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- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

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- Garg, Sambhav (2011): "Business Ethics" Paper presented at the Annual International Conference for the All India Management Association, New Delhi, India, 19–22 June.

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# A SURVEY OF DISCRETE IMAGE TRANSFORM METHODS IN IMAGE DATA COMPRESSION

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**ABSTRACT**

*Compression is the main goal of this work – we aim to represent an image using fewer bits per pixel, without losing the quality after reconstruction of the image. Image transforms are extensively used in image processing and image analysis. Transform is basically a mathematical tool, which allows us to move from one domain to another domain (time domain to the frequency domain). The transformation compact the image information in to a small number of coefficients. If an image is compressed using discrete transforms, it is usually divided into sub-images of 8x8 or 16x16 pixels to speed up calculation, and then each sub-image is transformed and processed separately. The same is true for image reconstruction with each sub-image being reconstructed and placed into the appropriate image position[5]. We present most important discrete transform methods such as Karhunen-Loeve transform (KLT), Discrete Cosine Transform(DCT) and Discrete Wavelet Transform(DWT). We have evaluated the performance of the transform methods using various measures,like computational complexity, parameters to be computer, and quality of image compressed.*

**KEYWORDS**
Compression, Transformation, Cosine, Wavelet, Filter Bank.

## 1. INTRODUCTION

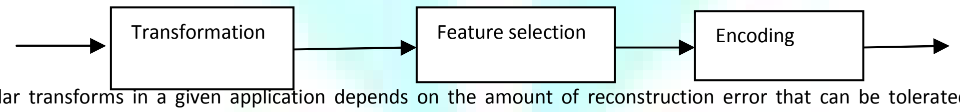
Image compression is an application of data compaction that can reduce the data quantity. We can classify data compaction algorithms into two categories – lossy and lossless compaction. If we apply the lossy compression, then the compacted data will be different from the original data, but large amount of data can be saved. If we apply the lossless compression, then the compacted data will be the same as the original data, but the amount of the reduction of data is limited. In image compression, we also classify the compression methods into lossy and lossless compression. In lossy compression, there is a basic tradeoff between the data rate and the quality.

Image compression algorithms aim to remove redundancy in a data in a way which makes image reconstruction possible, this is sometimes called information preserving compression[5]. It is necessary to find statistical properties of the image to design an appropriate compression transformation of the image; the more correlated the image data are the more data item can be removed.

The major steps of data compression procedure is shown in the figure1[7],

i) Transformation
ii) Feature selection, and
iii) Encoding

**FIGURE 1: SCHEMATIC DIAGRAM REPRESENTING THE MAJOR STEPS OF DATA COMPRESSION PROCEDURE**




The choice of a particular transforms in a given application depends on the amount of reconstruction error that can be tolerated and the computational resources available [3].

## 2. TRANSFORMATION

### *2.1. INTRODUCTION*

The goal of the transformation process is to de-correlate the pixel of each sub-image, or to pack as much information as possible into the smallest number of transform coefficient.

Transformation is a very useful tool in image compression. It is used to transform the image data in time domain to frequency domain. By transforming the data into frequency domain, the spatial redundancies in time domain can be minimized.

The transforms do not change the information content present in the signal (input) and it is to be noted that all the transforms will not give frequency domain information.

Image transform is basically a representation of an image there are two reasons for transforming an image from one representation to another;

1) The transformation may isolate critical components of the image patterns so that they are directly accessible or analysis.
2) The transformation may place the image data in a more compact form so that they can be stored and transmitted efficiently.

The advantage of using transformations is that the energy of the transformed data is mainly condensed in the low frequency region and is represented by a few transform coefficients. Thus, most of these coefficients can be discarded without significantly affecting the reconstructed image quality.

For efficient compression, the transform should have the following properties;

1. De-correlation – the transform should generate less correlated or uncorrelated transform coefficients to achieve high compression ratio.
2. Linearity – this principle allows one-to-one mapping between pixel values and transform coefficients.
3. Orthogonality – orthogonal transform have the feature of eliminating redundancy in the transformed image.

Transform play a significant role in various image processing applications such as image analysis, image enhancement, image filtering and image compression.

