CODAS LAB

UNIVERSIDAD DE GRANADA

Image Reconstruction with Tucker Decomposition: Performance Impact of FFT

Comparison of tensor decomposition and FFT-based approaches for image compression and reconstruction

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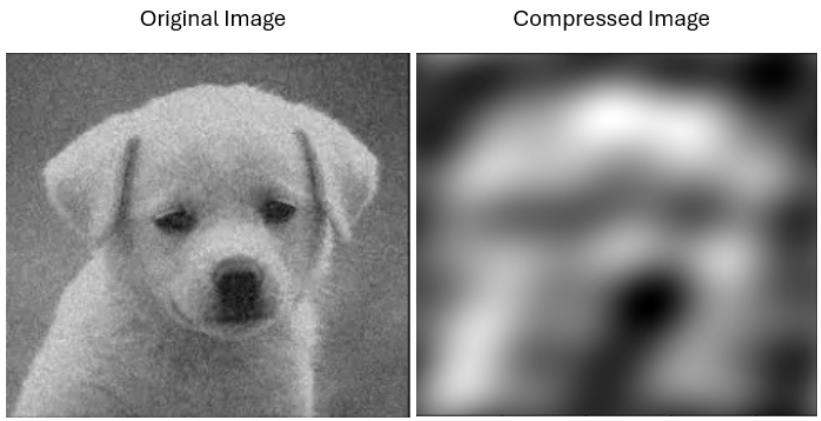
Introduction

- Image compression.
- Tucker decomposition.
- FFT = frequency-domain view.
- Comparison: Spatial vs. FFT-Tucker.



Version Comparision

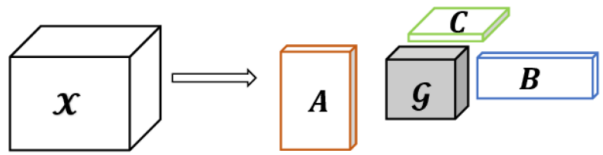
Mathematical Background

Tucker Decomposition

- Factorizes tensors into core + factor matrices
- Reduces dimensionality
- Extracts key features from 4D data

Tucker Decomposition

$$\mathcal{X} \approx \mathcal{G} \times_1 U^{(1)} \times_2 U^{(2)} \times_3 U^{(3)} \times_4 U^{(4)}$$

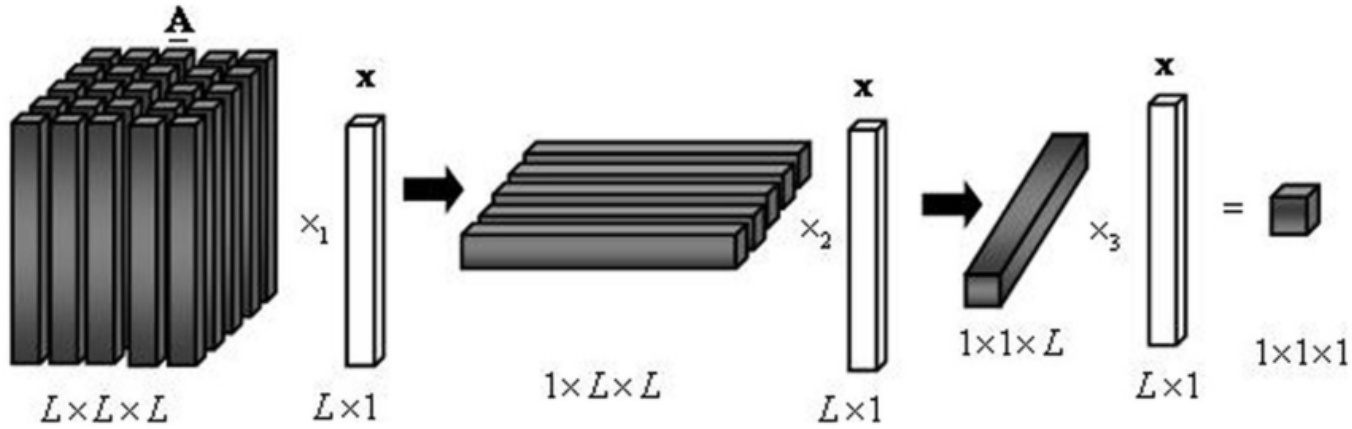


Mathematical Background(cont.)

