WAVELET-BASED COMPRESSION OF SEGMENTED IMAGES

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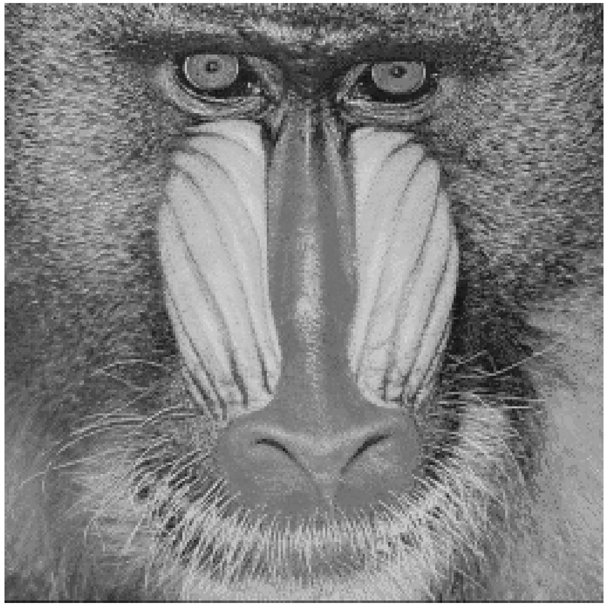
Main goal

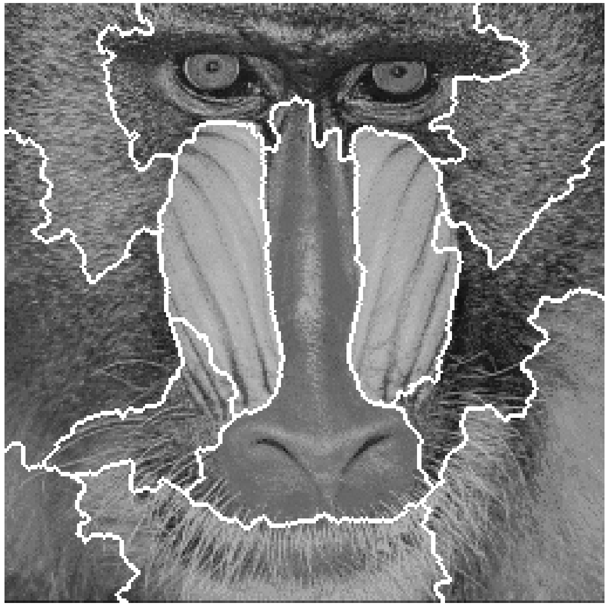
- Effective compression of segmented images using wavelet transform
- Separated coding of image segments for possible individual reconstruction or retrieval

Complete scheme of coding process:

- Segmentation of an image
- Polygonal approximation of segments (improves coding efficiency)
- Texture approximation/coding



Sample input image (Baboon)

