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PAPER

Parameter Embedding in Motion-JPEG2000 through ROI for Variable-Coefficient Invertible Deinterlacing

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SUMMARY In this paper, a coefficient-parameter embedding method into Motion-JPEG2000 (MJP2) is proposed for invertible deinterlacing with variable coefficients. Invertible deinterlacing, which the authors have developed before, can be used as a preprocess of frame-based motion picture codec, such as MJP2, for interlaced videos. When the conventional field-interleaving is used instead, comb-tooth artifacts appear around edges of moving objects. On the other hand, the invertible deinterlacing technique allows us to suppress the comb-tooth artifacts and also guaranties recovery of original pictures. As previous works, the authors have developed a variable coefficient scheme with a motion detector, which realizes adaptability to local characteristics of given pictures. However, when this deinterlacing technique is applied to a video codec, coefficient parameters have to be sent to receivers for original picture recovery. This paper proposes a parameter-embedding technique in MJP2 and constructs a standard stream which consists both of picture data and the parameters. The parameters are embedded into the LH_1 component of wavelet transform domain through the ROI (region of interest) function of JPEG2000 without significant loss in the performance of comb-tooth suppression. Some experimental results show the feasibility of our proposed scheme.

key words: *invertible deinterlacing, intra-frame-based coding, SNR scalability, variable processing, Motion-JPEG2000, ROI (Region of Interest)*

1. Introduction

Interlaced scanning is popularly used as a broadcasting TV format and known to offer a shorter update interval than progressive scanning within the same spatial resolution and transmit bandwidth. Frequently, it is necessary or preferable to handle an interlaced video as a progressive scanned one, that is, a frame sequence. For example, an advanced TV receiver interpolates missing lines to recreate a frame sequence for improving the perceptual quality. This kind of technique is popularly known as deinterlacing. Additionally, coding applications sometimes require constructing a frame picture from successive field pictures. Usually, the field interleaving technique is simply employed to achieve this purpose. Unfortunately, this process causes horizontal comb-tooth artifacts at edges of moving objects. In the case of transform-based coding such as Motion-JPEG2000 (MJP2) [2], the comb-tooth artifacts consisting of vertical high frequency components are enhanced by their quantization process in the transform domain, and those result in flickering around edges of moving objects. To suppress the unfavorable artifacts, a pre-processing technique was proposed so that the standard decoding without extra processing can serve pictures of which comb-tooth artifacts have already been suppressed [1]. Especially, it is effective for low and middle bit-rate applications.

For high bit-rate applications, however, the filtering approach degrades the picture quality since the pre-filter blurs the original pictures. It should be noticed here that such behavior may not be suitable for scalable codecs. As a previous work, to solve this problem, we developed invertible deinterlacing with sampling density preservation as a preprocess of scalable intraframe-based coding [5]–[7]. This technique can suppress the comb-tooth artifacts, while maintaining the quality recovery. The original invertible deinterlacing* was, however, not necessarily suitable for the local properties of a given picture since the coefficients of the deinterlacing filters were fixed. Later, we further proposed invertible deinterlacing with variable coefficients, where coefficients of the filter vary according to a given picture [8]. Compared with the fixed-coefficient deinterlacer, perceptual quality is improved as a result. For the application to video codec systems, however, the variable-coefficient invertible deinterlacing has to transmit the coefficient parameters to the receivers for recovering the original pictures. In this work, we deal with this transmission issue and propose a parameter-embedding technique in MJP2. Our proposed technique keeps a standard stream which consists both of the picture data and parameters. We suggest embeding the parameters into the LH_1 component of the wavelet transform domain through the ROI (region of interest) function of JPEG2000. It will be verified that the performance of comb-tooth suppression is preserved through this process.

This paper is organized as follows: Sect. 2 outlines the invertible deinterlacer with sampling-density preservation, describes an adaptive deinterlacing with a motion-detection filter, and summarizes the performances. Section 3 proposes a procedure of parameter embedding method. Section 4 evaluates the performance, followed by conclusions

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*Here, we use the term 'invertible' to indicate that an inverse system analytically exists and to distinguish our technique from the deinterlacing popularly used in advanced TV receivers.

in Sect. 5.

2. Invertible Deinterlacing

As a previous work, we proposed a deinterlacing technique that preserves sampling density and possesses the invertibility [5]. In this section, let us briefly review invertible deinterlacing with variable coefficients as a preliminary.