Definition: Reshaping an N-dimensional tensor into a matrix along mode n.

$$X_{(n)} \in \mathbb{R}^{I_n \times \prod_{m \neq n} I_m}$$

- Rows correspond to the n-th mode
- Columns correspond to all other modes
- Used in tensor decompositions like Tucker



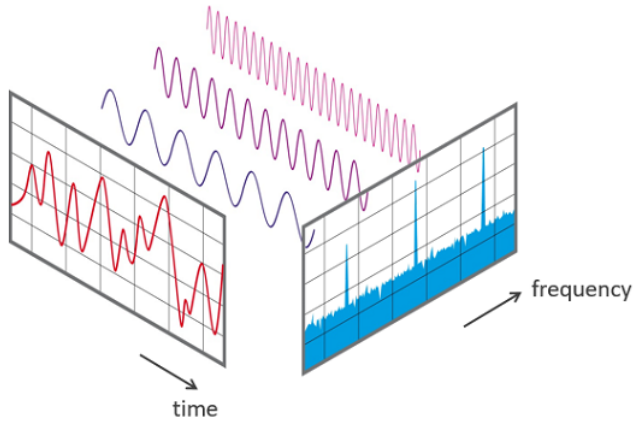
Mathematical Background(cont.)

Fourier Transform

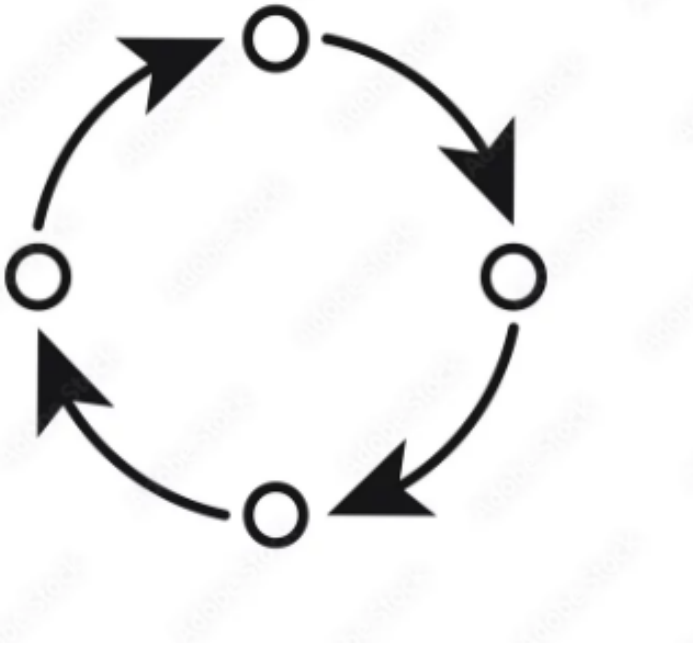
- Converts data to frequency domain
- Highlights patterns & periodicity
- Applied on 3D image tensors

Fourier Transform

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi kn/N}$$



Methodology

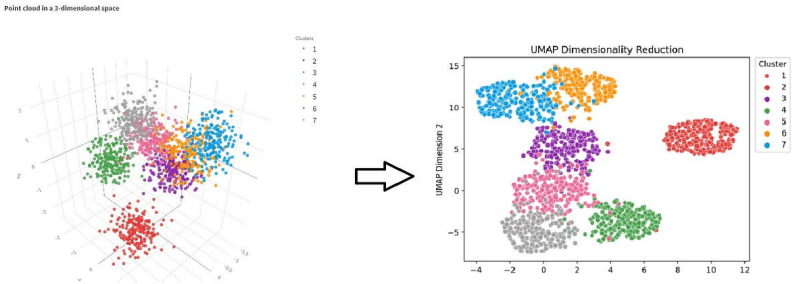


- Load dataset
- Apply 3D RFFT
- Spatial Tucker decomposition
- FFT-Tucker decomposition + iFFT reconstruction
- Compare metrics

