Recognition Impact of JPEG2000 Part 2 Wavelet Packet Subband Structures in Polar Iris Image Compression

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Outline

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- Compression in Biometric Systems
- Aim of this Work
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Introduction

In biometric systems, the compression of acquired sample data may become imperative under certain circumstances, due to the amount of data involved and potentially weak network links between sensor and feature extraction / matching module.

Lossy compression techniques maximize the benefit in terms of data reduction. However, the distortions introduced by compression artifacts may interfere with subsequent feature extraction and may degrade the matching results.

Lossless compression avoids any impact on recognition performance but is generally known to deliver much lower compression rates. An additional advantage of lossless compression algorithms is that these are often less demanding in terms of required computations as compared to lossy compression technology (which is beneficial for the sketched target-scenario often involving weak or low-power sensing devices).

Compression in Biometric Systems: Standards

- ISO/IEC 19794 standard on "Biometric Data Interchange Formats": current version supports JPEG and JPEG2000 (and WSQ for fingerprints) for lossy compression and JPEG-LS for lossless compression. The most recent version (ISO/IEC FDIS 19794-6) supports only JPEG2000 for lossy compression and PNG for lossless compression. The latter recommendation is mostly based on the NIST Iris Exchange (IREX) program recommendations.

- ANSI/NIST-ITL 1-2011 standard on "Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information": for lossy compression JPEG2000 is supported, and JPEG2000 as well as PNG for the lossless case.

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Aim of this Work

Focus: Lossy JPEG2000 compression of polar iris sample imagery (as obtained from rectilinear images by the rubbersheet transform after iris detection).

Methods: Application of several variants of JPEG2000 Part 2 conformant wavelet packet selection techniques to polar iris images (experimental study on achieved compression ratio vs. recognition accuracy).

Questions:

1. Can JPEG2000 Part 2 outperform the Part 1 of the standard by applying adaptive wavelet packet selection ?

2. Is rate-distortion optimal wavelet packet selection more beneficial for iris recognition performance in terms of matching accuracy ?

Wavelet Packet Selection in JPEG2000 Part 2

- Fixed scheme: The WSQ decomposition scheme is used (developed for fingerprints).

- Rate-independent: Application of the *best basis algorithm* by assessing coefficient properties after the transform (independent of JPEG2000). The following *cost functions* are considered:
  - Logarithm of coefficient energy ($loge$).
  - Entropy of coefficients (EIC).
  - l^p norm of coefficients for $p = 1, 2$.

- Rate-distortion optimal wavelet packet basis selection in JPEG2000.

Experimental Settings

- **Software**: JJ2000 reference implementation with custom Part 2 extensions
- **Sample Data**: CASIA V3 Interval data set (2639 images from 391 eye classes with 320×280 pixels), extracted polar iris images with 512×64 pixels (32782 byte in uncompressed form, compressed down to 409 byte with 0.1 bpp at a compression rate of 80.
- **Scenarios**: CCC, where both templates involved in matching are compressed, and CUC, where the template generated from the compressed sample is matched against the database containing templates derived from uncompressed iris images.
- **Feature extraction and matching**: Ko et al. (spatial domain features) and Monro et al. (DCT domain features).

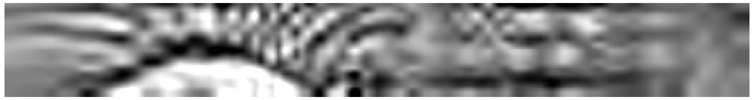
Visual Examples

(a) uncompressed

(b) JPEG2000 Part 1

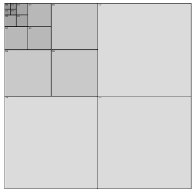
(c) R/D optimal

(d) *loge*-function

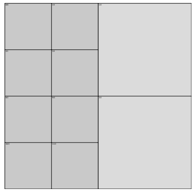


(e) *EIC*-function

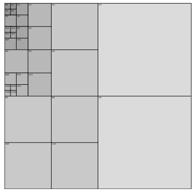
(f) WSQ



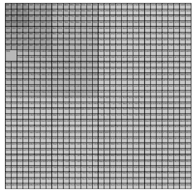
(g) JPEG2000 Part 1



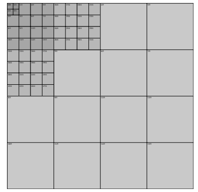
(h) R/D optimal



(i) *loge*-function



(j) *EIC*-function



(k) WSQ

Examples of the CASIA image S1073L01 in uncompressed (a) and compressed (b) - (f) versions (0.8 *bpp* using decomposition depth 5). The corresponding wavelet packet bases are depicted in figures (g) - (k).

