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Image Resizing with Enhancement Technique on DCT Domain

T. Romen Singh, O. Imocha Singh

Abstract— ***This paper presents an image resizing technique with enhancement process so as to get an enhanced resized image. This technique is applied on single DCT domain and it is based on the energy compaction and de-correlation property of DCT. Resizing is based on energy compaction while enhancement is based on de-correlation property of CDT. In this technique, resizing is implemented on arbitrary ratio of dimension of the resized image. Enhancement technique is applied by rescaling the AC and DC values of the DCT matrix of the input image. Since it is applied on single DCT domain there is no blocking artefact like block domain. The performance of this technique is compared with other related techniques using PSNR, RMSE and CCC and found outperform.***

Index Terms—Image Resizing, Arbitrary Ratio, DCT, Enhancement, Power-Law.

I. Introduction

Image resizing is a process of changing in dimension of the image in arbitrary ratio along vertical and horizontal direction. Proportional resizing along the diagonal maintain the structure of the original image while resizing in arbitrary ratio of dimension, the structure of the image may be deformed. When enlarging the image, it may cause edge blurring with artefact of the image. Hence it is required to adjust the edge structure of the image according to the resized factor. When enlarging an object optically, its visibility is clearer than the original one. But it is difficult to maintain the visibility of the image when resizing in digital form. Many resizing techniques are developed so far, but still they have the problem of blurring when enlarging. DCT domain techniques [1]-[11] are based on DCT energy compaction property while spatial domain resizing techniques bi-cubic(BC) bi-linear(BL), and directed linear [13] are based on interpolation operation. Pixel replication(PR) is different from the others.

Arbitrary ratio image resizing is an important technique. It helps images and video streams are tailored to the communications networks over which the streams travel and to the end user display devices upon which they will be presented. Most of the multimedia components especially image, video and video conferencing stream compression techniques JPEG, MPEG and H.26X based on block DCT domain. Resizing techniques applied on this block DCT domain are efficient regarding computational time factor and hence such techniques are desirable.

Dugad and Ahuja [1] proposed a method for resizing an image by powers of two (both up sampling and down sampling) that is carried out entirely in the DCT domain. Their technique used simple DCT scaling and took advantage of clever factorization to dramatically reduce the computations required. Park, and Oh [2] used symmetric convolution to implement arbitrary resizing factors and produced higher final image quality than the method of Dugad and Ahuja but at a greater computational complexity. By approximating the derived mapping they were able to greatly reduce the computational complexity while maintaining quite a bit of the final image quality. Zhao, Kankanhalli, and Chua [3] presented an algorithm for scaling images by factors of 1.25 and 1.5 directly in the DCT domain. Their method implicitly uses interpolation and scaling matrices.

This paper is organized as follows. Section II describes DCT. Section III describes the proposed technique. Section IV describes the experimental result and Section V gives the conclusions

II. Discrete Cosine Transformation (DCT)

A Discrete Cosine Transform (DCT) is expressed as a sequence of finitely arranged data points in terms of a sum of cosine functions oscillating at different frequencies. DCT is an important one in science and engineering. It helps in image, audio and video compression techniques. In the image transform applications like other transforms, the DCT attempts to de-correlate the image data. After de-correlation each transform coefficient can be encoded independently without losing compression efficiency. We can apply one dimensional (1-D) and two dimensional (2-D) DCT in image processing applications.

A. *One-Dimensional DCT (1-D)*

The most common DCT definition of a 1-D sequence of length N is expressed as

$$A(i) = \alpha(i)\sum_{x=0}^{N-1} I(x)\cos\left[\frac{\pi(2x+1)i}{2N}\right] \quad (1)$$

for i= 0,1,2, .. N− 1.

