Unidade Curricular

“Informação e Codificação”

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https://www.ua.pt/pt/uc/15264

Outline

- Guiding questions
- Transform Coding
- Subband coding
- Wavelets

TRANSFORMS, SUBBANDS, AND WAVELETS

Importance of source modeling:

- The foundation of any data compression scheme.
- Requires understanding the process or signal from multiple perspectives

Signal representations:

- **Time/Space domain**: Common representation of signals (e.g., voice as a function of time, images as functions of space).
- **Frequency domain**: Alternative representation highlighting frequency components of the signal.

Relationship between representations:

- Time and frequency views are different representations of the same signal.
- The transition between these representations is possible through mathematical transformations.

Guiding questions

What is the purpose of applying transforms like the Discrete Cosine Transform (DCT) in image, video, and audio compression?

What is subband coding, and how is it applied in audio compression standards like MP3?

How do wavelets differ from DCT in representing audio or image data?

What transform coding methods are used in the presented standards, and why was it chosen?

TRANSFORM CODING

Transform coding uses transforms to represent signals, often in the frequency domain

Human perception is limited to narrow frequency bands:

- Spatial frequencies for images.
- Temporal frequencies for audio.

Transforms reveal correlation structures in the signal.

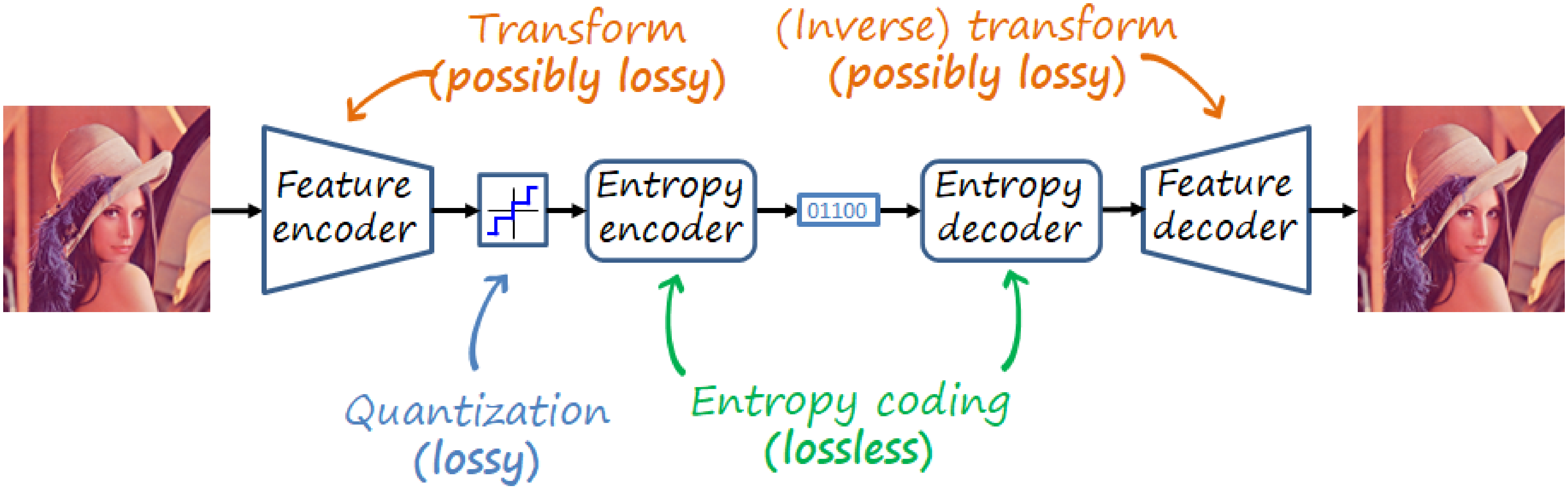
Compact most of the signal energy into a few components, facilitating compression by ignoring low-energy parts.

Efficient bit allocation ensures focus on the most critical coefficients.

Transform Coding Process:

- Transform: Convert data into the transform domain (e.g., frequency domain).
- Quantization: Reduce precision of transform coefficients to save space.
- Coding: Encode quantized coefficients efficiently.