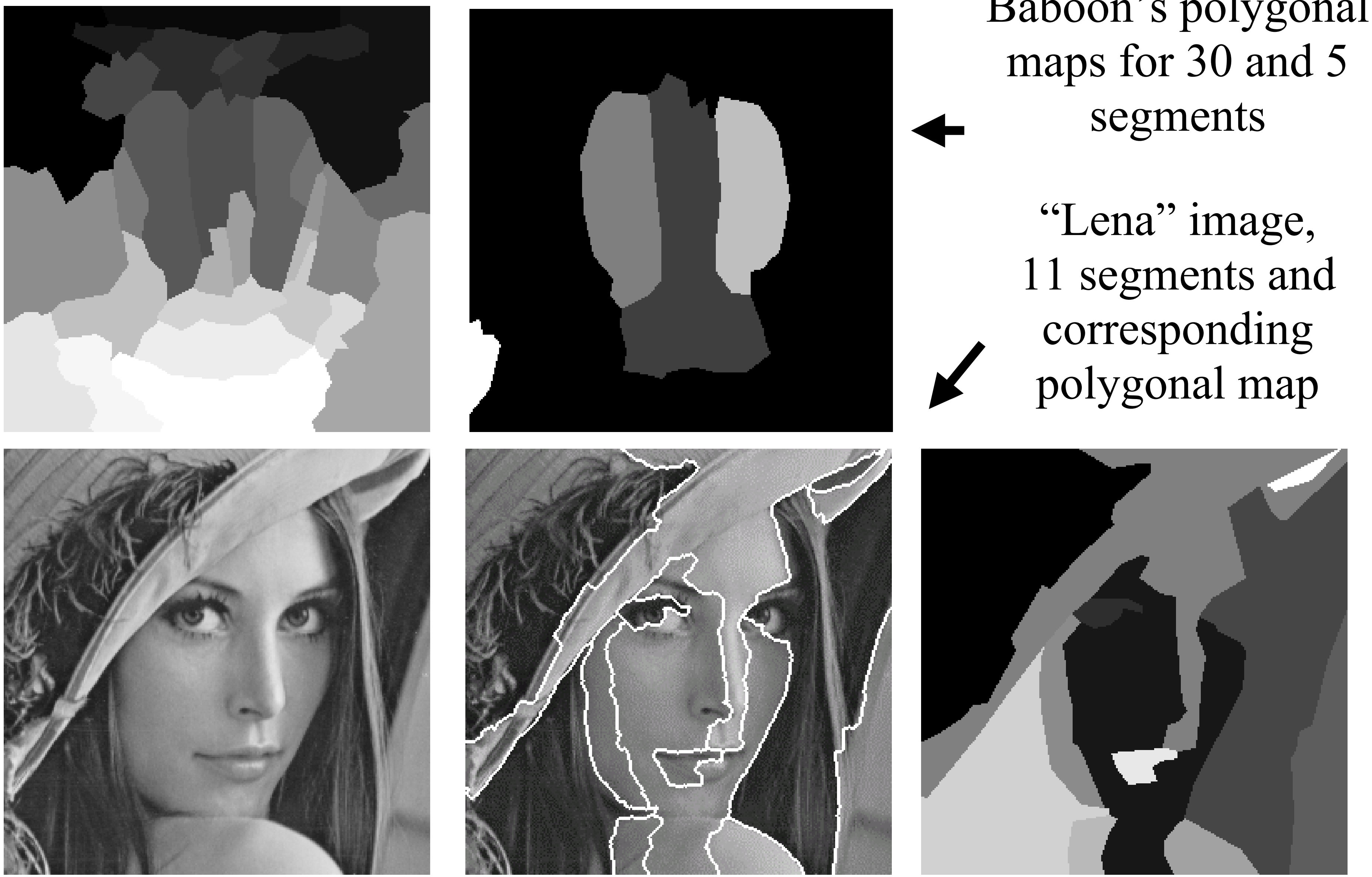


Segmented into 12 segments

Map of polygonal approximations for 12 segments

Unsupervised segmentation method for colour –texture regions used in [1].

a) *finding boundaries: 8-directional algorithm based on LML (left-most-looking) rule*
b) *approximating boundaries with polygons*


Baboon’s polygonal maps for 30 and 5 segments
“Lena” image, 11 segments and corresponding polygonal map

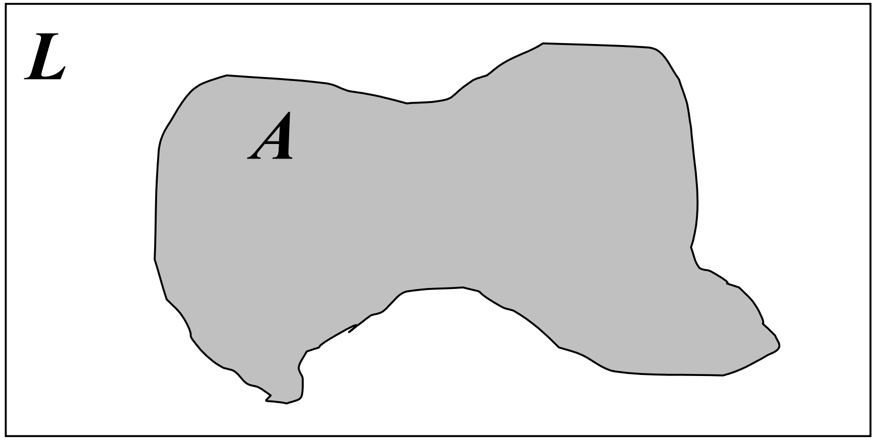
Our choice for segment texture approximation/coding:

Pure wavelet approach,
2D DWT + SPIHT coding algorithm
(WSEG)

Properties

- *Proportional bit allocation* for each segment from total bit budget
- *2D DWT on rectangle* ***L*** with dimensions of power two circumscribing the segment ***A***
- *Independent texture coding* for image segments
- *Modified SPIHT algorithm* to code individual image segments

Rectangle ***L*** circumscribing the segment ***A***



How to perform the transform on rectangle ***L*** with possibly best approximation properties for segment ***A*** ?

A) Iterative approach according to Kaup [2], used also in [1][3].

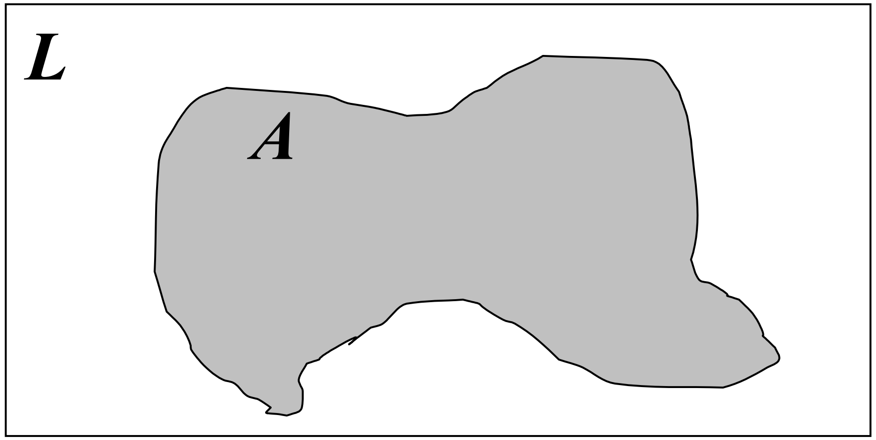
- in each step we add only one contribution to optimally chosen **orthogonal** basis function (best successive approximation property)
- When the approximation is sufficient, the coefficients are coded with respect to given bit budget

Drawbacks of approach A

1) The choosing and adding contributions for individual basis functions in bigger segments is very *time expensive*

   Solution is e.g.: Triangularisation of segments to create smaller regions

2) There is no check if the coder will use our carefully chosen basis functions, i.e. no test if the contributions are *optimal in the sense of additional costs of coding*