2.1 Application Scenario [6]

We suggest an application scenario of invertible deinterlacer. Intraframe-based scalable coding such as MJP2 is assumed here as shown in Fig. 1. The deinterleaver indicates the inverse process of interleaving. An invertible deinterlacer is used as a pre-filter. The comb-tooth artifacts are suppressed beforehand for low bit-rate decoding, whereas the original quality is maintained by the reinterlacer, when decoding an interlaced video at high bit-rate.

2.2 Variable-Coefficient Processing [8], [9]

We have verified that flickering due to the comb-tooth artifacts can be avoided for low bit-rate decoding. The still parts are, however, unexpectedly blurred due to the pre-filtering process. Actually, a simple temporal filter corresponding to the field interleaving is rather preferable for still parts. Local adaptability can be achieved by introducing a variable coefficient technique. A pair of filters for deinterlacing and reinterlacing is possibly selected as follows [8], [9]:

$$H_n(\mathbf{z}) = 1 + \left(1 - \frac{\alpha_n}{2}\right) z_T^{-1} + \frac{\alpha_n}{4}\left(z_V^{1} + z_V^{-1}\right), \quad (1)$$

$$F_n(\mathbf{z}) = z_T^{-1}\left\{\frac{2}{2-\alpha_n} + z_T^{-1} - \frac{\alpha_n}{2(2-\alpha_n)}\left(z_V^{1} + z_V^{-1}\right)\right\} \quad (2)$$

where α_n is a parameter in the range of $0 \leq \alpha_n < 2$ and subscript n denotes a parameter index. Different filter modes are selectable among temporal, vertical-temporal and vertical filters by controlling α_n. In particular, if $\alpha_n = 1$, the transfer function becomes identical to that given by the fixed-coefficient deinterlacer designed and evaluated in the article [5]. Additionally, if $\alpha_n = 0$, the deinterlacer reduces to the conventional simple field-interleaver so that the original pixel values are maintained.

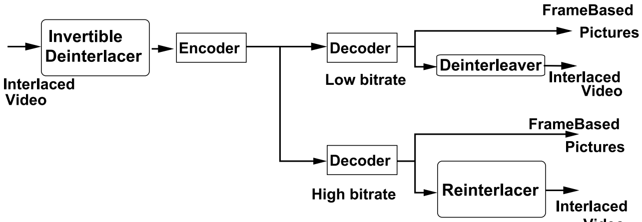


Fig. 1 Intraframe-based coding system with deinterlacer. *(J. Uchita, S. Muramatsu, T. Ishida, H. Kikuchi and T. Kuge, Parameter Embedding Method of Variable-Coefficient Invertible Deinterlacing into Motion-JPEG2000 through ROI, Proceeding, Proc. of MWSCAS2004, © 2004 IEEE.)*

The variable-coefficient filtering has an in-place implementation as shown in Fig. 2, where the black, white and gray circles indicate pixels on a bottom field, a top field and a bottom field in the deinterlaced frame, respectively. Note that the perfect reconstruction property is verified by this implementation independently of parameter α_n.

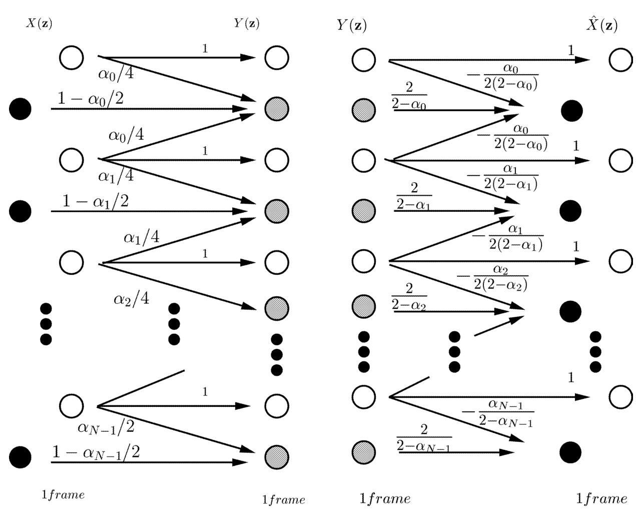
2.3 Adaptive Control Method

The parameter α_n can have any value in the range of $0 \leq \alpha_n < 2$. The value, however, should be transmitted to decoders for reinterlacing, if the inverse process is desired. Thus, it is of interest to limit the possible quantities for efficient transmission of α_n. In addition, the reduction of the computational complexity is another concern. To cope with these two practical requirements, we proposed to switch the value of α_n between 0 and 1 [8], [9].