Results: Share of Part 1 Transform

	depth two	depth three	depth four	depth five
EIC	0.0	0.0	0.0	0.0
$loge$	77.83	49.35	10.3	1.86
$l^1 norm$	99.72	99.63	82.75	23.56
$l^2 norm$	99.91	99.81	98.61	64.19

$\longrightarrow$ A significant share of selected decomposition schemes are in effect dyadic decomposition schemes as specified in JPEG2000 Part 1 (except for the EIC cost function).

$\longrightarrow$ This effect decreases for increasing wavelet decomposition depth.

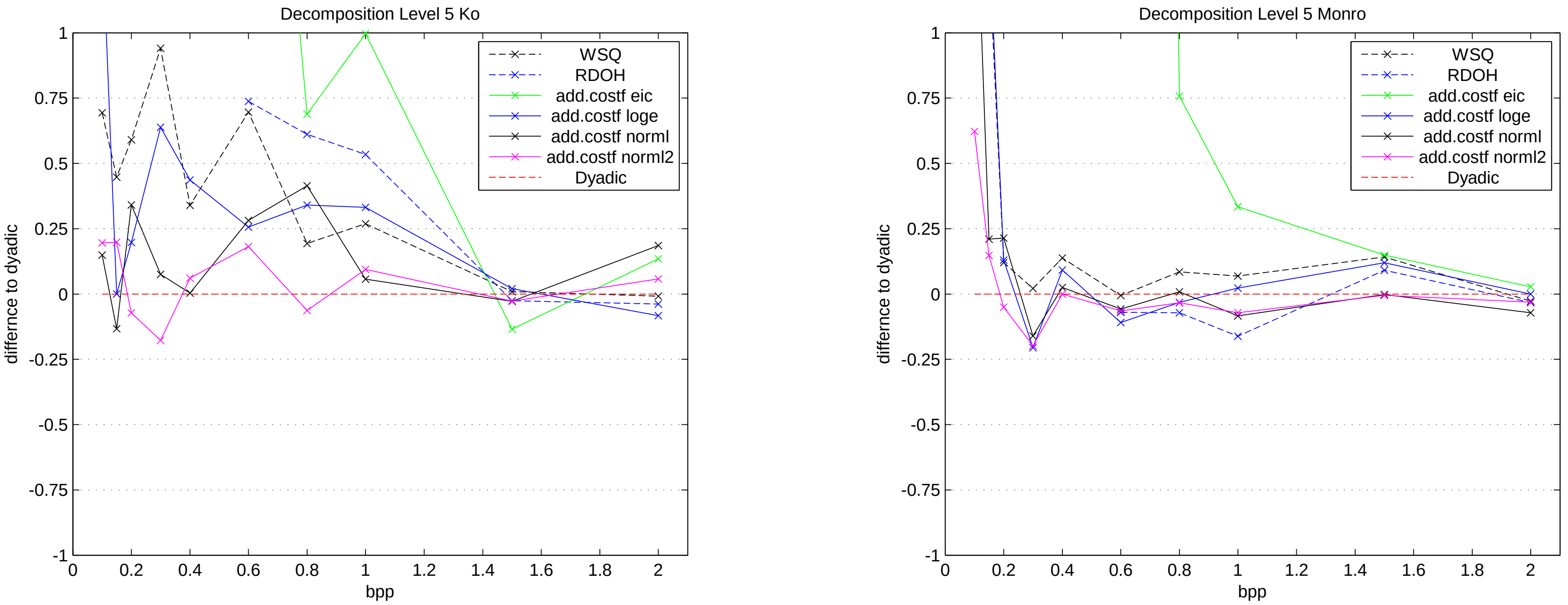
Results: Share of Part 1 Transform

$\boldsymbol{rd}$ bpp	depth two	depth three	depth four	depth five
0.1	**99.81**	66.05		
0.2	**99.54**	48.61	45.18	
0.3	**99.35**	65.96	65.96	
0.4	**98.79**	**90.26**	**89.61**	
0.6	**94.62**	**90.26**	**90.26**	**90.54**
0.8	45.27	**90.17**	45.08	45.08
1.0	56.59	57.42	57.51	57.05
1.5	20.59	20.69	20.69	20.69
2.0	39.24	40.07	40.07	40.07

$\longrightarrow$ Rate-distortion based selection: In the medium bitrate range, a large share of selected decompositions are the dyadic ones. For low bitrates, in case of a low decomposition depth we also find a large share of Part 1 decompositions.