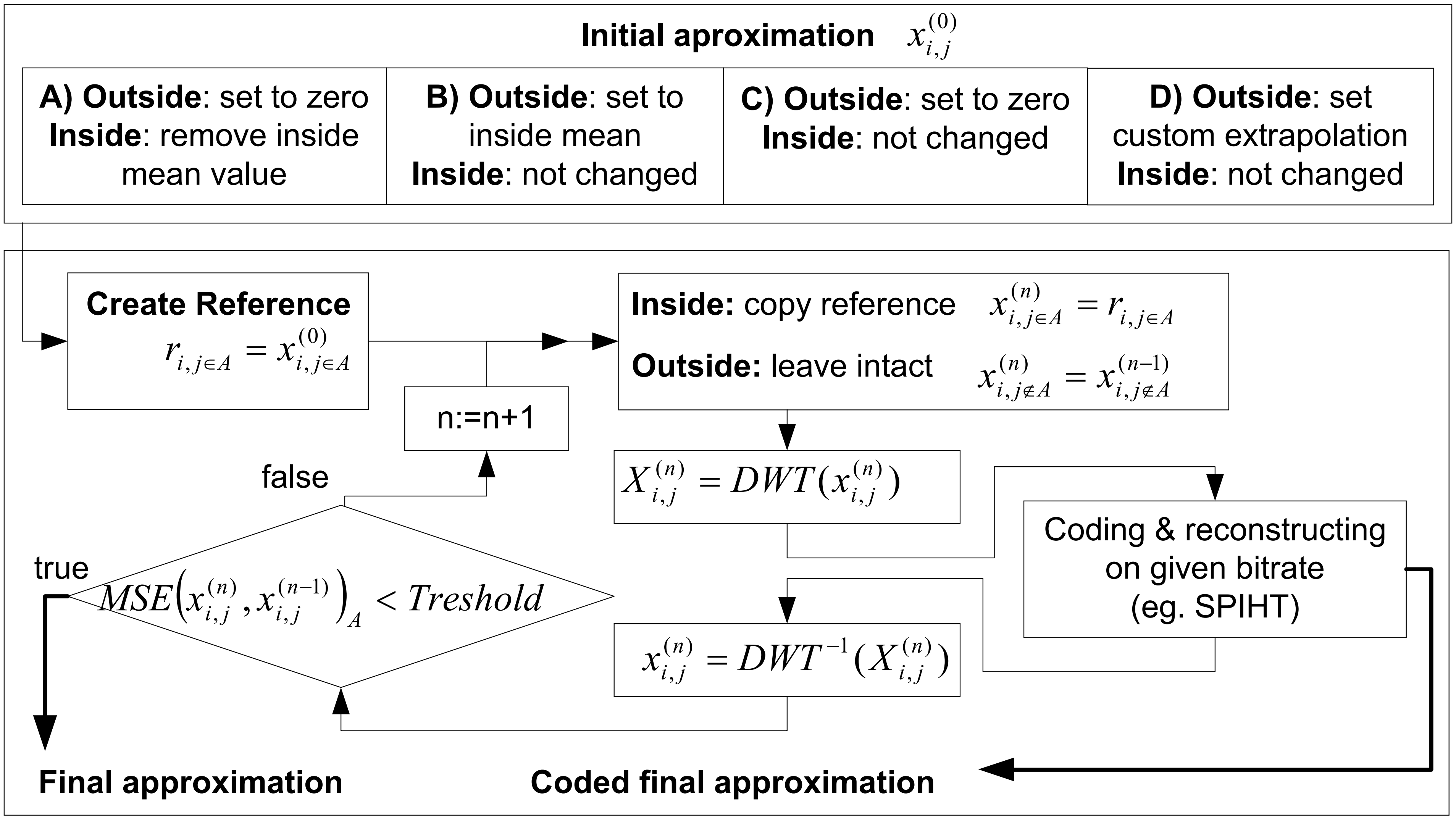


How to choose the values in region ***L-{A}*** to minimize the representation of segment ***A***?

B) Our solution - Let's the segment ***A*** to create its extension on ***L*** itself.

Iterative approach:

*F*or given *initial extrapolation* we find best segment approximation with respect to given coder and bit budget *(optimising the initial extrapolation)*


Initial aproximation $x_{i,j}^{(0)}$
A) Outside: set to zero
Inside: remove inside mean value
B) Outside: set to inside mean
Inside: not changed
C) Outside: set to zero
Inside: not changed
D) Outside: set custom extrapolation
Inside: not changed
Create Reference
$r_{i,j\in A} = x_{i,j\in A}^{(0)}$
Inside: copy reference $x_{i,j\in A}^{(n)} = r_{i,j\in A}$
Outside: leave intact $x_{i,j\notin A}^{(n)} = x_{i,j\notin A}^{(n-1)}$
n:=n+1
$X_{i,j}^{(n)} = DWT(x_{i,j}^{(n)})$
false
Coding & reconstructing on given bitrate (eg. SPIHT)
true
$MSE\left(x_{i,j}^{(n)}, x_{i,j}^{(n-1)}\right)_A < Treshold$
$x_{i,j}^{(n)} = DWT^{-1}(X_{i,j}^{(n)})$
Final approximation
Coded final approximation

Properties of our approach

- Our algorithm does *not find* global optimal representation, only given initial extrapolation finds better approximation with respect to given coder and bit budget.