In order to detect regions prone to yield comb-tooth artifacts, we suggested applying a horizontal-low-pass filter $D_H(\mathrm{z})$ and vertical-high-pass filter $D_V(\mathrm{z})$ prior to deinterlacing. The output of comb-tooth detector is quantized into binary value by thresholding. A decision scheme of thresholding is described in the articles [8], [9]. The invertible deinterlacing with variable coefficients locally suppresses the comb-tooth artifacts, while guaranting the perfect reconstruction by reinterlacing.

2.4 Parameter Reduction Scheme [10]

Simultaneous transmission of parameters decreases the bit-rate assigned to the picture data within a specified bit-rate. As a previous work, to reduce the coefficient parameters,



(a) Deinterlacing (b) Reinterlacing

Fig. 2 Efficient implementation of deinterlacing with variable coefficients, where the symmetric extension method is applied. *(J. Uchita, S. Muramatsu, T. Ishida, H. Kikuchi and T. Kuge, Parameter Embedding Method of Variable-Coefficient Invertible Deinterlacing into Motion-JPEG2000 through ROI, Proceeding, Proc. of MWSCAS2004, © 2004 IEEE.)*

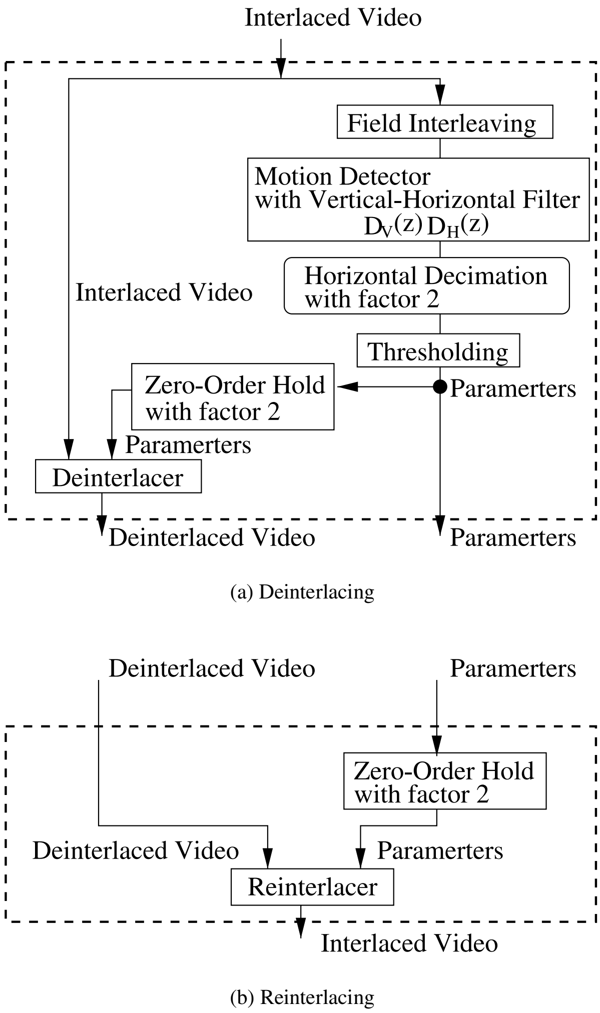


Fig. 3 Parameter reduction scheme [10]. *(J. Uchita, S. Muramatsu, T. Ishida, H. Kikuchi and T. Kuge, Parameter Embedding Method of Variable-Coefficient Invertible Deinterlacing into Motion-JPEG2000 through ROI, Proceeding, Proc. of MWSCAS2004, © 2004 IEEE.)*

we proposed a parameter reduction method without significant loss of comb-tooth suppression capability [10]. Figures 3 (a) and (b) show the flow chart of the procedure in deinterlacing and reinterlacing, respectively. As a result, the amount of the parameters are reduced and the quality of recovered pictures are improved from the original full parameter method at the same total bit-rate. The details of this reduction method was shown in the article [10]. This work employs this technique as will be shown in the following section.

Note that sending the coefficient parameters to receivers is still necessary, and the simultaneous transmission of parameters is preferable to the separate transmission.

3. Proposed ROI Approach

In this section, we propose to embed the coefficient parameters into MJP2 through ROI so that we can make all data one standard bit-stream without significant loss of the performance.