### *2.2 DISCRETE IMAGE TRANSOMS IN IMAGE DATA COMPRESSION*

Image data representation by coefficient of discrete image transform is the basic idea of this approach. The transform coefficients are ordered according to their importance, such that, according to their contribution to the image information content, and the least important coefficient are omitted. Coefficient importance can be judged, for instance, in correspondence to spatial or gray-level visualization abilities of the display; image correlation can then be avoided and data compression may result.

***Karhunen-Loeve Transform***

Karhunen-Loeve Transform, abbreviated KLT, is the most important and optimal transform coding method that can reduce the correlation[8]. Assume one input vector **X** with length *N*×1, and the correlation can be represented by the autocorrelation matrix $\mathbf{C_X}$ defined in equation 1.1.

$$\mathbf{C_X} = E\left[(\mathbf{X}-E[\mathbf{X}])(\mathbf{X}-E[\mathbf{X}])^T\right] = \begin{bmatrix} E[x_0^2] & E[x_0x_1] & \cdots & E[x_0x_{N-1}] \\ E[x_1x_0] & E[x_1^2] & \cdots & E[x_1x_{N-1}] \\ \vdots & \vdots & \ddots & \vdots \\ E[x_{N-1}x_0] & E[x_{N-1}x_1] & \cdots & E[x_{N-1}^2] \end{bmatrix} \quad \text{- 1.1}$$

The maximal decorrelation can be achieved if we can diagonalize the matrix 1.1. That is, we must maximize the value of $E[x_i^2]$ and minimize $E[x_ix_j]$ by means of transformation, where $i \neq j$. We represent the autocorrelation matrix of the output vector **Y** as $\mathbf{C_Y}$, which is defined in the equation 1.2.

$$\mathbf{C_Y} = E\left[(\mathbf{Y}-E[\mathbf{Y}])(\mathbf{X}-E[\mathbf{Y}])^T\right] \quad \text{- 1.2}$$

We can substitute **Y** with **AX**, so the equation in 1.2 can be expressed as

$$\mathbf{C_Y} = E\left[(\mathbf{AX}-E[\mathbf{AX}])(\mathbf{AX}-E[\mathbf{AX}])^T\right] \quad \text{- 1.3}$$

Suppose we subtract every elements of **X** from its mean, then the original vector forms a zeros mean sequence. The transformed vector is also a zero mean sequence, so the equations 1.2 and 1.3 can be reduced to equation 1.4

$$\mathbf{C_Y} = E\left[(\mathbf{AX})(\mathbf{AX})^T\right] \quad \text{- 1.4}$$

After some mathematical manipulation, we can obtain the following relationship between $\mathbf{C_Y}$ and $\mathbf{C_X}$ as stated in the equation 1.5.

$$\mathbf{C_Y} = \mathbf{AC_XA}^T \quad \text{- 1.5}$$

We can achieve optimal decorrelation through diagonalization, which means that **A** is composed of the *eigenvectors* of the autocorrelation matrix $\mathbf{C_X}$. After transform, the autocorrelation matrix $\mathbf{C_Y}$ becomes

$$\mathbf{C_Y} = \begin{bmatrix} \lambda_0 & 0 & \cdots & 0 \\ 0 & \lambda_1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_{N-1} \end{bmatrix} \quad \text{-- 1.6}$$

where $\lambda_0$, $\lambda_1$,..., $\lambda_{N-1}$ are the eigenvalues of the correlation matrix.

The largest advantage of KLT is that it can achieve optimal decorrelation [8]. However, it takes large amount of computation to find the eigenvectors for the image to be compressed. On the other hand, the decoder needs all the eigenvectors for decoding the compressed image, so all the eigenvectors must be stored into the bitstream as well as the transform coefficients **Y.** Therefore, KLT is not adopted in the existing image and video compression standards.

***Discrete Cosine Transform***

Discrete Cosine Transform, abbreviated DCT, is an approximation of KLT and widely used in many existing image and video compression standards.