TRANSFORM CODING



https://www.lherranz.org/2022/08/24/neural-image-compression-in-a-nutshell-part-1-main-idea/

Transforms of interest

Discrete Fourier transform (DFT)

Karhunen–Loéve transform

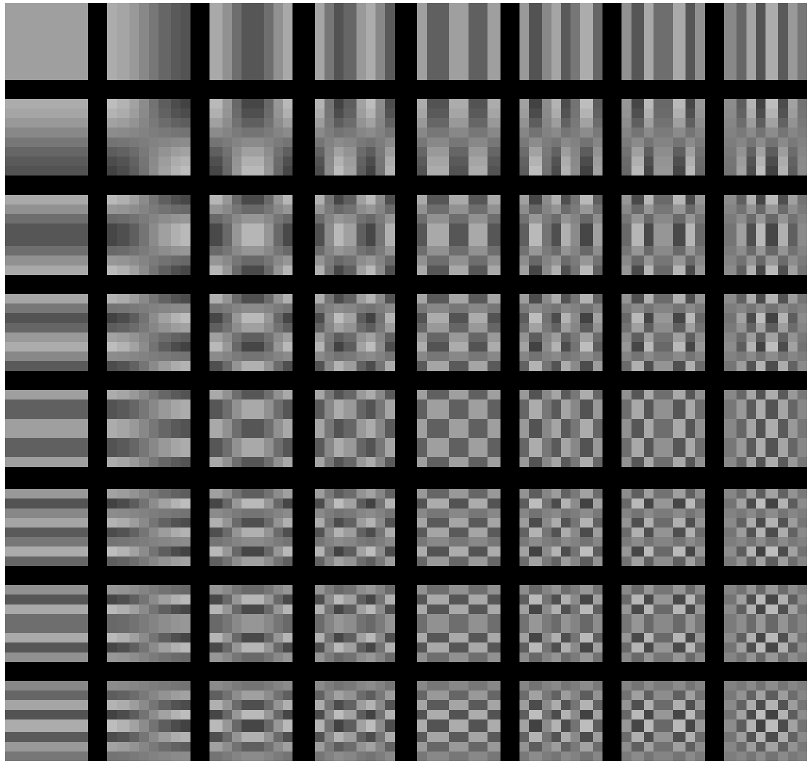
Discrete cosine transform (DCT)

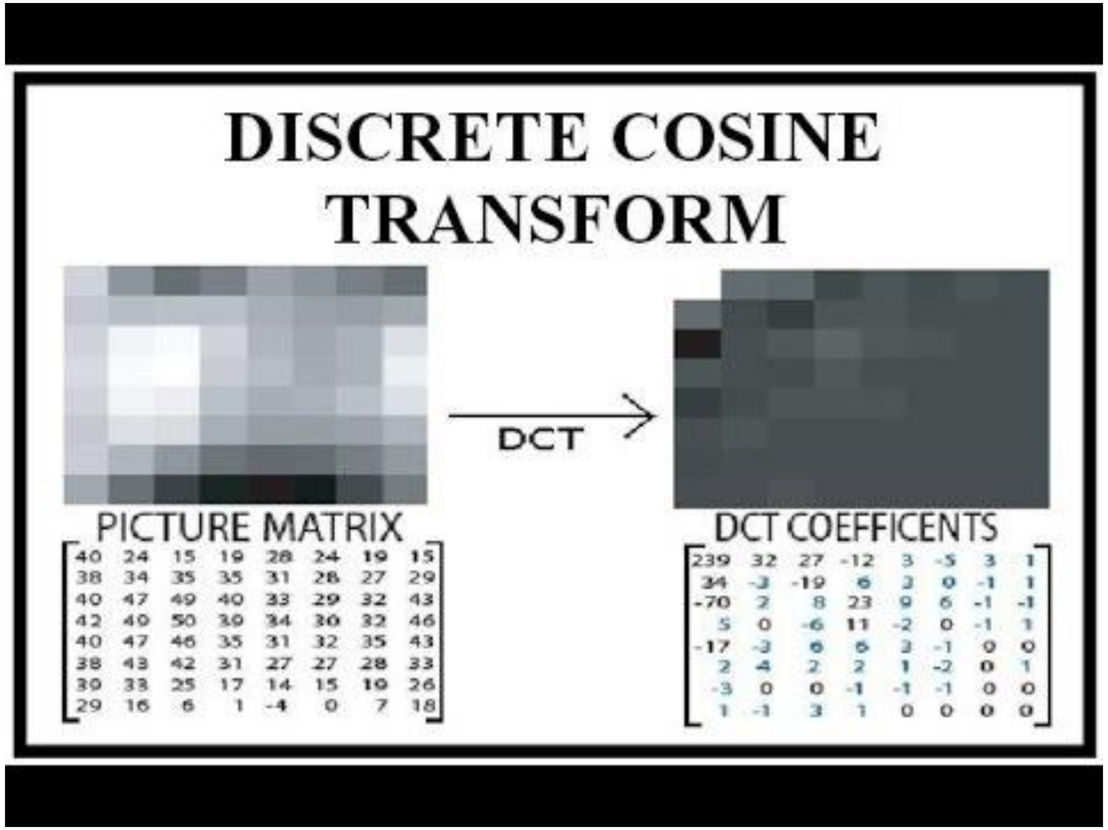
Modified discrete cosine transform (MDCT) - overlap transforms

https://www.youtube.com/watch?v=0Kmg1BT9Wxc
https://www.mathworks.com/help/audio/ref/mdct.html