Similarly, the inverse transformation is defined as

$$I(x) = \sum_{i=0}^{N-1} \alpha(i)A(i)\cos\left[\frac{\pi(2x+1)i}{2N}\right] \quad (2)$$

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* Correspondence Author
Dr. T. Romen Singh*, Department of Computer Science, Manipur University, Canchipur, Imphal, Manipur, India.
O.Imocha Singh, Department of Computer Science, Manipur University, Canchipur, Imphal, Manipur, India.

for $x= 0,1,2, \ldots N-1$.

where $I(x)$ is the input dataset where $A(i)$ is the DCT domain dataset. In both equations (1) and (2) $\alpha(i)$ is defined as

$$\alpha(i) = \begin{cases} \frac{1}{N} & \text{for } i=0 \\ \frac{2}{N} & \text{for } 1 \le i \le N\text{-}1 \end{cases} \quad (3)$$

It is clear from (1) and (3) that for $i = 0$

$$A(i) = \sqrt{\frac{1}{N}} \sum_{x=0}^{N-1} I(x) \quad (4)$$

This is the average value of the sample sequence. This value is referred to as the *DC* Coefficient. All other transform coefficients are called the *AC* Coefficients. Any changes to DC value will result major changes to $I(x)$ of .(2) resulting overall increase or decrease pixel values, while any changes to AC co-efficient result minor changes to $I(x)$ unlike DC changes.
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B. Two-Dimensional DCT(2-D)

The 2 Dimensional (2-D) DCT is a direct extension of the 1-D case and is given by

$$A(i,j) = \alpha(i)\alpha(j) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} I(x,y) \cos\left[\frac{\pi(2x+1)i}{2M}\right] \cos\left[\frac{\pi(2y+1)j}{2N}\right]$$

for $i=0,1,2, \ldots M-1,\ j = 0,1,2, \ldots N-1$ (5)

where M is the number of rows and N is the number of columns of the input image.

The inverse transform is defined as

$$I(x,y) = \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \alpha(i)\alpha(j) A(i,j) \cos\left[\frac{\pi(2x+1)i}{2M}\right] \cos\left[\frac{\pi(2y+1)j}{2N}\right]$$

for $x = 0,1,2, \ldots M-1,\ y = 0,1,2, \ldots N-1.$ (6)

$$\alpha(i) = \begin{cases} \frac{1}{M} & \text{if } i = 0 \\ \frac{2}{M} & \text{if } 1 \le i \le M\text{-}1 \end{cases} \quad (7)$$

$$\alpha(j) = \begin{cases} \frac{1}{N} & \text{if } j = 0 \\ \frac{2}{N} & \text{if } 1 \le j \le N\text{-}1 \end{cases} \quad (8)$$

From (7) and (8), if i=0 and j=0 then we get

$$\alpha(i)\alpha(j) = \sqrt{\frac{1}{M}} \times \sqrt{\frac{1}{N}} = \sqrt{\frac{1}{MN}} \quad (9)$$

From (5) and (9) we get

$$A(i,j) = \sqrt{\frac{1}{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} I(x,y) \quad (10)$$

This value is the average of the image I and like 1-D it is referred to as the DC coefficient while others are AC coefficients. The 2-D basis functions can be generated by multiplying the horizontally oriented 1-D basis functions with vertically oriented set of the same functions. The basis functions exhibit a progressive increase in frequency both in the vertical and horizontal direction.

C. Properties of DCT

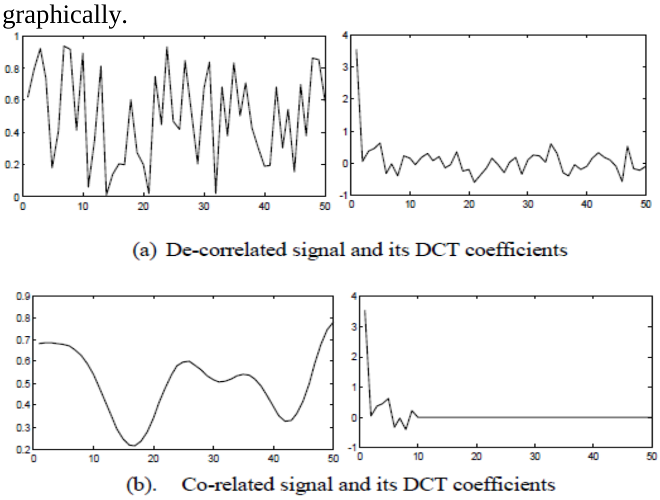
DCT has many properties from mathematical point of view. Some of the properties are very useful in image processing applications like in image compression. The following are common properties of DCT.