3.1 Overview of ROI Maxshift Method

JPEG2000 supports ROI coding. The ROI function achieves non-uniform distribution of the image quality between a specified region and the background region. According to the ROI Maxshift method defined in JPEG 2000 part I (baseline algorithm), the background bit-planes are down-shifted below all of the ROI coefficients [2]. ROI can have any shape, which does not need to be transmitted to decoder side. At decoder side, the decision whether a coefficient belongs to the background or not is obtained by comparing the number of bits in the current coefficient with nominal maximum number of magnitude bit-plane in each subband. From these reasons, we propose to use the ROI shape for transmitting the positions where deinterlacing is applied to.

3.2 Choice of Target Subband

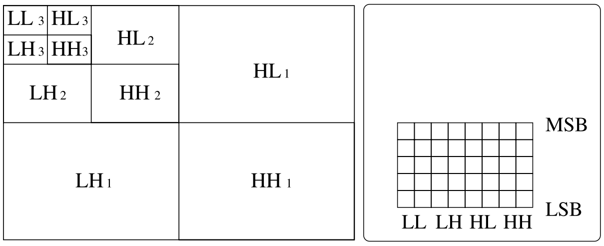
The ROI function of MJP2 can independently specify its shape in each subband. To reduce the influence of embedding coefficient parameters to ROI on the image quality, we propose to embed the parameters to one subband domain. Note that the size of parameters is $W/2 \times H/2$ and fits to one of level-1 subband domain, where W and H denote the width and hight of the original picture or one tile.

The coefficient parameters are determined by the output of a horizontal-low-pass and vertical-high-pass filter, that is comb-tooth detection filter. Thus, the LH_1 subband coefficients should be treated carefully to recover the original picture. From this reason, coefficient parameters are embedded into subband LH_1 as ROI so that those coefficient parameters can be shared among an encoder and decoders. Figure 4 (a) shows notation of subband and bit-plane of wavelet transform domain. Figure 4 (b) exemplifies the situation when coefficient parameters are embedded into LH_1.

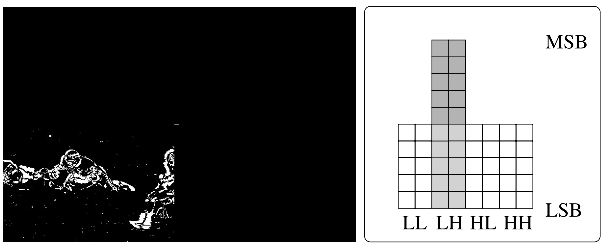
3.3 Progression Order

There are five different progression orders supported in JPEG2000 [2]. The LRCP (Layer Resolution Component Position) progression is one of the main progression types. The LRCP progression arranges code-stream firstly in terms of layer and then in terms of resolution. Since our invertible deinterlacer is meaningful for the SNR scalability, we here investigate only the LRCP progression case. When the LRCP progression is used, a problem arises. If only the LH_1 subband given priority in the stream, disagreeable pictures are yielded at low bit-rate decoding.

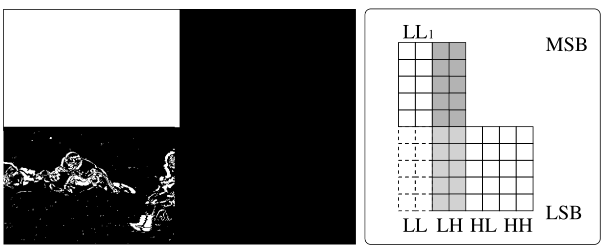
To solve this problem, we suggest embedding coefficient parameters into subband LH_1 as ROI, and to set also the entire coefficients in subbands $LL_n (= \{LL_{n+1}, HL_{n+1}, LH_{n+1}, HH_{n+1}\})$ as ROI, where n is the depth of wavelet tree levels. With regard to the choice of n, we



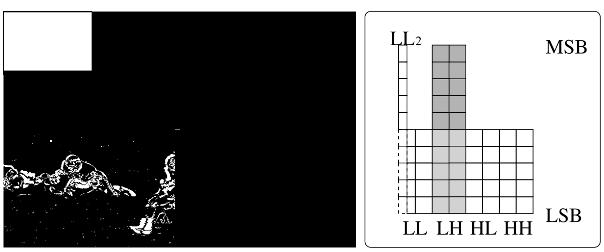
(a) Notation of subbands



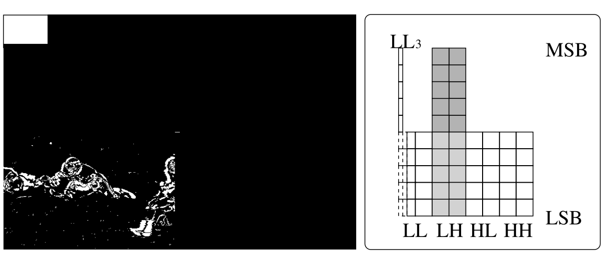
(b) Proposed mask without LL



(c) Proposed mask with LL (n=1)