Example: DCT

https://www.youtube.com/watch?v=Q2aEzeMDHMA





https://www.mathworks.com/help/images/discrete-cosine-transform.html

SUBBAND CODING

- Working with signals in the frequency domain allowed us to use their spectral structure and develop transform coding approaches.
- Combines temporal/spatial and spectral domains for signal processing.
- Decomposes signals into multiple frequency bands, enabling tailored encoding for each band.
- Low-Frequency Bands:
  - Signals tend to be smooth.
  - Exploits sample-to-sample correlation for efficient encoding.
- High-Frequency Bands:
  - Signals are sparse.
  - Enables specialized encoding schemes suited to sparse data.
- Leverages human perception's spectral and temporal limitations - allows selective ignoring or discarding of less important components to improve compression.
- Uses band-specific encoding to maximize efficiency:
  - Coarser quantization for less perceptually critical components.
  - Finer quantization for bands where errors are more noticeable.

Example

Analysis

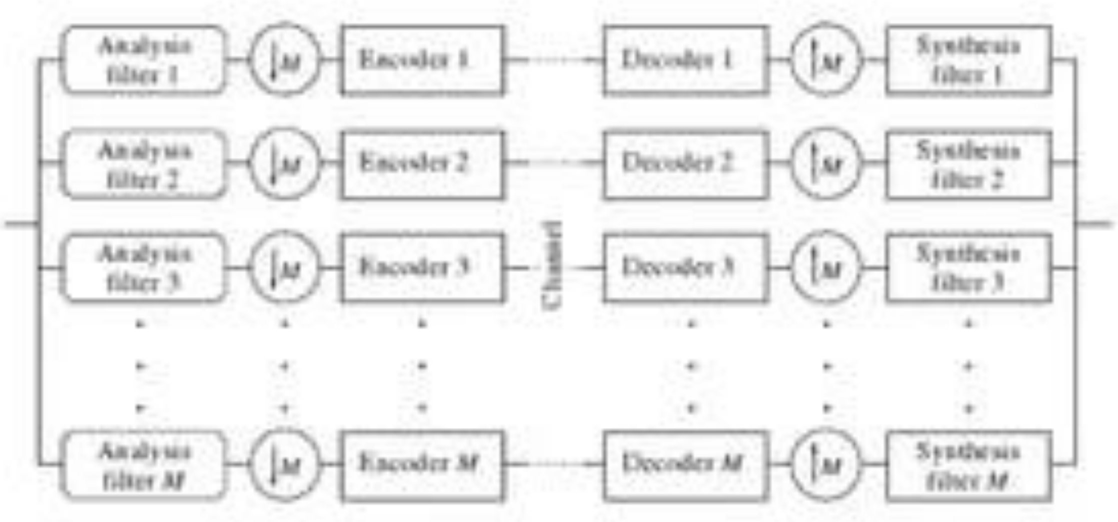
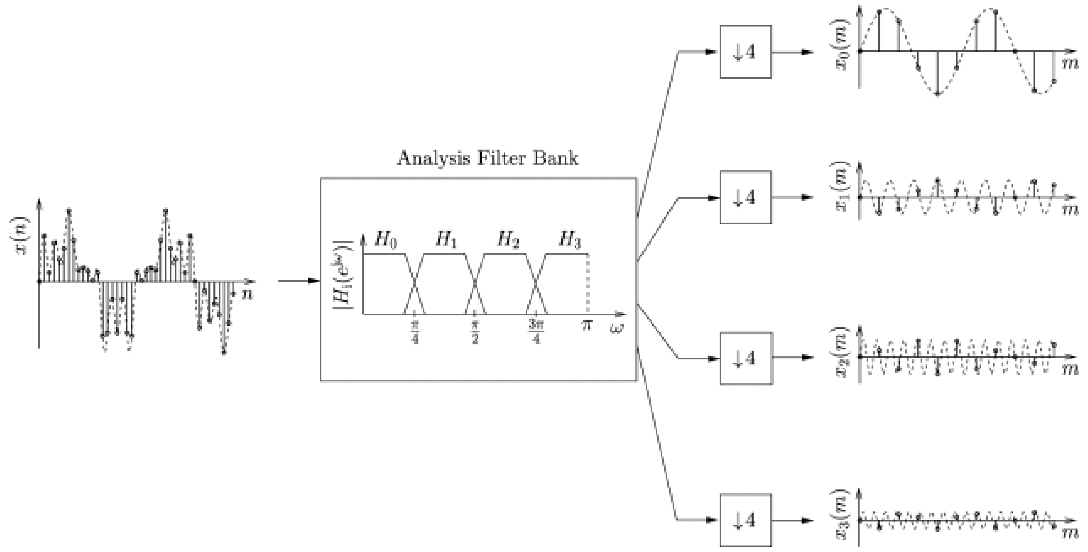