1. De-correlation

The important feature of DCT is the removal of redundancy between neighboring pixels. It also leads to uncorrelated transform coefficients which can be encoded independently. Amplitude of the DCT co-efficient of the correlated image is very small at all lags while uncorrelated image gives large at all lags. Hence, it can be inferred that DCT exhibits excellent decor relation properties. Figure 1 shows the correlated and uncorrelated image signal and their respective DCT co-efficient.

2. Energy Compaction

DCT has the ability to pack input image data into as few coefficients as possible. This allows the quantize to discard coefficients with relatively small amplitudes without introducing visual distortion in the reconstructed image. DCT exhibits excellent energy compaction for highly correlated images. In addition to their respective correlation properties, the uncorrelated image has more sharp intensity variations than the correlated image in their respective DCT coefficients. It means that uncorrelated image produce high frequency content than the correlated images to DCT coefficients. From this reason we know that, the uncorrelated image has its energy spread out, whereas the energy of the correlated image is packed into the low frequency region towards DC value. Fig.1 shows the energy compaction of uncorrelated and correlated images in DCT coefficients graphically.



(a) De-correlated signal and its DCT coefficients

(b). Co-related signal and its DCT coefficients

Fig 1. DCT coefficients of Co-related and De-correlated Signals

III. PROPOSED ALGORITHM

This proposed technique of image resizing in arbitrary order is applied on single DCT domain. Its process is very simple and can be preceded as the following algorithm:

Algorithm

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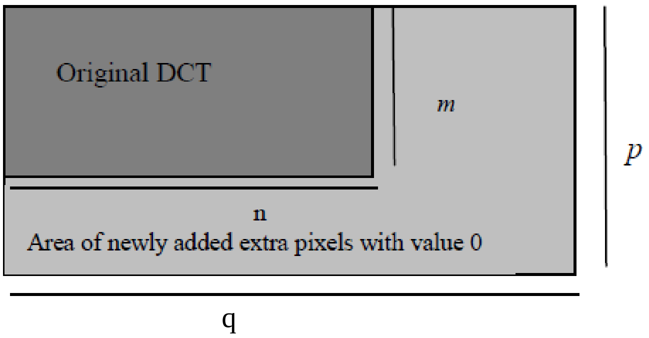
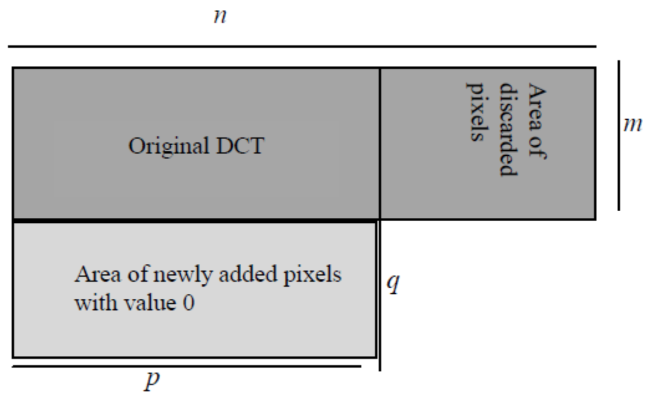
i. Take an image $I_{m\times n}$.
ii. Take DCT of $I_{m\times n}$ as $A_{m\times n}$
iii. Resize $A_{m\times n}$ to $A_{p\times q}$ simply by adding or discarding pixels without changing the original pixel value at their respective position in $A_{m\times n}$.
iv. Calculate $\partial = \frac{1}{2}\left(\frac{p}{m}+\frac{q}{n}\right)$ as resizing factor.
v. Apply global DCT domain power-law application on $A_{p\times q}$ with the resizing factor ∂ .
vi. Take inversed DCT of $A_{p\times q}$ as resized image I' of I.
vii. Stop.