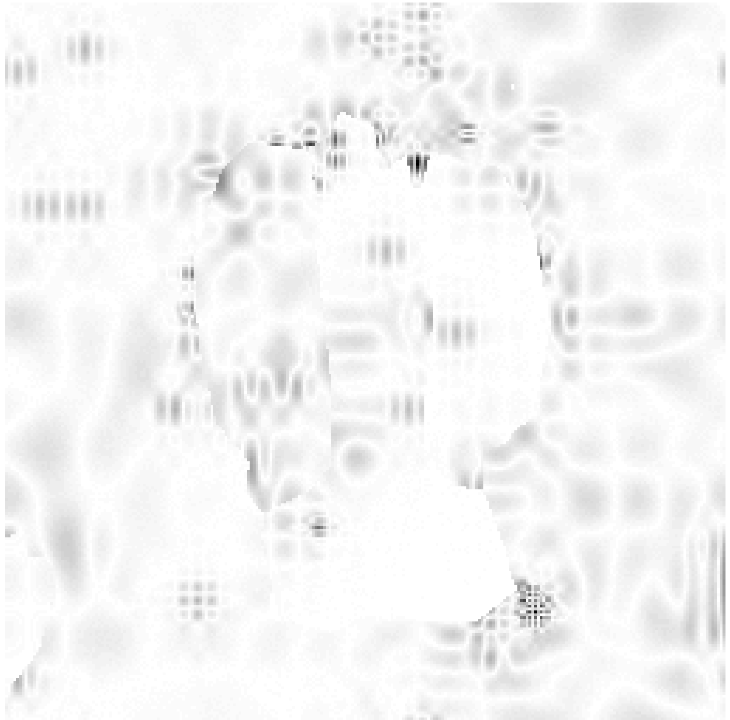
- The DWT does need to be orthogonal as in [1][3], bi-orthogonal condition is for iteration sufficient

- Result of iterative process - MSE enhancement
  - about 1 - 1.5 % of MSE using mean initial extrapolation (case A,B)
  - about 10% of MSE using zero initial extrapolation (case C)

- Typically needed 2-7 iterations for each segment (when setting threshold for successive MSE difference to 0.001)

Example of iterative process effect

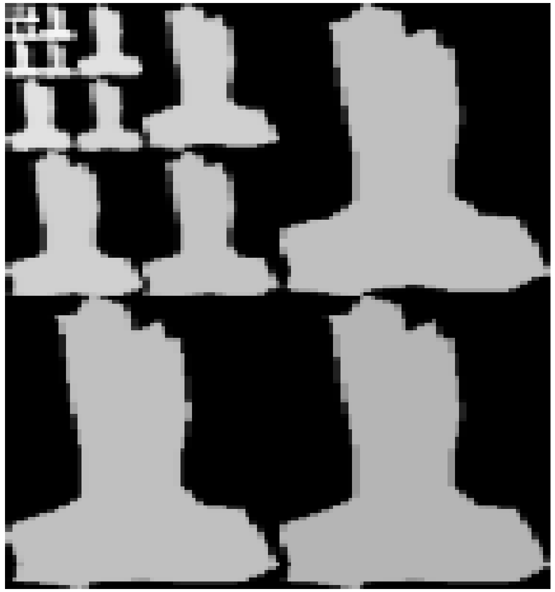
Baboon's polygonal
map for 5 segments



Absolute differences between initial
and iterated segment approximations.
(Battle-Lemaire filters, final bit rate
0.1 bpp, 7 iterations,
extrapolation with mean)

SPIHT modification

Baboon's polygonal map for 5 segments



Spectral Segment mask for Baboon's nose segment used in modified SPIHT for coefficient validity test

How to create spectral segment mask?

