# Image processing applications using Fourier Transform

## CVT PRESENTATION

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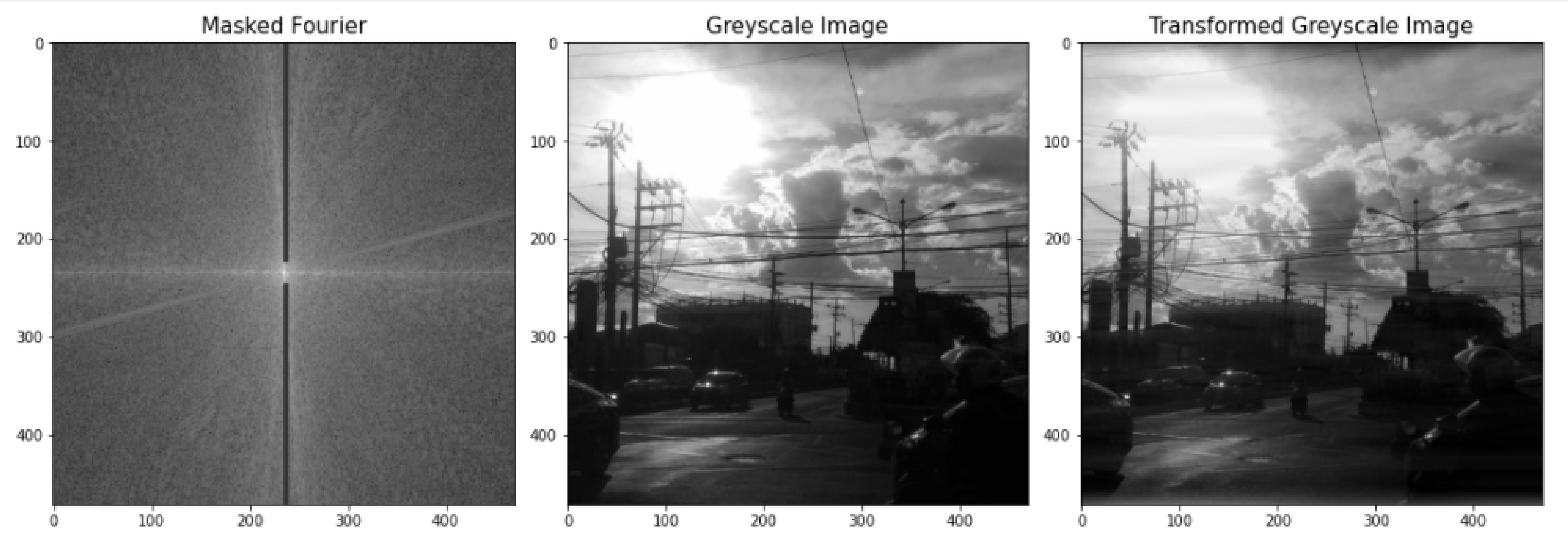
# What is image processing?

- Image processing is a method used to perform operations on an image to extract useful information or to enhance its feature.
- It is used in numerous fields and is quite prevalent in this day and age
- Applications include:
  - Image compression,
  - Texture analysis,
  - Image registration,
  - Pattern recognition etc



# APPLICATION 1: IMAGE COMPRESSION

- DFT is used to convert an image from the spatial domain into frequency domain, in other words it allows us to separate high frequency from low frequency coefficients and neglect or alter specific frequencies.
- The proposed compression algorithm involves several steps:

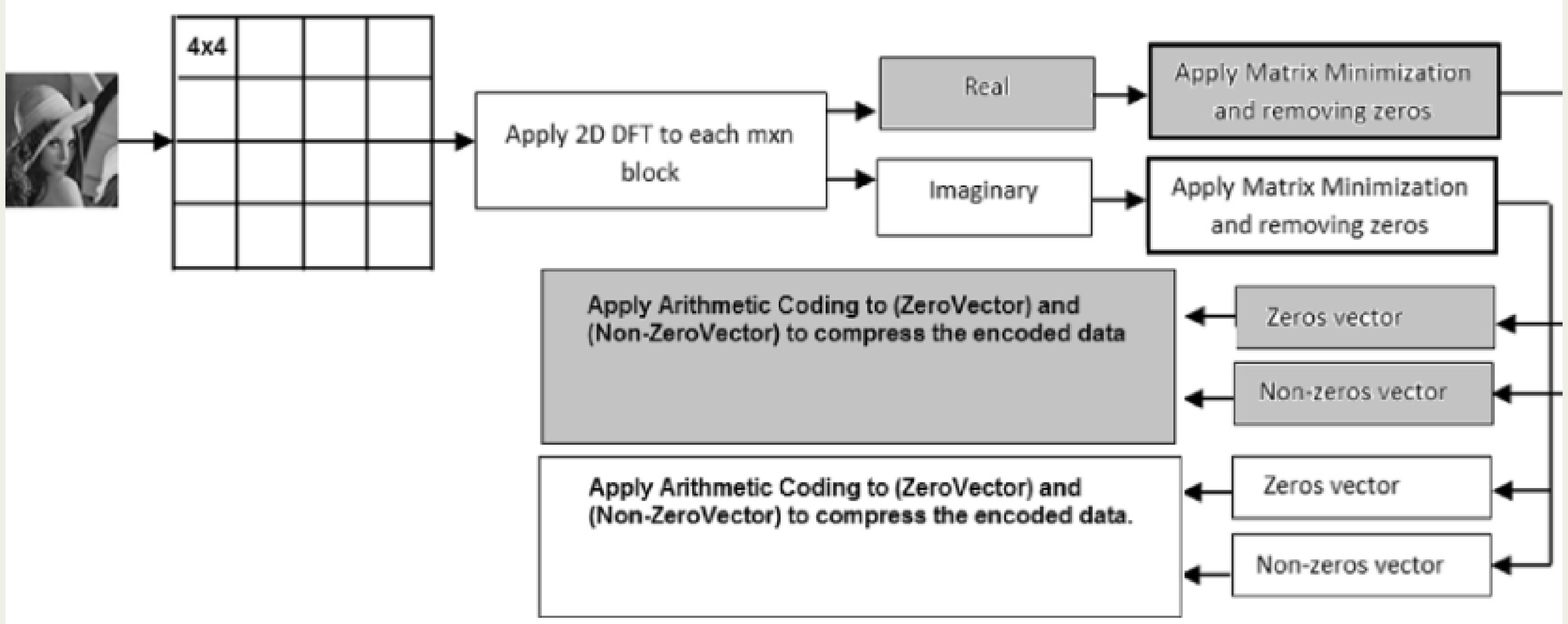



**Fig. 1.** The proposed compression method.

1. The original image is divided into non-overlapping blocks and the Discrete Fourier Transform (DFT) is applied to each block independently to represent the image in the frequency domain, resulting in real and imaginary components.

2. Matrix Minimization algorithm is applied to each component, followed by removing zeros and applying Arithmetic coding to compress the data.

| | | | | |
|---|---|---|---|---|
| Matrix = 4x4 | 15 18 26 48<br>14 19 27 31<br>16 21 32 31<br>16 25 35 32 | Convert Matrix to frequency domain by DFT | Real= (Matrix) | 406 -59 -44 -59<br>7 10 -21 0<br>8 5 -14 5<br>7 0 -21 10 |
| | | | Imaginary= (Matrix) | 0 59 0 -59<br>17 14 3 -26<br>0 21 0 -21<br>-17 26 -3 -14 |