A. Resizing process

Based on the resizing algorithm, this process can be processed in two Phases:



a. Resize $I_{m\times n}$ to $I'_{p\times q}$ by adding zeros along horizontal and vertical



b. Resize $I_{m\times n}$ to $I'_{p\times q}$ by adding zeros along horizontal and vertical

Fig .2. Block diagram of resizing mage $I_{m\times n}$ to $I'_{p\times q}$

1. Resizing Phase

In this phase, the DCT coefficient matrix $A_{m\times n}$ of the input image $I_{m\times n}$ is resized to $A_{p\times q}$ by discarding or adding some pixels to $A_{m\times n}$ as shown in Fig. 2 as block diagram, Fig. 3 as graphical representation. If $p>m$ and $q>n$, $p\times q$ - $m\times n$ pixels are added with value 0 to $A_{m\times n}$ so as to get $A_{p\times q}$ as in Fig. 2.a. If $p<m$ or $q<n$, $m\times n$ - $p\times q$ pixels are discarded from $A_{m\times n}$ as in Fig. 2.b.

2. Enhancement Phase

After resizing the $A_{m\times n}$ to $A_{p\times q}$ global DCT domain power law application technique[13] is applied on $A_{p\times q}$ to get an enhanced resized image as output image $I'_{p\times q}$. Since the DC value represents the average value of the image, it takes a major role to manipulate the brightness of the reconstructed image. As the image dimension is changed, the DC value has to change accordingly so as to maintain the image brightness.

Based on this idea the DC value is changed when resizing with the following relation:

$$\partial = \frac{1}{2}\left(\frac{p}{m}+\frac{q}{n}\right) \qquad (11)$$

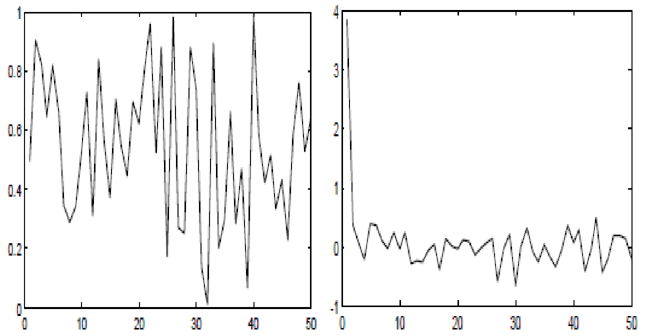
$$D = \partial d \qquad (12)$$

where d is the DC value of $A_{m\times n}$ and D is the DC of $A_{p\times q}$. The term ∂ is the resizing factor. This term multiplies to all elements of $A_{p\times q}$ so as to maintain the brightness of $I'_{p\times q}$ like $I_{m\times n}$. Any changes in AC value along their respective phase direction will effect to the global contrast and edge contrast causing edge sharpening/smoothening of the reconstructed image. So as to make enhance the reconstructed image, $A_{p\times q}$ has to be manipulated. Global DCT domain power law application [13] is applied to manipulate it. The way of manipulation is as follows:

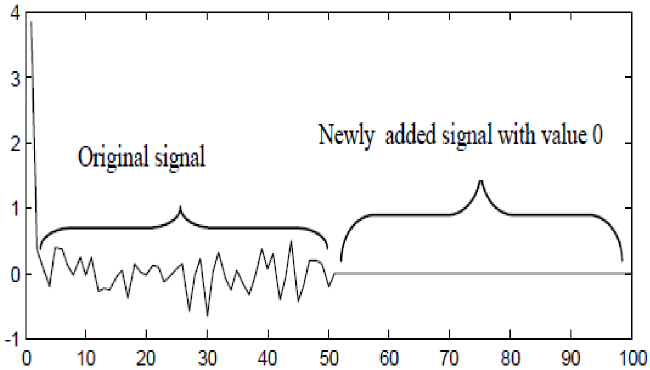
$$A(i,j) = \begin{cases} K_b \partial A(i,j) & \text{If } i=j=0 \\ K_c A(i,j)\,|\,I(i,j)\,|^{(\gamma-1)} & \text{If } i\neq 0 \text{ or } j\neq 0 \end{cases} \qquad (13)$$

for $i=0..p-1$, $j=0..\ q-1$

where $\partial = \frac{1}{2}\left(\frac{p}{m}+\frac{q}{n}\right)$ K_b, K_c and γ are constants. According to the value of p and q, the dimension of the resized image may be arbitrary. If p and q are proportional to m and n , the resizing process is similar to image zooming in and out.



