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# Module-2

# Image Transforms

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# Introduction to Image Transforms

- **Definition:** A mathematical tool that represents an image in a different domain (e.g., frequency domain).
- **Need for Transforms:**
  - **Mathematical Convenience:** Simplifies complex operations like convolution into simple multiplication.
  - **Data Compression:** Packs most image energy into a few coefficients.
  - **Feature Extraction:** Highlights edges or patterns for recognition.
  - **Fast Computation:** Enables efficient algorithms like the Fast Fourier Transform

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# Two-Dimensional Orthogonal & Unitary Transforms

**General Formulation:** A 2D transform maps an image f(x,y) to a set of coefficients $V(u,v)$ using a forward transformation kernel.

- **Unitary Transform:** A linear transform where the transformation matrix $A$ satisfies $A^{-1} = A^H$ (conjugate transpose).
- **Orthogonal Transform:** A special case where the matrix $A$ is real and unitary ( $A^{-1} = A^T$).
- **Separability:** If the 2D kernel can be split into two 1D kernels, the transform can be computed row-by-row then column-by-column, greatly reducing computation time.

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# Properties of Unitary Transforms

- **Energy Conservation:** Total signal energy is preserved ($||f||^2 = ||V||^2$), according to the 2D Parseval relation.
- **Energy Compaction:** Most of the image information is concentrated into a few small-index coefficients near the origin.
- **De-correlation:** Highly correlated input pixels are transformed into uncorrelated output coefficients, facilitating easier compression.
- **Rotation Invariance:** A unitary transform acts as a rotation of the image vector in $N^2$-dimensional space.

# 2-D Discrete Fourier Transform (DFT)

- **Concept:** Represents an image as a sum of sinusoidal basis images.
- **Key Features:**
  - **Complex Values:** Provides both magnitude and phase information.
  - **Periodicity:** The transform and its inverse are periodic.
  - **Applications:** Frequency domain filtering, noise removal, and texture analysis.

# Discrete Cosine Transform (DCT)

- **Definition:** Uses only cosine basis functions and produces real coefficients.
- **Advantages:**
    - **Excellent Energy Compaction:** Close to the optimal Karhunen-Loève Transform (KLT) for most images.
    - **Real and Fast:** Avoids complex numbers and has efficient "fast" implementations.
- **Primary Use:** The standard for lossy image compression (e.g., JPEG)

# Harr Transform

- **Mechanism:** A simple wavelet transform using square-shaped basis functions.
- **Mathematical Operations:** Uses only simple additions and subtractions to decompose data into averages and differences.
- **Strengths:**
  - Extremely fast to compute.
  - Excellent for detecting sharp transitions or sudden changes in an image.
  - Provides multi-resolution representation.

# Conclusion & Comparison

- **DFT** is best for frequency analysis and filtering.
- **DCT** is superior for compression due to energy compaction.
- **Haar** is ideal for fast, multi-scale edge detection and analysis