$\longrightarrow$ in scenarios with a large share of Part 1 schemes, improvements can hardly be expected !!

Results: EER in CCC Scenario



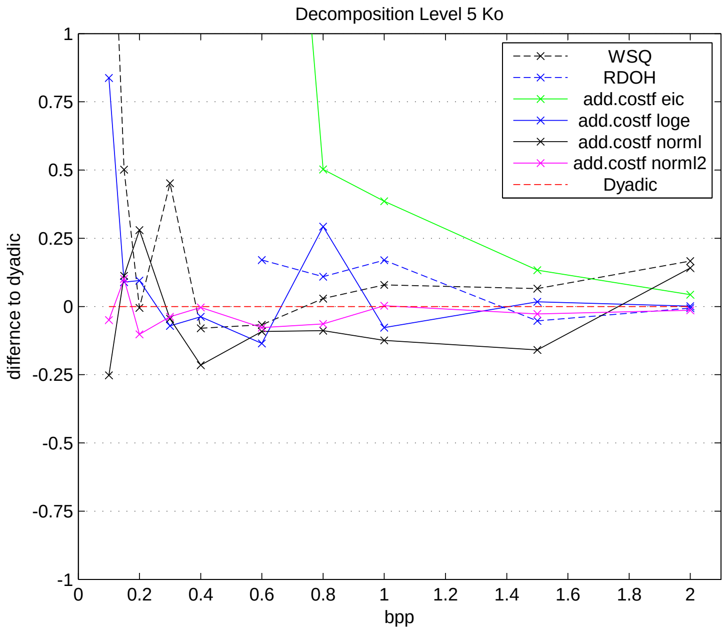
(l) Ko (9.27) (m) Monro (1.26)

EER relative to JPEG2000 Part 1 using 5 decomposition levels.

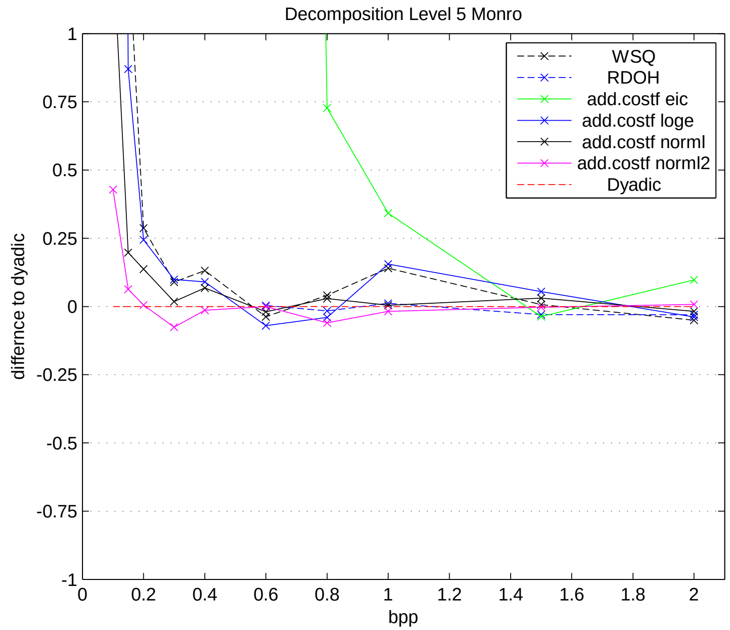
⟶ For Ko-based recognition, Part 1 decomposition is best for almost all settings.

⟶ For Monro-based recognition, at least at some particular midrange bitrate(s), Part 2 schemes outperform the dyadic decomposition.

Results: EER in CUC Scenario



(n) Ko (9.27)



(o) Monro (1.26)

EER relative to JPEG2000 Part 1 using 5 decomposition levels.

$\longrightarrow$ For Ko-based recognition, EER is improved for most bitrates considered for the two $l^{1,2}norm$-functions.

$\longrightarrow$ For Monro-based recognition, we hardly see better EER as compared to the dyadic case, as opposed to the CCC scenario.

Conclusion

- Wavelet packet tend to generate dyadic decomposition schemes in many cases (JPEG2000 Part 1 is a reasonable choice also for iris imagery overall).

- Optimal PSNR performance does not guarantee a good recognition performance, which shows that optimisation of compression schemes for pattern recognition applications must not be guided by the traditional notion of rate/distortion performance.

- Some cost functions like the EIC-function and the fixed WSQ scheme are not at all suited for the target image type.

- Future work: Optimisation of ROC behaviour in the wavelet packet selection process.

Thank you for your attention !

Questions ?