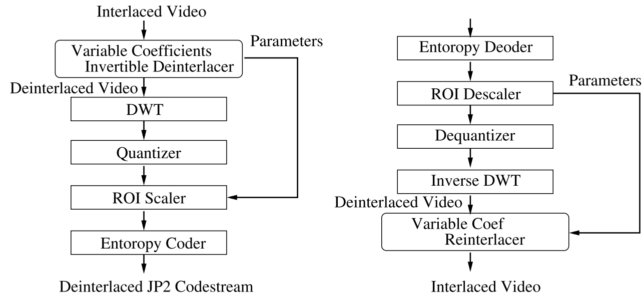
(d) Proposed mask with LL (n=2)



(e) Proposed mask with LL (n=3)

Fig. 4 Notation of subband and ROI masks. *(J. Uchita, S. Muramatsu, T. Ishida, H. Kikuchi and T. Kuge, Parameter Embedding Method of Variable-Coefficient Invertible Deinterlacing into Motion-JPEG2000 through ROI, Proceeding, Proc. of MWSCAS2004, © 2004 IEEE.)*

will discuss in the next section. As a result, we can obtain a proper image for low bit-rate decoding. Figure 4 (c)-(e) shows the bit-plane state of $n = 1, 2$ and 3, respectively. It becomes possible to avoid getting only the LH_1's ROI information in the early process of decoding.



(a) Encoder (b) Decoder

Fig. 5 Proposed encoder and decoder. *(J. Uchita, S. Muramatsu, T. Ishida, H. Kikuchi and T. Kuge, Parameter Embedding Method of Variable-Coefficient Invertible Deinterlacing into Motion-JPEG2000 through ROI, Proceeding, Proc. of MWSCAS2004, © 2004 IEEE.)*

In addition, we suggest replacing the bit-plane of the least significant bit (LSB) in LL_n of ROI to zero so as to preserve some bits in non ROI coefficients that would be pushed out if the replacement weren't applied. We verified that we can achieve a similar quantization through the expounded quantization supported in JP2.

3.4 Processing Flow

A variable-coefficient invertible deinterlacer with parameter reduction scheme can be integrated into an encoder and a decoder of JPEG2000 as shown in Figs. 5 (a) and (b). The coefficient parameters from deinterlacer are passed to the ROI Scaler, and the ROI process is applied to LH_1. All coefficients in LL_n are set as ROI. For a high bit-rate decoder, the information on LH_1 of the ROI mask is detected at ROI Descalers, and they are passed to the reinterlacer. Lastly, a picture is reconstructed. At a low bit-rate decoder, or a standard decoder, the reinterlacing process is skipped.

4. Performance Evaluation

In order to show the significance of our proposed parameter embedding approach, let us evaluate the performance in terms of the comb-tooth suppression capability at low bit-rate decoding and in terms of PSNR to see the quality recovery at high bit-rate decoding. In this evaluation, successive frame pictures of Football (720× 480 pixel, 8-bit, grayscale), Mobile&Calendar (720×480 pixel, 8-bit, grayscale) and NewYork2 (720×480, 8-bit, grayscale) sequences are used. Every frame picture is encoded at 2.0 bpp by using JPEG2000 and then decoded at both of 2.0 and 0.1 bpp.

4.1 Low Bit-Rate Decoding

Figures 6 (a)-(f), 7 (a)-(c) and 8 (a)-(c) show the decoded pictures at 0.1 bpp, where n denotes the depth of LL levels in which entire coefficients are maxshifted as ROI. The

(a) Simple field interleaving (b) Separate transmission [10] (c) ROI transmission ($n = 1$)

(d) ROI transmission ($n = 2$) (e) ROI transmission ($n = 3$) (f) ROI transmission without ROI in LL

Fig. 6 Decoded pictures at low bit-rate (0.1bpp) for Football.

(a) ROI transmission ($n = 1$) (b) ROI transmission ($n = 2$) (c) ROI transmission ($n = 3$)

Fig. 7 Decoded pictures at low bit-rate (0.1bpp) for Mobile&Calendar.