(a) Input image signal (I_{50}) (b) DCT of Input image signal (A_{50})



(C) RESIZED DCT SIGNAL SIMPLY BY ADDING ZEROS TO THE NEWLY ADDED PIXEL POSITIONS (A_{50} TO A_{100})

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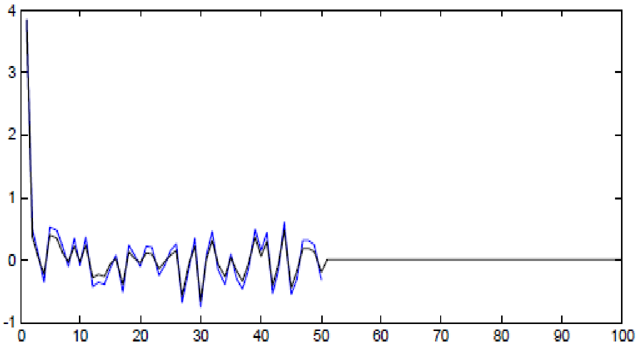
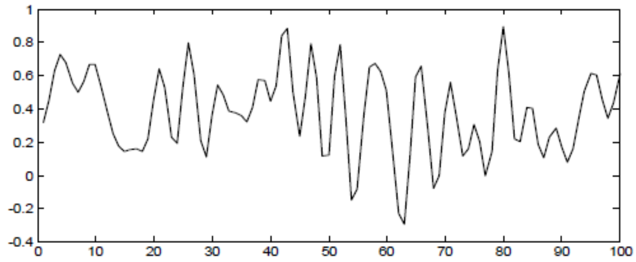


(d) Rescaled DCT of the resized DCT A_{100}



(e) Reconstructed image signal as the resized image I'_{100}

Fig. 3. Graphical representation of resizing of I_{50} to I'_{100}

IV. Experimental Result

Proposed technique is tested and compared qualitatively and quantitatively with several common techniques like Pixel Replication (PR), Bi-linear (BL), and Bi-cubic (BC).

Qualitative analysis provides a set of image comparisons to the readers for visual analysis. Fig. 5 shows the result of different techniques of resizing with a scale of 4 proportionally. It is difficult to rank a technique by just looking at visual results. It is required to measure the result for analysing quantitatively. The quantity measuring tools: root mean squared error (RMSE), peak-signal-to-noise-ratio (PSNR), and cross-correlation coefficient (CCC) are used as quantitative analysis tool.

A. RMSE, PSNR and CCC Calculation

$$RMSE = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(I(i,j) - I'(i,j))^2} \quad (14)$$

$$PSNR = 10\log 10\left[\frac{1}{RMSE^2}\right] \quad (15)$$

$$CCC = \frac{\left[\sum_{i=1}^{M}\sum_{j=1}^{N} I(i,j)I'(i,j) - MNab\right]}{\sqrt{\left[\sum_{i=1}^{M}\sum_{j=1}^{N} I'^2(i,j) - MNa^2\right]\left[\sum_{i=1}^{M}\sum_{j=1}^{N} I^2(i,j) - MNb^2\right]}} \quad (16)$$

where I' is the resized image and I is the original image, M and N are the image dimension, a and b are the corresponding average pixel values in each image.

It should be noted that lower values of RMSE indicate higher accuracy, while values closer to 1 indicate higher accuracy in cross-correlation coefficient (CCC) values. In the case of PSNR higher values indicate higher accuracy.

For analysing the performance of the proposed technique with these measuring tools, the original image was first down sampled by a factor 2. This lower resolution image is then up sampled by a factor of 2 using a variety of resizing techniques, and comparison is performed between the different techniques and proposed algorithm (resize without enhancement factor) using the original image. If enhancement is applied, the tools may give more error. Hence comparison is taken without enhancement factors. Enhancement factor is applied for qualitative analysis as shown in Fig. 5 and 6.

Table 1 to 3 show the results of PSNR, RMSE and CCC on various images for different techniques.

It is found from the experimental result that this new technique is outperformed.