Our approach – "2D DWT" of single segment map. But using DWT with modified convolution kernel:

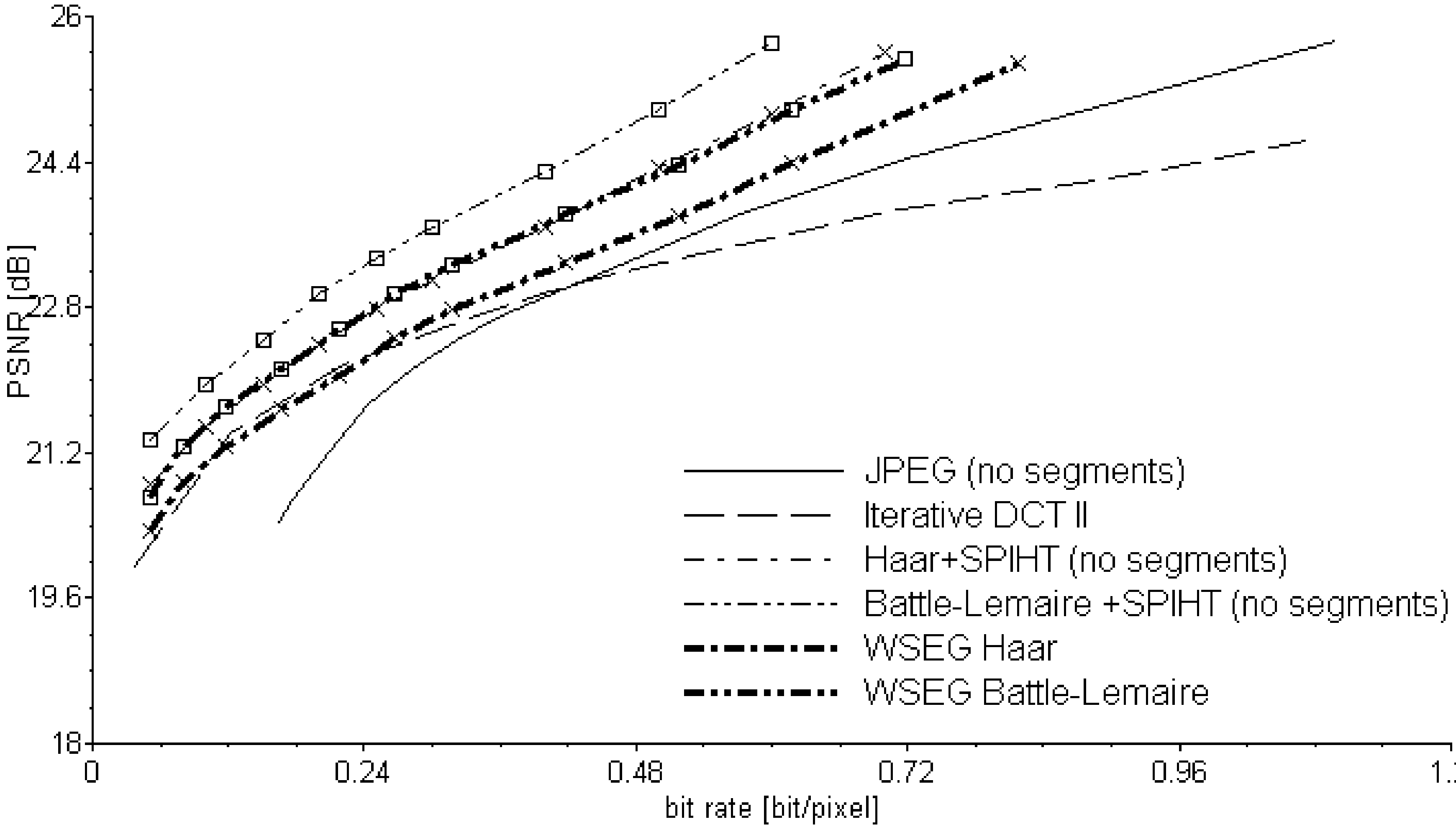
Instead $y(n)=x(n)*h(n)$
we use $y(n)=x(n)*|h(n)|$

<u>Result:</u> Nonzero spectral values create the spectral segment mask
<u>Properties:</u> filter set independent and fast solution