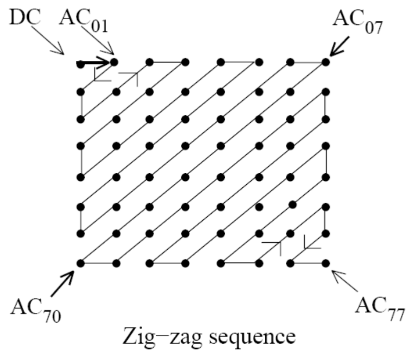
The DCT based encoder can be thought of as essentially compression of a stream of 8x8 blocks of image samples. Each 8x8 block makes its way through each processing step, and yields output in compressed form into the data stream.

Because adjacent image pixels are highly correlated, the 'forward' DCT (FDCT) processing step shown in equation 2.1, lays the foundation for achieving data compression by concentrating most of the signal in the lower spatial frequencies. For a typical 8x8 sample block from a typical source image, most of the spatial frequencies have zero or near-zero amplitude and need not be encoded.

In principle, the DCT introduces no loss to the source image samples; it merely transforms them to a domain in which they can be more efficiently encoded. After output from the DCT, each of the 64 DCT coefficients is uniformly quantized in conjunction with a carefully designed 64-elements quantization table.

At the decoder, the quantized values are multiplied by the corresponding QT elements to recover the original unquantized values. The Inverse DCT processing is shown in the equation 2.2. After quantization, all of the quantized coefficients are ordered into the 'zig-zag' sequence and the same is shown in the Figure2. This ordering helps to facilitate entropy encoding by placing low-frequency non-zero coefficient before high-frequency coefficients. The DCT coefficient, which contains a significant fraction of the total image energy, is differentially encoded.

**FIGURE 2: ZIG-ZAG SEQUENCE**




**Forward 2-D Discrete Cosine Transform**

$$F(u,v) = \frac{2}{\sqrt{MN}} C(u)C(v) \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\left[\frac{\pi(2x+1)u}{2M}\right]\cos\left[\frac{\pi(2y+1)v}{2N}\right]$$

for $u = 0,\dots,M-1$ and $v = 0,\dots,N-1$

$$\text{where } C(k) = \begin{cases} 1/\sqrt{2} & \text{for } k=0 \\ 1 & \text{otherwise} \end{cases}$$

\- 2.1

where *f*(x,y) is the element in spatial domain, and *F*(u,v) is the DCT coefficient in the frequency domain.

**Inverse 2-D Discrete Cosine Transform**

$$f(x,y) = \frac{2}{\sqrt{MN}} \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} C(u)C(v)F(u,v)\cos\left[\frac{\pi(2x+1)u}{2M}\right]\cos\left[\frac{\pi(2y+1)v}{2N}\right]$$

for $x = 0,\dots,M-1$ and $y = 0,\dots,N-1$

\- 2.2

***Discrete Wavelet Tansform***

Wavelet transform [Antomini (1992), Lewis (1992)] is very similar to the conventional Fourier Transform, but it is based on small waves, called wavelet, which is composed of time varying and limited duration waves.

The wavelet transform decomposes an image into a set of different resolution sub-images, corresponding to the various frequency bands. This results in a multi-resolution representation of images with localization in both the spatial and frequency domain.

This is desirable in the case of image compression, but it is not possible in the case of Fourier and Cosine transforms which gives good localization in one-domain at the expense of the other. The main advantage of wavelet based image compression is,

1) Wavelets have non-uniform frequency spectra which facilitate multi-scale analysis.
2) The multi-resolution property of the wavelet transform can be used to exploit the fact that the response of the human eye is different to high and low frequency components of an image.
3) Discrete wavelet transform can be applied to an entire image without imposing block structure as used by the Discrete Cosine transform, thereby reducing blocking artifact.

A discrete wavelet transform can be implemented through either Filter bank scheme or Lifting scheme. In the discrete wavelet transform, an image signal can be analyzed by passing it through an analysis filter bank followed by decimation operation.

Lifting scheme is an efficient implementation of a Wavelet transform algorithm. It is developed to improve wavelet transform and then extended to a generic method to create second generation wavelets. The second generation wavelets are much more flexible and powerful than first generation wavelets.