Image	BC	BL	Proposed
Apple(132 ×193)	27.6904	26.9239	29.3152
Lenna(512× 512)	33.0234	31.9163	33.7044
Mandrill(297×295)	41.2352	38.5383	42.4484
Scenery(240× 414)	23.3838	22.8231	23.6715

Table 1. PSNR Result

Image	BC	BL	Proposed
Apple(132×193)	0.0413	0.0451	0.0342
Lenna(512 × 512)	0.0223	0.0254	0.0206
Mandrill(297×295)	0.0087	0.0118	0.0075
Scenery(240 × 414)	0.0677	0.0723	0.0655

Table 2. RMSE Result

Image	BC	BL	Proposed
Apple(132 193)	0.9932	0.9919	0.9953
Lenna(512 512)	0.9989	0.9986	0.999
Mandrill(297 295)	0.9998	0.9997	0.9999
Scenery(240 414)	0.9826	0.9802	0.9837

Table 3. CCC Result

Fig. 4. Pictures used in quantitative analysis in Tables 1 to 3

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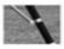
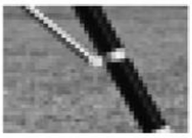
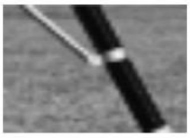


(a) Original (41× 36)

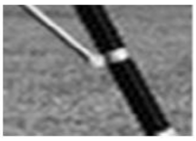


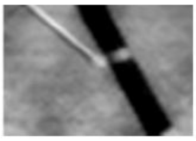
(b) Resizing with PR



(c) Resizing with BL

(d) Resizing with BC





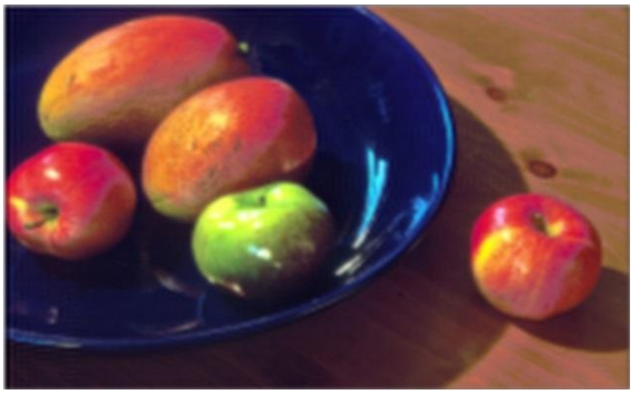
Resizing with propose technique
(e) Without enhancement (f) With enhancement at K_b=1, K_c= 1.3 and γ=1.5

Fig.5. Resizing result of different techniques with a resizing factor of 4.

(a) Original image (124 ×188)

(b) Downsize to 31× 47)

(c) Resize to 31×188)



(d) Resize to (248×376) with no enhancement

(e) Resize to (248×376) with enhancement at K_b=1, K_c= 1and γ=0.9

(f) Resize to (248×376) with enhancement at K_b=1, K_c= 1.3 and γ=0.8

Fig. 6. Result of resizing of an image in different dimension with different enhancement factors

V. CONCLUSION

This paper proposes a new technique for image resizing at arbitrary order with enhancement technique. Most of the resizing technique so far proposed, do not have any enhancement component. The experimental results show the effectiveness of the algorithm in comparison with other techniques.

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AUTHORS PROFILE

Dr. T. Romen Singh received the degree of BSc. Comp. Sc. and MCA from Manipur University Canchipur, Manipur, India in 1993 and 1997 respectively. He also received Ph.D degree in IT from Assam University, Silchar, Assam, India recently. His research area of interest is Digital image enhancement, binarisation, Multimedia System. He published 9 papers in international journals and one in IEEE conference proceedings in this related area. He is working as quest lecturer in Computer Science Department, Manipur University.

O.Imocha Singh received the degree of BSc. Maths. Hons from Gauhati University Assam, India in 1975, M.Sc. Maths in 1978 from AMU, Aligarh, India and M.Phil in Computer and System Sciences in 1980 from J.N.U, New Delhi, India. Since then he has been working in Manipur Govt. Colleges and joined to Manipur University in 1985. Presently he is working as Associate Professor in Computer Science Department, Manipur University, India. His area of interest is Theorem proving, NLP, Formal Language and Automata Theory, Dataware-Housing & Data Mining and Digital image Processing. His research area of interest is Digital image Processing and published 6 papers in international journals in this area. He also completed two DeitY, Govt. of India research projects on computer networks during 2008-2013 and undergoing 3rd project on the same area.

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