9947
8	Shruti	0.9513	0.9808	0.9631	0.9981
9	Ravi	0.8825	0.9367	0.9137	0.9975
10	Ajay	0.9236	0.9601	0.9368	0.9972
SSIM	**Average**	**0.9538**	**0.9741**	**0.9648**	**0.9939**

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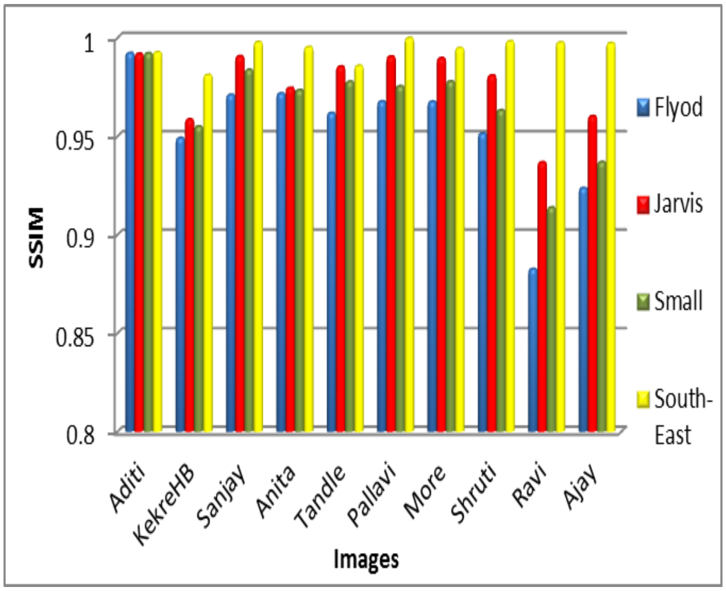

Figure 9: SSIM for Block size 4x4

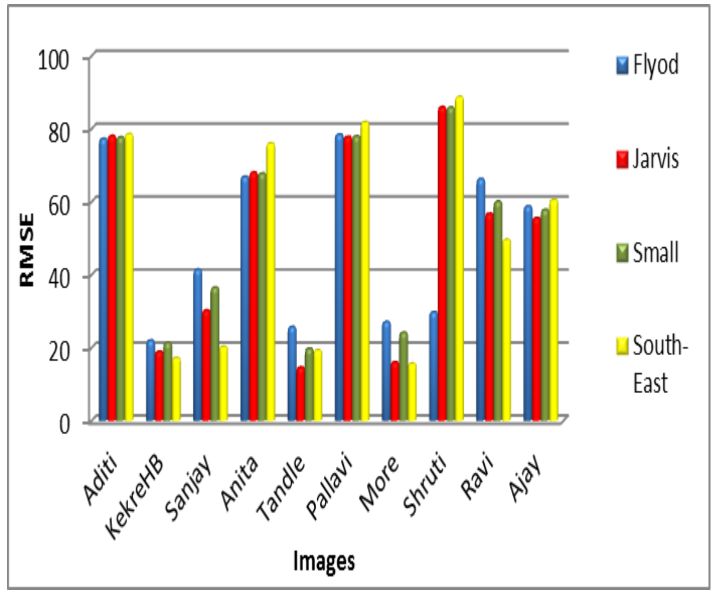

Figure 10: RMSE for Block size 4X4

3.3. Root Mean Square Error (RMSE):

Table 3 shows the RMSE values between reconstructed and original images. The values vary greatly depending on the image data itself. It means that variations, brightness, color variation and object and background size.

TABLE 3

. ROOT MEAN SQUARE ERROR (RMSE) FOR 4 BY 4 BLOCK SIZE

S.N.	Image	Floyd	Jarvis	Small	SE
1	Aditi	77.1865	77.9616	77.5721	78.4787
2	Kekre	21.8982	18.8506	21.2831	17.0944
3	Sanjay	41.3457	30.13	36.4178	20.1957
4	Anita	66.8022	67.9616	67.6717	75.9117
5	Tandle	25.6216	14.511	19.6612	19.2269
6	Pallavi	78.3497	77.7341	77.8589	81.7234
7	More	26.9932	15.9328	24.078	15.5427
8	Shruti	29.6627	85.8805	85.7827	88.6681
9	Ravi	66.1793	56.6216	59.9934	49.4907
10	Ajay	58.673	55.4799	57.7212	60.4238
RMSE	**Avg.**	**49.2712**	**47.0113**	**52.8040**	**50.6756**

For example, the image Tandle has very low RMSE values, having range from 14 to 19 across all the operators. On the other hand, the image Aditi has RMSE values in the range of 77-79. It is observed that there are great variations in RMSE reading throughout Table-3 across images and half tone operators. It happens because of the property of operators. The image Shruti has RMSE values of approximately 86 for the Jarvis, Small and South East operators and a value of 29.66 using the Floyd operator. Overall, the operators show RMSE range from 47 to 52, which is acceptable. The entire four half tone operator generates binary image. However, from Table 3, it is observed that RMSE is not same. Because it is the property of individual, half tone operator. Figures 8, 9 and 10 are the graphical representation of Table 1, 2 and 3 respectively.