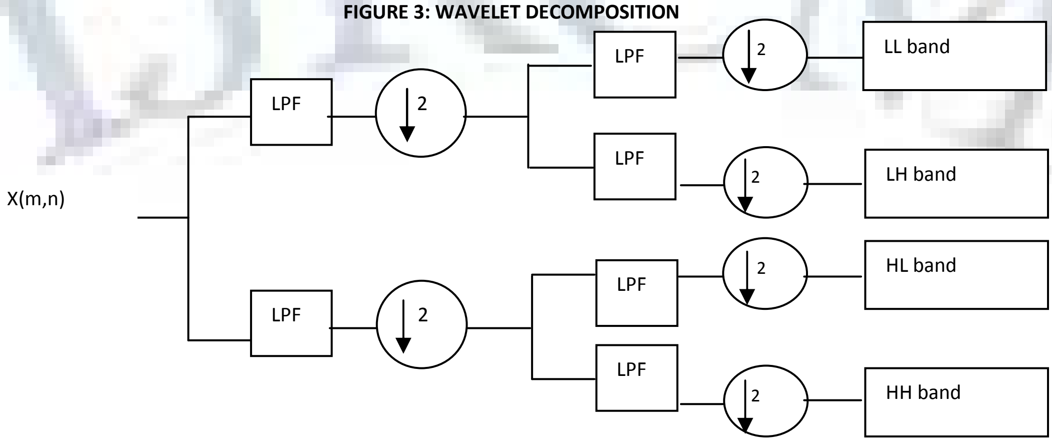
The analysis filter-bank consists of a low-pass and high-pass filters at each decomposition stage. When the input signal passes through these filters, it splits into two bands,

1) The Low-pass filter – which corresponds to an averaging operation, extracts the coarse information of the signal.
2) The high-pass filter – which corresponds to a differencing operation, extract the detail information of the signal.

The output of the filtering operation is then decimated by two. A two dimension transom is accomplished by performing two separate one dimension transforms.

First, the image is filtered along the row and decimated by two. It is then followed by filtering the sub-image along the column and decimated by two. This operation splits the image into four bands, namely LL, LH, HL, and HH respectively.

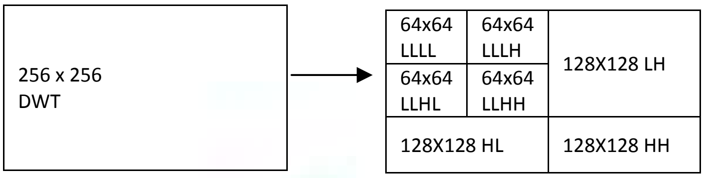
**FIGURE 3: WAVELET DECOMPOSITION**



Further decomposition can be achieved by acting upon the LL sub-band successively and the resultant image is split into multiple bands. The following figure4 shows the size of the input image and the size of the image at different level of decompositions.

So, after the first level of decomposition we have 4 sub-bands, 7 sub-bands at the second level, 10 at the third level, and son on. One of the most important parameters to decide upon is the number of coefficient should be preserved to compress the image[7].

**FIGURE 4: DECOMPOSITION OF INPUT IMAGE WITH SIZE**




Sub band coding: Sub band coding is a procedure in which the input signal is sub divided into several frequency bands. Sub band coding can be implemented through "filter bank".

A filter bank is a collection of filters having either a common input or common output. The basic idea in a filter bank is to partition a signal dyadic ally at the frequency domain.

When the filters have a common input, they form an Analysis bank. The analysis filter bank splits the signal into equal frequency bands. When the filters have a common output, they form a Synthesis bank. The synthesis filter bank reconstructs the signal from the two filtered and decimated signals.

Wavelet-based image compression scheme overcomes the problem of blocking artifacts. Wavelet transform is employed in the JPEG 2000 standard.