Effect of SPIHT modification for segmented image coding

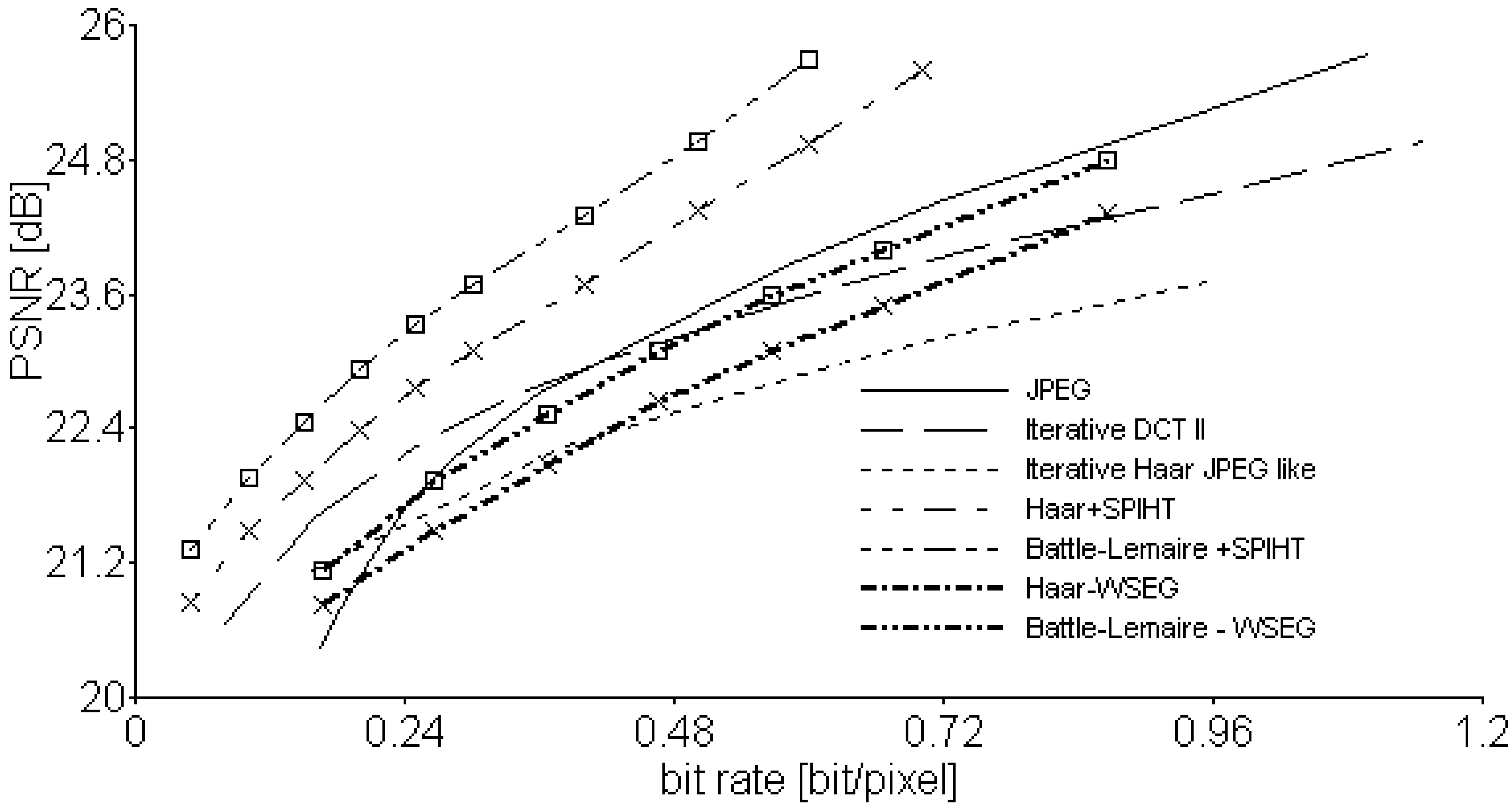
➔ **about 1% of MSE, mostly for lower compression ratios**

RESULTS



Compression results for segmented “baboon” image with 5 segments

Inefficiency of proposed method as the number of segments grows ("Baboon" image with 12 segments)



Baboon image compressed at 0.1 bpp

not segmented (DWT with BattleLemaire(BL) filters +SPIHT)

WSEG with 5 segments (DWT with BL filters +SPIHT)

Iterative DCTII with 5 segments