(a) ROI transmission ($n = 1$) (b) ROI transmission ($n = 2$) (c) ROI transmission ($n = 3$)

Fig. 8 Decoded pictures at low bit-rate (0.1bpp) for NewYork2.

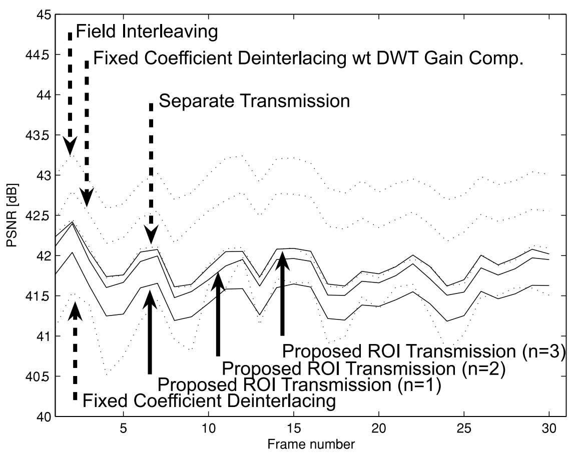


Fig. 9 High bit-rate results for Football.

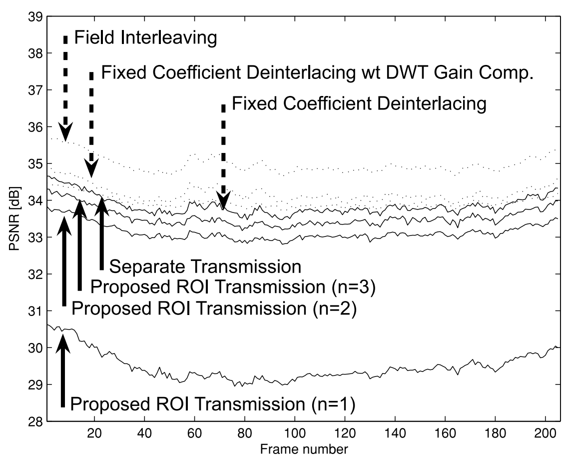


Fig. 10 High bit-rate results for Mobile&Calendar.

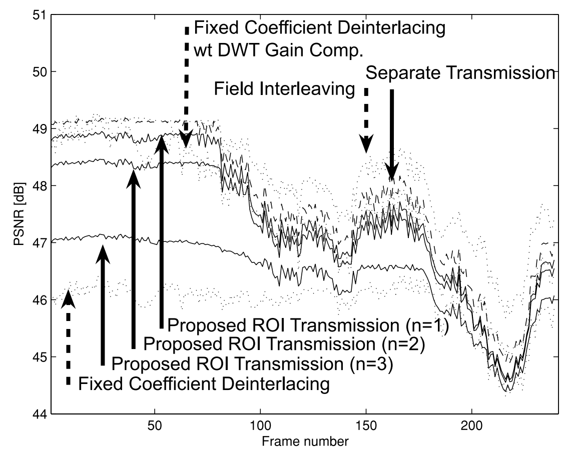


Fig. 11 High bit-rate results for NewYork2.

simple field interleaving does not require any transmission of parameters.

The comb-tooth artifacts produced by the simple field interleaving are clearly perceived in Fig. 6 (a). In contrast, those artifacts are significantly suppressed by the invertible deinterlacer as shown in Figs. 6 (b)-(f). The deeper the entire maxshift operation is applied to LL_n components, the blurer the result becomes. We can recognize that the maxshift operations to LL_1 or LL_2 are moderate at low bit-rate decoding in this experiment.

4.2 High Bit-Rate Decoding

Figures 9, 10 and 11 plot PSNRs of decoded pictures to evaluate the performance in the case of high bit-rate decoding. The reinterlacer is used to recover the original quality at decoder side. Here, the following methods are compared:

- Separate transmission [10]
- Proposed ROI transmission ($n = 1$)
- Proposed ROI transmission ($n = 2$)
- Proposed ROI transmission ($n = 3$)

In the graph, results before reinterlacing are also given. Quality recovery of reinterlacing can be verified. For reference, the following three schemes are also shown:

- Field interleaving
- Fixed coefficient deinterlcing [3]–[6]
- Fixed coefficient deinterlacing with DWT gain compensation [12]

In our proposed ROI transmission techniques, PSNR values are improved as the depth n increases. When $n = 3$, it reaches to the result of separate transmission technique with parameter decimation. Increasing n is, however, affects the low bit-rate decoding. Actually, the technique without LL maxshift shows the best among the proposed techniques, although the pictures in low bit-rate decoding is not acceptable. We see a tradeoff between the performances in low and high bit-rate decoding. Although the optimal choice of n highly depends on the target sequence, the proposed method for $n = 1$ or $n = 2$ gives a good compromise in this experiment.