**Fig. 2.** DFT applied to a 4 × 4 matrix of data.

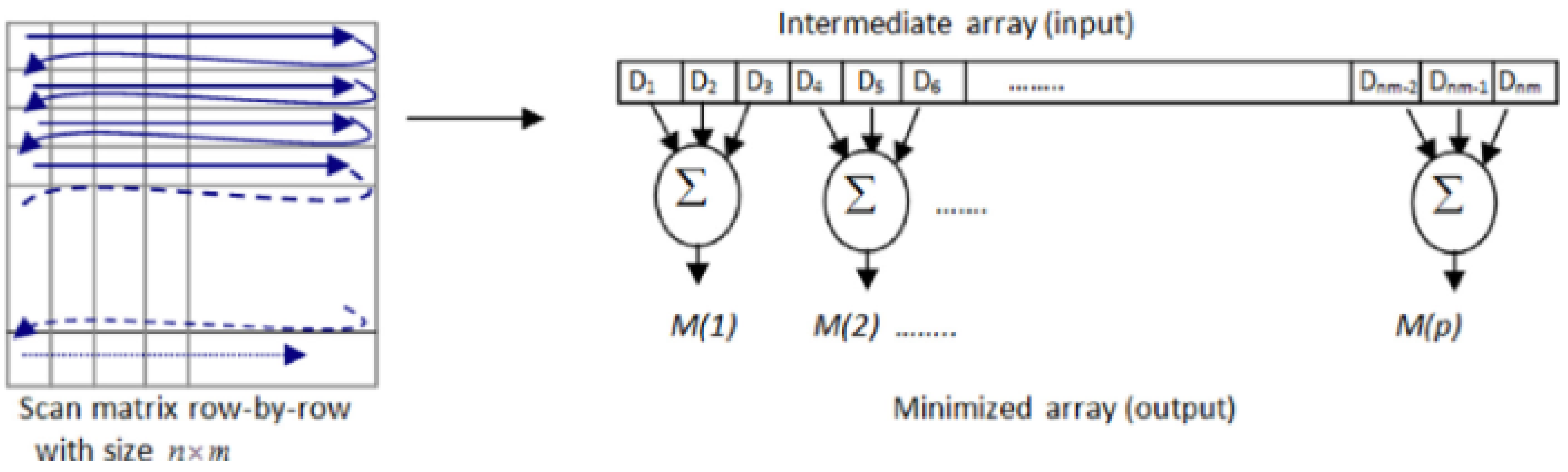



**Fig. 5.** The Matrix Minimization method for an m x n matrix [10–12].

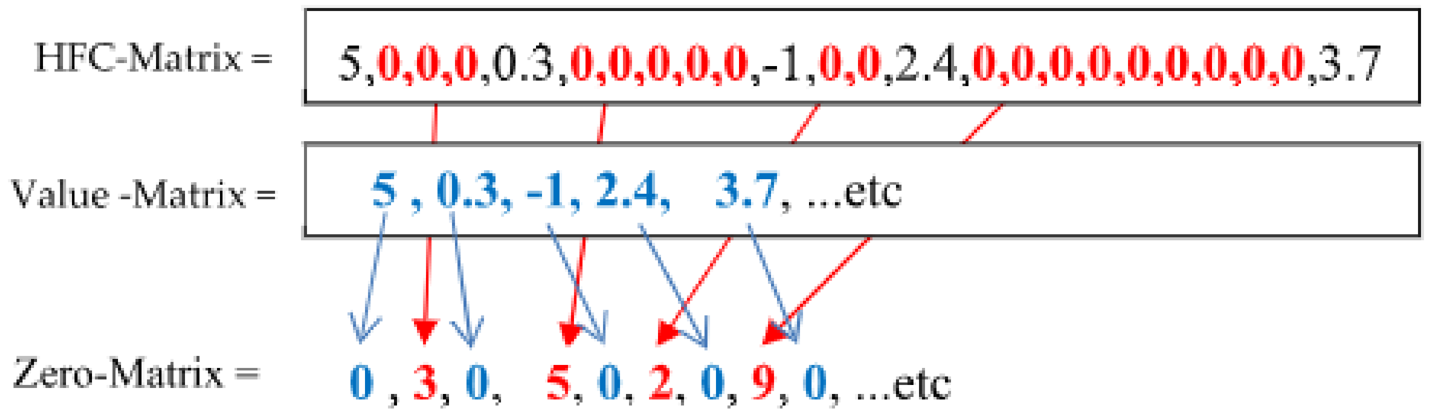



**Fig. 6.** Separating zeros and nonzero from HFC matrix and coding zero and non-zero values into Zero and Value matrices.

3. Uniform quantization is then applied to both parts, involving dividing each element by a quantization factor and rounding the outcomes to increase the compression ratio.

