Advanced Techniques for Signal and Image Compression/Reconstruction With Wavelets

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FOREWORD

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ADVANCED TECHNIQUES FOR SIGNAL AND IMAGE COMPRESSION / RECONSTRUCTION WITH WAVELETS

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PRESENTATION OVERVIEW

- WAVELET-BASED TECHNIQUES AND ITS APPLICATIONS IN THE UNDERSEA ENVIRONMENT FOR DATA COMPRESSION
- PERFORMANCE COMPARISON WITH OTHER TRADITIONAL DATA COMPRESSION / RECONSTRUCTION TECHNIQUES
- INTRODUCTION TO THE ENERGY-BASED METHOD FOR WAVELET COEFFICIENT SELECTION
- PERFORMANCE COMPARISON BETWEEN GLOBAL THRESHOLD AND ENERGY-BASED METHODS

INTRODUCTION

- WAVELETS & WAVELET TRANSFORMS
  “The transformation of signals into a sum of small, overlapping waves offers a new method for analyzing, storing, and transmitting information”. - Gilbert Strang

- WAVELETS & WAVELET TRANSFORMS PROVIDE SIGNIFICANT ADVANCES IN MANY SCIENCES & ENGINEERING DISCIPLINES
  - DATA COMPRESSION
    - Image Compression / Reconstruction
  - SIGNAL ANALYSIS
    - Feature Extraction
    - Detection / Classification
  - SCIENTIFIC CALCULATIONS
    - Turbulence / Chaos
    - Complex Nonlinear Differential Equations
  - MEDICAL IMAGING
  - ARTIFICIAL NEURAL NETWORKS
OBJECTIVES

THE OBJECTIVES OF THIS PROJECT ARE

- DEVELOP DATA COMPRESSION / RECONSTRUCTION TECHNIQUES USING WAVELETS, WAVELET TRANSFORMS, AND WAVELET PACKETS
- DESIGN AND DEVELOP A NEW IMPROVED WAVELET COEFFICIENT SELECTION METHOD BASED ON ENERGY CRITERIA.

THE NEW TECHNIQUE HAS TO

- PROVIDE ACCURATE FEATURE EXTRACTION IN TIME-FREQUENCY LOCALIZATION
- PRODUCE AN IMAGE WITH COMPACT CAPACITY FOR STORAGE EFFICIENCY AND RAPID TRANSMISSION
- MAINTAIN THE INTEGRITY OF THE ORIGINAL DATA

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Wavelet-based Image Compression Technique

- WAVELET DECOMPOSITION OF A GIVEN IMAGE \(f(x,y)\):

\[
f(x,y) = \sum c_{nk} \psi_{nk}(x,y)
\]

where

- \(c_{nk}\) : coefficients
- \(\psi_{nk}(x,y)\) : wavelet function
- \(n, k\) : scale (frequency), location (time)

- INFORMATION CONTENT OF THE IMAGE \(f(x,y)\) IS APPROXIMATED IN THE FINITE SEQUENCE OF COEFFICIENTS \(c_{nk}\):

\[
f = f_{approx} = \{c_{nk}\}
\]

- UTILIZE WAVELET COEFFICIENT SELECTION ALGORITHM TO COMPRESS DATA
  - GLOBAL THRESHOLD
  - ENERGY-BASED

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Two-Dimensional Inverse Wavelet Transform

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EXISTING METHODS FOR IMAGE COMPRESSION BASED ON GLOBAL THRESHOLDING OF WAVELET COEFFICIENTS


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ENERGY-BASED WAVELET COEFFICIENT SELECTION

MOTIVATION:

- INSPIRED BY TREE STRUCTURE OF SIGNAL DECOMPOSITION AND RECONSTRUCTION WITH WAVELETS
  - Each level of the tree depends on the previous level

- EACH LEVEL OF WAVELET DECOMPOSITION TREE CONTAINS FINER APPROXIMATION AND DETAIL FROM PREVIOUS LEVEL

- UNDERWATER ACOUSTIC SIGNALS HAVE LARGEST WAVELET COEFFICIENTS CONCENTRATED IN FEW LEVELS
  - Global threshold-based selection is inadequate
ENERGY-BASED WAVELET COEFFICIENT SELECTION

METHOD:

- BASED ON CONSIDERATION OF MEAN ENERGY OF WAVELET COEFFICIENTS AT EACH LEVEL OF THE DECOMPOSITION TREE

- NUMBER OF WAVELET COEFFICIENTS SELECTED FROM A PARTICULAR LEVEL PROPORTIONAL TO THE MEAN ENERGY AT THAT LEVEL

- EACH LEVEL HAS ITS OWN LOCAL THRESHOLD FOR COEFFICIENT SELECTION: ENERGY CONSIDERATIONS PROVIDE A MECHANISM FOR DETERMINING THIS THRESHOLD

GLOBAL THRESHOLD vs. ENERGY-BASED THRESHOLD

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ENERGY-BASED WAVELET COEFFICIENT SELECTION

ALGORITHM:

- Let signal length = N, and Number of levels = M (N = 2^M)
- Number of wavelet coefficients at level k is N_k = \( \frac{N}{2^k} \) for k = 1, 2, ..., M
- Let the wavelet coefficients at level k be \( \{c_{kj}\} \), where j = 1, 2, ..., N_k
- Mean energy \( E_k = \frac{1}{N_k} \sum_{j=1}^{N_k} c_{kj}^2 \)
- If number of coefficients retained, \( N_R = \frac{\text{Percent Retention}}{100} \times N \)
- Number of coefficients selected from level k = \( \frac{E_k}{\sum E_k} \times N_R \)

PERFORMANCE COMPARISON FOR UNDERSEA BIOLOGICAL SOUNDS

![Graph showing performance comparison for undersea biological sounds](image-url)

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DISCUSSION:

- THE NEW METHOD PROVIDES IMPROVED PERFORMANCE

- THE NEW METHOD RETAINS WAVELET COEFFICIENTS ACROSS A WIDER RANGE OF DECOMPOSITION LEVELS

- CHOICE OF OPTIMAL BASIS FUNCTION FOR A PARTICULAR TYPE OF SIGNAL REMAINS AN OPEN ISSUE

- NEW METHOD PRESENTLY APPLIED TO SINGLE-DIMENSION SIGNALS, IMAGES TO BE ANALYSED.
CONCLUSIONS

- WAVELET-BASED METHODS PROVIDE SIGNIFICANT PERFORMANCE ENHANCEMENT OVER TRADITIONAL FOURIER-BASED METHODS FOR DATA COMPRESSION

- ENERGY-BASED METHOD SERVES AS A LOCAL COEFFICIENT SELECTION TECHNIQUE

- ENERGY-BASED METHOD PROVIDES IMPROVED PERFORMANCE OVER THE TRADITIONAL GLOBAL THRESHOLD METHOD

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