Fig-1. Block diagram of subband coding system

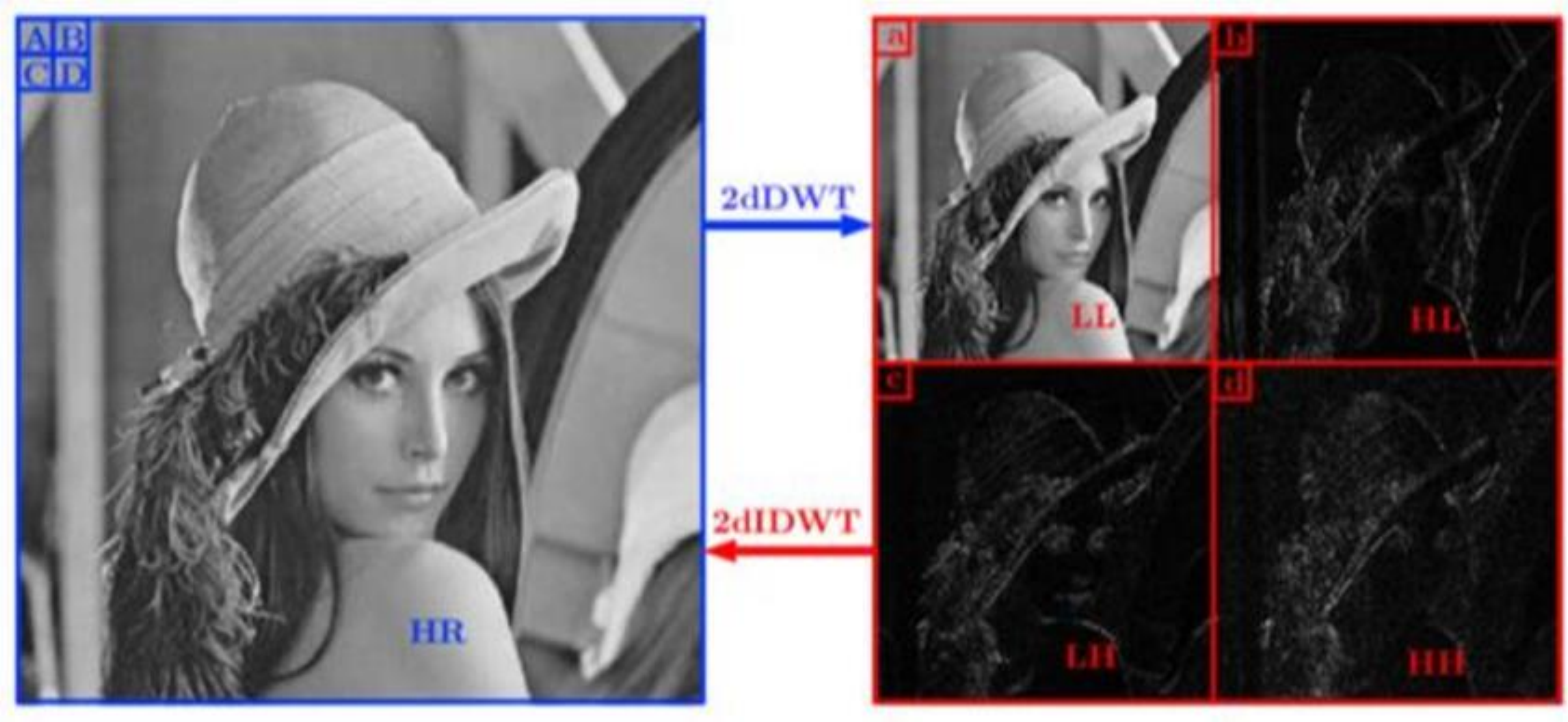


https://www.sciencedirect.com/topics/computer-science/synthesis-filter-bank

WAVELETS

- Wavelets enable time-frequency decomposition, capturing both temporal and spectral structures
  - Decomposes a signal into coarse and fine details at different scales.
  - Allows precise representation of transient signals and localized features.
- Useful for signals with non-stationary characteristics, where properties vary across time or space.
- Transform Coding: Assumes stationarity; averages over the entire signal, losing temporal resolution.
- Subband Coding: Separates frequency bands but lacks fine-grained temporal localization.
- Wavelet Transform: Provides a multiresolution analysis, adapting to both time and frequency variations.
  - Signal decomposition using analysis filter banks.
  - Downsampling, quantization, and encoding of filter outputs.
  - Decoding involves upsampling and synthesis filter banks to reconstruct the signal.

WAVELETS



https://www.siue.edu/~msong/Research/article.pdf

https://eeweb.engineering.nyu.edu/~yao/EL5123/lecture11_wavelet_JPG2K.pdf