4. Further, Low Frequency Coefficients (LFC) are separated from High Frequency Coefficients (HFC) in the real part, and Matrix Minimization is applied to reduce the size of HFC matrices.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Real= | 406 | -59 | -44 | -59 | | Qr= | 20 | -3 | -2 | -3 |
| | 7 | 10 | -21 | 0 | | | 0 | 1 | -1 | 0 |
| | 8 | 5 | -14 | 5 | After quantization | | 0 | 0 | -1 | 0 |
| | 7 | 0 | -21 | 10 | (real and imaginary is | | 0 | 0 | -1 | 1 |
| Imaginary= | 0 | 59 | 0 | -59 | divided by Q = 20) | Qi= | 0 | 3 | 0 | -3 |
| | 17 | 14 | 3 | -26 | | | 1 | 1 | 0 | -1 |
| | 0 | 21 | 0 | -21 | | | 0 | 1 | 0 | -1 |
| | -17 | 26 | -3 | -14 | | | -1 | 1 | 0 | -1 |

**Fig. 3.** Quantization and rounding off the real and imaginary components.

Let we have an Image of size MxN then F(u,v) is the F T of image f(x,y)

$$F(u,v) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)}$$

Where variable u = 0, 1, 2, …., M-1 and v = 0, 1, 2, …., N-1

260 KB Quantization value=10 | 138.2 KB Quantization value=25 | 88.1 KB Quantization value=45

(a) Decompressed Lena image, dimension = 1024 x 1024

- Using DCT (Discrete Cosine Transform) is a better compression technique because it allows for separating high frequency from low frequency coefficients, preventing frequency alteration while maintaining image quality.

- Decompression involves

1. reversing the compression process by decoding matrices using arithmetic decoding
2. reconstructing arrays based on Value and Zero matrices and reconstructing the High Frequency Coefficients (HFC) matrices.
3. A Sequential Search Algorithm is used to regenerate contracted values with the help of preserved MIN and MAX values from compression.
4. Finally, inverse quantization and Discrete Fourier Transform (DFT) are applied to reconstruct the compressed digital image.

- Image compression is used in web design, digital photography, video streaming, or medical imaging, etc. It is essential in maintaining efficiency and delivering an exceptional user experience in this digital world.

# APPLICATION 2: IMAGE REGISTRATION

- Image registration is a fundamental concept in image processing and computer vision that involves aligning and matching images or sets of images to achieve a common coordinate system or spatial reference frame.

- One of the applications of image registration using Fourier series in the medical industry is in the field of **functional MRI (fMRI) for functional connectivity mapping and brain region localisation.** Functional MRI is a powerful imaging technique used to study brain function by measuring changes in blood flow and oxygenation levels in response to neural activity.

# APPLICATION 3: TEXTURE ANALYSIS

*What do we mean by texture in an image?*

- Texture refers to the spatial arrangement of visual patterns in an image. Analyzing texture is crucial in various fields such as image processing, computer vision, and pattern recognition.
- Texture analysis aims to characterize and quantify the spatial patterns within an image, which can be useful for tasks like image classification, segmentation, and object recognition.

*Fourier series in texture analysis*

- In the context of texture analysis, the magnitude spectrum obtained from the Fourier transform can be interpreted as coefficients of a Fourier series.
- Each coefficient in the Fourier series corresponds to a specific spatial frequency component present in the texture.
- MAGNITUDE SPECTRUM: $[|F(u,v)|=\sqrt{}Re(F(u,v))2+Im(F(u,v))2]$

where $|F(u,v)|$) represents the magnitude at frequency coordinates $(u,v)$
($Re(F(u,v))$) and ($Im(F(u,v))$) denote the real and imaginary parts of the transformed value, respectively.

*Texture feature extraction*

- From the Fourier coefficients or magnitude spectrum, various texture features can be extracted for analysis.
- Common texture features include dominant frequencies, orientation, texture periodicity, and statistical properties of frequency components.
- These features capture the spatial frequency characteristics of the texture, which can be used for further analysis or classification tasks.

*Applications of texture analysis using fourier series*

- Classification: Texture features extracted from Fourier series coefficients can be used to classify images into different texture categories.
- Segmentation: Texture analysis techniques based on Fourier series can help segment images into regions with similar texture properties.
- Synthesis: Fourier-based texture synthesis methods can generate new textures based on learned features or statistical properties extracted from existing textures.

# APPLICATION 4: PATTERN RECOGNITION

- Pattern recognition is a fundamental task in image processing and computer vision.
- Fourier series can be applied in pattern recognition to analyze the frequency content of images.
- The two-dimensional Fourier transform of an image F(u,v) is given by:

$$F(u,v) = \iint_{-\infty}^{\infty} f(x,y)e^{-i2\pi(ux+vy)}\,dx\,dy$$

- Fourier descriptors are a set of complex numbers obtained by applying the Fourier transform to the boundary of an object in an image.

# Thank you!