The field interleaving scheme shows good results in the quality recovery. Although this technique is simple and any parameter transmission is not required, the performance in low bit-rate decoding is inferior to that of the other methods in terms of the comb-tooth suppression capability. The fixed coefficient deinterlacing is also performs well when employing a DWT gain compensation technique to improve the performance [12] and no parameter transmission is required. This technique, however, applies the filtering process to whole of picture, thus stillness parts are not guarded. For a variable coefficient case, the gain compensation technique is still under investigation. Tables 1, 2 and 3 summarize each result. The proposed method embed the paramters into LH_1 subband by using the ROI function of JPEG2000, which does not show significant loss in the performance of comb-tooth suppression.

4.3 Validity of ROI in LH_1 Subband

In order to confirm validity of selecting LH_1, we experiment embedding the coefficient parameters into each subband of

Table 1 Performances: Football. (Averages of 30 frames.)

	Low bit-rate(@0.1bpp)		High bit-rate(@2.0bpp)	
	Coding efficiency	Comb-tooth suppression	Coding efficiency	Local adaptability
Field interleaving	25.84 [dB]	Poor	42.94 [dB]	None
Fixed coefficients [3]–[6]	24.62 [dB]	Good	40.93 [dB]	Poor
Fixed coefficients with DWT gain compensation [12]	31.23 [dB]	Good	42.48 [dB]	Poor
Separate transmission [10]	24.67 [dB]	Good	41.92 [dB]	Good
Proposed ROI transmission (n=0)	15.97 [dB]	Bad	42.02 [dB]	Good
Proposed ROI transmission (n=1)	24.76 [dB]	Good	41.48 [dB]	Good
Proposed ROI transmission (n=2)	24.59 [dB]	Good	41.80 [dB]	Good
Proposed ROI transmission (n=3)	23.89 [dB]	Good	41.92 [dB]	Good

Table 2 Performances: Mobile&Calendar. (Averages of 240 frames.)

	Low bit-rate(@0.1bpp)		High bit-rate(@2.0bpp)	
	Coding efficiency	Comb-tooth suppression	Coding efficiency	Local adaptability
Field interleaving	29.72 [dB]	Poor	34.99 [dB]	None
Fixed coefficients [3]–[6]	17.92 [dB]	Good	33.95 [dB]	Poor
Fixed coefficients with DWT gain compensation [12]	29.24 [dB]	Good	34.19 [dB]	Poor
Separate transmission [10]	17.92 [dB]	Good	33.86 [dB]	Good
Proposed ROI transmission (n=0)	10.76 [dB]	Bad	33.57 [dB]	Good
Proposed ROI transmission (n=1)	17.96 [dB]	Good	29.48 [dB]	Good
Proposed ROI transmission (n=2)	17.57 [dB]	Good	33.13 [dB]	Good
Proposed ROI transmission (n=3)	16.13 [dB]	Good	33.54 [dB]	Good

Table 3 Performances: NewYork2. (Averages of 205 frames.)

	Low bit-rate(@0.1bpp)		High bit-rate(@2.0bpp)	
	Coding efficiency	Comb-tooth suppression	Coding efficiency	Local adaptability
Field interleaving	34.99 [dB]	Poor	48.18 [dB]	None
Fixed coefficients [3]–[6]	28.49 [dB]	Good	45.90 [dB]	Poor
Fixed coefficients with DWT gain compensation [12]	34.32 [dB]	Good	47.48 [dB]	Poor
Separate transmission [10]	28.73 [dB]	Good	47.79 [dB]	Good
Proposed ROI transmission (n=0)	24.62 [dB]	Good(bluered)	47.82 [dB]	Good
Proposed ROI transmission (n=1)	28.72 [dB]	Good	46.41 [dB]	Good
Proposed ROI transmission (n=2)	27.24 [dB]	Good	47.23 [dB]	Good
Proposed ROI transmission (n=3)	25.01 [dB]	Good	47.49 [dB]	Good

Table 4 Validity of ROI in LH_1 subband.