Clustering Attempts

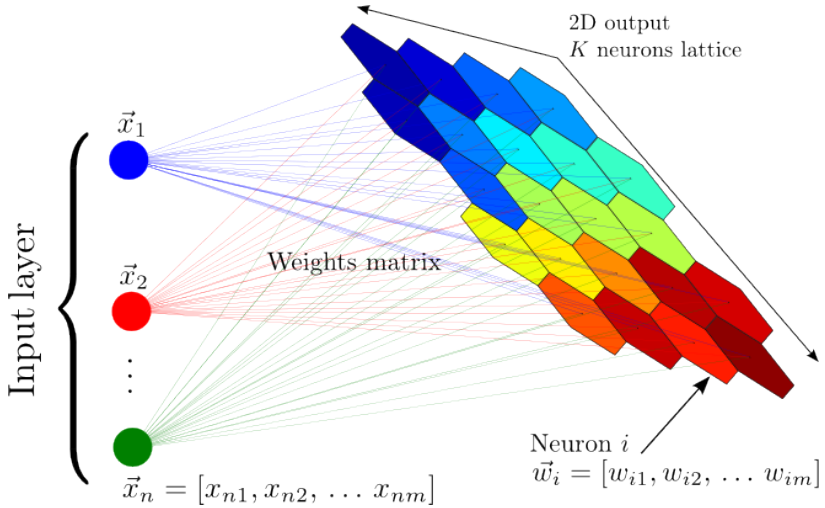
UMAP

- Non-linear dimensionality reduction.
- Expected clear clusters, but results were mixed.



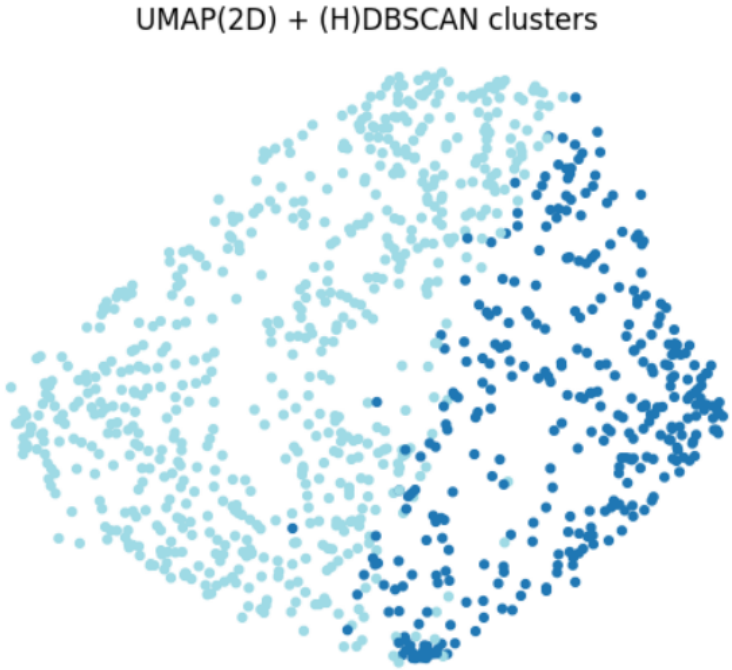
SOM (Self-Organizing Maps)

- Neural-network based clustering method.
- Failed to separate image categories effectively.

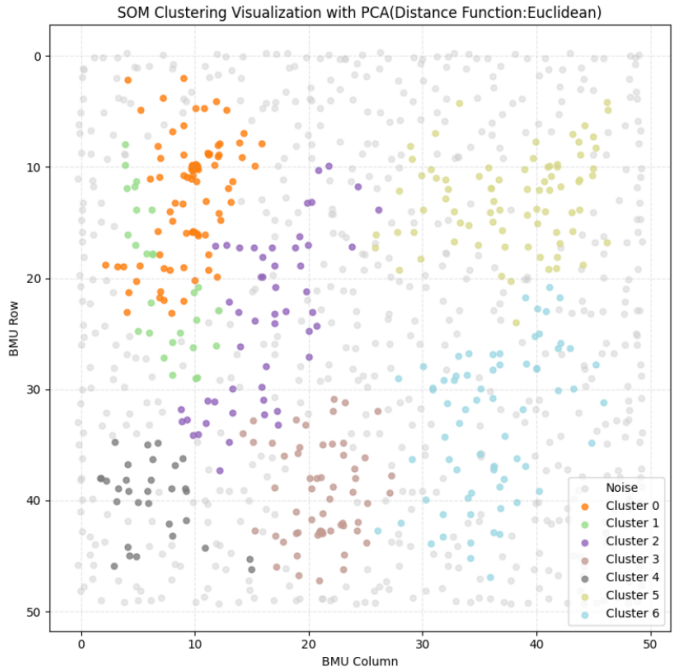


Clustering Results

UMAP



SOM



→ Since automatic clustering failed, images were grouped manually.