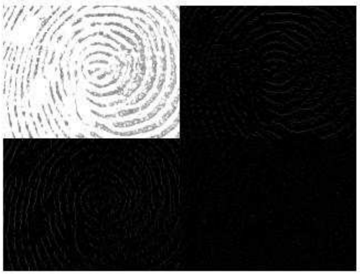
## 3. RESULTS

Matlab code to perform wavelet decomposition:

```
clc
clear all
a=imread('c:\1_1_1.jpg');
[p q r s]=dwt2(single(a),'db1');
b=[uint8(p),q;r,s];
imshow(b)
```

Result of the Wavelet decomposition:

(Original Image)



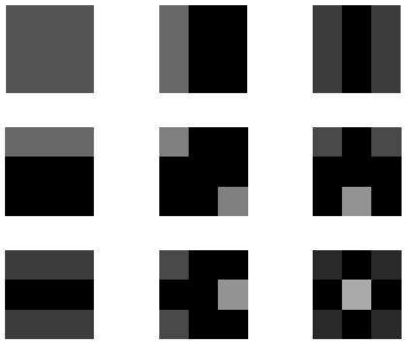
(1st level decomposition)

Matlab code to compute DCT basis:

```
clc
clear all
close all
m=input('basis mat dim');
n=m;
a2=ones(1,n)*sqrt(2/n);
a2(1)=sqrt(1/n);
a1=ones(1,m)*sqrt(2/m);
a1(1)=sqrt(1/m);
for u=0:m-1;
  for v=0:n-1
  for x=0:m-1
  for y=0:n-1
   a{u+1,v+1}(x+1,y+1)=a1(u+1)*a2(v+1)*...
      cos((2*x+1)*u*pi/(2*n))*cos((2*y+1)*v*pi/(2*n));
  end
  end
```

```
  end
end
mag=a;
figure(3);
k=1;
for i=1:m
for j = 1:n
subplot(m,n,k)
imshow(mag{i,j},256);
k=k+1;
end
end
```

Output for DCT basis n=3



## 4. CONCLUSION

The image transforms by themselves do not achieve any compression. Instead, they represent the image in a different domain in which the image data is separated into components of varying importance.

To remove correlated image data, the KLT is the most important one. This builds a set of non-correlated variable with decreasing variance.

The variance of a variable is a measure of its information content; therefore, a compression strategy is based on considering only transform variables with high variance, thus representing an image by only the first k coefficient of the transform.

The KLT is computationally expensive, with a two dimension transform of an MxN image having computational complexity $O(M^E N^E)$[5]. It is the only transform that guarantees non-correlated compressed data, and the resulting data compression is optimal in the statistical sense. This makes the transform basis vector image dependent, which also makes this transform difficult to apply for routine image compression. Therefore, the KLT is used mainly as a benchmark to evaluate other transforms.

DCT is real-valued and provides a better approximation of a signal with fewer coefficients. Compared to KTL, the largest difference is that the transform basis of DCT is fixed for all images, so we can save the computational time to find the basis and the storage of it. Although the DCT basis is not adaptive to all images, the decorrelation performance is not far from KLT. Therefore, DCT is a very popular transform method in the past decades.

In DCT the original image is divided into several square blocks before transform. The objective of this process is to segment the image into small blocks with high correlation and reduce the computational cost of DCT. DCT highly suffers by the problem of blocking artifact effect and it can also be regarded as the frequency analysis tool.

Wavelet transform compression technique is lossy compression technique and it is very much similar to that of DCT. However, for a given image quality wavelet transform coding achieves higher compression ratio than that due to DCT. Compression ratio as high as 200:1 may be achieved by this method.

By this survey we find that, for the given (desired) compression ratio (or amount of data reduction), the quality of image compressed by wavelet transform is significantly better than that by DCT. Here, a low-pass filter and a high-pass filter are applied- on the input image along horizontal and vertical directions. Outputs of the filters are sub-sampled by a factor 2. In fact, the blocking effect is much less in the Wavelet Transform because its basic functions overlap one another and decay smoothly to zero at their end points.

Compression is achieved during the quantization of the transformed coefficients not during the transformation step. Quantization is the process of reducing the number of possible values of a quantity, thereby reducing the number of bits needed to represent it. Quantization is basically an irreversible process.

## REFERENCES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6. IAIS –IC-0110(V3),Wavalet Scalar Quantization,Grray-scale ingerprint compression specification 1997.
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**CITATION**

8. The JPEG web page: http://www.jpeg.org/
9. Wikipedia: http://es.wikipedia.org

**ANALYSIS TOOL USED**

10. MATLAB 7.0.1

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