Sequence	LH_1 [dB]	HL_1 [dB]	HH_1 [dB]
Football	41.48	31.22	31.90
Mobile&Calendar	29.48	28.62	28.00
NewYork2	46.41	38.72	39.33

LH_1, HL_1 and HH_1, respectively, and compare the performances in terms of their average PSNRs. Table 4 shows the results corresponding to each subband for Football, Mobile&Calendar and NewYork2 by encoding and decoding at bit-rate of 2.0 bpp. It is verified that the LH_1 subband is a moderate choice for embedding the parameters.

5. Conclusion

In this paper, we proposed applying variable-coefficient invertible deinterlacing to MJP2 and transmitting the coefficient parameters through the ROI function. By using our proposal, it became possible to share coefficient parameters in one standard MJP2 bit-stream among an encoder and decoders.

Since those coefficients are determined by the output of a horizontal-low-pass and vertical-high-pass filter, we suggested embedding them only into the LH_1 subband. In order to give a significant picture at low bit-rate decoding, we also considered setting all of a certain LL_n subband as ROI so that significant coefficients can survive.

It was shown that the depth of LL_n levels specified as ROI gives us a tradeoff relation in performances between low and high bit-rate decoding performances.

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References

[1] T. Kuge, "Wavelet picture coding and its several problems of the application to the interlace HDTV and the ultra-high definition images," Proc. IEEE ICIP, WA-P2.1, Sept. 2002.
[2] D.S. Taubman and M.W. Marcellin, JPEG2000: Image compression fundamentals, standards and practice, Kluwer Academic Publishers, 2002.
[3] S. Muramatsu, S. Sasaki, Z. Jie, and H. Kikuchi, "De-interlacing with perfect reconstruction property," Proc. IEICE DSP IEICE Digital Signal Processing Symposium, pp.427–432, 2001.
[4] S. Muramatsu, T. Ishida, and H. Kikuchi, "A design method of invertible de-interlacer with sampling density preservation," Proc. IEEE ICASSP, vol.4, pp.3277–3280, 2002.
[5] S. Muramatsu, T. Ishida, and H. Kikuchi, "Invertible deinterlacing with sampling density preservation: Theory and design," IEEE Trans. Signal Process., vol.51, no.9, pp.2243–2356, Sept. 2003.
[6] H. Kikuchi, S. Muramatsu, T. Ishida, and T. Kuge, "Reversible conversion between interlaced and progressive scan formats and its efficient implementation," Proc. EUSIPCO, no.448, vol.III, pp.275–278, 2002.
[7] T. Soyama, T. Ishida, S. Muramatsu, and H. Kikuchi, "Lifting architecture of invertible deinterlacing," IEICE Trans. Fundamentals, vol.E86-A, no.4, pp.779–786, April 2003.
[8] T. Ishida, T. Soyama, S. Muramatsu, H. Kikuchi, and T. Kuge, "A lifting implementation of variable-coefficient invertible deinterlacer with embedded motion detector," IEICE Trans. Fundamentals, vol.E86-A, no.8, pp.1942–1948, Aug. 2003.
[9] T. Ishida, S. Muramatsu, H. Kikuchi, and T. Kuge, "Invertible deinterlacer with variable coefficients and its lifting implementation," Proc. IEEE ICME, vol.III, no.IMSP-L5.3, pp.105–108, 2003.
[10] J. Uchita, T. Ishida, S. Muramatsu, H. Kikuchi, and T. Kuge, "A parameter decimation technique for variable-coefficient invertible deinterlacing," IEICE Trans. Fundamentals, vol.E87-A, no.6, pp.1363–1370, June 2004.
[11] J. Uchita, T. Ishida, S. Muramatsu, H. Kikuchi, and T. Kuge, "Parameter embedding method of variable-coefficient invertible deinterlacing into motion-JPEG2000 through ROI," Proc. IEEE MWSCAS2004, pp.II-425–II-428, July 2004.
[12] T. Ishida, S. Muramatsu, and H. Kikuchi, "Motion-JPEG2000 Codec Compensated for Interlaced Scanning Videos," IEEE Trans. Image Process., vol.14, no.12, pp.2179–2191, Dec. 2005.
[13] Canon, EPFL and Ericsson, http://jj2000.epfl.ch

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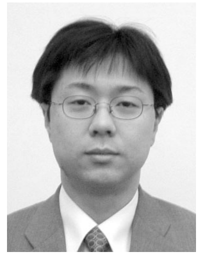

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