3.4. Inverse half tone images:

Figure 11(a).Original(KekreHB) Figure11(b).Floyd Half tone

Figure11(c). Floyd inverse

Figure11(d).Jarvis inverse

Figure11(e).Small inverse

Figure11(f). SE inverse

Figure 11(a) shows the original image (KekreHB) used as a sample image. From the images, it is clear that result obtained through Floyd- Steinberg operator gives better image quality than the result obtained from other operators.

We can conclude that the Floyd operator, while having a slightly lower SSIM, shows the best performance in terms of average CR and RMSE value. Being the same computational complexity of Floyd and Small half tone operator, for this technique Small operator is not giving the comparable results. Overall, the proposed UID block truncation method combined with half toning is very effective in compression of the original image at the 4x4 block size. Using a larger block size, e.g. 8x8, 16x16 and upwards negligible compression is obtained, owing to very few block matches occurring. At a block size of 2x2, excellent compression is obtained, with an average CR of 99%. However, at this block size, the time complexity greatly increases.

3.5. Test Images:

To carry out experimental results, the set of 10 test images are shown in Figure12 (a) to Figure12 (j). All the images are captured by Nikon-120 camera. The Nikon-120 camera specifications are as 14.1 Megapixel, 21-X zoom.

4 Conclusion and Future Scope

With the combination of half tone and proposed UID technique, we got an average CR from 45% to 66% on half tone data, which has CR 12.5% with acceptable inverse image quality. This technique is suitable for video data streaming where low bit-rate of data transmission can be achieved for optimization of bandwidth. Future work in continuation to this project is to parallelize this technique in order to reduce the time complexity by processing R-G-B planes. Also, the algorithm can be implemented on images larger than a size of 256x256 and using both odd and even block sizes. Block comparison and approximation can be performed based on block pattern from the look-up-table. Limitation of this technique is to implement on real-time video stream.

Figure12(a). Aditi

Figure12(b). Kekre

Figure12(c). Sanjay

Figure12(d). Anita

Figure12(e). Tandle

Figure12(f). Pallavi

Figure12(g). More

Figure12(h). Shruti

Figure12(i). Ravi

Figure12(j). Ajay

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AUTHORS

Dr. H. B. Kekre has received B.E. (Hons.) in Telecomm. Engg. from Jabalpur University in 1958,M.Tech (Industrial Electronics) from IIT Bombay in 1960, M.S. Engg. (Electrical Engg.) from University of Ottawa in 1965 and Ph.D. (System Identification) from IIT Bombay in 1970. He has worked Over 35 years as Faculty of Electrical Engineering and then HOD Computer Science and Engg. at IIT Bombay. For last 13 years worked as a Professor in Department of Computer Engg. at Thadomal Shahani Engineering College, Mumbai. He is currently Senior Professor working with Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, Vile Parle(w), Mumbai, INDIA. He has guided 17 Ph.D.s, 150 M.E./M.Tech Projects and several B.E./B.Tech Projects. His areas of interest are Digital Signal processing, Image Processing and Computer Networks. He has more than 450 papers in National / International Conferences / Journals to his credit. Recently twelve students working under his guidance have received best paper awards. Eight of his students have been awarded Ph. D. of NMIMS University. Currently he is guiding eight Ph.D. students. He is member of ISTE and IETE.

Dr. Tanuja K. Sarode has received M.E.(Computer Engineering) from Mumbai University in 2004, Ph.D. from MPSTME SVKM's NMIMS, Mumbai, INDIA. She has more than 11 years of experience in teaching. She is currently working as Associate Professor in Dept. of Computer Engineering at TSEC, Mumbai. She is member of IETE, ISTE, IAENG and IACSIT. Her areas of interest are Image Processing, Signal Processing and Computer Graphics. She has more than 130 papers in National/International Conferences/journal to her credit.

Sanjay Ramkrishna Sange has received M.E.(Computer Engineering) from Mumbai University in 2008. He is pursuing his PhD. from NMIMS, Mumbai. He is member of ISTE. His area of interest is Image Processing. He has presented/published 16 papers in National, International Conference/Journal. For one paper, he has received "Best Paper" award in 2010.