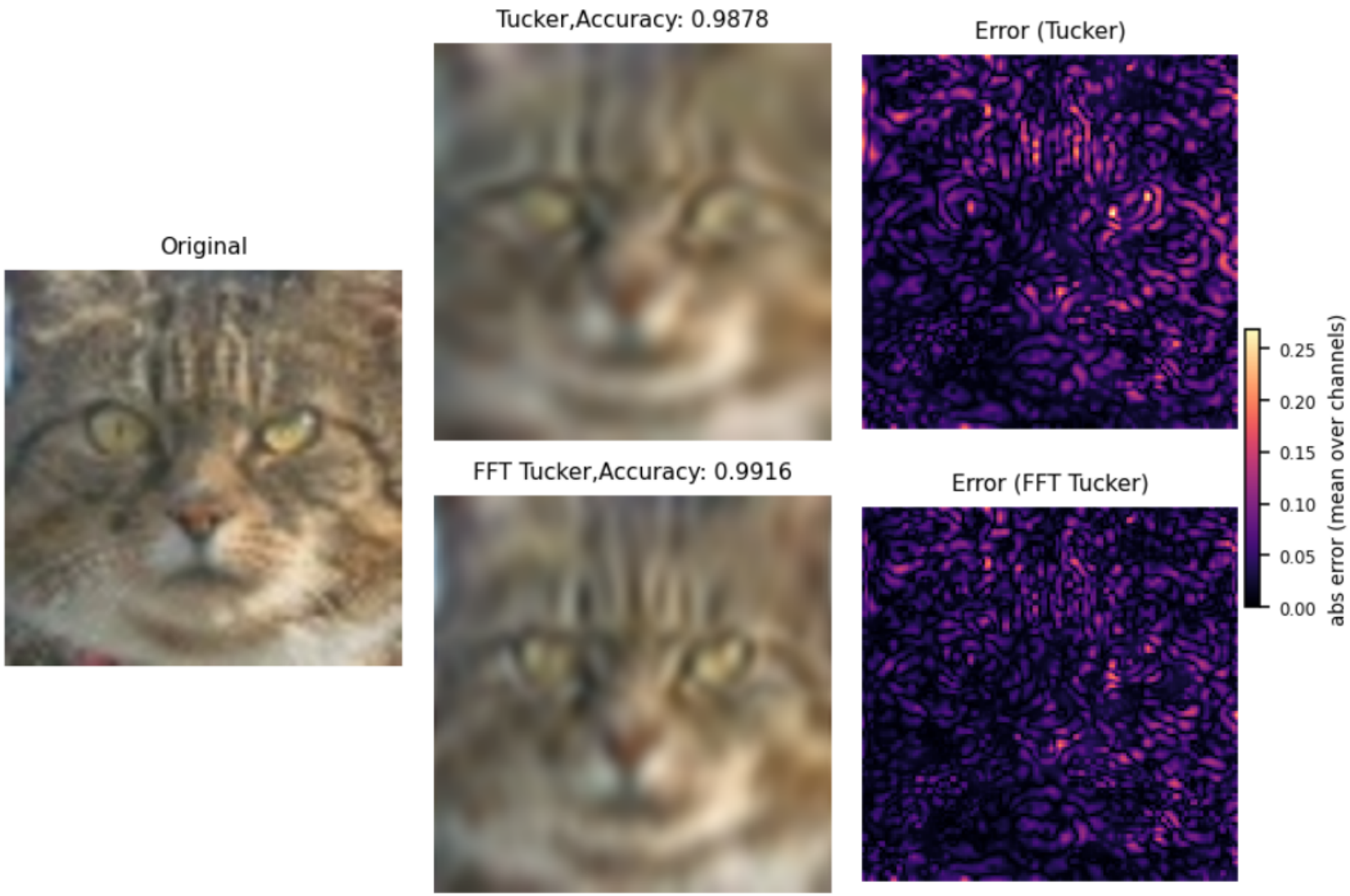
Results: Reconstructions

Example 1

Example 2

Original vs. Tucker vs. FFT-Tucker reconstructions

Comparision



Conclusion

- Spatial Tucker is simpler,but FFT-Tucker often has a better reconstruction accuracy.
- Tucker decomposition enables efficient image compression.
- UMAP and SOM clustering did not succeed $\rightarrow$ manual grouping used.

References

- https://www.geeksforgeeks.org/computer-vision/fast-fourier-transform-in-image-processing
- https://umap-learn.readthedocs.io/en/latest/embedding_space.html
- https://github.com/michelin/TorchSOM
- https://www.nti-audio.com/es/servicio/conocimientos/transformacion-rapida-de-fourier-fft